2023

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APEC Urban Energy Report

Driving Cities Through the Low Carbon Transition

APSEC

APEC Urban Energy Report 2023

Driving Cities Through the Low Carbon Transition

APEC Energy Working Group

June 2024

APEC Project: EWG 01 2023S

Produced by

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APEC#224-RE-04.4 ISBN: 978-981-94-0265-6

Foreword

APEC Sustainable Energy Center (APSEC) is pleased to present the APEC Urban Energy Report 2023 – Driving Cities Through the Low Carbon Transition. This report collects part of the research work undertaken by APSEC during the year 2023 within its pillar of the Cooperative Network of Sustainable Cities (CNSC).

In this report, APSEC continued its cooperation with its global partners: APEC cities (Manila, Greater Washington Region Clean Cities Coalition, Temuco in Chile); global organizations (GCoM, CDP, Climate Policy Initiative), Universities (Tokai University, the Hong Kong University of Science and Technology, Carleton University), the Asian Infrastructure Investment Bank (AIIB), the California-China Climate Institute, and an innovative enterprise (EntrepreneurCircle.World and MGT OPEN j.d.o.o.), as well as others mentioned in the Acknowledgements section. The lead-authorship, coordination and editing has been done by Prof. S. Defilla, President Assistant of APSEC. APSEC wishes to extend it special gratitude to its external and internal contributors.

APEC Sustainable Energy Center

Acknowledgements and Disclaimer

This study could not have been completed without numerous experts who provided invaluable contributions.

Specifically, we are grateful to the following experts and contributors:

Experts participating in the 7th APEC Workshop on Sustainable Cities organized by APEC Sustainable Energy Center and Hong Kong Polytechnic University on 14 March 2023, comprising delegates from Canada; Chile; China; Hong Kong, China; Korea; the Philippines; Singapore; Chinese Taipei; and United States.

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MENCHAVEZ Ralph, SAVP & Head of Commercial Strategy and Business Performance, MERALCO, is acknowledged for comments on the Philippine energy sector in section 2.1.3.

GUTIERREZ Chelso R., Senior Vice President, and ANGELES Eduardo S., Vice President, PHILGUARANTEE, are acknowledged for comments on the PHILGUARANTEE in section 2.1.4.

XIE Pengfei is hereby gratefully thanked for useful final comments on the report.

Preparation of drafts, statistics, graphics, and references: ABDULLAH Muhammad Ghazanfar, ALOQAB Khawla Taher Ahmed Mohammed, BARRETO BARBOSA Carlos Mauricio, LEANG Kakdamony Rack, MA Yi, QAISRA.

This report does not necessarily reflect the views or policies of the APEC Energy Working Group or individual APEC member economies. This report is to be interpreted as a scientific and analytic contribution. No APEC economy endorsing this report will be bound by any of its conclusions. The authored contributions of third parties do not necessarily reflect the views of these parties' institutions.

We hope that this report will serve as a useful basis for analytical discussion both within and among APEC member economies for the enhancement of sustainable urban development.

Purposes, Key Findings and Recommendations

Purposes

- Explain key financial instruments required to achieve carbon neutrality and define indicators measuring the step-by-step progress
- Describe the global carbon reporting frameworks and illustrate practical aspects of cities by case studies

Key Findings – Chapter 1

Since the Climate Neutral Network (CN Net) launched in 2008, net zero pledges have mushroomed making greenwashing become the main problem. UN decided to phase out its Climate Neutral Now Initiative by the end of 2024 and replace it by the Race to Zero and Race to Resilience initiatives, respectively. The Race to Zero comprises more than 1,000 cities worldwide pledging to net-zero by mid-century or sooner. Commitments must be made under a catalogue of stricter rules and principles. Atmospheric CO2 concentration continues to rise by 2ppm (part per million) every year, overtaking the 420ppm mark with no flattening in sight, compared to 200-300ppm during the last million years.

Cities face a density challenge. Cities are high density areas while renewables require large amounts of land. The report quantifies this challenge in detail. Given the high density of cities, energy efficiency is an indispensable instrument to attain carbon neutrality, coupled with industrial transformation from heavy industry to high-tech manufacturing. Cities face the challenge to create smart electrified urban transportation systems. In China, 81% of all new vehicles are electric vehicles. The building sector represents a major challenge for cities. In China, the shift from natural gas boilers to electric heat pumps in 2022 attained a record 10% year-on-year growth. The Chinese 14th Five-Year Plan states that by 2025 all new buildings in cities and towns will be built as green buildings, allowing China's building sector to achieve carbon peak in 2030. New storage technologies comprising batteries, compressed air and heat storage complement traditional pumped hydro storage. Heat storage will require an extensive network of underground heat transport and storage. Urban lifestyles represent a challenge to cities characterized by a high proportion of disposable items and carbon-intensive eating habits. Cities face a data collection challenge to manage their pathway towards carbon neutrality. Four categories of data should be collected annually or in shorter intervals and ideally be compatible with GIS systems, which will allow local data to be merged with near real-time satellite or air-borne data. Data should be made public and disseminated in machine-readable format. Data that is part of an accounting standard with sustainability requirements (e.g. GRI or ESG) will become cheaper to collect due to scale effects. Disasters are a great challenge to APEC cities which are affected by disasters more than global average. In 279 cities worldwide, the annual loss of GDP due to disasters is greater than their annual GDP growth. The mortality rate of disasters has drastically fallen since 1960, but the economic losses due to disasters are increasing.

Key Findings – Chapter 2

Green Finance instruments have been developed to bridge the financing gap of the green energy transition. Credit risk guarantees (CRG) are increasingly being used to de-risk renewable energy investments which are still perceived as having higher risks than fossil-based investments. CRG are granted as collateral to banks financing RE investments. The theoretical analysis determines the factors on which depend the optimal credit guarantee ratio for renewable energy (RE) loans. CRGs can be used to back green bonds, in conjunction with data-driven risk assessment, sustainability linked lending, green finance certification, and regulatory sandboxes experimenting with innovation. The analysis of CRGs in Metropolitan Manila involves the special Philippine context which is characterized by a moratorium on new coal power plants, the plan to massively scale up imported LNG, and the experienced failure of feed-in-tariffs which, due to a design problem, failed to increase renewables share but increased general electricity rates for the poor. The Philippines' electricity system is divided into three separated grids covering Luzon, the Visayas and Mindanao, respectively. Hydropower and geothermal remain the largest renewable sources. All the institutions of a modern power market are in place in the Philippines: transmission grid, the Energy Regulatory Commission ERC, the Philippine Wholesale Electricity Spot Market WESM, regulations favouring rural electrification by microgrid, possibilities for end-users demanding above 1MW to request market access as contestable consumers whereas the 1MW limit is gradually being lowered to 750 and 500kW. Policies on renewables have started in 2010 with feed-in-tariffs, complemented with renewable portfolio standards (2017/18) and a green auction energy program (2020) under which auctions for renewable energy started in 2022. It expects to achieve a 35% RE share in the economy's total power generation by 2030 and 50% by 2040. Philguarantee is the publicly owned Philippine guarantee institution. It provides several types of credit risk guarantees for large enterprises of both, the renewable and the conventional energy segments. Since the COVID-19 pandemic, CRGs for micro, small, and medium enterprises (MSMEs) have been added. The idea of a Global Credit Guarantee Facility (GCGF), formulated by the Climate Policy Initiative in 2023, could be explored further. The Philippines could develop this idea in the framework of the APEC Energy Working Group and APEC cross-fora cooperation.

The Cities Climate Finance Leadership Alliance (CCFLA), launched in 2014 by the United Nations, is the only multi-level and multi-stakeholder coalition of leaders committed to deploying city-level finance by 2030. CCFLA brings together over 80 member institutions covering a wide spectrum of institutions committed to boosting urban climate finance. The 2019 CCFLA report on the State of Cities Climate Finance provided the first comprehensive estimate of global urban climate finance and investment gaps. Of the USD5 trillion needed annually, only USD384 billion have been made available. CCFLA's net-zero carbon buildings workstream analysed four categories of barriers to investment in green or zero-carbon buildings: financial, investment risk/opportunity, market readiness, and regulatory barriers. CCFLA mapped policy and financial instruments that cities can use to drive investment in zero-carbon buildings and target four high-impact thematic areas: (1) cooling technologies, (2) embodied carbon (in construction activities), (3) adaptation, and (4) just transition. Two mechanisms were found to be particularly impactful for cities to install various types of low-carbon equipment – cooling being one of them – with no upfront cost: PACE (Property assessment for clean energy) and PAYS (Pay-as-you-save). Both mechanisms require implementation of several other measures, not all of which can be fully supported by cities alone.

Financing the circular economy of smart cities relies on four elements of success: 1) a solid business case such as Product-as-a-Service, Industrial Symbiosis, Closed Loop, Upcycling and Downcycling; 2) Infrastructure, especially financial infrastructure designed e.g. to co-finance a return scheme of materials to urban miners, i.e., companies that extract materials from waste and taxing polluters, 3) education, including engineering all aspects of the circular economy, 4) mindset, especially concerning financing decisions that far too frequently continue to rule out investing in viable circular companies due simply because these decisions are made with old knowledge, as well as, with a decades old mindset.

Carbonomics is a dynamic concept putting the carbon economy at the heart of climate-smart cities aiming to balance economic development with environmental responsibility. Cities often host fortune 500 companies which face similar problems like cities. Most of them incorporate ESG standards into their decision to enhance their market value, but they suffer from the vague definition of these standards. The compliance markets under Paris Agreement's Article 6.4 are set to increase to USD5-6 trillion by 2030, accelerated by the Carbon Border Adjustment Mechanism CBAM of the EU. The voluntary carbon markets VCM are less regulated, offer much lower carbon prices and greater potential for greenwashing. The EU Emissions Trading System continues to serve as a guide for global markets. To better capture emissions from embodied energy, smart cities are changing the method from production-based inventories to consumption-based inventories (CBI). Carbon Monitor Cities prepares near-real-time daily estimates of GHG emissions from 1,500 cities worldwide. Carbon Monitor Europe utilizes a daily tracking methodology capturing timely data on emissions across six sectors (power, industry, ground transportation, domestic and international aviation, and residential areas). Carbon rating agencies are shifting from analysing individual projects and sectors toward city-level, consumption-based GHG emissions assessments, but suffer from lack of universally accepted standards for quality assessments. A new series of VCMs has been evolving among others in Australia (Emissions Reduction Fund (ERF, 2014), US (Energy Transition Accelerator, 2022) and Japan (GX League, 2022). APEC cities can use a variety of financing mechanisms, among them concessional loans, insurance mechanisms, voluntary and cross-border carbon markets, or the usual green finance instruments such as green bonds.

Leveraging carbon neutrality incentives can be done through sustainability accounting. Environmental, social and governance (ESG) information is a subset of sustainability accounting. The outside-in approach describes the investor’s view of how ‘external’ forces such as climate change impact the firm and more specifically, its cash flows. This approach is exemplified in the recent (2023) accounting standards of the International Sustainability Standards Board (ISSB). The complementary inside-out approach describes a multi-stakeholder view of how the firm/city impacts on the world. It is exemplified in the Global Reporting Initiative (GRI 2021). Cities are more likely to use the inside-out approach. The SDGs, if applied to cities, are an example of an inside-out approach. Another approach uses the concept of the nine planetary boundaries (maximum planetary limits) which can be combined with the 12 elements of social foundation (minimum social needs) to yield the doughnut model which has been applied by the city of Amsterdam. Cities can use this framework in an 8-step procedure.

Accounts-based sustainability indicators for cities are developed by using an agent-based presentation of interactions among urban sectors (primary, secondary, tertiary, government, consumers and the rest of the world) and adding the industrial capital formation or consumption account. The three definitions of the GDP are derived and illustrated at the example of Hong Kong, China. It is shown that if public policy drives the energy transition, it should do so by public procurement rather than by subsidies and should be financed by the polluter pays principle. By generalizing the capital formation or consumption from the usual industrial capital to other forms of capital (environmental, human, financial), the generalized GDP can be defined which should better be called Gross Holistic Product GHP. It contains information that is collected in the System of Environmental-Economic Accounting (at the macro-level) and corresponds to corporate-level GRI or ESG information. From this, the Net Holistic Surplus as universal measure for sustainability is defined. The analysis also identifies the eight categories of sustainable or unsustainable cities.

Key Findings – Chapter 3

The Global Covenant of Mayors for Climate and Energy (GCoM) was created as organization to mitigate emissions of greenhouse gases, but the objectives of adaptation and energy access or energy mitigation have been added. GCoM is collecting data from its cities according to the Common Reporting Framework launched in 2018. The commitment of over 9,500 GCoM members is to set goals at least as ambitious as the NDC of their respective economy. At present, even the more ambitious goals of GCoM members do yet suffice to achieve the 1.5°C target of the Paris Climate Agreement. The data portal for cities contains information on 60,000 cities and communities, but it is not always up to date. GCoM and the Environmental Insights Explorer from Google have developed a tool for territorial information.

CDP is a global non-profit organization running the world’s largest environmental disclosure system for investors, companies, cities, states, and regions. In 2019, CDP and ICLEI - Local Governments for Sustainability established a unified climate reporting platform for local governments, known as CDP-ICLEI Track. Utilized by over 1,000 cities globally in 2022, CDP-ICLEI Track is one of the official reporting platforms for reporting to the Global Covenant of Mayors for Climate & Energy (GCoM), C40 Cities Climate Leadership Group, WWF’s One Planet City Challenge, as well as the United Nations’ Race to Zero and Race to Resilience. Cities supply data and information on overarching topics by questionnaire. Over half of all disclosing cities worldwide in 2022 were from APEC economies, nearly 80% of reporting APEC cities currently intend to identify emission sources and track its progress in its emission reduction targets. 80% of cities face extreme climate hazards, with 25% reporting that at least 70% of their population is threatened, requiring resilience measures. Cities face an estimated annual financing gap of nearly USD4 trillion globally to attain their long-term climate goals.

The APEC City Stats Platform has been set up to collect urban data in two dimensions (sustainability and disaster resilience) and three levels (communities of all size, medium-sized cities, and large cities.

San Francisco plays a pioneering role of climate actions in the State of California, just like the role that California plays in being a pioneer of climate actions in the U.S. San Francisco has reduced the emissions by about 30% below the 1990 level while it has increased its population by 20% and doubled its GDP in the last 20 years. California is committing to net zero for 2045, whereas San Francisco is setting the net zero goal for 2040. The key for success is the close cooperation of municipal authorities with economic and social stakeholders as well as the declaration of climate emergency in 2019 after a series of severe wildfires and droughts.

The Greater Washington Region Clean Cities Coalition is a public-private partnership covering DC, Maryland and Virginia. It was created in 1993 by President Bill Clinton. The priorities are on capacity building and electrification of transport. Since 1993, the GWRCCC has avoided approximately 42,250,000 tons of oil equivalent. The Bi-Partisan Infrastructure Law and Inflation Reduction Act provides for a further USD21.5 billion in funding for clean energy demonstrations and research hubs.

The city of Temuco, Chile, counts 300,000 citizens. Electrification rate is at only 26%. 81% of households use firewood for heating contributing to 94% of PM2.5 black carbon emissions which stay in the atmosphere for only days to weeks, but their warming potential is 1500 times as high as CO_2. Chile's NDC recognizes black carbon as a source to be included in carbon neutrality. Actions include thermal improvement of homes, replacement of heaters, development of district energy projects and monitoring black carbon emissions.

Recommendations

APEC cities should take an active role in shaping their energy supply and storage by public procurement (internationally competitive tendering) financed through the polluter pays principle (tradable certificates on compliance or voluntary markets, incentive taxes) or by the creation of green equity or the emission of green bonds backed by credit risk guarantees.

APEC should organize online or in-person capacity building for APEC cities on these issues within the framework of the APEC Energy Working Group (EWG) or its sub-groups.

APEC Energy Working Group (EWG), in cooperation with the Government of the Philippines, involving APEC cities and International Financial Institutions, may wish to explore the creation of an APEC-wide Credit Risk Guarantee for renewable electricity.

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1. Overview and Challenges

Since the Climate Neutral Network (CN Net) launched in 2008, net zero pledges have mushroomed making greenwashing become the main problem. UN decided to phase out its Climate Neutral Now Initiative by the end of 2024 and replace it by the Race to Zero and Race to Resilience initiatives, respectively. The Race to Zero comprises more than 1,000 cities worldwide pledging to net-zero by mid-century or sooner. Commitments must be made under a catalogue of stricter rules and principles. Atmospheric CO2 concentration continues to rise by 2ppm (part per million) every year, overtaking the 420ppm mark with no flattening in sight, compared to 200-300ppm during the last million years.

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1.1. Overview of Carbon Neutrality

1.1.1. Global Stocktake of Carbon Neutrality Pledges

Back in 2008, when the UNEP launched the Climate Neutral Network (CN Net), there were four economies (Costa Rica, Iceland, New Zealand and Norway)[1], four cities (Rizhao in China, Arendal in Norway, Vancouver in Canada and Växjö in Sweden)[2] as well as five corporations (Co-operative Financial Services from England, Interface Inc. from the United States, Natura from Brazil, Nedbank from South Africa and Senoko Power from Singapore)[3] that pledged to work towards the objective of climate neutrality. APEC was represented among the first movers in all three categories: economies, cities and corporations, respectively.

By 2023, the situation has totally changed. The pledges for carbon neutrality have mushroomed to such an extent that greenwashing has become the major problem. Greenwashing risked undermining the credibility and the meaning of carbon pledges. As a consequence, the UN decided to draw down the Climate Neutral Now Initiative[4] and set the timetable for its phasing out as follows (quote from the UNFCCC website):

- *Pledges will be received until 31 July 2023. After this date, no new pledges will be accepted;*
- *The 2023 calendar year is the last year for monitoring under Climate Neutral Now;*
- *Reports on 2023 emissions (or earlier years) will be received until 30 June 2024. After this deadline, no further reports will be accepted;*
- *Visual assets demonstrating participation in the initiative may be used until 31 December 2024.*

As an alternative, the UN offers its initiative based on two pillars called Race to Zero[5] and Race to Resilience[6], respectively. The Race to Zero comprises 11,000 members in all categories and is acting through 26 initiatives and networks. Their members have pledged to a common objective by setting 2050 as target date for net zero and setting the intermediary 2030 objective of halving the emissions by 2030, while abiding by well-defined methodologies involving strict control and transparency.

For cities, the Cities Race to Zero now comprises more than 1,000 cities worldwide which are pledging to net-zero in the 2040s or sooner, or by mid-century at the latest, and set an intermediary target showing their share in achieving a 50% global emissions reduction by 2030[7].

The Race to Resilience is a relatively young initiative and little information is available about its membership. It aims to catalyse action by non-state actors to build the resilience of 4 billion people from vulnerable groups and communities to climate risks. The Cities Race to Resilience is the organization specially designed for cities.

Prior to the decision to draw down the Climate Neutral Now Initiative, the UN Secretary General established a high-level group in 2022 to investigate the Credibility and Accountability of Net-Zero Emissions Commitments of Non-State Entities[8]. Its report was released in November 2023 under the title Integrity Matters: Net Zero Commitments by Business, Financial Institutions, Cities and Regions[9]. Net zero commitments shall be based upon five principles (quoted from the report):

1. *Ambition which delivers significant near— and medium —term emissions reductions on a path to global net zero by 2050*
2. *Demonstrated integrity by aligning commitments with actions and investments*
3. *Radical transparency in sharing relevant, non-competitive, comparable data on plans and progress*
4. *Established credibility through plans based in science and third-party accountability*
5. *Demonstrable commitment to both equity and justice in all actions*

Furthermore, the high-level group formulated the 10 following recommendations to guide the process (quoted from the report):

***1. Announcing a Net Zero Pledge**: A net zero pledge should be made publicly by the leadership of the non-state actor and represent a fair share of the needed global climate mitigation effort. The pledge should contain interim targets (including targets for 2025, 2030 and 2035) and plans to reach net zero in line with IPCC or IEA net zero greenhouse gas emissions modelled pathways that limit warming to 1.5°C with no or limited overshoot, and with global emissions declining by at least 50% by 2030, reaching net zero by 2050 or sooner. net zero must be sustained thereafter.*

***2. Setting Net Zero Targets**: Non-state actors must have short-, medium- and long-term absolute emissions reduction targets and, where appropriate, relative emissions reduction targets across their value chain that are at least consistent with the latest IPCC net zero greenhouse gas emissions modelled pathways that limit warming to 1.5°C with no or limited overshoot, and where global emissions decline at least 50% below 2020 levels by 2030, reaching net zero by 2050 or sooner.*

***3. Using Voluntary Credits**: Non-state actors must prioritise urgent and deep reduction of emissions across their value chain. High integrity carbon credits in voluntary markets should be used for beyond value chain mitigation but cannot be counted toward a non-state actor's interim emissions reductions required by its net zero pathway. High-integrity carbon credits are one mechanism to facilitate much-needed financial support towards decarbonizing developing economies. As best-practice guidelines develop, non-state actors meeting their interim targets on their net zero pathway are strongly encouraged to balance out the rest of their annual unabated emissions by purchasing high-integrity carbon credits. A high-quality carbon credit should, at a minimum, fit the criteria of additionality (i.e. the mitigation activity would not have happened without the incentive created by the carbon credit revenues) and permanence.*

***4. Creating a Transition Plan**: Non-state actors must publicly disclose comprehensive and actionable net zero transition plans which indicate actions that will be undertaken to meet all targets, as well as align governance and incentive structures, capital expenditures, research and development, skills and human resource development, and public advocacy, while also supporting a just transition. Transition plans should be updated every five years and progress should be reported annually. City or regional plans must:*

• Constitute a document (or series of documents) which lays out a strategic roadmap for reducing greenhouse gas emissions and strengthening climate resilience across the community.

• Be based on community engagement and consultation, and build in ongoing engagement, in particular with marginalised groups, workers and frontline communities.

• Include an assessment of existing conditions including baseline emissions, regular greenhouse gas inventories, a long-term emissions trajectory, accountability measures, climate risks and socioeconomic priorities.

•Cover all greenhouse gases for scope 1 and 2 for transport and stationary energy (buildings and facilities), and scope 1 and 3 for waste, per the Global Protocol for Community-Scale Greenhouse Gas Inventories. Emissions apply to the geographic area of the city and are not limited to a city government's operations. Large cities should make every

effort to report on scope 3 emissions, in particular those associated with sources of revenue and expenditure under the control of the revenue generating authority.

• Develop a detailed overview of the strategies and actions that cities will pursue for achieving reductions in greenhouse gas emissions and improvements in climate resilience over time, and the processes of monitoring, evaluation, reporting and revision.

***5. Phasing out of Fossil Fuels and Scaling Up Renewable Energy**: All net zero pledges should include specific targets aimed at ending the use of and/or support for fossil fuels in line with IPCC and IEA net zero greenhouse gas emissions modelled pathways that limit warming to 1.5°C with no or limited overshoot, with global emissions declining by at least 50% by 2030, reaching net zero by 2050. The transition away from fossil fuels must be just for affected communities, workers and all consumers to ensure access to energy, and avoid transference of fossil fuel assets to new owners. The transition away from fossil fuels must be matched by a fully funded transition toward renewable energy. For cities and regions:*

• On coal for power generation: (i) not allow permits for expansion of coal reserves, (ii) not allow development and exploration of new coal mines, (iii) not allow extension of existing coal mines, and (iv) no coal plants by 2030 in OECD countries and in the rest of the world by 2040.

• On oil and gas: (i) not allow permits for exploration for new oil and gas fields, (ii) not allow expansion of oil and gas reserves, and (iii) end oil and gas production.

• New fossil fuel-based electricity generation should not be permitted.

***6. Aligning Lobbying and Advocacy**: Non-state actors must align their external policy and engagement efforts, including membership in trade associations, to the goal of reducing global emissions by at least 50% by 2030 and reaching net zero by 2050. This means lobbying for positive climate action and not lobbying against it.*

***7. People and Nature in the Just Transition**: As part of their net zero plans, businesses, cities and regions with material land-use emissions must achieve and maintain operations and supply chains that avoid the conversion of remaining natural ecosystems— eliminating deforestation and peatland loss by 2025 at the latest, and the conversion of other remaining natural ecosystems by 2030. Financial institutions should have a policy of not investing or financing businesses linked to deforestation and should eliminate agricultural commodity-driven deforestation from their investment and credit portfolios by 2025, as part of their net zero plans.*

***8. Increasing Transparency and Accountability**: Non-state actors must annually disclose their greenhouse gas data, net zero targets and the plans for, and progress towards, meeting those targets, and other relevant information against their baseline along with comparable data to enable effective tracking of progress toward their net zero targets. Non-state actors must report in a standardised, open format and via public platforms that feed into the UNFCCC Global Climate Action Portal to address data gaps, inconsistencies and inaccessibility that slow climate action. Non-state actors must have their reported emissions reductions verified by independent third parties. Special attention will be needed to build sufficient capacity in developing countries to verify emission reductions. Disclosures ought to be accurate and reliable. Large financial and non-financial businesses should seek independent evaluation of their annual progress reporting and disclosures, including opinion on climate governance, as well as independent evaluation of metrics and targets, internal controls evaluation and verification on their greenhouse gas emissions reporting and reductions. A global central digital repository of climate disclosures that encompasses all* *reporting data points is needed (such as efforts to create the net zero Data Public Utility (NZDPU)). It is important that the open-source repository is:*

• able to accommodate varied levels of reporting capacity;

• accessible to all users while enabling non-state actors across the world to upload information at no extra cost (e.g. an agreed electronic format that allows easy bulk extraction);

• able to include data quality information and data validation checks to ensure it contains high-quality reliable and usable information;

• consistent with the recommendations of this expert group to the template and record level;

• overseen by the UNFCCC and feeds into its Global Climate Action Portal.

***9. Investing in Just Transitions**: To achieve net zero globally, while also ensuring a just transition and sustainable development, there needs to be a new deal for development that includes financial institutions and multinational corporations working with governments, Multilateral Development Banks and Development Finance Institutions to consistently take more risk and set targets to greatly scale investments in the clean energy transition in developing countries. Cities and regions:*

• Funding the transition is a key issue for cities and regions. Greater technical assistance is needed to enable cities to: (i) compete for domestic and international funds, (ii) structure infrastructure decarbonisation projects to be attractive to private finance either through green bonds or direct third-party investment, and (iii) utilise funding equitably for residents by facilitating just transition mechanisms at a local level (e.g. engaging with stakeholders, skills development, employment pathways, guaranteeing access to green jobs, etc.).

• Development banks must establish dedicated urban climate funds that city governments can access to develop projects and leverage private investment, particularly for Global South cities.

***10. Accelerating the Road to Regulation**: In order to ensure rigour, consistency and competitiveness, regulators should develop regulation and standards in areas including net zero pledges, transition plans and disclosure, starting with high-impact corporate emitters, including private and state-owned enterprises and financial institutions. The challenge of fragmented regulatory regimes should be tackled by launching a new Task Force on net zero Regulation that convenes a community of international regulators and experts to work together towards net zero.*

The global stocktake of sustainability and carbon neutrality should contain some information on the current evolution of atmospheric CO2 concentration. Atmospheric CO2 concentration is the key indicator for global climate change. Atmospheric CO2 has been growing in the recent decades at annual rates of around 2ppm (parts per million) and is now attaining 420ppm. The observations of Mauna Loa Observatory of Hawaii (picture below on the left) are taken to illustrate the increase of concentration since 1960[10]. The Mauna Loa observations may slightly diverge from global average concentration given in the picture below on the right[11].

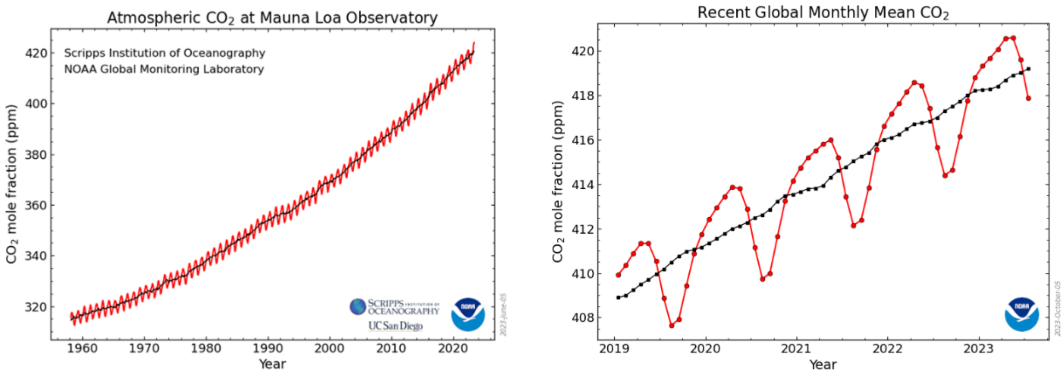

Figure 1: Rising CO2 concentration in the atmosphere

Source: NOAA Global Monitoring Laboratory

Looking at this data with bare eyes one could believe that the growth of atmospheric CO2 concentration is stronger than linear. Regardless of all policies proclaimed and enacted, the stock of atmospheric CO2 seems still to be out of control. By bare eyeballing, it seems not even slowing down. This visual impression might however be wrong. Only data analysis can tell whether there is a peaking ahead or not.

It is necessary to give an idea of what a CO2 concentration of 420ppm means in the long-term perspective. For this purpose, it can be recalled that during the past million years, CO2 concentrations varying between 200 and 300ppm were sufficient to control whether there was an ice age or not. Compared to these long-term historical values, today's CO2 concentrations above 400ppm may inaugurate a hot age, distinctively different from the ice ages and its intermittent warmer periods.

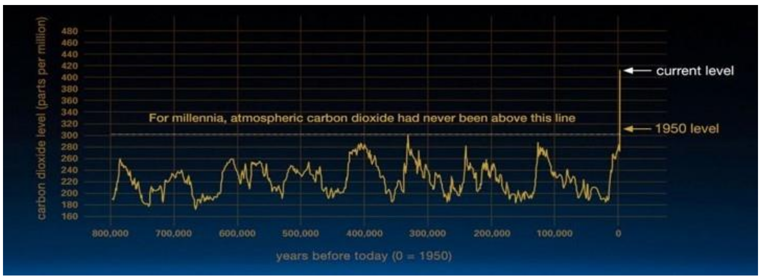

Figure 2: Atmospheric CO2 concentration of the last million years

Source: The Nature Conservancy[12]

The relative role of CO2 emissions and CO2 removals, respectively, can be shown in the waterfall diagram below, showing the year 2021. In 2021, CO2 emissions from fossil fuels and burning biomass were too high compared to the combined removal capacity of the land masses and oceans. CO2 that is not removed by land and oceans will stay in the atmosphere for centuries. This causes the present 2ppm annual increase of CO2 concentration in the atmosphere.

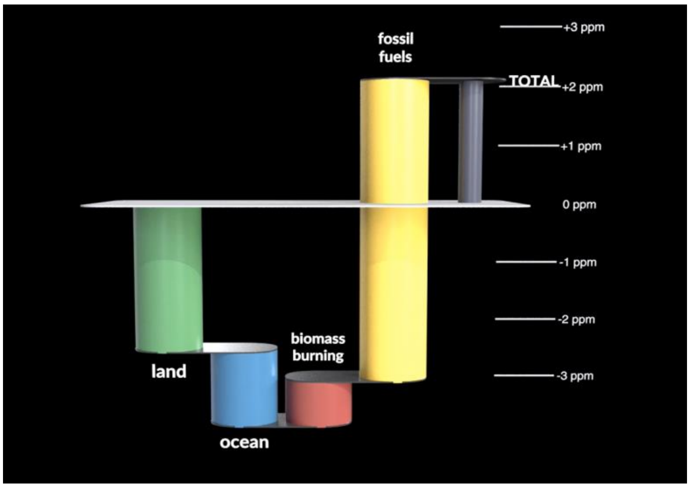

Figure 3: Role of CO2 emissions and CO2 absorptions during the year 2021

Source: NASA Scientific Visualization Studio[13]

It should always be stressed that CO2 is not the only greenhouse gas. However, due to its mean duration in the atmosphere of several hundred years and its constantly increasing net emissions rate, CO2 qualifies as the most important greenhouse gas and the key to regulate global mean temperature. In this context, it is important to recall the distinction between carbon neutrality (referring only to CO2) and climate or GHG neutrality (referring to all greenhouse gases. The IPCC glossary to the IPCC special report on the impacts of global warming of 1.5°C[14] defines the term of carbon neutrality as follows:

Carbon neutrality: *Condition in which anthropogenic carbon dioxide (CO_2) emissions associated with a subject are balanced by anthropogenic CO_2 removals. […] carbon neutrality generally includes emissions and removals within and beyond the direct control or territorial responsibility of the reporting entity.*

The present report focuses on carbon neutrality or, more precisely, on how the energy sector influences carbon neutrality.

1.2. Challenges of Carbon Neutrality for APEC Cities

Sections 1.2.1. to 1.2.4. contain the broad challenges identified as such under specific headings as shown below. Other challenges have been described in section 2.1.7. Carbonomics for Climate-Smart Cities, and in section 2.1.2. The Role of Credit Guarantee Schemes in Renewable Energy Development: A Theoretical and Policy Analysis.

1.2.1. The Density Challenge of Cities Facing Renewable Energy

Cities are known to be dense places facing congestions on roads and other infrastructures. The transformation to carbon neutral cities is rising a density challenge, complementary to the already existing congestion challenge. The critical challenge of cities planning to adopt the generation of renewable energy lies in the very nature of cities as concentrated high-density communities. This is difficult to reconcile with the deployment of renewable energies which requires large amounts of land resources.

The Five Principles for sustainable neighbourhood planning published by UNHABITAT in 2015[15] propose a minimum density for a sustainable city to be 15,000 inhabitants/km2, or 150 inhabitants per ha, or 1.5 inhabitant per are or 67m2/person (at ground level equivalent with floor area ratio equals 1). High population density is important for cities to maintain their comparative advantage in economies of scale, allowing cities to perform their role as engines of economic growth.

The population density of cities varies strongly within the cities as well as between the cities. The density is calculated by dividing the population by the administrative area of the city. This gives an average density. High density districts can have a much higher population density than the city average. Take the examples of Hong Kong China or Tokyo, whose average densities is around 6400 people per km2 for both cities. The neighbourhood around Mong Kok[16] reaches, however, a population density of 130,000 inhabitants/km2 and a floor area of 37m2/person for the surrounding Yao Tsim Mong district[17] which could well be the most densely populated area worldwide. The table below shows a selection of densely populated APEC cities calculated as average population density.

City	Population	Area km^2	Density per km^2	Economy	Year
Manila (Metro Manila)	1,846,600	43	43,064	The Philippines[18]	2020
Mandaluyong (Metro Manila)	425,758	11	38,495	The Philippines	2020
Pateros (Metro Manila)	65,227	2	37,061	The Philippines	2020
Caloocan (Metro Manila)	1,661,584	53	31,233	The Philippines	2020
Makati (Metro Manila)	629,616	22	28,975	The Philippines	2020
Pasig (Metro Manila)	803,159	31	25,530	The Philippines	2020
Pasay (Metro Manila)	440,656	19	23,640	The Philippines	2020
Navotas (Metro Manila)	247,543	12	21,507	The Philippines	2020
San Juan (Metro Manila)	126,347	6	21,524	The Philippines	2020
Marikina (Metro Manila)	456,059	23	20,144	The Philippines	2020
Union City (New Jersey)	66,455	3	20,047	United States[19]	
West New York (N Jersey)	49,708	3	19,060	United States	
Las Piñas (Metro Manila)	606,293	32	18,935	The Philippines	2020
General Mariano Alvarez	172,433	9	18,344	The Philippines	2020
Hoboken (New Jersey)	60,417	3	18,225	United States	2020

Table 1: Selection of some densely populated APEC cities

Source: APSEC

The global per capita total final energy consumption per year has peaked in 2018 at a level of 15MWh/person/year It will be slowly declining to 10.5MWh/person/year until the end of the century. For APEC economies, per capita TFC is shown in the table below. For future decades it expected that per capita TFC of those economies with low per capita TFC will increase, and per capita TFC of those economies with high per capita TFC will decrease. It is not expected, however, that per capita TFC of all economies converges to the same average level.

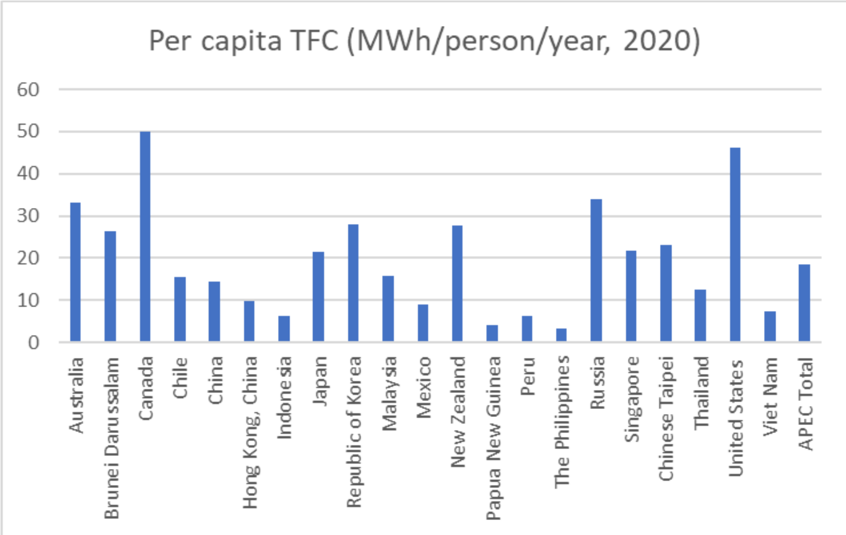

Figure 4: Per capita total final energy consumption of APEC economies for 2020

Source: APSEC based on StatsAPEC and EGEDA data

The theoretical potential for solar energy in global average can be calculated from the global energy balance. APEC Sustainable Urban Development Report pointed out that the incoming solar power in global and geographic average is 198W/m2 corresponding to 4.751kWh/day/m2 or 1735MWh/year/m2. The figure also allows showing the maximum theoretic potentials of wind energy (24W/m2) and hydropower (78W/m2) which are less than the theoretical potential of solar irradiation.

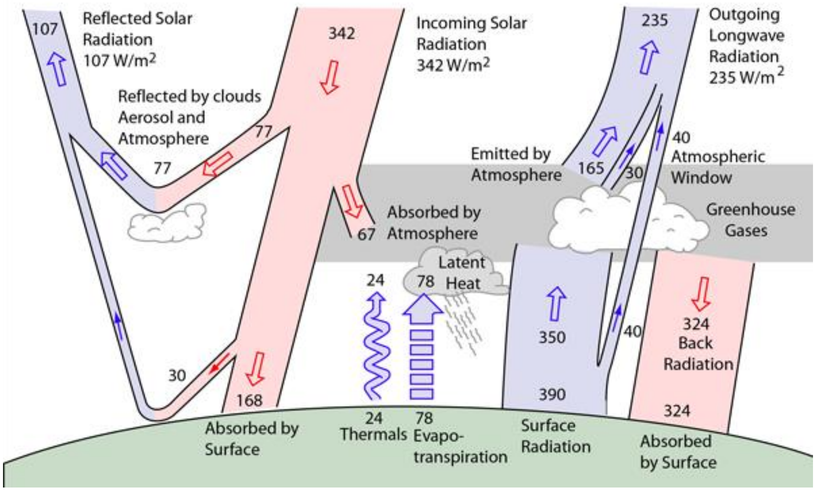

Figure 5: Global energy balance

Source: Kiehl & Trenberth[20]

To see which region has higher or lower photovoltaic potential, respectively, than the mentioned global average, this theoretical average potential has been mapped to the different regions of the globe. The PVOUT map published by the World Bank shows that above average solar PV potential is available in some areas in Australia; China; Chile; Maxico; Peru;

and the USA. However, all APEC economies have areas with higher than 3kWh/kWp potential, which is sufficient for making it available at current cost. Note that the PV potential is slightly different from the potential for concentrated solar power (CSP) which is shown in the Direct Normal Irradiation (DNI) map, also published by the World Bank.

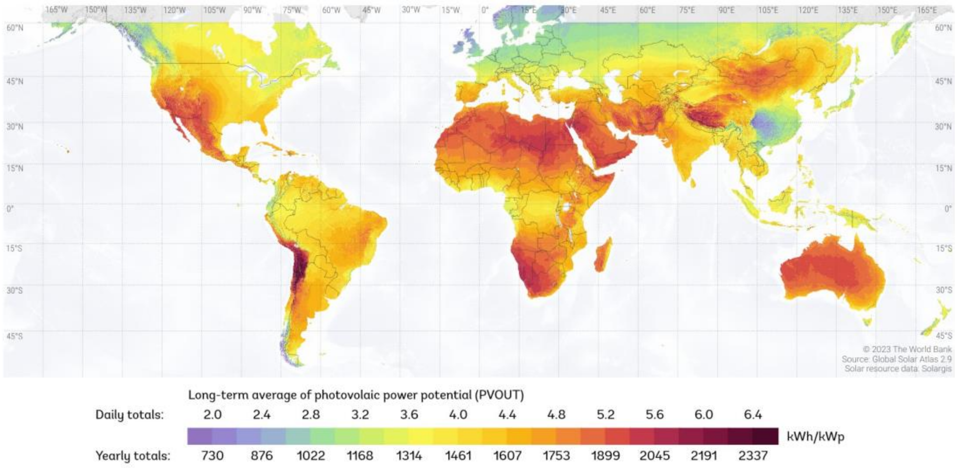

Figure 6: Global distribution of the PV potential (PVOUT map)

Source: Global Solar Atlas[21]

The practical potential of solar energy is given by the PVOUT value of each place, measured in terms of kWh/kWp, where kWp is the installed nominal capacity. The number of square meters PV corresponding to 1KWp depends on the type of panel and technology used. Using one of the most popular types of solar panels will require around 5.3m2 for a 1kWp installation[22]. The table below shows the per capita area of solar panels (in m2/person) to cover the annual total final energy, depending on irradiance (horizontal) and TFC of each APEC economy (vertical), where the latter are ordered by size. The concept of Decent Living Standards, mentioned in the table below, corresponding to 5MWh/year/person can be used to address this challenge.

As an example, how to read the table below, for covering the per capita TFC of the world by using the average global irradiance of 4.752kWh/day/kWp or 1736kWh/year/kWp, it requires an area of 46.15m/person of PV panels. Other example: to cover today's per capita TFC of Indonesia, which is mostly located in the 3.6kWh/day/kWp irradiance zone, it will require an area of 25.9m2/person of PV panels. As Indonesia wants to catch up and gradually approach world average per capita TFC level, this will require 60.92m2/person of PV panels. Note that 93% of the global population lives in areas where the average daily PV potential is in the range between 3 and 5kWh/kWp[23], equivalent to an annual PV potential between 1.1MWh/kWp and 1.8MWh/kWp.

	Daily totals kWh/kWp	2	2.4	2.8	3.2	3.6	4	4.4	4.752	4.8	5.2	5.6	6	6.4
	Yearly totals kWh/kWp	731	877	1023	1169	1315	1461	1607	1736	1753	1899	2045	2192	2338
TFC	(MWh/person), year 2020													
3.226	The Philippines	23.41	19.51	16.72	14.63	13.00	11.70	10.64	9.85	9.75	9.00	8.36	7.80	7.31
4.017	Papua New Guinea	29.15	24.29	20.82	18.22	16.19	14.57	13.25	12.27	12.14	11.21	10.41	9.72	9.11
5.000	Decent Living Standard	36.28	30.23	25.91	22.67	20.15	18.14	16.49	15.27	15.12	13.95	12.96	12.09	11.34
6.172	Peru	44.78	37.32	31.99	27.99	24.88	22.39	20.35	18.85	18.66	17.22	15.99	14.93	13.99
6.425	Indonesia	46.61	38.85	33.30	29.13	25.90	23.31	21.19	19.62	19.42	17.93	16.65	15.54	14.57
7.464	Viet Nam	54.15	45.13	38.68	33.85	30.09	27.08	24.62	22.79	22.56	20.83	19.34	18.05	16.92
9.015	Mexico	65.40	54.50	46.72	40.88	36.34	32.70	29.73	27.53	27.25	25.16	23.36	21.80	20.44
9.951	Hong Kong, China	72.20	60.17	51.57	45.12	40.11	36.10	32.82	30.39	30.08	27.77	25.79	24.07	22.56
12.646	Thailand	91.75	76.46	65.54	57.34	50.97	45.88	41.71	38.62	38.23	35.29	32.77	30.58	28.67
14.538	China	105.48	87.90	75.34	65.92	58.60	52.74	47.94	44.39	43.95	40.57	37.67	35.16	32.96
15.115	World	109.66	91.38	78.33	68.54	60.92	54.83	49.85	46.15	45.69	42.18	39.16	36.55	34.27
15.645	Chile	113.51	94.59	81.08	70.94	63.06	56.75	51.59	47.77	47.29	43.66	40.54	37.84	35.47
15.889	Malaysia	115.28	96.06	82.34	72.05	64.04	57.64	52.40	48.52	48.03	44.34	41.17	38.43	36.02
18.505	APEC	134.26	111.88	95.90	83.91	74.59	67.13	61.03	56.51	55.94	51.64	47.95	44.75	41.96
21.543	Japan	156.30	130.25	111.64	97.69	86.83	78.15	71.04	65.78	65.12	60.11	55.82	52.10	48.84
21.740	Singapore	157.73	131.44	112.67	98.58	87.63	78.87	71.70	66.39	65.72	60.67	56.33	52.58	49.29
23.040	Chinese Taipei	167.16	139.30	119.40	104.48	92.87	83.58	75.98	70.35	69.65	64.29	59.70	55.72	52.24
26.412	Brunei Darussalam	191.62	159.69	136.87	119.77	106.46	95.81	87.10	80.65	79.84	73.70	68.44	63.87	59.88
27.613	New Zealand	200.34	166.95	143.10	125.21	111.30	100.17	91.06	84.32	83.48	77.05	71.55	66.78	62.61
28.069	Korea	203.65	169.71	145.46	127.28	113.14	101.83	92.57	85.71	84.85	78.33	72.73	67.88	63.64
33.283	Australia	241.48	201.23	172.49	150.92	134.16	120.74	109.76	101.63	100.62	92.88	86.24	80.49	75.46
34.061	Russia	247.12	205.93	176.51	154.45	137.29	123.56	112.33	104.01	102.97	95.05	88.26	82.37	77.23
46.145	United States	334.80	279.00	239.14	209.25	186.00	167.40	152.18	140.91	139.50	128.77	119.57	111.60	104.62
50.010	Canada	362.83	302.36	259.17	226.77	201.57	181.42	164.92	152.71	151.18	139.55	129.58	120.94	113.39

Table 2: Required PV area (m2/person) as a function of irradiance and per capita TFC

Source: APSEC

Reverting to the density challenge, the above figures allow illustrating that due to the population density, it is only under exceptional circumstances possible for a city to satisfy its energy needs locally, i.e., to produce its energy within the city boundaries. The table below calculates the percentage of land area required for PV as a percentage of the total available land area for four different APEC cities. Manila City which is very densely populated but has a low per capita TFC and the highest irradiance of the compared cities, would require 116% of its total land area to satisfy its energy needy by means of PV solar energy produced locally. The calculation for Metro Manila, comprising the surrounding cities and whose population density is roughly half the density of Manila City, shows a need of 59% of its total land area to produce its energy locally. Hong Kong, China (HKC), due to its relatively lower average population density and its per capita TFC being only little higher than the one of Manila, would require only 28% of its area to power its TFC with locally produced PV energy. Lastly, Singapore, having a population density of 86 persons/ha and the highest TFC of the four cities, would require 77% of its area to satisfy its TFC by PV energy.

TFC/person (MWh/person)	City	Pop density (pers/km2)	Pop density (pers/ha)	PVOUT (kWh/kWp)	Required per capita PV area (m2/person)	Required PV area (m2/ha)	Percentage of land area required for PV (%)
7.000	Manila City	43064	431	1376	26.96	11611	116
7.000	Metro Manila	22000	220	1376	26.96	5932	59
9.951	Hong Kong, China	6400	64	1159	44.48	2847	28
21.740	Singapore	8592	86	1287	89.51	7691	77

Table 3: Required PV area for four APEC cities as a function of the specific city parameters

Source: APSEC

1.2.2. Urban Energy Challenges

Authored by Yin Baoquan and Huo Yujiao, APSEC

Urban energy supply and energy efficiency

In the context of urban energy transformation, in response to conflicts of interest and policy mismatches between traditional energy sources and new energy generation, policies related to new energy generation should be adjusted in due course, the current benchmark tariff policy should be reformed, and a renewable energy quota system and a green card trading system should be implemented. In the specific operation, the share of renewable energy in electricity consumption should be taken as a binding target, and the quota implementation program for the administrative region should be formulated in the form of a law on an annual basis. At the same time, renewable electricity in proportion to the quota is allowed to be traded across regions (grids) to address inter-regional differences in renewable energy resources. Based on the composite institutional arrangement, provinces whose renewable energy generation cannot reach the required quota can independently choose to purchase green certificates equivalent to the amount of quota obligation. The green certificate system, as a complement to the quota system, reflects, to a certain extent, the interaction between mandatory and voluntary linkages. The quota system can serve as a mandatory constraint on power grids, power generation enterprises and local governments, and help to solve the problem of grid-connected renewable energy generation. The purchase of green energy certificates is a voluntary transaction, which is a supplementary means for electricity suppliers and consumers to fulfil their annual quotas.

The power sector, which accounts for about 40% of global CO2 emissions from energy activities, plays a pivotal role in the energy system transition. At the same time, power is also a sector that is more mature in terms of scaling up existing energy transition solutions than sectors such as industry (heavy chemical industry, etc.), transportation (shipping, aviation, road freight, etc.), and buildings (large-scale heating, etc.).The role of the power sector in the energy transition can be summarized in two key points: zero-carbonization of production on the supply side of electricity and electrification of end-use on the consumption side of electricity. In China, from carbon peaking to carbon neutrality, zero-carbonization of electricity production and electrification of end-use energy will contribute about 31% and 16% of CO2 emission reduction, respectively, and are the two most important strategies to achieve net-zero carbon emissions.

Changing generation-side and consumption-side demands will result in increasing transformational challenges for municipal power operators, summarized as follows [24]:

1）With the installation of photovoltaic and energy storage devices in urban buildings, the number of generation devices in urban distribution substations has become more numerous, smaller, and fragmented, requiring distribution network companies to significantly increase the frequency and efficiency of data processing in planning, operation, and monitoring.

2）The spread of electric vehicles and charging piles has led to a rapid growth in charging loads. This has led to the need for grid companies to choose carefully between reinvesting in the grid and investing in new regulation technologies.

3）With the introduction of secondary dispatch for distributed energy access, it leads to an increase in the complexity of grid dispatch. Distribution grid companies will face technical and cost challenges in grid regulation.

4） With the continuous development of multi-energy complementary and energy interconnection technologies, distribution grid companies need to strengthen their interaction with other energy networks and improve their information collection and analysis capabilities in order to improve the reliability of grid operation and optimize grid planning schemes.

5）Distribution network operators lack effective market instruments to allocate flexibility resources within their supply areas for local consumption of renewable energy but will need to dominate regional flexibility markets in the future. Currently, the flexibility market needs to be further developed and its macroeconomic and market economic viability verified.

Electrification is at the heart of carbon neutrality, and the green transformation of electricity is the basis for achieving it. Due to its "standardization" and "controllability", high energy efficiency and energy-saving, clean energy use, electricity is an "enabler" of industrialization and a high-quality energy source. It is also a high-quality energy source. Electrification is also the least costly and most mature technological path to carbon neutrality, and will replace the consumption of fossil energy sources, such as coal and oil, through increased levels of electrification in end-use energy sectors such as transportation, industry and buildings.

According to the World Energy Agency (IEA)[25], by 2050, global electricity consumption will be 2.5 times higher than today. As measured by the International Renewable Energy Agency (IRENA)[26], electricity to account for half of global end-use energy in 2050。This means that under the 2°C target, global electricity consumption in 2050 would be twice as high as in 2019. According to the IEA's projections, under carbon neutral conditions, to meet future electricity demand additions, the average annual size of global renewable energy additions over the next 30 years would need to reach 700GW, four times the amount of new capacity added in 2019.The International Renewable Energy Agency (IRENA) expects about 86% of global electricity consumption to come from non-fossil energy sources (renewables and nuclear) in 2050, i.e., a seven-fold increase in low-carbon electricity compared to 2019.

Enterprises can directly reduce electricity costs through on-site distributed wind power generation projects. In the thermal power prices continue to rise under the situation, it is expected that commercial and industrial enterprises layout roof distributed photovoltaic willingness will be significantly increased. In addition, the upfront threshold for investing in on-site distributed wind power projects is expected to continue to come down, given the growth of specialized services in the market in recent years. Distributed wind power projects cannot be issued with official green certificates for the time being, and there are challenges in establishing the environmental rights and interests of the projects. Corporate users who take the contract energy management (EMC) mode of project development, need to be with the developer on the environmental rights and interests of additional agreements. Beijing Power Trading Centre Green Power Trading Implementation Rules distributed new energy generation projects that can be aggregated to participate in green power trading. If this model is promoted, the consumption side of distributed power generation projects can be broadened, and project economics are expected to be further enhanced.

However, there are currently limited intra-regional parity projects that have been connected to the grid in some areas, especially in areas of intense economic activity, while inter-provincial and inter-regional transactions are more difficult to carry out due to the capacity of the designed channel, the coordination of multiple entities, and the differences in the rules of each place. Tight provincial resources and the difficulty of outsourcing across provincial boundaries have combined to create a tight supply of green power, causing green power prices to rise at an accelerated rate. At the same time, due to the lack of a clear pricing mechanism for environmental rights and interests, bilateral price negotiations lack a theoretical basis, resulting in irregular fluctuations in environmental premiums.

Currently, there is a lack of price references for green power trading as the green power market is still in the initial stage of development, and there is no good interaction between the electricity market and other environmental markets (e.g. the carbon market). At the current stage, the green power transaction price is entirely negotiated between power generators and power users based on market supply and demand and their respective considerations of risk and environmental benefits, and does not reflect the true value of green power. Among them, the value of the current environmental rights and interests is only reflected in the green power transaction price minus the coal power benchmark price, there is a certain pricing failure. With the continuous improvement of the market and the gradual breaking down of barriers between markets, the value of green electricity and the value of environmental rights and interests can be effectively guided between different markets. At that time, the pricing mechanism of green power will also be clearer, the value of green power's electric energy will be determined mainly in the power market-oriented trading, while the pricing logic of its environmental value is expected to be clarified with the maturity of the carbon market, and for the key urban energy-using units, the supply of electricity that can be procured will be diversified, while the calculation of carbon emissions and the future model based on the contractual energy management will also help to promote the key industries, buildings and the transportation sector's energy transformation and energy saving and carbon reduction.

Energy supply and carbon efficiency of urban industry

The influence of industrial structure upgrading on carbon emission efficiency has certain time lag and spatial transmission effects, and the upgrading and rationalization of industrial structure helps to improve the carbon emission efficiency of neighbouring areas[27]. In the industrial sector energy saving and emission reduction are mainly achieved by optimizing production processes, and deep decarbonization requires further fuel substitution, changes in production methods and substitution of new materials. For example, at this stage, the decline in carbon intensity in the steel industry comes mainly from improvements in scrap production and energy efficiency. However, with technological progress, steelmaking efficiency and reuse are approaching technological limits, and further decarbonization requires fundamental changes in production methods and new technological breakthroughs, such as the possibility of using hydrogen or bioenergy instead of coal as a reducing agent in blast furnace steelmaking and electrification of the production energy supply process. Decarbonization of cement production requires, first and foremost, zero carbon emissions from fuels, such as the use of green hydrogen and biomass fuels to replace traditional fossil fuels. From a comprehensive point of view, the technologies that need to be focused on for carbon peaking and carbon neutrality in the industrial sector include hydrogen-rich gas smelting, high-value recycling of steel slag, refining of synthetic chemicals from industrial wastes and biomass, renewable energy chemistry, non-fossil-based materials, synthetic biology-based green industrial manufacturing, and recovery and recycling of inorganic industrial solid wastes.

Carbon emissions in some cities mainly come from the manufacturing industry. Taking Northeast China as an example, the region is an important manufacturing base, and the distribution of carbon emissions from industry sectors shows that carbon emissions mainly come from the manufacturing industry. Due to the impact of industrial composition and economic level on urban energy consumption, it poses a strong challenge to diversify and target urban carbon neutral pathways.

There are huge differences in the proportion of industrial energy use and energy efficiency levels in different cities, and the stage of development is clearly characterized. Take the three industrial cities of Shanghai, Suzhou and Luoyang as an example, the industrial output value of Shanghai is ranked first in the economy, and the industry is dominated by high-end manufacturing and high-tech industries, and the energy consumption per unit of GDP has been as low as 0.42tons of standard coal per CNY10,000, which is the best level for this kind of city; Suzhou's industry is in the stage of transition from manufacturing to high-end manufacturing and high-tech industries; Luoyang's industry is dominated by traditional industries, and high-tech industries are still in the layout stage.

Take Beijing, Nanjing, Lanzhou three tertiary industries accounted for more than 60% of the city as an example, Beijing industrial elimination of high energy-consuming industries, a high proportion of high-tech industries so that industrial energy consumption accounted for the proportion of the whole society's energy use as low as 34.3%; Nanjing's industrial structure initially completed the upgrading of the industry to the electronic information industry and petrochemical industry as the backbone of the energy consumption per unit of GDP is 0.59tons of standard coal / million yuan; Lanzhou industry is still in the high energy-consuming stage, with heavy industry accounting for more than 98% of industrial energy consumption, and energy consumption per unit of GDP is as high as 0.96tons of standard coal / million yuan.

The iron and steel and cement industries in the industrial sector, for example, are both energy-intensive and account for about 16% and 15% of carbon emissions, respectively[28][29]. The first step in decarbonizing the steel industry is to promote the transformation of the production process from blast furnace to electric arc furnace smelting. However, at present, China's iron and steel industry, due to factors such as insufficient supply of scrap resources and high industrial electricity prices, the economy of the electric arc furnace production route is not as good as that of blast furnace steelmaking, and the proportion of crude steel production of the electric arc furnace production route in 2019 will be only 10.4%, which is far lower than the global average of 27.7%. In addition, more thorough low-carbon steelmaking methods (such as hydrogen steelmaking) are still waiting for technological breakthroughs to achieve large-scale application, while further decarbonization requires breakthroughs in hydrogen metallurgy technology.

The path to decarbonization in the cement industry is even more difficult. Carbon emissions from cement production come from the forging process of the limestone raw material itself, and a feasible decarbonization path is to subvert the raw material from the bottom up by replacing the limestone raw material with a non-petrochemical-based material, with a corresponding zero-carbon replacement of the fuel. Progress on this technology path is slow because the corresponding industrial processes need to be changed, involving all links in the industry chain.

In general, the upstream and downstream of the industrial production process are highly interrelated, and changes in the existing production process will inevitably bring about changes in the overall industrial chain. At the same time, a large number of production equipment has a long-life cycle, once rebuilt and renovated, the cost is high, and even lead to stranded assets and bad bank loans, so there is also a long distance between technological breakthroughs and industrialization.

Energy supply and energy efficiency of urban transportation

In terms of energy efficiency and carbon emissions, road passenger transport, aviation and trucks are the modes of transport with the lowest energy efficiency use, with the energy intensity of road freight increasing by 11% over the period 2000-2019. The report shows that the transport sector emits 770 million tons (Gt) of carbon dioxide (CO2) in 2021, which is about 20% of total global carbon emissions. Of this, road transport alone accounts for more than three-quarters of emissions (76.6%, or 5.9Gt of CO2), followed by maritime transport (11%) and aviation (9.2%).

Looking at different economies and regions, Asia-Pacific and North America account for more than half of the global transportation energy use in 2022. The United States consumes about 23.3EJ of energy for transportation, followed by China (15.2EJ) and India (4.4EJ). The Asia-Pacific region has the highest average annual growth rate of 4.7% in transportation energy demand from 2011-2019, driven by India and China (with growth rates of over 6%). Africa and Latin America and the Caribbean have the lowest demand (3.7%).

With economic development, automobiles will become the largest area of energy consumption, and Governments and industries are increasingly concerned about promoting the entire transportation sector in a low-carbon direction. Measures taken by various economies in the area of transportation: firstly, attention is being paid to the area of public transport to improve the quality of green travel and to give priority to the allocation of travel space and right-of-way; and secondly, the optimization of the urban transport structure on the basis of science and technology and the enhancement of the whole chain of service systems for green travel.

Japan has proposed a clear "decarbonization" timeline, expecting to achieve "carbon neutrality" by 2050, and has made smart mobility an important path for economic growth, focusing on digital communications, artificial intelligence, automation, big data and other technologies to promote the optimization of urban transport structures. Governments such as Chile and Peru have issued green transport strategies or transport decrees to harmonize vehicle purchasing standards and encourage the use of electric or zero-emission vehicles. Zero-emission vehicles are also being promoted in surface transportation. China's transportation sector, which accounts for 15 per cent of the economy's end-use carbon emissions, is still in a relatively rapid stage of development and is expected to continue to grow for a long time to come. At this stage, China has introduced three main paths for carbon neutral transportation: carbon reduction at the power generation end, carbon reduction at the consumption end and carbon reduction at the supporting facilities. Among them, the focus of carbon reduction on the consumption side is to optimize the transportation structure, including the promotion of new energy vehicles, etc., and the carbon reduction of supporting facilities includes the promotion of the development and construction of intelligent transportation[30].

Carbon emissions from the transportation sector have not yet peaked, and decarbonization in commercial vehicles and civil aviation faces technical bottlenecks. In the United States, the European Union and Japan, emissions from the transportation sector peaked at about 845, 423 and 575 passenger cars per 1,000 people, while China currently has only 173[31], and the number of automobiles is still growing continuously. Currently, China's greenhouse gas emissions from road, civil aviation, rail and water transport account for 76 to 80 per cent, 10 to 13 per cent, 2 to 3 per cent and 6 to 11 per cent, respectively, of the total emissions from the transportation sector[32].According to Zhang (2019), China's road traffic carbon dioxide emissions were nearly 1.09 billion tons in 2017 (excluding motorcycles, two-wheeled and three-wheeled vehicles), an increase of nearly five times from 220 million tons in 2010 (Energy Research Institute of the National Development and Reform Commission, 2017).

Renewable energy utilization[33]: By region, in the transportation sector, the United States is the largest consumer of renewable energy in the world. Data from the Report show that in 2019, renewable energy consumption in the transportation sector in the United States amounted to 1.6EJ, or about 40% of the global share, followed by Brazil (0.9EJ), while in Europe, three economies - France, Germany and Spain - together accounted for 44% of the region's renewable energy consumption.

In terms of growth rate, the Asia-Pacific region is the fastest-growing region in terms of renewable energy use. Renewable energy demand in the region is growing at a CAGR of 13.9% from 2010-2019. Indonesia is the largest economy in the region in terms of renewable energy demand in 2019 (~0.17EJ), followed by China (~0.12EJ).

In terms of the different types of renewable energy, renewable electricity accounts for 10 per cent of the renewable energy used for transportation, with an average annual growth rate of 7 per cent in the use of renewable electricity from 2010 to 2020. In 2020, demand for renewable electricity grows by 5.4%, despite a slowdown in transportation electricity use (down 3% compared to 2019). Second, biofuels account for about 90% of transportation renewable energy use. biofuel use grew at an average annual rate of 5% from 2010-2020 and is expected to quadruple over the next decade.

Thanks to the development of the "pure electric drive" industrial route in China's electric vehicle sector, policy subsidies, and automobile purchase restriction policies, China has made rapid progress in the electrification of road transportation (Yuan Zhiyi, 2020), with pure electric vehicles accounting for 81% of new energy vehicle ownership in 2018, higher than the global average of 71% (International Energy Agency, 2019).Currently, EVs in China are mainly used in the passenger car sector, while heavy-duty truck carbon emissions currently account for 40% to 55% of China's road traffic CO2 emissions, and there is still a lack of electrification technologies for commercial mass production. According to IEA projections, future growth in oil demand and carbon emissions from the global transportation sector will mainly come from freight transport, with China's freight emissions growth accounting for 90% of global freight traffic carbon emissions growth (IEA, 2017).

At present, the battery energy density of pure electric technology is limited, which restricts the range of trucks, and it is difficult for conventional power batteries to provide the strong power required by trucks; although hydrogen fuel cells are more adaptable in principle in the field of heavy-duty trucks, the current process of hydrogen production, which is mainly based on "grey hydrogen", still has high carbon emissions, and is subject to infrastructural constraints, and the storage and transportation of fuels are still facing technical barriers. Although some domestic car companies have started mass production of hydrogen cars, the market size is very small and only in the demonstration stage. In addition, the deep decarbonization of civil aviation is also a technical challenge at this stage, biomass fuels and hydrogen may be a key measure, but the high cost is the biggest obstacle to the promotion of the current stage, the future of many technical routes still need to be further explored.

With the development of electric vehicle technology, the cost continues to fall, and the electrification of road transportation has become the most mature way of carbon reduction in the field of transportation. With the advancement of charging pile infrastructure construction, the extension of range and the acceleration of charging efficiency brought about by the continuous advancement of battery technology, the use scenarios of electric passenger vehicles will continue to expand, and electrification and decarbonization of road transportation will gradually be realized. Rail transport is generally more efficient, low-carbon and easier to electrify than road and air and ship transport. However, decarbonization of transport currently faces the problem that electrification technologies for commercial mass production are still immature. Moreover, at this stage, the application of new zero-carbon fuels such as hydrogen, biomass fuels and liquid ammonia to transportation is not yet economical, and the best path to achieve carbon neutrality needs to be further explored. Based on the above background, the technologies that should be focused on for decarbonization in the transportation sector include high-performance electric vehicles, hydrogen fuel cell vehicles, electrification of heavy-duty vehicles, high-capacity rail transit, green ships, transportation adaptive energy systems, driverless, intelligent transportation systems, low-carbon construction and operation and maintenance of transportation infrastructure, energy-saving and emission reduction renovation of existing transportation hub facilities, and solar highways.

Research data show that the per capita energy consumption of urban public transportation is about 1/4 of that of private cars, and the public transportation sharing rate of most urban residents in China is between 10 and 30%, which is a big gap from the level of about 50% to 60% of the cities with higher public transportation sharing rate in the international arena. According to the current structure of China's urban energy use and public transportation sharing rate estimates, every 1% increase in the urban public transportation sharing rate can reduce urban energy consumption by seven to eight ten thousandths.

The main challenges currently facing the urban transportation sector are：

1）The penetration rate of newly constructed charging pile networks, especially public charging piles, significantly lags behind the growth rate of new energy vehicles

2）Although a unified and perfect charging technology standards and requirements have been defined, a high degree of marketization requires cross-sale e-commerce charging settlements, cross-economy roaming charging, and there is a need to further break down technical and market barriers, reduce charging costs and improve user charging experience

3）The uncontrolled charging of electric vehicles in high-density areas such as small districts, office buildings, shopping centres, etc., and the contradiction between the capacity of the entire distribution platform area is increasingly highlighted, and the impact on the power grid has yet to be further tested on the ground

4）After the new crown epidemic, people will travel mainly by electric cars and bicycles, supplemented by public transportation, while more travel through low-carbon modes such as shared electric rentals and shared electric bicycles will be the future trend. This poses new challenges to the planning and upgrading of transportation and its associated power networks.

Dr Lailai Li, Chief Representative of WRI China, said, "Chinese cities are in dire need of in-depth research at the industry level. The experience of developed economies is that industrial, building and transportation emissions each account for 1/3, while there are cities in China where transportation emissions only account for 10%, which will certainly be a major growth driver in the future and should be the focus of emission control." Dr Lailai Li also pointed out that "there are several difficulties in reaching the peak of urban transportation: first, the contradiction between the growth of production and life transportation demand and emission reduction; second, the transportation industry itself, such as the uncertainty of technological advances; and third, the separation of the industry-driven and urban management authority."

The Transition and Challenges: How the Zero-Emission Vehicle Transition Can Help Peak Carbon and Reduce Carbon Emissions in China's Automotive Sector predicts that, under current policy scenarios, the automotive sector is expected to peak at 1,746 million tons of carbon around 2027. Carbon emissions will not decline immediately after peaking, but will form a three-year emissions plateau, during which the average annual change in carbon emissions is less than 1 percent. If the existing policy scenarios are developed, carbon emissions from the automotive sector will decrease by 11% in 2035 compared to the peak; analysing by vehicle type, carbon emissions from the passenger car sector will peak in 2027, with an annual emission of about 940 million tons; emissions from the passenger car sector have already reached the peak and will maintain a decreasing trend year by year; and carbon emissions from the truck sector will peak in 2028, with an annual emission of 719 million tons.

Energy supply and energy consumption of urban construction

Buildings are one of the most important sources of carbon emissions in cities, and how to reduce the energy consumption and carbon emissions of the large number of buildings that have been built in cities is an important challenge for cities to move towards carbon neutrality. As energy-saving and low-carbon retrofitting of existing buildings involves not only energy, but also safety, comfort, economy and many other elements, cities are now carrying out urban renewal, building energy efficiency improvement, energy-saving retrofitting of existing buildings, and the application of renewable energy in buildings.

For new buildings, upgrading their building energy efficiency standards can significantly reduce their energy demand. For example, China has promulgated the General Specification for Building Energy Efficiency and Renewable Energy GB55015-2021, which upgrades the level of building energy efficiency from the point of view of the mandatory standard, and at the same time guides ultra-low-energy, nearly-zero-energy and zero-energy buildings by means of the Near-Zero-Energy Building Technical Standard GB55015-2019 and other buildings.

At the forefront of initiatives to achieve carbon neutrality in the building sector is the energy efficiency retrofit of buildings. In the buildings sector, high energy prices and the search for a reliable energy supply away from fossil fuels are driving a shift from natural gas boilers to electric heat pumps, making 2022 a record year for heat pump installations, boasting 10% year-on-year growth[34]. However, the current economics of the relevant building technologies need to be further improved and stock replacement is still difficult, and the need to improve the economics of retrofitting through technological advances is key to stock replacement in the building sector. In addition, the promotion of zero-carbon buildings also requires a variety of energy sources to coordinate and provide system solutions. From a comprehensive point of view, decarbonization of the building sector needs to focus on technologies including low-carbon building materials, building "gas to electricity", intelligent construction, building the whole process of intelligent design and control, the building of the optical storage of direct and flexible integration, building intelligent micro-grids, and low-carbon/zero-carbon building intelligent integration.

Buildings are the main consumers of urban power grids, and electrification of buildings enhances their own power consumption and promotes the growth of power consumption. The new building with "optical storage, flexible and direct" power supply and distribution technology has strong power flexibility, which can realize power decoupling and off-grid operation and enhance the reliability of the power system. The grid meets 99% of the basic reliability needs, and the building solves the additional 0.X% reliability needs according to its own characteristics. In addition, building flexibility enhancement can also promote the participation of building distributed energy systems in the peak and frequency regulation services of the urban power grid, and promote the consumption of more renewable energy sources; reduce the peak value of building loads, and alleviate the pressures of increasing the capacity of the district distribution grid and the peak regulation pressure of the urban power grid.

As new energy vehicles gradually shift from the B-end market to the C-end market, the average parking time of private cars throughout the day is as high as 80%, and the necessity of fast charging gradually decreases. Considering the impact of EV charging on the peak load of distribution transformers, the operation mode of charging piles around the building should be based on slow charging, and the need for orderly charging, bidirectional charging and discharging technology support. In the future, the distribution network of residential communities and public buildings and car charging piles need to be constructed in an integrated manner, and the degree of coupling between building power consumption and transportation power consumption will be higher and higher.

With the continuous upgrading of building energy efficiency standards, the marginal effect of energy efficiency improvement in new buildings has gradually appeared, and in order to further tap the potential of building energy efficiency, it is inevitable to move from single building to regionalized scale development, and from the demand side of the building to the synergistic transformation of the supply and demand of the building. Regional building energy development is for building groups, parks and even towns to consider the supply, transmission, distribution and consumption of multiple energy sources, such as cooling, heating and electricity, and it is an important way for building energy efficiency and green buildings to move from single-unit performance improvement to large-scale development.

The building sector is projected to peak carbon later or become the latest major sector to achieve carbon neutrality in China. According to the projections of the Specialized Committee on Energy Consumption Statistics of the China Building Energy Efficiency Association (2019), China's carbon emissions from the building sector will continue to increase, with peak time expected to be around 2039, which is nine years later than when the economy as a whole is projected to achieve carbon neutrality. In terms of the source of carbon emissions, carbon emissions from the operational phase of buildings accounted for 21.9% of carbon emissions in 2018, mainly from heating/cooling for residential and industrial use.

To achieve carbon neutrality, on the one hand, it is necessary to promote the development of ultra-low-energy-consumption buildings, eliminate existing fossil-energy heating methods, and effectively reduce the use of energy in buildings by combining distributed renewable energy sources and advanced heat-pump technologies based on passive thermal insulation. On the other hand, the large-scale low-carbon transformation of the stock of buildings is difficult, and the previous large-scale "coal-to-electricity conversion" in rural areas has brought a greater burden to local finances. Fully utilizing the potential of biomass, industrial waste heat that does not produce additional carbon emissions, and solar heat to replace electricity demand, and improving the economics of retrofitting through technological advances are key to replacing stock in the building sector.

Scaling up near-zero-energy buildings

Vigorously developing near-zero-energy buildings is one of the key technologies to address energy conservation and carbon reduction in the building sector. Near-zero-energy buildings can minimize building heating, air conditioning and lighting demand through passive building design and technical means, and significantly improve the efficiency of energy equipment and systems through active technologies, so that the building's own capacity and the building's use of energy are nearly balanced, and the building's energy consumption is reduced to the greatest extent possible during the operation of the building. If high-energy buildings are transformed into near-zero-energy/emission buildings, not only can carbon emissions be reduced, but they can also provide a healthier and more comfortable indoor environment for people. In addition to the use of high-performance envelopes and energy-efficient equipment in new buildings to maximize the use of renewable energy, a smart approach to retrofitting existing buildings can create new economic growth points for cities, such as urban renewal in various cities. However, at present, the existing buildings in the city are intricate and complicated, and the level of energy saving, management level, property ownership, energy system and so on are widely differentiated. How to systematically consider the energy system and transportation system from the city through the urban renewal is full of challenges, and the establishment of a building energy management platform based on digitization is particularly urgent and important.

The Ministry of Housing and Urban-Rural Development's "14th Five-Year Plan" for Building Energy Efficiency and Green Building Development clearly states that by 2025, all new buildings in cities and towns will be built as green buildings, the efficiency of building energy use will be steadily improved, the structure of building energy use will be gradually optimized, the trend of growth in building energy consumption and carbon emissions will be effectively controlled, and a green, low-carbon and recycling way of building development will be formed, so that a solid foundation will be laid for the urban and rural construction field to reach carbon peak before 2030. By 2025, the energy-saving renovation of existing buildings will be completed in an area of more than 350 million square meters, more than 0.5 billion square meters of ultra-low-energy and near-zero-energy buildings will be constructed, the proportion of assembled buildings in new buildings in cities and towns in the current year will reach 30%, the installed capacity of solar photovoltaic in new buildings will be more than 0.5 billion kilowatts, and more than 0.1 billion square meters will be used for geothermal energy building application, and the rate of renewable energy substitution for buildings in cities and towns will reach 8%, and the proportion of electricity consumption in building energy consumption exceeds 55%.At the same time, the "14th Five-Year Plan" period of building energy efficiency and green building development of nine key tasks - to enhance the quality of green building development, improve the level of energy efficiency in new buildings, strengthen the existing building energy efficiency and green renovation, promote the application of renewable energy, the implementation of the building electrification project, the promotion of new green construction methods, promote the application of green building materials, promote regional building energy synergies, and promote the construction of green cities.

On 5 July 2023, China's Ministry of Housing and Urban-Rural Development (MOHURD) "Circular on Promoting Urban Renewal in a Solid and Orderly Manner"[35] pointed out that it adheres to the urban physical examination as a first step, plays a role in coordinating the planning of urban renewal, strengthens the guidance of refined urban design, innovates sustainable implementation modes of urban renewal, and clarifies the bottom-line requirements of urban renewal.

Up to now, more than 20 provinces and cities in China have cumulatively issued more than 100 incentive policies for near-zero energy buildings. For example, the Nanjing Green Building Demonstration Project Management Measures issued in March last year clearly states that priority should be given to the support of near-zero-energy buildings and zero-energy buildings, and that ultra-low-energy, near-zero-energy, and zero-energy buildings should be subsidized in accordance with RMB30/square meter, RMB80/square meter, and RMB100/square meter, respectively. Implementation Opinions" issued by the Inner Mongolia Autonomous Region in April last year on strengthening the development of building energy efficiency and green buildings also pointed out that it encourages the development of passive ultra-low-energy buildings, near-zero-energy buildings pilot demonstration, and promotes the development of passive ultra-low-energy and near-zero-energy buildings.

According to the latest data released by the China Academy of Building Research, carbon emissions in the operation phase of near-zero-energy-consumption public buildings can be reduced by 55.4% compared with the baseline building, and the level of energy consumption in the construction phase can be reduced by more than 60% compared with the standard and industry-standard buildings. Based on vigorously developing near-zero-energy buildings, promoting energy-saving technological transformation of existing buildings and comprehensively promoting renewable energy buildings, China's building sector is expected to achieve carbon peak in 2030, and the peak value of carbon peak is expected to drop from 3.15 billion tons to 2.6 billion tons.

Heat pumps

With the development of the air source heat pump industry, based on the performance of the heat pump to improve the air source heat pump in construction, transportation and other areas of application is more and more extensive, of which the more important is the air source heat pump heating, air source heat pump for domestic hot water and air energy and solar energy coupling and so on. Air can not only be applied to domestic at the same time can also be used in agriculture and animal husbandry, such as vegetable greenhouses.

In the process of promoting clean heating in China, a large number of air-source heat pumps installed, subject to the amount of financial subsidies, transformation cycle and energy efficiency assessment and other impacts, most of the cities clean heating renovation, is only a replacement of the heat source, will be a small furnace burning loose coal, into the air-source heat pumps, not the building envelope and other renovations, a large number of air-source heat pumps installed to bring the grid station transformer capacity overload and other issues, but also for the subsequent industrial upgrading and development and so on have had an impact.

For a given urban area, the urban energy system is coupled together with each other, and cannot be solved from only one perspective and one subsystem to solve the problem of integrated urban energy, but requires systematic planning, and how to harmonize the multiple objectives of energy conservation, cleanliness, development, and economy has become a major issue in the context of the dual-carbon strategy.

At present, the performance of air-source heat pumps in ultra-low-temperature conditions has yet to be verified, while some projects due to the quality of the installation, and the weak connection with the building envelope, there is a large noise, and the end of the equipment is not a high degree of match, affecting the larger-scale use of air-source heat pumps.

Municipal and industrial waste heat

Urban manufacturing, food processing industry, etc. will produce a large amount of waste heat, waste heat. Using these waste heat and waste heat for centralized heating will replace a large amount of coal, and the energy-saving effect will be very significant[36]. Although factories, power plants, and waste incineration plants can provide sufficient waste heat, many underground heat storage facilities and heat transport tunnels are required to store and transport this heat to urban areas during the winter months. To minimize heat loss during storage and transportation over long distances, these underground facilities and tunnels have high requirements for burial depth and lining[37].

Ho et al. concluded that the key to converting the greenhouse gas emissions from domestic waste incineration and power generation is to reduce the water content of the waste and increase the power generation capacity of the waste[38].Recovery of waste heat from waste-to-energy incineration for district heating or industrial steam preparation in many European economies[39], higher carbon offset than most incineration plants in China that only recover electricity. Seven different combinations of heat and power recovery in incineration plants were studied by Damgaard et al[40],the results show that when the recovered energy is changed from alternative coal energy to alternative natural gas energy, the carbon reduction effect from waste-to-energy incineration will no longer be significant.

New energy storage systems

The term "new energy storage" refers to energy storage technologies other than pumped storage, mainly including electricity and heat storage. Among them, electricity storage technologies include lithium-ion batteries, compressed air energy storage, etc., which can transform low-quality and low-value electricity into high-quality and high-value electricity after storage and release and is an important link in realizing "green power" from generation to application.

Guangdong Provincial Development and Reform Commission pointed out that the new energy storage industry has a broad market and huge development potential, and the development of new energy storage power plant is an important initiative to enhance the regulation capacity, comprehensive efficiency, safety and security of energy and power system and support the construction of a new power system, and it is an important area for realizing the goal of carbon peaking and carbon neutrality. Planning to guide the rational layout of independent energy storage, in the new energy large-scale convergence and consumption constraints, power demand fluctuations, transmission corridors and station site resource constraints and other regional planning layout of independent energy storage power station. Strongly encourage the development of user-side energy storage, and support industrial and commercial enterprises, industrial parks, etc. to build new energy storage power stations. Actively promote the construction of virtual power plants, promote new energy storage power plants and industrial controllable equipment load, charging and switching facilities, distributed photovoltaic and other resources aggregation application, in Guangzhou, Shenzhen and other places to carry out virtual power plant pilot, and gradually cultivate the formation of million kilowatts of virtual power plant response capacity.

The distributed lithium-ion energy storage system built by China Tower has deployed power-switching grid points in more than 280 cities across the economy, providing more than 2 million power-switching services for 900,000 takeaway riders and courier boys every day.

New energy storage to achieve large-scale development, must further overcome technical difficulties, reduce unit costs. To be based on China's energy resource endowment, continuous technological innovation, in the cost of doing "subtraction" at the same time in the scale of doing "addition", as soon as possible the formation of standards and norms, to promote high-quality development of the industry, in the integration of safe and stable supply of energy and green and low-carbon development. We will take a solid step forward on the road of integrating the safe and stable supply of energy and green and low-carbon development.

Spending habits

In the area of consumption, poor consumption habits add more carbon emissions. The cheap and fast way of producing garments represented by fast fashion, the low utilization rate of garments and the extremely fast renewal rate, from raw materials to the waste stage cause great waste of resources and generate a large amount of carbon emissions. In addition, the purchase and use of energy-intensive products also generates large amounts of CO_2, such as large appliances, electronic equipment and automobiles, etc. The greater the proportion of clean energy used in the production of automotive products, the smaller the CO_2 emission factor. Plastic in the production and processing process will release a large amount of carbon dioxide, so a large number of plastic products, such as plastic bottles, plastic bags and plastic packaging will not only pollute the environment will also produce a large amount of CO_2, through the 2023 Hebei Province, 11 cities in the college student research data show that the phenomenon of unreasonable dietary structure of college students is very serious, the use of disposable tableware is more than 40% of the students use disposable tableware more than 20 times a week .The use of a large number of old equipment is not timely updated to buy energy-saving new equipment, such as old air conditioners, old refrigerators, etc., which tend to increase power consumption because of the aging of the equipment and the decline in functionality, adding a lot of unnecessary carbon emissions and energy consumption.

Eating habits

Consumption of large quantities of meat and dairy products, especially from intensive livestock farming, significantly increases the carbon emissions associated with food production, especially since the production of red meat (beef and lamb) among the meats consumes a large quantity of resources and increases carbon emissions. Some studies have shown that income growth will increase the population's demand for carbon-intensive animal foods such as beef and mutton, but agricultural mitigation technologies have limitations in mitigating carbon emissions from the food system, and that while formulating mitigation policies, it is also necessary to strengthen the transformation of the population's dietary structure into one that is characterized by a shift in the dietary structure of fruits, vegetables, and other plant foods, as well as the dietary structure of animals, which is characterized by a low level of animal meat and a high level of poultry, eggs, milk, and aquaculture products[41]. Large-scale aquaculture and fishing not only stresses ecosystems but also produces large amounts of carbon dioxide. In addition, carbon emissions are increased by the choice of processed and semi-finished foods, which are often labour-intensive production processes that include steps such as heating, freezing, dehydrating, and packaging, which consume electricity to keep things cold and consume petroleum, among other things, for transportation, which increases storage and transportation costs and generates significant carbon emissions compared to freshly made foods.

1.2.3. Weak Environmental Data and Accounting

What is not known, cannot be managed. For a city to manage sustainability, it requires data. SDG Indicator 11.a.1[42] mentions the *Number of countries that have national urban policies or regional development plans that (a) respond to population dynamics; (b) ensure balanced territorial development; and (c) increase local fiscal space*.

This can be resumed under the heading *substance of cities* in the first bullet-point below. This report shows, however, that besides data on substance, three other types of data are important to measure sustainability; they are mentioned in the following bullet points below. Basically, the required data fall into the following four categories:

- Data on the demographic, geographic economic and social substance of the city (population, land, economy)
- Data recording the interactions of agents among each other (for e.g. capturing scope 3 emissions and going over to consumption-based inventories CBI, see section 2.1.7)
- Data recording the interactions of agents with the environment
- Data on the emerging green economy sector of the city

Concerning the quality of data, the challenge for cities is to collect data which:

- Is collected at regular time intervals, at least annually; some cities introduce daily near real-time data collection
- Is related to the geographic information system (GIS)
- Is based upon internationally harmonized definitions of the underlying concepts so that it is comparable among stakeholders
- Is accompanied by authentication protocols guaranteeing authenticity
- Can be checked for accuracy
- Is delivered on a secure infrastructure
- Is open data that is publicly available in machine-readable format
- Is collected in a cost-effective manner

In June 2023 the UNFCCC has released the version 1.0 of its new UNFCCC Recognition and Accountability Framework[43] for international consultation. It is expected to be adopted at the COP28 held in the United Arab Emirates in December 2023 and should apply to non-state actors. Concerning data management, this framework mentions the important points stated above but fails to mention time-regularity, relation to the GIS system, and cost-effectiveness of data collection.

The regularity of data collection related to a carbon neutrality pathway lasting for several decades ahead goes without saying. Some cities start collecting daily data (see section 2.1.7).

The compatibility with the GIS is creating the link to land planning as well as to air-borne and satellite-based observation. Land planning is the part of urban planning for which the cities have the core competence. Data originates from official acts concerning land, including land-related transactions. The GIS is assembling all these data into a single coherent system capable to receive data from multiple sources. Among these sources are all the local administrations as well as city-dwellers. Taking the example of CO2 emissions, local administrations provide what is called the bottom-up inventory. This bottom-up inventory can be cross-checked with satellite-based observation measuring the so-called atmospheric budget.

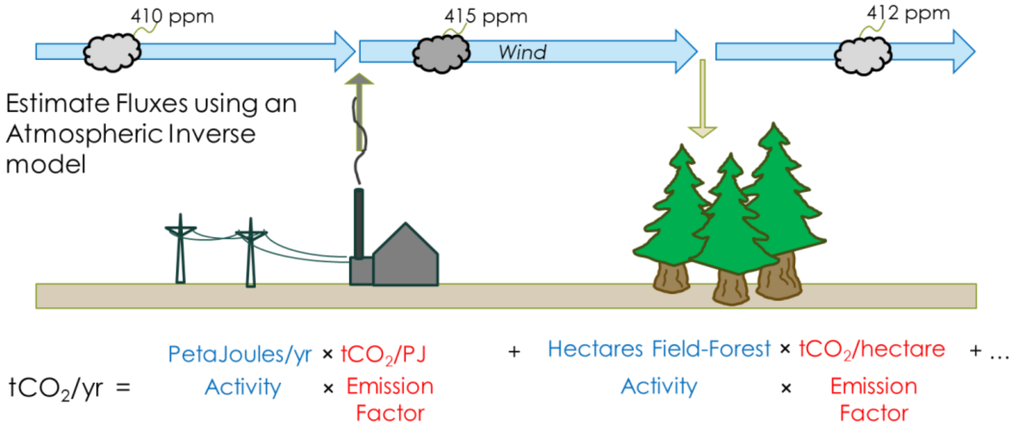

Figure 7: Complementarity between bottom-up and top-down data

Source: David Crisp[44]

Satellite-based observations are capable of tracing CO2 and CH4 emissions to the individual observable earth surface cell of the GIS system, but they cannot trace them back to the individual emitter. Satellite-based observations are therefore anonymized information. This is their great advantage. Other advantages are that satellite-based observations are available at daily or lower frequency and free of cost, requiring cities, however, to build up their capacity to extract them from the giant amount of other data and to visualize them for the use they intend to make. As the APEC Green Finance Report 2023[45] mentioned, central governments can provide the framework for cities to use satellite-based data. Addressing this issue, Geoscience Australia launched the first Open Data Cube (OCD)[46][47] in 2017, making data available in a user-ready format on open-source software (Python, GitHub).

The comparability of data is necessary to allow meaningful interpretations of the data sets. The World Council on City Data (WCCD) has been working together with the International Standardization Organization (ISO) to standardize the definition of sustainability indicators for cities. Preliminary works started back in 2008 against the following background:

- cities have a lot of data
- the comparability of data and indicators was impossible
- differences of definitions existed in what was being measured,
- different methodologies existed of how measurement was being undertaken
- different boundaries of a city existed (metropolitan area, regional area, city administrated boundary)

In 2014, the ISO published the first standard of the series on Sustainable Cities and Communities, namely ISO Standard 37120 on Indicators for City Services and Quality of Life, defining 104 key performance indicators, with standardized methodologies and standardized definitions of city boundaries. This was the first time that cities could compare data. The World Council on City Data (WCCD) started its activity in 2014 and has since then implemented the ISO 37120 standard in 50 to 100 cities worldwide.

Since 2014, the WCCD and ISO have elaborated further standards in the Sustainable Cities and Communities series:

ISO 37122 on Indicators for Smart Cities

ISO 37123 on Indicators for Resilient Cities, in partnership with UN DRR

These three standards together comprise a set of 252 indicators, of which about a third is relevant for the clean energy transition.

Unfortunately, all the data collected by WCCD is confidential and proprietary and is being shared only among the WCCD member cities. This does not satisfy the recommendation of the UN on public access of information outlined above which is required for scientific analysis.

Among the other reporting frameworks, GCoM Canada discusses the comparability issues of three frameworks: Partners for Climate Protection (PCP), Building Adaptive and Resilient Communities (BARC) and Global Covenant of Mayors (GCoM). The table below shows the differences between the frameworks. According to that analysis, cities reporting under PCP or BARC can easily improve their reporting to make it GCoM compatible. Note that GCoM requires “some high-level data reported publicly through the GCoM website” and guarantees that “City specific data will only be used publicly following consultation with the reporting city”. For more information on the GCoM see their contribution in section 3.1.1.

PCP	BARC	GCoM
Focuses on capacity development, technical assistance and peer learning as a Canadian network focused on greenhouse gas reductions and community energy.	Focuses on capacity development, technical assistance and peer learning as a Canadian network focused on climate risk response, adaptation and resilience.	Focuses on raising ambition of local governments and their contributions toward global goals through consistent standards, reporting and access to a global network of peers.
• Regional coaches through the regional climate advisors • Help desk for technical assistance and milestone reviews • In-person training and networking opportunities • Online community with the PCP hub • PCP milestone tool for guided completion of framework steps	• Dedicated liaison for consultation, technical support, and guidance throughout the adaptation planning process • Established milestone-based framework that is flexible and customizable to assist in the creation and implementation of adaptation and resilience plans • Networking, training and opportunities to engage with thought leaders • Online BARC Tool access to record climate impacts, workshop results, vulnerability and risk data, and adaptation actions in a centralized place	• Help desk for technical assistance • Domestic and international communications support, networking and recognition • Technical support for reporting mitigation and adaptation data • A global coalition of 10,000+ cities • Some high-level data reported publicly through the GCoM websites • Support for cities through the data4cities, innovate4cities and invest4cities initiatives • International exchange and city pairing opportunities.

Table 4: Comparison of PCP, BARC and GCoM reporting frameworks

Source: GCoM Canada[48]

The cost-effectiveness of the data collection is a challenge that is most often forgotten. It shall be mentioned here among the challenges of collecting data. For cities, collecting of data represents a considerable financial burden. Hence the role of accounting standards with sustainability disclosure such as the Global Reporting Initiative GRI[49] or environmental, social and governance (ESG)[50] aspects. Accounting standards requiring sustainability disclosure accelerate the collection of sustainability data.

As cities are heavily interdependent on their hinterland and this interdependence is not going to vanish with carbon-neutrality, it is not necessary to only focus on data related to cities or municipalities. One of the multiple problems of urban data is the lack of definition of the concept of "city" itself. The APEC Sustainable Urban Development Report – From Models to Results[51] described in detail the problem of the definition of "city". The problem is that the concept "city" does not have an internationally standardized definition. Contrary to, e.g. the definition of "poverty", which has been internationally standardized, the concept of "city" has not. Each economy uses its own definition of what it means by "city". Most economies use a minimum population threshold to define whether an agglomeration is a city or not. It may strike to note how low these thresholds are sometimes set. Four economies consider a "city" to be an agglomeration already at a threshold of already 200 inhabitants, whereas 23 economies (the biggest group) set this threshold to 2000 inhabitants. One economy uses a threshold of 50,000 inhabitants for defining a city (see fig. below)[52].

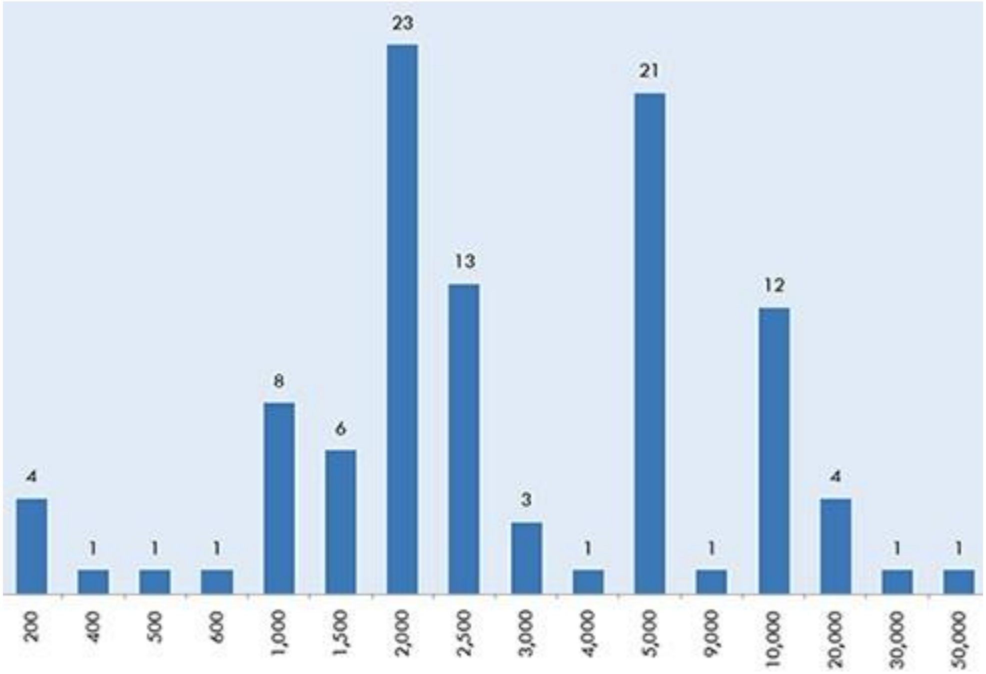

Figure 8: Minimum population threshold for defining a city

Source: Chandan Deuskar[53]

Besides a minimum threshold, some economies also use a minimum population density per square kilometre to qualify a city. Section 1.2.1. describes the density challenge of cities. The lowest density threshold is used by Germany (150persons/km2) and highest one by China and the Seychelles (1,500 persons/km2). Note that the Five Principles for Sustainable Neighbourhoods[54] elaborated by UN Habitat mention for a sustainable neighbourhood a minimum density of 15,000 persons/km2.

Some economies use a combination of both, minimum population threshold and minimum population density, to qualify cities.

Besides the "city", also the "agglomeration" takes increasing importance. The World Development Report 2009[55] was the first document that introduced a standardized definition of "city" which it called "agglomeration" instead. In that report, an "agglomeration" has been defined as an area whose core has:

- a population density over 150persons/km2
- a population of over 50,000 inhabitants
- and can be reached from outside within 60 minutes travel time

Describing the required key data sets in more detail:

- Population: always available. Problems arise when local units are split up, re-defined, re-named and re-assembled, together with other local units, a process happening within a movement of local administrative and political reforms which may or may not be designed to improve local management. If that happens, a local time series is being disrupted. Former data is not comparable to new data anymore. Much too rare are the correspondence tables showing how the old and the new data fit together. This phenomenon is for instance visible in the US where local administrative reform is happening constantly.

- Land Area: always available, with the same problems as with the land area just mentioned above.

- GDP (sometimes re-named Regional GDP or RGDP, to distinguish it from the economy's GDP): often available in local currency units, as its main components such as wages, taxes and enterprises' profits are needed to implement local fiscal policies. The challenge is to convert local currency GDP to constant purchasing power parity GDP. There exists no methodology yet to create a consistent system of temporal and spatial deflators. Methodologies vary greatly and results are heavily dependent on the methodology. For more information on this issue see section 2.3.2.

Besides these three categories of data, cities should collect basic energy and environmental data such as the following:

- Energy: rarely available at local level. The reason is that energy policies have traditionally not been implemented at local level. Local sustainability issues became a focus of policies after the 1992 UN Summit held in Rio introduced the concept of Local Agenda 21. Not all economies have given their cities a role to manage their energy development.

- Renewables: data on local renewable energy is rarely available, for the same reason as just mentioned for energy.

- Emissions: rarely available at local level. Growing interest under the Sustainable Development Goals (SDGs) to measure local emissions to assess the local environmental impacts of industry and transport, with focus on emissions harming health, such as the fine particulate matter (e.g., PM2.5 and PM10), see SDG indicator 11.6.2[56]. As for local CO2 emissions, the motivation for their collection has also been motivated in the Local Agenda 21 after the 1992 Earth Summit. The first global emissions disclosure organization, the CDP, was created in the year 2000. See the contribution by CDP in section 3.1.2.

- Green sector employment and value-added. This is the category for which there is least data, not only at city-level, but also internationally. IRENA keeps a series of employment in the renewable energy industry. However, the renewable electricity sector, while undoubtedly being the core of the green sector, is too narrow to capture the entire scope of the green sector. Green sector value-added is even known than green sector employment. The upcoming green sector taxonomies as presented in the APEC Green Finance Report are a way to define the green sector. They include at least the supply chain of all materials, equipment and services needed to build up a viable renewable energy generation industry.

Furthermore, APEC cities are well advised to collect data on disaster resilience:

- Data on local Disaster Resilience: Available for those APEC cities that have taken training in the Disaster Resilience Scorecard for Cities[57], which has now been integrated into the "Making Cities Resilient 2030" program of the UN Office for Disaster Risk Reduction, the worldwide leading effort to address disaster resilience of cities and local communities in a systematic way. While data on local Disaster Resilience can be very broad, the priority area is certainly data on disaster response, the basis for emergency actions in case of disasters, containing data on early warning systems, food gap, shelter gap, fuels gap, as well as staffing for first responder needs. See the next section for disasters as challenge for carbon neutrality.

1.2.4. Disasters as Challenge for Carbon Neutrality

Disasters can be a severe challenge for cities on their path towards carbon neutrality. The APEC Integrated Urban Planning Report – Combining Disaster Resilience with Sustainability (2021)[58] has shown how disasters impact APEC cities and what can be done to mitigate the impact. Due to the Ring of Fire, APEC cities are more exposed to disasters than global average. Two different categories of impacts should be distinguished: Impacts of disasters on the economic activity, and impact of disasters on human life (mainly deaths due to disasters). The mentioned APEC report shows in detail which disasters cause what type of impact in the APEC region. Below the main points are summarized.

Economic impact of disasters

The main challenge of disasters for cities wishing to become carbon neutral originates from the economic loss. The path towards carbon neutrality requires considerable economic resources to be invested into new infrastructures, but frequent disasters can destroy the investments made into these infrastructures. In 279 cities worldwide, the GDP loss due to disasters was larger than the GDP growth during the years 2018 – 2019. This means that in these cities, disasters annihilate the economic surplus that these cities need to develop themselves, including to develop towards carbon neutrality.

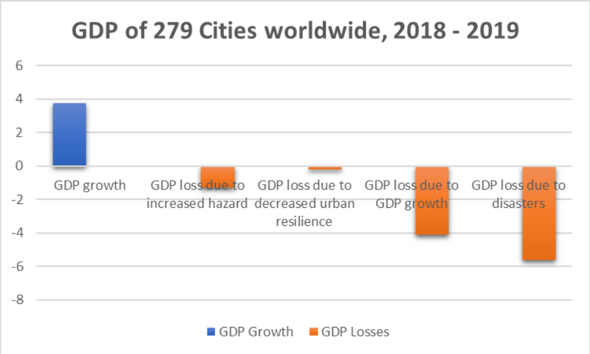

Figure 9: GDP growth and GDP loss due to disasters

Source: APEC Integrated Urban Planning Report[59]

Deaths due to disasters

Disasters impact cities also by causing death. The mentioned APEC report analyses in detail the disaster mortality of the APEC region in the period 1900 – 2020. In the first sixty years from 1900 – 1959, disaster mortality was very different from the second sixty years from 1960 – 2018. The difference is mainly due to improved infrastructure. Between these two periods of 60 years each, deaths due to drought in the APEC region have diminished by a factor 258, deaths due to epidemics by a factor 73 (before COVID-19), deaths by floods by a factor 65, but deaths by earthquakes have diminished only by 7%. Note that the scale of the ordinate of the figure below on the left is a factor 10 larger than the scale of the ordinate on the right-hand figure.

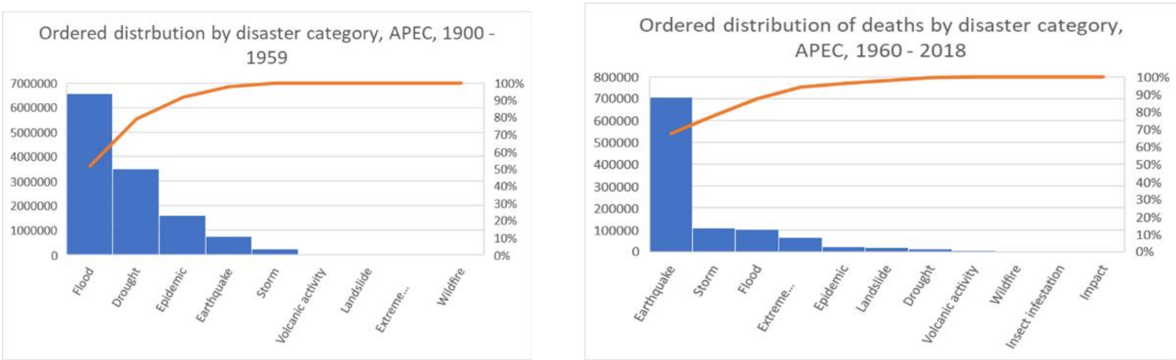

Figure 10: Deaths due to disasters in the APEC region, 1900 – 1959 and 1960 - 2018

Source: APEC Integrated Urban Planning Report[60]

However, since 1960, deaths from hydrometeorological disasters show a statistically significant increase in the APEC economies, whereas deaths due to geological disasters show a statistically not significant decrease. Deaths due to epidemics show a statistically not significant increase.

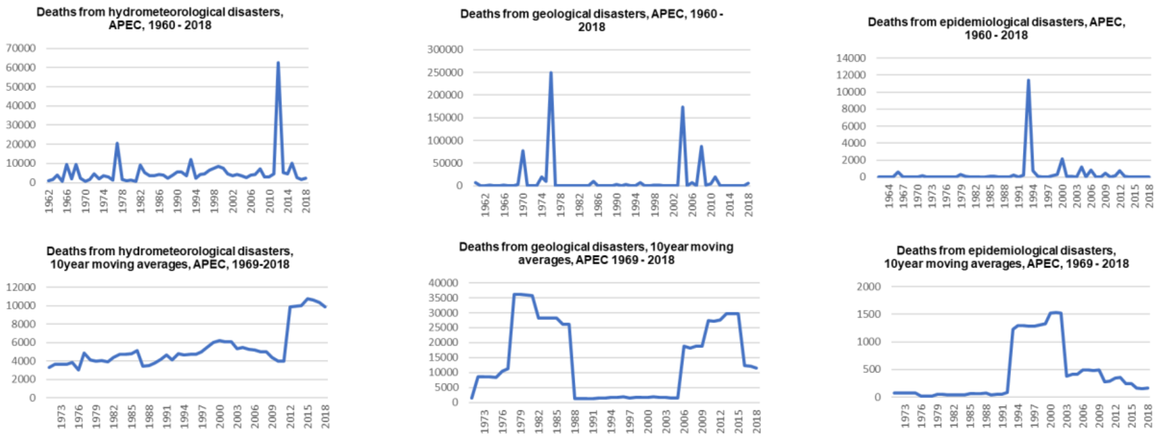

Figure 11: Deaths due to disasters in the APEC region, 1960 - 2018

Source: APEC Integrated Urban Planning Report[61]

This basically resumes to the fact that the disaster resilience measures taken to-date have the tendency to diminish the human losses of disasters but fail to diminish the economic losses. COVID-19 has confirmed this trend as the human losses of COVID-19 were mitigated due to all sorts of measures taken. In sum, the COVID-19 losses attained 6.9 million by December 2023, comparing to 40 – 50 million for the Spanish Flue of 1919[62], whereas the economic loss of COVID-19 left a visible scar in global GDP. Climate change is already causing severe droughts in many parts of the world. But contrary to what happened 100 years ago, when people died amidst droughts, in future they are likely to migrate away from droughts.

Disaster Resilience

Since its integration into the "Making Cities Resilient 2030" (MCR) program, the UN Disaster Risk Reduction Office has started publishing the disaster resilience of cities and local communities in form of a spider diagram assessment comprising both levels, the preliminary and the detailed assessment. An example can be given by the preliminary level assessment of the city of Baguio, the Philippines[63]. The key disaster resilience information is shown in the figure below. It distinguishes the most probable hazard (drought) from the most severe disaster known (a killer earthquake of 1990). The spider diagram shows the resilience for each of the 10 "Essentials" (resilience areas) which are described in detail in the "Disaster Scorecard for Cities".

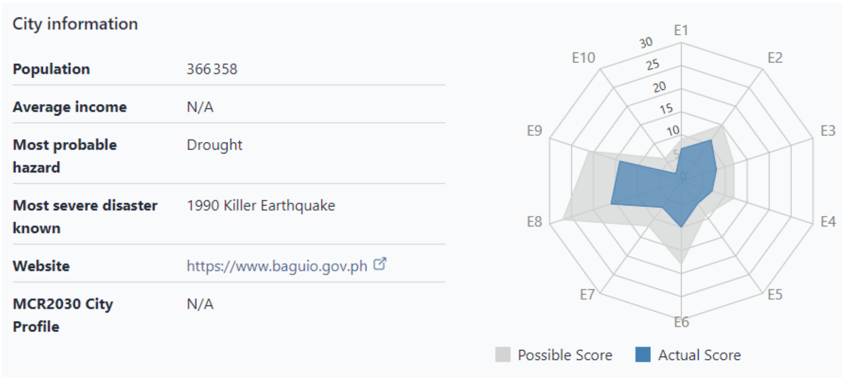

Figure 12: Disaster Resilience Score of the City of Baguio in the Philippines

Source: UN Office of Disaster Risk Reduction[64]

The Scorecard allows showing the city's disaster resilience for each Essential. As an example, the city of Baguio's score in Essential 8, Infrastructure Capacity, is shown in the figure hereafter. The resilience assessment over 9 different infrastructures, comprising among others the key infrastructures water, energy, transport and communication, is shown in the figure hereafter. As this refers to the preliminary assessment, the only levels that are distinguished are 0, 1, 2 and 3. In the detailed assessment, the levels 4 and 5 are added to the scale, allowing to distinguish comparatively higher resilience levels.

Figure 13: Example of the Disaster Resilience Score of Essential 8, Infrastructure Capacity

Source: UN Office of Disaster Risk Reduction[65]

However, too few APEC cities integrate disaster resilience into their urban planning. The creation of a Loss and Damage Fund within the framework of the UNFCCC is expected to have an incentivising effect on cities to start disaster resilience planning.

2. Instruments for Cities to Attain Carbon Neutrality

Green Finance instruments have been developed to bridge the financing gap of the green energy transition. Credit risk guarantees (CRG) are increasingly being used to de-risk renewable energy investments which are still perceived as having higher risks than fossil-based investments. CRG are granted as collateral to banks financing RE investments. The theoretical analysis determines the factors on which depend the optimal credit guarantee ratio for renewable energy (RE) loans. CRGs can be used to back green bonds, in conjunction with data-driven risk assessment, sustainability linked lending, green finance certification, and regulatory sandboxes experimenting with innovation. The analysis of CRGs in Metropolitan Manila involves the special Philippines' context which is characterized by a moratorium on new coal power plants, the plan to massively scale up imported LNG, and the experienced failure of feed-in-tariffs which, due to a design problem, failed to increase renewables share but increased general electricity rates for the poor. The Philippines' electricity system is divided into three separated grids covering Luzon, the Visayas and Mindanao, respectively. Hydropower and geothermal remain the largest renewable sources. All the institutions of a modern power market are in place in the Philippines: transmission grid, the Energy Regulatory Commission ERC, the Philippine Wholesale Electricity Spot Market WESM, regulations favouring rural electrification by microgrid, possibilities for end-users demanding above 1MW to request market access as contestable consumers whereas the 1MW limit is gradually being lowered to 750 and 500kW. Policies on renewables have started in 2010 with feed-in-tariffs, complemented with renewable portfolio standards (2017/18) and a green auction energy program (2020) under which auctions for renewable energy started in 2022. It expects to achieve a 35% RE share in the economy's total power generation by 2030 and 50% by 2040. Philguarantee is the publicly owned Philippine guarantee institution. It provides several types of credit risk guarantees for large enterprises of both, the renewable and the conventional energy segments. Since the COVID-19 pandemic, CRGs for micro, small, and medium enterprises (MSMEs) have been added. The idea of a Global Credit Guarantee Facility (GCGF), formulated by the Climate Policy Initiative in 2023, could be explored further. The Philippines could develop this idea in the framework of the APEC Energy Working Group and APEC cross-fora cooperation.

The Cities Climate Finance Leadership Alliance (CCFLA), launched in 2014 by the United Nations, is the only multi-level and multi-stakeholder coalition of leaders committed to deploying city-level finance by 2030. CCFLA brings together over 80 member institutions covering a wide spectrum of institutions committed to boosting urban climate finance. The 2019 CCFLA report on the State of Cities Climate Finance provided the first comprehensive estimate of global urban climate finance and investment gaps. Of the USD5 trillion needed annually, only USD384 billion have been made available. CCFLA's net-zero carbon buildings workstream analysed four categories of barriers to investment in green or zero-carbon buildings: financial, investment risk/opportunity, market readiness, and regulatory barriers. CCFLA mapped policy and financial instruments that cities can use to drive investment in zero-carbon buildings and target four high-impact thematic areas: (1) cooling technologies, (2) embodied carbon (in construction activities), (3) adaptation, and (4) just transition. Two mechanisms were found to be particularly impactful for cities to install various types of low-carbon equipment – cooling being one of them – with no upfront cost: PACE (Property assessment for clean energy) and PAYS (Pay-as-you-save). Both mechanisms require implementation of several other measures, not all of which can be fully supported by cities alone.

Financing the circular economy of smart cities relies on four elements of success: 1) a solid business case such as Product-as-a-Service, Industrial Symbiosis, Closed Loop, Upcycling and Downcycling; 2) Infrastructure, especially financial infrastructure designed e.g. to co-finance a return scheme of materials to urban miners, i.e., companies that extract materials from waste and taxing polluters, 3) education, including engineering all aspects of the circular economy, 4) mindset, especially concerning financing decisions that far too frequently continue to rule out investing in viable circular companies due simply because these decisions are made with old knowledge, as well as, with a decades old mindset.

Carbonomics is a dynamic concept putting the carbon economy at the heart of climate-smart cities aiming to balance economic development with environmental responsibility. Cities often host fortune 500 companies which face similar problems like cities. Most of them incorporate ESG standards into their decision to enhance their market value, but they suffer from the vague definition of these standards. The compliance markets under Paris Agreement's Article 6.4 are set to increase to USD5-6 trillion by 2030, accelerated by the Carbon Border Adjustment Mechanism CBAM of the EU. The voluntary carbon markets VCM are less regulated, offer much lower carbon prices and greater potential for greenwashing. The EU Emissions Trading System continues to serve as a guide for global markets. To better capture emissions from embodied energy, smart cities are changing the method from production-based inventories to consumption-based inventories (CBI). Carbon Monitor Cities prepares near-real-time daily estimates of GHG emissions from 1,500 cities worldwide. Carbon Monitor Europe utilizes a daily tracking methodology capturing timely data on emissions across six sectors (power, industry, ground transportation, domestic and international aviation, and residential areas). Carbon rating agencies are shifting from analysing individual projects and sectors toward city-level, consumption-based GHG emissions assessments, but suffer from lack of universally accepted standards for quality assessments. A new series of VCMs has been evolving among others in Australia (Emissions Reduction Fund (ERF, 2014), US (Energy Transition Accelerator, 2022) and Japan (GX League, 2022). APEC cities can use a variety of financing mechanisms, among them concessional loans, insurance mechanisms, voluntary and cross-border carbon markets, or the usual green finance instruments such as green bonds.

Leveraging carbon neutrality incentives can be done through sustainability accounting. Environmental, social and governance (ESG) information is a subset of sustainability accounting. The outside-in approach describes the investor’s view of how ‘external’ forces such as climate change impact the firm and more specifically, its cash flows. This approach is exemplified in the recent (2023) accounting standards of the International Sustainability Standards Board (ISSB). The complementary inside-out approach describes a multi-stakeholder view of how the firm/city impacts on the world. It is exemplified in the Global Reporting Initiative (GRI 2021). Cities are more likely to use the inside-out approach. The SDGs, if applied to cities, are an example of an inside-out approach. Another approach uses the concept of the nine planetary boundaries (maximum planetary limits) which can be combined with the 12 elements of social foundation (minimum social needs) to yield the doughnut model which has been applied by the city of Amsterdam. Cities can use this framework in an 8-step procedure.

Accounts-based sustainability indicators for cities are developed by using an agent-based presentation of interactions among urban sectors (primary, secondary, tertiary, government, consumers and the rest of the world) and adding the industrial capital formation or consumption account. The three definitions of the GDP are derived and illustrated at the example of Hong Kong, China. It is shown that if public policy drives the energy transition, it should do so by public procurement rather than by subsidies and should be financed by the polluter pays principle. By generalizing the capital formation or consumption from the usual industrial capital to other forms of capital (environmental, human, financial), the generalized GDP can be defined which should better be called Gross Holistic Product GHP. It contains information that is collected in the System of Environmental-Economic Accounting (at the macro-level) and corresponds to corporate-level GRI or ESG information. From this, the Net Holistic Surplus as universal measure for sustainability is defined. The analysis also identifies the eight categories of sustainable or unsustainable cities.

2.1. Green Finance for the Urban Energy Transition

2.1.1. Overview of Green Finance Instruments

Green finance instruments have become an indispensable means of financing the clean energy transition. The APEC Green Finance Report - Unlocking the Urban Energy Transition[66] has analysed in detail the need and role of green finance in the energy transition of cities. Hereafter is a summary of important elements. Prior to starting a talk about green finance, it should be recalled on what basis "greenness" is defined. The special characteristic of green finance, as opposed to ordinary or "grey" finance, is to be directed towards green activities. Green finance can be defined as finance promoting green industries or green activities. It can also be understood as a means to balance direct consumer- and producer-oriented subsidies on fossil fuels which globally still outnumber support in favour of renewables by a factor four[67]. The definition of green activities has been addressed by individual jurisdictions in so-called taxonomies of green industries. These taxonomies are explicitly defined lists of green activities. The two best known taxonomies are the Chinese taxonomy called China Green Bond Endorsed Project Catalogue first released in 2015[68] and revised in 2021, a taxonomy based upon the whitelist approach including only those activities that are undoubtedly sustainable (e.g., manufacturing of solar panels or wind turbines), and the EU Taxonomy Regulation which entered into force in 2020[69], based upon the technical screening criteria (TSC) approach. The TSC approach allows to consider larger parts of the economy as green or at least contributing to sustainability under certain conditions.

Both, EU and China, have started work towards identifying commonalities and differences in their respective approaches and outcomes of green taxonomies. A joint Working Group has been created within the International Platform for Sustainable Finance (IPSF). This Working Group published its result in November 2021 under the name "Common Ground Taxonomy (CGT) – Climate Change Mitigation"[70].

Green finance comprises the totality of financing instruments destined to finance green activities. The best-known green finance instruments are green bonds. The first ever issued green bond was emitted in 2007 by the World Bank and the European Investment Bank (EIB).

Green bonds are emitted on the open market and can be traded. The total volume of emitted green bonds has reached USD1 trillion worldwide.

Contrary to green bonds, green loans are more recent, are today mainly emitted by the International Financial Corporation (IFC), a member of the World Bank Group. In terms of volume, they are less developed than green bonds (USD33 billion) and are bilateral operations between a lender and a taker. Green loans are not traded on the market.

The third – and probably the most important – green finance instrument is green equity. The discussion about rising the role of green equity has taken place in the COP26 in Glasgow in 2021 and is mainly motivated by the finding that the energy transition could not be financed by debt (bonds, loans) alone, but required a high proportion of equity financing. Ideally equity constitutes a major part of finance for the clean energy transition, whereby equity might attract debt where necessary, creating a catalytic multiplier effect of the type proposed by the Catalytic Capital Consortium (2019)[71]. The IEA[72] estimates the investment need for the clean energy transition to be around USD4 trillion per year. If e.g., USD1 trillion is covered by green bonds, the remaining USD3 trillion must be covered by green equity and green guarantees. Contrary to debt, equity and guarantees do not have to be reimbursed and bear the main risk of a project.

To attract green equity and green guarantees, the receivers need a favourable investment climate for green investments. Improving the investment climate for green investments can be done in many ways. One way is to set up a publicly organized credit risk guarantee scheme as described in the sections below. This serves to diminish the risk of green projects and hence to promote the supply of equity for such projects. Another way is to hold internationally competitive tendering for commissioning large renewable projects. This instrument is known to have diminished the price of large-scale solar and wind energy to record-low levels[73]. A third way of improving the investment climate for green electricity is introducing feed-in tariffs (usually offered to households and small captive consumers) or power purchase agreements (usually concluded between electricity producers and large consumers or cities having the possibility to choose their electricity supplier). Lastly, microgrids can be a way to bring solar electricity to rural disconnected communities. The example of Barefoot Colleges that originated in India in the 1990s but has now become global[74], shows impressive results.

For cities, green finance is a new source of finance for green projects in areas such as renewable energy, energy efficiency, sustainable waste management, sustainable land use, biodiversity conservation, clean transportation, clean water, or climate adaptation projects. In all these areas, cities may choose between green equity financing (usually provided within a public-private partnership) or issuing green bonds.

Public private partnerships to promote renewable energy in developing and emerging economies have developed for several decades. A critical analysis of such projects can be found in Kaminsky (2022)[75]. The World Bank keeps a database for private participation infrastructure (PPI)[76] in the energy, transport, water and sewerage, ICT backbone, and Municipal Solid Waste (MSW) sectors.

Municipal green bonds have been used by cities since about 2014[77]. On 11 January 2019, S&P launched a specific Green Municipal Bond Index[78]. The global volume of annually emitted municipal green bonds has stagnated in recent years around a level of about USD10 billion annually. On a more general level, the role of multilateral development banks in the green bond market has been overtaken by financial and non-financial (e.g., property) corporate issuers. Note also the steadily rising part of sovereign emitters.

Concerning the Philippines in particular, the introduction of feed-in tariffs in 2008 was contested in court and found to be compatible with the constitution in 2012. Contrary to what happened almost everywhere else, the feed-in tariffs did not increase the share of renewable electricity in total final energy consumption. In fact, renewable electricity generation increased from 2014 to 2018 but then dropped again. In the same period, TPES and TFC strongly increased until 2019, see figures below.

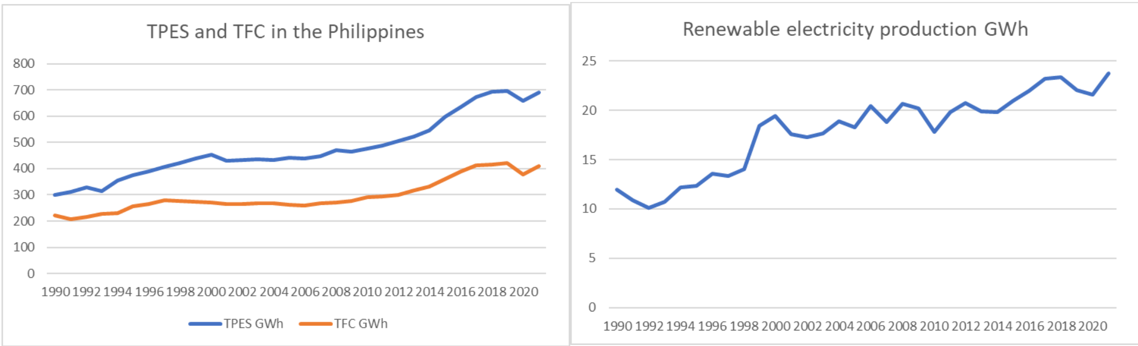

Figure 14: Evolution of the TPES, TFC and renewable electricity in the Philippines

Source: APSEC based on Compendium of Philippine energy statistics and information[79]

As a result, the share of renewable electricity in TPES and in TFC, respectively, decreased in the Philippines in the years 2012 to 2019 as shown in the figure below. The cause of this unfortunate development has been analysed by several authors. A discussion paper evaluating the feed-in tariff policy of the Philippines concludes that feed-in tariffs have decreased the share of renewables in the Philippines while at the same time made electricity more expensive for the average consumers[80]. The root cause may be that the Philippine feed-in tariffs do not distinguish between size of the production unit, that the quotas for each technology may have been too big, and that no price or quantity distinction was made between different locations, therefore failing to take into consideration the regional demand gap differences[81]. Recall that the Philippines has three disconnected electricity grids: Luzon, the Visayas and Mindanao. Offering the same tariff for all production sizes and regions incentivizes investors to set up the largest possible production units in the region with lowest cost, allowing them to get the biggest profits, but obliging authorities to curtail the existing producers in regions where the addition of FIT created a production surplus. This disequilibrium may have put unnecessary charges on the average consumer who pays for FITs by a surplus on his electricity rate.

In contrast to the decreasing renewables share in the Philippines in the period 2012 – 2019, the global context of renewable energy share is starting to take off steadily in the same period (2012 – 2019). During their 2023 meeting, APEC Leaders have encouraged efforts to triple renewable energy capacity globally through existing targets and policies by 2030[82]. During the recent COP28, nearly 120 governments have supported tripling the installed renewable electricity capacity. Without efficient measures to incentivise production of affordable renewable energy, the Philippines might rapidly be left behind the rest of the world.

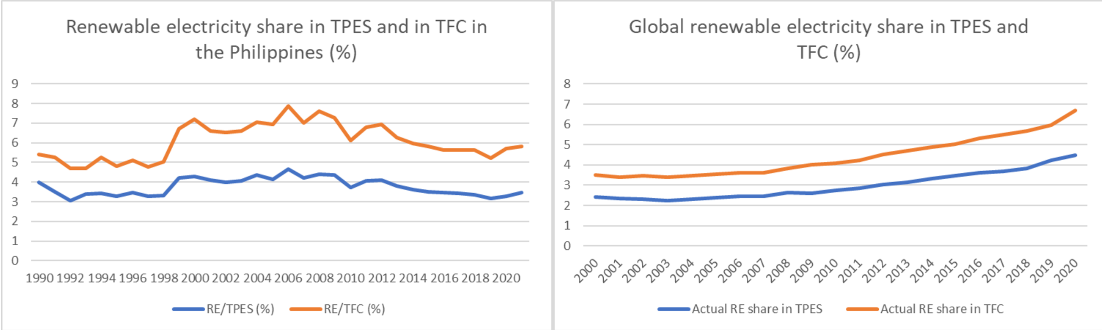

Figure 15: Renewable electricity share in TPES and TFC in the Philippines and World

Source: APSEC based on data of various sources

This global upward trend is primarily motivated by the fact that renewable electricity has now become the cheapest electricity generation method. The task for the public authorities is now to allow market penetration of renewable electricity to happen without obstacles, and facilitating any accompanying measures that are needed to accelerate this trend. The Credit Risk Guarantee (CRG) is among the measures improving penetration of renewables. It should, however, not be seen as the only measure to attain this task but accompanied by measures such as power purchase agreements (PPA) for large producers, a revised FIT scheme at municipal level for small rooftop prosumers, possibly also covering fix battery energy storage, public private partnerships and the access of cities to green bonds, to name but a few instruments.

PHILGUARANTEE, the official credit risk guarantee authority, has been running a credit risk guarantee scheme in the Philippines under its priority sectors guarantee group for large renewable electricity producers since 2018. This has been extended, since 2021, to SME small commercial producers. The housing guarantee group delivers guarantees to housing but does not include non-commercial rooftop household electricity prosumers making up more than a third of the current electricity market. In view of these circumstances, it is suggested to the Philippines' authorities to explore extending the CRG to small consumers wishing to set up rooftop PV, a measure that might be done within the housing guarantee scheme.

The first of three following sections describes the credit risk guarantee from a theoretical point of view, then the second section outlines the context of the Philippines electricity market. The third section focuses on the CRG as offered at present by PHILGUARANTEE and describes the benefits and risks of creating an APEC wide regional credit guarantee scheme following a discussion proposal of a multilateral CRG made recently by the Climate Policy Initiative.

2.1.2. The Role of Credit Guarantee Schemes in Renewable Energy Development: A Theoretical and Policy Analysis

Authored by Dr. Farhad Taghizadeh-Hesary, Associate Professor at School of Global Studies & TOKAI Research Institute for Environment and Sustainability (TRIES), Tokai University, Japan, and Vice-President of The International Society for Energy Transition Studies (ISETS).

Introduction

With the larger goals of sustainable development and environmental protection, advancing renewable energy (RE) deployment is essential globally. The RE sector has grown in importance within the modern energy landscape, driven by the need to mitigate climate change and a shared resolve to rely less on conventional fossil fuels. Reducing financial risks that naturally come with investments in RE, caused by the volatile nature of the sector and the sizeable capital expenditures required by such projects, is essential to realizing this transition.

Environmental concerns and the search for sustainable energy sources have fuelled the urgent need for a global transition from conventional energy sources to renewable ones (Ullah et al., 2021)[83]. In response to these difficulties, creating credit guarantee programs has become a tactical tool to support the growth of RE projects (Chang et al., 2019)[84]. These programs are essential in reducing the elevated risk-return ratios and significant capital costs connected to green infrastructure. Credit guarantee programs serve as a financial safety net, shielding project owners from potential financial responsibilities and facilitating the execution of RE projects. However, to effectively implement them, one must have a sophisticated understanding of several crucial factors.

First and foremost, defining the negative outcomes these plans can reduce is crucial. Adverse events include a variety of potential difficulties, such as market volatility and natural disasters (Tran et al., 2017)[85]. The active participation of governmental and financial institutions and exploring novel financing strategies for RE projects is essential (He et al., 2019 & Smirnova et al., 2021)[86][87].

A review of the literature and the theoretical analysis in this report show that credit guarantee programs are essential in spurring the growth of RE projects. These programs, referred to as "de-risking guarantee schemes", are a crucial financial tool strategically created to increase investor confidence, reduce risk, and create an environment favourable for developing RE projects. De-risking guarantee schemes serve as a financial safety net, protecting parties with vested interests in RE projects from market volatility and unpredictability. This research design was influenced by the growing need to fully comprehend and navigate the complex world of credit guarantee schemes as practical tools for advancing RE development within the purview of the Asia-Pacific Economic Cooperation (APEC) region. The study aims to provide a theoretical analysis to logically show the role of credit guarantee schemes in filling the finance gap of RE projects, especially considering the optimal credit guarantee ratio for RE loans.

APEC has taken on a significant role in formulating and implementing sustainable energy policies to promote switching to RE sources in a globalized world. The idea to create an APEC-wide de-risking guarantee scheme for RE has emerged in this context, and it calls for in-depth theoretical and policy analysis. This report aims to clarify the complex rationale behind such schemes by delving into their theoretical underpinnings and strategic imperatives. It also plots a course toward realizing a functional pilot project, symbolic of the plan's potential advantages, located in the thriving neighbourhoods of Metropolitan Manila, a renowned APEC city.

This in-depth study unfolds over the following pages, navigating the literature to identify finance's crucial role in the energy transition (Section II). The importance of credit guarantee schemes in developing RE is discussed in detail, highlighting case studies supporting our position. Then, we provide the theoretical background to determine the optimal credit guarantee ratio for RE loans (Section III). As this research journey's contours become apparent, we move toward a synthesis of findings and policy recommendations (Section IV) that emphasizes the transformative potential of credit guarantee schemes, not just as financial instruments but as visionary catalysts ready to accelerate the trajectory of RE development in the APEC region and beyond. A new era in which the switch to sustainable energy sources assumes a resonance far beyond the realm of purely theoretical consideration is being ushered in thanks to the profound implications of our study, which resonate with stakeholders ranging from governmental organizations and financial institutions to RE project developers.

Literature Review

a) Importance of Finance in the Energy Transition

Scholarly research and policy discussions now centre on finance's role in easing the switch from conventional to RE resources. The multifaceted role that finances play in accelerating the energy transition is critically examined in this literature review, which also clarifies the significance of financial mechanisms and evaluates the opportunities and challenges associated with financing RE projects.

The Crucial Role of Finance

This section focuses on finance's crucial role in moving the RE sector across multiple dimensions. Pathania et al. (2014) provide evidence in their study that finance and financial innovation are essential aspects of every energy transition[88]. First and foremost, finance, for example, foreign direct investment and financial development, plays a central role as an investment catalyst for RE projects and initiatives (Zhang et al., 2023)[89]. In way to construct, operate, and maintain the RE infrastructure, from solar installations to wind farms, financing is essential to these projects. Such projects are difficult to implement without sufficient funding. Second, the crucial role of finance in accelerating advancements in RE technologies is a crucial component highlighted by researchers like Steffen et al. (2018)[90], Taghizadeh-Hesary and Yoshino (2019)[91], and Le et al. (2020)[92]. Research and development expenditures must be significant if novel solutions in RE are to be developed and commercialized. Finance motivates these ground-breaking innovations, accelerating their development and putting downward pressure on the overall costs related to RE production. By reducing their cost, RE sources become more competitive and are positioned as viable alternatives to traditional energy sources.

Additionally, researchers such as Smirnova et al. (2021)[87], Kim et al. (2016)[93], and Zhang et al. (2023)[94] have highlighted the fundamental relationship between finance and the transformation of the renewable energy markets. The demand for RE sources is boosted by monetary incentives, government subsidies, and right investment strategies, among other key factors. These mechanisms have an extensive effect, promoting market expansion, fostering competition, and significantly assisting in diversifying energy sources. They thus pave the way for a vibrant and sustainable energy landscape that aligns with the demands of the modern world.

Challenges and Opportunities

The literature on RE financing deftly explains various challenges and corresponding opportunities, illuminating the complexity of this changing environment. The inherent capital intensity of RE projects is the main issue consistently identified across studies (Wang et al., 2023) [95]. Significant upfront investment is needed to develop and deploy renewable infrastructure, erecting a significant financial barrier that may deter potential investors. As a result, there is a growing need to investigate creative financing options designed to lessen the heavy financial burden project developers are bearing. Uncertainty in policy and regulations also appears as a persistent issue affecting RE financing (Rubini et al., 2012 & Liu et al., 2021)[9697]. Consistent policies are inextricably linked to the stability and allure of the RE sector to potential investors. Investment risks are created by uncertainty, including the possibility of frequent policy changes, which can also impede the smooth inflow of capital into the industry. Maintaining a transparent regulatory environment that inspires investor confidence becomes crucial to supporting the sector's long-term growth. Moreover, the problem of accessing finance, especially for innovative and small-scale renewable projects, emerges as a pervasive and formidable challenge resonating across various academic inquiries (Smirnova et al., 2021)[98]. Particularly in decentralized and community-driven initiatives that frequently struggle with pronounced challenges in accessing conventional financing conduits, bridging the gap is imperative. In order to achieve this, creative financial solutions and cooperative alliances are actively being investigated to make the necessary access possible and promote a more diverse participation in the RE sector. Additionally, the issue of access to financing, particularly for small-scale and innovative renewable projects, emerges as a pervasive and formidable challenge resonating across various academic studies (Smirnova et al., 2021; Butu et al., 2021)[99].

The rapid pace of technological advancements in the field of RE has caused a recent increase in discussion of technological risks (Kempa et al., 2021)[100]. Allocating funds to innovative technologies that have not been thoroughly tested involves potentially introducing unforeseen difficulties and uncertainties. As a result, it is essential to ensure that financiers are fully informed about the technological landscape and the associated risks to secure investment and maintain the culture of ongoing innovation. This thorough examination of the difficulties and possibilities posed by the financing environment for RE emphasizes the sector's dynamism. It emphasizes the importance of developing flexible strategies, ground-breaking financing options, and stroboscopic frameworks that can deftly navigate the complexities associated with this multifaceted domain.

Opportunities in Financing Renewable Energy Projects

Many opportunities in RE financing beckon, encompassing various innovative aspects that highlight the sector's dynamism. Within this landscape, financing innovation is a prominent feature, as evidenced by the emergence of progressive financial means such as crowdfunding platforms, peer-to-peer lending, and green bonds (Le et al., 2020 & Elie et al., 2021; Karim et al., 2022; Taghizadeh-Hesary et al. 2023)[101,102,103]. These instruments have grown in popularity, providing new opportunities for diversifying funding sources and democratizing investment opportunities. In addition to this surge of innovation, government policies and incentives have a significant impact. They are a solid foundation for propelling RE investments forward. Tax credits, feed-in tariffs, and renewable portfolio standards have emerged as pillars in this domain (Liu et al., 2019 & Yang et al., 2019)[104 105]. These mechanisms reduce investment risks and generate stable and predictable revenue streams, fostering an environment conducive to long-term growth.

Furthermore, technological advancements in RE continue unabated, ushering in transformative shifts (Chen et al., 2018)[106]. These advancements, characterized by cost savings and increased energy production efficiency, catalysed the sector's growth. They increase the economic viability of renewable projects, making them more appealing to a broader range of investors. Furthermore, RE investments have begun to assume a broader mantle, economic resilience, beyond finance (Awerbuch et al., 2006 & Ven et al., 2017)[107108]. In an era beset by climate change and energy security challenges, investments in renewables demonstrate economic diversification and serve as a beacon of sustainability, gradually reducing reliance on fossil fuels and enhancing energy security as well (Amin et al., 2022)[109]

b) Role of Credit Guarantee in Renewable Energy Development

The critical role of credit guarantee mechanisms in RE development has gained prominence in the discourse of sustainable energy transition. This literature review section critically examines credit guarantee schemes' multifaceted role in underpinning and catalysing RE ventures, providing a nuanced perspective on their significance, impact, and emerging trends.

Facilitating Renewable Energy Investment

Credit guarantees are steadfast guardians of RE investment, providing strong risk-mitigation capabilities (Bedendo et al., 2013)[110]. Their importance in protecting lenders and investors from potential defaults or unfavourable circumstances has been repeatedly emphasized. These risk-reducing characteristics promote investor confidence, effectively reducing perceived investment risks and facilitating a solid flow of capital into the industry. Furthermore, as the market for RE develops, so does its reliance on investments from the private sector. Credit guarantees are emerging as potent catalysts in an era where public funding alone can no longer satisfy the capital requirements of RE projects (Wall et al., 2019)[111]. Through these mechanisms, private financiers are encouraged to participate in funding initiatives actively, diversifying the sector's traditional reliance on government funding. Credit guarantees also serve as an example of allocating scarce public resources effectively (Zecchini et al., 2009)[112]. Governments can increase their financial support by encouraging private investment, which will help to build a large and durable RE infrastructure while reducing the strain on public finances. Taghizadeh-Hesary and Yoshino (2019)[113] introduced the green credit guarantee scheme. Their theoretical study shows the establishment of green credit guarantee schemes and returning a portion of the tax revenue generated initially from the spillover effect of green energy supply to investors. It can reduce the risk of green finance and increase the rate of return of green energy projects, respectively.

Enabling Market Competitiveness

Credit guarantees are crucial in increasing competition in the RE market (Chang et al., 2019)[114] By reducing the alleged risks attached to them, these mechanisms help level the playing field for RE. As a result, RE sources can compete more successfully with conventional energy sources, which have historically been perceived as carrying fewer risks, encouraging healthy competition. Furthermore, more energy diversification has been linked to creating credit guarantee schemes (Baltuttis et al., 2020)[115]. Credit guarantees increase energy security and resilience by reducing reliance on fossil fuels and reducing exposure to geopolitical risks associated with traditional energy sources. Credit guarantees have also been shown to help foster technological innovation in RE. As a result of the assurance they offer, RE projects are more appealing to investors, fostering an environment favourable to the creation and application of cutting-edge solutions. In turn, these developments increase the sector's global competitiveness.

Mitigating Barriers and Challenges

Credit guarantees are becoming increasingly valuable tools in the field of RE, capable of overcoming market obstacles. These obstacles, ranging from high startup costs to technological risks, frequently loom large and obstruct the development of RE projects. Credit guarantees serve as a financial safety net that helps these projects get over early obstacles and take off. Credit guarantees also promote inclusivity by democratizing access to capital, especially for SMEs and community based RE projects (Boocock et al., 2005)[116]. These projects frequently struggle to obtain conventional financing because of their size or perceived risk. Credit guarantees fill this gap and guarantee diversity in the RE sector. Additionally, credit guarantee schemes provide a degree of stability in environments characterized by policy and regulatory uncertainty (Caselli et al., 2019)[117]. Knowing that their investments are supported by financial security gives investors a sense of confidence. Furthermore, it has not gone unnoticed that credit guarantees can be adjusted to novel financing strategies. These mechanisms easily accommodate emerging paradigms like green bonds, impact investments, and blockchain-based crowdfunding. This adaptability fits with the RE industries and investors' aspirations for sustainability, ensuring that financing models remain responsive to the changing environment.

c) Case Studies of Public and Private Credit Guarantee Schemes

This section embarks on a comprehensive analysis of specific case studies concerning credit guarantee schemes within the RE sector. This review aims to shed light on the crucial achievements and priceless lessons learned from these endeavours through a thorough analysis of public and private credit guarantee mechanisms.

Analysing Specific Case Studies

Case studies of credit guarantee schemes shed light on their practical impact and efficacy while offering priceless insights into their crucial role in attracting investments for RE projects.

One notable instance is the Kreditanstalt für Wiederaufbau Green Energy Program in Germany (Hubert and Cochran, 2013)[118]. This government-sponsored program has become a shining example of how credit guarantees can significantly increase the financing for RE sources. The program effectively reduces risks by guaranteeing lenders and encouraging financial institutions to support RE initiatives. Such success tales demonstrate the critical role of public credit guarantee programs in creating an environment conducive to investment in RE projects.

In the private sector, the case of the Solar Energy Insurance Company (SEIC) in the US provides an illuminating example of the function of specialized insurance organizations in enhancing investor confidence in the RE sector. The strategy used by SEIC, which entails providing credit enhancement for solar projects, exemplifies the cutting-edge ways that private credit guarantee mechanisms can improve the risk-reward profile of investments. In order to create customized solutions to deal with the particular difficulties of financing RE, this case study emphasizes the significance of private sector involvement and innovation.

Policymakers, financiers, and project developers can learn much from putting these case studies into the larger context of financing RE. These actual instances show the viability and efficiency of credit guarantee programs, both public and private, in releasing the enormous potential of investments in RE. They, therefore, have a significant bearing on this paper's investigation of the function of credit guarantees in reducing the risk associated with RE projects and facilitating their transformation from concept to reality.

Highlighting Key Successes and Lessons Learned

Analysing case studies of credit guarantee programs reveals their successes while also teaching important lessons that can influence policy and practice in the future for the RE industry. These case studies highlight the many benefits of credit guarantee mechanisms, especially regarding risk reduction and market confidence. Researchers and professionals learn more about how credit guarantees can successfully reduce risks related to investments in RE by examining these real-world examples. Furthermore, these cases highlight the value of open risk assessment methodologies and the need for public and private sector cooperation to inspire investor confidence. This important realization highlights the crucial function of credit guarantees in promoting market stability, a necessary condition for luring sustainable investments.

Another central theme of these case studies is the involvement of the private sector in financing RE. Success stories like those of the Solar Energy Insurance Company (SEIC) highlight private organizations' remarkable nimbleness and creativity in filling market gaps and promoting investment. These case studies prove that market-driven solutions can significantly benefit RE financing. Additionally, they stress the significance of regulatory frameworks that foster the participation of the private sector. The lessons learned from these case studies are invaluable for policymakers and financial institutions looking to effectively use private sector expertise and resources to meet financing needs for RE.

The case studies also highlight how crucial it is to customize credit guarantee programs to meet the needs of the RE industry. Public credit guarantee corporations, like KfW in Germany, should aim to boost private investment in the financial market instead of crowding it out. For instance, KfW operates with just one office in Frankfurt, and rather than directly lending to RE projects, it provides guarantees or subsidized loans to private financial institutions. This strategic approach encourages private sector involvement in RE initiatives while avoiding the crowding-out effect that direct lending might create. By collaborating with private intermediaries, KfW not only fosters RE growth but also maintains a vibrant and competitive financial market. In doing so, KfW serves as a prime example of how public credit guarantee corporations can facilitate and enhance financial market dynamics while promoting sustainable economic development. (Taghizadeh-Hesary and Yoshino, 2020)[119]

The KfW Green Energy Program in Germany has demonstrated that programs that align with market conditions and economywide priorities are more likely to be successful. The ability of credit guarantees to respond to the changing requirements of the RE landscape is made possible by flexibility and adaptability in scheme design, which emerges as fundamental success factors. These cases also offer important insights into governance frameworks that can boost the efficiency of credit guarantee mechanisms and encourage sustainable investment in RE sources. Additionally, while highlighting successes, these case studies highlight instances where plans encountered difficulties or did not produce the desired results. These failures teach stakeholders priceless lessons that help them improve credit guarantee systems for future endeavours. Critically analysing these cases and drawing lessons from them can help create credit guarantee programs for the RE industry that are more reliable and resilient.

Theoretical Background

This section provides a theoretical approach inspired by Yoshino and Taghizadeh-Hesary (2019)[120] and Taghizadeh-Hesary et al. (2022)[121] to consider the optimal credit guarantee ratio for RE loans. Based on their study, the credit guarantee ratio depends on three factors: (i) the financial soundness of the lender (bank), (ii) the economic climate, and (iii) the policies of the state for supporting RE projects. Economically, sound lenders may access a higher guarantee ratio, while a more appropriate economic climate and government policies may lower the guarantee ratio. Adopting the same credit guarantee ratio for all banks will result in a moral hazard and will not give enough motivation to the financial institutions to enhance their soundness. To model the guarantee ratio, we can start with the policy objective function (Eq. (1)):

$$U = w_1(L - L^*)^2 + w_2(\rho - \rho^*)^2 \tag{1}$$

In Eq. (1), U denotes the state objective function. Furthermore, ($L - L^*$) and ($\rho - \rho^*$) are two different state objectives: stabilizing the quantity of loans and setting the nonperforming loans (NPL) ratio to the desired ratio. w_1 and w_2 represent the policy weights related to L and ρ.

In Eq. (1), the desired level of the loan (L^*) equals $(1 + \alpha)L_{t-1}$, where α shows the desired growth rate of the loans received by REs and is determined by the state. Moreover, in this equation, ρ^* denotes the desired level of the nonperforming loans ratio (NPL/L) and is obtained by the equation $\rho^* = (1 - b)\rho_{t-1}$, where b indicates changes in the desired NPL ratio. The RE loan demand function can be written as Eq. (2):

$$L = l_0 - l_1 r_L + l_2 Y^e \tag{2}$$

Here, l_0 shows the fixed RE demand for loans. r_L and Y^e represent the interest rate of the loans (with the coefficient of l_1) and the expected GDP, respectively.

A bank can maximize its profit through equations 3 and 4:

$$Max \quad \pi = r_L(L)L - \rho(g.Y.P_L.P_s.M.Z)L - r_D D - C(L.D) \tag{3}$$

$$\text{Subject to} \quad (1-\rho)L + \rho L = D + A \tag{4}$$

In Eq. (3), $g, Y,\ P_L, P_S, M,$ and Z show the credit guarantee ratio, GDP, land price, stock price index, money supply, and financial profile of the banks, respectively. Furthermore, r_D Represents the interest rate for deposits, while D and C indicate deposits and the bank's operational costs.

Considering Eq. (2), the interest rate on loans to Res can be written as Eq (5):

$$r_L = \frac{1}{l_1}(l_0 + l_2 Y^e - L) \tag{5}$$

To calculate the equilibrium loan amount, the first-order condition (FOC) of Eq (5) should be considered as Eq. (6):

$$\frac{\partial \pi}{\partial L} = -\frac{1}{l_1} \times L + \left[\frac{1}{l_1}(l_0 + l_2 Y^e - L\right] - \rho(\ g.Y.P_L.P_s.M.Z) - r_D\text{-}\rho_L = 0 \tag{6}$$

Writing Eq. (6) for L shows the equilibrium loan amount for REs as Eq. (7):

$$L = \frac{l_1}{2}\left[\frac{l_0}{l_1} + \frac{l_2}{l_1} Y^e - \rho(\ g.Y.P_L.P_s.M.Z) - \ r_D - \rho'_L\right] = 0 \tag{7}$$

Next, the FOC of Eq. (5) with regards to the optimal credit guarantee ratio (g) can be obtained with Eq. (8):

$$\frac{\partial U}{\partial g} = 2w_1\,(L - L^*) \cdot \frac{\partial L}{\partial g} + 2w_2(\rho - \rho^*) \cdot \frac{\partial \rho}{\partial g}$$

$$= 2w_1\,(L - L^*) \cdot (\frac{-l_1}{2} \cdot \frac{\partial \rho}{\partial g}) + 2w_2(\rho - \rho^*) \cdot \frac{\partial \rho}{\partial g} \tag{8}$$

Eq. (3) expresses that the bank's profit is a function of several factors, including the default risk ratio (ρ), and we need to obtain a model to capture the influencing factors on ρ through Eq. (9):

$$\rho = F(g.Y.P_L.P_s.M.Z) \tag{9}$$

To expand the model in Eq. (9), we follow Yoshino and Taghizadeh-Hesary (2019)[122] and Yoshino et al. (2019)[123]. Considering the studies mentioned above, Eq. (9) can be expanded as Eq. (10):

$$\rho = F(g.Y.P_L.P_s.M.Z) = -\alpha_1 g - \alpha_2 Y - \alpha_3 P_L - \alpha_4 P_S + \alpha_5 M - \alpha_6 Z \tag{10}$$

Finally, we can rewrite the optimal credit guarantee ratio (Eq. (8)) with Eq. (10) as Eq. (11):

$$g = -\frac{1}{\alpha_1\left(\frac{w_1 l_1^2}{4} + w_2\right)} \cdot w_1 \frac{l_1^2}{4}\left(\frac{l_0}{l_1} + \frac{l_2}{l_1} Y^e - \ r_D - \rho'_L\right) + \frac{l_1}{2\alpha_1} L^* - \frac{w_2}{\alpha_1}\rho^* - \frac{\alpha_2}{\alpha_1} Y - \frac{\alpha_3}{\alpha_1} P_L - \frac{\alpha_4}{\alpha_1} P_S + \frac{\alpha_5}{\alpha_1} M + \frac{\alpha_6}{\alpha_1} Z \tag{11}$$

Eq. (11) expresses that g (optimal credit guarantee ratio: the percentage of bank loans to RE projects that need to be guaranteed by the credit guarantee scheme) is a function of several factors, and we can simplify Eq. (11) to the Eq. (12):

$$g = \alpha_0 + \alpha_1 L_{RE} + \alpha_2 L_{RE}^{*} + \alpha_3 \rho_{RE}^{*} + \alpha_4 L_F + \alpha_5 r_D + \alpha_6 Y^e + \alpha_7 w_1 + \alpha_8 w_2 + \alpha_9 \rho' + \alpha_{10} P_L + \alpha_{11} P_S + \alpha_{12} Y + \alpha_{13} M + \alpha_{14} Z \quad (12)$$

As is clear from Eq. 13, the optimal credit guarantee ratio for supporting RE development depends on several factors such as actual loans to RE projects, the desired loan level to RE (government objective), the desired default risk ratio of loans to RE projects (government objective), fixed demand for loan, deposit interest rate, expected GDP, the weight for stabilizing the loans RE projects, the weight for reducing the nonperforming loan ratio, marginal increase of nonperforming loans by increase of additional loans, price of Land, price of a stock, GDP, money supply and the financial profile of banks. These need to be considered by policymakers in order to have an efficient and financially sustainable credit guarantee scheme.

Conclusion and Policy Recommendations

Based on our sound theoretical analysis, we present a comprehensive summary of the findings from our investigation into the optimal credit guarantee ratio for RE loans. Our research has highlighted the intricate interplay between three key factors that affect the optimal credit guarantee ratio. Lending institutions, especially banks, must first and foremost be in good financial standing. Due to these institutions' solid financial profiles, they can access higher credit guarantee ratios (for example, 80% or 90% of their loans to RE projects would be guaranteed by the credit guarantee corporation), which enhances their capacity to manage the risks associated with loan defaults expertly. Based on this model, banks with lower creditworthiness would receive a lower guarantee ratio (for example, 50% or 60%).

Secondly, the state of the economy has a significant impact on the credit guarantee ratio. This implies that the credit guarantee ratio is a dynamic variable. During an economic recession, when most projects face challenges in securing financing, riskier projects like RE would encounter even more significant difficulties. In such times, it becomes necessary to increase the credit guarantee ratio. Conversely, the ratio should be gradually reduced when the economy is experiencing growth and prosperity.

Thirdly, government policies designed to support the RE sector significantly impact how risks associated with RE projects are perceived, affecting the credit guarantee ratio. Our research shows how proactive policies, like feed-in tariffs, subsidies, or tax returns, can significantly lower credit guarantee ratios and encourage financial institutions to fund RE projects.

Our thorough analysis has produced several practical policy recommendations, each supported by workable implementation strategies and each bearing the utmost significance for advancing financing for RE:

Dynamic Credit Guarantee Ratios: The proposal for dynamic credit guarantee ratios is crucial in the context of financing for RE. We ensure credit guarantees remain responsive to market changes by allowing these ratios to change in real time based on economic conditions and lender health. This strategy not only protects against moral hazard but also encourages lending discretion. This recommendation is significant because it has the potential to create a stable and flexible financing environment for RE projects by striking a delicate balance between risk-sharing between the public and private sectors.

Green bonds backed by Credit Guarantee: The promotion of green bonds as a means of financing RE projects is extremely important. Taghizadeh-Hesary et al. (2021)[124] proposed a self-sustaining funding mechanism by issuing green bonds to RE projects and offering government-backed credit enhancements. As a result, financing for RE projects is more diverse and more aligned with sustainability objectives. It is an example of a shift toward environmentally responsible and market-driven financing, reducing reliance on conventional credit guarantees and promoting RE development.

Data-Driven Risk Assessment: Risk assessment is a crucial function of a credit guarantee scheme, aimed at identifying high-risk projects and preventing their inclusion within the guarantee program. Investing in data analytics and artificial intelligence tools is crucial for risk assessment. Modern risk assessment is revolutionized by advanced predictive analytics, which gives credit guarantee corporations a more precise way to evaluate credit risk. This could lessen the need for excessively high credit guarantee ratios, improving financing efficiency and reducing reliance on public funds. This policy suggestion emphasizes the strategic value of using data-driven insights to guide decision-making in RE financing, enhancing sector performance overall.

Sustainability-Linked Lending and Guarantee: An innovative and effective strategy involves adopting sustainability-linked lending practices, where interest rates are tied to the sustainability achievements of RE projects. This approach transforms responsible lending into a tangible reality by aligning borrower incentives with environmental objectives. It motivates borrowers to pursue sustainability goals while simultaneously reducing default risks. This recommendation underscores the importance of integrating environmental considerations into lending processes to catalyse a positive shift in the financial sector's perspective on renewable energy. Additionally, guarantee corporations must also evaluate the sustainability of these projects to prevent greenwashing.

Green Finance Certification: Sustainability efforts are recognized and rewarded by creating a certification program for financial institutions actively supporting RE projects. Certified institutions can benefit from cost-effective funding options and preferential treatment in credit guarantee programs. This suggestion acknowledges the crucial role that financial institutions have played in advancing the goals of RE. More institutions are encouraged to participate actively in sustainable finance, which increases their contributions to the RE industry.

Regulatory Sandboxes: A controlled environment is created by creating regulatory sandboxes to test and improve novel financial products and credit guarantee systems explicitly made for RE. This suggestion encourages experimentation and a culture of innovation without the restrictions of conventional regulations. It promotes the creation of innovative solutions that can advance the industry by encouraging creative thinking and flexible methods of financing RE.

It is essential to recognize the limitations of this research even though our theoretical analysis and policy recommendations provide useful insights into improving credit guarantee mechanisms for RE projects. First off, while our theoretical framework is comprehensive, it may need to be empirically validated to determine its applicability and effectiveness in the real world. Due to the complexity of financial markets and the numerous variables affecting credit guarantee ratios, empirical studies that consider regional differences and market dynamics are warranted. Second, the suggested policy recommendations aim to offer a comprehensive method of financing RE. However, there may be practical difficulties in implementing these suggestions, such as political and regulatory obstacles, resource limitations, and varying readiness levels. Thirdly, while the transition to RE has many facets, our analysis primarily concentrates on financial and policy issues. To ensure a thorough understanding of the implications of these policy recommendations, future research should examine the broader socio-economic and environmental impacts of these recommendations. Last but not least, the landscape of the RE industry is constantly changing due to technological developments, market trends, and policy changes. Despite being thorough, our research only captures a moment in time. Therefore, policies and strategies must be continuously monitored and adjusted to stay in line with the constantly shifting dynamics of RE financing. Despite these drawbacks, our research offers a valuable starting point for further investigation and improvement of financing strategies for RE within the APEC region. Future research projects can build on these insights to address the changing opportunities and challenges in this important area.

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2.1.3. Demand Side Conditions of a Credit Risk Guarantee – The Case of the Philippines

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Introduction

Credit Risk Guarantees serve to improve the competitiveness of comparatively new renewable energy technologies that are perceived to be risky or expensive by the market and therefore need an appropriate public instrument for levelling the playing field of competitiveness (see preceding section).

Competitiveness of renewable electricity should be established with respect to coal fired electricity, which has been the cheapest electricity source in the past decades.

The Philippines has, however, decided to suspend new coal fired power after an issuance of a Coal Moratorium Advisory in December 2022. The AmBisyon Natin 2040 vision for 2020 – 2040, and the corresponding energy strategy provides replacing coal with imported LNG. Even though the long-term energy scenario is at present under revision, the role of imported LNG is nonetheless expected to become more important than today. In future, the main competitor of renewable electricity could be imported LNG. In this context, the role of the Credit Risk Guarantee, combined with other appropriate instruments like international tendering of renewables, power purchase agreements, feed-in tariffs, guarantees of origin for renewable electricity, green bonds, is to provide sufficiently strong incentives to the development of renewable electricity as a locally produced alternative to imported LNG. Locally produced electricity has multiple advantages over imported LNG: Improve energy security, improve foreign currency reserves, increase the number of domestically created jobs, and of course diminish the CO2 emissions, to mention but a few.

In the Philippines, the credit risk guarantee as well as feed-in tariffs are available for large electricity consumers; these consumers are free to choose their supplier. However, the credit risk guarantee as well as feed-in tariffs are not yet available for households who represent the largest electricity consuming category, making up around a third of total electricity consumption and are locked in a captive market without possibility to choose their supplier.

Global electricity consumption is expected to grow steadily until 2040, with the Asia-Pacific region gaining in share and Southeast Asia contributing significantly (Figure below)[125].

Their increase in generation capacity is largely dependent on coal generation[126]. Among the fast-growing economies, the Philippines shows a stable growth rate (Figure below), being average in Southeast Asia.

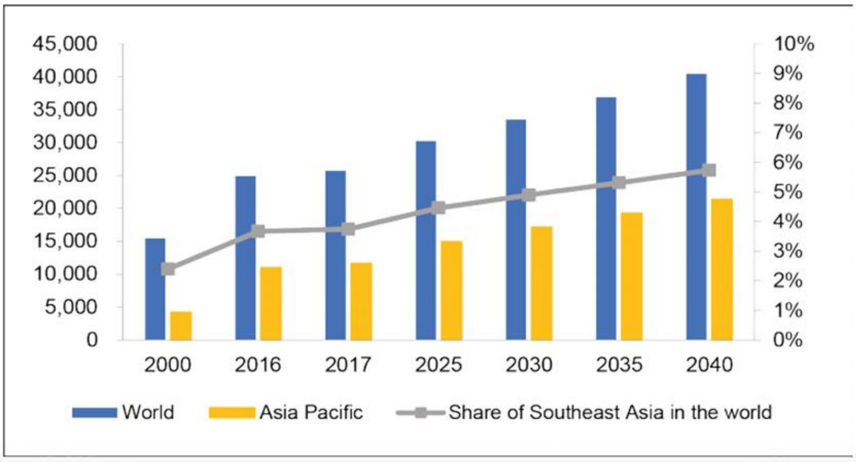


Figure 16: Electricity Generation of the World and Asia (TWh)

Source: World Energy Outlook 2018. International Energy Agency IEA[127]

The electricity sector in the Philippines provides electricity through power generation, transmission, and distribution to many parts of the Philippines. The Philippines is divided into three electrical grids[128], one each for its three islands namely Luzon, the Visayas and Mindanao.

As per the Department of Energy's Power Demand and Supply Highlights of 2018, a total of 99,765 GWh was produced where 52% came from coal, 23% from renewable sources (mostly geothermal and hydro), and the remaining from natural gas.

In April 2022, the Philippines had 95.21% Household Electrification Rate, based on the latest status of energization provided by the National Electrification Administration (NEA) for the electric cooperatives (ECs), Local Government Unit-Owned Utilities (LGUOUs) and Private-Investor-Owned Utilities (PIOUs) as of December 2021. Said level corresponds to 25.017 million energized households (HHs) out of 22.98 million identified and targeted household population based on the 2015 Census of the Philippine Statistics Authority (PSA)[129].

Power Situation

Total Gross Power Generation[130]

In 2020, the Philippines' gross power generation amounted to 101,756GWh, indicating a 4% (106,041GWh) decrease from the previous year. Meanwhile, electricity production in the economy reached 111,516GWh in December 2022, as compared with 106,115GWh in the previous year.

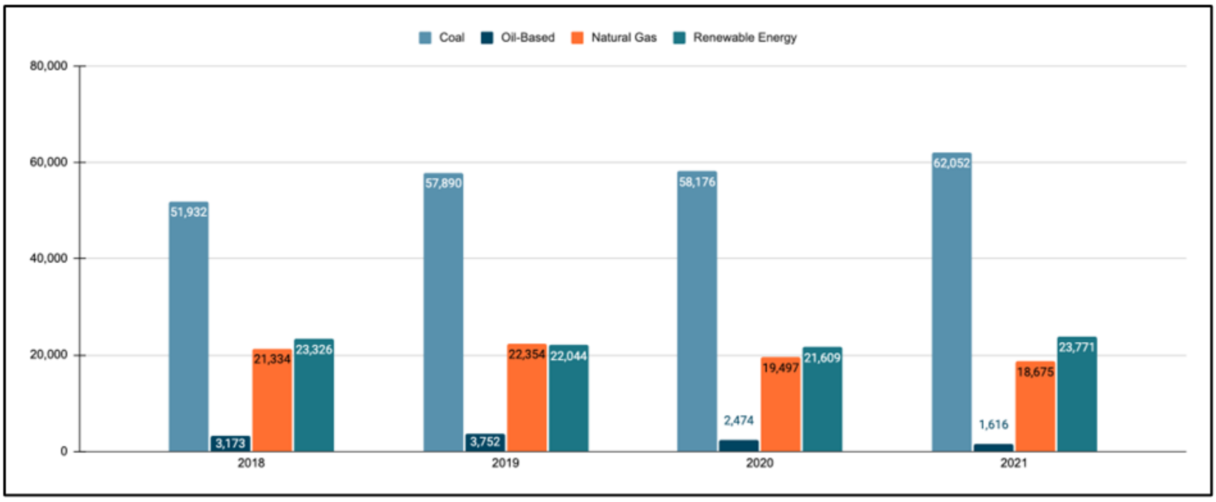


Figure 17: Power Generation by Source in GWh, In The Philippines

Source: DOE, Key Energy Statistics[131]

Electricity in the Philippines is produced from various sources such as coal, oil, natural gas, biomass, hydroelectric, solar, wind, and geothermal sources. According to data from the DOE Power Statistics, the allocation of electricity production can be seen in the Figure above.

Total Installed Generating Capacity

In 2020, the total installed capacity in the Philippines was 26,286MW, which is 2.8% increase from last year's 25,531MW. Of which, 11,103MW was on the Luzon Grid, while 2,202MW was on the Visayas and 1,978MW on the Mindanao[132].

Grid installed capacity in 2021 grew by 2.4% up by 632MW (26,882MW) from the previous year[133].

In 2022, the Philippines had a total installed capacity of around 28.3 thousand megawatts, with over 12 thousand megawatts coming from coal-powered power plants, 3.83 thousand megawatts on oil-based and 3.73 thousand megawatts on natural gas. On the other hand, power facilities running on renewable energy had a total installed capacity of around 8.26 thousand megawatts. Among these renewable energies, hydropower is the largest renewable energy source with a capacity of 3.74 thousand megawatts, followed by geothermal (1,952MW), and solar (1,530MW).

Peak Demand

In 2020, the Philippines' total non-coincidental peak demand reached 15,282MW, which is 299MW or -1.9% lower than the peak demand in 2019 (15,581MW)[134]. Among the three major grids of the economy, Luzon Grid has the lowest difference in peak demand which is 241 or -2.1 lower than last year. Meanwhile, Visayas and Mindanao have only 23MW and 36MW peak demand difference lower than in 2019.

This decline in demand can be greatly attributed to the effect of COVID-19 pandemic, which put the economy under different levels of community quarantine beginning 15 March 2020[135].

The declaration of community quarantine caused huge economic losses in a number of businesses and commercial establishments, resulting in an evident slowdown in the operations of the commercial and industrial sectors. Additionally, the travel restrictions put in place by the Government of the Philippines across the entire economy limited the movement of the people which further hindered the otherwise expected demand growth.

Peak demand slightly rebound in 2021 with 16,036MW or a 4.9% increase from last year. All-time peak demand on Luzon was recorded at 11,640MW, in Visayas was 2,252MW and on Mindanao was 2,144MW.

This increase in demand is the result of the ease of community quarantine restrictions compared to 2020 which allowed more public establishments in the economy's capital to operate at limited capacities, provided that all workers or employees are fully vaccinated against COVID-19 and the establishments strictly maintain minimum public health standards.

In 2022, peak demand records of the entire economy is at 16,596 megawatts, The island of Luzon recorded the highest peak demand in the Philippines at 12,113 megawatts. Meanwhile, the island of Visayas accounted for a peak power demand of 2,316 megawatts, while Mindanao had a total peak power demand of 2,167 megawatts.

Electricity Sales and Consumption

The total electricity sales and consumption grew by 6.3%, with an absolute level of 106,041GWh by the end of 2019 from 99,765GWh of the previous year. As the rate of inflation slowed down to an average of 2.5% in 2019 from a noticeably higher rate of 5.2% in 2018, the economy as expected experienced a boost in electricity consumption.

The sector with the largest consumption remains the residential (38.68%), followed by the industrial (31.58%) and the commercial (21.79%) sectors.

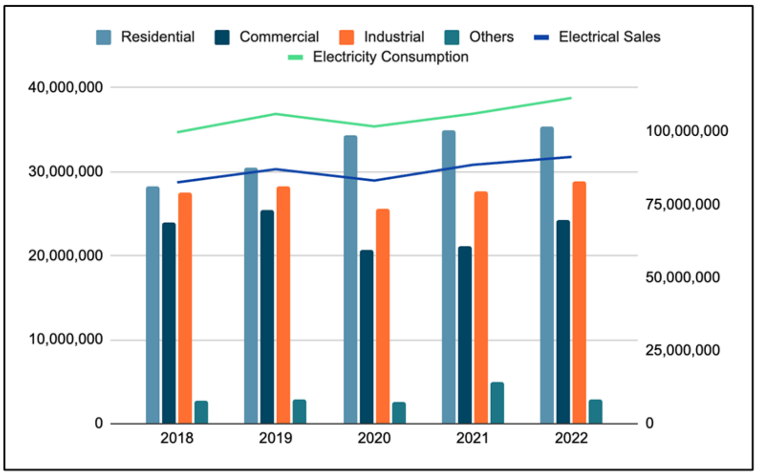


Figure 18: Power Generation by Source in GWh, in the Philippines

Source: DOE 2022 Power Statistics[136]

Electricity consumption of the economy in 2020 was recorded at 101,755,720 megawatt-hours which is -4.04% decrease from last year. On average, the electricity consumption in the Philippines reached around 897 kilowatt-hours in 2020, a slight decrease from the average consumption in the previous year[137].

The total electricity consumption in the Philippines amounted to 106,114,713 megawatt-hour in 2021, indicating a 4.28% increase from the previous year. Residential sector or the household sector, was the largest electricity-consuming sector, with a total consumption of around 34.98 million megawatt-hour. This was followed by the industrial sector, with about 28 million megawatts-hour of electricity consumed[138].

In 2022, the Philippines Electricity Consumption data was reported at 11,516,000 megawatts-hour. This records an increase from the previous number of 106,115,000 megawatts-hour for 2021[139].

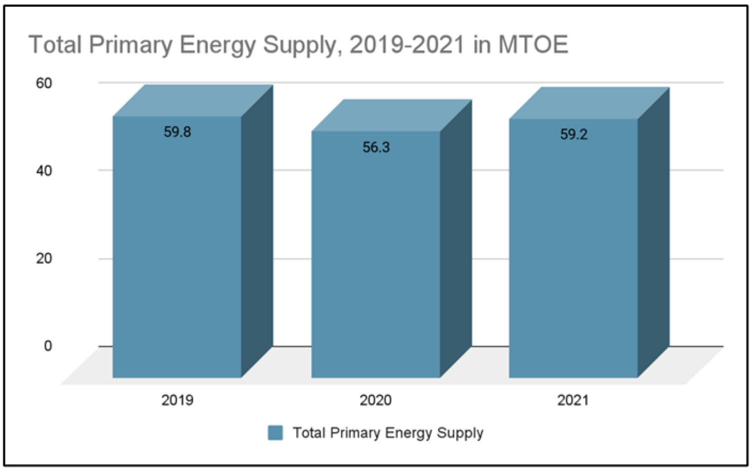


Figure 19: Total Primary Energy Supply of the Philippines

Source: DOE 2021 Power Statistics[140]

Total primary energy supply (TPES) for 2021 reached 59.2MTOE compared to its previous level of 56.6MTOE, an uptick of 4.7 percent although slower compared to the 7.8 percent escalation in energy demand. Total net imported energy grew faster by 7.6 percent to 28.9MTOE vis-a-vis the sluggish 2.1 percent growth in indigenous energy as its aggregate levels reached 30.3MTOE. With this, energy self-sufficiency fell by 1.31 percentage points from 52.5 percent in 2020 to 51.1 percent in 2021 (Figure above)[141].

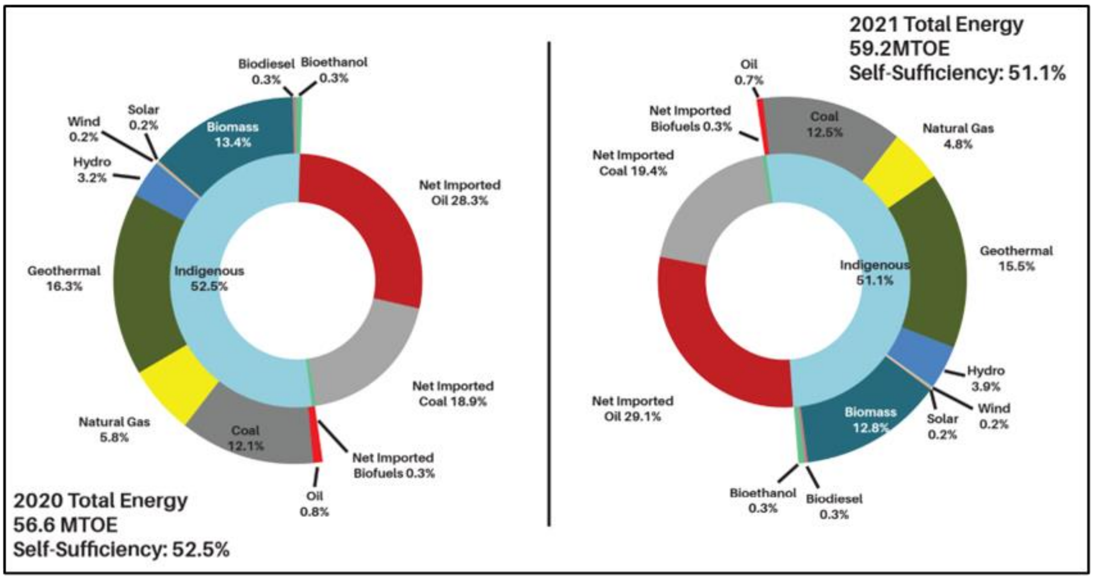


Figure 20: Total Primary Energy Mix by Fuel (% Shares), 2020-2021

Source: DOE Philippine Energy Situationer 2021[142]

The economy's primary energy mix is comprised of indigenous and imported energy sources, such as coal, natural gas, and renewable sources[143].

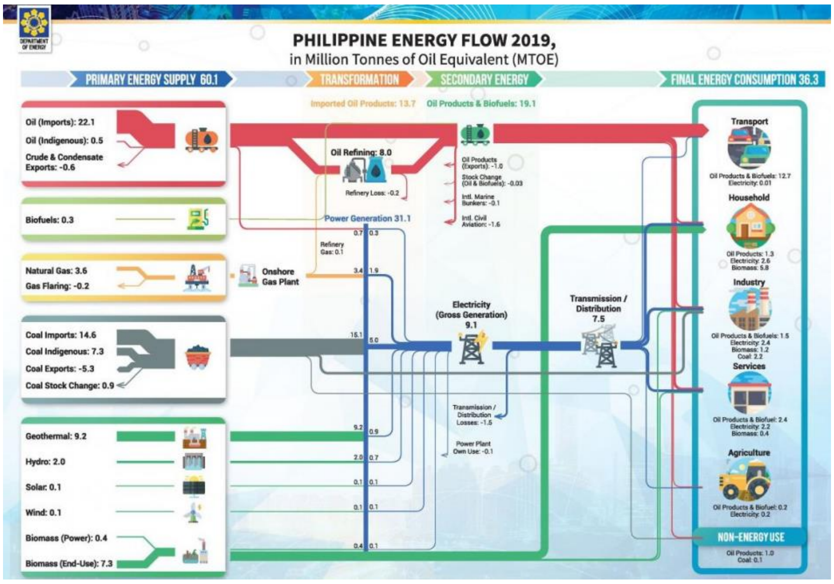


Figure 21: Sankey diagram of the Philippine energy flows

Source: DOE[144]

Coal remained as the economy's top energy source with its 31.9 percent share to TPES. Its aggregate supply level climbed by 7.8 percent to 18.9MTOE buoyed by the upswing in local production and net importation for power generation. Total oil supply comes next with a 29.8 percent share at 17.7MTOE level for a 7.9 percent expansion year-on-year that was sustained by robust net importation despite dismal indigenous production. With natural gas' share of 4.8 percent (2.8MTOE), total fossil fuels accounted for two-thirds (66.5 percent) of the energy mix for 2021. Aggregate renewable energy completed the remaining 33.5 percent share of the mix, as its supply grew by 2.9 percent to reach 19.9MTOE during the year.

The self-sufficiency rate of energy also reflects the availability of energy sources of the economy. In 2021, indigenous energy accounts for 51.1% of the economy's total primary energy supply[145]. The rest of the share comes from imported energy, with 29.1% oil, 19.4% coal, and 0.3% biofuels[146]. The fact that approximately half of the total energy supply depends on external sources poses a potential risk for energy availability.

Energy Security in the Philippines

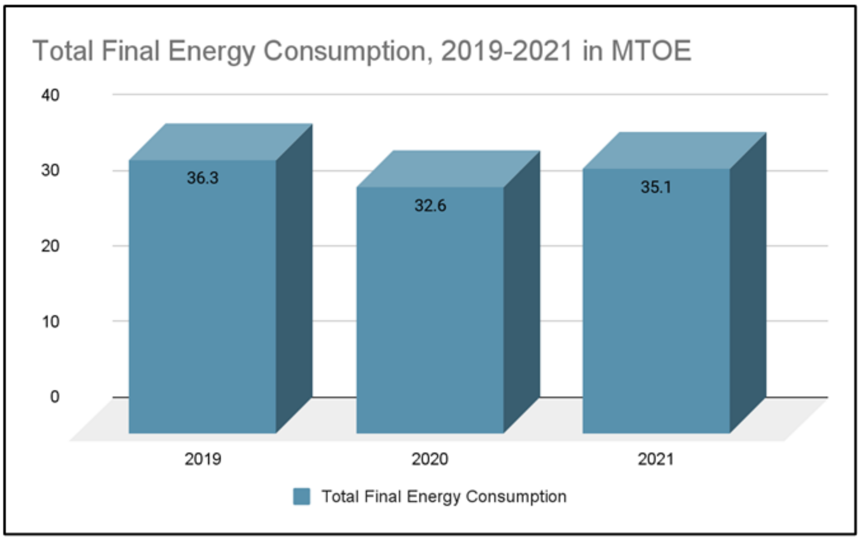


Figure 22: Total Final Energy Consumption (TFEC) 2019-2021 in MTOE

Source: DOE 2021 Power Statistics[147]

The economy's total final energy consumption (TFEC) in 2019 went up by 1.6 percent to 36.3 million tons of oil equivalent (MTOE) from its year-ago level of 35.7MTOE[148].

The year 2021 marked the gradual easing of community quarantines, and the revival of major economic activities, and the resumption of major transportation routes across the economy. These developments pushed the economy's total final energy consumption (TFEC) to increase by 7.8 percent to 35.1 million tons of oil equivalent (MTOE) from its year-ago level of 32.6MTOE. 31.3 % of it comes from the transport sector followed by the household sector, industry and services with 29.0 and 6.8 and 4.8% shares respectively.

Under the Reference Scenario, the total final energy consumption of the Philippines is expected to increase at an average rate of 4.8 percent annually, from its 2018 level of 34.3 million tons of oil equivalent (MTOE) to 96.7MTOE in 2040 (Figure 20)[149]. However, since the current growth rate of installed generation capacity from 21,423MW in 2016[150] to 62,300MW in 2040[151] is slower than that of electricity consumption, improvement in the economy's reserve margin will be difficult to achieve.

Average Electricity Rate

In terms of electricity pricing for the retail market as of December 2020, based on the DOE's 40th Electric Power Industry Reform Act (EPIRA) Implementation Status Report, the Philippines' average electricity rate was around PHP8.13/kWh, PHP0.07 centavos lower compared with September 2020 level economywide average systems rate[152].

The Manila Electric Company or Meralco had an overall average retail electricity rate of PHP 8.24 per kWh in 2021 which is 3.5% increase from PHP7.96 per kWh in 2020.

In 2022, Meralco had an average retail electricity rate of PHP9.52 kWh, reflecting an increase from the previous year, amidst increase of pass-through charges brought about by higher global fuel price, spot market price, and peso depreciation[153]. Meralco is the largest private distribution utility company in the Philippines that distributes power in Metro Manila, and its adjacent provinces. It mainly covers 38 cities and 73 municipalities and its franchise area of over 9,685km^2 is just 3% of the total land area of the Philippines, but accounts for 55% of the economy's electricity output.

In December 2021, the economy's average electricity rate is around PHP9.42/kWh, or PHP0.69/kWh higher compared with the September 2021 central average system rate. In terms of major grids based on the three major island groups in the Philippines, the Luzon grid rate is PHP9.25/kWh, which is PHP0.61/kWh higher than last September 2021. Meanwhile, the Visayas grid rate has increased by PHP0.34/kWh, rising from PHP8.44/kWh in September 2021 to PHP8.78/kWh in December 2021. Lastly, the Mindanao grid rate has increased by PHP0.90/kWh from PHP9.37/kWh to PHP10.28/kWh[154].

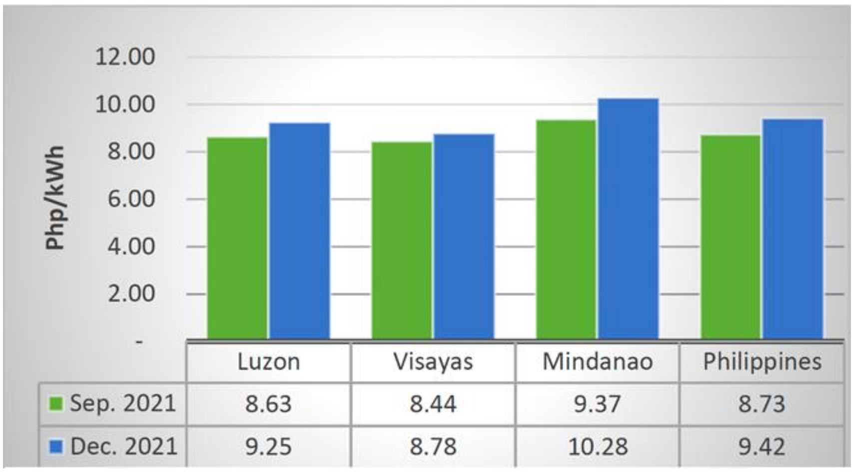


Figure 23: Average Systems Rate

Source: NEA and Monthly Operations Report of PDUs[155]

On the other hand, the Electric Cooperatives' December 2021 average systems rate is PHP10.45/kWh, higher by PHP0.55/kWh from September 2021. The rates in the Luzon and Mindanao grids have increased by PHP0.73/kWh and PHP1.26/kWh, respectively. The Visayas grid, on the other hand, has dropped by PHP0.83/kWh[156].

Figure 24: Electric Cooperatives' Average Systems Rate

Source: NEA and Monthly Operations Report of PDUs[157]

The central average systems rates of Private Distribution Utilities (PDUs) and Ecozones posted an overall decrease by PHP0.52/kWh from PHP7.64/kWh in December 2020 to PHP7.12/kWh in March 2021. Luzon, Visayas and Mindanao grids posted a decrease in rate by PHP0.16/kWh, PHP1.37/kWh and PHP0.03/kWh, respectively[158].

The year-on-year Load-Weighted Average Price (LWAP) increased and posted a significant change by an average of 47.1 percent, from PHP5,266/MWh (USD96.62)[159] in 2021 to PHP7,746/MWh (USD142.13)[160] in 2022.

The drastic increase was driven by, among others, the high level of capacities on the outage of the plants, congestions resulting from transmission line outages, and the changes in the offered behaviour of the trading participants considering various notable events (i.e., Indonesian Coal Ban etc.) which subsequently affected the resulting market prices. Impositions of market interventions likewise contributed to the increase in the price outcome[161].

The uptrend in LWAP, as shown in Figure above, was also shaped by the increased demand level that caused the decreased supply margin.

The increase in ramp-limited capacities likewise contributed to this reduced supply in the grid. Ramping limitation arises when generator power output is restricted from delivering its maximum offered capacity due to the plants' intrinsic ramp rates, as submitted by the generators, and the merit ordering despite having sufficient available capacity offered in the market. This is particularly true when large generating plants with slower ramp rates and relatively cheaper offer prices are unable to quickly generate power to meet the sudden change in demand[162].

As a result, slow-ramping generators can only be scheduled based on their offered ramp rate, capacities, and suggested prices. To accommodate the demand requirement, the next more expensive offer block that can respond to the demand will be scheduled to accommodate the demand requirement.

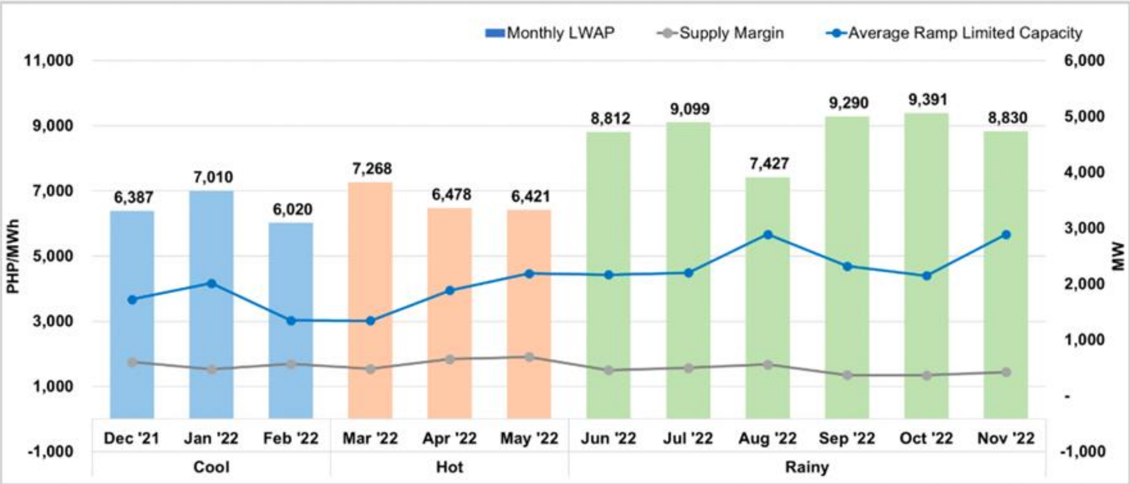


Figure 25: Monthly System Load-Weighted Average Price (LWAP) and Hourly Supply Margin, Dec. 2021 to Nov. 2022

Source: Annual Market Assessment Report, PEMC, 2022[163]

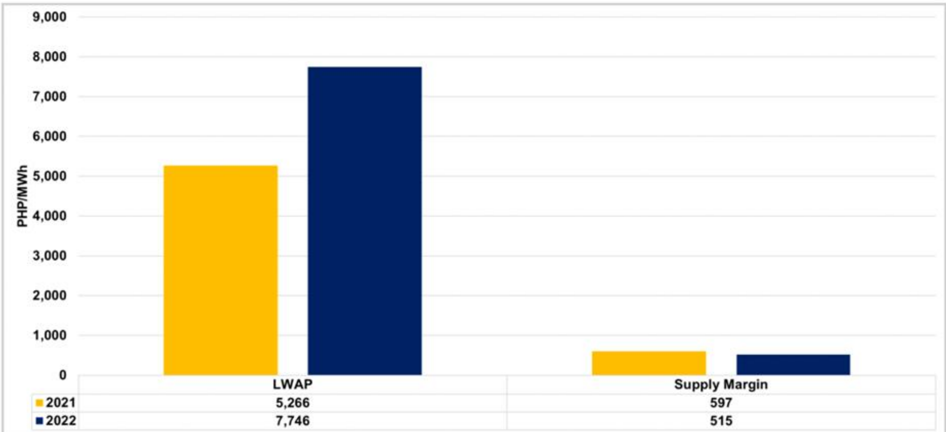


Figure 26: System Load-Weighted Average Price (LWAP) and Average Supply Margin, 2021 vs 2022

Source: Annual Market Assessment Report, PEMC, 2022[164]

Average prices per season posted higher level of average LWAP experiencing notable changes come the 2022 billing period:

Season	Average LWAP	2021 Exchange	Average LWAP	2021 Exchange	%

	2021	Rate 1 USD= PHP49.28	2022	Rate 1 USD= PHP49.28	Change
Cool Dry	PHP2,395/MWh	48.60/MWh	PHP6,451/MW	130.90/MW	169%
Hot Dry	PHP5,585/MWh	113.33/MWh	PHP6,703/MW	136.01/MW	20%
Rainy	PHP5,376/MWh	109.09/MWh	PHP8,810/MWh	178.77/MW	64%

Table 5: Average LWAP 2021 and 2022, MWh

Source: Annual Market Assessment Report, PEMC, 2022[165]

The trend of the price is the inverse trend of the average supply margin as depicted in the table below:

Season	Average Supply Margin 2021	Average Supply Margin 2022	% Change
Cool Dry	2,415MW	550MW	(77%)
Hot Dry	1,503MW	609MW	(61%)
Rainy	462MW	452MW	(2.2%)

Table 6: Trend of price in 2021 and 2022, MWh

Source: Annual Market Assessment Report, PEMC, 2022[166]

Energy Per Capita

Energy per capita values likewise improved during the second year of the pandemic as restrictions were lifted and the movement of people and goods increased. The amount of energy per person went up by 4.0 percent, which translated to 0.54TOE in 2021 from 0.52TOE in 2020.

Likewise, electricity and oil per capita picked up by 3.2 percent and 7.7 percent, respectively during the year[167].

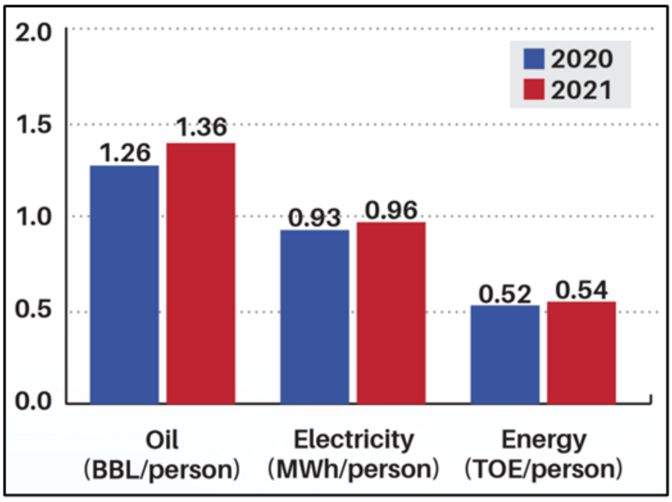


Figure 27: Energy per Capita, 2020 vs 2021

Source: Philippine Energy Situationer 2021, DOE, 2021[168]

Energy Sector Market Reform and Restructuring[169]

The Philippines' electric power industry is a result of several reforms from the shared responsibility of public and private entities to the monopoly established by the State to the market-based system operating at present.

Operations and maintenance of the Philippines' power grid and its associated assets and facilities were initially operated and maintained by the Philippine central authorities through National Power Corporation (NAPOCOR/NPC) and National Transmission Corporation (TransCo) from 3 November 1936 to 15 January 2009 for 72 years and two months.

Since 15 January 2009, operations and maintenance of the grid have been in the private sector, where it is being operated and maintained by the National Grid Corporation of the Philippines (NGCP). Ownership of the grid, however, has been with the central authorities since NAPOCOR's creation in 1936, whereas TransCo currently owns it since 1 March 2003.

Overview of the Main Stakeholders in the Energy Sector in the Philippines

1936–2009: Power Grid Operations and Maintenance under the Government of the Philippines

- NAPOCOR/NPC: 3 November 1936 to 1 March 2003

From 3 November 1936 to 1 March 2003, central authorities-owned National Power Corporation (NAPOCOR/NPC) owned, operated, and maintained the transmission grid and its related assets and facilities.

- Republic Act 9136 or EPIRA: 2001

A power crisis plagued the economy in the 1992 prompting the central authorities to enact Republic Act No. 7468 or the Electric Power Crisis Act of 1993 (Power Crisis Act). With NPC owing approximately USD16.39 billion to creditors by 2001, the energy sector, as structured, was no longer sustainable. An overhaul of the electric power industry sector was engineered, sparked by the passage of Republic Act No. 9136 or the Electric Power Industry Reform Act of 2001 (EPIRA) on 8 June 2001. EPIRA is the foundational law of the economy's current market-based energy system.

Due to the implementation of EPIRA or Republic Act 9136 one year and nine months earlier on 8 June 2001, which was signed by then President Gloria Macapagal Arroyo, NAPOCOR/NPC took over the operations, maintenance, and ownership of the power grid to another central authorities-owned corporation National Transmission Corporation (TransCo) on 1 March 2003.

- National Transmission Corporation (TransCo): 1 March 2003 to 15 January 2009

TransCo operated and maintained the grid from 1 March 2003 to 15 January 2009, and also serves as the grid's owner since March 2003, and responsible for making sure that NGCP complies with the standards set by its concession agreement with NGCP, congressional franchise, and other relevant laws.

2009–present: Power grid operations and maintenance under private sector

- National Grid Corporation of the Philippines (NGCP): 15 January 2009 to 1 December 2058.

Through the implementation of Republic Act 9511 and a congressional franchise of 25 years renewable for another 25 years for a total of 50 years, TransCo turned over the operations and maintenance of the power grid to the privately-owned National Grid Corporation of the Philippines (NGCP) on 15 January 2009, with the latter operated and maintained the grid since the said date of January 2009, transferring the grid's operation and maintenance from central authorities to a private sector. Assuming it secures a renewal, NGCP's franchise will end on 1 December 2058.

Power generation in the Philippines is not considered as a public utility operation, which means interested parties do not need to secure a congressional franchise to operate a power generation company. However, power generation is regulated by the Energy Regulatory Commission (ERC)[170] who must issue a certificate of compliance to interested parties to ensure that the standards set forth in the EPIRA are followed. Under Section 43 of the EPIRA, the ERC is tasked to promote competition, encourage market development, ensure customer choice and penalize abuse of market power in the electricity industry. Section 38. Creation of the Energy Regulatory Commission - There is hereby created an independent, quasi-judicial regulatory body to be named the Energy Regulatory Commission (ERC). For this purpose, the existing Energy Regulatory Board (ERB) created under Executive Order No. 172, as amended, is hereby abolished.

The Philippines has had a fully functioning electricity market since 2006 called the Philippine Wholesale Electricity Spot Market (WESM) and is operated by an independent market operator.

2001

- Philippine Wholesale Electricity Spot Market (WESM)

The WESM is a centralized venue for buyers and sellers to trade electricity as a commodity where prices are determined based on actual use (demand) and availability (supply). It was created pursuant to Republic Act 9136, also known as the Electric Power Industry Reform Act (EPIRA) of 2001. The WESM began commercial operations in Luzon in June 2006 and in the Visayas in December 2010.

- Philippine Electricity Market Corporation (PEMC)

In November 2003, the PEMC was incorporated as a non-stock, non-profit corporation upon the initiative of the Department of Energy (DOE) with representatives from the various sectors of the electric power industry. The PEMC served as the autonomous group market operator and governing body of the Philippine Wholesale Electricity Spot Market (WESM) for over ten (10) years.

As provided in the Electric Power Industry Reform Act (EPIRA), PEMC transferred the operations of the WESM to the Independent Electricity Market Operator of the Philippines (IEMOP) on 26 September 2018 upon the endorsement of the DOE and the electric power industry market participants. The Independent Electricity Market Operator of the Philippines (IEMOP) is a non-stock, non-profit corporation established in May 2018 that serves as the Independent Market Operator of the Wholesale Electricity Spot Market (WESM) and the Central Registration Body (CRB) for the retail electricity market. It is headed by a professional Board of Directors whose members are independent of government and of the market participants.

PEMC continues to govern the WESM, primarily through the PEM Board of Directors and the WESM Governance Committees. PEMC's role is to remain steadfast and proactive in its mission to ensure that there is POWER, EFFICIENCY, MARKET, and COMPETITION in the energy industry through the effective and efficient governance of the WESM.

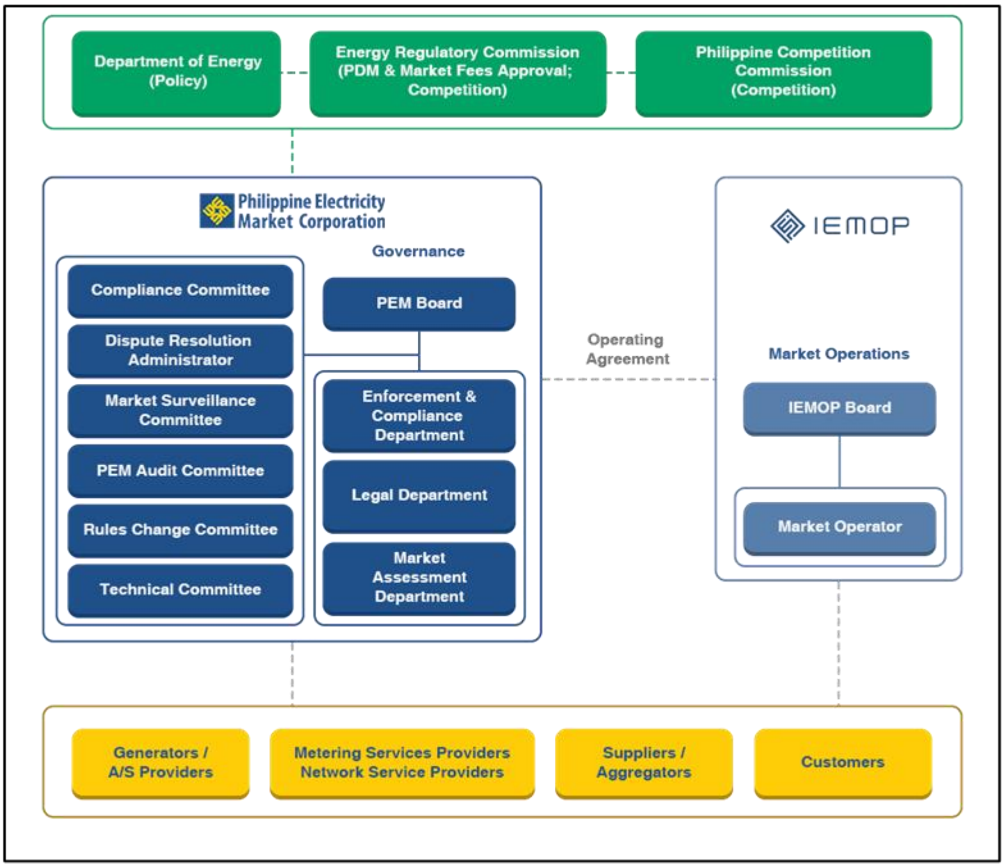


Figure 28: WESM Governance Structure

Source: WESM[171]

- Independent Electricity Market Operator of the Philippines (IEMOP)

The Independent Electricity Market Operator of the Philippines, Inc. (IEMOP) is a private, non-stock, non-profit corporation that functions as the market operator of the Wholesale Electricity Spot Market (WESM). It assumed WESM operations in September 2018. IEMOP's board of directors is composed of individuals independent from the power industry stakeholders and the central authorities as mandated by the Electric Power Industry Reform Act (EPIRA).

IEMOP facilitates the fulfilment of one of EPIRA's main goals – competition at the retail level. The reforms instituted in Republic Act No. 9136 culminate in Retail Competition and Open Access (RCOA). RCOA grants electricity end-users, starting with those having demands of 1MW or higher, the power of choice of electricity supplier. With such power of choice, they can contract with retail electricity suppliers (RES) rather than be supplied by distribution utilities as part of the captive market. With more and more retail electricity suppliers signifying interest in serving these contestable customers and as the contestability threshold is further lowered from 1MW to 750kW, at which level aggregation will already be allowed, and thereafter further lowered to 500kW, robust competition will be sustained and enhanced, both at the retail and wholesale levels[172].

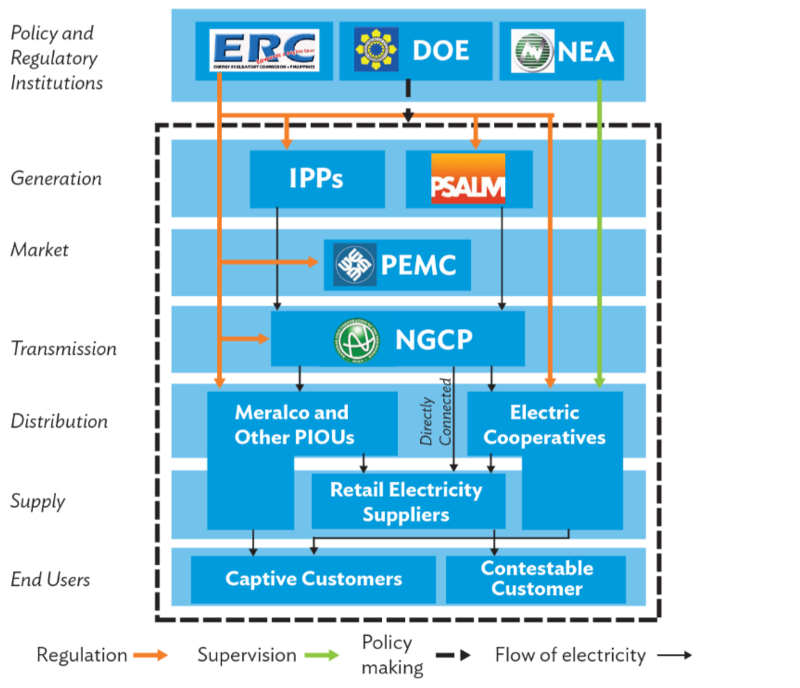
IEMOP, as the Central Registration Body for RCOA, is determined to cater to the needs of the ever-expanding retail market. It is committed also to pursue and support all initiatives to further refine the existing retail market rules and processes as part of its mandate to promote further transparency, efficiency, and competition in the WESM[173].

- Department of Energy (DOE)

The DOE is the executive department of the Philippines' central authorities responsible for preparing, integrating, manipulating, organizing, coordinating, supervising, and controlling all plans, programs, projects and activities of the central authorities relative to energy exploration, development, utilization, distribution and conservation[174].

The department was vested with additional powers and functions under the following policies:

1. Republic Act No. (RA) 8479 or the "Downstream Oil Deregulation Act of 1997"[175] ,
2. Republic Act No. (RA) 9136 or the "Electric Power Industry Reform Act of 2001"[176] ,
3. Republic Act No. (RA) 9367 or "Biofuels Act of 2006", RA 9513 or "Renewable Energy Act of 2008, RA 11234 or "Energy Virtual One Stop Shop Act", RA 11285 or "Energy Efficiency and Conservation Act"[177],
4. Republic Act No. (RA) 11592 or "LPG Industry Regulation Act", RA 11646 or "Microgrid Systems Act"[178] , and
5. Republic Act No. (RA) 11697 or "Electric Vehicle Industry Development Act."[179]



DOE = Department of Energy; ERC = Energy Regulatory Commission; IPP = independent power producer; NEA = National Electrification Administration; NGCP = National Grid Corporation of the Philippines; PEMC = Philippines Electricity Market Corporation; PIOU = private investor-owned utility; PSALM = Public Sector Assets and Liabilities Management Corporation.

Figure 29: Structure of the Power Industry in the Philippines

Source: Asian Development Bank[180]

Distribution and Retail

The distribution sector in the Philippines is served by regulated distribution utilities which encompass private investor-owned utilities, electric cooperatives, and Ecozone utility enterprises. Distribution utilities directly connect and bill consumers and purchase wholesale electricity through bilateral contracts or from the spot market.

Since the introduction of retail competition and open access in December 2012, these distribution utilities have been complemented by unregulated retailers classified as retail electricity suppliers and local retail electricity suppliers.

Mini Grid Sector Development

In the Philippines, rural electrification by extending the existing electricity grid to remote areas is often not viable, leaving microgrids, especially those using renewable energy sources, as an ideal solution.

In the 2021 status report on the implementation of the EPIRA of 2001, the Department of Energy (DOE) said there were 1.62 million households still without access to electricity.

Of the number of households that still have no electricity, 1.55 million reside within the franchise areas of electric cooperatives.

With a total of 13.63 million households connected to distribution networks, electric cooperatives are serving only 89 percent of the 14.3 million households within their business areas.

To accelerate total electrification in areas with no electricity access, the Philippine Senate Committee on Energy filed the Microgrid Systems Act in 2019. The Act further aims to provide reliable electric services to every household in the economy. It will mandate the Department of Energy to annually release the list of unserved and underserved areas for prospective accredited Microgrid Service Providers[181].

Status of Renewable Energy in Asia and the Philippines

The Philippines is home to abundant solar, wind, and other renewable energy resources, and indicated several potential wind and solar generation sites and their capacities based in the USAID 2018 Report[182] .

The current penetration rate of renewable sources (excluding hydroelectric) is approximately 15% (Figure 5). As the share of hydroelectric is 10.5% in 2015, the economy's renewable share is still 25%. For further increases in renewable resources, more wind generation and solar PV need to be introduced, because the potential of other resources (e.g., geothermal or hydroelectric) is limited.

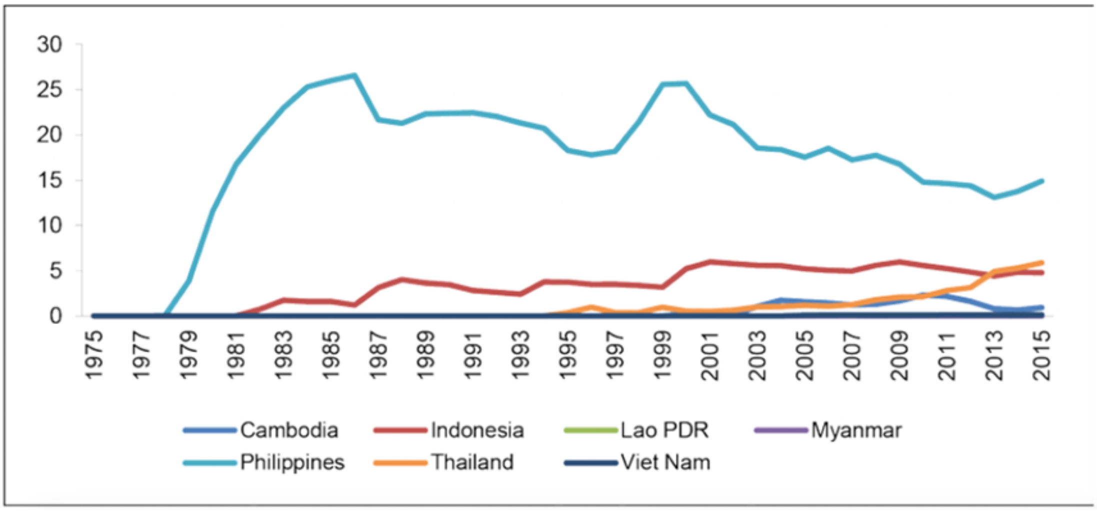


Figure 30: Southeast Asian Electricity Production from Renewable Sources Excluding Hydroelectric (%)

Source: World Bank 2018[183]

The central authorities of the Philippines set out the Republic Act 9513 or the Renewable Energy Act of 2008, the first comprehensive legislation on renewable energy in Southeast Asia. It aims to further accelerate the development of the economy's renewable energy resources, which include hydropower (which we have been using since the 1950s), geothermal, wind, solar, and biomass.

One of the main objectives of the act is to achieve energy self-reliance, mitigate climate change, and promote socio-economic development in rural areas[184].

Said policy also allowed the DOE to lay the groundwork for advancing the economy's renewable and locally produced energy. Enabling policies and regulatory framework have been institutionalized to further mobilize and accelerate its deployment. Ambitious goals for scaling up RE capacities have been outlined through the National Renewable Energy Program (NREP) to intensify RE's contribution to the economy's energy mix.

Corresponding rules and guidelines have been formulated to facilitate the implementation of all RE policy mechanisms[185].

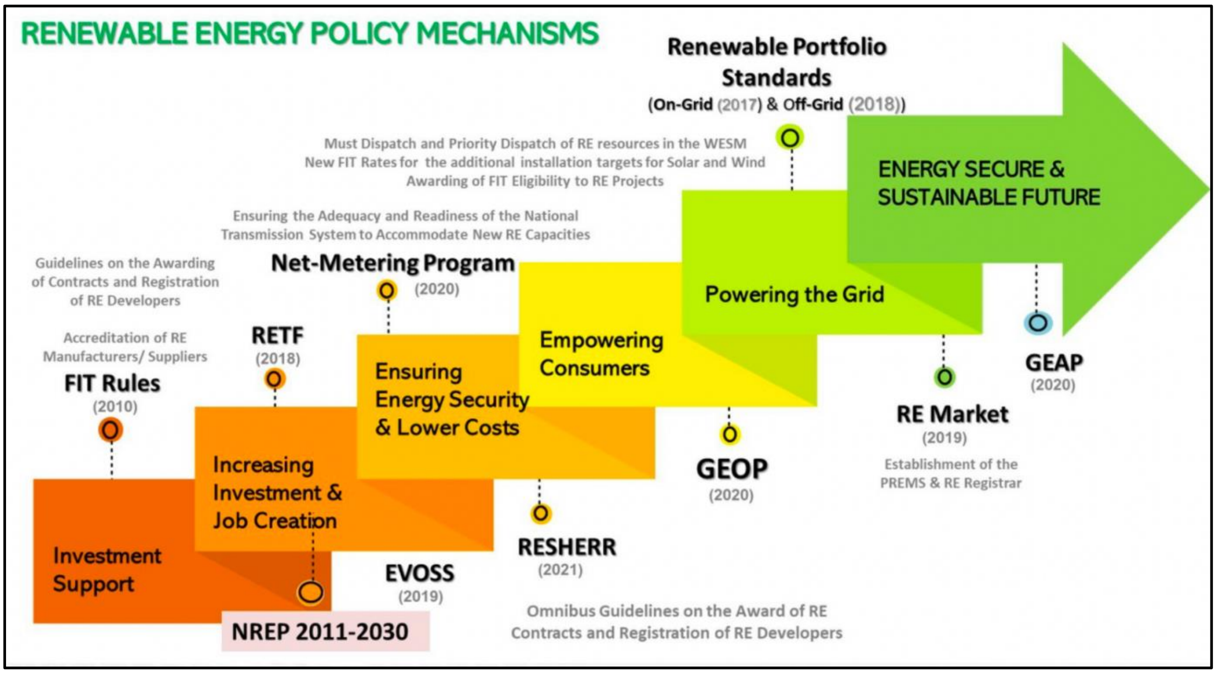


Figure 31: Renewable Energy Policy Mechanism in the Philippines

Source: DOE Energy Plan [186]

Green Energy Auction Program (GEAP)

As the government takes the gradual shift from fossil to cleaner and more sustainable energy technologies, one significant milestone is the issuance of the Green Energy Auction Program (GEAP) on 14 July 2020 that sets the framework for the facilitation of immediate and timely investment for new and additional Renewable Energy (RE) capacities. This will ensure that there will be adequate supply under a competitive process.

The GEAP provided additional market options by auctioning RE capacities from qualified RE suppliers and promoted a competitive setting of RE supply in the economy. As a further improvement, the DOE issued Department Circular (DC) 2021-11-0036 on 3 November 2021 on the revised Guidelines for the GEAP in the Philippines. This established the implementation framework for GEAP and provided clarity on the roles of implementing agencies/entities[187].

The policy has two components: a) the Green Energy Tariff (GET) which provides price signals on the commercial value of electricity generated from RE facilities that resulted from a competitive process and set the benchmark price for Distribution Utilities (DUs) under the Opt-in Mechanism, and b) the Green Energy Auction (GEA) which facilitates the determination of RE facilities that are eligible under the GEAP. The GEA shall be administered by the DOE through the Green Energy Auction Committee (GEAC)[188] .

On 9 February 2022, the Notice of Auction (NOA) for the 1st round of GEA for RE was published with a total RE capacity of 2,000 Megawatts (MW) from hydro, biomass, solar and wind. Of the total, 1,400MW will be auctioned in Luzon, 400MW in the Visayas, and 200MW in Mindanao[189].

The issuance of the Renewable Energy Market (REM) Rules establishes the market for the trading of RE Certificates (RECs). It also prescribes the required processes for the orderly implementation of the Renewable Portfolio Standard (RPS) Rules for both on- and off-grid areas[190].

The Guidelines for the Operationalization of Renewable Energy Trust Fund (RETF) in 2018 effected the issuance of Special Order (SO) 2019-01-0003 on 11 January 2020 and created a committee for the administration of the RETF.

The implementation of the market-based policy on Renewable Portfolio Standards (RPS) for On- and Off-Grid requires load-serving entities to source an agreed portion of their supply from eligible RE facilities. It expects to achieve a 35% RE share in the economy's total power generation by 2030. The realization of the Green Energy Option Program (GEOP) provides end-users the option to choose renewable resources as their energy source.

On 22 April 2020, the rules and procedures in the issuance, administration, and revocation of GEOP Operating Permits of RE suppliers were issued.

The Net-Metering Program (NMP) allows end-users to install up to 100 kilowatts (kW) of RE systems to reduce their electricity bills and sell the surplus to the grid. The amended net-metering rules issued on 22 October 2020 encouraged electricity end-users' participation through enhanced policies and commercial arrangements.

Another milestone in RE resource development is the issuance of DC2020-11-0024 on 20 October 2020, governing the conduct of the 3rd Open and Competitive Selection Process (OCSP) in awarding RE Service Contracts (RESCs).

The DOE also issued policies that rationalize bureaucratic processes and regulatory procedures affecting the timely implementation of RE projects and thus attracting more significant private investments in RE[191] .

- The Omnibus Guidelines Governing the Awarding and Administration of RE Contracts and the Registration of RE Developers13 enabled the non-issuance of RE contracts for projects intended for own-use and/or for non-commercial uses provided they comply with the registration requirements as stipulated in the circular.

- The Guidelines on the Duty-Free Importation issued on 13 February 2020 governs the processing and approval of applications for Certificate of Endorsement (COE) on duty-free importation of machinery, equipment, materials, and spare parts used for RE operations. This includes the application of COE involving temporary exportation, sale, transfer, assignment, donation, or other modes of disposition of originally imported capital equipment/machinery like spare parts.

Instituting the necessary RE policies and support mechanisms coupled with unwavering collaboration with the private sector have secured favourable investments for RE development. From 2016 to 2021, a total of 64415 RESCs were awarded with an aggregate potential capacity of 38.4GW. The realization of these projects created a total investment of PHP165.6 billion offering employment opportunities to 189,023 Filipinos.

During the same period, a total of 1,809.7MW has been installed, providing additional capacities to the economy's energy system. The bulk of which was sourced from solar projects with 1,221.7MW, 398.1MW from biomass, 151.4MW from hydro, 22.5MW from geothermal and 16.0MW from wind projects[192].

Renewable Energy Roadmap 2020-2040

In response to the government's long-term vision of AmBisyon Natin 2040 which expects that Filipinos will have a strongly rooted, comfortable and secure life by 2040, the DOE formulated the Philippine Energy Plan (PEP) 2020-2040 that embodies a clear set of objectives, namely[193]:

a. Increase the production of clean and indigenous sources of energy to meet the growing economic development of the economy;

b. Decrease the wasteful utilization of energy through the use of energy efficiency tools and strategies; and

c. Ensure the balance between the provision of reliable and reasonably priced energy services, support for economic growth, and protection of the environment.

The PEP will lay down the foundation to ensure that Filipinos gain from the deliverables set forth in the energy roadmaps by 2040, specifically covering the following areas such as Ensuring Energy Services 24/7; Creating Wealth for Filipinos; Consumer Empowerment; and Philippine Agenda with the International Community[194].

The PEP aims to reach 35% of renewables in the power mix by 2030, and 50% by 2040 under a Clean Energy Scenario (CES) (35% in a Reference Scenario (REF)). To achieve this target, the economy will need PHP25.3 billion (USD490 million) of green investments for pre-developments under the CES scenario and PHP17.9 billion (USD347 million) under the REF scenario[195].

REFERENCE SCENARIO

- Present development trends and strategies continue;
- **35.0 percent renewable energy share** in the power generation mix by 2040;
- **LNG importation starting 2022;**
- Energy Consumption levels that **support an accelerated economic expansion post COVID-19;**
- **Current blending schedule for biofuels (2.0 percent biodiesel and 10.0 percent bioethanol)** maintained until 2040;
- **5.0 percent penetration rate of electric vehicles** for road transport (motorcycles, cars, jeepneys) by 2040; and
- **Current efforts on EEC as a way of life** continues until 2040.

CLEAN ENERGY SCENARIO

- **35.0 percent and 50.0 percent RE share** in the power generation mix by 2030 and 2040;
- **5.0 percent blending for biodiesel starting 2022;**
- **1.5 percent increase in aggregated natural gas consumption** from the transport and industry sectors between 2020 and 2040;
- **10.0 percent penetration rate of electric vehicles** for road transport (motorcycles, cars, jeepneys) by 2040;
- **5.0 percent energy savings** on oil products and electricity by 2040; and
- At least **12.0 percent reduction in the GHG emission** for the Nationally Determined Contribution (NDC)

Figure 32: Comparison between scenarios

Source: Philippine Energy Plan 2020-2040[196]

The economy's renewable energy transition would guarantee energy security and self-sufficiency, accompanied by reduced reliance on imports. It would also boost local economic development and promote a favourable investment climate. Naturally, this would result in more jobs and reduce health and welfare costs.

Currently, the economy has some of the most profitable government incentives for rural electrification. These should transform into attractive opportunities for private investment. However, private companies are yet to show considerable interest in energy access initiatives.

Access to financing remains a massive problem. Currently, only a few local banks support renewable energy projects in some regions. Furthermore, in recent years there have been significant decreases in investment. For example, in 2019, they were down 77% by USD300 million[197].

On 22 December 2022, the Department of Energy issued a Coal Moratorium Advisory following the adoption of the clean energy transition strategy, in response to the global call to advocate for social and climate justice. Said policy aims to improve the sustainability, reliability, and flexibility of the economy's energy system, by prohibiting the construction of new greenfield coal-fired power plants. The restrictions on endorsing new coal power facilities will not affect power projects that have already gained approval, such as pipelined committed and indicative projects with substantial accomplishments. More importantly, the initiative allows for a smooth transition and encourages the entry of more RE capacity into the grid and off-grid system[198].

According to the Global Energy Monitor's annual report on global coal energy use[199], the Philippines ranked 7th across the world in terms of New Coal-fired Power Capacity in 2022.

Also based on the report, the operational capacity of coal-fired power plants in the economy doubled in the past decade. Annual capacity, on the other hand, is starting to plateau.

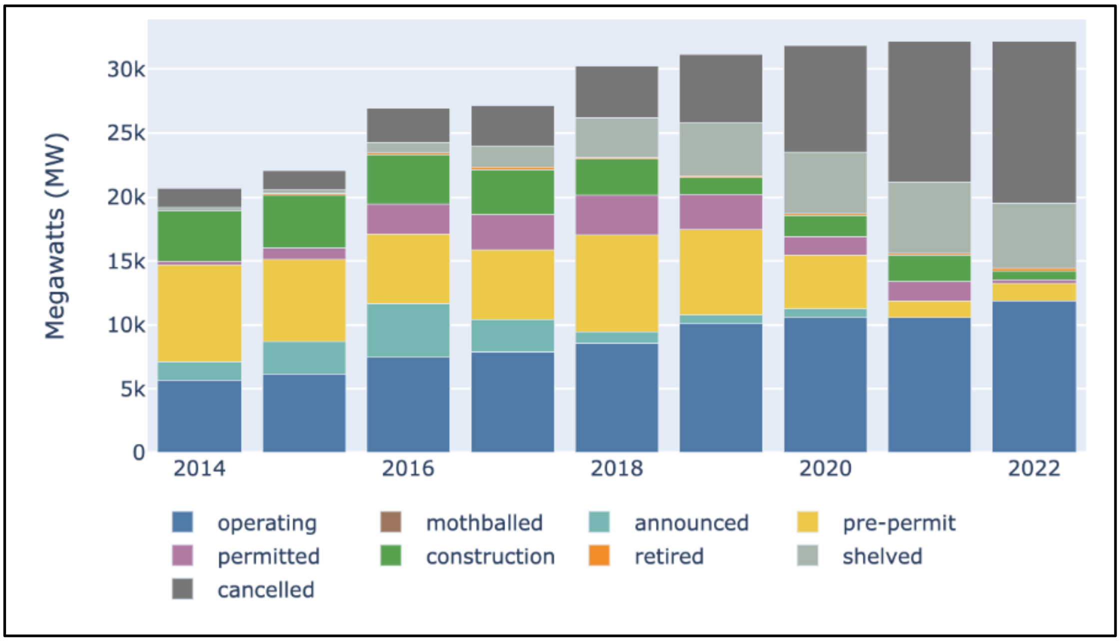


Figure 33: Coal Power Capacity by Status, 2022

Source: 2022 Global Energy Monitor[200]

Data showed coal-fired power plants in the Philippines are estimated to generate a combined 11,893MW, ranking one of the highest in Southeast Asia[201].

Clean and renewable energy sources such as geothermal, hydro, wind, biomass and solar energy are among the Philippines' few competitive advantages – especially since the economy has no significant deposits of fossil fuels. Its continued dependence on imported fuel has made Philippine electricity rates among the highest in Asia.

However, the central government commissioned some of the new coal-powered plants in various areas of the economy such as Bataan, and Iloilo.

The findings of the Global Energy Monitor's annual report on global coal energy use emphasized the economy's dependence on coal energy, notwithstanding its efforts to transition to renewable energy. The economy's energy mix is largely dominated by traditional energy, which includes electricity from coal-fired power plants and natural gas.

Nonetheless, the Philippines is looking to boost renewables in its current energy mix, which it hopes will achieve 35 percent and 50 percent renewable energy share in the power generation by 2030 and 2040, according to the Philippine Energy Plan 2020-2040.

With minimum fossil fuel resources, the Philippines has heavily depended on oil and coal imports for power generation. Consequently, this brings the economy to price-changeable and supply constraints. Due to this continued dependence on foreign fuel, the Philippines has some of Southeast Asia's highest electricity costs.

It is crucial, however, that the economy needs to continue to make great efforts towards moving away from import-dependence to one of domestic power production sourced from its vast renewable energy potential.

Over time, this shifting energy situation in the Philippines, if sustained, will ultimately eat into fossil fuel's dominance and dramatically reduce everyday energy costs across the island economy.

Against this background, one of the recommendations of this report is that the Philippines might phase out its present feed-in tariffs scheme, which is available only to large electricity producers, and explore instead possibilities to give cities a role in shaping their energy supply by means of power purchase agreements or similar instruments concluded with electricity suppliers of their choice. Cities should have the possibility to finance rooftop PV or urban PV or urban storage on their territory using the polluter pays mechanisms (tradable certificates, incentive taxes) or by the creation of green equity or the emission of green bonds backed by credit risk guarantees. Cities should be enabled to organize internationally competitive tenders outside their territory for electricity procurement and electricity storage. Imported LNG should not benefit from subsidies or promotional policies of any kind.

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2.1.4. International Financial Institutions' Innovative Use of CRGs

Authored by Ping Yean Cheah, Asian Infrastructure Investment Bank AIIB

Several prominent international financial institutions (IFIs) which are active in providing credit risk guarantees (CRGs) in Asia / APEC region, include:

1. Asian Development Bank (ADB): ADB provides credit enhancement products, including guarantees, to support infrastructure projects in Asia and the Pacific. These guarantees help mitigate credit risks and attract private sector investment.

2. Asian Infrastructure Investment Bank (AIIB): THE AIIB offers credit risk guarantees to support sustainable infrastructure projects, including those related to energy transition and renewable energy, in Asia and elsewhere among its 109 member economies. These guarantees provide comprehensive coverage against commercial and credit risks for loans, notes and bonds. They are priced similarly to AIIB loans where a Risk Adjusted Return On Capital (RAROC) model[202] applies. RAROC is a financial tool used by financial institutions to assess risk and returns of a loan. It helps an institution to determine if the loan is profitable and aligned with its risk appetite.

For commercial guarantees, AIIB'S PARTIAL DEBT GUARANTEE (PDG) has a maximum maturity of 23 years. Other considerations include:

a) Project Eligibility: The product is available for eligible infrastructure projects that meet the Bank's criteria, which typically focus on sustainable infrastructure development, including sectors such as energy, transportation, water, and digital infrastructure.
b) Coverage and Guarantee Amount: The PDG covers a pre-determined percentage of the loan amount, which is agreed upon between the AIIB and the lender. The amount of the guarantee varies depending on the specific project and risk profile.
c) Tenure and Conditions: The tenure and conditions of the guarantee are negotiated between the AIIB and the lender. The guarantee period may align with the loan tenor or have a specific ALTERNATIVE duration. The terms and conditions of the guarantee, including fees and premiums, are determined based on the Bank's risk assessment of the project.
d) Project Monitoring: AIIB actively monitors the progress and performance of the projects for which it provides PDGs. This includes regular reporting and evaluation of the project's financial and operational aspects. The Bank's environmental and social standards apply.
e) Collaboration with Lenders: AIIB works closely with the lenders throughout the process, from project appraisal to disbursement and monitoring. It provides technical assistance and guidance to lenders to enhance their capacity in assessing and managing infrastructure project risks.

The diagram below demonstrates how the Partial Debt / Credit Guarantee (PDG) works.

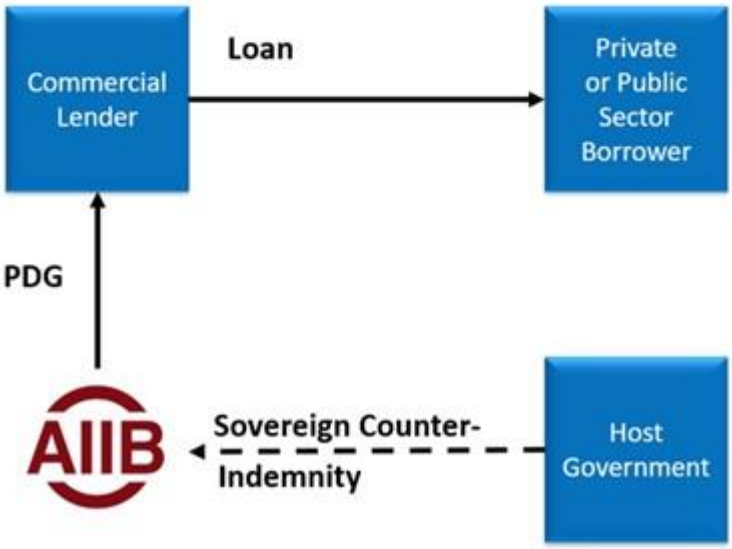


Figure 34: AIIB's Partial Debt / Credit Guarantee scheme

Source: (AIIB, Dec 2022)[203]

3. International Finance Corporation (IFC): IFC, a member of the World Bank Group, provides credit risk guarantees to support private sector projects. These guarantees help enhance the creditworthiness of projects and attract investment.

Each IFI has its own specific criteria, terms, and conditions attached to its CRGs (AIIB, 2023)[204]. Within the members of the World Bank Group, the International Finance Corporation (IFC) and the Multi-lateral Investment Guarantee Agency (MIGA) provide risk mitigation products, but they have different focuses and approaches.

1. IFC: The IFC primarily focuses on providing financing and advisory services to private sector projects in developing economies. It offers credit risk guarantees as part of its suite of risk mitigation products. The IFC's credit risk guarantees aim to enhance the creditworthiness of projects, attract private sector investment, and help mitigate risks associated with default or non-payment by borrowers. These guarantees are typically provided to lenders and investors to protect them against losses due to borrower default.

2. MIGA: MIGA specializes in providing political risk insurance and guarantees to investors in developing economies. Its focus is on mitigating risks related to political events, such as government actions, expropriation, currency transfer restrictions, and political violence. MIGA's guarantees protect investors against non-commercial risks that may arise from political instability or changes in government policies. Unlike the IFC's credit risk guarantees, MIGA's guarantees are typically provided directly to investors, rather than lenders.

In summary, while both the IFC and MIGA provide risk mitigation products, the IFC's credit risk guarantees primarily focus on enhancing the creditworthiness of projects and protecting lenders and investors against default risks; while MIGA's guarantees focus on mitigating political risks for investors in developing economies (AIIB, 2023)[205].

Risk types covered by a CRG

The CRG offered by most IFIs cover the following common risk types:

1. Default Risk: Risk of the borrower or project sponsor being unable to repay the loan or meet their financial obligations.

2. Political Risk: Risks associated with changes in government policies, regulations, or political instability that may impact the project's financial viability.

3. Currency Risk: Risk of fluctuations in exchange rates that may affect the borrower's ability to repay the loan in the agreed currency.

4. Force Majeure Risk: Risks arising from unforeseen events such as natural disasters, wars, or other events beyond the control of the borrower that may disrupt the project's operations or financial performance.

5. Technology Risk: Risk associated with the performance and reliability of the energy transition technology being financed, such as renewable energy generation or energy efficiency measures.

One example of a successful credit risk guarantee in energy transition financing is the "Scaling Solar" program in Zambia, which was supported by the IFC.

For this project, a credit risk guarantee was arranged to attract private sector investment in the development of two solar power plants with a combined capacity of 80 megawatts. The guarantee covered the risk of default by the borrower, ensuring that lenders would be repaid even if the borrower faced financial difficulties. This reduced the perceived credit risk and allowed the project to secure long-term financing at favourable terms.

The credit risk guarantee provided by the IFC[206] played a crucial role in mobilizing private sector investment and accelerating the development of renewable energy infrastructure in Zambia. This instrument helped mitigate the risks associated with the project, and catalysed lending totalling about USD1.2 billion from lenders such as the African Development Bank (AfDB), the European Investment Bank (EIB) the French Development Agency (AFD) and the Development Bank of Southern Africa (DBSA).

The AfDB also provides credit risk guarantees (CRGs) to support energy transition projects. One example of a successful energy transition project that adopted a credit risk guarantee from the AfDB is the "Noor Solar Complex" in Morocco[207].

The Noor Solar Complex is one of the world's largest concentrated solar power (CSP) projects, located in Ouarzazate, Morocco. The AfDB provided a credit risk guarantee to support the financing of the project, which aimed to increase the share of renewable energy in Morocco's energy mix.

The credit risk guarantee provided by the AfDB helped mitigate the risks associated with the project, making it more attractive to lenders and investors. It covered the risk of default by the borrower, ensuring that lenders would be repaid even if the borrower faced financial difficulties.

The Noor Solar Complex project successfully attracted private sector investment and financing, with the AfDB's credit risk guarantee playing a crucial role in mobilizing funds. Other lenders were the IFC, the EIB and KFW. The project has contributed significantly to Morocco's energy transition by increasing the economy's renewable energy capacity and reducing its dependence on fossil fuels.

The EIB also provides credit risk guarantees (CRGs) for energy transition projects. One example of a successful energy transition project that adopted a credit risk guarantee from the EIB is the "Windpark Fryslân" project in the Netherlands[208].

The Windpark Fryslân project involves the construction of a large offshore wind farm in the IJsselmeer Lake, consisting of 89 wind turbines with a total capacity of 382.7MW. The EIB provided a credit risk guarantee to support the financing of the project, which aims to increase the share of renewable energy in the Netherlands and contribute to the economy's energy transition goals.

The credit risk guarantee provided by the EIB helped attract private sector investment and financing for the project. It covered the risk of default by the borrower, ensuring that lenders would be repaid even if the borrower faced financial difficulties.

The Windpark Fryslân project successfully secured financing from among others, Rabobank and NWB Bank, with the support of the EIB's credit risk guarantee, enabling the construction and operation of the wind farm.

The Philippine Guarantee Corporation

Philippine Guarantee Corporation, also known as Philguarantee, is a government-owned corporation in the Philippines that provides credit risk guarantees to support various sectors, including energy projects. Philguarantee has been involved in supporting energy projects in the Philippines. The Sarangani Energy Corporation (SEC) Power Plant in Maasim, Sarangani Province, although a coal-fired one, is one such example.

Philguarantee (March 2020)[209] was appointed by the World Bank to be Program Manager of the **Philippine Renewable Energy Development Project (PHRED) and the existing Electric Cooperative Partial Credit Guarantee Program (ECPCG). PHRED** emphasises investments in the energy efficiency and renewable energy market segment in the rural electrification sector, that are less likely to obtain commercial financing. ECPCG focuses on guarantees to additional investments in renewable energy generation in all parts of the Philippines, including the off-grid areas.

This appointment demonstrates Philguarantee's commitment in supporting energy transition projects in the Philippines, particularly in the renewable energy sector.

Philguarantee’s product for renewable energy projects covers cash flow risks incurred by renewable energy providers. Its flagship guarantee product offered by the PGC is the Sustainable Energy Credit Guarantee Facility (SEGF). This guarantee covers the performance obligations of the renewable energy provider, including the payment of obligations related to the project, such as debt service payments, operating expenses, and other financial obligations. In the event of default or non-performance by the renewable energy provider, the PGC can provide compensation to the project's lenders or investors to cover the cash flow risks. Specific terms and conditions of the guarantee product, including the coverage and eligibility criteria, would be outlined in the agreement between the renewable energy provider and the PGC (Philguarantee, 2023)[210].

However, Philguarantee's products cover start-up risks, only if their off-take is guaranteed. One of the guarantee products offered by Philguarantee is the MCGF. This product addresses the needs of micro, small, and medium enterprises (MSMEs), including those in the renewable energy sector, by providing credit enhancements to help them access financing from banks and financial institutions. This can help mitigate start-up risks by providing additional security to lenders (Philguarantee, 2023)[211].

In the event of a natural disaster, such as a tropical windstorm or flood, that affects the creditworthiness of the guarantee taker, e. g. a MSME, Philguarantee's MCGF may provide additional security to the lender. This helps mitigate the risk associated with the disaster and enables the MSME to maintain its creditworthiness, ensuring continued access to financing.

Electricity market segments

Under its Medium-Large Enterprises Credit Guarantee Facility, Philguarantee (2023) [212] provides credit risk guarantees (CRGs) to large energy producers in various electricity market segments in the Philippines. These segments can be broadly divided into two:

1. Conventional Power Generation: This includes large-scale power plants that utilize conventional sources such as coal, natural gas, or oil for electricity generation.

2. Renewable Energy Generation: This includes power plants that generate electricity from renew-able sources such as solar, wind, hydro, biomass, or geothermal energy.

The general terms and conditions for granting credit risk guarantees to large energy producers may vary depending on the specific circumstances and requirements of each project. However, some common aspects of CRGs include:

1. Coverage: The CRG typically covers the repayment obligations of the energy producer, ensuring that lenders or investors are protected in case of default or non-payment.

2. Loan Amount: The CRG is usually tied to a specific loan amount or financing facility provided to the energy producer.

3. Tenure: The CRG may have a defined tenure, which aligns with the repayment period of the loan or financing facility.

4. Premiums: The energy producer is required to pay premiums to the PGC for the credit risk guarantee. The premium amount is determined based on factors such as the project's risk profile, loan amount, and tenure.

5. Eligibility Criteria: The energy producer must meet certain eligibility criteria set by the PGC, which may include financial viability, creditworthiness, and compliance with relevant regulations and environmental standards.

Providing credit risk guarantees (CRGs) to individual households or communities in the renewable energy producer market is a concept that has gained traction in recent years. This approach, often referred to as community-based or decentralized renewable energy, aims to empower individuals and communities to generate their own renewable energy. Guarantee providers normally assess the following factors related to practicality of CRGs for such markets:

1. Scale and Complexity: Providing CRGs to individual households or communities can be more challenging compared to larger enterprises. The scale of individual projects may be smaller, and the administrative complexity of managing numerous guarantees for a dispersed market can be higher. However, advancements in technology and streamlined processes can help address these challenges.

2. Financial Viability: Ensuring the financial viability of individual household or community-based renewable energy projects is crucial. CRGs can play a role in attracting financing by mitigating the credit risk associated with these projects. However, it is important to assess the creditworthiness and repayment capacity of individual households or communities to determine the feasibility of providing CRGs.

3. Regulatory and Policy Support: Supportive regulatory frameworks and policies are essential for the practical implementation of CRGs for individual households or communities. Governments can play a role in creating an enabling environment by providing incentives, streamlining administrative processes, and establishing clear guidelines for renewable energy producers.

4. Technical Assistance and Capacity Building: Providing technical assistance and capacity building support to individual households or communities is important to ensure the successful implementation and operation of renewable energy projects. This can include training on project development, maintenance, and financial management.

5. Collaboration and Partnerships: Collaboration among stakeholders is crucial for the practical implementation of CRGs for individual households or communities. This can involve partnerships between financial institutions, government agencies, community organizations, and renewable energy developers to share risks, leverage resources, and ensure the long-term sustainability of the projects.

While there may be practical challenges, providing CRGs to individual households or communities in the renewable energy producer market can help democratize access to clean energy and promote local ownership. It requires a tailored approach, supportive policies, and collaboration among stakeholders to make it a viable and scalable solution.

Philguarantee (2023)[213] indirectly supports renewable energy projects that benefit individual households or communities through its guarantee programs for MSMEs. For example, the PGC's MCGF program can enhance the creditworthiness of micro, small, and medium enterprises (MSMEs), including those involved in renewable energy projects. This, in turn, can facilitate access to financing for MSMEs engaged in providing renewable energy solutions to households or communities.

An APEC wide CRG system favouring renewables for APEC economies, especially in South-east Asia – Benefits and Risks

Setting up a region-wide credit risk guarantee (CRG) for renewable energy projects across APEC (Asia-Pacific Economic Cooperation) economies may be a complex undertaking but successful cases have proven that the benefits far outweigh the risks.

A case in point is the Asian Development Bank's Credit Guarantee and Investment Facility (CGIF) that provided growth capital to support CGIF's guarantee operations. Established in 2010, the CGIF issued 31 guarantees from inception until March 2019. These issuances deepened the bond market in ASEAN and acted as a catalyst with the following key contributions:

a. As of March 2019, out of 22 bond issuers the CGIF supported, 11 tapped bond markets for the first time with the help of the CGIF guarantees

b. CGIF guaranteed bonds helped to widen the investor base such as the Viet Nam bond market

c. From the 22 bond issuers, one third undertook cross border bond issuances, thus fostering financial integration among ASEAN members states.[214]

If a similar mechanism was created at APEC scale, its potential to promote investments and accelerate the deployment of renewable energy infrastructure in the region would be enormous. Some considerations regarding the viability of such an initiative are listed below:

1. Regional Co-operation: Establishing an APEC wide CRG would require strong cooperation and coordination among APEC economies. It would involve aligning policies, legal frameworks, and risk assessment methodologies to ensure consistency and effectiveness across borders.

2. Collective Regional Political Will and Commitment: The success of a region wide CRG would depend on regional political will and broad commitment of APEC economies to support renewable energy development. Governments would need to collaborate and provide the necessary regulatory and financial support to facilitate the implementation of the CRG.

3. Risk Assessment and Mitigation: Developing a commonly accepted, robust risk assessment framework is crucial to ensure the viability of the CRG. It would involve evaluating the creditworthiness of projects, assessing economy-specific risks, and implementing risk mitigation measures to protect investors and lenders.

4. Financial Resources: Adequate financial resources would be required to establish and sustain a region wide CRG. Funding could come from a combination of public and private sources, including contributions from participating economies, IFIs, and private sector investors.

5. Legal and Regulatory Framework: Harmonizing legal and regulatory frameworks across APEC economies would be essential to facilitate the implementation of the CRG. This would involve addressing legal barriers, standardizing documentation, and ensuring enforceability of guarantees across jurisdictions.

6. Technical Expertise and Capacity Building: Building technical expertise and capacity within participating economies would be necessary to effectively administer the CRG. This could involve knowledge sharing, training programs, and collaboration with international financial institutions and industry experts.

A region wide CRG for APEC economies potentially offers significant opportunities for promoting renewable energy investments and collaboration. It requires a comprehensive and collaborative approach involving governments, financial institutions, and other stakeholders to ensure its viability and success where international organisations and IFIs are best fit to play the role of convenor.

The Climate Policy Initiative (2023)[215] proposes the establishment of a Global Credit Guarantee Facility (GCGF) to address financing challenges in the energy transition of APEC economies. More specifically, this paper outlines the potential cost reduction of capital through risk mitigation using a well-structured and appropriately sized GCGF. It presents three different approaches for sizing the GCGF, ranging from conservative to optimistic, with varying levels of funded and callable capital. The paper highlights that the GCGF could result in significant leverage in debt mobilization, with ratios ranging from 28x to 250x. For the analysed sample set of 40 economies, the GCGF could lead to an average reduction in risk premia of 3%-6% and an average improvement in credit ratings of 2-6 notches.

This paper further outlines the granularity of each approach, proposes potential fund structures, and provides recommendations for further development of the GCGF concept.

APEC Energy Working Group, in collaboration with the Government of the Philippines, may wish to adopt this GCGF and develop it into a full investment proposal. The model needs to be further validated with empirical data, analysis of the cost of capital, foreign exchange and political risks for cross border climate finance. Risks emerging from political and currency exchange turmoil may be transferred to the Multilateral Investment Guarantee Agency and a Currency Exchange Fund. The GCCF may focus on financing climate-aligned renewable projects in selected APEC economies.

The Energy Working Group may use APEC cross-fora cooperation as a mechanism to pool different stakeholders of the energy and financial system and help build political momentum. Global climate-related events such as COP, the G20 meetings, the Bridgetown initiative[216] are platforms to further advocate this facility. The MDBs could be engaged at design stage for their expertise views on the institutional structure.

In summary, the time is ripe for such a regional facility to be established to accelerate adoption of renewables at urban level and augment the flow of capital to urban, regional and state-owned enterprises.

2.1.5. Urban Climate Finance in the Energy Sector: The Case of Green Buildings

Authored by Francisco Martes Porto Macedo, Climate Policy Initiative

About the Cities Climate Finance Leadership Alliance

Launched in 2014 by the previous United Nations Secretary General, the Cities Climate Finance Leadership Alliance (CCFLA) is the only multi-level and multi-stakeholder coalition of leaders committed to deploying city-level finance by 2030. Since 2019 Climate Policy Initiative has hosted the Secretariat for CCFLA.

CCFLA brings together over 80 member institutions covering a wide spectrum of institutions committed to boosting urban climate finance. Members include public and private finance institutions, city networks, the United Nations systems, research and academic institutions, as well as national governments.

Urban climate finance landscape

In 2019 CCFLA launched the report State of Cities Climate Finance[217], which provided the first comprehensive estimate of global urban climate finance and investment gaps, developed by tracking a broad range of sources of finance for climate adaptation and mitigation activities located in urban geographic areas or activities directly serving city dwellers (Picture below). The methodology combined detailed project-level investment commitment data reported by donors and investors with estimates of sector-level capital expenditure developed using sector-installed capacity data and investment cost data, currently for transport and buildings activities only.

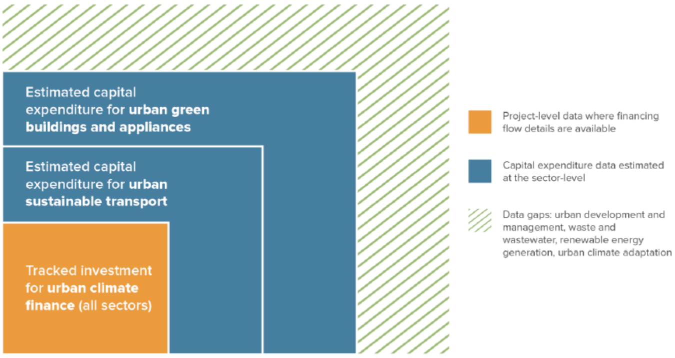


Figure 35: CCFLA membership

Source: CCFLA

The report indicated that USD384 billion were invested annually, falling short of the approximate USD5 trillion needed annually as estimated in the last edition of the State of City Climate Finance report published in 2015. This gap could widen if investments don't rapidly increase, as approximately 2.5 to 3 billion people are expected to move from rural to urban areas by 2050. Half of this global urban population growth is expected to take place in Africa and Asia.

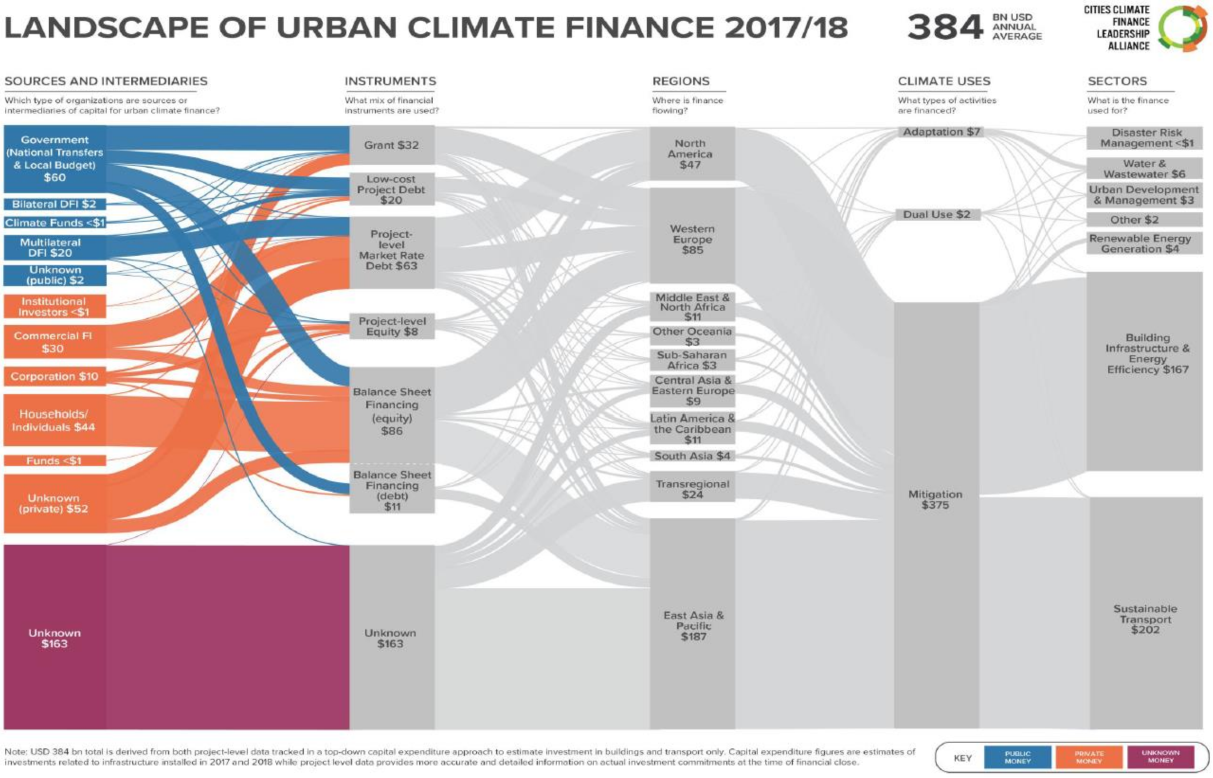


Figure 36: Landscape of urban climate finance 2017 – 2018

Source: CCFLA

Of the total USD384 billion, the most significant proportion of finance was invested in the East Asia and Pacific region, driven by China, and in developed economies, particularly in Western Europe (with USD85 billion) and North America (USD47 billion) (Picture below). Financing for China featured significantly in the capital expenditure estimates for urban transport and buildings. For instance, USD34 billion spent on electric buses was almost entirely in China. This reflects China's low-carbon public transport policy as a key policy objective, including providing subsidies and quotas for electric vehicles, with cities moving to deploy an increasing amount of electrically powered passenger and freight transport.

In Latin America and the Caribbean, USD11 billion was invested, mostly in Argentina and Brazil, and this is a fraction of the USD416 billion of financing opportunities available each year, according to IFC studies. Important to emphasize there were vastly insufficient amounts of urban climate finance being invested in crucial regions such as South Asia and Sub-Saharan Africa, which saw an annual average investment of USD4 billion and USD3 billion, respectively.

It is fundamental to highlight that domestic actors provided 86% of urban climate finance, reminding us of the key role played by ambitious and comprehensive climate action policies led by governments and the local finance ecosystem.

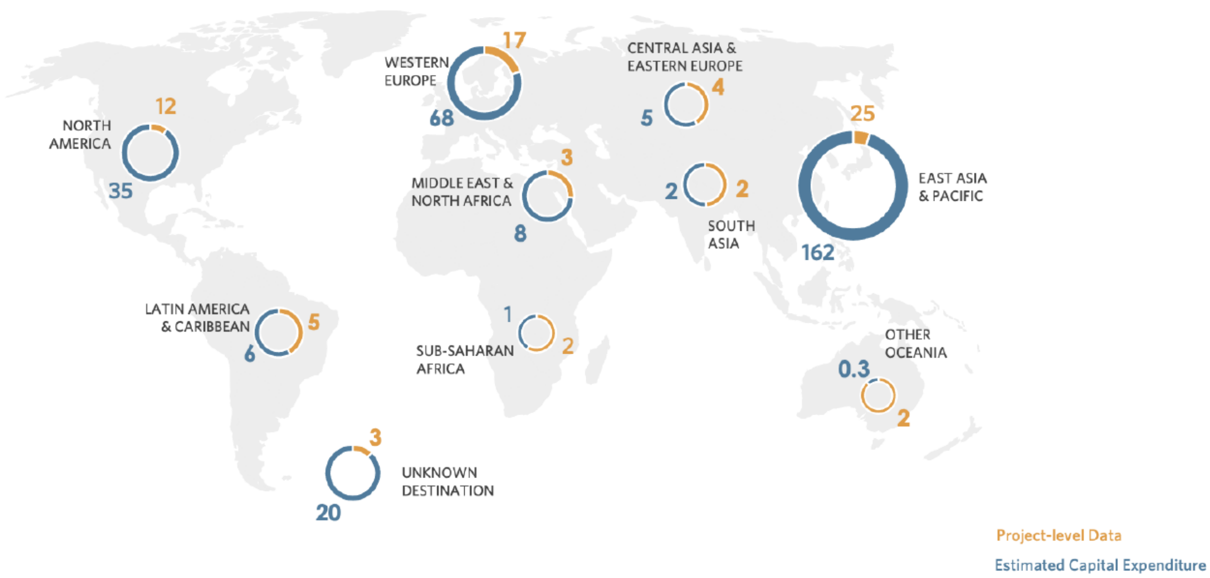
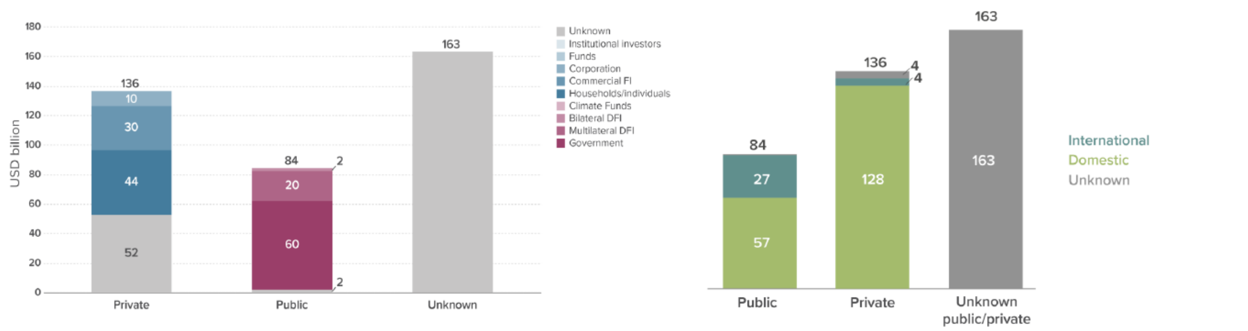


Figure 37: Urban climate finance by destination region, 2017-2018 (USD billion)

Source: CCFLA

In terms of the sources of investment, the report shows a 60/40 split in private and public sources of finance in 2017/2018 (Picture below, left). National governments financing projects domestically were the highest single contributing finance provider (providing USD60 billion), driven by spending on urban transport and buildings.

Domestic private finance was the main source of capital overall, amounting to USD128 billion (Picture below, right). This corresponds mostly to household expenditure on private electric vehicles and energy efficiency in buildings as well as commercial bank investment in the buildings sector and corporations in waste-to-energy and wastewater management projects.



Urban climate flows by providers, annual average 2017-2018 (USD billion)

Urban climate finance flows by financing institution type, annual average 2017-2018 (USD billion)

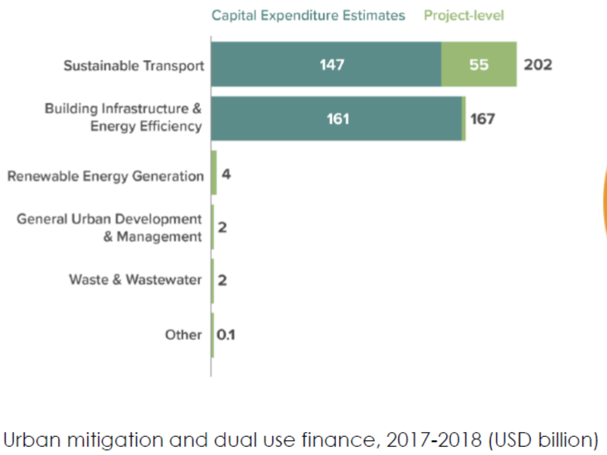
Figure 38: Urban climate finance flows by providers (left) and financing institutions (right)

Source: CCFLA

In waste-to-energy and wastewater management projects, urban climate finance has been spent on mitigation in sustainable transport and building infrastructure and energy efficiency.

The analysis of urban mitigation and dual use projects shows that most finance flowed to the sustainable transport and building infrastructure and energy efficiency sectors (Picture below, left).

The breakdown of urban building investments (Picture below, right) indicates that expenditure on energy efficiency in appliances, equipment, and lights accounted for the most significant proportion of investment in buildings across regions, corresponding to USD41 billion on average in 2017-2018. Energy efficiency improvements of existing buildings attracted USD40 billion, driven by investments in Europe and North America. The investment in energy efficiency measures integrated into the construction of new buildings, driven by China, amounted to USD26 billion.



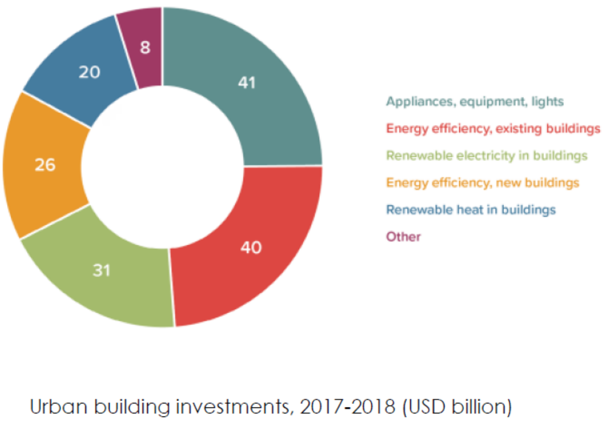


Figure 39: Urban climate finance flows by climate objective (l) and urban building investments (r)

Source: CCFLA

Barriers to investment in green buildings

Today, 37% of energy related GHG emissions are from buildings, including 10% that is from materials and construction. Translated in financial terms, this represents an investment need of more than USD5 trillion for low carbon alternatives and a large investment gap of USD300 to 500 billion. Cities are at the centre of the building transition, and it is where most of this investment will be needed as:

(1) urban population and economic growth will drive the demand for building,

(2) the bulk of the existing building stock is in cities, and

(3) the decarbonization of buildings can support cities' social, environmental, and economic agendas.

In its 2022 Financing Net Zero Carbon Buildings report and 2023 Net Zero Carbon Buildings in Cities: Interdependencies between Policy and Finance report [218], CCFLA conducted a meta-assessment of existing studies on barriers to investments in low-carbon buildings to understand how to realise the market opportunity in net zero carbon buildings. This led to identifying 22 main barriers to investing in zero-carbon buildings, assessed by relevance using the average ranking method. The study focused on how cities can use policy and financial instruments to drive investment in net zero carbon buildings and target four thematic areas: (1) cooling technologies, (2) embodied carbon (in construction activities), (3) adaptation, and (4) just transition.

The picture below shows that the perception of the relevance of barriers varies over these thematic areas. For instance, financial barriers emerge as the most significant group of barriers, followed by the uncertainty associated with investments in a relatively new/emerging sector. Additionally, the study showed that these barriers are not "isolated problems" but are strongly interconnected. In other words, a barrier and how it is addressed can in turn, have an impact on other barriers and associated mitigation efforts. For example, market readiness barriers have a fundamental influence and impact on other barriers in the system and precede regulatory barriers in their ability to further influence the development of the market. Financial barriers represent the single most important set of barriers of the residential sector.

Barrier type	Barrier name	Perceived priority	Influences other barriers	Influenced by other barriers
Financial barriers	Lack of access to affordable finance	10.0	0.2	0.8
	Lack of awareness of funding options	10.0	0.1	0.3
	Limited supply of dedicated financing instruments	9.0	0.2	0.6
	Inability to pay for upfront costs	8.5	0.1	1.0
Investment risk/ opportunity barriers	Asset class has insufficient project scale	10.0	0.2	0.1
	High investment costs compared to alternatives	10.0	0.2	0.3
	Low or fluctuating energy prices	10.0	0.2	0.1
	Long payback on investment	8.7	0.2	0.5
	Perceived technical performance risk	7.6	0.2	0.5
	Split incentive between landlords and tenants	7.6	0.2	0.1
	Low priority investment	7.2	0.3	0.8
	Lack of awareness / appropriate information on opportunity	6.8	0.1	0.2
	Lack of performance data	6.8	0.8	0.2
	High or uncertain maintenance / operation costs	2.5	0.1	0.2
Market readiness barriers	Limited experience with technical solution	8.0	1.0	0.1
	Lack of expertise / skills	7.0	0.4	0.1
	Limited technical product supply	5.8	0.5	0.4
Regulatory barriers	Lack of building regulation support	7.4	0.3	0.1
	Lack of standard technologies	7.0	0.5	0.1
	Lack of information standards and labeling	6.0	0.4	0.1
	Long permitting / access to land	6.0	0.2	0.2
	Social risk / community opposition	1.0	0.2	0.1

Figure 40: List of surveyed barriers and perceived priority by specific thematic area

Source: CCFLA

The following explanations will help interpreting the above figure: Investment barriers are not “isolated” but strongly interconnected. “Perceived priority” (a) is assessed based on average barrier rankings observed across eight sectoral studies and meta-assessments. Priority indicates the severity level of the barrier to impeding progress in the net zero building sector. Perceived priority ranges from highest priority (10) to lowest priority (1) and is defined by building sector stakeholders' perception of barrier importance (as opposed to a quantifiable measurement of impact or probability). Influence on other barriers" (b) and propensity to be "Influenced by other barriers" (c) was measured with scores ranging from 0 (low) to 1 (high).

The report also looks at over 44 financial instruments and 31 policies instruments that have either been widely implemented, piloted, or proposed across the 6 different categories of technologies or sources of emission, showing that there are policies and financial instruments that target all sources of buildings related to emissions and technology (Picture below). These include specialized policies like mandatory construction waste landfill diversions or financial instruments like "pay-as-you-save" that address specific issues. There are also broad policies and financial instruments like expedited permitting or capital cost subsidies that can apply to any technology or source of emissions. The figure below maps policy and financial instruments to mitigation and adaptation outcomes and the four high-impact thematic areas.

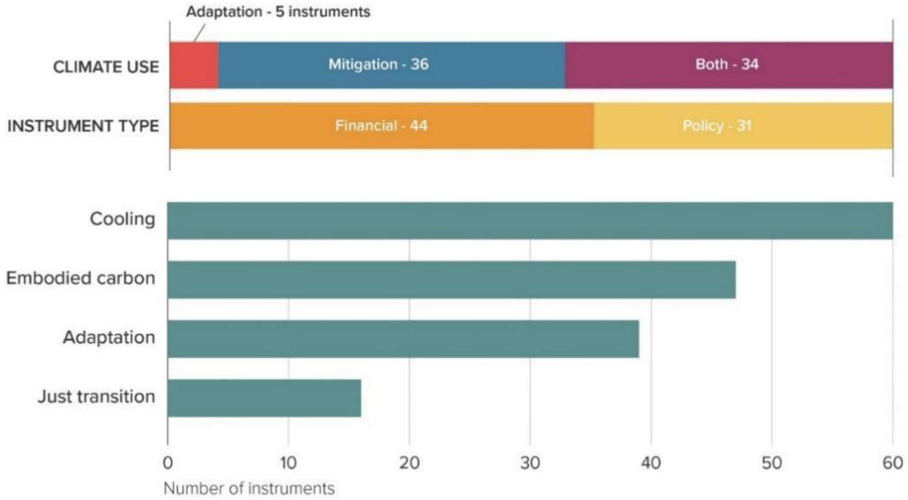


Figure 41: Policy and financial instruments covering surveyed technologies

Source: CCFLA

The report used system mapping to develop a pathway which is able to reflect the complexity of the building sector and applied graph and network theory to examine the structure of the system and identify specific paths and instruments that cities can deploy to optimize their support to the net-zero transition of the building sector (first picture below), which is exemplified in the second picture further down for the case of PACE (property assessment for clean energy) and PAYS (pay-as-you-save) programs, which were two mechanisms found to be the most impactful pathways to install various types of low-carbon equipment – cooling being one of them – with no upfront cost.

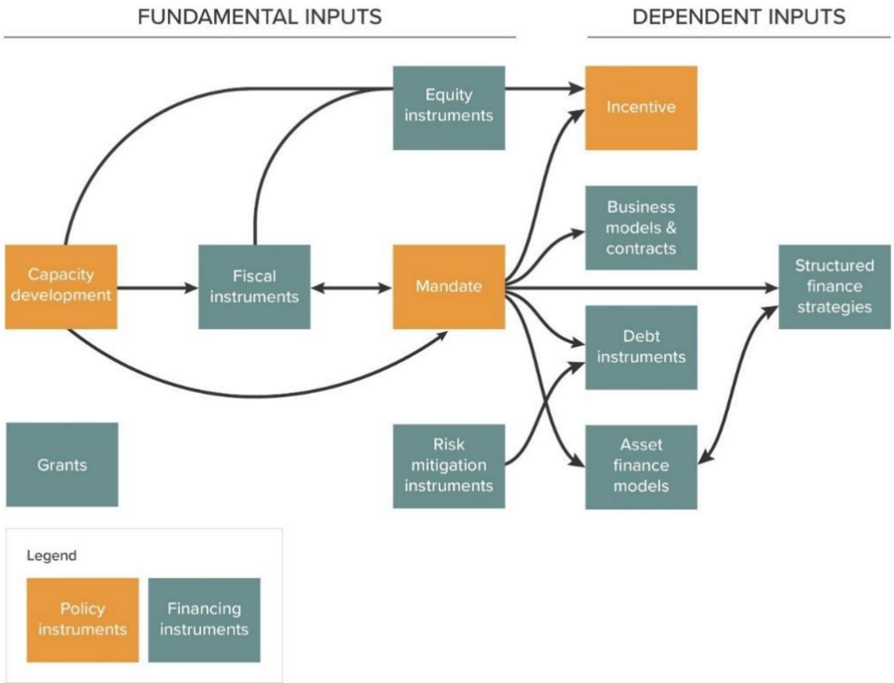


Figure 42: Policy and financial instruments interdependencies

Source: CCFLA

Policy and financial instruments are linked by interdependencies. Fundamental inputs are policy and financing instruments that systemically enable other instruments; these should be in place before dependent inputs to make dependent inputs more effective in achieving outcomes. We grouped the 75 policy and financing instruments into 11 categories for simplification (see figure above).

In the former (PACE), cities can cover upfront costs and get repaid in the form of readjusted property taxes that reflect the value added to the building. In the latter (PAYS), the equipment "pays for itself" as the consumers only repay the equipment when measured energy savings are achieved compared to BAU for the equipment. However, both instruments rely on the implementation of several other measures, not all of which can be fully supported by cities. These include the installation of Advanced Metering Infrastructure (AMI, I014), and reliable cooling equipment labels.

It is fundamental to understand that these are generalized assessments, and every city is unique and has different priorities, regulatory and market conditions, and climatic conditions to account for which and what instrument and when we need prioritizing action but important is to: (1) see the interconnectedness of policies and instruments and (2) identify which pathways are generally most impactful.

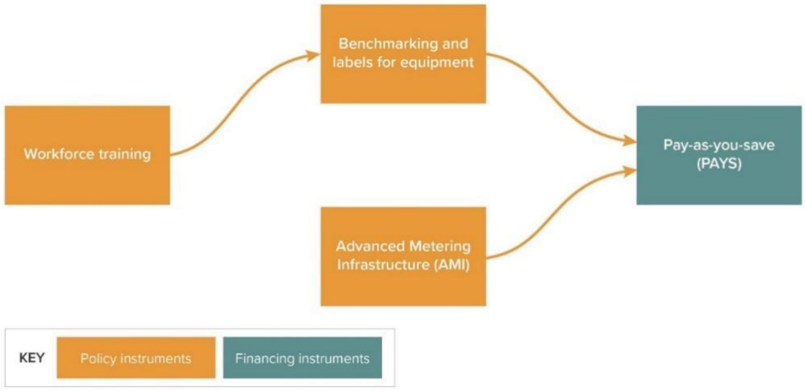


Figure 43: Example of a pathway for cooling solutions using the PAYS program

Source: CCFLA

As an example, take the financing and construction of affordable housing in Africa. CPI's *The Lab* is an incubator in charge of developing financial instruments to accelerate the transition to network carbon buildings in Africa, where there is a huge potential with a lot of migration to the main cities and a lot of infrastructure still to be developed. CPI developed an instrument that would allow people in cities to buy affordable, energy efficient housing on the one hand, but also that would create a pipeline for the private sector to keep on developing this infrastructure. There was an issue of making the market happen. On the one hand, it needed to create possibilities for people to afford the houses, but on the other hand, it had to create the possibilities for the companies themselves with financial support to really start developing these infrastructures. This exemplified working hand in hand with the private finance sector as well as real estate developers.

The production of low-carbon buildings can be scaled up provided there are sound policies in place and a clear government orientation given to the market. China gives an example of how it could be done to build the stock of carbon neutral buildings.

Finally, the work shows that implementing successful instruments requires collaboration from many stakeholders. For instance, support and coordination with state/provincial and economy-wide governments will be essential to address the climate challenges of the building sectors fully. Private sector action is also critical, so is the role of DFIs in de-risking these investments is very important. More specifically:

- City governments, along with industry and civil society partners, can play a key role in implementing capacity development activities for the design and construction industry, as well as buildings owners. For instance, procurement of net zero carbon technologies in public buildings will allow Cities not only to directly contribute to the reduction of emissions but also to incentivize private action by leading the way.
- Governments at all levels can create fiscal instruments to incentivize green buildings. For instance, mandate instruments such as phasing out of fossil-dual-based appliances and adoption of energy-efficient building codes allow to deliver on multiple goals.
- Governments can support the use of a wide range of financial instruments, but financial institutions, including DFIs, must provide the capital for building developers and owners to make investments.

2.1.6. Financing the Circular Economy: Four Elements of Success for Smart Cities

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Introduction

In 2007, humanity passed a milestone threshold. For the first time in human history, the amount of people living in urban areas, as opposed to rural, exceeded 50% (Kourtit, et al., 2012)[219]. Moreover, this trend is going to continue to increase to 70% by 2050 (Romano et al., 2023)[220]. The impact of this growth on cities varies depending in which economy the city is situated, its financial resources and municipal management. Some cities have even excelled achieving a good ratio of the cost and the quality of living, a lack of pollution and efficient resource allocation. This is because, as Lnenicka et al. (2022)[221] state, cities are dynamic systems that undergo transformation and adjustments, depending on the grade of innovation capability and willingness to reinvent.

Nonetheless, due to this dramatic increase in urbanisation, most cities are facing a variety of challenges, as such a dramatic raise in population requires a much higher priority to be placed on resource input and output. As Nogueira et al. (2020)[222] argue, in cities, social, ecological, and technical systems are deeply intertwined since the parts of one distinct subsystem belong to, and can dynamically affect, the others.

To manage these challenges, one solution is the Smart City concept which integrates its buildings, healthcare services, education, public mobility services, living and environmental aspects, etc., with help of digital technologies like Artificial Intelligence (AI), Internet of Things (IoT) big data, and data analytics. The goal is to increase the capacity to manage information and resources and to improve the quality of lives for its people. The use of information technology has been considered as a key factor that defines the smartness of a city since it can sense, monitor, control and communicate most of the city's services like transport, electricity, environment control, crime control, social, emergencies and other aspects. (Ramaprasad et al., 2017)[223].

Coinciding with this urbanisation, municipalities are also being confronted with two other and perhaps even more crucial challenges, namely climate change and pollution. Thankfully, despite these two daunting challenges, the circular economy can help mitigate both concerns if the going-circular transition is applied at the systemic level and also if cities are committed to investing in this transition.

Four Elements of Success for Circular Smart Cities

Circular Smart Cities

Cities are responsible for over 70% of the world's energy-related CO_2 emissions and an increasing share of global waste that is expected to rise to 3.4 billion tonnes (3,400,000,000,000kg) in 2050 (Romano et al., 2023)[224]. Hence, to offer its citizens a liveable and truly sustainable life, cities need to finance technological solutions that help realise full circularity. To avoid any confusion that might derive from over 114 currently available circular economy definitions (Kirchherr et al., 2017) [225], this illustration artfully defines what is meant by the circular economy.

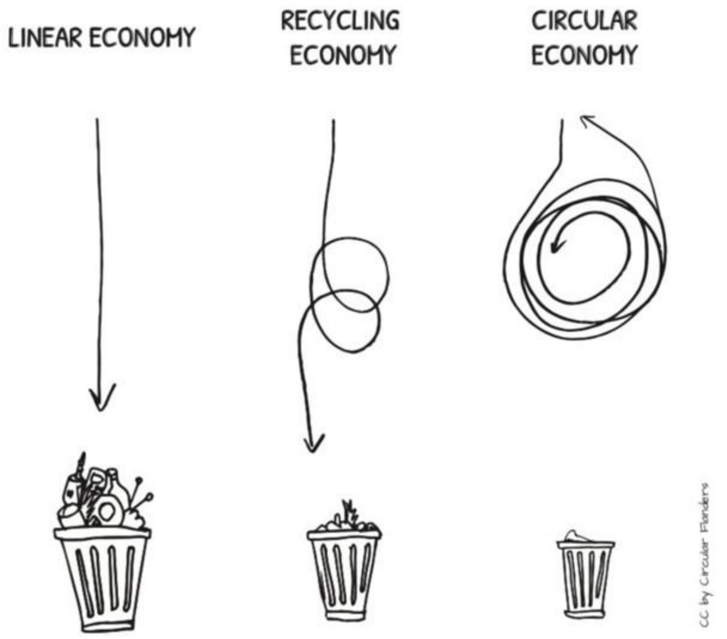

Figure 44: Illustration of the term “Circular Economy”

Source: Circular Flanders

According to Formisano et al. (2022) [226], cities have attempted to incorporate sustainability into their smart city model. They propose defining the pillars of sustainability for a city and assess smart technologies that can support these pillars. However, before taking this first step, it is essential to acknowledge, as seen in this Circular Flanders graphic, that waste is a valuable resource as it can be turned into raw material again. As Meadows (2008) [227] states, “…*system structure is the source of system behaviour*”. In the prevailing production system of behaviour, all resources are taken from the Earth but once turned into products, they lose their value at the end of their lifecycle because consumers value only their functionality, not the initial effort that went into getting the resources and turning them into products.

While there are now more and more companies (re-)discovering value in waste, products from the initial planning stage are still not yet designed for circularity. Toxopeus et al. (2021) [228] also argue that economywide and municipal policy makers can also provide support by implementing regulations that stimulate the re-use of materials. In addition, the circular transition will automatically make clear business sense if the relevant commodity price increases to such an extent that *“… the total investment cost of going circular is lower than the overall price of the resource caved over a certain defined time*”.

While the author of this paper agrees that a solid business case is obviously paramount to any business activity, it is not enough. That is where and why a circular smart city can support the transition to the circular economy by providing the infrastructure that supports material flows, the education that prepares its graduates with the know-how to seize these circular opportunities and finally a change in mindset that facilitates people seeing products for what they actually are, namely a source of valuable materials.

The Business Case

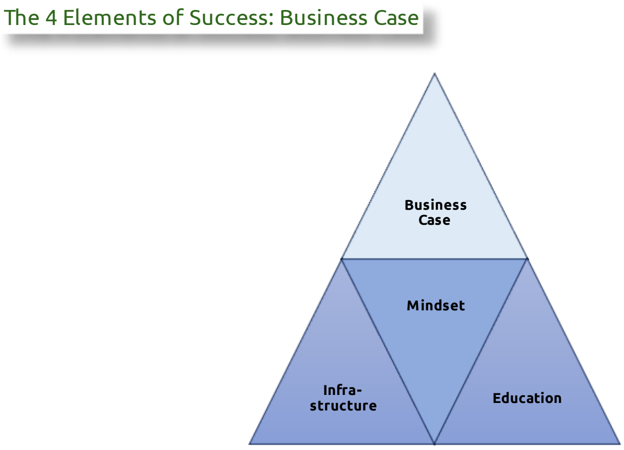

Figure 45: Four Elements of Success, Element one: Business Case

Source: Own Illustration

At the centre of the transition to the circular economy, there can now be found many novel business models. Among the most well-known, and thus widely implemented models, are Product-as-a-Service, Industrial Symbiosis, Closed Loop, Upcycling and Downcycling. Despite the growing familiarity of these models, there remain high financing risk concerns from banks because their current risk detection tools have still not been programmed to identify them within the new business models (Ozili, 2021)[229].

For example, the business model Product-as-a-Service does not foresee or consider the actual exchange of ownership during the purchasing process. In this model, clients merely rent a service and the product ownership remains with the producer. One of the benefits of this business model is that the producer is incentivised to increase the longevity of its products. However, a downside is that revenue predictions need to be changed as the product price will be paid over its entire lifecycle. Kierans & Chen (2021) [230] conducted qualitative interviews with a group of investors and some of them pointed out that the predictability of future revenue flows of circular companies is difficult. This topic will be explored again in the next section.

Another circular model known for its innovation is Industrial Symbiosis where the waste of one company's production process becomes a valuable raw material for the next company. Here, it is vital for circular smart cites to create secondary markets where an evaluation of the value of secondary materials can be realised and trusted. (Goovaerts & Verbeek, 2018)[231].

Yalçın & Foxon (2021)[232] also concur that there remain high financing risk concerns from banks and argue that the circular economy might not survive without government support. Banks and financial institutions report to their shareholders and thus they will likely only finance circular solutions that are undoubtably profitable. Despite this, as more and more investment companies (Hedge Funds and Private Equity) do deploy capital to the circular economy, profitability prospects in the circular economy will widen (Ozili, 2021)[233].

However, as we will now discuss, the majority of producing companies have built their international supply chains as a one-way, exit street and change will require significant investment in their infrastructures. Who will finance these changes?

Infrastructure

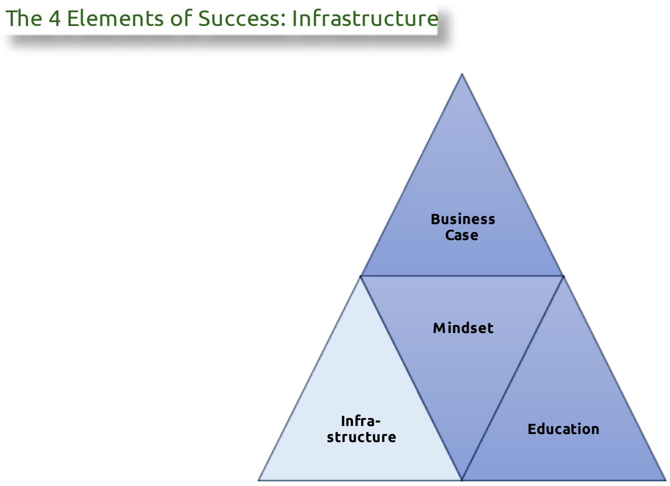

Figure 46: Four Elements of Success, Element two: Infrastructure

Source: Own Illustration

The topic of infrastructure has many facets. As discussed before, integrating a smart, digital infrastructure to understand city's inflows and outflows is one aspect of it. However, the author considers financial infrastructure as one of the most important, as financial liquidity is essential to spur innovation. This can be a solid banking system that offers loans to circular startups, as well as an active business angel and a VC network for newly identified growth companies. Some infrastructure projects are complex and thus costly and thus they need municipal and even federal or economy-wide financing options. Financial infrastructure can help accelerate the validation of the previously mentioned business cases. As discussed, a solid business case is needed for financing, but it remains true that when considering infrastructure, financing institutions must adjust their calculations to consider these circular business models which differ dramatically from the traditional linear models.

To illustrate, a company that decides to get its products back, be it with Extended Producer Responsibility (EPR) or within the business model Product-as-a-Service, might not have the capacity to dismantle their returned products to extract materials for reuse, refurbishment, remanufacture or repurpose. They may have to look for a partner company that has the requisite capabilities for creating a circular value network (Toxopeus at al., 2021)[234]. As mentioned with risk predictions, from a bank's perspective, this is another uncertainty variable added to the equation. "*Once a business enters into a collaborative model, the borrower's creditworthiness will be strongly correlated with the solidity and reliability of the value chain*" (Dewick et al., 2020)[235]. In certain cases, the cost to recover waste might exceed the market value of recycled waste products (Ozili, 2021)[236].

A truly smart city in both senses – technologically-advanced and with a smart leadership – can use these challenges to its advantage, especially if it is a home to many manufacturing companies. For example, the city can co-finance a return scheme of materials and earn taxes from so called urban miners, i.e., companies that extract materials from waste. Plus, it goes without saying that the municipal government should be taxing polluters much more.

Hence, a city needs technological solutions that can track the flow of products, components, and materials. The resulting data can be used for improved resource management and decision making across different stages of the industry lifecycle (Kristofferson et al., 2020)[237].

This data would help predict waste flows and adjust the time lag for some materials. For example, if a company were to design a modular, completely reusable device today, this device would come back for reuse at the end of its lifecycle and then serve as a raw material. This could be in about two years for a smartphone or four to five years for a laptop, or as long as fifteen years for an automobile. Plus, it must be remembered that these materials are exposed to depreciation and thus this needs to be considered when pricing these secondary materials.

In the Kierans & Chen (2022)[238] article, some investors favoured a blended-financing solution that covers a long-time investment horizon (10-15 years). One investor expressed it as: "*Put money into non-proven technologies or ways of thinking, stimulate and encourage collaboration between the top companies and supply incentives to investors and then support this with market incentives*." A smart city can support this development with incubator and accelerator programmes.

Additionally, a circular smart city can use infrastructure technology to direct local food production into the city which would increase food independency and also create incentives for local farmers. If done properly, it could even dramatically decrease the plastic pollution problem by utilising alternative food packaging solutions.

All these solutions would also naturally require an upgrade a city's transportation infrastructure because the environment cannot be healed if goods are transported in old trucks, as the recent example from Poland in a conversation with a Business Angel showed or likewise by using old freight trains which caused noise pollution in the Rheingau, Germany.

Currently, most infrastructure financial decisions are made by individuals educated in the linear production mindset. Hence, education will need to be shifted so that training institutions can teach a more contemporary and wiser understanding of our overall business and city ecosystems and their impact on mankind and their environment. With improvements in education, a smart city can better involve its citizens as they will have a better understanding of the impact of producing goods will have on their own overall health and the liveability of their city.

Education

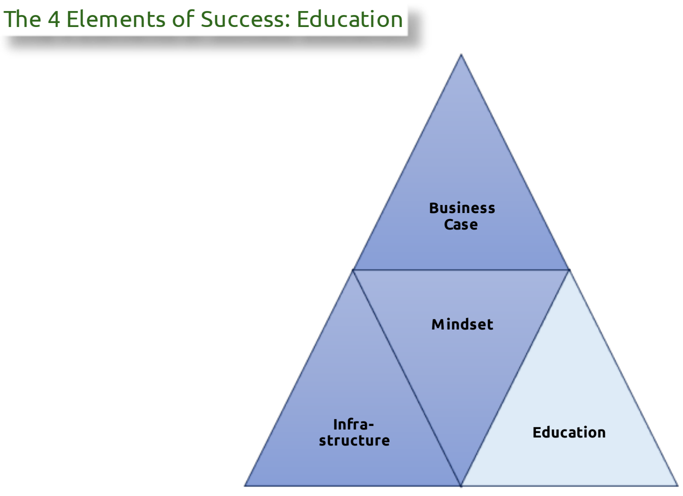

Figure 47: Four Elements of Success, Element three: Education

Source: Own Illustration

The author personally worked within business schools and universities in Europe and Asia for over two decades and is thus well aware that the issue of reducing waste and more recently the circular economy have been neglected at best, and ignored at worst, in business education. "*Lack of knowledge and technical skills around the circular design of products and services impede practical applications*" (Yalçın & Foxon, 2021)[239].

Thus, educating enough leaders who can lead the way down the path to accomplish a circular transition is a prevalent and omnipresent challenge. Rethinking and retooling current production systems will require future-thinking business leaders, engineers, designers, etc. Recognising this, Finland, for example, has made education headlines with the announcement that the circular economy will be taught as early as elementary school (SITRA, 2019)[240].

Plus, in regard to training, the European Union's Right to Repair law begs the question if the EU will have enough technicians and specialists to repair these products. Economies like Germany are already facing worker skill shortages, especially in the *Mittelstand* (Burstedde & Schüler, 2020)[241]. Attracting young talent into manual jobs that are less glamourous than IT careers might prove to be very challenging even though the lack of repair shops and personnel could be overcome by far-sighted individuals using technology to create a map of the existing repair shops and thereby help citizens to the right addresses in their vicinity. Municipalities working with other government levels should be initiating educational programmes in order to increase the number of qualified, trained repair professionals. These educational opportunities can also be initiated by private individuals who can train the trainers and empower more people to embrace circular employment opportunities as a means to not only address environmental matters but also help partially solve long-term unemployment problems.

Thus far in the discussion, the Business Case, Infrastructure and Education were mentioned as factors that are holding back the present decision makers in business, banks and financial institutions to fully embrace circular initiatives because they were educated in, and familiar with, the linear model of business. The author has discussed some of the challenges inherent within each of these three factors and now the attention is turned to the fourth factor which is the Mindset.

The 4 Elements of Success: Mindset

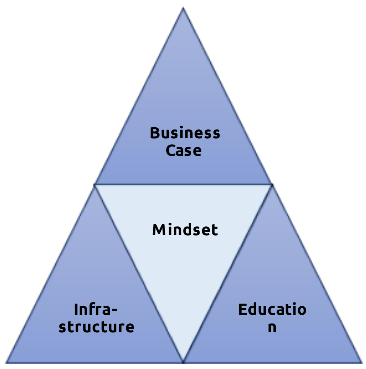

Figure 48: Four Elements of Success, Element four: Mindset

Source: Own Illustration

Mindset

This fourth element Mindset is a key, central factor influencing the other factors. Senge (1990)[242] refers to it as metanoia or a shift of mind. It relates to a deep learning that allows us to "…*reperceive the world and our relationship to it*" and thereby extend our capacity to create. It requires a more profound mental shift than simply applying the old models to solve present or future challenges. As an example, without a shift in mindset, Goovaerts and Verbeek (2018)[243] argue that a viable circular business might likely be considered riskier, especially if it is a small or a medium-sized company with a short track record, limited access to financial resources and thereby in a volatile financial position. Clearly, the out-dated linear models will continue to endure and the promising resolutions and opportunities inherent in the circular economy will never be embraced unless there is the wide acceptance of a new mindset based on a far deeper and more open understanding of how the economy should work.

On the consumer side, the prevalent attitude of owning products outright, versus only leasing them for a period of time, is an example of a significant mindset change that is much needed. In many economies, for example in the world's largest consumer market China, owning a new product is seen as a sign that one can afford it and thereby by purchasing products outright one achieves an elevated status in society. Conversely, owning a used product is frowned upon. A change in this attitude will require a seismic mindset shift to where consumers feel that there is social prestige to be gained by oneself - and their peers – alternatively seeing formerly discarded products not as garbage but as a practical, prudent sourcing of raw materials.

In the author's research when questioning investors on what they thought about the role of mindset, some pointed out the need of more open-mindedness and a deeper questioning of our production and consumer habits. The urgent need for a long-term thinking mindset was raised by a respondent from Germany who criticised so called Sustainability Weeks:

"*Dedicating a week to sustainability and believing that problems can be solved in one week does not work because after the week is over people carry on as before*." (Kierans & Chan, 2022)[244]

Other investors expressed similar views: "*My company did an interesting work on what we need to do to reach carbon zero and a change in mindset was the biggest factor. How we see things is a critical way of how we understand things and the way we understand things changes how we act*." (Kierans & Chan, 2022)[245].

Since business education has neglected environmental studies for such a long time, one research respondent stated that it will be difficult to change the "*neo-liberal*" way of thinking. Financing decisions far too frequently continue to rule out investing in viable circular companies due simply because these decisions are made with old knowledge, as well as, with a decades-old mindset.

When it comes to the issue of changing mindsets, another respondent referenced that even though he started with sustainability financing twenty-five years ago only now, an entire generation later, are things starting to pick up.

Conclusion

As stated in this article, the Smart City concept is gaining acceptance by municipalities across the world because – among other considerations – it integrates the city's governance responsibilities over buildings, healthcare services, education, public mobility services, living and environmental aspects, etc., with assistance of contemporary smart, digital technologies like Artificial Intelligence (AI), Internet of Things (IoT) big data, and data analytics.

The goal of these “smart” efforts is to increase the capability for a city to manage its information and resources and especially to improve the quality of life for all its citizens. However, due to the trend of increasing urbanisation, cities are now also facing the immediate challenges of managing climate change, air and ground water pollution and especially waste. It is the premise of this paper that all of these daunting challenges confronting can best be mitigated with the help of the circular economy.

The author argues that a smart city’s investment into “smartness” should include up-to-date, circular solutions that can track the flow of products, components, and materials. Circular companies have always been clamouring for this source of data. To give just one example, identifying waste as a potential production material, as seen with the Industrial Symbiosis business model, is crucial for the success of these circular enterprises. Hence, the collection of, and the dissemination of circular data, will undoubtedly not only increase a city’s services to its business industry but further the reputation of the city as a circular hub. In so doing, these cities will attract more businesses, and their tax revenue.

In addition, to assist its corporate citizens to financially succeed, a smart city must invest in the infrastructure that is crucial to help circular companies manage their waste flows and help them retrieve their production resources. This issue of supporting industry financially is a key responsibility for municipalities for only cities with sound financial networks will appeal to circular, future-of-business industries. Moreover, as discussed, as circular business models are often perceived to be of greater risk by banks and investors compared to traditional linear models, municipal leadership might need to consider stepping-in to help shoulder part of the financial risk their companies face.

Also as highlighted, another enabler of a long-term, sustainable integration of the circular into smart cities is education. The current decision makers, corporate and municipal, were all trained understanding that business followed the principles of linear production. The circular model is totally new to the establishment. To illustrate, a circular smart city should follow the latest changes comparable to Europe’s “Right to Repair” legislation which minimises waste by mandating more repairs. Education will help train a new generation of municipal leaders who will see the circular transition as an opportunity to reduce pollution, increase liveability for their citizens, create jobs, earn more municipal tax income and increase the competitiveness of their city.

The fourth and the most important enabler for cities to embrace the circular economy is mindset as an open mindset is a prerequisite for the adoption of the other three elements.

The transition to the circular economy is a transformative, systemic shift that cannot be reached with a little bit of recycling. A fundamental and groundswell shift in understanding circular business models, financial infrastructure investment, the education and training of its citizens and a contemporary mindset shift are all required.

Only then, can cities be truly smart.

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2.1.7. Carbonomics for Climate-Smart Cities

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The structure of APEC Cities COP21, The Paris Agreement and the Art of the Possible vis-à-vis 2100 Warming predictions

Climate change is an urgent and global issue that compels us all to act collectively. Against this backdrop, the Asia-Pacific Economic Cooperation (APEC), an intergovernmental forum designed to promote free trade among Pacific Rim economies, has emerged as a key player in fostering sustainable development, particularly in urban settings. The 2015 Paris Agreement, commonly referred to as COP21, acts as another pillar that sets international standards for climate action[246].

Within the framework of APEC, which includes 21 member economies, cities often act as the focal points where economic agendas and environmental goals converge. The unique composition of APEC cities allows them to become hubs of innovation and change. These cities have been adopting sustainable guidelines aimed at significantly reducing greenhouse gas (GHG) emissions (Andreichyk & Tsvetkov, 2023)[247]. This involves a broad range of strategies, from prioritizing green technologies and sustainable public transport to effective waste management (Bach & Kim, 2019)[248]. The criteria that cities must meet to participate in APEC's framework are comprehensive. They often include factors such as the population size, economic contributions, and a city's demonstrated commitment to sustainability. Interestingly, cities like Hong Kong, China; Singapore; and Seoul have managed to find a harmonious coexistence between economic growth and environmental sustainability (Rui & Othengrafen, 2023; Qian, 2023; Chulet et al., 2023)[249][250][251].

When considering global initiatives like COP21, the Paris Agreement aims to limit global warming to well below 2°C compared to pre-industrial levels, urging economies to make additional efforts to restrict the temperature increase to 1.5°C (Schleussner et al., 2016)[252]. Achieving this ambitious 1.5°C target would require us to stick to a 570 gigaton (Gt) CO2 cumulative carbon budget from 2018 to 2050 (Henderson et al., 2020)[253]. Thus, the goals laid down by COP21 are not just visionary but also provide actionable milestones that cities can use to shape their environmental policies.

The necessity for action becomes even more urgent when one considers the current climate models, which paint a varied yet unsettling picture of what the Earth might look like in the year 2100. Depending on the level of action or inaction, the scenarios range from moderate warming to severe consequences, including increased sea-levels and frequent extreme weather events (Varotsos et al., 2023)[254]. These changes are likely to affect densely populated areas, especially those near the coast, more severely than other regions (Tracker et al., 2021)[255]. APEC cities, a majority of which are coastal hubs, stand at the forefront of these climate challenges. Hence, they must prepare for both worst-case and best-case scenarios, focusing on infrastructure that can withstand sea-level rise, heatwaves, and storms. Additionally, local zoning laws and land use policies must be aligned with sustainability principles to ensure long-term resilience.

To effectively address these challenges, APEC cities need to take the Paris Agreement as a foundational blueprint but also consider local specificities and long-term environmental projections. For instance, Hong Kong, China has been proactively investing in seawalls and flood barriers in anticipation of current and future sea-level rise. On the other hand, cities like Singapore are investing in green urban spaces that serve as carbon sinks, contributing not just to local well-being but also to the broader objectives of National Determined Contributions under the Paris Agreement (Chulet et al., 2023; Hong & Guo, 2023)[256][257].

Tackling the challenges posed by climate change requires a nuanced approach that balances ambition with realism. The Paris Agreement sets the course, but the journey itself will be complex, requiring strategic planning and action, especially in APEC cities that face the dual challenge of economic development and environmental sustainability. Both undue optimism and excessive caution could be detrimental, emphasizing the need for a well-balanced, data-driven strategy that takes into account the long-term projections up to 2100.

Fortune 500 Climate Targets, ESG and Sustainability

Faced with the escalating challenges of climate change, the role of Fortune 500 companies becomes increasingly pivotal. As pillars of global economic activity, these corporations have considerable sway over resource distribution, public perception, and the broader environmental landscape (Persakis et al., 2023; Ciocirlan & Pettersson, 2012)[258][259]. This level of influence carries with it an obligation to engage in sustainable practices, notably those outlined by Environmental, Social, and Governance (ESG) standards.

The notion of ESG has evolved from a corporate social responsibility tick-box to a substantive framework that has an undeniable impact on a company’s market value and its long-term viability. Within this context, many Fortune 500 companies are redefining their business objectives to align with climate goals (Thaker, 2019)[260]. This is not just altruistic; there is an increasing recognition that climate change poses substantial risks to business continuity and profitability.

Taking a cue from international agreements like COP21, Fortune 500 companies have started integrating actionable climate targets into their business models. The framework for international cooperation laid out by COP21 serves as a blueprint for how corporations can adopt similar cooperative strategies, thereby aligning their business operations with the global fight against climate change. Yet, the urgency and long-term nature of climate change necessitate commitments that extend well beyond immediate business cycles or even the scope of current ESG metrics. It is imperative that Fortune 500 companies look beyond the usual five- or ten-year planning horizons to make meaningful multi-decadal commitments. The process of aligning corporate strategies with long-term climate goals can manifest in various ways across different industries and geographic locations. For instance, tech giants like Apple, Google, and Microsoft are pioneering the shift to renewable energy, while other sectors may focus on creating more sustainable supply chains, reducing waste, or enhancing operational efficiency to reduce carbon footprints (Pakulska & Poniatowska-Jaksch, 2022; Patchell & Hayter, 2021)[261262].

The challenge is not merely setting ambitious goals but ensuring they are realistic, actionable, and continuously monitored. Striking a balance between profitability and sustainability is a complex but essential task. A failure to adapt to this changing landscape could compromise a company's market position and, by extension, its ability to contribute to the global sustainability effort. The path towards meeting long-term climate targets is rife with complexity, yet fraught with urgency. Fortune 500 companies are uniquely positioned to turn the tide, but this will require a carefully calibrated approach. One that aligns immediate business objectives with broader sustainability goals and international frameworks like COP21 and extends this alignment into long-term strategies that take into account the unsettling projections for climate by 2100.

Aggregate Confusion: The Divergence of ESG Ratings

The ascent of ESG considerations in the financial sector has given birth to an array of ESG rating agencies, each with its own methodology and definitions. Institutions like Sustainalytics, Moody's ESG, S&P Global, Refinitiv, and the now-discontinued KLD, have become arbiters of corporate sustainability, wielding influence over critical financial and investment decisions (Finogenova, 2023; Dimson et al., 2020)[263264]. However, despite their growing clout, a close examination reveals a landscape riddled with inconsistencies and divergent practices that create a cloud of uncertainty for investors, policymakers, and corporations alike.

Central to this ambiguity is a vague set of terms and definitions. The questions of "What constitutes sustainability?" or "What is considered a green initiative?" lack definitive answers. Without universally accepted definitions, these rating agencies employ disparate criteria for evaluating sustainability and corporate governance (Escrig-Olmedo et al., 2019; 2010)[265266]. While one agency may place heavier emphasis on carbon emissions, another might prioritize labour practices, and yet another may focus on corporate governance structures. The outcome is a lack of comparability across ratings, making it difficult for investors to gauge the actual ESG performance of a company. This inconsistency creates a conundrum for decision-makers who increasingly rely on ESG ratings for investment and strategic planning. In a setting where nuanced differences in ratings can lead to dramatic shifts in capital allocation, the lack of standardization poses serious challenges. For example, a high rating from one agency could attract a surge of investment, whereas a low rating from another might result in divestment, both affecting the company's financial stability and capacity to engage in sustainable practices.

It's worth noting that this landscape is not simply about generating ratings; it's also about establishing a framework that can guide corporations and investors towards a more sustainable future. As these agencies continue to serve as de facto standard-setters, their incongruent methodologies can result in skewed incentives and misaligned priorities. Companies may find themselves focusing on metrics that cater to a specific rating methodology, thereby neglecting other equally crucial aspects of sustainability.

Although ESG rating agencies have become influential forces in contemporary financial markets, the inconsistency in their methodologies and the vagueness of their definitions contribute to a lack of clarity (Veenstra & Ellemers, 2020)[267]. This inconsistency stands as a significant hurdle to achieving the kind of clear, focused, and unified action that is desperately needed to address the multifaceted challenges posed by climate change and social inequalities.

The Status of Carbon Pricing in 2021

Carbon pricing is known to be a necessary, but not sufficient, element to address the growing emissions. The two main forms of carbon pricing are carbon incentive taxes and emissions trading systems. Among these two, carbon taxes are easier to implement by authorities, whereas the emissions trading systems have been shown to be the least cost option to limit emissions[268].

Unfortunately, carbon pricing is still not being implemented systematically across the world. The map below, published by the World Bank, shows the jurisdictions having implemented carbon pricing in 2021. The large circles represent cooperation initiatives on carbon pricing between subnational jurisdictions. The small circles represent carbon pricing initiatives in cities. In previous years, Australia was marked as having an ETS in operation. However, the Safeguard Mechanism functions like a baseline-and-offsets program, falling outside the scope of the definition of ETS used by the World Bank report. Therefore, the system was removed from the map. Rio de Janeiro and Sao Paolo were marked as considering the implementation of an ETS based on scoping work done in 2011 and 2012 respectively. Given there have been no updates since, the these were removed from the map.

Carbon pricing initiatives are considered “scheduled for implementation” once they have been formally adopted through legislation and have an official, planned start date. Carbon pricing initiatives are considered “under consideration” if the government has announced its intention to work towards the implementation of a carbon pricing initiative and this has been formally confirmed by official government sources. The carbon pricing initiatives have been classified in ETSs and carbon taxes according to how they operate technically. ETS not only refers to cap-and-trade systems, but also baseline-and-credit systems as seen in British Columbia.

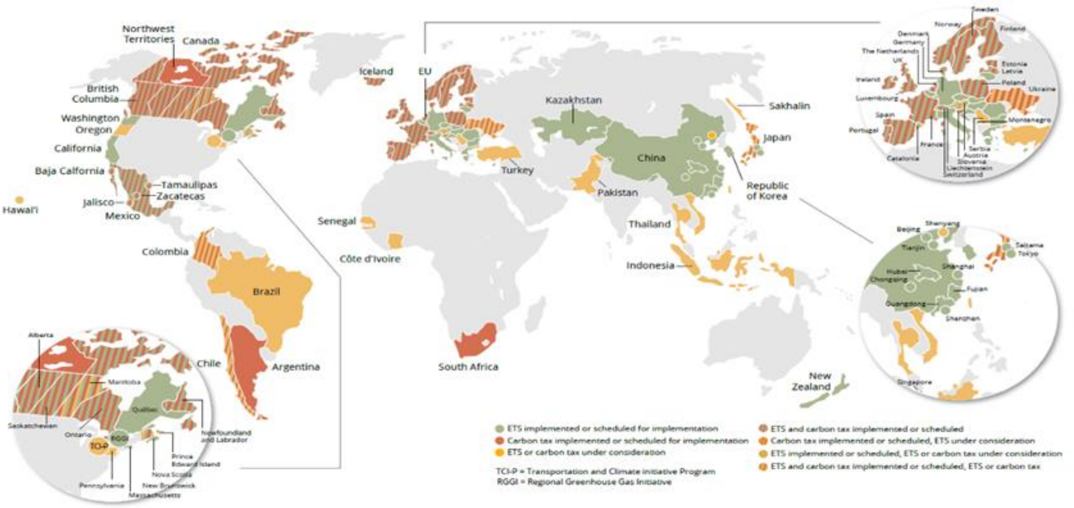

Figure 49: Carbon Pricing Map

Source: World Bank[269]

A systematic use of carbon pricing would not only set the right incentives for agents to change their behaviour but would also produce substantive funds that could be used as green finance, thereby helping to close the financing gap of the low-carbon transition. According to the IEA Net zero by 2050 Roadmap[270], annual global energy investment to reach the 1.5° target should jump to from 1% to 4.5% of global GDP (corresponding to approximately USD5 trillion annually) in the next few years of which most should be directed to clean energy.

Global Compliance Markets to grow to USD5-6 Trillion by 2030

The ascendancy of compliance markets related to environmental governance is an indisputable phenomenon, set to reach a staggering value of USD5-6 trillion by 2030. Understanding the trajectories that have led us to this point and the challenges that lie ahead requires a deep dive into key policy tools and market forces, notably the Global Carbon Market and EU's regulatory mechanisms.

As of 2021, the Global Carbon Market was valued at USD851 billion, a figure dominated by the European Union's Emissions Trading System (EU ETS), which alone accounted for 90% of that value (Refinitiv Carbon Market Year in Review. 2022; Vilkov & Tian, 2023)[271][272]. The EU ETS has become the bellwether of carbon pricing, its emissions allowances (EUA) having surged from under EUR10 per metric tonne of carbon in early 2018 to above EUR90 recently (Ampudia et al., 2022)[273]. This meteoric rise underscores the market's perception of carbon credits as the best-performing asset class of 2021, bolstering the EU's influence in shaping global carbon pricing models. However, the European Parliament's endorsement of the Carbon Border Adjustment Mechanism (CBAM) in March 2021, added another layer of complexity to this already intricate landscape. Scheduled to take effect from 2023, CBAM is a game-changer, designed to level the international playing field for European raw material producers (Bellora & Fontagne, 2023; Lim et al., 2021)[274][275]. It aims to replace free carbon allowances under the EU ETS for those industries, in essence, taxing the carbon content of emission-intensive imports into the EU.

While the CBAM holds potential for creating a more equitable international carbon market, it does not come without its own set of challenges. Industrial companies are lobbying to maintain their free allowances, a situation that sets the stage for claims of "double protection." Such a setup is fraught with the risk of triggering legal challenges under the World Trade Organization rules from Europe's trading partners, thereby adding another layer of uncertainty to this burgeoning market. The twin forces of evolving EU policies and the escalating valuation of the carbon market underscore the complexity of achieving sustainability goals while maintaining economic competitiveness. Achieving this balancing act will be instrumental in the coming years, especially as compliance markets burgeon to multi-trillion-dollar scales.

By 2030, the stakes will be higher than ever. Regulatory and market forces will have to operate in tandem to avoid conflicts that could undermine the integrity of global compliance markets. It will require international cooperation, clear regulatory guidelines, and above all, the will to prioritize long-term sustainability over short-term gains.

Carbon Markets 101

Carbon markets are often categorized into two distinct types: compliance markets, also known as emission trading schemes and voluntary markets (Liu et al., 2015)[276]. Starting with Compliance Markets, they serve as the backbone of regional, economy-wide, and even international climate policies. Governed by "cap-and-trade" regulations (Betsill & Hoffmann, 2011)[277], these markets operate under predefined carbon allowances issued by authorized governmental organizations. The allowances are then traded in secondary markets. The core objective of such a structure is to incentivize businesses to reduce their emissions, given that lower emissions can translate to financial gains through the sale of unused allowances. As of now, the Paris Agreement's Article 6.4 and previous mechanisms under the Kyoto Agreement set the stage for these markets, with the United Nations often acting as the supervisory body (Marcu, 2016)[278].

In contrast, voluntary markets operate largely outside governmental control. In these markets, private entities willingly purchase carbon credits to offset their emissions. The credits are linked to specific climate change mitigation projects, which can range from renewable energy initiatives to afforestation efforts (Michaelowa et al., 2023; Tjon Akon, 2023)[279][280]. While their unregulated nature often draws criticism for a lack of transparency and potential for "greenwashing", they nevertheless offer an alternative pathway for organizations to engage in climate action (Miltenberger et al., 2021)[281].

Another emerging concept is Compliance Offset Markets, which function under international accords but aim to facilitate voluntary participation (Sapkota & White, 2020)[282]. Under schemes like the UNFCCC REDD+ projects, these markets offer another layer of complexity but also potential for unifying global efforts. The financial metrics in these markets are just as varied as their operational frameworks. For example, according to data from carboncredits.com, the highest carbon credit buy in compliance markets can go up to EUR90. In sharp contrast, tech-based offsets in voluntary markets can be acquired for as low as USD0.80. These stark differences in pricing underscore the market's fluctuating nature and the urgent need for a standardized, globally accepted framework. However, the biggest challenge facing these markets is the vast divergence in ESG ratings, valuation methodologies, and even basic definitions of what constitutes a 'green' initiative. Despite these challenges, the upside potential is massive; the green finance sector, of which carbon markets are a part, has shown tremendous growth amid increasing awareness and urgency to combat climate change.

Timeline of EU ETS Carbon Price

EU ETS represents not just a regional effort but a global archetype in driving down carbon emissions through market mechanisms. Initially conceived as an experimental model, the EU ETS has undergone several transformative phases. The early years were characterized by high volatility as market participants and regulators were both finding their footing. Despite these teething issues, this phase was critical for setting the foundational regulations that would shape future iterations.

As the system matured, market stability became more palpable. Companies were no longer operating in a cloud of regulatory ambiguity; instead, they now had a clearer framework for action. The stabilizing market also saw an influx of institutional investors, who began to see the burgeoning potential of carbon credits as an asset class.

It can be seen from Figure below that EU ETS has grown to a staggering market value of approximately USD851 billion in 2021, a 164% jump from the previous year (Varsani & Gupta, 2022)[283]. It is no longer a standalone entity but has influenced the establishment of around 30 similar emission trading systems globally. Moreover, it's worth noting that the EU ETS alone comprises about 90% of the global carbon credit turnover, a testament to its efficacy and influence.

According to Varsani & Gupta (2022)[284], the initial phase, lasting three years, served as a trial period to lay the groundwork for carbon trading and to set up its pricing structure. During this stage, carbon prices were relatively low due to an oversupply in the market, a situation exacerbated by the lack of accurate emissions data. Phase 1 laid the foundation for collecting verified emissions data, which subsequently informed Phase 2. Armed with this data, regulators set emissions caps for various companies and curtailed the supply of carbon allowances. However, the global financial crisis of 2008 led to reduced economic activity, decreasing the demand for these allowances, and causing a drop in carbon prices. The abundance of carbon allowances in Phases 1 and 2 set the stage for Phase 3, which was primarily aimed at managing the excess supply. Various reforms like "backloading," the Market Stability Reserve, and the yearly reduction of the carbon allowance cap contributed to a rise in carbon prices during this phase. The Phase 4 enacted stricter policy initiatives aimed at curbing carbon emissions. For example, the rate of annual reduction for the carbon allowance cap was increased to 2.22%, up from the previous 1.74%. Additionally, this phase emphasized the creation of financial frameworks to support low-carbon innovations, aiding energy-intensive industries in transitioning to a low-carbon economy.

The EU ETS, though successful, operates alongside smaller and less regulated Voluntary Carbon Markets (VCMs). While the EU ETS is a state-enforced mechanism designed to bring about legally mandated emission reductions (Clo, 2011)[285], VCMs allow companies and individuals to voluntarily offset their carbon footprint. The coexistence of these two different types of markets—each with its own set of regulations, impacts, and market sizes—adds layers of complexity to the global carbon trading landscape. The EU ETS has now entered a critical phase that focuses on achieving net-zero emissions targets and serving as a guide for global markets (Backe et al., 2023; Sengur & Altuntas, 2023)[286287].

Figure 50: Timeline of EU ETS Carbon Price from Jan 2013 to Jan 2023

Source: Trading economics[288]

Climate Smart Cities: Consumption-based Inventory

As cities emerge as vital players in the arena of climate change, it becomes imperative to scrutinize not just how they contribute to carbon emissions but also how they consume. It is in this context that Climate Smart Cities must focus on a Consumption-based Inventory (CBI) approach, a methodology that extends beyond traditional boundaries of emissions calculations. Bai et al. (2016)[289] have stressed the necessity of a holistic, systems-based approach for the sustainability of cities. This involves considering both production and consumption as interconnected elements, while also accounting for factors like upstream supply chain impacts leading to cities (Reisch et al., 2016)[290] and the energy embedded in products as explored by Lenzen et al. (2006)[291]. This perspective was further underscored by a groundbreaking report from the C40 Cities network in 2018, which utilized consumption-based emission inventories to gauge the carbon footprint of urban consumers for the first time (Schroder et al., 2019)[292]. According to this report, traditional methods of measuring carbon footprints through production-based sectoral inventories underestimate the per capita carbon footprints of cities by a factor of two to three.

Historically, carbon accounting methods were primarily production oriented. Cities would calculate their emissions based on what was emitted within their geographical boundaries. While useful, such approaches overlook a significant aspect of carbon responsibility: consumption. In modern economies, cities consume products manufactured elsewhere, use services outsourced to other regions, and engage in activities that, although not directly emitting within the city limits, have far-reaching implications for global emissions (Mendes, 2022; Parasher et al., 2019)[293294]. CBI aims to fill this gap by providing a comprehensive account of a city's carbon footprint, taking into consideration the emissions associated with goods and services consumed within the city, regardless of where those emissions occur.

Take the example of Portland, a city recognized for its progressive stance on sustainability. While most cities might focus on emissions produced within their territories, Portland's climate action plan goes a step further (Yao et al., 2023; Harrison & Donnelly, 2011)[295296]. It includes emissions from consumables, offering a more holistic view of the city's carbon footprint. This innovative approach reflects how urban planning can impact not just local but global ecosystems. Implementation of CBI starts with meticulous data collection, accounting for all goods and services consumed within the urban environment. Next, a life-cycle assessment of these items assesses their entire carbon footprint, from production to consumption. The final stage involves attributing these calculated emissions back to various consumer activities (Hakamies et al., 2023; Ipsen et al., 2019)[297298]. This comprehensive view offers a multi-faceted lens through which cities can evaluate their carbon impact, making it an essential tool for any Climate Smart City.

Cities can make data-driven decisions, tailoring policies to address specific areas of high consumption-based emissions by using CBI. Such targeted interventions can range from promoting local produce to reduce food miles, encouraging the use of sustainable construction materials, or revisiting waste management systems (Besklubova et al., 2023)[299]. By focusing on both the supply and demand aspects of carbon emissions, a CBI enables cities to adopt a dual strategy to fight climate change. Climate Smart Cities have the opportunity, and indeed the responsibility, to pioneer new methodologies in carbon accounting. CBI provides a more nuanced, comprehensive understanding of a city's carbon footprint, highlighting areas for targeted action and policy development. It is not just about how much a city emits, but also about how and what it consumes. By addressing both these aspects, cities can take a more rounded approach to becoming truly climate smart.

Consumption-based GHG Emissions Inventory for Oregon

While the concept of consumption based GHG emissions inventory is now gaining traction globally, its application at a state level offers another layer of insight. Oregon serves as a compelling case study in this context, especially considering the growing ambition to not just neutralize but also actively remove carbon emissions (Lazarus et al., 2011)[300]. Such an ambitious goal aligns well with significant initiatives elsewhere, like the USD10 billion program aimed at greening Saudi Arabian cities.

Oregon's approach toward a consumption-based inventory stands out because it looks beyond just curbing emissions produced within the state. It also focuses on emissions resulting from products and services consumed within Oregon, regardless of where those emissions originated. This comprehensive measurement allows for a more realistic portrayal of the state's carbon footprint, as well as highlighting opportunities for targeted interventions to achieve carbon neutrality or even carbon negativity. According to the study conducted by Erickson et al. (2012)[301]. Oregon has shifted from the traditional production-based method of calculating GHG emissions to a consumption-based approach. This new methodology revealed that the state's emissions are 47% higher than previously estimated, underscoring the importance of including emissions from consumed goods and services, regardless of their origin. The study suggests that a consumption-based perspective not only provides a more accurate picture of a state's carbon footprint but also opens new avenues for reducing GHG emissions through targeted local and state policies. It argues that consumption-based frameworks should complement, rather than replace, traditional production-based methods for a more effective climate change strategy. Oregon's consumption-oriented emissions inventory calculates the global GHG emissions resulting from the state's usage of various goods and services such as vehicles, food, energy, appliances, and apparel (Figure below; the consumption-based GHG emissions inventory tracks emissions produced in Oregon and around the world due to the products and services Oregonians consume).

Oregon's focus on a consumption based GHG emissions inventory provides a more accurate, nuanced view of its environmental impact. By looking at carbon emissions from a consumption perspective, the state is better equipped to enact policies that aim not just for carbon neutrality but also for carbon removal, setting a valuable precedent for other regions and even economies to follow.

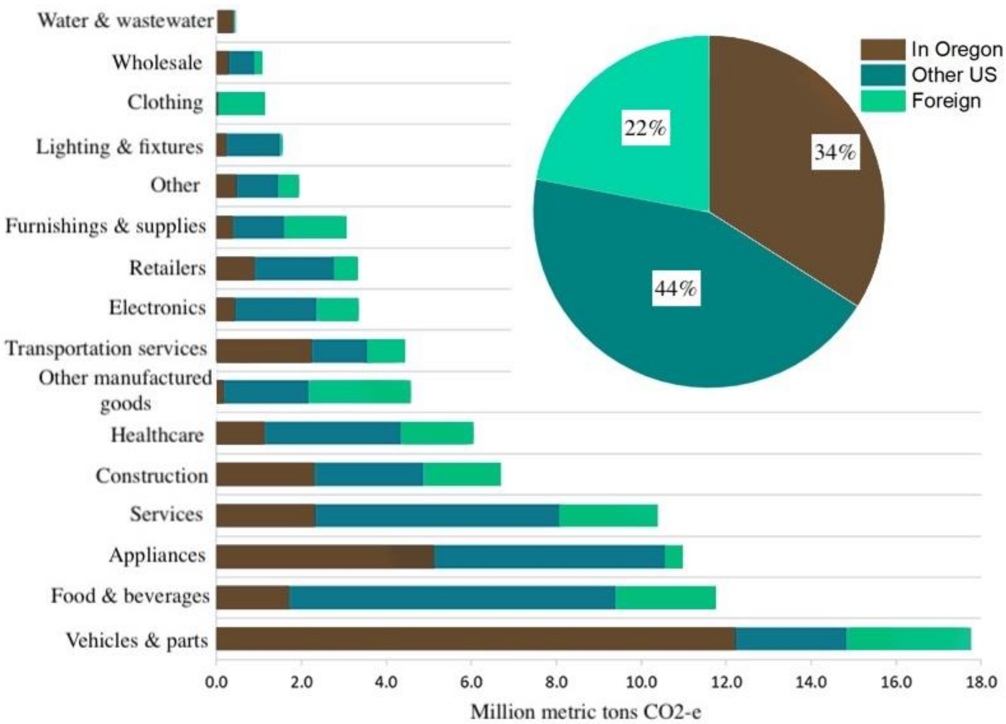

Figure 51: Consumption-based GHG emissions inventory of emissions of Oregon

Source: Oregon[302]

Climate Smart Cities: defining boundaries

In the discourse on Climate Smart Cities, one of the less explored but crucial elements is defining the 'boundaries' for GHG emissions inventories and carbon accounting. These boundaries can range from the city's geographic limits to the larger realm of influence that a city holds through its consumption-based activities. In a bid to drive data-driven climate action, numerous cities have employed sector-based GHG inventories, often aligned with frameworks like the Global Protocol for Community-Scale GHG Emission Inventories. Traditional sector-based approaches primarily account for GHG emissions generated within city limits from energy usage, whether from direct combustion (known as scope 1 emissions) or from grid-sourced electricity, heating, and cooling (scope 2 emissions) as shown in Figure below.

Additionally, these inventories also cover emissions from waste treatment processes. However, this method falls short of capturing the full carbon footprint of a city as it often neglects emissions from consumed goods and services that originate outside city boundaries (scope 3 emissions) (C40, 2018)[303].

A recent study, spearheaded by the C40 Cities Climate Leadership Group in collaboration with the University of Leeds, the University of New South Wales, and Arup (C40, 2018)[304], examined consumption based GHG emissions in 79 cities. The research aims to provide cities with a more holistic view of their total emissions and opportunities for reducing emissions beyond their geographical borders. Astonishingly, the data revealed that 80% of the surveyed cities had greater GHG emissions when viewed through a consumption-based lens compared to a sector-based approach. Additionally, the report highlighted significant variations in consumption-based emissions per capita across different regions.

The follow-up report by C40 Cities, titled "The Future of Urban Consumption in a 1.5°C World", identifies sectors with the most significant potential for emissions reduction in cities. These sectors include food, buildings and infrastructure, clothing and textiles, electronics and electrical appliances, private transport, and aviation. The report provides in-depth insights into potential interventions that cities can undertake to reduce emissions from these sources. Defining the boundaries of GHG emissions in Climate Smart Cities is not merely a question of geography but also of methodology. A broader, more inclusive approach that incorporates scope 3 emissions is essential for a more accurate and actionable climate strategy.

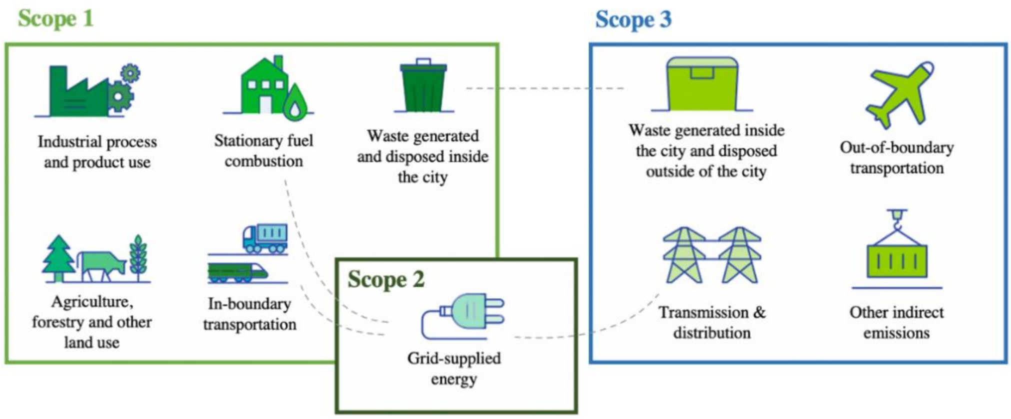

Figure 52: Boundary and scope definition

Source: GCP Global Protocol on Accounting Greenhouse Gases[305]

Carbon Monitor Cities near-real-time daily estimates of GHG emissions from 1500 cities worldwide

The emerging trend of near-real-time carbon monitoring in cities represents a significant step forward in how we understand and manage urban carbon footprints. The ability to gather daily estimates of CO2 emissions is not just a technological achievement; it also provides cities with an invaluable tool for immediate and long-term climate action planning. Over 70% of the world's fossil-fuel CO2 emissions originate in cities, underscoring the need for accurate city-level emissions data to aid global climate change mitigation (Han et al., 2020)[306]. Despite this, a standardized, global dataset for city-level emissions is still absent. Most emissions inventories exist at the economy level, partly because gathering city-specific fossil fuel consumption data is challenging. Moreover, many existing inventories, including those reported to the United Nations Framework Convention on Climate Change (UNFCCC), are outdated, often lagging by a year or more (Kosma & Gallagher, 2023)[307]. This hampers city-level efforts to set meaningful benchmarks and track advancements towards goals like achieving net-zero emissions by 2030 or 2050.

Carbon Monitor Cities refines near-real-time economywide emission data from the Carbon Monitor into a city-level dataset, following a four-stage process (Figure below, Huo et al., 2022)[308]. Initially, Global Gridded Daily CO2 Emission Datasets are formed, covering multiple sectors and offering high-resolution spatial and temporal emission maps. These are then tailored to specific cities using Global Administrative Areas or Functional Urban Areas, depending on regional definitions. Subsequent stages involve adjustments for residential and transport sectors, error correction, and data validation. The finalized dataset, covering 2019-2021, focuses on five major sectors that contribute to over 70% of a city's fossil fuel CO2 emissions, according to Huo et al. (2022)[309].

The study conducted by Ke et al. (2023)[310] introduces "Carbon Monitor Europe," a near-real-time dataset tracking daily fossil fuel and cement emissions in 27 European Union economies and the UK from January 2019 to December 2021. This comprehensive dataset, segmented into six key sectors — power, industry, ground transportation, domestic and international aviation, and residential areas — addresses the glaring limitation of current official inventories, which only provide annual data with significant time lags. Utilizing a daily tracking methodology, the research captures timely data on emissions across six sectors. This granularity is especially significant for adapting to fast-changing events like COVID-19 and geopolitical tensions. The work refines existing Carbon Monitor systems, offering a resource that enhances the effectiveness of climate policies and interventions.

Liu et al. (2020)[311] developed the Carbon Monitor, a near-real-time dataset that offers daily CO2 emission estimates at the economy-wide level since 1 January 2019. The dataset covers a broad range of sectors, utilizing diverse data sources such as hourly electrical power generation data from 31 economies, industry production data from 62 economies/regions, and daily mobility data from 416 cities worldwide. The dataset captures the dynamic fluctuations in CO2 emissions, highlighting daily, weekly, and seasonal variations, as well as the impact of events like the COVID-19 pandemic. The authors show an 8.8% decline in global CO2 emissions for the first half of 2020 compared to the same period in 2019 and discuss its potential implications for scientific research and policymaking.

The complexity of carbon accounting at the city level often resembles that of an industrial value chain, akin to a retailer's logistics network. Cities are unique in that they serve as both consumers and producers of emissions. For instance, some industrial production may occur within the city, making the city partially responsible for these emissions. This overlap between consumption and production within city limits adds a layer of complexity to carbon accounting but also opens up opportunities.

This near-real-time carbon monitoring has broader implications, especially in the realm of project development and financing. Cities, acting as project developers, can tap into carbon credits as a potential financing mechanism. Essentially, by accurately accounting for emissions on a near-real-time basis, cities can better design projects aimed at reducing emissions. These projects can then qualify for carbon credits, which can be sold or traded to finance further climate initiatives. The real-time data provides the robust evidence needed for such projects, making them more attractive to intellectual and academic project developers who are seeking to calculate emissions reductions with a high degree of accuracy.

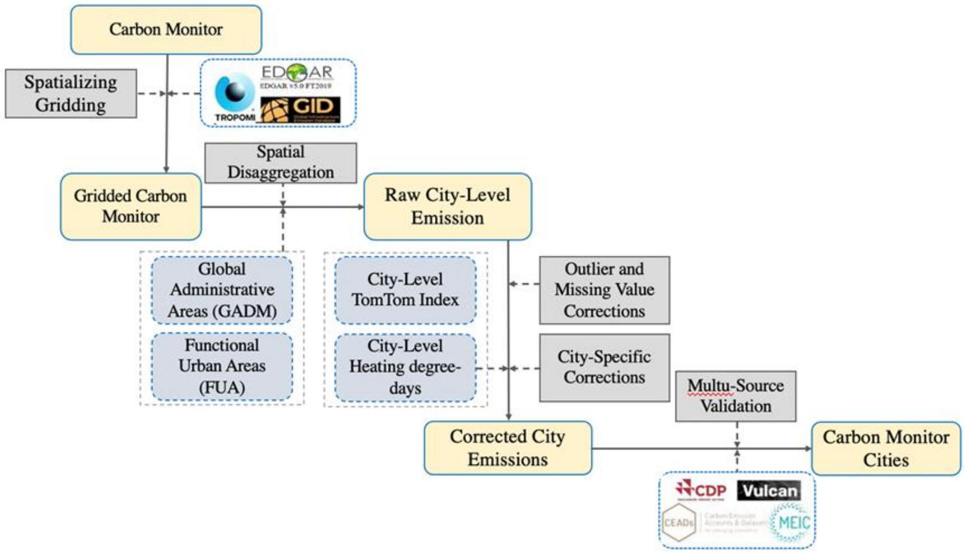

Figure 53: The main workflow of carbon monitor cities

Source: Adopted from Huo et al., 2022[312]

Carbon Rating Agencies

Traditionally, Carbon Rating Agencies have focused on assessing the carbon footprint of individual projects and sectors, there's a growing shift toward city-level, consumption-based GHG emissions assessments. For years, Carbon Rating Agencies have been an essential component of the global effort to transition to a more sustainable future. Focused on sectors such as energy, agriculture, and manufacturing, these agencies have been providing certifications, conducting audits, and assigning carbon ratings primarily to businesses and projects (Semet et al., 2021; Lotay, 2009) [313314] . Their work has informed investors, policymakers, and the public about the carbon impact of various initiatives.

In September 2023, Carbon Market Watch released a study, "Rating the raters," examining the contributions of four major carbon credit rating agencies: BeZero, Calyx Global, Sylvera, and Renoster. The report critically assessed their methodologies and their impact on the Voluntary Carbon Market (Dufrasne, 2023, Mair, 2023)[315316]. Carbon Rating Agencies do not issue carbon credits but evaluate the quality of credits generated by certified projects. They give medium to low scores more often than not, signifying their meticulous evaluation processes. This rigorous scrutiny stands in contrast to the more liberal approvals often seen in standard carbon crediting. Despite the rigorous methodologies, the lack of universally accepted standards for quality assessments makes it difficult for buyers to compare carbon credits adequately. Key findings and recommendations of the rating agencies assessment according to Mair (2023)[317]:

(i) The absence of a globally accepted, comprehensive standard for gauging the quality of carbon credits presents a core challenge to the carbon market, making stakeholders more wary when dealing with these credits.

(ii) The carbon credit rating agencies under review aim to fill the standardization void by differentiating between high-quality and subpar carbon credits. They assert that their evaluations enhance transparency, reduce risks to reputation, and facilitate equitable pricing mechanisms.

(iii) Among the agencies reviewed, Renoster stands out for its unique approach, which minimizes subjective evaluations. The company primarily relies on algorithm-driven assessments and, while it considers leakage, opts not to include it in its final rating calculations.

(iv) There are notable differences in the methodologies employed by different agencies to assess carbon credits. For example, while the majority of agencies apply explicit tests in their evaluations, Renoster's tests are generally more implicit.

(v) Further disparities were identified in how agencies calculate the total score of a project based on its 'additionality' metrics. Other divergences involve the examination of issues such as double issuance, double counting, co-benefits, safeguards, leakage management, buffer robustness, long-term stability markers, and the transparency of ratings.

Voluntary Carbon Credits Marketplace Expanding Fast

The carbon credits market is emerging as a promising frontier for both environmental impact and investment. As a noteworthy recent development, Hong Kong, China has joined the global landscape of this market, contributing to a wave of large-scale investments that range between USD500 million to USD1 billion worldwide. These investments, like Blackstone's USD400 million stake in Xpansiv or Deutsche Börse AG's substantial support for Singapore's AirCarbon Exchange (ACX), underscore the strategic interest in fostering a market that is not just robust but also credible.

When discussing carbon credits, it's crucial to differentiate between compliance and voluntary credits. Compliance credits are a legal requirement for companies operating within certain regulatory frameworks, while voluntary credits offer companies a way to go beyond legal obligations, usually for ethical reasons, public relations gains, or longer-term strategic alignments with sustainability goals (Kreibich & Hermwille, 2021; Streck, 2021)[318][319]. Although different in their motivations, both types of credits play complementary roles in a market whose aim is to reduce GHG emissions.

The study of Kreibich & Hermwille (2021)[320] examines the contrasting dynamics of demand and supply in the voluntary carbon market, particularly in the context of the Paris Agreement. It notes that while many companies have committed to achieving net-zero emissions — potentially boosting the demand for carbon credits — the supply side struggles with aligning its business models to the new legal frameworks. Specifically, if companies use carbon credits to offset emissions, these credits should be aligned with the host economies' Nationally Determined Contributions to maintain environmental integrity. However, operationalizing this is a complex challenge requiring political backing. Kreibich & Hermwille (2021)[321] underscored a glaring discrepancy between the growing demand for carbon credits and the certification schemes' ability to supply these legitimately. It warns that the voluntary carbon market faces a critical juncture. On one side are entities advocating for the continued use of non-compliance credits, which could jeopardize the market's credibility. On the other side are organizations looking to establish NDC support units that would be traded alongside traditional carbon credits.

The question of treating carbon as a commodity is another intricate issue that the market faces. If carbon credits are to be commoditized, stakeholders must agree that the credits, irrespective of where and how they are produced, offer a standardized amount of carbon reduction (Barchiesi, 2007)[322]. This idea is complicated by the fact that the actual impact of a carbon credit can vary based on numerous factors, including the project it funds and the methodology used to measure emissions reductions. For the carbon market to mature and stabilize, this is a challenge that needs addressing, lest the market faces risks of oversupply and price volatility.

The carbon market is rapidly gaining traction as a key player in global efforts to combat climate change, attracting substantial investment from industry heavyweights. Hong Kong, China recently entered the arena with the launch of Core Climate, an international marketplace designed for trading voluntary carbon credits and instruments, on 28 October 2022. This follows a series of significant financial commitments aimed at constructing a seamless global trading infrastructure for high-quality carbon credits. For instance, Blackstone invested USD400 million in Xpansiv, a U.S.-based company, on 6 July 2022. Adm Neumann also raised USD70 million for the sale of tokenized carbon credits on the blockchain. In Singapore, AirCarbon Exchange secured an undisclosed but substantial investment from Deutsche Borse AG, while Climate Impact X has amassed a paid-up capital of USD42.4 million as of August 2022, with backing from notable investors like Temasek, SGX, DBS, and Standard Chartered. Ripple confirmed its role as one of the founding partners of Thallo, a web three carbon credit marketplace based on the XRP Ledger, on 4 October 2022. Moreover, the London Stock Exchange is in the process of launching a Voluntary Carbon Market to channel large-scale financing into climate mitigation projects. These developments indicate a burgeoning market that's poised for growth, with investments that range somewhere between USD500 million to an undisclosed multi-billion-dollar figure, aimed at fortifying the carbon trading infrastructure globally (Figure below).

Looking ahead, the trajectory of the carbon credits market is promising but uncertain. The voluntary carbon market, especially, has shown signs of rapid growth, as evidenced by its valuation surpassing USD1 billion in 2021. The expansion suggests that the marketplace is increasingly being seen as an actionable strategy for combating climate change, not just by corporations but also by individuals.

In sum, the rapidly expanding voluntary carbon credits marketplaces are a testament to the growing recognition of the critical role that market-based mechanisms can play in global sustainability efforts. The market, while promising, is complex and evolving, shaped by a multitude of factors ranging from large-scale investments to regulatory frameworks and the actions of individual investors. As such, understanding this landscape in its entirety is key for anyone looking to navigate it successfully.

Figure 54: Xpansiv CBL Voluntary Carbon Market Metrics

Source: Adopted from Xpansiv[323]

The Evolving New Voluntary Carbon Market

The evolution of the voluntary carbon market (VCM) over the past two decades serves as a testimony to the potential for market-based solutions to address the global climate crisis. From its experimental roots to the latest innovations in financial derivatives, the VCM is a dynamic ecosystem, promoting participation from governments, the private sector, and individuals (Spilke & Nugent, 2022)[324]. The conceptual framework for the VCM finds its roots in the 1997 Kyoto Protocol. This international agreement led to the creation of formal mechanisms like the Clean Development Mechanism, International Emissions Trading, and Joint Implementation to manage carbon emissions. Over time, nearly 8,000 projects under the Clean Development Mechanism have been established in more than 100 economies, leading to the creation of 1.9 billion certified emissions reductions (Michaelowa et al., 2019)[325]. The market, originally centralized around the Clean Development Mechanism and the European Union Emissions Trading System, has since been decentralized. Instead of a single governing entity, the VCM is managed by an ecosystem of self-regulating, standard-setting organizations and certifiers. This transition has allowed greater adaptability and freedom for participating entities to offset their emissions.

As the Clean Development Mechanism solidified its role as a primary compliance market during the mid-to-late 2000s, a growing roster of corporations and governmental bodies started to engage in alternative, voluntary schemes. In a noteworthy initiative in 2003, the World Wildlife Fund (WWF) collaborated with various international non-profit entities to create a voluntary carbon offset framework and database known as the Gold Standard. This was designed to enhance the effectiveness of carbon offset projects and generate value for those developing these projects (Gold Standard, n.d.)[326]. A coalition of industry representatives and environmental pioneers established the Verified Carbon Standard, also known as Verra. As of now, Verra operates the most bustling registry in the voluntary carbon market, having issued nearly a billion credits (Party et al., 2023)[327]. These emerging standards aimed to instil a level of integrity and quality within carbon markets, while also maintaining registries that were both secure and user-friendly. Both the emerging voluntary carbon market and the established Clean Development Mechanism were paving the way for a market system characterized by greater functionality and transparency.

The VCM involves a mix of organizations like carbon offset programs, project developers, and buyers, which range from corporations to cities and universities. These players are connected through brokers and financial firms that handle carbon credit transactions. Registries like Verified Carbon Standard and Gold Standard set the guidelines for project monitoring and carbon credit issuance. Once projects meet these standards, they receive credits indicating the amount of CO2 reduced, which buyers can then 'retire' to offset their own emissions (Spilke & Nugent, 2022)[328].

Retail providers aid in connecting developers and buyers, offering market insights and sometimes holding credit inventories. These providers often help finance early-stage projects by committing to minimum purchases. However, the market has faced transparency issues. Bilateral sales agreements and varying project types create an opaque setting with high transaction costs. This has led to criticism over low credit prices for certain projects and even questions over the actual environmental impact of some credits. Exchanges like CBL Xpansiv are now becoming more active, aiming to standardize terms and improve market transparency. These platforms facilitate price discovery and add liquidity, transforming the VCM from an opaque to a more transparent market.

Lately, various initiatives have sprouted from both governmental and corporate realms, aiming to bolster the reliability and efficiency of voluntary carbon markets. These include the development of trading frameworks to novel certification methods for projects (Dawes et al., 2023)[329]. Although voluntary and compliance markets are separate, they are increasingly intersecting. Numerous initiatives have fashioned a blended model where governmental authorities take a more proactive role in shaping and overseeing the voluntary trading of carbon credits among companies. The five voluntary initiatives outlined below capture some of the sector's current diversity.

(i) In February 2022, the London Stock Exchange (LSE) introduced a new market designation aimed at enhancing the quality and transparency of voluntary carbon markets. Funds or companies looking to invest in carbon-reducing projects must meet specific reporting criteria, including alignment with UN Sustainable Development Goals, to earn this designation. Investors can then buy shares in these designated entities and receive carbon credits. The LSE identifies three core advantages: 1) boosting funding for carbon-reducing projects, 2) enhancing market transparency and regulation, and 3) facilitating the purchase of carbon credits for companies and investors. The initiative aims to transition trading from an opaque over-the-counter model to a more transparent marketplace.

(ii) In November 2022, the European Commission proposed an EU Carbon Removal Certification Framework to standardize and verify carbon removal projects. This would encompass initiatives like forest restoration, carbon capture, and direct air capture. If approved, a third-party would evaluate projects against EU-developed methodologies, with certified results listed in a public registry to avoid double-counting. The certification could serve multiple purposes beyond voluntary carbon markets. It could help projects gain public or private funding, label eco-friendly building materials, and expand financing options for carbon removal technologies. Unlike most voluntary systems where private entities set standards, this EU initiative would place the government in a regulatory role, aiming to boost underdeveloped technologies like direct air capture.

(iii) Unveiled at COP27, the Energy Transition Accelerator is a collaboration among the U.S. Department of State, Bezos Earth Fund, and the Rockefeller Foundation. Focused on developing economies, it aims to facilitate climate finance and green development. Companies aiming for net-zero can purchase carbon credits from projects that either retire coal plants or boost renewables in select developing economies. Stakeholders like Chile, Nigeria, PepsiCo, Microsoft, and Bank of America have shown interest.

(iv) Launched in 2014, Australia's Emissions Reduction Fund (ERF) encourages businesses and communities to reduce GHG emissions or sequester carbon. Administered by the Clean Energy Regulator (CER), the ERF issues Australian Carbon Credit Units (ACCUs) to qualifying projects. While the majority of ACCUs are bought by the government, demand from voluntary buyers is growing. The ERF also has a Safeguard Mechanism, requiring large emitters to stay within a regulated emissions cap, or purchase ACCUs to offset excess emissions. The cap will gradually lower, aligning with Australia's 2050 net-zero target.

(v) Launched in 2022 by Japan's Ministry of Economy, Trade, and Industry (METI), the GX League aims to contribute to Japan's 2050 carbon neutrality goal. Unlike compulsory emissions trading systems, the GX League allows voluntary corporate participation but mandates compliance with self-set emissions targets. METI will publish these targets in a database to boost financial sector transparency. Companies exceeding their goals can sell extra reductions on the GX League's carbon exchange, while those failing must purchase carbon credits to cover the deficit. Hosted by the Japan Exchange Group, the carbon market will feature a variety of credit types, including J-Credits and Joint Crediting Mechanism credits. Price floors and ceilings for carbon will be annually set by METI, with plans to raise these limits over time. With over 600 companies participating, accounting for about 40% of the emissions, the GX League shows promising initial engagement compared to other schemes like the EU ETS. While voluntary, the GX League mimics a compliance system in its stringent focus on transparency and may face challenges in standardizing a diverse credit supply within its set price range.

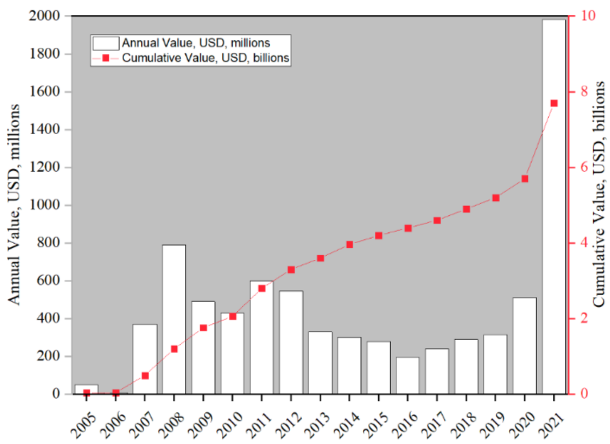

Figure 55: Global Voluntary Carbon Markets size by Value of traded credits

Source: Adopted from Dawes et al., 2023[330]

Challenges of Carbon Neutrality for APEC Cities and Potential Pathways to Action

Achieving carbon neutrality poses significant technical and financial challenges for cities within the APEC region. First and foremost, the diversity in economic development and infrastructure across APEC cities complicates the standardization of carbon reduction strategies. Developing economies may face financial constraints in implementing sustainable technologies and transitioning to renewable energy sources, while more advanced economies might encounter resistance to restructuring established, carbon-intensive industries. Coordinating efforts among cities with distinct urban planning and transportation systems adds another layer of complexity. Moreover, the scale and rapid urbanization in many APEC cities exacerbate issues related to energy consumption, transportation emissions, and waste management. Addressing these challenges requires a collaborative approach, innovative policies, and substantial investments in research, technology, and infrastructure. Balancing economic growth with environmental sustainability remains a delicate task, demanding commitment from APEC cities to navigate these hurdles and transition toward a carbon-neutral future.

A variety of financing mechanisms are available to support climate mitigation, energy transition and the pathway to sustainable APEC cities.

Concessional loans are designed to provide affordable financing to support economic development in low- and middle-income economies. Vulnerability criteria in allocation mechanisms for concessional funding are typically used to identify and prioritize economies and communities that are most vulnerable to the impacts of climate change and in need of financial assistance. The specific criteria used can vary depending on the funding mechanism and the goals of the funding program, but some common vulnerability criteria include:

I. Exposure to climate risks: Vulnerability criteria may consider an economy's exposure to climate risks, such as sea-level rise, drought, or extreme weather events. Economies that are highly ex-posed to these risks are more likely to experience adverse impacts and may require assistance to build resilience and adapt.

II. Sensitivity to climate risks: Vulnerability criteria may also consider an economy's sensitivity to climate risks, such as the extent to which its economy or population is dependent on climate-sensitive sectors, such as agriculture or tourism. Economies that are highly sensitive to climate risks may require assistance to diversify their economies and build resilience to these risks.

III. Adaptive capacity: Vulnerability criteria may also consider an economy's adaptive capacity, or its ability to respond to and recover from the impacts of climate change. Economies with low adaptive capacity may require assistance to build the necessary infrastructure, institutions, and capacity to adapt to changing climatic conditions.

IV. Social vulnerability: Vulnerability criteria may also consider an economy's social vulnerability, such as the extent to which marginalized communities, such as indigenous peoples or women, are disproportionately affected by climate change. Economies with high levels of social vulnerability may require assistance to address the social and economic inequalities that exacerbate the impacts of climate change.

V. Economic vulnerability: Vulnerability criteria may also consider an economy's economic vulnerability, such as the extent to which it relies on external sources of income or has limited fiscal capacity to respond to climate change. Economies with high levels of economic vulnerability may require assistance to diversify their economies and build resilience to changing climatic conditions.

Concessional loans can provide climate finance by offering affordable financing to support climate mitigation and adaptation projects in low- and middle-income economies. Here are some ways that concessional loans can provide climate finance:

- Financing climate-focused projects: Concessional loans can be used to finance climate-focused projects, such as renewable energy generation, energy efficiency improvements, and climate-resilient infrastructure. These projects can help to reduce greenhouse gas emissions and build resilience to the impacts of climate change.
- Supporting climate policy reforms: Concessional loans can be used to support climate policy reforms, such as the implementation of carbon pricing mechanisms, the development of climate action plans, and the promotion of sustainable land use practices. These policy reforms can help to create an enabling environment for climate mitigation and adaptation efforts.
- Leveraging private sector investment: Concessional loans can be used to leverage private sector investment in climate-focused projects. By providing seed funding or other forms of financial support, concessional loans can help to reduce the risks associated with these investments and make them more attractive to private investors.
- Providing technical assistance: Concessional loans can be used to provide technical assistance to support the development and implementation of climate-focused projects. This can include support for project design, feasibility studies, and capacity building activities.
- Supporting climate risk management: Concessional loans can be used to support climate risk management efforts, such as the development of climate risk insurance schemes or the establishment of early warning systems for climate-related hazards. These efforts can help to reduce the financial risks associated with climate change and build resilience to its impacts.

Concessional loans can be designed as Debt for Nature Swaps. Debt for Nature Swaps are agreements between debtor economies and creditors in which the debtor economy agrees to protect its natural resources in exchange for debt relief or concessional financing. These swaps involve the conversion of a portion of the economy's debt into a local currency fund, which is then used to support conservation and sustain-able development projects.

Concessional loans can be used as part of a Debt for Nature Swap by providing the financing needed to support conservation and sustainable development projects. In exchange for the concessional loan, the debtor economy would agree to implement specific conservation or sustainable development measures. These measures could include the protection of natural habitats, the promotion of sustainable land use practices, or the implementation of climate mitigation or adaptation measures.

The use of concessional loans in Debt for Nature Swaps can be an effective way to address both environmental and economic challenges. By providing financing for conservation and sustainable development projects, Debt for Nature Swaps can help to protect natural resources and promote economic development in debtor economies. At the same time, the use of concessional loans can help to reduce the debt burden on these economies and provide them with access to affordable financing for other development priorities.

Effective global safety nets can play an important role in mitigating the impact of climate catastrophes and other unpredictable events. Here are some ways to develop and implement such safety nets:

I Establish a global risk-sharing mechanism: A global risk-sharing mechanism could be established to help economies manage the financial risks associated with climate catastrophes and other unpredictable events. This mechanism could involve pooling resources from multiple economies and providing financial assistance to economies that have been affected by a cata-strophic event.

II Develop and implement early warning systems: Early warning systems can help economies pre-pare for and respond to climate catastrophes and other unpredictable events. These systems could include weather monitoring, early warning alerts, and other systems designed to provide timely information to decision-makers.

III Build resilience in vulnerable communities: Investing in community resilience can help mitigate the impact of climate catastrophes and other unpredictable events. This could involve in-vesting in infrastructure, such as sea walls and other protective measures, as well as supporting community-based adaptation efforts.

IV Establish contingency funds: Contingency funds can provide immediate financial assistance to economies that have been affected by a climate catastrophe or other unpredictable event. These funds could be established at the regional or global level and could be used to provide emergency relief and support recovery efforts.

V Encourage private sector involvement: The private sector can play an important role in developing and implementing global safety nets. This could involve providing financial support, expertise, and other resources to help economies prepare for and respond to climate catastrophes and other unpredictable events.

VI Ensure equity and fairness: Global safety nets should be developed in a way that ensures equity and fairness for all economies, particularly those that are most vulnerable to the impacts of cli-mate change. This could involve providing additional support to vulnerable economies and ensuring that resources are distributed in a way that is fair and transparent.

Deploying insurance mechanisms with a fair and efficient economic model requires a coordinated and collaborative effort from multiple stakeholders, including insurers, governments, international organizations, and civil society.

- Develop risk-based pricing: Insurance mechanisms should be priced based on the level of risk that they are designed to cover. This means that higher-risk activities or regions should pay higher premiums, while lower-risk activities or regions should pay lower premiums. This approach ensures that the cost of insurance is fairly distributed based on the level of risk.
- Promote transparency: Insurance mechanisms should be transparent in terms of their pricing, terms, and conditions. This means that customers should have a clear understanding of what they are paying for and what risks are covered.

- Encourage private sector involvement: The private sector can play an important role in deploying insurance mechanisms, as they can provide expertise, capital, and other resources. Governments can encourage private sector involvement by providing incentives, such as tax breaks or subsidies, to insurance companies that offer coverage for climate-related risks.
- Establish contingency funds: Contingency funds can provide additional support to insurance mechanisms by providing a source of funding for claims that exceed the capacity of the insurance mechanism. These funds can be established at the regional or global level and can be used to provide emergency relief and support recovery efforts.
- Support capacity building: Deploying insurance mechanisms requires building capacity in vulnerable communities to help them understand the risks they face and how to mitigate them. This could include providing technical assistance, supporting education and training programs, and building institutional capacity.
- The widespread adoption of Climate Resilient Debt Clauses, including zero-cost clauses, and other automatic liquidity provision mechanisms could make the financial system and vulnerable economies more able to absorb shocks from climate-related events.
- Climate Resilient Debt Clauses are contractual provisions that can be included in debt agreements to provide relief to borrowers in the event of climate-related shocks. These clauses can include a range of measures, such as debt moratoriums, interest rate reductions, and debt forgiveness. By providing automatic relief to borrowers, these clauses can help reduce the financial impact of climate-related events and help ensure debt sustainability.
- Zero-cost clauses, in particular, are a promising approach to promoting the adoption of Climate Resilient Debt Clauses. Zero-cost clauses are designed to provide relief to borrowers without imposing any additional costs on creditors. This makes them an attractive option for both borrowers and creditors and can help promote the widespread adoption of Climate Resilient Debt Clauses.
- In addition to Climate Resilient Debt Clauses, other automatic liquidity provision mechanisms can also help vulnerable economies absorb shocks from climate-related events. For example, catastrophe bonds, which are debt securities that are designed to pay out in the event of a catastrophic event, can provide a source of immediate liquidity to economies that have been affected by a climate-related event. Other mechanisms, such as insurance products and contingency funds, can also provide automatic liquidity provision to help economies respond to climate-related events.

The adoption of Climate Resilient Debt Clauses, zero-cost clauses, and other automatic liquidity provision mechanisms can help promote financial stability and sustainability in vulnerable economies and reduce the impact of climate-related shocks on the financial system. By working together to promote these mechanisms, governments, international organizations, and the private sector can help build resilience in vulnerable communities and support the global effort to mitigate the impacts of climate change.

Voluntary and cross-border carbon markets can be leveraged and expanded to reduce emissions and generate additional financing to mitigate the impacts of climate change on a fair basis by implementing the following measures:

- Standardization and transparency: Standardization and transparency of carbon accounting methodologies and reporting can help to build trust in the carbon markets and facilitate cross-border transactions. Establishing clear and consistent standards for carbon accounting and re-porting can help to ensure that the carbon credits generated through these markets are credible and verifiable.
- Incentivizing participation: Incentivizing participation in voluntary and cross-border carbon markets can help to expand their reach and impact. This can be done by offering financial incentives, such as tax credits or subsidies, to companies and organizations that participate in these markets. Governments can also require companies to purchase carbon credits as part of their climate mitigation strategies.
- Addressing additionality: Ensuring that the carbon credits generated through these markets represent real emissions reductions is critical to their credibility. Carbon projects should be de-signed to achieve emissions reductions that would not have occurred in the absence of the carbon market. This is known as "additionality." Establishing clear additionality criteria and independently verifying emissions reductions can help to ensure that the carbon credits generated through these markets represent real emissions reductions.
- Ensuring fairness and equity: Ensuring that the benefits of carbon markets are distributed fairly and equitably is important to their long-term sustainability. This can be done by ensuring that the benefits of carbon credits flow to the communities that are most affected by climate change and by promoting the participation of developing economies in these markets.
- Leveraging private sector investment: Expanding the carbon markets will require significant private sector investment. Governments can leverage private sector investment by establishing policies and regulatory frameworks that create a favourable investment climate for carbon projects.

Cross-border revenue streams are financial flows that cross borders and can be used to accelerate decarbonization efforts. Some examples of cross-border revenue streams that can help accelerate decarbonization include:

- Carbon pricing and trading systems: These are mechanisms that put a price on greenhouse gas emissions and allow companies to trade emissions credits. Revenue generated from the sale of credits can be used to fund decarbonization efforts.
- Green bonds: These are fixed-income securities issued by governments, supranational organizations, or corporations to fund environmentally friendly projects, including renewable energy and energy efficiency initiatives.
- Climate finance: This refers to the financing of projects and programs that help reduce green-house gas emissions and adapt to the impacts of climate change. It includes public and private funding from developed economies to developing economies, as well as private investments in renewable energy and other low-carbon technologies.

- Renewable energy exports: Economies with abundant renewable energy resources, such as wind and solar, can export excess energy to neighbouring economies, generating revenue and helping to reduce greenhouse gas emissions.
- Carbon capture and storage (CCS) projects: These projects involve capturing carbon dioxide emissions from industrial processes and storing them underground. Revenue can be generated from the sale of carbon credits and from the use of captured carbon for enhanced oil recovery.
- Increase energy efficiency: Improving energy efficiency can help reduce carbon emissions by reducing the amount of energy required to produce goods and services. This can be achieved through the use of energy-efficient technologies, such as more efficient engines, improved insulation, and better lighting.
- Fuel switching: One of the most effective ways to reduce carbon emissions is to transition to low-carbon fuels such as renewable energy sources like solar, wind, and biofuels. In the ship-ping industry, fuel switching can involve the use of cleaner-burning fuels such as liquefied natural gas (LNG) or biofuels instead of heavy fuel oil. In the fossil fuel sector, fuel switching can involve switching from coal to natural gas, which emits less carbon dioxide. In shipping, this could include the use of electric or hybrid electric propulsion systems, or the use of low-carbon fuels like hydrogen or ammonia.

Funding support may include (but not limited to):

- Suffered loss and damage as a result of climate change. This could include financial support for rebuilding homes, businesses, and critical infrastructure.
- Supporting climate-resilient agriculture: The fund should support activities that help farmers adapt to changing weather patterns and develop more climate-resilient crops and agricultural practices.
- Supporting ecosystem-based approaches: The fund should support activities that protect and restore ecosystems, such as mangroves, coral reefs, and wetlands, that provide critical services such as coastal protection and water regulation.
- Providing technical assistance: The fund should provide technical assistance to vulnerable economies to help them develop and implement adaptation and mitigation strategies. This could include support for capacity building, technology transfer, and knowledge sharing.

Conclusions

APEC cities seeking to leverage climate finance and emerging voluntary carbon markets can adopt a strategic path to action. Initiating with a comprehensive carbon emissions assessment, cities should establish ambitious reduction targets in alignment with global climate objectives. Concurrently, the development or enhancement of supportive regulatory frameworks is crucial for attracting investments and ensuring a conducive environment for businesses engaging in carbon reduction initiatives. Stakeholder engagement, including collaboration with businesses, community groups, and NGOs, is essential for diverse perspectives and shared responsibility. Identifying and prioritizing carbon offset projects, such as renewable energy installations and sustainable urban development, ensures a diversified and impactful approach. Embracing innovative technologies enhances energy efficiency and supports transparent reporting mechanisms. Building local capacity through training and resources for various stakeholders facilitates effective participation in voluntary carbon markets. Collaboration with financial institutions and international partnerships further supports financing options and knowledge exchange. Ensuring local policies align with international standards and promoting innovation in sustainability contribute to a holistic and competitive strategy. This strategic approach positions APEC cities to contribute significantly to global carbon reduction efforts while fostering local sustainable development.

The concept of carbonomics is dynamic and evolves with advancements in technology, changes in policy, and a growing understanding of sustainable practices. Climate-smart cities aim to balance economic development with environmental responsibility, creating a model for urban living that minimizes negative impacts on the climate.

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Nomenclature

APEC	Asia-Pacific Economic Cooperation
GHG	Greenhouse gas
ESG	Environmental, Social, and Governance
CBAM	Carbon Border Adjustment Mechanism
EU ETS	European Union's Emissions Trading System
CBI	Consumption-based Inventory
VCM	Voluntary carbon market

2.2. Accounting as Systematic Collection of Sustainability Indicators

2.2.1. Leveraging Carbon Neutrality Incentives Through Sustainability Accounting

Authored by Leanne Keddie, Carleton University

This write-up is based on a presentation given recently to APEC delegates of the recent Workshop on Sustainable Cities titled 'Leveraging incentives through sustainability accounting to move towards carbon neutrality'; the workshop was held on 14 March 2023. What follows are thoughts on an expanded discussion of the presentation that can be found on the APEC website.

A discussion in the area of sustainability accounting must begin with defining what sustainability is. While there is no singular definition that is universally accepted, one widely accepted working definition comes from the United Nations' Brundtland Report (1987) which states that "sustainable development that *meets our needs today without compromising the needs of those in the future*" (emphasis added). This makes sustainability an inherently planetary concept and one that is multi-generational in its thinking. These are two critical components in approaching the topic of sustainability and will frame the discussion here.

Moving from a broad definition of sustainability, one must now discuss what sustainability accounting purports to be. Again, definitions here may be contentious. If sustainability is a planetary and multi-generational concept, then sustainability accounting at the firm or city level is about measuring, analysing and reporting a company's/city's social, environmental and economic impacts.

As a subset of this broad sustainability accounting definition, many will have heard the term ESG. ESG is defined as the environmental, social and governance information about a firm and is, arguably, a subset of the broader sustainability accounting area. While many use the terms 'sustainability' and 'ESG' interchangeably, there are many in the sustainability accounting field, who will argue that these terms are not interchangeable. Because ESG is specifically used in an investor context, one must understand the information these investors typically look for (for more discussion on the definitions and what these mean, see L. Keddie 2021). This brings us to the contentious topic of materiality (Jørgensen, Mjøs, and Tynes 2021).

While various approaches to materiality have been discussed, here the focus is on two key terms: single and double materiality. Generally, one can equate single materiality with an ESG approach. In other words, investors interested in ESG information are primarily concerned with how 'external' forces impact the firm and more specifically, its cash flows. So, investors may be interested in understanding a firm's greenhouse gas (GHG) emissions because, among other reasons, many jurisdictions have enabled carbon pricing/taxes which increase firm costs and thus reduce profits. This is an example of an outside-in approach where investors are concerned about the risks and opportunities a firm faces from the outside in (in other words, how these forces affect firm cash flows). This singular focus on the outside-in perspective is known as 'single materiality' and is best exemplified by the International Sustainability

Standards Board (ISSB) accounting standards which seek to serve investors in this capacity (ISSB 2023). Moving to the double materiality approach, and returning to the definition above of sustainability accounting, this approach would include the investor focus on cash flows (outside-in) but would also include firm/city impacts on the world (e.g., a firm's/city's impacts on its environment, social impacts, economic impacts, etc.). The addition of this second perspective can be thought of as an inside-out approach or better understanding the impact of the firm/city on the world. This approach is best exemplified by the accounting standards of the Global Reporting Initiative (GRI) (GRI 2021). This set of sustainability accounting standards takes a broader approach including meeting the needs of investors as well as other stakeholders. It is critically important to note that ESG accounting does not equate to sustainability accounting since it is not taking a holistic approach to including a firm's/city's impact on the world (recall the earlier definition of planetary sustainability).

The hope is that by providing these definitions and perspectives, it will begin to become obvious that different accounting standards will meet different users' needs. In fact, a memorandum of understanding was signed by both the ISSB and the GRI to work together to create a two-pillar system of sustainability accounting reporting to meet a wide variety of users' needs (IFRS Foundation 2022). Firms, or in this case, cities, will need to consider their needs and their stakeholders to first select the best approach to sustainability accounting for their needs. Since cities are unlikely to have investors, using the ISSB standards is unlikely to meet their reporting needs; the GRI standards on the other hand are likely to be a better fit.

Cities are similarly under pressure to better account for their impacts on the world. In thinking about these impacts, there are different strategies, approaches and frameworks that can be used (for a great infographic on some of the major frameworks, standards and their overlap, see (GRI 2022)). One popular framework comes from the United Nations' (UN) Sustainable Development Goals (SDGs) (United Nations 2015). One can think of this as humanity's checklist, goals that a large number of economies have broadly agreed upon to guide the path to being more sustainable. The goals are as follows:

1. No poverty;
2. Zero hunger;
3. Good health and well-being;
4. Quality education;
5. Gender equality;
6. Clean water and sanitation;
7. Affordable and clean energy;
8. Decent work and economic growth;
9. Industry, innovation and infrastructure;
10. Reduced inequalities;
11. Sustainable cities and communities;
12. Responsible consumption and production;
13. Climate action;
14. Life below water;
15. Life on land;
16. Peace, justice and strong institutions; and
17. Partnership for the goals (United Nations 2015).

These goals are often referred to by their number (e.g., cities may reference their commitment to UN SDG 11). Along with these goals come a number of sub-metrics that can be used as targets/goals for cities and firms alike (UN 2023).

Figure 56: The United Nations' Sustainable Development Goals

Source: United Nations[331]

Another approach cities may take is to work on the development of a circular economy. For many, the modern economy has been built on a very linear system: 1) natural resources are obtained from the earth; 2) products are created from these natural resources; 3) products are consumed/used by the population; and 4) products are disposed of as waste. While obviously a wasteful approach, it is also costly in terms of the energy needed to continually obtain new natural resources, the costs for disposal and waste management, as well as the costs to human health and society. For these reasons and more, the concept of the circular economy is gaining traction. This approach posits that natural resources obtained from the earth can be designed in such a way as to ensure their continued use through the development of new products, recycling, reusing or repurposing them to minimize waste and harm to society and the planet.

A third possible approach is that of Doughnut Economics, Kate Raworth's ground-breaking approach to marrying economics with planetary science (Raworth 2017). In this approach, cities can think of that limits of the planet based on the best science we have today: the ecological ceiling. These planetary boundaries as they are known, comprise the critical earth systems that, if the boundaries of these systems were exceeded, pose an existential threat to us as humans. They are as follows:

1. Climate change;
2. Ocean acidification;
3. Chemical pollution;
4. Nitrogen & phosphorous loading;
5. Freshwater withdrawals;
6. Land conversion;
7. Biodiversity loss;
8. Air pollution; and,
9. Ozone layer depletion (Rockström et al. 2009).

These boundaries form the outer layer of Kate's doughnut model. For the inner layer, she creates a smaller circle that includes what she terms the 'social foundation' for humanity; a conceptual floor, of humanity's basic needs to survive within the context of a planet with limits.

It is between this lower social foundation and the outer ecological ceiling that the possibility of a 'safe and just space for humanity' exists. This social foundation comprises the following elements:

1. Food;
2. Health;
3. Education;
4. Income & work;
5. Peace & justice;
6. Political voice;
7. Social equity;
8. Gender equality;
9. Housing;
10. Networks;
11. Energy; and,
12. Water (Raworth 2017).

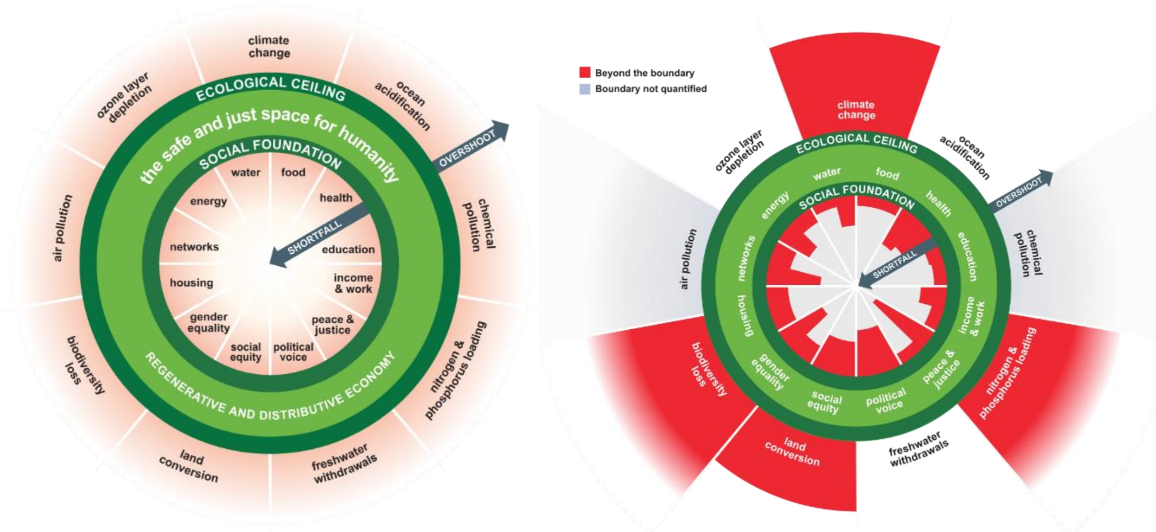

Figure 57: The Doughnut of Social and Planetary Boundaries

Source: Raworth (2017)[332]

As one example of how this may look at the city level, we can look to Amsterdam (Doughnut Economics Action Lab et al. 2020). As a city, Amsterdam examined how they were serving the population within their geographic boundaries and at the land, water and air systems that support their citizens. Since GHG measurement is fairly advanced in comparison to other areas, this will be the focus here to demonstrate this framework. In particular, carbon sequestration was broken down into four areas: 1) How nature does it; 2) To work like nature; 3) City target and 4) City snapshot. From there, the city set goals to reduce its own GHG emissions to 55% below 1990 levels by 2030 and to 95% below by 2050 (Doughnut Economics Action Lab et al. 2020)[333]. Once goals like these are set, sustainability accounting can then be leveraged to create incentives towards achievement.

The first step for a city looking to leverage incentives is to engage with stakeholders. There is a need to determine who the city is communicating to and what kind of information these stakeholders want/need. From this engagement, it should be clearer what sustainability accounting standards will help meet the city and other stakeholder needs. From this point on, it is important to take action; progress not perfection should move the discussion and reporting forward. Any metrics determined in the communication stage can be mapped to actions the city is already taking and/or plans to take. Incentives can form a key part of the strategy here to make progress on determined goals.

Once a city has selected a framework and the appropriate sustainability accounting standards to meet city and stakeholder needs, this reporting can be leveraged to help achieve carbon neutrality. The use of social and environmental metrics in compensation plans is not new. Work in the US context finds large companies in the S&P 500 setting goals in these areas beginning before 2015 (S. L. Keddie and Magnan 2023). Most commonly found in the short-term/annual bonus plan, the proportion of companies using these types of goals has risen from approximately 1/3 in 2015 to nearly 59% in 2021 (Keddie, S. L., Callery, P., Mojai, A. 2023).

Cities can use similar strategies to move their sustainability initiatives forward. These practices can be adapted and applied to a city's context to help meet their needs. Incentives can be financial (where it makes sense) or non-financial. Financial rewards can include cash bonuses similar to the firms in the S&P 500 or could be non-financial such as recognition rewards, promotions/title changes amongst others. In order to leverage incentives well, the best practice is to ensure that the goals that are set are clear, quantitative and time-bound (e.g., using the SMART goal system – specific, measurable, achievable, relevant and time-bound). Returning to our Amsterdam example, the city set a goal with a 1990 baseline, a city-defined boundary and a quantitative goal of reducing emissions by 55% below 1990 levels by 2030 and to 95% below 1990 levels by 2050 (Doughnut Economics Action Lab et al. 2020). This is a great example of a clear, quantitative and time-bound goal. To improve this, and make it more usable day to day, cities should state the goal explicitly (e.g., how many metric tonnes of CO2 equivalents must be reduced and what the measurement system will be, for example The GHG Protocol (The GHG Protocol 2023)). The ongoing reporting on progress towards these goals can be achieved using the GRI standards for example and by providing financial and non-financial goals for meeting interim targets. To ensure consistency and accuracy in the reporting, it is also best practice to ensure that these measurements and the corresponding reporting are assured by knowledgeable auditors.

The literature on the use of social and environment metrics/goals (here forth ESG incentives) in compensation plans is still emerging. Kolk and Perego (2014) were arguably the first to identify 'sustainable bonuses'; in their work, they question whether these bonuses were useful or just window-dressing (in other words, greenwashing). Subsequently, additional work appeared giving us greater insight in the use of these incentives. Mass and Rosendaal (2016) give the first in depth look at the use of these incentives internationally finding that they typically appear in the short-term compensation plan, are primarily social in nature, and are mainly used by 'dirty' industries. From here, Maas wondered whether these incentives were being used by firms trying to increase their ESG performance but finds that this is not the case (Maas 2018). Findings indicate that both poor performing firms and strong performing firms use ESG incentives however, only those with 'hard' or quantitative metrics, rather than 'soft' qualitative goals, improve their ESG performance (Maas 2018). Multiple studies find that the use of ESG incentives is associated with positive financial performance (Flammer, Hong, and Minor 2019; Hong, Li, and Minor 2016; Abdelmotaal and Abdel-Kader 2016) implying some positive financial benefits from their use. Recent work finds that in U.S. corporate settings, there are instances of excess bonuses being obtained though this is not widespread (S. L. Keddie and Magnan 2023) but it remains an empirical question as to whether these risks and benefits will translate into government settings.

Until the research in this area deepens, organizations are left with applying the existing knowledge in the literature to new settings, taking a leap of faith so to speak. For cities today contemplating incentivizing employees to move towards carbon neutrality, expert advice, leveraging the literature and taking that leap of faith, is as follows:

1. Consult stakeholders broadly to ascertain their needs/concerns.
2. Building on the feedback from stakeholders, select an appropriate framework (e.g., UN SDGs) and/or sustainability accounting standard (e.g., GRI).
3. Select metrics/goals (social/environmental) that reflect the priorities of the city from both a risk, opportunity and impact perspective (in other words, what risks (opportunities) does the city need to address (have) in this space and what impacts is it having on society both positive and negative). There is no need to 'reinvent the wheel', existing metrics and guidance can be found through organizations like the GRI. An excellent resource cities should consider reviewing is entitled 'Public sector sustainability reporting: time to step it up' (Adams 2023).
4. Ensure that the metrics/goals are explicit, time-bound (SMART goals for example), quantitative where possible, qualitative where citizens' experience is indicative, leveraging existing systems of data collection to begin with but moving to new data collection processes as the measurement matures. These metrics should be measured clearly, and aggressive goals set.
5. Engage auditors to ensure metrics are rigorously measured and audited. This will increase the quality of your information and trust in your metrics.
6. Align compensation plans with the goals. This may mean different goals for different areas as some may have control over social factors (e.g., inequality) while others may have more control over environmental factors (e.g., GHGs).
7. Commit relevant financial or non-financial resources to the achievement of these goals. This may mean 10-30% on average in a cash bonus setting or could be reflected in non-financial ways such as promotions, awards, public recognition, etc.
8. Refine and rework. Monitor progress frequently (as your data collection processes allow) and make changes as needed. The world is changing quickly, and you may need to update your goals/metrics frequently.

Cities have the opportunity to significantly move forward to achieve carbon neutrality. The information outlined here includes key resources to do this. From the implementation of appropriate sustainability accounting standards to leveraging this information to incentivize employees to achieve aggressive carbon neutrality goals, the resources are available; it will be up to the will of the cities and its people to use these resources to achieve carbon neutrality goals.

2.2.2. Towards Accounts-Based Sustainability Indicators for Cities

Indicator systems are a common way to measure and visualize multidimensional information. The APEC Sustainable Urban Development Report – From Models to Results[334] describes in detail some of the well-known indicator systems used to measure sustainability of cities. The advantage of using indicator systems is to allow aggregating quantities of entirely different dimensions in a single scalar indicator, which can then be the basis for a comparison.

On the way between data and indicators, accounting plays a key role. An accounting system is a way to order and structure basic data before it is assembled to indicators, as is shown in the figure below.

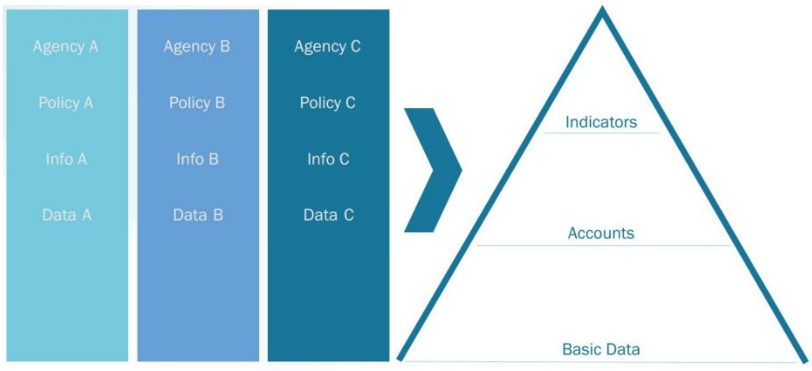

Figure 58: Accounts as essential element between basic data and indicators

Source: United Nations[335]

The basic principle of accounts is that they have two sides, one showing negative effects and one showing positive effects occurring during a period. At the end of the period, the balance between the two effects can be calculated. The balance is a kind of indicator for the sum of negative and positive effects. This corresponds exactly to the objective of sustainability analysis which should allow identifying and quantifying the partial negative effects (such as environmental pollution and degradation, health deterioration, indebtedness) and partial positive effects (such as restoration of biodiversity, job creation, creation of infrastructures and creation of wealth) and determine which ones prevail at the end of the period.

This section attempts to show how accounting, if understood as bridge between basic data and sustainability indicators, can not only greatly improve understanding of sustainability and disaster resilience, but that can fill an essential gap – namely to formulate the key indicator which, if maximized, maximizes overall sustainability of a community.

The demonstration in this section uses an agent-based presentation. This presentation describes interactions between agents as well as interactions of the agents with nature. The agent-based presentation allows seamless aggregation of agents to industries, of industries to sectors, of sectors to economies, and of economies to the world, with disaggregation also being possible if data exist. As mentioned, the strength of this presentation is that it can simultaneously address interactions of the community with nature as well as with other communities. This has been mentioned in section 1.2.3. on the data challenges of cities.

One of the merits of keeping accounts and disclosing them publicly is to accelerate the collection of data. Economic decisions are shaped by published information, the most important of which are published accounts of agents as well as all types of prices (including interest rates, wages etc.).

The accounting world undergoes at present a wave of changes and adaptations designed to address sustainability issues. The description below integrates key elements and ideas from the following tracks:

- Corporate accounting: Two approaches address the subject of sustainable accounting in two different approaches: the outside-in approach is exemplified in Environmental, Social, Governance (ESG) accounting which captures the investor's view and measures the impact of external factors such as climate change onto the firm, especially its cash flow and its profits. The Sustainable Accounting Standards Board (SASB) has recently started publishing financial reporting standards along this approach[336]. The contrary inside-out approach, exemplified by the Global Reporting Initiative (GRI 2021)[337], incorporates a multistakeholder view and measures the impact of a corporation on the world. For cities, this approach may be the relevant one for keeping pace with sustainability accounting as cities are not profit-making entities (see also section 2.3.1).
- The UN System of National Accounting (SNA 2008) has been complemented in 2012 by the System of Environmental-Economic Accounting (SEEA 2012). The SNA is now being revised at the OECD by the High-Level Group on the Measurement of Economic Performance and Social Progress (HLEG) which published its final report *For Good Measure – Advancing Research on Well-being Metrics Beyond GDP* in 2018[338] and a companion volume *Beyond GDP: Measuring what counts for Economic and Social Performance*[339].
- The International Standard Industrial Classification ISIC Rev. 4 is undergoing a revision which is, however, not impacting the coarse presentation shown further down, see following paragraphs.

The analysis below will be made first on flows, where the available material is more abundant and the impact on well-being and sustainability is important. The input-output table of Hong Kong, China is taken as example. The traditional presentation as well as the agent-based presentation of the input-output table are shown for comparison. This allows identifying the deficits of current accounting.

The agents used for the agent-bases presentation are defined in reference to the International Standard Industrial Classification ISIC Rev. 4[340]. This classification is extremely useful, as it distinguishes between 21 sections and 99 divisions of industrial activities. At present, ISIC Rev. 4 is undergoing revision[341]. At the level of sections (A to U, below), the revision splits the section J into two, adding one more section, thereby shifting the sections from K to U by one letter (from L to V). As all the explanations concerning the agent-based presentation are based on a coarse level of sectors and do not use the more granular levels of sections and divisions, the ongoing revision of ISIC does not have any impact on what is explained below.

The individual categories of ISIC have been aggregated into the following 21 sections:

Section	Divisions	Description
A	01–03	Agriculture, forestry and fishing
B	05–09	Mining and quarrying
C	10–33	Manufacturing
D	35	Electricity, gas, steam and air conditioning supply
E	36–39	Water supply; sewerage, waste management and remediation activities
F	41–43	Construction
G	45–47	Wholesale and retail trade; repair of motor vehicles and motorcycles
H	49–53	Transportation and storage
I	55–56	Accommodation and food service activities
J	58–63	Information and communication
K	64–66	Financial and insurance activities
L	68	Real estate activities
M	69–75	Professional, scientific and technical activities
N	77–82	Administrative and support service activities
O	84	Public administration and defence; compulsory social security
P	85	Education
Q	86–88	Human health and social work activities
R	90–93	Arts, entertainment and recreation
S	94–96	Other service activities
T	97–98	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use
U	99	Activities of extraterritorial organizations and bodies

Figure 59: Industries defined in the International Standard Industrial Classification ISIC Rev. 4

Source: UN Statistics Division[342]

The coarse classification that is used in the explanations of the agent-based presentation below groups the ISIC Rev.4 sections and divisions into the following six sectors:

The primary sector, noted "A", corresponds to ISIC industry sections A, B, D, E. The symbol naming the sector, A, is underlined to distinguish it, if necessary, from the symbol naming a quantity A. The primary sector as defined here contains all activities related to raw materials and agriculture. It also contains any activity related to energy, including the electricity industry. More broadly, the primary sector also contains any present or future activity designed to repair damaged natural capital.

The secondary sector, noted "B", corresponds to ISIC industry sections C, F, regrouping all industrial activity as well as construction. More broadly, the secondary sector also contains any activity that repairs damaged produced capital (as is already the case at present).

The tertiary sector, noted "R", corresponds to ISIC industry sections G, H, I, J, K, L, M, N, P, Q, R, S. The tertiary sector contains the central bank as well as the financial industry and is therefore the primary producer of financial capital. Moreover, the tertiary sector also contains the education industry (P) and the health industry(Q) and is therefore responsible to regenerate part of human capital.

The public sector or government, noted "G", corresponds to ISIC industry section O. The public sector includes all activity related to public security. Compulsory social security is considered as being part of public security and is, therefore, included in the public sector.

The private households' sector, noted "C", includes ISIC industry section T but goes well beyond this section. Private households are not considered as an industrial activity and are, therefore, not part of ISIC. The private households' sector describes the role of households as consumers as well as producers of goods for their own use. Beyond that, households have an intergenerational role of regenerating human capital which is recognized in this system.

The sector rest of the world, noted "X", designates everything that is outside the city. It contains ISIC industry section U but may go beyond that, depending on whether or not the analysis includes global flows taking place within the rest of the world.

It may be useful to show hereafter how the agent-based presentation can be derived from scratch from conventional corporate accounting. In conventional corporate accounting, the flows are recorded according to expenses (on the left) and receipts (on the right). The balance net surplus appears, however, on the left and the balance net loss on the right to ensure identical totals on both sides. Either an agent has a net surplus or a net loss, but not both. The balances in the figure below are marked in colour as they change side: a net surplus is in the expenses side and a net loss in the receipts side. Both, red and blue balance numbers are positive or zero (>=0), but red numbers in balances have the meaning of losses, as is the case in everyday language. In an agent-based presentation, expenses and receipts are further specified by partitioning them agent by agent. For two aggregate agents (Energy Agents A and Bankers R) this is shown in the figure below.

A: Energy Agents' Expenses	**A: Energy Agents' Receipts**
To energy agents A	From energy agents A
To manufacturers B	From manufacturers B
To bankers R	From bankers R
To government G	From government G
To households C	From households C
To the world X (imports)	From the world X (exports)
To Balance S+ (net current surplus)	To Balance S- (net current loss)
SUM AA	**= SUM AA**

R: Bankers' Expenses	**R: Bankers' Receipts**
To energy agents A	From energy agents A
To manufacturers B	From manufacturers B
To bankers R	From bankers R
To government G	From government G
To households C	From households C
To the world X (imports)	From the world X (exports)
To Balance S+ (net current surplus)	To Balance S- (net current loss)
SUM RR	**= SUM RR**

Table 7: Agent-based presentation for two aggregate agents, energy agents A and bankers R

Source: APSEC

The arrows point to information which is shown twice: The energy agents' receipts from the bankers are the same as the bankers' expenses to the energy agents. Also, the exchanges within each aggregate agent (e.g., from energy agents to energy agents) is shown twice. This double information can be eliminated by displaying the accounts in matrix form. In a matrix, the expenses remain in the columns of the matrix, whereas the receipts are turned by 90° and displayed in rows. The result is shown in the table below. Note that the naming of symbols in the matrix indicates the flow of goods or services. Thus, AB shows the flow of energy from A to B. The corresponding payment takes place in the opposite direction and hence goes from B to A. This table introduces three sub-totals as well as the following supplementary items:

Flows	A	B	R	V=Σ	G	C	U=ΣΣ	X	Q=ΣΣΣ	S-	ΣΣΣΣ
A	AA	AB	AR	**AV**	AG	AC	**AU**	AX	**AQ**	**AS**	**AA**
B	BA	BB	BR	**BV**	BG	BC	**BU**	BX	**BQ**	**BS**	**BB**
R	RA	RB	RR	**RV**	RG	RC	**RU**	RX	**RQ**	**RS**	**RR**
V=Σ	**VA**	**VB**	**VR**	**VV**	**G**	**C**	**VU**	**X**	**VQ**	**VS**	**V**
T	TA	TB	TR	**T**	TG	TC	**TU**	TX	**TQ**	**TS**	**GG**
W	WA	WB	WR	**W**	WG	WC	**WU**	WX	**WQ**	**WS**	**CC**
U=ΣΣ	**UA**	**UB**	**UR**	**UV**	**UG**	**UC**	**UU**	**UX**	**UQ**	**US**	**U**
Z	ZA	ZB	ZR	**Z**	ZG	ZC	**ZU**	ZX	**ZQ**	**ZS**	**XX**
Q=ΣΣΣ	**QA**	**QB**	**QR**	**QV**	**QG**	**QC**	**QU**	**QX**	**QQ**	**QS**	**Q**
S+	**SA**	**SB**	**SR**	**S**	**SG**	**SC**	**SU**	**SX**	**SQ**	**0**	
ΣΣΣΣ	**AA**	**BB**	**RR**	**V**	**GG**	**CC**	**U**	**XX**	**Q**		

Table 8: Six-sector flow accounting in a symmetrical input output table (IOT)

Source: APSEC

A first intermediate total V = Σ is the aggregate of primary, secondary and tertiary industry. The term VV stands for intermediate consumption (VA+VB+VR), which is also equal to the intermediate production (AV+BV+RV) of the three industry sectors.

A second intermediate total U = ΣΣ represents the city, i.e., the aggregate of all preceding sectors, namely V, the government G and the private sector C, so that VV+G+C=VU, and VV+T+W=UV. Note that to respect usual naming conventions, the corresponding row of column G (government) is noted T (taxes), and the corresponding row of column C (households) is noted W (wages). Taxes T are net of subsidies and transfers. In extreme cases where subsidies and transfers of the government towards one of the other sectors are larger than taxes, the corresponding term of line T could be negative.

A third intermediate total Q = ΣΣΣ, representing the world, is the aggregate of all the preceding columns, namely U and the rest of the world X so that VU+X=VQ and UV+Z=QV. Still in respect of usual naming conventions, the corresponding row of column X (exports) is named Z (imports). The term ZX indicates the equivalent flows of UU happening in the rest of the world. If the analysis should include the rest of the world, the term ZX is non-zero. If the analysis is just concentrating on one city, the data in term ZX is neglected and ZX is zero.

The balance row (S+) and the balance column (S-) indicate surplus (profit) or loss of each sector, respectively. In one period, each sector can be either profitable or loss-making, but not both. Due to the balance row and column, the overall sum of sums (ΣΣΣΣ) of each row is the same as in each column. In this table all numbers, including losses S-, are positive or zero, but S- has the meaning of a loss.

This table allows demonstrating a first important proposition: In a pure trading world, the total surplus (SQ) is equal to the total loss (QS). Mathematically this is stated by:

SQ = QS or SQ – QS = 0, shown by purple colour

This means that if there was only trading, one or several sectors should bear the losses so that one or several other sectors can make profits. It is not possible to have a pure trading world in which all the agents (A, B, R, G, C, X) simultaneously make profits. In a pure trading world, some agents must make losses to allow for other agents to make profits. A pure trading system is an example of a so-called zero-sum game. A pure trading world is a very problematic world as it can only grow by increasing inequalities. Flows can only grow if profits grow, but if profits of some agents grow, losses of others grow alike. A pure trading world is a closed world.

The above should not be misinterpreted. Trade is by far the most important catalyst for making production and consumption economically viable. Without trade, production and consumption cannot attain levels of scale. Fortunately, the reality is a combined system with trade as well as production-consumption. Trade represents the interaction among agents, whereas production and consumption represent the interaction between agents and the environment. Whereas trade happens within the exchange circuit that causes money to flow (in the opposite direction of the sale of goods or services), production and consumption are outside the monetary circuit and need to be recorded by means of an inventory of produced and consumed goods or services. This inventory is done at least once a year before closing the accounts. To have compatibility with the exchange or monetarized part of the accounting system, each inventory item is multiplied by its production or acquisition cost or, if these are not available, its regeneration cost. Current accounting practice is to add annual changes in produced goods in a supplementary capital account showing gross capital formation or investment I on the receipts side so that it can add to the other receipts, and gross capital consumption, divestment or depreciation D in the expenditure side that can add to all other expenditure.

For reasons of clarity, the table below, as well as all other tables, separate the balance into two parts: the trade balance (J) is recording the balance of monetary flows (expenses minus receipts), whereas the capital balance (K) is recording the balance of gross capital formation minus gross capital consumption which are determined by inventory. An agent (e.g., energy agent A) cannot have simultaneously a surplus and a loss trade balance in the same year, he can have simultaneously gross capital formation and gross capital consumption in the same year, provided that two different types of capital are involved for which it does not make sense to take only the net balance.

A: Energy Agents' Expenses	**A: Energy Agents' Receipts**
To energy agents A	From energy agents A
To manufacturers B	From manufacturers B
To bankers R	From bankers R
To government G (taxes)	From government G
To households C (wages)	From households C
To the world X (imports)	From the world X (exports)
Trade balance J (net surplus)	Trade balance J (net loss)
Capital balance K (net surplus)	Capital balance K (net loss)
Gross capital consumption D	Gross capital formation I
SUM AA	**= SUM AA**

Table 9: Single sector A's account after adding a capital account

Source: APSEC

If e.g., energy agent A sets up a new power plant, this is recorded under gross capital formation, whereas if a disaster damages or destroys part of Agent A's office premises in the same year, this is recorded under gross capital consumption. However, for reversible capital flows such as inventory or stock sales and purchases, the only the net capital flow or net capital balance is recorded in the capital account I (in case of net inventory increase) or D (in case of net inventory decrease). The balances are marked in colour (red or blue) as they change side: the surplus appears in the expenses' column and the loss in the receipts' column.

Again, the above can be shown in matrix form representing all aggregate agents. This gives rise to the input-output matrix with investments, divestments, trade balance and capital balance. This table is useful for all the theoretical discussions and derivations.

Flows	A	B	R	V=Σ	G	C	U=ΣΣ	X	Q=ΣΣΣ	J	K	I	ΣΣΣΣ
A	AA	AB	AR	AV	AG	AC	AU	AX	AQ	AJ	AK	AI	AA
B	BA	BB	BR	BV	BG	BC	BU	BX	BQ	BJ	BK	BI	BB
R	RA	RB	RR	RV	RG	RC	RU	RX	RQ	RJ	RK	RI	RR
V=Σ	VA	VB	VR	VV	G	C	VU	X	VQ	VJ	VK	I	V
T	TA	TB	TR	T	TG	TC	TU	TX	TQ	TJ	TK	TI	GG
W	WA	WB	WR	W	WG	WC	WU	WX	WQ	WJ	WK	WI	CC
U=ΣΣ	UA	UB	UR	UV	UG	UC	UU	UX	UQ	UJ	UK	UI	U
Z	ZA	ZB	ZR	Z	ZG	ZC	ZU	ZX	ZQ	ZJ	ZK	ZI	XX
Q=ΣΣΣ	QA	QB	QR	QV	QG	QC	QU	QX	QQ	QJ	QK	QI	Q
J	JA	JB	JR	JV	JG	JC	JU	JX	JQ	0			
K	KA	KB	KR	KV	KG	KC	KU	KX	KQ				
D	DA	DB	DR	D	DG	DC	DU	DX	DQ				
ΣΣΣΣ	AA	BB	RR	V	GG	CC	U	XX	QQ				

Table 10: Input output table (IOT) with investment, divestment and trade and capital balances

Source: APSEC

In the above table, U stands again for the city and Q for the world. The sum of global trade profits is represented by the term JQ, and this is equal to QJ, the sum of total trade losses. This is the zero-sum part of the table. On the contrary, the sum of global capital surplus KQ is not equal to the sum of global capital loss QK. This is the non-zero-sum part of the table. For agent A and its capital account K, KA = max(AI – DA);0, and AK = max(DA – AI);0 and likewise for the other agents and for the trade balance account J. With this convention, all numbers of the above table are positive or zero.

In practice, the table above is simplified by concentrating all the balance terms in two lines J and K. The net capital balance is the difference between the gross capital production and gross capital consumption, thus: K = I – D. If I > D, the net capital balance will be a positive number. If I < D, it will be a negative number. Likewise for the trade balance J. For agent A, AQ-QA>0 is a surplus, the contrary a loss. The balance terms are now brown, indicating that each of them can be positive or negative. The blue term JA of the above table is different from the brown term JA of the table below, as JA = JA – AJ, and similar for the other brown terms, in particular **KQ** = **KQ** – **QK**.

	A	B	R	V=Σ	G	C	U=ΣΣ	X	Q=ΣΣΣ	I	ΣΣΣΣ
A	AA	AB	AR	AV	AG	AC	AU	AX	AQ	AI	AA
B	BA	BB	BR	BV	BG	BC	BU	BX	BQ	BI	BB
R	RA	RB	RR	RV	RG	RC	RU	RX	RQ	RI	RR
V=Σ	VA	VB	VR	VV	G	C	VU	X	VQ	I	V
T	TA	TB	TR	T	TG	TC	TU	TX	TQ	TI	GG
W	WA	WB	WR	W	WG	WC	WU	WX	WQ	WI	CC
U=ΣΣ	UA	UB	UR	UV	UG	UC	UU	UX	UQ	UI	U
Z	ZA	ZB	ZR	Z	ZG	ZC	ZU	ZX	ZQ	ZI	XX
Q=ΣΣΣ	QA	QB	QR	QV	QG	QC	QU	QX	QQ	QI	Q
J	JA	JB	JR	J	JG	JC	JU	JX	0		
K	KA	KB	KR	K	KG	KC	KU	KX	KQ		
D	DA	DB	DR	D	DG	DC	DU	DX	DQ		
ΣΣΣΣ	AA	BB	RR	V	GG	CC	U	XX	AQ		

Table 11: Input output table (IOT) with investments, divestments, trade and capital balances

Source: APSEC

The table above can now be used to derive GDP. To do this, we define the consolidated surplus of the primary, secondary and tertiary sectors as: S= J + K + D. GDP is conventionally defined in three ways called expenditure approach, income approach and value-added approach.

GDP1 at expenditure approach: Y = G + C + X – Z + I

GDP2 at income approach: Y = T + W + S

GDP3 at value-added approach: Y = (V – Z) – VV

From the above table, consider the following:

Consider V = VV + G + C + X + I = VV + T + W + Z + S

Which transforms to Y = G + C + X – Z + I = T + W + S

And also: Y = (V – Z) – VV = T + W + S

This gives the three definitions of the GDP, bearing in mind that all the terms are positive or zero, except the term S which can be positive, zero or negative, hence the brown colour. Gross surplus is negative if S = J + K + D < 0 if J + K < – D, where D is always positive. In other words, the sum of both balances must be smaller than – D.

The table also allows defining the Net Domestic Product, defines as GDP minus the divestments or depreciations D, noted NDP = GDP – D.

For deflating macroeconomic aggregates, the most natural choice would be to use the sum of all domestic transactions defined above by the term UU, bearing in mind that each summand of UU is itself a sum $\Sigma p_i q_i$ of its individual components. This is the deflator that matters for monetary policy.

For deflating the GDP, a specific deflator is constructed to include all the terms of GDP, namely: G + C + X – Z + I. This deflator is different from the above one.

For deflating the consumer basket which matters for consumers, the consumer basket is used, which is defined as: C = AC + BC + RC.

In case an energy-based measurement unit for value[343] or a single reference item such as the Big Mac[344] is considered, the deflator is the basket of goods produced and sold by energy agent A, represented in AC in the table above, or a single item of that AC basket such as the Big Mac. The term AC corresponds also to the basket of what is called non-core inflation comprising food and energy.

Besides the question of choosing the aggregate, there are methodological difficulties linked to the type of index calculation. It can make a (big) difference whether a local currency series is first deflated with respect to the base year and thereafter converted to the common currency (normally USD), or whether it is first converted to the common currency (USD) and thereafter deflated to the base year. Similarly, it makes a difference whether simple exchange rates of a particular time (e.g. end-of-year) are used, or consumer basked based (purchasing power parity) exchange rates. Among the numerous index methods proposed, no method up to now manages to produce a single deflator system taking account in a satisfactory manner of price and quantity variations occurring in time as well as in the currency space. For cities applying an accounts-based methodology, it is important to always use the same kind of deflator computed from the same organization by the same method.

GDP is a gross flow indicator and for this reason, it is normally positive, except in very special circumstances as described below. In the expenditure approach, GDP is positive only if G + C + X + I > Z. This is violated only in very special conditions such as in the case of, e.g., a micro-island community having no exports and no investments, and where government spending and private consumption are smaller than the imports. Note that at global level, exports equal imports and hence the consolidated global GDP is given by Y = G + C + I. This cannot be negative as all terms are positive.

In the income approach, GDP is positive only if T + W + S > 0, or, if S is substituted by its constitutive terms, T + W + J + K + D > 0. As T, W and D are always positive, a negative GDP occurs when J + K < – (T + W + D), i.e., when the sum of both balances J and K are smaller than – (T + W + D), where each of these three terms are always positive.

For GDP to be positive in the value-added approach, Y = V – Z – VV > 0 if V > Z + VV. As V includes Z and VV as two of its summands, and Z and VV are always positive, the value-added approach can show a negative GDP only if all other summands of V are made explicit. As the only potentially negative components of V are J and K, the positivity condition of the value-added approach will yield the same result as in the income approach. The meaning of the above explanations for policymaking are explained in the box below.

Even though GDP is defined in three different ways, the expenditure approach is different from the other two approaches as it is the only definition containing neither explicitly nor implicitly the balance term S (which may be positive or negative). To increase GDP, it is necessary to have an increase of any term of the expenditure approach. For public policy the relevant term is G (= public procurement). An increase in G will increase GDP. If instead, public policy diminishes taxes T or increases subsidies (= negative taxes T), GDP does not change, but only the balance term S changes. This mathematical result can be verified in numerical GDP simulation using the above agent-based presentation.

For the Net Domestic Product (NDP) to be positive in the expenditure approach, this requires the G + C + X – Z + I – D > 0, or G + C + X + I > Z + D. This condition can be failed in such circumstances if imports and divestments or depreciations are sufficiently large compared to the left-hand terms.

For NDP to be positive in the income approach, this requires T + W + J + K + D – D > 0, or J + K > – (T + W). This is violated if the sum of both balances J and K is smaller than – (T + W), which are both always positive.

For the NDP to be positive in the value-added approach, V – Z – VV – D > 0. The three terms Z, VV and D are summands of V. For the positivity to be violated, it requires that V – D < Z + VV. As V has no other negative summands than J and K, the positivity condition is violated in the same case as in the income approach.

To revert to the construction of accounts-based indicators, the balances shown in brown in the above table, as well as the GDP, NDP and all the indicators defined below belong to the category of accounts-based indicators.

At this point it is possible to use a real input-output table to apply the above methodology. The above points can be illustrated and discussed by applying the above methodology to the economy of Hong Kong, China. The Asian Development Bank periodically elaborates input output tables for East Asian economies. The latest available full scale input output table for Hong Kong, China, is available for the year 2018. It shows data converted to millions of current USD[345].

Sector	Code	Agriculture, Hunting, Forestry, and Fishing	Mining and Quarrying	Light Manufacturing	Heavy Manufacturing	Utilities	Construction	Trade Services	Hotels and Restaurants	Transport Services	Telecommunications	Financial Intermediation	Real Estate, Renting, and Business Activities	Public Administration and Defense	Education, Health, and Social Work	Other Personal Services	Final Consumption Expenditure by Households	Final Consumption Expenditure by Nonprofit Organizations Serving Households	Final Consumption Expenditure by Government	Gross Fixed Capital Formation	Changes in Inventories and Valuables	Exports	Gross Output
		AHF	MIN	LMF	HMF	UTL	CON	TRD	HRS	TSP	TEL	FIN	BUS	PAD	EHS	OSV	F1	F2	F3	F4	F5	EXP	
Agriculture, hunting, forestry, and fishing	AHF	0	-	8	0	2	1	3	75	13	0	0	0	0	1	1	298	-	-	0	(1)	114	515
Mining and quarrying	MIN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Light manufacturing	LMF	8	-	482	104	41	360	1,475	537	376	208	349	341	62	212	107	3,640	-	-	309	(76)	7,365	15,902
Heavy manufacturing	HMF	0	-	17	200	1	2	409	4	21	24	22	28	8	8	12	680	-	-	687	(19)	10,439	12,542
Utilities	UTL	3	-	169	36	506	132	712	878	386	212	467	1,023	247	458	468	2,343	12	-	27	-	559	8,639
Construction	CON	3	-	11	1	10	27,920	71	26	201	30	31	276	662	78	30	1	-	-	31,040	-	201	60,592
Trade services	TRD	53	-	1,863	2,452	571	1,945	7,073	970	2,566	386	600	574	165	695	499	20,673	-	-	4,086	(79)	130,569	175,659
Hotels and restaurants	HRS	1	-	38	4	18	83	910	319	244	169	374	295	48	164	128	23,245	-	-	105	-	80	26,224
Transport services	TSP	1	-	173	18	15	354	5,270	110	8,790	1,356	994	574	60	131	160	8,608	-	-	176	-	28,109	54,900
Telecommunications	TEL	4	-	203	30	42	275	6,227	254	3,401	4,300	2,493	1,497	268	351	550	4,230	42	-	1,048	-	3,642	28,857
Financial intermediation	FIN	3	-	754	95	334	603	15,074	656	2,110	1,176	20,387	8,022	213	847	1,139	32,298	-	523	843	-	22,868	107,945
Real estate, renting, and business activities	BUS	13	-	717	119	212	1,145	22,784	2,887	2,746	2,694	6,344	7,566	715	1,772	3,033	33,812	-	-	12,843	-	2,316	101,718
Public administration and defense	PAD	0	-	12	2	5	106	324	38	209	44	122	85	224	39	43	1,644	-	20,963	42	-	139	24,042
Education, health, and social work	EHS	1	-	38	5	12	77	927	54	179	145	318	295	100	499	92	9,294	14,100	13,202	212	-	140	39,689
Other personal services	OSV	5	-	163	28	78	316	4,546	262	682	818	1,260	1,997	238	381	2,618	10,187	687	-	1,058	-	1,013	26,338
Total imports	**IMP**	**179**	**-**	**7,866**	**8,906**	**1,882**	**9,421**	**32,223**	**7,419**	**11,990**	**3,799**	**6,304**	**4,805**	**962**	**3,159**	**2,694**	**79,973**	**472**	**444**	**24,241**	**681**	**-**	**207,419**
Total intermediate consumption	**r60**	**274**	**-**	**12,514**	**11,999**	**3,728**	**42,740**	**98,029**	**14,487**	**33,912**	**15,360**	**40,064**	**27,378**	**3,975**	**8,796**	**11,575**	**230,928**	**15,313**	**35,132**	**76,716**	**506**	**207,556**	**890,981**
Taxes less subsidies on products	r99	6	-	75	23	89	115	1,821	261	505	174	1,254	910	19	156	791	6,034	157	28	912	(97)	-	13,234
CIF / FOB adjustments on exports	r61	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Direct purchases abroad by residents	r62	0	-	104	6	60	122	1,216	124	829	301	868	408	51	427	1,002	21,499	-	-	-	-	-	27,015
Domestic purchases by nonresidents	r63	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	(37,485)	-	-	-	-	-	(37,485)
Value-added at basic prices	r64	236	-	3,209	513	4,762	17,615	74,593	11,352	19,654	13,023	65,759	73,023	19,997	30,309	12,969	-	-	-	-	-	-	347,015
International transport margins	trs	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gross output	**r69**	**515**	**-**	**15,902**	**12,542**	**8,639**	**60,592**	**175,659**	**26,224**	**54,900**	**28,857**	**107,945**	**101,718**	**24,042**	**39,689**	**26,338**	**220,975**	**15,471**	**35,159**	**77,628**	**409**	**207,556**	**1,240,759**

Table 12: Input output table (IOT) of Hong Kong, China, 2018. Source: ADB[346]

This data can be converted to the agent-based methodology described above simply by aggregating the industries to the six sectors of the coarse table. Since 2008, Hong Kong, China, has been applying the Hong Kong Standard Industry Classification HSIC Version 2.0[347], whose coarse structure is identical with the coarse structure of ISIC Rev. 4[348]. The resulting simplified table uses exactly all the information of the original disaggregated table above as it adds no further information.

	A	B	R	V=Σ	G	C	U=ΣΣ	X	Q=ΣΣΣ	I	ΣΣΣΣ
A	511	346	4697	5554	247	2653	8454	673	9127	27	9154
B	63	29097	4876	34036	732	4321	39089	18005	57094	32036	89130
R	1363	11498	166734	179595	15532	157176	352303	188737	541040	20371	561411
V=Σ	1937	40941	176307	219185	16511	164150	399846	207415	607261	52434	659695
T	100	333	6776	7209	21234	7835	36278	139	36417	954	37371
W	4998	21337	300682	327017	19997	0	347014	0	347014	0	347014
U=ΣΣ	7035	62611	483765	553411	57742	171985	783138	207554	990692	53388	1044080
Z	2121	26425	77568	106114	1457	64459	172030	0	172030	24922	196952
Q=ΣΣΣ	9156	89036	561333	659525	59199	236444	955168	207554	1162722	78310	1241032
J	-29	-31942	-20293	-52264	-22782	110570	35524	-35524	0		
K	26	31941	20292	52259	857	0	53116	24922	78038		
D	1	95	79	175	97	0	272	0	272		
ΣΣΣΣ	9154	89130	561411	659695	37371	347014	1044080	196952	1241032		

Table 13: Input-output table of Hong Kong, China 2018 in the agent-based presentation

Source: APSEC, based upon ADB data

Trade surplus J of agent A is 9127 – 9156 = - 29, and similar for all other agents. For the world the trade surplus is 1162722 – 1126722 = 0, shown in purple. The capital surplus K of each agent as well as the capital surplus of the city U and of the world Q can be positive or negative, hence the brown numbers.

The GDP of this economy can be calculated in the tree ways:

GDP1 at expenditure approach: G + C + X – Z + I = Y

$$16511 + 164150 + 207415 - 106114 + 52434 = 334396$$

GDP2 at income approach: T + W + S = Y, where S = J + K + D

$$7209 + 327017 + (-52264) + 52259 + 175 = 334396$$

GDP3 at value-added approach: (V – Z) – VV = Y

$$(659695 - 106114) - 219185 = 334396$$

The NDP is given by GDP – D = NDP

$$334396 - 175 = 334221$$

This figure of the NDP is not complete as the only depreciation of assets it contains is originating from diminutions of inventory which is a very minor part of what is expected to be the sum of depreciations and capital consumptions of Hong Kong, China, that happened during the year 2018.

The above points to a lack of completeness of the information shown in traditional input-output tables. Basically, the incompleteness of information shown is of two types:

- Firstly, the GDP is much more often used than the NDP. GDP considers no gross capital consumption or depreciation or divestment. This is motivated by economic agents whose interests are basically to show solid and large assets on which they are basing their activity. They have less interest to show their capital consumption and do so only if it is unavoidable. To motivate agents to show their capital consumption, GRI or ESG disclosure rules can bridge part of the gap for corporate accounting, and the System of Environmental-Economic Accounting (SEEA) for economywide accounting.
- Secondly, conventional accounting is incomplete as it only considers so-called “produced” assets, neglecting three other types of assets as will be shown below.

Concerning the widening of the types of assets to be included, the APEC Integrated Urban Planning Report – Combining Disaster Resilience with Sustainability describes in detail that altogether there are four types of capital that must be considered in sustainability analysis[349]. The mentioned report groups the 17 SDGs in four concentric spheres (environment, society, economy, governance), whereby each sphere is defined as a function of an incremental specific medium of interaction. For the environmental sphere, the medium of interaction is energy. For the social sphere, the mediums of interaction are energy and information (which is a special form of energy also called negentropy). For the economic sphere, the mediums of interaction are energy, information and money (which is a special form of quantitative information), and for governance, the mediums of interaction are energy, information, money and finance (which is a special form of money). For each sphere, a distinct category of assets can be identified. For the environment, it is environmental assets, for the society it is social assets, for the economy it is industrial assets, and for governance it is financial assets.

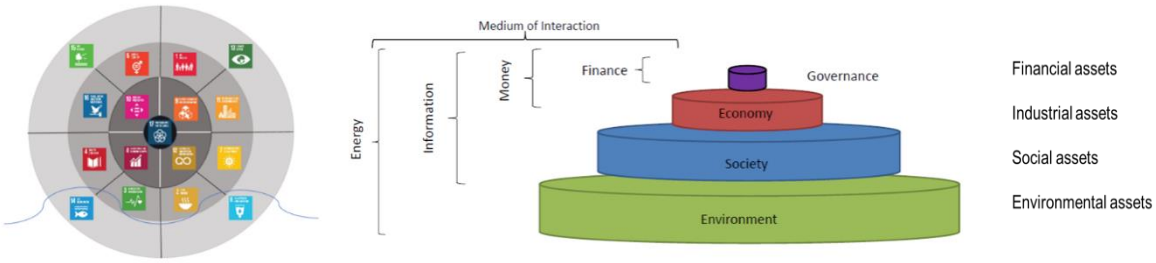

Figure 60: Concentric spheres of sustainability

Source: APSEC[350]

The substantive description of the missing types of assets can best be done by identifying the scope which the term “investment I” (or gross capital formation) receives for each type of asset, respectively, as well as the scope which the term “divestment D” (or depreciation or gross capital consumption) receives for each type of asset. For each type of asset, it is important to state the way how this asset is consumed and regenerated, respectively. Identification of consumption and regeneration of each asset type is crucial, as these two are indispensable to assess whether there is progress towards or away from sustainability. If consumption and regeneration of each asset type are sufficiently well known, knowledge of the full stocks of each asset may not be necessary to describe sustainability. The measurement of the full stock of an asset may, however, be necessary to describe disaster resilience and the vulnerability of a city or community.

Basically, the Gross capital consumption D and Gross capital formation I shown further above are disaggregated and widened into the mentioned four types of capital. For the energy agent A, the structure of his accounts becomes as follows:

A: Energy Agents' Expenses	**A: Energy Agents' Receipts**
To energy agents AA	From energy agents AA
To manufacturers AB	From manufacturers BA
To bankers AR	From bankers RA
To government AG (taxes)	From government GA
To households AC (wages)	From households CA
To the world AX (imports)	From the world XA (exports)
Trade balance AJ (net surplus)	Trade balance JA (net loss)
Capital balance AK (net surplus)	Capital balance KA (net loss)
Environmental capital consumption AE-	Environmental capital formation AE+
Social capital consumption AH-	Social capital formation AH+
Industrial capital consumption AI-	Industrial capital formation AI+
Financial capital consumption AF-	Financial capital formation AF+
SUM AAA	**= SUM AAA**

Table 14: General structure of the accounts system, exemplified for energy agent A

Source: APSEC

The discussion will now briefly focus on the disaggregation of the capital formation and consumption accounts and the widening of scope just described. This is exemplified for energy agent A. Recall the rule mentioned earlier that both sides of the table contain gross variations where the consumption and formation of the asset are very different from each other. Thus, gross produced capital formation is a process related to the construction and installation, whereas gross produced capital consumption is related to different types of depreciation, which are very different from construction. On the contrary, an inventory or price increase is simply the inverse of the respective inventory or price decrease. What is of interest for such reversible operations is the net variation at the end of the period.

The first type of capital is environmental capital E. The table below gives typical examples for each type of capital consumption and capital formation, but it does not claim completeness. MSW stands for municipal solid waste. The lines of the table above reflect the different spheres of the environment: biosphere, atmosphere, hydrosphere, lithosphere with the special categories of soil and land.

To make the link to accounts-based indicators, each term of the above-mentioned table as well as each term of the following tables, can be understood as an accounts-based indicator.

A: Energy Agents' environmental capital conumption AE-	A: Energy Agents' environmnental capital formation AE+
Gross environmental capital consumption and depreciation through: Overuse of biological resources (firewood) Air pollution, incl CO2 and all other pollutants Consumption or pollution of water resources Extraction of energy and mineral resources Pollution of soil resources Land loss through sea level rise and subsidence **Net** Sale of land, **net** land price drops	**Gross** environmental capital formation through: Reforestation, biodiversity restoration Air depollution, CO2 absorption, O2 production Wastewater treatment Recycling of metals and minerals and MSW Cleaning up of landfills and of soil pollution Land reclamation in coastal cities **Net** Acquisition of land, **net** land price rises

Table 15: Environmental capital consumption and formation of energy agent A

Source: APSEC

Environmental assets in general can be divided according to the sphere from which they originate, into assets originating from the biosphere, atmosphere, hydrosphere, and lithosphere. The particularity of environmental assets is that they are difficult to regenerate. If they cannot be regenerated (e.g. fossil energy resources), an alternative way to determine their value by a proxy is to take the generation cost of the same quantity of renewable energy. If environmental assets can be regenerated, they have a regeneration cost that should be used to quantify their value. Furthermore, if they can be regenerated, they may become produced assets. For this reason, the term "produced assets" used in the System of National Accounts (SNA, 2008), the authority defining the GDP, creates confusion and is not used in the present description. They should be called "produced environmental assets". The System of Environmental-Economic Accounting (SEEA)[351] calls some of them "cultivated resources". Take the example of a forest growing due to reforestation policies. The SEEA considers such forest as a produced or cultivated environmental asset as this forest has an organization monitoring its growth and a production cost. Thus, the SEEA opens the way to consider that the domain of produced environmental assets should gradually increase while of "natural" assets gradually disappear due to destruction. This is why both terms "produced" and "natural" are confusing and should not be used. It is preferable to use the term "environmental assets" or "produced environmental assets" and "industrial assets" or "produced economic assets" to separate the two categories clearly.

Specifically, assets originating from the biosphere identified in the SEEA are timber resources, aquatic resources (including fish), and other biological resources. If they are not regenerated, their value is determined by price times quantity of biomass of the depreciated asset. As the overuse of biological resources creates a rent, authorities have started to take part of this rent by selling depletion permits (fishing permits, logging permits, hunting permits) for depleting biological resources. If the funds collected by selling depletion permits are invested to regenerate the asset, the asset becomes a regenerated environmental asset. Assets originating from the biosphere depreciate though overusing (deforestation, overfishing, overhunting), or more generally through loss of natural habitat and biodiversity. Traditional use of biomass is the most relevant example of overusing assets originating from the biosphere. Globally, 7% of total final energy consumption is still based on traditional use of biomass, with very slow improvement rates[352]. Sub-Saharan Africa still experiences growth of the traditional use of biomass, whereas in East and Southeast Asia the traditional use of biomass has been more than halved since 1990.

The assets originating from the atmosphere, as identified in the SEEA, are atmospheric oxygen and nitrogen. CO2 is not yet listed among the natural assets in the SEEA even though CO2 is the essential resource for green plants to produce oxygen. The Introduction to Ecosystem Accounting, a recent appendix to the SEEA, describes the carbon account and states that it is not yet complete[353]. Atmospheric assets regenerate in (bio)chemical processes taking place either with or without human intervention. The regeneration cost for "clean atmosphere" is not available. Instead, a partial pollution cost becomes available for those pollutants where a "polluter pays principle" has been installed, either by way of incentive taxes or by quotas and the obligation to buy emissions certificates, mainly for SO2 and CO2. If quotas correspond to the natural regeneration rate, the price of certificates times the volume of sold certificates reflects the value of the depleted air resource. If the quotas are larger than the natural regeneration rate, then the price of certificates multiplied by the volume of sold certificates is lower than the value of the depleted air resource. The atmospheric assets depreciate either through air pollution or through consumption of specific air components such as oxygen or CO2. As polluting a clean resource is equivalent to consuming it, the polluter pays principle also covers resource consumption. The SEEA identifies the following atmospheric pollutants: CO2, CH4, N2O, NOx, HFC, PFCs, SF6, CO, non-methane VOC, SO2, NH3, heavy metals, POP, particulates such as PM10, PM2.5, and dust). The financial resources collected from emission certificates should be affected to regenerating or cleaning the polluted air. Thus, the atmosphere becomes a partially produced environmental resource. Without regeneration, the cycle is not closed.

Assets originating from the hydrosphere as identified in the SEEA are the three categories of freshwater resources: surface water, groundwater, and soil water. Hydrological assets depreciate either though water consumption or through water pollution. The water pollutants identified by the SEEA are nitrogen compounds, phosphorus compounds, heavy metals, other substances and organic compounds. Hydrological assets regenerate either without human intervention through rainfall, or with human intervention through wastewater treatment. The cost of overuse of hydrological assets beyond the natural regeneration rate is measured by the volume of used water times the price (if it exists). In cases where the authorities have identified a rent for overuse of the overuse of hydrological assets, they started taking a resource rent (e.g., a resource fee for hydropower) calculated independently from the size of investments made to use the resource. Hydrological assets regenerating with human intervention through wastewater treatment become produced environmental assets in the sense of the SEEA. The price of regenerated water reflects the investment in the wastewater treatment facility.

Assets originating from the lithosphere are mined and mineral energy resources, soil resources and land. For mineral energy resources, the UNECE has elaborated a detailed three-dimensional classification and the specifications of its application[354]. Mineral energy resources depreciate through extraction and consumption of the resources. The production cost of mineral energy resources is not the extraction cost as extraction does not include regeneration. Fossil or geological energy resources cannot be regenerated, as it is physically impossible. It is, however, possible to regenerate them indirectly, by producing for each extracted tonne oil equivalent the same quantity of renewable energy as a replacement. In this way, fossil or geological energy resources have an indirect regeneration cost. As the process of using mineral resources creates an extraction rent, authorities have started to take part of this rent by taking royalty payments for fossil fuel extraction. Royalties on mineral extraction should be spent on indirectly regenerating lost mineral resources. Non-energetic mineral resources and metals can be indirectly regenerated by recycling. The recycling cost equals the regeneration cost. Where authorities levy a royalty on mining of non-energetic resources, the proceeds should be used for financing recycling of minerals, including urban mining as explained in the next paragraph.

Soil resources identified in the SEEA are construction materials, the soil nutrients nitrogen N, phosphor P, potassium K, and soil carbon C. To these, thermal use of soil resources should be added. Soil assets depreciate either through extraction and consumption of soil assets or through soil pollution, mainly through leaks from pipelines, chemical spills, and solid waste disposal. Specifically, construction materials originating from the lithosphere are concrete, steel and other metals, glass, stone, asphalt, brick, mud and clay, plastic, foam, tiles. Construction waste is by far the largest waste category of cities. Construction materials require human intervention for their regeneration. They can be regenerated by recycling, a process which is also called urban mining. Urban mining initially only applied to recycling rare urban metals, especially from smart phones[355], but nowadays it designates recycling of any urban construction material such as concrete, asphalt, steel, wood, glass, lighting, window frames, and consumer products. The stocked materials are much larger than the annual inputs and outputs. As an example, the global copper balance for 2018 is shown in the figure below. Concrete can be infinitely recycled[356], but this process requires energy. The main challenge of making modern cities circular is, therefore, to make available renewable energy for cities in sufficient quantities in the urban area and in the hinterland.

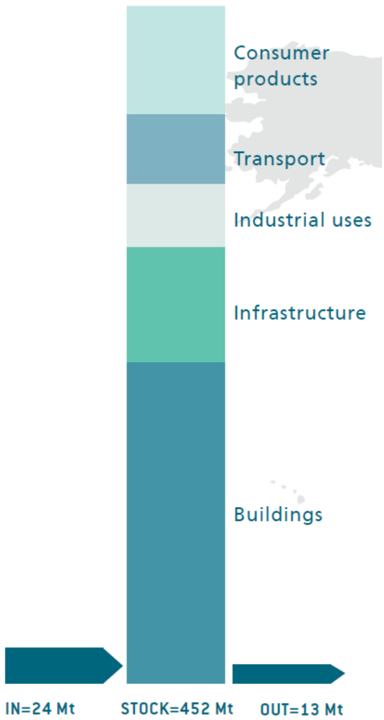

Figure 61: Global Copper balance for 2018 Source: Fraunhofer ISI[357]

The above-mentioned soil nutrients nitrogen N, phosphor P, potassium K, and soil carbon C are mostly related to agriculture. These soil resources are depreciated by consumption of the specific elements and can be regenerated by human intervention in agricultural processes known as biological or regenerative agriculture[358]. Soil can also depreciate by soil pollution, especially around landfills, where it has to be regenerated by heavy human intervention. In places where this happens, a clean and nutrient rich soil is a produced environmental asset in the sense of the SEEA and its regeneration cost per m3 may be known.

Thermal use of soil resources comprises deep underground geothermal energy as well as reversible near-surface underground heat storage. Deep geothermal resources are originating from nuclear reactions taking place within the earth core whereby the residual heat can be extracted and used to generate electricity. If such sources are not showing signs of depletion, deep underground geothermal energy can be considered as renewable. The other form of thermal use of soil resources is the use of near-surface underground heat storage by geothermal probe, either for simple heat extraction or combined with an overground heat source for reversible heat storage use. In this case the resource is man-made, and its regeneration cost is related to infrastructure cost. In the context of the clean energy transition, underground heat storage is expected to receive increased importance for cities and densely populated areas. In APEC, all the cities or municipalities having thermal energy storage projects are located in Canada and China[359].

The most important asset originating from the lithosphere is land. Land is not a produced asset[360]. The SNA considers land as a natural resource and merges it with soil resources[361]. However, contrary to soil, land refers the pure area expressed in square meters or hectares. Land area includes area under major rivers and lakes but excludes continental shelf and exclusive economic offshore zones. Land should not be confused with buildings and infrastructures using land, nor with resources contained in soil. Land is regenerated in long-term geological timeframes through tectonic plate movement as well as through sea level decline. Land is lost through coastal erosion, subsidence in coastal cities (the gradual sinking of land by over-extraction of groundwater or the massive weight of buildings on it) as well as sea level rise. Like all natural assets, land has zero production cost but may have high prices in cities due to scarcity, no matter whether land is sold or leased. As the land price has no relation to any cost of production of land, the land price is a resource price and is sometimes considered as a resource rent. In successful cases of transit-oriented development (TOD), authorities use the resource rent for land to finance the transit infrastructure (so-called Land Value Capture LVC) whose proceeds are used to build affordable housing near subway stations, see APEC Integrated Urban Planning Report (2021). In exceptional cases where land is produced by land reclamation from the sea, this is preceded by heavy investment which makes such land a produced asset with a price that is related to the investment cost.

The second type of capital is social capital H.

A: Energy Agents' social capital consumption AH-	**A: Energy Agents' social capital formation AH+**
Gross social capital consumption through: Deterioration of workers' health conditions **Net** Decrease of workforce (departures, layoffs, job suppression) **Net** Decrease of the volume of long-term leased capital (network decrease) **Net** Decrease of other long-term leased services	**Gross** social capital formation through: Upskilling of workers **Net** Growth of workforce (recruitment, job creation) **Net** Growth of the volume of long-term leased capital (network growth) **Net** Growth of other long-term leased services

Table 16: Gross social capital consumption and formation of energy agent A

Source: APSEC

The generic definition of social assets is to be long-term leased assets. The largest and by far most important category is human assets or human capital. Contrary to owned assets which may give rise to capital formation or capital consumption, leased assets are usually only recorded as expenses and receipts. The interest to record the leased economy also under the aspect of capital formation and consumption comes from network science. Networks have become an important interdisciplinary research topic but are not yet duly reflected in capital accounting. By considering the workers of an enterprise or organization as members of a network, the network capital of an enterprise or organization can be recorded. The problem with this type of discrete relational networks is their volatile nature. Defining discrete relational networks as a set of contractual exclusive lease arrangements will avoid including volatile network assets into the value calculation. The explanations below focus on leased human capital, but their basic mechanism is also valid for other forms of leased capital.

Human capital and defined by the OECD as the stock of knowledge, skills and other personal characteristics embodied in people that helps them to be productive[362]. There is no universally agreed definition of human capital yet. Most often in literature, the stock of human capital is measured only by its educational input by counting the number of education years of people. Taking only education does not account for changes of health levels and the associated cost. As increased health costs may be caused by industrial activities impacting people by pollution, it may become necessary to include health cost into human capital. The three sectors contributing to formation of human capital are households, education and health industries. The cost of human capital should be evaluated by including the contribution of each of these three contributing sectors. Human capital is a produced asset that is leased to enterprises. While produced assets are commonly recorded by their production cost, leased assets are commonly recorded by the lease price. As human capital has the characteristics of both, a produced and a leased asset, both approaches, i.e. production cost and lease price, should be used. The cost approach should be compared to the alternative approach analysing human capital as a leased asset, as presented hereafter. This alternative approach values human capital by its potential lease price which is the potential income during the professional life span of the worker. As a result, human assets H are defined as a product of three dimensions. These mark the contribution of each of the three sectors (households, education, health industry) to human capital:

$$Human\ assets\ H = population\ \times skills\ level\ of\ each\ person\ \times health\ level\ of\ each\ person$$

In the alternative lease approach, the skills should be measured in terms of the potential income that a given skill can generate in one year multiplied by the number of remaining years until the end of the professional lifetime. Unemployed people may have skills but no income from employment. For this reason, the potential income should be taken. The health level is approximated by the individual life expectancy and expressed in years. Recall that for the pre-industrial era (1770), life expectancy has been estimated to be 28.5 years[363]. Modern medical care extends life expectancy by a factor of approximately 3. The health level is a factor representing the life expectancy at birth/duration of professional life. In developed economies where professional life is approximately half of the entire life, this dimensionless factor is around 2. With the above conventions, the lease approach of human capital asset is measured in persons x constant USD/(person year) x remaining number of professional years x a dimensionless health factor, which simplifies to constant USD.

Human capital is produced and lost in the households (sector C) by natural demographic growth or decline, transferred to the tertiary sector (R) for increase through education and regeneration through health treatment, and transferred to all the sectors (primary, secondary, tertiary, government, rest of the world) through recruitment for economic use. This means that the tertiary sector has two types of human capital: the workers recruited as staff members and the students or patients, respectively, received as clients to improve their skills or to regenerate their health. The human capital stock of each sector is positive and equals the number of filled jobs multiplied by the two factors shown above. Unemployed and retired persons are considered as being active in the household sector C, independently of any payment they receive in this status. Gross human capital formation of the energy sector A in one year is calculated as upskilling of the existing workforce plus gross recruitment of new workers by the sector A in one year. Gross human capital consumption of the energy sector A is calculated as deterioration of existing workers health level plus gross number of departures, layoffs or job suppressions in one year. The net human capital formation or consumption of sector A is the difference between its gross human capital formation and its gross human capital consumption. The energy transition requires a substantive amount of re-skilling. The above, relatively simple way of measuring variations of human capital should be useful to describe this re-skilling process and put it in relation with the other accounting aggregates.

The third type of assets is industrial capital I (called "produced capital" in the System of National Accounts:

A: Energy Agents' industrial capital consumption AI-	A: Energy Agents' industrial capital formation AI+
Gross industrial capital consumption through: Gross produced fix capital consumption **Net** Inventory decrease or price drop **Net** Valuables' inventory decrease or price drops	**Gross** industrial capital formation through: Gross produced fix capital formation **Net** Inventory increase or price rise **Net** Valuables' price rises or inventory increase

Table 17: Industrial capital consumption and formation of energy agent A

Source: APSEC

Industrial capital (or "produced" capital as defined in the System of National Accounts) are defined as non-financial assets produced within the production boundary of the city[364]. As most production is made in the industrial sector, they can be called industrial assets. Industrial assets have a production cost and, if leased, a lease price. Conventionally, industrial assets are valued at the production cost whereas leased assets are valued at the lease price. There are three types of industrial assets: fixed assets, inventories and valuables. Fixed assets are produced assets that are used repeatedly or continuously in production for more than one year. They include dwellings, buildings, structures, machinery and equipment, cultivated assets (livestock for breeding, vineyards), intangible assets, computer software, and entertainment, literary or artistic originals. Fixed assets depreciate through various types of physical losses (e.g., abrasion of tyres/brakes, erosion/corrosion of infrastructure, roads, etc.). Inventories are assets that are used within the regular activity of an enterprise either as consumable raw materials or as products for sale. Valuables are produced assets that are not used for production or consumption but are acquired and held primarily as stores of value as they are expected to gain value over time.

The fourth type of capital is financial capital:

A: Energy Agents' financial capital consumption AF-	A: Energy Agents' financial capital formation AF+
Gross financial capital consumption through: Liability increase or net debt increase Issuing (one's own) new equity shares Issuing (one's own) bonds, receiving new loans **Net** Sale of one's own or third-party securities **Net** Sale of "green" electricity certificates (RECs) **Net** Increase of liquidity or cash	Gross **financial** capital formation through: Liability decrease or net debt decrease Buying back (one's own) equity shares Reimbursing (one's own) bonds or debts **Net** Acquisition of one's own or third-party securities **Net** Acquisition of "black" emissions certificates **Net** Decrease of liquidity or cash

Table 18: Financial capital consumption and formation of energy agent A

Source: APSEC

Financial assets are entirely man-made assets and are the only asset category divided into negative (liabilities) and positive (assets) types. It is easier to understand financial assets as negative financial liabilities. Each financial asset owned by a creditor takes its origin in a liability of a debtor counterparty. If a debt disappears, the corresponding asset also disappears. The description below simplifies the description to the minimum necessary to illustrate the basic functioning of financial liabilities and assets in this accounting system.

Liquidity or liquid money is the most important financial asset. It is defined as cash and easily cash-convertible financial assets. Liquidity is issued by the central bank (sector R), for which it is a liability, and made available to the other sectors of the economy which thereby increase their debt held by the central bank. Liquidity is positive for any liquidity holder. Bankruptcy is defined as the point when liquidity of an agent reaches zero. Liquidity of a sector increases when this sector has a net trading surplus or receives more loans than it reimburses. Liquidity of a sector decreases when this sector has a net trading deficit or pays back more debts than it receives new loans. At constant global liquidity supply, global trade is a zero-sum game. In theory, there is no limit to borrowing. Central banks are so-called lenders of last resort. The borrowing sector consumes financial capital or increases its financial liabilities, whereas the lending sector forms financial capital or decreases its financial liabilities.

A coal power plant that is obliged to buy carbon trading (or "black") certificates from the government is obliged to form financial capital in replacement of the environmental capital that has been damaged by CO_2 emissions.

A green electricity producer who is allowed to emit and sell renewable electricity (or "green") certificates (RECs) is allowed to consume financial capital in reward for the green and environmentally friendly electricity produced, whereas those enterprises who are obliged to buy RECs as a method to satisfy green portfolio standards are obliged to form financial capital.

Financial assets more generally are the financial Instruments defined in International Accounting Standard 32 (IAS 32)[365]. Financial assets include liquidity (including bank deposits), receivables (loan receivables or trade receivables), bonds of other entities held, equity shares of other entities held, and any other securities held. Financial liabilities include trade payables, bank borrowings, bonds issued by the entity. Equity is a contract that evidences a residual interest of the shareholder in the assets of the entity after deducting all liabilities. For the equity-issuing entity, equity is a kind of a financial liability, for the shareholder it is a financial asset.

Financial capital consumption is the net increase of liabilities or debt of the entity, financial capital formation is the net liability decrease or net debt decrease.

> The two just quoted examples are ways to internalize so-called externalities or market failures using the “polluter pays” principle. The case of the coal power plant represents a negative externality, whereas the case of the renewable electricity producer represents a positive externality. It is recommended that regulations internalize market failures by creating specific markets of the kind just mentioned. Creating markets means creating quotas and a system of tradable certificates as shown above. Tradable certificates have been shown to be the least cost option to stop the production of new externalities. However, stopping the production of new externalities is only the first step as it does not remove the damage already created before. To remove damage of past externalities, a second step is required whereby the government uses the proceeds collected from the sale of certificates (or raised from incentive taxes) to procure the clean environment by public procurement (thereby increasing the term G of the GDP, see further up), in the same way as the government procures e.g. a street network or security-related infrastructures. For procuring renewable electricity, internationally competitive tendering combined with Power Purchase Agreements (PPA) are best practice methods.

Bankruptcies have up to now only be known to happen in the financial sector as explained above. The generalization to four types of capital outlined in this section gives actually rise to four types of bankruptcies:

- Financial bankruptcies occurring at the point when the stock of liquidity, the key financial asset of an agent, reaches zero. Financial bankruptcies can be avoided by borrowing.
- Industrial or supply chain failures reached at the point when a key input feedstock of an agent reaches zero. Electricity is an example of such a key input. Electricity grid failures create blackouts and are a type of supply chain bankruptcies.
- Social bankruptcy, usually known as skills shortage, occurring when the level of key technical skills of an industry falls to zero. If an industry seeks to engage new skilled workers, insufficient wage levels offered for skills can be identified as cause of a skills shortage. Where skills are already engaged by an enterprise and wage levels are deemed insufficient, workers going on strike are also a type of social bankruptcy.
- Environmental bankruptcy, occurring when the level of a key environmental resource of an agent or a city falls to zero. The key resource to create an environmental bankruptcy is freshwater. Lack of precipitation causes draught which is a type of environmental bankruptcy.

Precipitation is defined as any kind of water that falls from clouds as a liquid or a solid. The World Bank, based upon FAO annual questionnaires, publishes the average precipitation of economies. The figure below shows the average precipitations of APEC economies. In global average, precipitations are estimated to be around 1000mm/year[366]. Under climate change, precipitations may drop also in areas of traditionally high precipitation such as Panama. Recent news about the lack of rain to fill the locks of the Panama Canal[367] can serve as warning signal. In glacier-rich regions, climate change may increase the availability of freshwater by accelerated glacier melting. For a recent global inventory on glacier melting under climate change see WGMS[368].

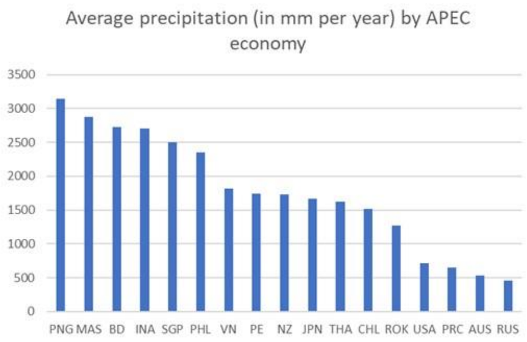

Figure 62: Average precipitation of APEC economies

Source: APSEC using FAO/World bank data[369]

The point of the above explanations on different types of assets is to be able to define a generalized GDP which can be called Gross Holistic Product (GHP). It is defined like the GDP, simply by generalizing the investment term I to include all the types of gross capital formation described in the two tables above and noted II. Referring to energy agent A, the generalized gross capital formation or investment of sector A can be called AII, where AII = (AE+) + (AH+) + (AI+) + (AF+). Similarly, the generalized gross capital consumption or divestment of sector A can be called DDA, where DDA = (AE-) + (AH-) + (AI-) + (AF-). In general, for any agent, these generic definitions are: II = (E+) + (H+) + (I+) + (F+) and DD = (E-) + (H-) + (I-) + (F-). Where the above tables state net capital formation or net capital consumption, the generalized investment II and generalized divestment DD, respectively, are meant to include the net terms. The generalized GDP will be derived in the two following tables.

Compared to the similar input output table (IOT) with investment, divestment and trade and capital balances shown further above, the table below has changed in the three last rows and three last columns. The scope of investment and divestment has been widened to include altogether four types of capital, which in sum is noted II for the generalized investments and DD for the generalized divestments. The sum of the last line and column is larger than in the similar earlier table, hence noted AAA for agent A, and similar for the other agents.

Flows	A	B	R	V=Σ	G	C	U=ΣΣ	X	Q=ΣΣΣ	J	KK	II	ΣΣΣΣ
A	AA	AB	AR	AV	AG	AC	AU	AX	AQ	AJ	AKK	AII	AAA
B	BA	BB	BR	BV	BG	BC	BU	BX	BQ	BJ	BKK	BII	BBB
R	RA	RB	RR	RV	RG	RC	RU	RX	RQ	RJ	RKK	RII	RRR
V=Σ	VA	VB	VR	VV	G	C	VU	X	VQ	VJ	VKK	II	VVV
T	TA	TB	TR	T	TG	TC	TU	TX	TQ	TJ	TKK	TII	GGG
W	WA	WB	WR	W	WG	WC	WU	WX	WQ	WJ	WKK	WII	CCC
U=ΣΣ	UA	UB	UR	UV	UG	UC	UU	UX	UQ	UJ	UKK	UII	UUU
Z	ZA	ZB	ZR	Z	ZG	ZC	ZU	ZX	ZQ	ZJ	ZKK	ZII	XXX
Q=ΣΣΣ	QA	QB	QR	QV	QG	QC	QU	QX	QQ	QJ	QKK	QII	QQQ
J	JA	JB	JR	JV	JG	JC	JU	JX	JQ	0			
KK	KKA	KKB	KKR	KKV	KKG	KKC	KKU	KKX	KKQ				
DD	DDA	DDB	DDR	DD	DDG	DDC	DDU	DDX	DDQ				
ΣΣΣΣ	AAA	BBB	RRR	VVV	GGG	CCG	UUU	XXX	QQQ				

Table 19: Input output table (IOT) with generalized investment and divestment. Source: APSEC

While the above table is used to make mathematical derivations, the table that will be used in practice is again simplifying the balances in two single lines, which can be positive or negative, hence the brown colour of the terms.

	A	B	R	V=Σ	G	C	U=ΣΣ	X	Q=ΣΣΣ	II	ΣΣΣΣ
A	AA	AB	AR	**AV**	AG	AC	**AU**	AX	**AQ**	AII	**AAA**
B	BA	BB	BR	**BV**	BG	BC	**BU**	BX	**BQ**	BII	**BBB**
R	RA	RB	RR	**RV**	RG	RC	**RU**	RX	**RQ**	RII	**RRR**
V=Σ	**VA**	**VB**	**VR**	**VV**	**G**	**C**	**VU**	**X**	**VQ**	**II**	**VVV**
T	TA	TB	TR	**T**	TG	TC	**TU**	TX	**TQ**	TII	**GGG**
W	WA	WB	WR	**W**	WG	WC	**WU**	WX	**WQ**	WII	**CCC**
U=ΣΣ	**UA**	**UB**	**UR**	**UV**	**UG**	**UC**	**UU**	**UX**	**UQ**	**UII**	**UUU**
Z	ZA	ZB	ZR	**Z**	ZG	ZC	**ZU**	ZX	**ZQ**	ZII	**XXX**
Q=ΣΣΣ	**QA**	**QB**	**QR**	**QV**	**QG**	**QC**	**QU**	**QX**	**QQ**	**QII**	**QQQ**
J	JA	JB	JR	**J**	JG	JC	**JU**	JX	**0**		
KK	KKA	KKB	KKR	**KK**	KKG	KKC	**KKU**	KKX	**KKQ**		
DD	DDA	DDB	DDR	**DDV**	DDG	DDC	**DDU**	DDX	**DDQ**		
ΣΣΣΣ	**AAA**	**BBB**	**RRR**	**VVV**	**GGG**	**CCC**	**UUU**	**XXX**	**QQQ**		

Table 20: Table used to define the Gross Holistic Product GHP

Source: APSEC

With the above notations, the Gross Holistic Product (GHP) can be defined in the same way as the GDP has been defined in the similar table used further above. Define consolidated holistic surplus of the primary, secondary and tertiary sectors as: SS = J + KK + DDV

Consider VVV = VV + G + C + X + II = VV + T + W + Z + SS

Which transforms to GHP = G + C + X – Z + II = T + W + SS

And also: GHP = (VVV – Z) – VV = T + W + SS

Similar to the GDP, the GHP is also defined in three ways:

GHP1 at expenditure approach: GHP = G + C + X – Z + II

GHP2 at income approach: GHP = T + W + SS

GHP3 at value-added approach: GHP = (VVV – Z) – VV

The Net Holistic Product NHP can be defined in a similar way as the Net Domestic Product NDP, by deducting gross holistic capital consumption from the GHP: NHP = GHP – DDV.

The GHP shares many characteristics with the GDP. It is even less an indicator for sustainability as GHP is larger or equal to, but not smaller than GDP. It can be negative only if the G + C + X + II < Z, which is even less likely for the GHP than for the GDP as II is larger than I.

In corporate accounting, GDP is equal to the sum of gross value-added of the producing sector. Likewise, the GHP is the sum of holistic value-added of the producing sector which adds the three other types of capital formation described above to the conventional gross value-added. Conventional gross value-added appears to understate the true amount of gross value-added of corporate entities of the productive sector. The detailed comparison with similar terms described by GRI or ESG accounting remains to be spelled out.

The main reason for defining the GHP and NHP is that the data to calculate these two indicators is needed to define a global-level sustainability indicator as well as a city-level sustainability indicator and the equivalent sustainability indicators for each sector. A secondary reason for defining the GHP is to show that the GDP is incomplete in its own logic as it does not include all the types of assets that are necessary for describing economic performance.

The unique sustainability indicator emerging from the above can be called Net Holistic Surplus (NHS). The Net Holistic Surplus (NHS) or Net Holistic Loss (NHL) is calculated as Gross Holistic Surplus (GHS) minus Gross Holistic Loss (GHL).

From the table further above that contained the Input output table (IOT) with generalized investment and divestment and the table used to define the Gross Holistic Product GHP, the Net Holistic Surplus can be calculated for any agent, e.g., agent A, as (JA – AJ) + (KKA – AKK) = JA + KKA. For the city U, this is calculated as (JU – UJ) + (KKU – UKK) = JU + KKU. At global level Q, the Net Holistic Surplus is calculated as JQ + KKQ – (QJ + QKK) = KKQ + 0. For the global level and only for this level, JQ = QJ, hence KKQ – QKK = KKQ + 0

The World Bank calculates a somewhat similar term to the Net Holistic Surplus NHS called Net Adjusted Savings Rate (NASR)[370] which presents some similarity and some differences with the Net Holistic Surplus. The first difference is that NASR it is expressed as a savings rate, more precisely, as a share of Net Adjusted Savings in GNI (Gross National Income). The GNI is very similar to the GDP, see the APEC Green Finance Report[371] for a quantitative comparison between GNI and GDP for all APEC economies.

Letting aside the difference of being defined as a rate, the Net Adjusted Savings (NAS) is defined by the following formula:

NAS = GNS – Dh + CSE – ΣRn,i – CD , where the terms are:

GNS = Gross National Saving (corresponding to SS = J + KK + DDV further above)

Dh = Depreciation of produced capital (corresponding to DDV above)

CSE = Current (non-fixed capital) expenditure on education which is the educational part of the cost of creating human capital. As mentioned above in the explanations concerning human assets, the cost side of human capital should include the contribution of all three sectors: households, education and health industry. In the above input-output tables, education and health costs are included in the exchange part of the table as they all create monetary flows as compensation. In ISIC Rev.4, all forms of education are in division P, which is part of the tertiary sector R, whereas the medically treated health cost is part of the income of the health sector which ISIC Rev.4 includes in division Q which is also part of the tertiary sector R in the above tables. Education and health costs are therefore included in the term RG (if it is paid by the government) or RC (if it is paid by the households). In both cases, education and health costs are included in GDP as they are either government spending, included in term G of the GDP, or consumer spending included in term C of the GDP.

Rn,i = Rent from depletion of natural capital i; where rent of fossil energy resources coal, oil and gas is defined as: Rent = (Production Volume) times (International Market Price - Average

Unit Production Cost). Here, it is not understandable why the depletion rent is used instead of the regeneration cost. The loss of natural capital should be determined by the regeneration cost or similar.

CD = Damages from carbon dioxide emissions. The global marginal social cost of a metric ton of carbon emitted is assumed to be USD20 in 1995 (Fankhauser, 1994). This is deflated for other years using the U.S.A. GDP deflator. This is a proxy for the degradation of health level with a somewhat arbitrary chosen USD20/tCO2 price. Methodologically, it would be preferable to separate the degradation of health level into two parts, one which is being medically treated and one which is not. The part of damages from carbon dioxide emission which is being medically treated is part of the income of the health sector which ISIC Rev.4 includes in division Q which is part of the tertiary sector R in the above tables. If paid by households, it is included in the term RC; if paid by government, it is part of RG. Not all damages are, however, being medically treated. The damages that are not being medically treated should be added as other part of (AH-) and should be estimated by shortened life expectancy of the damaged individuals, as proposed in the approach presented above.

Another point is that the Net Adjusted Savings should be put into relation with the other macroeconomic aggregates such as the GDP or the beyond GDP discussion, or new corporate accounting principles such as GRI or ESG. This is what the above agent-based presentation is doing.

To summarize the comment on the Net Adjusted Savings, it can be seen as an interesting first development to represent the fact that corporate and economywide accounting are not complete and need to add environmental and social degradation. For corporate accounting, GRI and ESG disclosure are steps in the right direction. For National Accounting, the System of Environmental Economic Accounting (SEEA) represents an indispensable complement, but it still excludes human capital which is being partially added by the Net Adjusted Savings. The above methodology addresses all these issues in a coherent way that allows for seamless disaggregation or aggregation.

Based on what has been explained above, the above methodology allows presenting the typology of the eight basic categories of sustainability (or lack of sustainability, respectively) of any agent or any city.

The eight basic categories of sustainability (or lack of sustainability, respectively) of any city can be distinguished, depending on the relative size of the four quantities JU, UJ, KKU and UKK, in other words, by looking at whether the Net Holistic Surplus (NHS) defined above is positive or negative, and by decomposing the HNS into its two components, namely trade and capital, respectively. Using the terminology developed further above, for the city U, there is Net Holistic Surplus if (JU + KKU) > (UJ + UKK), Net Holistic Break even if (JU + KKU) = (UJ + UKK), and Net Holistic Loss if (JU + KKU) < (UJ + UKK). This is very simple to understand, yet the eight different categories mark entirely different patterns of sustainability or lack of sustainability, respectively.

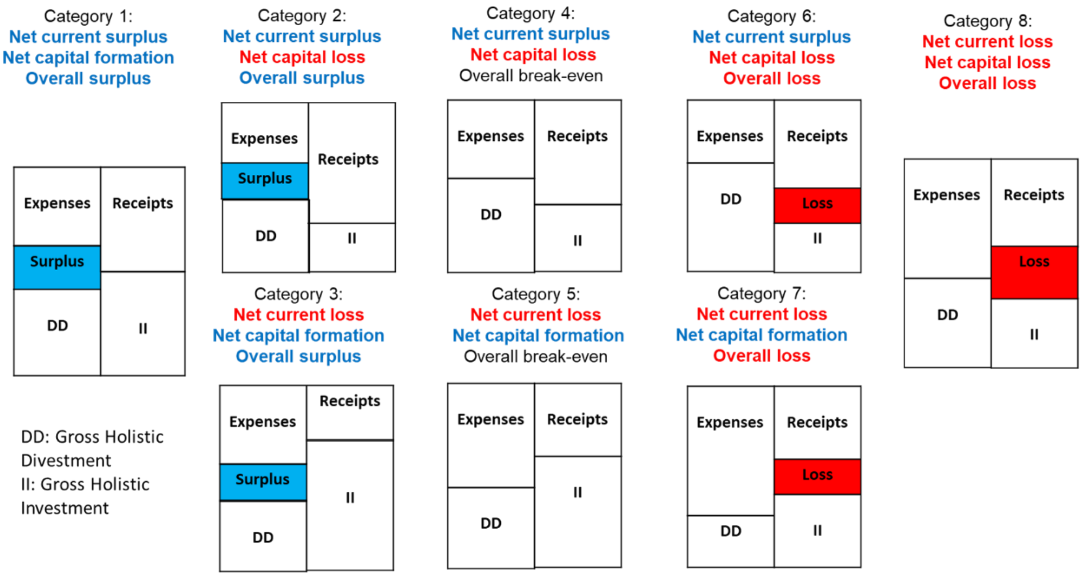

Figure 63: The eight basic categories of sustainable and unsustainable cities

Source: APSEC

Category 1: This city is sustainable in all regards. The current exchange or trade balance of the city with the rest of the world is positive, and simultaneously the net capital formation of the city on its territory is positive (gross holistic investment II is larger than gross holistic divestment DD). Materially speaking, this city exports more goods and services to the rest of the world than vice-versa and hence makes a positive material contribution to the rest of the world. Simultaneously the city also increases the overall stock of capital on its territory and hence makes a positive contribution to its own substance.

Category 2: This city is overall sustainable. Its current exchange or trade balance with the rest of the world is positive, yet it consumes more of its capital than it regenerates, but the net capital consumption is smaller than the net trade balance. This city makes a positive material contribution to the rest of the world, but this contribution happens to a certain degree at the expense of the city's own capital stock.

Category 3: This city is overall sustainable, even though its exchange or trade balance with the rest of the world is negative, the net capital formation on its territory is still positive. This city receives a material contribution from the rest of the world, but it uses this contribution to regenerate its own capital stock which grows to a larger extent than the net contribution the city receives from the rest of the world.

Category 4: This city is overall at a break-even situation. Its exchange or trade balance with the rest of the world is positive, but this is at the expense of its net capital formation on its territory which is negative by the same amount. This city makes a positive material contribution to the world, but this happens entirely at the expense of its own capital stock.

Category 5: This city is overall at a break-even situation. Its exchange or trade balance with the rest of the world is negative, but it uses the resources gained through trade with the rest of the world to regenerate its own capital stock. This city receives a material contribution from the rest of the world and uses all this trade surplus to regenerate the capital stock on its territory.

Category 6: This city is overall unsustainable, even though its exchange or trade balance with the rest of the world is positive. This happens at the expense of its own capital stock which is consumed at a higher rate than the trade surplus with the rest of the world. This city makes a material contribution to the rest of the world, but to do so, it depletes the capital stock of its territory and receives a material contribution from its substance which exceeds the contribution of the city to the rest of the world.

Category 7: This city is overall unsustainable. Its exchange or trade balance with the rest of the world is negative, but it manages to use a part of its trade surplus to regenerate the capital on its own territory. This city receives a material contribution from the rest of the world and uses part of this contribution as a contribution to regenerate its own capital stock.

Category 8: This city is unsustainable in all regards. Its trade balance with the rest of the world is negative. Furthermore, it uses more of its own capital than it regenerates. This city receives a material contribution from the rest of the world as well as a material contribution from its own substance.

Looking now at the example of Hong Kong, China, presented in the input-output table further above, the city has a current surplus as well as a capital surplus, falling therefore into category 1 (sustainable in all regards). The point made here is, however, that three types of capital formation and capital consumption (environmental, human, financial) are either not represented at all yet, or still insufficiently represented in the above table. If they were, the city could be in categories 1, 2, 4, or 6, depending how high the holistic capital production-consumption balance is compared to the other flows already shown in the input-output table.

The meaning of capital stock or substance in the explanations above can be summarized as follows. A given city is more sustainable than another city if it has:

- High endowment with natural assets and relatively low levels of pollution. Typically, cities are not located at places where mineral resources can be found. However, cities can be located above groundwater or near surface water reserves which should be considered as natural assets. Concerning the atmospheric assets, most cities are polluters rather than cleaners. As for biological assets, cities could in principle be built in symbiosis with biodiversity. For example, the 2020 masterplan of the new Indonesian capital Nusantara[372] tries to reconcile urbanity with nature. Should this promise be realized, it would, however, be the first time in history that a biofriendly city is built.
- High quality of human skills and relatively little negative impacts on health levels. Cities typically are characterized by both aspects.
- Well-developed and disaster resilient infrastructures and relatively little unrecycled waste. Cities typically are characterized by both aspects.
- High consolidated external creditor position and relatively low external debts. Cities typically are characterized by both aspects.

The question as to whether the above bullet points indicate whether a city consumes resources of future generations can now be answered as follows: Bullet points 1 to 3 indicate accumulation or overconsumption of local resources for which – at present – no debt towards future generations is created, whereas bullet point 4 indicates accumulation or overconsumption of distant resources, for which at present a debt is created. Depending on how rapidly this debt is reimbursed will determine to what extent this debt remains on the shoulders of present or future generations.

The above allows introducing the equivalents of balance sheets, showing the state at the beginning and the end of the year, as proposed by the System of Environmental-Economic Accounting (SEEA)[373]. The tables below show what a balance sheet in the agent-based presentation looks like. The agents shown in columns are the same as in the flow tables. In the tables below, all terms referring to the beginning of the period have the index (t_o) to differentiate them from the equivalent terms at the end of the period (t_1). Environmental, human, and industrial assets cannot be negative and are shown in black. Net financial assets can be positive, zero or negative and are shown in brown. The holistic accumulated surplus can in principle also be positive, zero or negative. The holistic accumulated surplus is negative if

$$EKA(to) + HKA(to) + IKA(to) + FKA(to) < 0, \text{ i.e. } FKA(to) < -(EKA(to) + HKA(to) + IKA(to))$$

This is the case if accumulated chronical debt is larger in absolute numbers than the other assets taken togeter. For this to be the case, the agent must have made holistic accumulated losses during many preceding years.

The opening holistic annual surplus accounts are zero by definition and are shown in purple.

ASSETS AT BEGINNING OF PERIOD 1				INDUSTRY			CITY-LEVEL		WORLD
	A	B	R	V	G	C	U	X	Q
Environmental assets	EKA(to)	EKB(to)	EKR(to)	**EKV(to)**	EKG(to)	EKC(to)	**EKU(to)**	EKX(to)	**EKQ(to)**
Human assets	HKA(to)	HKB(to)	HKR(to)	**HKV(to)**	HKG(to)	HKC(to)	**HKU(to)**	HKX(to)	**HKQ(to)**
Industrial assets	IKA(to)	IKB(to)	IKR(to)	**IKV(to)**	IKG(to)	IKC(to)	**IKU(to)**	IKX(to)	**IKQ(to)**
Net financial assets	FKA(to)	FKB(to)	FKR(to)	**FKV(to)**	FKG(to)	FKC(to)	**FKU(to)**	FKX(to)	**FKQ(to)**
Holistic accumulated surplus (opening)	ΣHSA(to)	ΣHSB(to)	ΣHSR(to)	**ΣHSV(to)**	ΣHSG(to)	ΣHSC(to)	**ΣHSU(to)**	ΣHSX(to)	**ΣHSQ(to)**
Holistic annual surplus (opening)	0	0	0	0	0	0	0	0	0

Table 21: Assets at the beginning of period

Source: APSEC

At the end of the period, the resulting assets are calculated by initial assets plus gross asset formation minus gross asset consumption. For the environmental assets of energy agent A, this is $EKA(t_1) = EKA(t_o) + (AE+) + (AE-)$, and similar for the other capital forms and agents. The holistic accumulated surplus of agent A is given by:

$\Sigma HSA(t_1) = EKA(t_1) + HKA(t_1) + IKA(t_1) + FKA(t_1)$, where $FKA(t_1)$ includes the net trade surplus of the period as well as the net lending – borrowing surplus activity of the period.

ASSETS AT END OF PERIOD 1				INDUSTRY			CITY-LEVEL		WORLD
	A	B	R	V	G	C	U	X	Q
Environmental assets	EKA(t1)	EKB(t1)	EKR(t1)	**EKV(t1)**	EKG(t1)	EKC(t1)	**EKU(t1)**	EKX(t1)	**EKQ(t1)**
Human assets	HKA(t1)	HKB(t1)	HKR(t1)	**HKV(t1)**	HKG(t1)	HKC(t1)	**HKU(t1)**	HKX(t1)	**HKQ(t1)**
Industrial assets	IKA(t1)	IKB(t1)	IKR(t1)	**IKV(t1)**	IKG(t1)	IKC(t1)	**IKU(t1)**	IKX(t1)	**IKQ(t1)**
Net financial assets	FKA(t1)	FKB(t1)	FKR(t1)	**FKV(t1)**	FKG(t1)	FKC(t1)	**FKU(t1)**	FKX(t1)	**FKQ(t1)**
Holistic accumulated surplus (closing)	ΣHSA(t1)	ΣHSB(t1)	ΣHSR(t1)	**ΣHSV(t1)**	ΣHSG(t1)	ΣHSC(t1)	**ΣHSU(t1)**	ΣHSX(t1)	**ΣHSQ(t1)**
Holistic annual surplus (closing)	HSA	HSB	HSR	HSV	HSG	HSC	HSU	HSX	HSQ

Table 22: Assets at the end of period

Source: APSEC

The holistic annual surplus in the closing accounts reflect the sum of both, current and capital balance described earlier: $\Sigma HSA(t_1) – \Sigma HSA(t_o) = HSA$, the Net Holistic Surplus of agent A identified in the earlier tables, and similar for the other agents. Thus, at the level of the city U, $\Sigma HSU(t_1) – \Sigma HSU(t_o) = HSU$, where $HSU = JU + KKU$. For the opening in the next period, the holistic annual surplus is added to (or, if negative, deducted from) the holistic accumulated surplus so that the opening in the new period is zero again.

As liquidity was mentioned to be decisive for causing bankruptcy, it should be noted, for reason of completeness, how the liquidity balance of each agent evolves during the period. This is shown in the table below. Net Financial Assets (for energy agent A: FKA) of the table above are first divided into two parts: liquidity L (for energy agent A: LA(to)) which is always positive, and illiquid money M (for energy agent A: MA(to)), which is the balance lent – borrowed and can have any sign. The variation of liquidity for each agent due to trade during the period 1 is taken from the table used to define the GHP above. It can be positive, zero or negative. The liquidity variation due to borrowing – lending is reflected in the balance (for energy agent A: (AF-)-(AF+)) as shown in the table below. It can be positive, zero or negative. Remind that borrowing is the consumption of financial capital and lending is the creation of financial capital. This inverts the signs in the corresponding row, as shown in the table below. The last row shows the resulting liquidity at the end of period 1. It is always positive. The lent – borrowed balance as well as the borrowing – lending balance at global level are zero. The sum of liquidity held by all agents worldwide LQ(to) and LQ(t1), respectively, is normally equal to the corresponding liquidity debt of the issuing central banks.

LIQUIDITY				INDUSTRY			CITY-LEVEL		WORLD
	A	B	R	V	G	C	U	X	Q
Liquidity L at the beginning of period 1	LA(to)	LB(to)	LR(to)	**LV(to)**	LG(to)	LC(to)	**LU(to)**	LX(to)	**LQ(to)**
Net illiquid finanial assets M (lent - borrowed)	MA(to)	MB(to)	MR(to)	**MV(to)**	MG(to)	MC(to)	**MU(to)**	MX(to)	**0**
Variation from trade	JA	JB	JR	**JV**	JG	JC	**JU**	JX	**0**
Variation from borrowing - lending	(AF-)-(AF+)	(BF-)-(BF+)	(RF-)-(RF+)	**(VF-)-(VF+)**	(GF-)-(GF+)	(CF-)-(CF+)	**(UF-)-(UF+)**	(XF-)-(XF+)	**0**
Liquidity at the end of period 1	LA(t1)	LB(t1)	LR(t1)	**LV(t1)**	LG(t1)	LC(t1)	**LU(t1)**	LX(t1)	**LQ(t1)**

Table 23: Liquidity variation during period 1

Source: APSEC

Environmental and human assets are not yet part of the System of National Accounts (SNA) and would be zero in SNA balances, whereas financial assets are partially included.

To revert to the issue of accounts-based indices, recall that the holistic annual surplus is a comprehensive annual sustainability indicator for each agent as well as for the city and for the world. It reflects the balance of interactions of agents among each other as well as their interaction with nature in the four types of assets. It can be accumulated over the years in the holistic accumulated surplus and thus represent the historical sustainability record of each agent as well as the city or the world. Depending on how GRI or ESG disclosure requirements develop in future, the missing information will be made available sooner or later. The conceptualization made in this section represents an important prerequisite to data collection for an accounts-based sustainability indicator.

3. Urban Reporting Frameworks and Case Studies

The Global Covenant of Mayors for Climate and Energy (GCoM) was created as organization to mitigate emissions of greenhouse gases, but the objectives of adaptation and energy access or energy mitigation have been added. GCoM is collecting data from its cities according to the Common Reporting Framework launched in 2018. The commitment of over 9,500 GCoM members is to set goals at least as ambitious as the NDC of their respective economy. At present, even the more ambitious goals of GCoM members do yet suffice to achieve the 1.5°C target of the Paris Climate Agreement. The data portal for cities contains information on 60,000 cities and communities, but it is not always up to date. GCoM and the Environmental Insights Explorer from Google have developed a tool for territorial information.

CDP is a global non-profit organization running the world's largest environmental disclosure system for investors, companies, cities, states, and regions. In 2019, CDP and ICLEI - Local Governments for Sustainability established a unified climate reporting platform for local governments, known as CDP-ICLEI Track. Utilized by over 1,000 cities globally in 2022, CDP-ICLEI Track is one of the official reporting platforms for reporting to the Global Covenant of Mayors for Climate & Energy (GCoM), C40 Cities Climate Leadership Group, WWF's One Planet City Challenge, as well as the United Nations' Race to Zero and Race to Resilience. Cities supply data and information on overarching topics by questionnaire. Over half of all disclosing cities worldwide in 2022 were from APEC economies, nearly 80% of reporting APEC cities currently intend to identify emission sources and track its progress in its emission reduction targets. 80% of cities face extreme climate hazards, with 25% reporting that at least 70% of their population is threatened, requiring resilience measures. Cities face an estimated annual financing gap of nearly USD2.4 trillion globally to attain their long-term climate goals.

The APEC City Stats Platform has been set up to collect urban data in two dimensions (sustainability and disaster resilience) and three levels (communities of all size, medium-sized cities, and large cities.

San Francisco plays a pioneering role of climate actions in the State of California, just like the role that California plays in being a pioneer of climate actions in the U.S. San Francisco has reduced the emissions by about 30% below the 1990 level while it has increased its population by 20% and doubled its GDP in the last 20 years. California is committing to net zero for 2045, whereas San Francisco is setting the net zero goal for 2040. The key for success is the close cooperation of municipal authorities with economic and social stakeholders as well as the declaration of climate emergency in 2019 after a series of severe wildfires and droughts.

The Greater Washington Region Clean Cities Coalition is a public-private partnership covering DC, Maryland and Virginia. It was created in 1993 by President Bill Clinton. The priorities are on capacity building and electrification of transport. Since 1993, the GWRCCC has avoided approximately 42,250,000 tons of oil equivalent. The Bi-Partisan Infrastructure Law and Inflation Reduction Act provides for a further USD21.5 billion in funding for clean energy demonstrations and research hubs.

The city of Temuco, Chile, counts 300,000 citizens. Electrification rate is at only 26%. 81% of households use firewood for heating contributing to 94% of PM2.5 black carbon emissions which stay in the atmosphere for only days to weeks, but their warming potential is 1,500 times as high as CO2. Chile's NDC recognizes black carbon as a source to be included in carbon neutrality. Actions include thermal improvement of homes, replacement of heaters, development of district energy projects and monitoring black carbon emissions.

3.1. Urban Carbon Reporting Frameworks

3.1.1. Challenges and Opportunities of the Global Covenant of Mayors to Collect Urban Energy and Climate Data

Authored by Peter Haems, Global Covenant of Mayors

The Global Covenant of Mayors for Climate and Energy (GCoM) is the World's second-largest alliance of cities with around 12,500 local and regional government signatories including around one billion inhabitants worldwide. The GCoM is co-funded by the European Union and Bloomberg Philanthropies. Supporting partners are, among others, C40 Cities, CDP, ICLEI, UCLG and UN Habitat. GCoM is established worldwide, having regional covenants in many parts of the world, such as in Canada; Japan; Korea; the United States; East Asia; Southeast Asia; Latin America; Oceania and others. The GCoM members take the commitment to implement policies and measures to reduce greenhouse gas emissions, to prepare for climate impacts and increase sustainable energy access.

For the above purpose, the GCoM members collect data. In 2018, a Common Reporting Framework (CRF) was launched. The CRF ensures robust assessment, target setting, integrated climate action planning and monitoring, as well as streamlined reporting across all three pillars of the initiative. The GCoM has a mitigation pillar, an adaptation pillar and a more recently introduced energy access and energy poverty pillar. The CRF allows collecting data in a standardized way while leaving some flexibility to regional covenants, giving them the possibility to set priorities.

For each of the tree pillars, cities can earn badges and showcase their progress. Each of the badges contains three steps. As an example, for the mitigation pillar, the first step consists of elaborating a baseline emissions inventory, the second step of setting the emissions reductions targets, and the third step of elaborating and submitting a mitigation plan. The GCoM does not oblige cities to keep the order of these steps, but instead allows the cities to change the order of these steps if they think it better for their development.

The energy access and energy poverty pillar is structured along three attributes: secure, affordable and sustainable energy. These attributes are reflecting SDG 7 as well as the latest findings from across the energy community. Cities can earn badges across the attributes. Besides the possibility for cities to earn badges, a number of other opportunities of the CRF were identified. These are summarized in the figure below.

- ***Functions as a simplified MRV system – measure, report, verify - tracking progress over time***
- ***Enhances transparency and visualizes political commitment***
- ***From data to information to knowledge that informs local climate action and acceleration***
- ***Leads to improved data quality with increasing accuracy and coherence over time***
- ***Identifies data gaps, to be addressed/resolved with GCoM support***
- ***Clusters and hosts data for city staff, academia and researchers – exchange on experiences***
- ***Widespread reporting enables mapping of domestic, regional and global trends – informs need for improvement and financing/investment***
- ***Enables data aggregation, comparison and monitoring over time***
- ***GCoM global streamlined reporting process provides a robust benchmark***

Figure 64: Further opportunities arising from the Common Reporting Framework

Source: GCoM

The CRF allows the GCoM every year to report detailed progress to the Conference of Parties of the Climate Convention. Based on current targets and actions, the GCoM cities could collectively reduce global emissions by 2.3GtCO2e annually in 2030 compared to a business-as-usual (BAU) trajectory[374]. The figure below illustrates graphically the meaning of this impact. The commitment of over 9,500 GCoM members is to set goals at least as ambitious as the NDC of their respective economy. The aggregate baseline scenario of all GCoM members shows an increase of emissions till 2050. The aggregate NDCs show a diminution, but the aggregate GCoM plans are more ambitious than the NDCs. However, even these ambitious plans do not suffice to achieve the 1.5°C target of the Paris Climate Agreement.

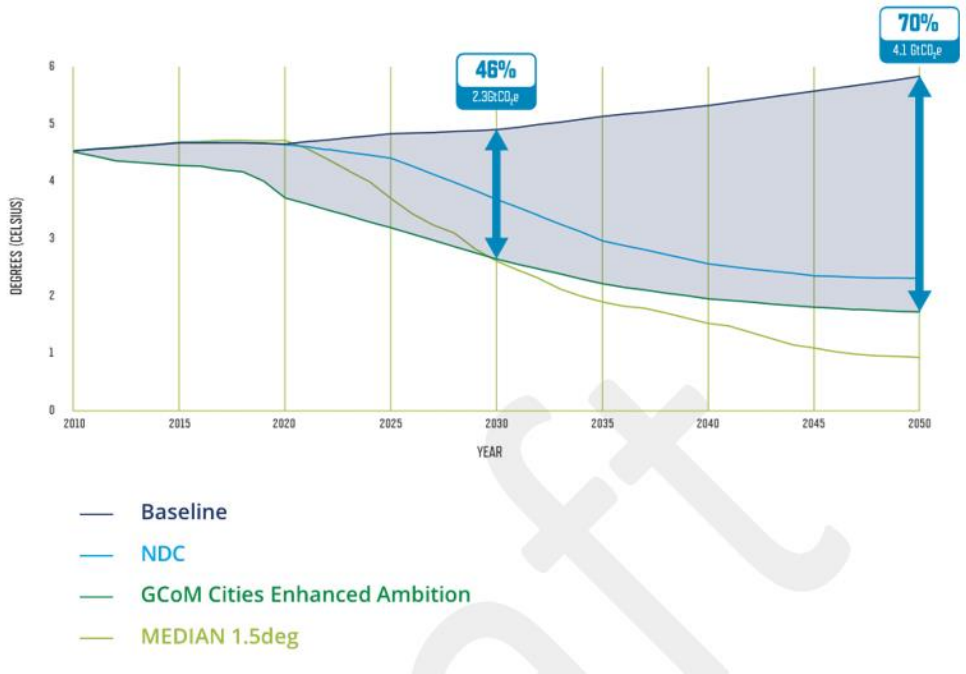

Figure 65: GCoM signatory emissions scenarios 2010 – 2050

Source: The 2022 GCoM Impact Report – Energizing City Climate Action

This data has been elaborated using the nearest neighbour model. A white paper has been presented showing this methodology and how it allows aggregating the GCoM signatories to aggregate figures.

A number of challenges remain and should be seen clearly. An emission inventory is not an easy challenge for many cities. The GCoM has in its statutes the objective to grow the number of adhering member cities, and if the entry requirements are too high, this could hamper that growth.

- ***How do we avoid that the complexity of the reporting drives away existing cities and creates barriers to potential new cities?***
- ***How do we continue to offer more flexibility and local relevance?***
- ***How do we optimize the resource balance of cities between reporting and implementation of climate projects?***
- ***How do we better demonstrate the benefits and impacts of the aggregated reporting?***

Figure 66: Challenges remaining for the Common Reporting Framework

Source: GCoM

Flexibility is introduced into the GCoM by the third pillar favouring secure, affordable and sustainable energy. Through this pillar, the Common Reporting Framework offers flexibility to cities as they can prioritize secure, affordable and sustainable energy as the most important attribute. Cities can choose a relevant indicator which is available in their cities to satisfy the requirements of the CRF.

On the basis of feedback received from cities, the GCoM has started a process of reflecting on some changes. As a result, the CRF currently undergoes a simplification to increase the consistency and to become less demanding. This effort is driven by the experience of reporting platforms and city networks. It has been decided to diminish remarkably the number of questions asked to cities within the CRF. Furthermore, the application of the CRF by cities requires additional clarification and guidance.

Another direction of improvement decided by the GCoM alliance is that it should make the reporting exercise easier and more automated by providing sufficient tools. One of these tools is the data portal for cities. This helps cities to fill critical information gaps in the areas of stationary energy, transport and waste in information collected at the higher levels. The data portal for cities contains information of over 60,000 communities. Nonetheless, one of its problems is that the data is often obsolete as it is not regularly updated.

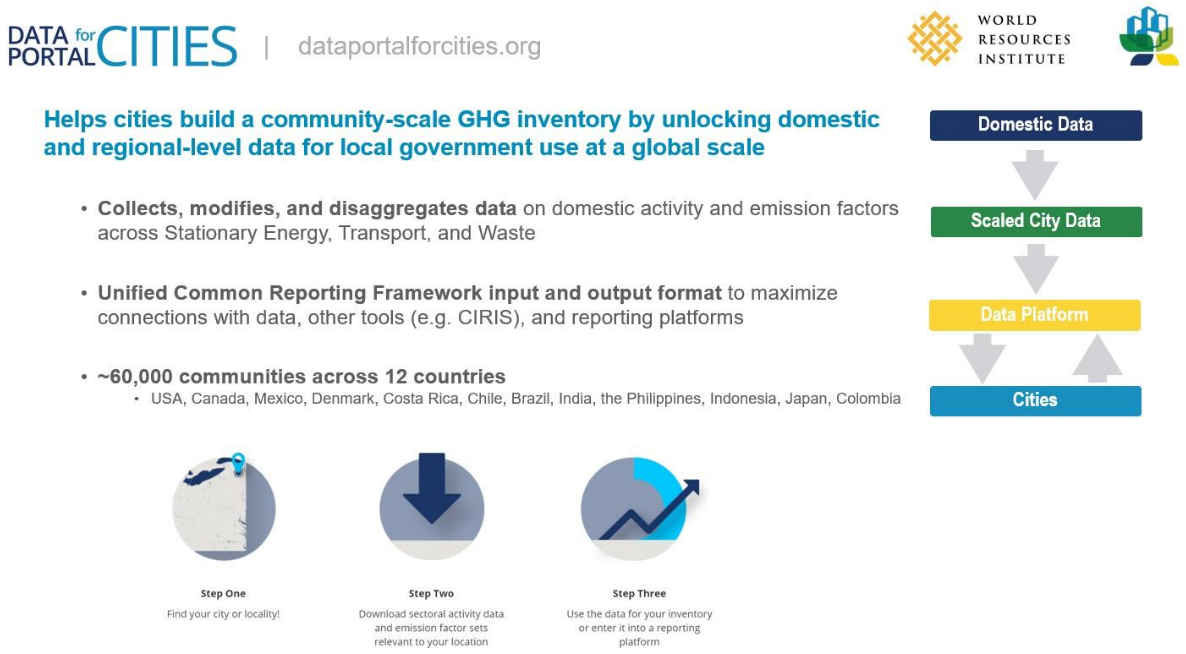

Figure 67: The Data Portal for Cities

Source: GCoM

Another tool of the GCoM has been developed under its collaboration with the Environmental Insights Explorer from Google. This tool has been developed as an instrument facilitating the transition to a low carbon future of communities. This platform contains a lot of freely available data about cities allowing them to help measuring emission sources on their territory. As an example, in the database about buildings there is data about heating, cooling, powering residential and non-residential buildings. Furthermore, a rooftop tool evaluates the potential of rooftop solar energy by taking account of the solar resource and weather patterns, air quality and others.

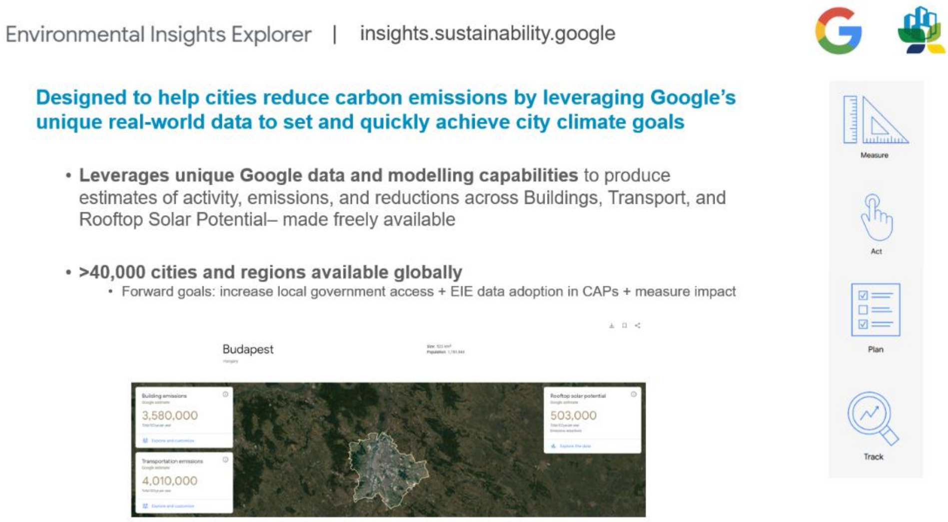

Figure 68: The Environmental Insights Explorer

Source: GCoM

The above two platforms may be a help for cities to report their data, but they may still not be available for many cities in the developing world such as sub-Saharan cities which lack resources anyway to collect and report data.

Besides the GCoM and the CDP platforms which are of global nature, there are also a number of regional or economy-wide platforms collecting data. Indonesia, to take an example, has its own platform collecting data. To avoid cities to be obliged to report on several data platforms, the possibility should be created for GCoM cities to make available their data through such other platforms. Problems may arise in cases where emissions data are not considered as public data but remain subject to restrictions as far as transmission to GCoM is concerned. GCoM has proposed a system of annotation keys allowing cities to signal whether a given set of data is available for transmission or not. GCoM will not publish data signalled as confidential but may still use it in the aggregation calculations of the type shown further above. Most member cities of GCoM are in favour of reporting their data to the GCoM given that they have taken this commitment from the start. Cities that cannot commit to this process do not become members of the GCoM. GCoM members that do not report data lack the capacity to collect it.

Concerning the quality of the data, it is checked in two steps. The first step is for the city to report the data. Thereafter an internal validation of data called First Level Validation is made at the GCoM. This controls the completeness and plausibility of the data. The feed-back given to cities flags such data that seems mis-reported. Only after the First Level Validation can the city receive the badge. The GCoM has a second validation step in which data is analysed from the fit-for-purpose perspective. The questions examined in this second validation procedure are whether the steps taken by the city to improve its emissions score are appropriate and efficient.

To conclude this section, it should be recalled that besides the reporting tasks as implemented in the Common Reporting Framework, the GCoM increasingly focuses on the action part. Cities need tools, knowledge and guidance on topics like how to get access to finance, how to perform prefeasibility studies and similar topics. This area is a major challenge for cities and the GCoM wishes to contribute to addressing it.

3.1.2. Climate Change Data and Governance in APEC Cities: Latest Trends and Insights from CDP

Authored by Hanah Paik (Associate Director – Cities, States & Regions) / Karishma Kashyap (Asia Pacific Lead – Cities, States & Regions), CDP

This section first presents the overarching framework of CDP, laying out the background, CDP's work on cities and disclosure, with an overview of key data points that CDP collects information on. Then it throws its focus on mitigation, present specific analysis on topics like governance and the topic of the oversight of issues and how they have impacted planning. It demonstrates and compares how the APEC economies have supported cities in collecting data, GHG inventories and in setting targets. Thereafter it presents the importance of adaptation and resilience issues that are also critical in low carbon transition and concludes with some further thoughts.

Background on CDP and CDP Cities, States and Regions (CStaR)

CDP is a global non-profit organization that runs the world's largest environmental disclosure system for investors, companies, cities, states, and regions. Founded in 2000 and working with more than 740 financial institutions with over USD130 trillion in assets, CDP pioneered using capital markets and corporate procurement to motivate companies to disclose their environmental impacts, and to reduce greenhouse gas emissions, safeguard water resources and protect forests. Almost 20,000 organizations around the world disclosed data through CDP in 2022, including more than 18,700 companies worth half of global market capitalization, and over 1100 cities, states and regions. Fully TCFD (Task Force on Climate Related Financial Disclosure) aligned, CDP holds the largest environmental database in the world, and CDP scores are widely used to drive investment and procurement decisions towards a zero carbon, sustainable and resilient economy[375].

In 2019, CDP and ICLEI - Local Governments for Sustainability came together to establish one unified climate reporting platform for local governments and councils, now known as **CDP-ICLEI Track.** Utilized by over 1000 cities globally in 2022, CDP-ICLEI Track is one of the official reporting platforms for reporting to the Global Covenant of Mayors for Climate & Energy (GCoM), C40 Cities Climate Leadership Group, WWF's One Planet City Challenge, as well as the United Nations' Race to Zero and Race to Resilience campaigns, among others.

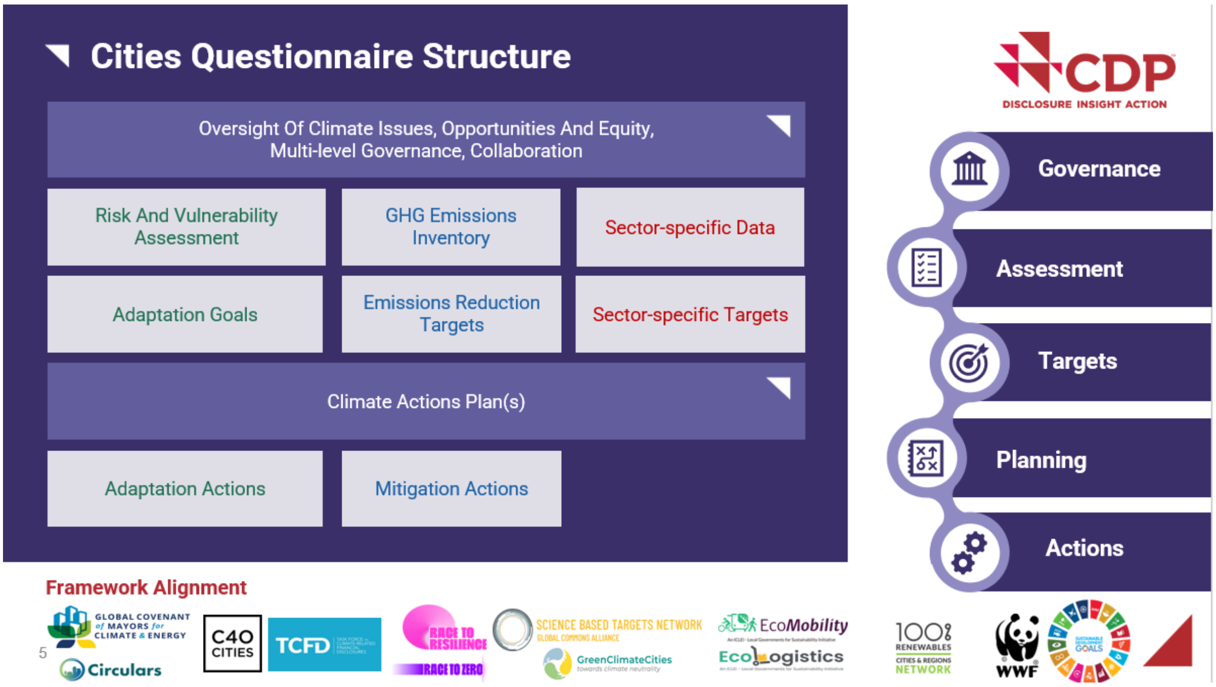

Figure 69: A visual breakdown of the CDP-ICLEI Track Cities questionnaire

Source: CDP[376]

For more than two decades, CDP has built the most comprehensive international collection of self-reported environmental data for investors, companies, cities, states and regions, and public authorities, enabling stakeholders to make better informed decisions. Today, with the most extensive dataset on corporate and city action, CDP is recognized by the world's economy as the gold standard of global environmental reporting.

The 2022 cities questionnaire requested cities to report against overarching topics of governance, assessments, targets, planning, and actions related to climate change and the environment. These sections are further broken down into mitigation, adaptation, and sector-specific indicators, see the figure above. Within these sub sections, CDP analyses the emissions data, risk and vulnerability assessments, targets, planning and actions that the cities are taking towards decarbonisation and climate resilience. CDP also has sections on various sector-specific data such as heat, water, energy, waste, public health, etc., and a section looking at opportunities for growth and partnerships through climate action.

In 2022, over 1000 cities globally disclosed to CDP-ICLEI Track about their environmental impact. The reported data shows:

- **21 times increase** in the number of **cities reporting** since 2011. 1090 cities from 94 economies reported through CDP-ICLEI Track in 2022.
- **44% of cities** that reported in 2022 have a **city-wide emissions reduction target**.
- **30 times more cities** reported a **city-wide emissions reduction target** from 16 in 2011 to 482 in 2022.
- **77% of cities** that reported in 2022 are **taking emissions reduction actions**. 4481 emissions reduction actions were reported by cities in 2022.

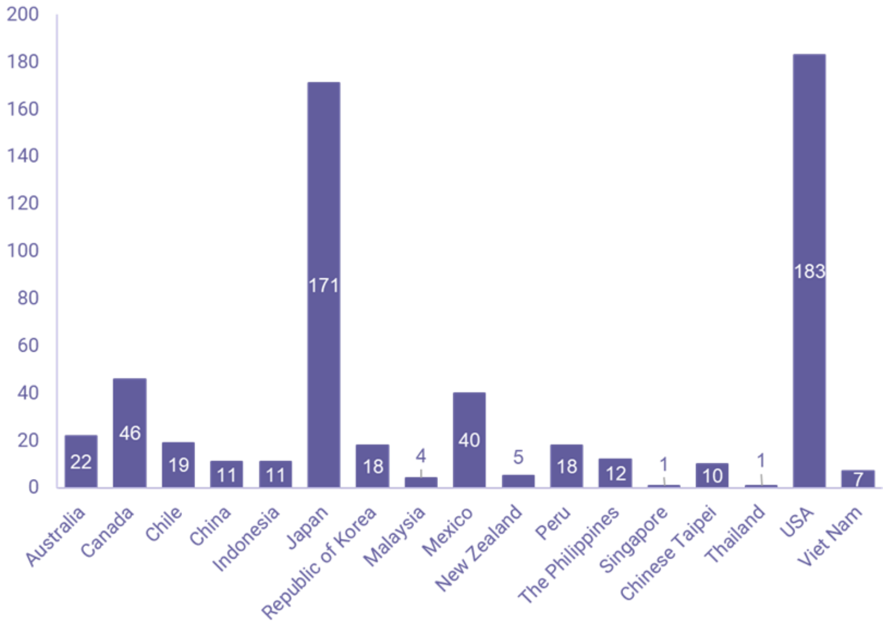

Figure 70: Number of APEC Cities reporting to CDP in 2022

Source: CDP[377]

Looking at APEC cities more closely, over half of all disclosing cities worldwide in 2022 were from APEC economies, with 94% of them recognising the need to assess the wider benefits and opportunities of climate action, see figure below. Such understanding has driven local governments to work closely with the relevant agencies and committees on climate-related issues, as well as to adopt climate-informed perspectives in their policy-making processes.

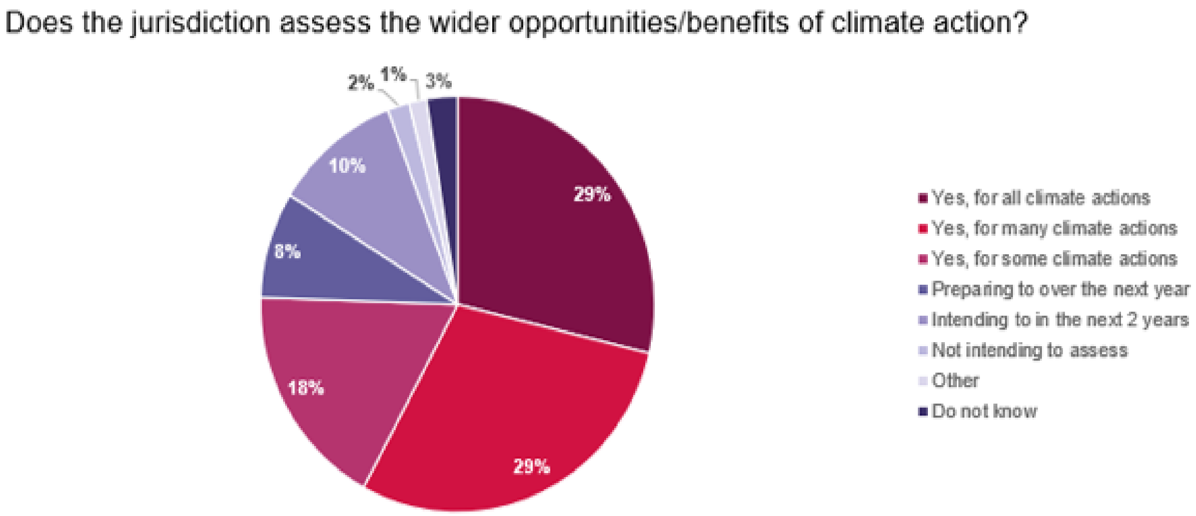

Figure 71: Breakdown of responses by APEC cities

Source: CDP[378]

With respect to the critical issues of greenhouse gas (GHG) emissions inventories, emissions reduction targets, and climate action plans, APEC cities report that their engagement with regional governments is highest, particularly with regards to climate action, although engagement with central and lower levels of government are relatively lower.

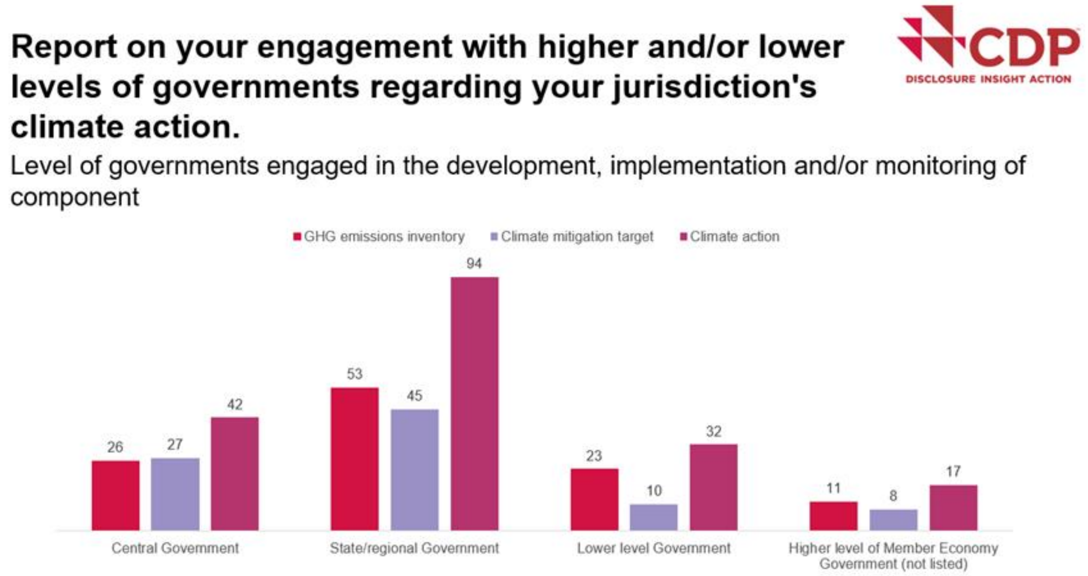

Figure 72: Level of engagement

Source: CDP[379]

On average, across reporting APEC cities, only 31 cities engaged their central governments, and 21 cities engaged their lower levels of government in the development, implementation, and monitoring of these components, compared to an average of 64 cities that had engaged their state/regional governments.

This indicates that more can be done to build the financial and technical capacities within local governments through engagement across different levels of government.

Climate change mitigation

For cities to be active participants towards the low carbon transition, there is a need for governments to actively understand and consider climate-related issues to generate holistic strategies that effectively address environmental concerns. By reporting their governance strategies on environmental issues, CDP can assess a city's climate leadership, management of environmental issues and its preparedness for the impacts of climate change.

Of the 579 APEC cities which disclosed through CDP-ICLEI Track in 2022, 211 reported that their councils (or equivalent) were informed by relevant departments, committees and/or subcommittees about climate-related issues. Additionally, 199 cities noted that climate-related issues were considered by their government when undertaking plans and/or strategies, whilst 136 reported that such issues were considered in budgeting and/or major capital expenditures. This indicates that cities are beginning to build climate-related issues into strategic and financial decision-making. As 76% of disclosing cities reported that they are assessing the wider environmental, social, and economic opportunities and benefits of climate action, oversight of climate issues would allow cities to constructively integrate their related climate concerns with their overall planning and harness the opportunities available in their transition to a green and sustainable future.

This recognition of the significance of climate-related issues has prompted APEC economies to render more support to cities in collecting environmental data, setting targets, and advancing climate actions such as GHG inventories. As GHG inventories are critical in helping a city identify emission sources and track its progress in its emission reduction targets, it is encouraging to see nearly 80% of reporting APEC cities currently intending to undertake such measures. Additionally, an increase in climate governance can be observed in the emission reduction targets undertaken by APEC cities. Overall, nearly 70% of reporting APEC cities have created or are planning to introduce GHG emission reduction target(s) in the next few years. Of these respondents, nearly half of APEC cities within the Asia Pacific region noted that they have or are planning to set GHG reduction targets, with many of them setting holistic targets to further advance their city's climate action. Climate change mitigation actions are a critical cornerstone in a city's climate action plan to reach targets. Hence, they must be considered when supporting cities through the low-carbon transition.

Through CDP-ICLEI Track in 2022, Davao City in the Philippines reported its local climate action plan to prioritize issues outlined in Sustainable Development Goal 13 (Take urgent action to combat climate change and its impacts), creating a comprehensive strategy that addresses climate action across various areas. In addition to improving their capacity to mitigate and adapt to climate hazards, the city is also seeking to incorporate climate change into central decision-making processes, increase community awareness and ensure the inclusion of local green, youth, and marginalized communities in their strategies. Similarly, in Malaysia, the Iskandar Regional Development Authority has created targets that aim to engage all facets of society from domestic society and vulnerable communities to the private sector. The Authority has also prioritized the harmonization of development and growth objectives with the continued development of a low carbon society, accelerating capacity building across institutional and human resources. Through such examples, APEC cities present the diverse and innovative ways in which they have set targets in their journey towards a low carbon transition, highlighting the commitment across members in working towards a sustainable future.

The importance of climate change adaptation and resilience

Emission reductions undoubtedly play a critical role in the transition towards a low carbon society which seeks to reduce the quantities of GHGs in the atmosphere (Peaker 2012[380]). The low carbon transition often focuses on encouraging states to divest from carbon intense resources, such as fossil fuels, to low carbon sources, like biomass energy, as a means of climate change mitigation (Wu et al. 2020[381]; Bao et al. 2010, pp.16[382]; Kumar 2022[383]). However, the world must also be prepared for the current and future impacts of the climate crisis as average temperatures and the frequency of extreme weather events continue to increase[384]. Data reported through CDP-ICLEI Track in 2022 shows that 80% of cities face significant climate hazards, with such hazards threatening at least 70% of the local population in almost 1 in 3 cities[385]. Additionally, 25% of cities are facing high-risk hazards such as extreme heat which is expected to continue to increase in intensity and frequency (*Ibid.*).

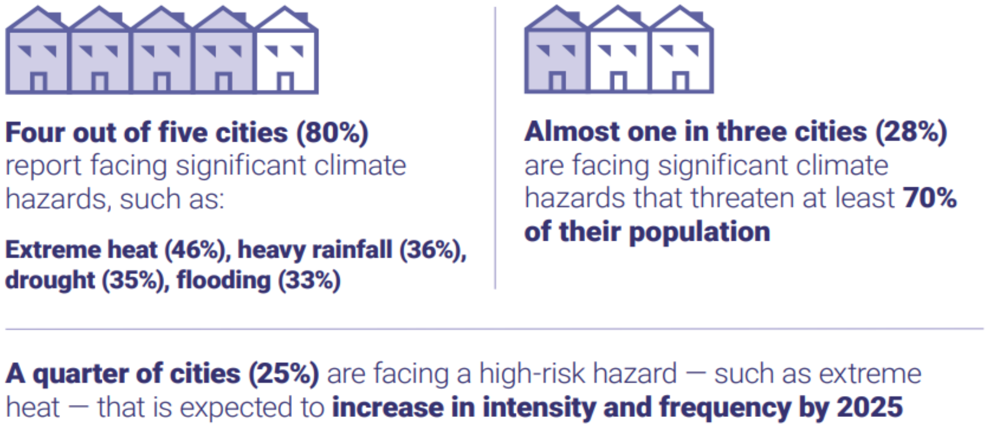

Figure 73: Graphic illustrating CDP statistics regarding climate hazards

Source: CDP[386]

Given such realities, cities must go beyond emissions reduction to consider climate resilience by incorporating key adaptation strategies in their climate action. Climate adaptation refers to calibrating existing 'ecological, social, or economic systems' to manage current or anticipated climate stimuli and their subsequent consequences (IPCC 2001[387]). Such alterations will allow for communities to ameliorate the damages and capitalize on the opportunities presented by climate change (UNFCCC n.d[388]). These changes are critical in the process of low carbon transition which would also seek to reduce emissions caused by loss of forests and ecological communities through adaptative measures such as sustainable forest management (The Royal Society 2008[389]).

To accelerate local resilience, cities should undertake a climate risk and vulnerability assessment (CRVA) to identify key areas and populations of concern. Knowledge of the local context, opportunities and challenges empowers stakeholders to collaborate and generate adaptation goals that effectively target and ameliorate these issues, creating co-benefits that support local social and economic development and climate action.

However, it is critical to note that while several APEC cities are catalysing change, there remains a significant financial and expertise gap that hinders some cities from taking more meaningful action within their jurisdiction. In 2022, a total of 665 climate related projects were reported by APEC cities and all of them needed funding/financing or assistance. The top three sectors that needed funding were waste management (144 projects), transport (106 projects) and renewable energy (97 projects), demonstrating the key sectors cities are focusing their adaptation plans on. Such attention to these areas also provides insight into the potential frontlines in which the critical battles against the impacts of climate change will take place for cities.

With an estimated annual financing gap of nearly USD2.4 trillion globally, cities require institutionalized mechanisms to access public and private financing to allow them to attain their long-term climate goals (UNFCCC 2019)[390]. Pre-existing inequalities between developed and developing economies also require nuanced policies which account for the different contexts cities exist within. Such holistic considerations would subsequently open the door for equitable aid that effectively promotes sustainable cities for all.

Sectoral focus

Cities remain a critical stakeholder in the global low carbon transition due to their role in GHG emissions generation, using nearly 67% of global energy resources and contributing to over 70% of CO_2 emissions globally (UNFCCC 2020[391]). To adequately address climate change through adaptation and/or mitigation action, cities must be able to identify and transform key sectors within their jurisdictions with critical environmental impacts. Such knowledge empowers them to subsequently formulate comprehensive strategies that address the unique challenges and opportunities within these areas. Cities report that the built environment, transportation, and energy are key contributors towards urban emissions, accounting for a total of 56% of all sectors disclosed by APEC city respondents. Of the respondents who provided a breakdown in community-wide emissions (see 2023 Questionnaire, 2.1d), nearly half of the sectors attributed with GHG emissions were due to fossil-fuel energy related activities. Furthermore, of the 177 APEC city respondents who disclosed their transportation mode share data, three quarters of cities reported that private motorized vehicles accounted for half or more of the modal share. Such insights are reflective of existing research highlighting the significant role of these sectors in GHG emissions globally.

Conclusion

Although the world saw a decline in emissions during the COVID-19 pandemic due to extensive disruptions, the resumption of activities has catapulted emissions to pre-pandemic levels, increasing by a record 6% in 2021 and <1% in 2022 (International Energy Agency (iea) 2022[392]; iea 2023[393]).

The range and severity of the impacts of climate change is rising sharply, and cities and their communities are at the frontline. The data reported by cities to CDP-ICLEI Track in 2022 shows the extent of vulnerabilities cities are currently confronting. CDP's Cities on the Route to 2030 report[394] shows that four in five cities (80%) report facing significant climate hazards in 2022, such as extreme heat (46%), heavy rainfall (36%), drought (35%) and urban flooding (33%). At the same time, almost two thirds of cities (64%) are already experiencing significant impacts from climate hazards. This has a sizeable effect on the inhabitants of the world's cities, with nearly a third of cities (28%) reporting being exposed to significant climate hazards that threaten at least 70% of their population. Between 2010 and 2020, deaths from floods, droughts and storms were 15 times higher in highly vulnerable regions, compared to regions with very low vulnerability[395.]. Building resilience to the risks and impacts brought about by climate change, while mitigating further global warming through decarbonisation must occur in parallel.

The extent of future warming depends on how the world and our cities act now to reduce emissions. The IPCC states that "urban systems are critical for achieving deep emissions reductions and advancing climate resilient development"[396]. Cities can and do lead the way on climate action by transparently reporting environmental data, setting science-based targets and taking tangible and effective action. Putting people at the front and centre of this action will reap multiple benefits and create a more sustainable and liveable future for people and the planet.

3.1.3. APEC City Stats Platform

The preceding sections described the global efforts under way by several organizations aiming at improving the collection of data at local level.

This section explains the creation and development of APEC City Stats platform (http://apeccitystats.tju.edu.cn/client/homePage) of local data collected within the APEC context[397].

APEC City Stats can be described as a database that has the following characteristics:

- Apprehend sustainable development of APEC cities and provinces in line with the basic principles of APEC as they have emerged since the creation of APEC in 1989, having a strong focus on economic development and on the diffusion of smart and clean technologies.

- Take due account of the higher-than-average disaster exposure of APEC economies, hence giving more or less equal weight to disaster resilience and to sustainability.

- Stay within the indicator framework of the best-defined global indicator sets, being the Sustainable Development Indicators for the sustainability dimension (see the SDG metadata repository[398]), and the Disaster Resilience Scorecard for Cities[399] for the disaster resilience dimension.

- Implement a graduation approach by distinguishing between an elementary level or level one, designed for small cities and local communities that are only just starting the data collection, an intermediary level or level two, designed for medium-sized and rapidly growing cities having a potential to rapid transformation, and a higher level or level three, designed for large cities that need to plan comprehensive in-depth transformation towards carbon neutrality.

- Systematic use of the data multiplier effect by collecting as few as possible elementary input data and developing them by mathematical relations into as many as possible derived output indicators.

- Facilitated data update by allowing cities to download the existing data in the same template that is needed for uploading the updates.

- Visual data quality and plausibility control prior to publication of data.

Concerning the data, the database makes the distinction between the two dimensions sustainability and disaster resilience, as well as a differentiation by levels (one to three).

In the sustainability dimension at level one, the data requirements are limited to seven data series, among them the building blocks of the Kaya identity[400]:

Emissions = population x (emissions/energy) x (energy/GDP) x (GDP/capita)

In the terminology of the Sustainability Indicator Framework, these elementary data blocks are defined as:

- Total population
- Gross domestic product at current prices
- Total energy supply
- Total CO2 emissions equivalent
- Scope 1 CO2 emissions equivalent from sources within city boundaries
- Scope 2 CO2 emissions equivalent from sources attributable to grids related to the city
- Total local land area

Among the above data, the most difficult to measure for cities are CO2 emissions. The subdivision of CO2 emissions into scope 1 and scope 2 has been integrated into the database to avoid a certain ambiguity in the term "Total CO2 emissions equivalent". While in theory this term is very clear, in practice there might be confusion as most cities that measure only scope 1 emissions will naturally consider these as total CO2 emissions.

As was mentioned above, the data base uses the data multiplier effect to generate supplementary data series by using mathematical formulae. For sustainability level one, the number of available data series is thereby increased from 7 input series to 80 output series. Among the series produced in this way are the different types of GDP. The original input series consisting of GDP at current prices can be transformed first to GDP at constant prices and then to GDP at purchasing power parity 2017 (PPP2017), by using the GDP deflators and the PPP conversion factors, respectively. The database integrates the PPP conversion factors elaborated by the International Comparison Program (ICP) of the World Bank which is authoritative in this area. The most recent PPP benchmark was made for the year 2017[401]. PPP benchmarks are calculated roughly every six years. Earlier benchmarks are available for the years 2011 and 2005. The PPP calculation for future benchmark years may entail a retrospective revision of earlier PPP calculations[402].

The disaster resilience data of level one is based on the Detailed Assessment of the Disaster Resilience Scorecard for Cities[403]. It comprises 17 data series, all related to the topic of disaster response as described in Essential 9 (Ensure effective disaster response) of the Scorecard and assessed by cities on a scale 0 to 5. In substance, this topic assesses the efficiency of the city's early warning system (existence and outreach) as well as different types of gaps (staffing, equipment, food, shelter, staples, fuel) and drills. The Indonesian city of Manado has carried out a self-assessment of Essential 9 and made available the results in the database. This shows the insufficiencies of the city in disaster response and is thereby helping the city to improve its situation. More recently, the Disaster Resilience Scorecard for Cities has itself created three graduation levels for cities.

Going on to describing data collected at sustainability level 2, the focus lies on indicators that are showing the extent of penetration of new technologies. This is measured by indicators in three areas. Firstly, the access to electricity and to clean cooking fuels, the renewables share and the installed renewable capacity. These indicators are all part of SDG7 (affordable and clean energy). Secondly, the development of the manufacturing sector, measured by its value-added, its employment force, the value-added of small and medium-sized manufacturing enterprises, the number of researchers, and the share of high-tech and medium-tech industries, measured as share of high R&D intensity industry, comprising ISIC Rev. 4 divisions 21 (Pharmaceuticals), and 26 (Computer, electronic and optical products), and share of medium R&D intensity industry, comprising ISIC Rev. 4 divisions 30 (Other transport equipment), 29 (Motor vehicles, trailers and semi-trailers), 28 (Machinery and equipment n.e.c.), 20 (Chemicals and chemical products), and 27 (Electrical equipment). These indicators are part of SDG9 (industry, innovation and infrastructure) which shows the readiness of a city to participate in the production of the upcoming clean technologies. Thirdly, the role of mobile phone networks (3G, 4G, 5G and higher), broadband internet by speed category (250kB/s to 2MB/s, 2MB/s to 10MB/s, and > 10MB/s), and the proportion of the population using internet. These indicators are part of SDG9 and SDG17 (partnerships for the goals) and measure some key characteristics of smart cities. Sustainability level two collects altogether 21 input data sets and multiplies them to 84 output data series.

The level two of the disaster resilience dimension incorporates Essentials 1 (Organize for resilience), 2 (Identify, understand and use current and future risk scenarios), 3 (Strengthen financial capacity for resilience), and 10 (expedite recovery and build back better) of the Disaster Resilience Scorecard for Cities. Altogether 29 assessment criteria are collected. These Essentials are all related to the area of city governance (Essentials 1 – 3) and response planning (Essential 10). In other words, the level two of the database concentrates on soft tools (governance, planning), still leaving out the hardware and infrastructures which are the expensive parts of disaster resilience. The Indonesian city of Manado has done the assessment of its disaster resilience at level 2 and communicated the data to the database. In many areas, the city is not judging itself sufficient yet.

Level 3 of the database is destined for large cities having a need to plan for a profound transformation towards sustainability and carbon neutrality. This level is not yet operational. The level is itself subdivided into three levels noted 3a, 3b and 3c.

Sustainability level 3a basically implements the 21 input indicators that are necessary to address SDG11 (Sustainable cities and communities) and uses these to create in total 84 output indicators. The corresponding disaster resilience Essential 4 (Pursue Resilient Urban Development) comprises an inventory of population, employment, business and agriculture at risk in the city, as well as the use of codes, ecosystem services, land use zoning and sustainable building design standards such as REDi, LEED, GreenStar and BREEAM to improve resilience.

Sustainability level 3b uses 5 input data series derived from SDG indicators which make special mention of local level conditions. Among these are the participation of woman and youth (defined as less than 45 years old) in local assemblies and the participation of local communities in water management issues. Furthermore, the inventory of endangered local agricultural breeds is included in this level. The database creates 12 output data series. The corresponding disaster resilience level 3b is composed of 28 assessments, stemming from Essential 5 (Safeguard natural buffers to enhance the protective functions offered by natural ecosystems), Essential 6 (Strengthen institutional capacity for resilience), and Essential 7 (Understand and strengthen societal capacity for resilience), all focusing on the social and institutional fabric to create disaster resilience.

Finally, sustainability level 3c uses 25 input data series to produce 93 output series. These are from a variety of areas such as access to basic household services, to water, water management and wastewater treatment, quantity of waste and degree of waste treatment and recycling, plastic waste, the extent of the forest area, as well as the number of homicides. The corresponding disaster resilience area is Essential 8 (Increase infrastructure resilience), which contains 32 data series to measure the degree of infrastructure resilience of the city. Resilience of most infrastructures is expressed in terms of a loss factor. Take for instance the electrical energy loss factor. If “a” is the estimated number of days to restore regular service areawide and “b” is the percentage of user accounts affected, then the electrical energy loss factor is given by “a” times “b”. Example: for a 1.5 day’s loss of service for 10% of user accounts in a city, the electricity loss factor is 15 percentage days; for a 3 days’ loss of service for 50% of user accounts in the city the electricity loss factor is 150 percentage days. The database uses similar loss factors for water/sanitation, electricity, gas, road, rail, airport, river/seaport, bus/taxi, and communications.

Besides that, the database uses a critical asset loss factor which, for electricity, is called electricity critical asset (ECA) loss factor. This relates only the critical assets that are lost. If “a” is the estimated number of days to restore regular service areawide and “b” is the percentage of critical assets affected, then the ECA loss factor is given by “a” times “b”. Example: for a 3 days’ loss of service for 50% of critical assets in city, the ECA loss factor is 150 percentage days. A critical asset is any asset for which a loss factor is being monitored (see above). Thus, critical electricity supplies are those electricity supplies that maintain the water/sanitation, electricity, gas, road, rail, airport, river/seaport, bus/taxi, and communications services in operation. The ECA loss factor is smaller or equal to the electricity loss factor. Critical asset loss factors are calculated for water/sanitation, electricity, gas, road, and communications.

For some infrastructures, a cost of restoration factor is calculated. This is the likely cost of lost service and restoration as percentage of annual billed revenue. It is a disaster cost borne by the service provider. Such cost of restoration factors are calculated for water/sanitation, electricity, gas, bus/taxi, communications.

Besides these loss and restoration factors, some other indicators are collected, relating to bed days lost, critical bed days lost (e.g. in hospital services), loss of teaching time, loss of education data, continuity of computer systems and data critical to government continuity.

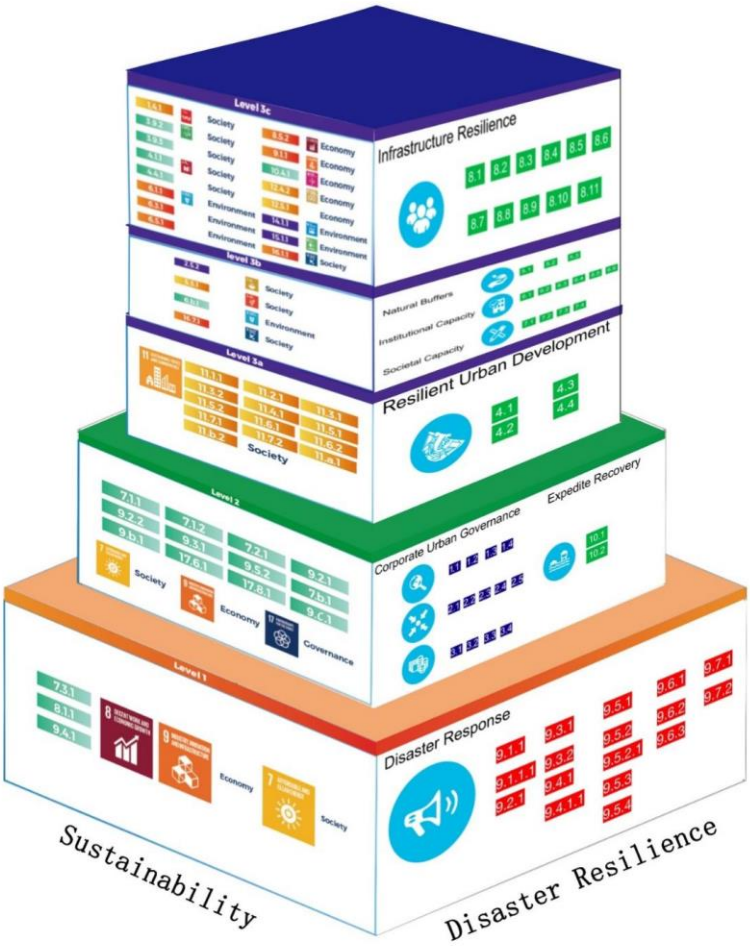

Figure 74: Sustainability and Disaster Resilience Data in the APEC CityStats Database

Source: APSEC

3.2. Case Studies of APEC Cities

3.2.1. Cities in Transition to Carbon Neutrality: The Case of San Francisco

Authored by Fan Dai, California-China Climate Institute.

This report is shared as a summary of the understanding and research made on the topic of climate policies and targets, focusing specifically on the San Francisco Bay area. We hope that sharing this knowledge is helpful for cities wishing to decarbonize.

Cities play an important role in the transition to carbon neutrality. First, cities host more than 56% of the world population and account for about two thirds of the global carbon emissions, while they are producing around 70% of the world GDP. Further, considering the surface areas of cities, they only occupy about 2% of the land surface while they are consuming about 70% of global resources and energy and produce about 70% of the wastes. In other words, cities are concentrated hubs of large amounts of population consuming considerable amounts of energy and resources but are small in terms of land surface. Coastal cities like San Francisco are at the frontier of diverse climate change impacts, such as extreme heat, flooding and drought. People located in Hong Kong, China are also vulnerable by these types of events that have been experienced more frequently in the past few years. Facing these events, many cities have published or are publishing their carbon neutrality targets or pledges, but a lot remains to be done to ensure effective actions to achieve those targets. These are a few facts that are important to keep in mind when talking about cities and their role in the transition to carbon neutrality.

The case of San Francisco plays a pioneering role of climate actions in the State of California, just like the role that California plays in being a pioneer of climate actions in the U.S. and globally. The fact that San Francisco is at the frontier of the regional, state and local actions, can be seen in how it has reduced the emissions by about 30% below the 1990 level while it has increased its population by 20% and doubled its GDP in the last 20 years. California has nine counties in the northern Bay Area and San Francisco is one of those. San Francisco is proving that aggressive climate goals could be achieved while the economy, as well as public health and the environment for residents remain healthy. This analysis will deepen about what exactly is happening in San Francisco, and how that could be a reference for what could be done in other cities.

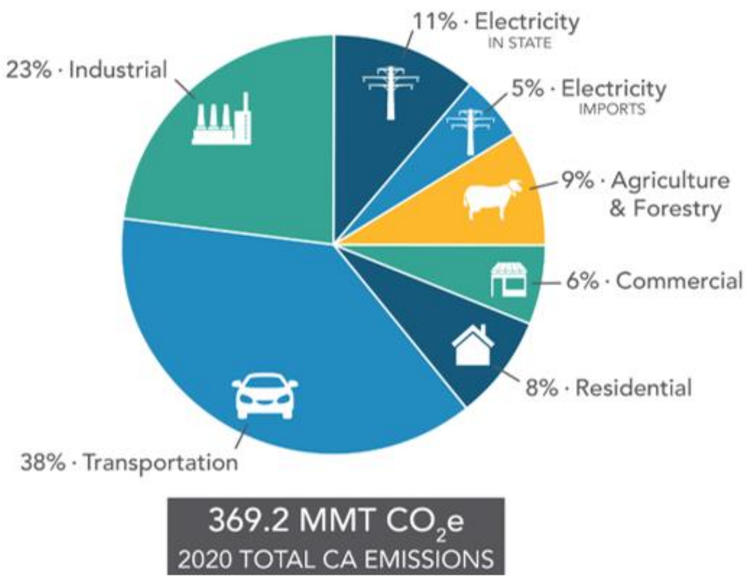

Figure 75: California’s GHG Inventory, 2020

Source: California-China Climate Institute

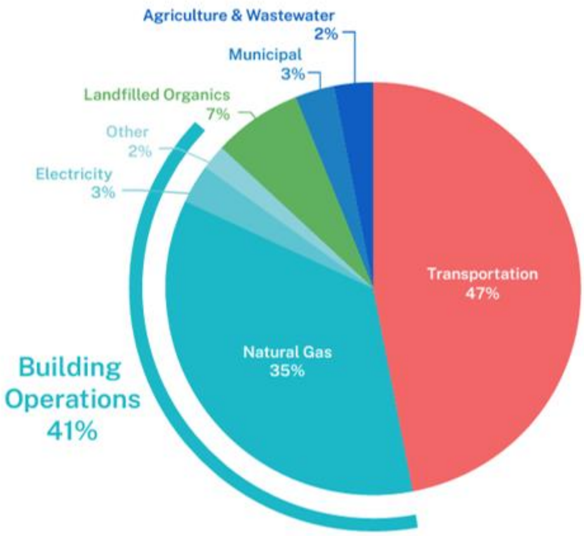

Figure 76: San Francisco's GHG Inventory, 2019

Source: California-China Climate Institute

The above images of emission sources represent the inventory for California as a state, and the inventory for San Francisco as a city, respectively. In these two charts, the common element is the transportation share in terms of percentage accounting for total emissions. Transportation represents 38% and 47% of total emissions of California and San Francisco, respectively, and is therefore the biggest share. This raises the question of what can be done to electrify transportation. But the second figure shows under the heading of building operations, a term that includes gas and electricity, that buildings consume a lot of energy and produce a lot of carbon emissions. In San Francisco, buildings are the second biggest source of emissions after transportation. As a third point to be raised, there are a lot more actions to be taken in terms of the green shipping industry, given that San Francisco is also a big port, receiving a lot of goods from other economies, particularly from China across the Pacific. Some actions are deployable in other coastal cities that are showing a similar situation or having similarly big shipping portfolios in their industrial sectors.

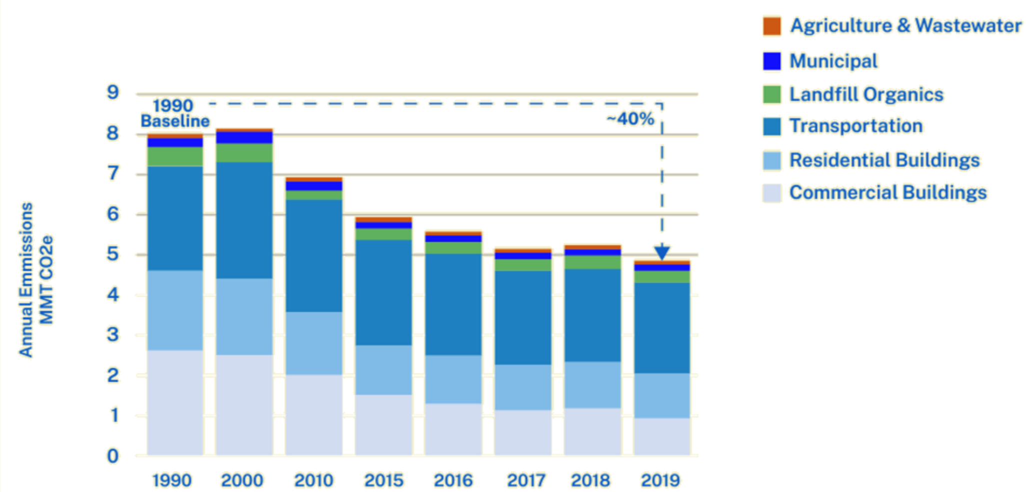

Figure 77: Emissions from Baseline (1990 to 2020)

Source: California-China Climate Institute

The figure above is an emissions chart from the baseline year 1990 to 2019, which is the latest data available today. As shown in the figure, San Francisco is a city which has peaked its emissions. Some cities in developing economies, and particularly cities with a huge population, may not be peaking yet, but once a city has peaked, the downward trend will start. In San Francisco's case, the downward trend is relatively stable pointing downward, but as the figure shows, the downward trend can exceptionally be broken for a year or so, as was the case in the year 2018 when emissions again increased a little. This up and down movement cannot be avoided. In general, once the emissions peak in the city and the city has sufficiently aggressive climate action and plans in place, the projected emission will normally be decreasing from the point where they have peaked.

Going back to what exactly San Francisco has committed for carbon neutrality, there are a couple of things to identify, and this gives us a better idea of where exactly that fits in the global and regional picture. At a global scale, driven by the Paris Agreement and the 1.5 degrees scenario, carbon neutrality by mid-century has often been promulgated. Most of the parties to the Paris Agreement have committed to carbon neutrality by the mid-century to keep the temperature rise within 1.5 degrees. Against this background, California has taken the commitment of net zero for 2045. San Francisco is even more ambitious than California, setting the net zero goal for 2040. Compared to California, San Francisco's 2040 net zero is more ambitious; the city has progressively adopted ambitious policies to reduce emissions while simultaneously decoupling emissions from economic growth. That is the kind of basic logic here.

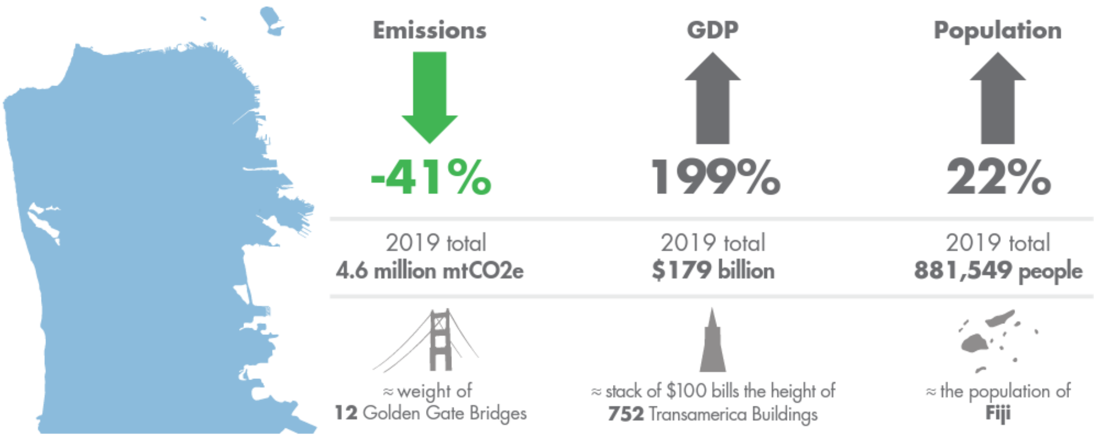

Figure 78: Emissions, GDP and population trends of San Francisco 1990 to 2019

Source: California-China Climate Institute

Since 1990, San Francisco already reduced emissions by 41%, while its GDP has grown by 199% and its population has grown by 22%. These developments are illustrated in the figure above. The weight of emissions reductions shown in the figure equals 12 times the weight of the Golden Gate bridge. The additional GDP produced is equivalent to a stack of USD100 dollar bills of the height of 752 Transamerica Buildings, and the population increase during the 1990 – 2019 period is equivalent to the population of Fiji. This illustrates how, in the last decades, environmental action has coincided and even driven economic growth. That's the key message here for a lot of cities that are still facing resistance about adopting those aggressive targets on emission reduction as well as other measures to really cut their emissions in the key emitting sectors.

YEAR	MILESTONE
2004	San Francisco's First Climate Action Plan
2013	San Francisco's updated Climate Action Plan
2015	0-50-100 Roots Climate Action Framework Launched
2016	Emissions Reduced by 30% Below 1990 Levels
2017	50% Low Carbon Trips Achieved – New Goals Set to 80%
2018	Mayor Breed Commits to Net-Zero Emissions by 2050
2019	San Francisco Board of Supervisors Declares a Climate Emergency
2019	100% Renewable Electricity Requirement for Large Commercial Buildings
2019	Emissions Reduced by 41% Below 1990 Levels (6 years ahead of schedule)
2020	Natural Gas Banned in New Construction
2021	Mayor Breed Advances Updates to Climate Action Goals in Chapter 9 of the Environment Code, Commits to Net-Zero Emissions by 2040, San Francisco Board of Supervisors Approves

Figure 79: Policy Milestones

Source: California-China Climate Institute

Back in 2004, California has adopted aggressive energy efficiency standards that are often called performance standards. This means setting a low bar for buildings. These efficiency standards were accompanied by the clean fuel standards tackling the transportation sector to meet those minimal standards for cars. As a result, emissions were brought down because of those standards. Later, California introduced zero emission vehicles (ZEV) mandates by which incentives were given for driving electric vehicles. After 2007 to 2010, more and more consumers were incentivized to go green energies to due to the cap-and-trade program that was put in place covering first the major electricity sectors and then extended to cover the upstream and the fuels. All these measures helped a lot in bringing down emissions from the transportation sector and from the industrial sector as well.

Considering the policy milestones of San Francisco, the city in 2018 committed to its net zero emission goal by 2050. In 2021, the net zero emission goal has been moved forward to 2040. Within less than five years, there has been a huge enhancement of the ambition, obviously supported by evidence of what could be achieved and supported by a well-designed suite of policies for those targets to be matched today to the city. The US federal administration and Congress are prioritizing climate action. But cities are still playing a really important role here. In the case of San Francisco, the city has created plans for implementing the policies and crafted those community engagement frameworks to address climate change and mitigate the impacts of both air pollution and environmental stressors. And some of those key milestones here are highlighting the sort of the path the city has gone through. As of today, the target of 2040 carbon neutrality and net zero emissions is already being legislated. It is in the city's environmental code and has, therefore, an enforcement mechanism, making it accountable.

This story is not just about some targets that are being pledged and could be replicated elsewhere. It's also about setting a good example for cities that are seriously considering making targets and making sure they can achieve them in the end of day. At that point, some kind of legislation will be necessary and helpful to support the achievement of the ambition and the end goal.

Take the example of the climate emergency declared by San Francisco in 2019. In the past, before climate change was high on the agenda, we used to refer to climate change as global warming. At that time, nobody linked those climate disasters to the human impact already caused by climate change. The first time San Francisco did this was when the scale and the size of the impacts reaching the population and the economy were bigger and bigger. In 2019, San Francisco had a time of very severe droughts as well as wildfires, the situation was extremely bad, air quality level was not healthy to the point people had to be kept indoors to be prevented from air pollution, and this was happening frequently in the region, not just the city of San Francisco, but also the surrounding areas like in Southern California and Northern California. That's when the city supervisor decided to declare the climate emergency because the state, and particularly the city, were being vulnerable, and the disasters were impacting people's everyday lives. By the way, the climate emergency has never been repealed since 2019, posing an important element of the context for setting the ambitious goals adopted thereafter.

The new target was released by the mayor in 2021 to achieve for San Francisco to become a net zero emission city by 2040. It was following months of community engagement that the city has conducted, where a lot of feedback has been collected from grassroots organizations, individual citizens, and where the detailed plan delivers a clear pathway across several sectors to eliminate the city's remaining carbon emissions by 2040.

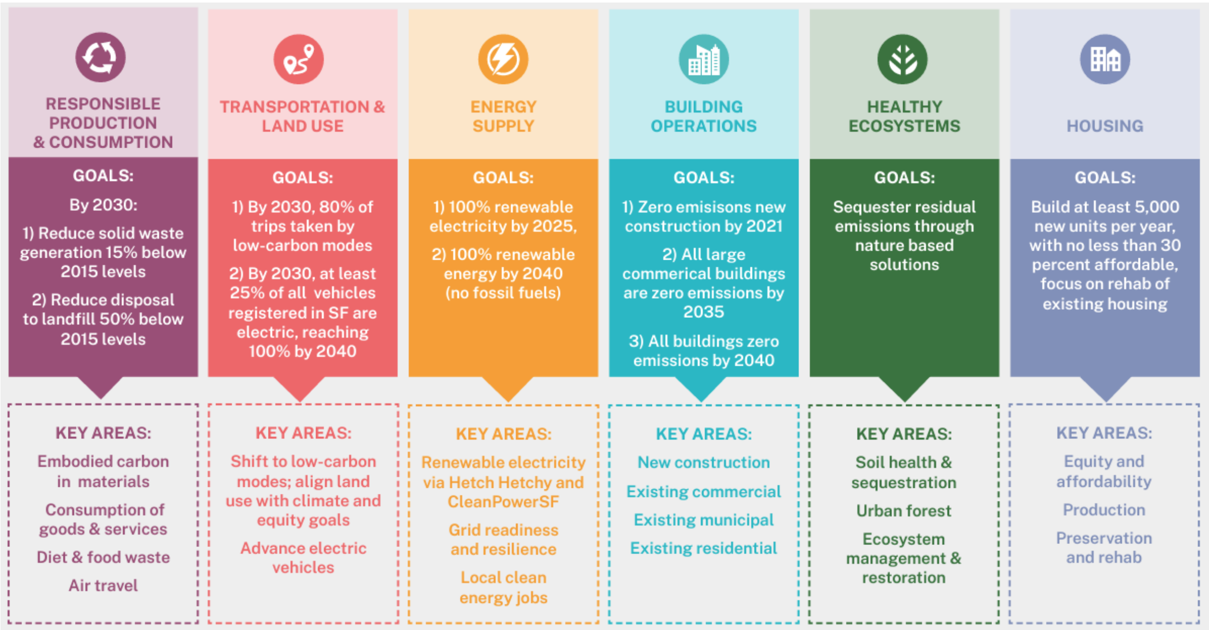

Figure 80: Policy Goals

Source: California-China Climate Institute

Looking into the road map implies giving a snapshot of how the city is tackling its carbon neutrality target by a suite of different policies put in place, disaggregated by subsectors. These may have different goals each, even though the city has planned to take a comprehensive approach already by implementing all these goals. The figure above shows the subsectors, together with their sectoral goals to be achieved along the lines of near-term, mid-term and long term. These are the most promising sectors. Just to highlight a few of them hereafter:

- Circular economy: the goal is to reduce solid waste generation by the year 2030 by 15% over 2015 levels and reduce the disposal to landfill by 50% over 2015 levels by 2030. The sectors for which his goal is most important have been identified; among them the food industry and the air travel industry. In terms of public consumption and production, there is a measure being put in place to reduce food waste and embrace plant diets.

- Transportation and land use: By 2030, 80% of trips should be taken by low-carbon modes, and 25% of vehicles registered in San Francisco should be electric vehicles, reaching 100% by 2040. Among the measures to be taken in the transportation and land use sectors are investments in public and active transportation projects, increased density and mixed use the land near transit so people can start driving less by taking public transportation, accelerating adoption of zero emission vehicles and expansion of public charging infrastructure, utilizing pricing levers to reduce private vehicle use, minimize congestion and implement and reform parking management programs.
- Energy supply should go over to 100% renewable electricity by 2025 and phase out all fossil fuels by 2040. The creation of local jobs in the clean energy industries will go hand in hand with this development.
- For building operations, the goal is to bring down emissions of new and existing buildings. New buildings should already be zero emission as of 2021, large commercial buildings by 2035, all other buildings by 2040.
- Healthy ecosystems: San Francisco has several measures taken here to ensure maintaining a healthy ecosystem, including enhancing and maintaining the urban forests and open space in San Francisco, the state parks and green space that will be readily maintained to keep up and help maintain the public health and healthy ecosystem in urban areas. Some of these nature-based solutions (NbS) are shared and common in other cities like in New York.
- Housing: Housing, which has often been referred to as the big headache because, on the one hand, housing price is high in the Bay Area in general; and on the other hand, the energy efficiency level in the housing is low because a lot of houses in this area are outdated. Only new buildings satisfy the Title 24 Codes, whereas existing ones are facing a lot of pressure to increase their energy efficiency levels. For housing, it needs to increase compact housing production near transit stations as well as raise the efficiency levels of the existing houses, including public housing.

To resume, this is a comprehensive plan that has already been adopted, and its implementation progress is quite robust. Within the plan, there is a robust analysis, which, by different projections and different years, gives a very detailed picture outlining what will be done. And if those measures are being taken effectively, it shows what results they will lead to. These measures are expected to lead to improved health and a reduced air pollution, reducing pollution both indoors and outdoors, and to increased community resilience from accelerating disasters. As a coastal city, San Francisco has become aware of drought situations and flooding disasters. Improving the resilience and the resource access of communities, particularly those advantaged communities in the city, has been a big topic in the plan as well as in the process of making the plan. A lot of workshops and stakeholder meetings have been conducted to make sure these communities are actively engaged and are included. Nobody being left behind, the decision-making process, which is worth highlighting and worth looking at, should be addressing different income groups. In the example of San Francisco, important groups are race and different age groups. To ensure that they were all being considered in this process was important, and San Francisco has done a good job by including the diversity of those groups in its goals.

Figure 81: Policy Goals

Source: California-China Climate Institute

Lastly, we should mention the resilience dimension, because San Francisco has a very long-standing relationship with natural disasters, not just earthquakes that happened in the early nineties, but also other natural disasters or what are called climate impacts, like extreme heat events and reduced air quality caused by air pollution from wildfires in the recent years. These impacts, as well as other threats such as coastal flooding and droughts, are projected to increase in this area in their frequency and severity in the coming decades. Resilience is an important aspect of the climate plan of San Francisco, and because of the overlap between climate resilience and other efforts such as pandemic and earthquake proof buildings, preparedness, readiness and fire safety and other efforts, the city has taken a more comfortable, robust and more holistic approach in addressing the community resilience as a whole.

What the city did was promulgating a plan which is called the Hazards and Climate Resilience Plan (HCR Plan), consisting of a resilience plan across different agencies of the city, which was adopted by the city water supervision back in 2020, identifying hazards and associated vulnerabilities and consequences and presented strategies to reduce risk and adapt to those unavoidable climate impacts. This approved plan, shown in the figure above, is key for the city to build up its climate resilience and readiness to face some of those natural disasters that could be caused by climate. And to highlight two impact areas that have been assessed while the plan was put together: One is on adaptation (left side in the figure) and the other is on mitigation side (right side in the figure). For the community, adaptation, resilience, information and services available were based on the lessons learnt from concrete events, including extreme events, that happened before and could be happing again in the area. On the right side is shown what could be done to bring down emission levels to reduce the frequency and the severity of those climate disasters that could happen in this area.

While the San Francisco economy has grown considerably, it has also seen some of the widest income disparities appearing, and that is what often is addressed in climate justice. What has been done up to now in San Francisco is benefiting the whole society, not only some small groups. The centre shows some elements of the Just Energy Transition. This is how the adaptation and mitigation aspects of those policies are going hand in hand and making sure that the communities that are most vulnerable in this area are covered and prepared for those disasters.

Concerning the social and political conditions necessary for adopting the ambitious targets and measures outlined above, two different driving forces have played a role. Firstly, there was a political process, driven by the mayor and her staff which has been really the big driving force behind it, also the city council who has appointed their staff to be responsible for different aspects of the plan. And the mayor elaborated the plan, which was formulated across different agencies. It is a pretty robust and very well supported plan put together by the city. At the political level, the biggest driving force has definitely been the mayor and her crew at city level. But more broadly, the communities were also represented in the process. San Francisco is like some of those Bay Area cities, including Hong Kong China and others. It is very close to Silicon Valley where there are a lot of big companies who were also part of this process. Therefore, in a wider sense, most of the economy was also part of this process. It was clear that they all agreed that it was an urgent task to set the target of carbon neutrality for 2050 then later to move it forward to ten years earlier.

3.2.2. Strategies for Clean Energy and Transportation: The Case of the Greater Washington Region Clean Cities Coalition

Authored by Antoine M. Thompson, Greater Washington Region Clean Cities Coalition

The Greater Washington Region Clean Cities Coalition is headquartered in Washington DC and covers DC, Maryland and Virginia. It is a Public Private Partnership (PPP) focusing on clean transportation, environmental protection, air quality, and environmental justice. The fact of being a PPP plays an essential role in facilitating the dialogue between all actors involved in the electrification of buses and trucks, namely private sector car manufacturers, battery manufacturers, public sector agents of cities and towns promoting the EV infrastructures, and user groups such as schools, hospitals, shopping malls and so on. The GWRCCC is a non-profit organization that has been created in 1993 by President Bill Clinton. This is one of over 75 organizations working closely with the US Department of Energy and other Federal and local agencies stretching from DC all the way to Hawaii. Since 1993, the GWRCCC has avoided 13 billion gasoline gallons equivalent (corresponding to approximately 42,250,000 tons of oil equivalent).

The services of the GWRCCC include education and training, programs and events, deployment of vehicle technology, fleet coaching (the US fleet is causing more than 25% of US greenhouse gases every year), providing funding opportunities and assistance, advocacy, public and private partnership development, business opportunities, networking, community engagement and service.

The priorities of the GWRCCC are supporting members and partners, strengthening member services, helping to secure funding and grants for local communities from the Bi-Partisan Infrastructure Law and Inflation Reduction Act (in the US, all politics is local), equity initiatives, training fleet managers, members and public and private sector leaders, providing a vision and leadership, legislative advocacy in climate, energy and transportation policies, deployment of vehicle and building technologies and infrastructure, promote fuel diversity (any fuels that can help reaching the net zero goal), and support emerging technologies. The last years have seen a large development of new technologies in this direction.

Among the GWRCCC programs and projects are the Mid-Atlantic Electrification Project, the Mid-Atlantic Electric School Bus Experience Program, fleet training and education, climate solutions involving biodiesel and green hydrogen, workforce development (which is specially needed in times of transition), education and technical assistance, environment justice and racial equity events and initiatives which addresses low air quality and insufficient daily transportation needs of disfavoured communities. With these programs and projects, the GWRCCC will help installing over 375 level two EV charging stations servicing shopping centres, community centres, office buildings, hotels in the region over the next two years. GWRCCC is also deploying 12 fast charging level three EV charging stations in the District of Columbia, allowing to charge a vehicle in about 15 to 30 minutes.

Figure 82: Inauguration of an EV charging station in the Greater Washington Region

Source: GRWCCC

The Mid-Atlantic Electric School Bus Experience Program is working to electrify the school buses of the region, offering riding drives for education. This is part of a major US clean school bus initiatives to which over USD5 billion have been allocated over the last 5 years. It is based upon a Federal 3-year grant from the US Department of Energy complemented by local funding, involving fleet manager and staff education and training, programs and events, advocacy, public and private sector project development, business opportunities, networking and community engagement. The program involves buying 100 cars for a ridesharing company. The present fleet of US school buses consists of diesel vehicles which are known to pollute the air. The program involves replacing them by electric school buses.

Through funds granted by the Environmental Protection Agency's Diesel Emissions Reduction Act (DERA) program, GWRCCC and DC Water have secured funds to purchase an additional 12 trucks equipped with Optimus Technologies' 100% biodiesel (B100) advanced fuel system technology. Using B100 allows DC Water to reduce their Scope 1 CO_2 emissions in their heavy-duty fleet vehicles by over 90%.

Figure 83: Electric school bus and biodiesel truck

Source: GRWCCC

The Bi-Partisan Infrastructure Law, officially known as Inflation Reduction Act, further enhances the industrial capabilities of the cleantech transportation industry of the United States. The law provides for making historic investments in biofuels, propane, hydrogen, natural gas, electric vehicles EV charging, and renewable energy. It will provide USD21.5 billion in funding for clean energy demonstrations and research hubs, including:

- USD8 billion for clean hydrogen, USD10 billion for carbon capture, direct air capture and industrial emission reduction
- USD2.5 billion for advanced nuclear
- USD1 billion for demonstration projects in rural areas and USD500 million for demonstration projects in economically hard-hit communities
- USD5 billion for clean school buses
- More than USD7 billion in the supply chain for batteries
- Additional USD1.5 billion for clean hydrogen manufacturing and advancing recycling RD&D
- Create a new USD750 million grant program to support advanced energy technology manufacturing projects in coal communities.

3.2.3. Energy Transition: Temuco's Challenges to Mitigate and Monitor Black Carbon

Authored by Patricio Figueroa Espindola, Head Environmental Department, Temuco City, Chile

Introduction

The population of Temuco is approximately 300,000 citizens. This city corresponds to the Capital of the La Araucanía Region and is located 678 km south of Santiago de Chile. According to the Temuco Local Energy Strategy (Since 2016), energy consumption corresponds to approximately 26% electrical and 74% thermal, caused mainly by the high thermal demand of homes, during 8 cold months each year. This means that Temuco's central environmental problem lies in a scenario of energy poverty, which has persisted for many years. This same scenario is repeated throughout central-southern Chile:

- ✓ Poor thermal insulation
- ✓ Use of Old Stoves (no new standard)
- ✓ Solid fuels such as wood, with a high percentage of humidity.
- ✓ Ignorant users on issues such as air quality and energy efficiency.

Likewise, 81% of homes in central and southern Chile consume firewood and its derivatives for heating. In the case of Temuco, atmospheric emissions derived from residential combustion of firewood contribute approximately 94% of particulate matter emissions 2.5. Each year, in Temuco and Padre Las Casa, approximately 600,000 m3 of firewood are consumed, most of which have humidity percentages greater than 25%, which favours incomplete combustion processes. Atmospheric emissions from residential firewood combustion constitute a large contribution to Black Carbon emissions globally. In this sense, domestic energy represents 43% of global black carbon emissions worldwide. a short-lived climate forcer, which warms the atmosphere by effectively absorbing light, exacerbating the warming of air and surfaces in the regions where it is concentrated, altering climate patterns and ecosystem cycles. Although black carbon lasts only days to weeks in the atmosphere, it produces significant direct and indirect impacts on climate, snow, ice, agriculture, and human health. In addition to having a warming impact up to 1500 times stronger than CO2.

Temuco has concentrations of hazardous air pollutants five times higher than the WHO limits. According to the Atmospheric Decontamination Plan of Temuco and Padre Las Casas for particulate matter 2.5, limits are established to classify air quality according to 5 categories (Table below).

Classification	Daily average limits to PM 2,5 (Ug/m3)
Good	Lower than 50
Regular	50 - 79
Alert	80 - 109
Pre-Emergency	110 - 169
Emergency	Higher than 170

Table 24: Average Limits for Particulate Matter Concentration PM2.5

Source: Atmospheric Decontamination Plan for Temuco and Padre Las Casas

Black carbon under the economy-wide gaze

The update of the Nationally Determined Contribution (NDC) of Chile 2020 recognizes the importance of the PNP to achieve carbon neutrality by 2050 and is committed to the goal of reducing emissions of this pollutant by at least 25% by 2030, regarding to the base year 2016.

(Gallardo et al., 2020). The NDC estimates total NC emissions for Chile at 10.2 thousand tons in 2016, with the residential sector responsible for 36% (Figure below).

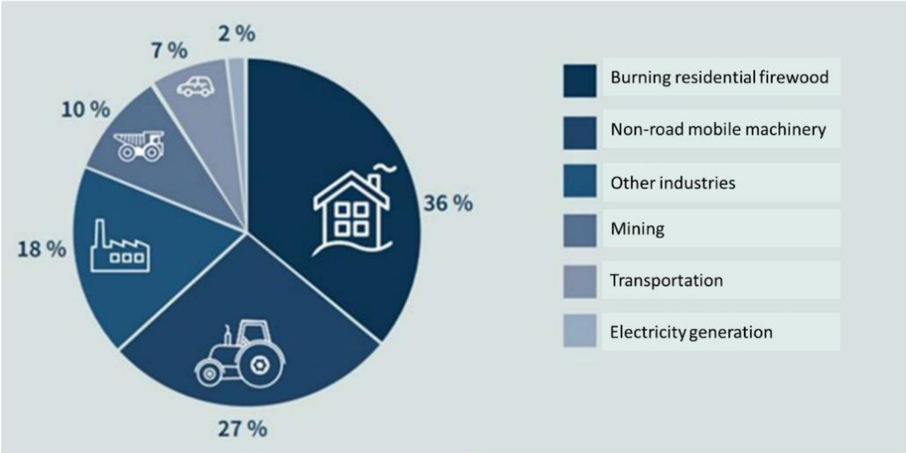

Figure 84: Sectoral distribution of black carbon emissions in Chile for the year 2016

Source: Gallardo et al., 2020[404]

In 2020, total NC emissions reached 19.8kT, which represented a 49% increase since 1990 and a 6% increase compared to 2018 (table below). The trend of the series is dominated for most of the period by emissions resulting from the burning of fossil fuels and biofuels, which are accounted for in the Energy sector. However, in some years (1998, 1999, 2002, 2014, 2015 and 2017) the emissions derived from forest fires, accounted for in the LULUCF sector, change the trend of the series, becoming an important part of the emissions of CN at the economy-level. The latter is clearly reflected in 2017, where the economy's total emissions reached 31.4kt of CN and emissions from forest fires reached a level similar to emissions from the Energy sector.

Sector	1990	2000	2010	2013	2016	2018	2020
1.- Energy	11,38	14,68	15,03	16,83	17,05	16,98	16,7
2.- IPPU	0,01	0,01	0,01	0,01	0,01	0,01	0,01
3. Agriculture	0,73	0,49	0,28	0,31	0,36	0,36	0,29
4. LULUCF	0,91	0,43	0,91	0,25	1,03	0,84	2,43
5. Waste	0,22	0,24	0,32	0,36	0,38	0,42	0,34
TOTAL	**13,25**	**15,86**	**16,56**	**17,77**	**18,84**	**18,61**	**19,77**

Table 25: National Black Carbon Inventory of Chile

Source: CN (KT) emissions by sector, 1990-2020 series[405]

Environmental impacts of black carbon

The characteristic that makes black carbon a substance of climatic relevance is, first of all, its ability to absorb solar radiation, leading to warming. On a global scale, black carbon is estimated to give rise to a forcing of between approximately 0.2 and 1W/m2 (Gustafsson and Ramanathan, 2016), which, in the upper range, is of the same order of magnitude as the forcing global by carbon dioxide but, as its atmospheric residence time is a few days, its mitigation has an immediate effect on its abundance in the climate system (Masson-Delmotte et al., 2018; Stocker et al., 2013). It should be noted that at the regional level this forcing can be up to double the global average, for example (Mallet et al., 2016; Mena-Carrasco et al., 2014). Second, black carbon can affect cloud formation and abundance by altering atmospheric stability or acting as a condensation nucleus for water and ice clouds (Bond et al., 2013; Boucher et al., 2013). Third, when deposited in the cryosphere, black carbon can make surfaces more absorbent and accelerate fusion processes (Ménégoz et al., 2014; Molina et al., 2015; Rowe et al., 2019). The above is graphed in figure below.

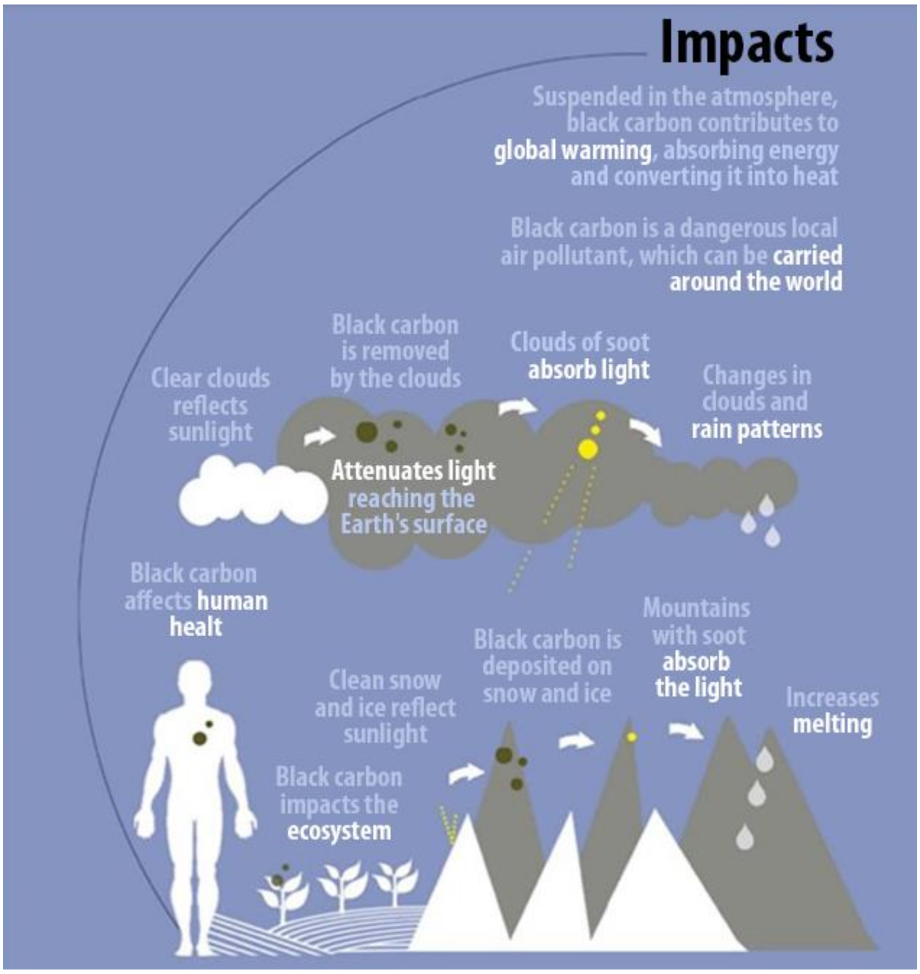

Figure 85: Scheme of the multiple impacts associated with black carbon

Source: Temuco City

Main challenges for black carbon mitigation

As described previously, among the main challenges to mitigate black carbon in Temuco are the increase in the pace of thermal improvement of homes, the increase in the replacement rate of heaters and the development of district energy generation projects.

a) Thermal Improvement of Homes

Temuco currently has an estimated stock of 80,000 homes, of which today approximately only 25% have thermal improvement according to legal standards. The development of this measure is considered structural because a home that has thermal improvement reduces its energy demand. Furthermore, in the process, it reduces the activity level of the heaters and therefore, atmospheric emissions are reduced.

b) Replacement of heaters

Since 2015, Chile has had a standard for heaters; today, it is estimated that through the Heater Replacement Program of the Ministry of the Environment, approximately 15,000 units of the 27,000 committed have been replaced, equivalent to 55% and approximately 30%. of the total number of heaters. This action makes it possible to replace the use of technology that runs on wood with another that runs on pellets, electricity, or another cleaner fuel.

c) Development of District Energy Projects

As is known, heating in homes in the south-central area is supplied by individual systems such as wood stoves, which in most cases are inefficient and do not have emissions control, to which is added the poor quality of the fuel. such as wet firewood, generate enormous environmental impacts in terms of air quality, due to the existence of thousands of polluting sources in a city that emits particulate matter in large quantities and for prolonged periods of time.

A district energy system replaces thousands of polluting sources, delivering clean and sustainable energy, so by eliminating polluting sources, large quantities of particulate matter are no longer emitted, and can even eliminate 99% of the pollution generated by an individual source. To the extent that more users in the residential sector connect to the system, more pollution will be reduced, which would contribute significantly to the improvement of the city's air quality, and therefore to the health of the population.

A district heating project evaluated in the city of Temuco, which covers around 10,000 users, would reduce 575 tons of PM10 particulate matter per year, which is equivalent to 11% of the PM10 emissions of the entire city. This would produce avoided health costs equivalent to 21,000 million pesos annually.

Main challenges for monitoring black carbon emissions.

Given its high contribution to the impacts of the greenhouse effect, it is considered extremely relevant to be able to develop an inventory of local black carbon emissions in Temuco, which would constitute a precise base scenario to carry out management with mitigation actions. Likewise, it is considered pertinent to develop monitoring stations to measure black carbon concentrations in Temuco. In this sense, there should be at least one optical black carbon monitor, such as aethalometers or multi-angle absorption spectrometers, in at least one station of each urban surveillance network. This would be complementary to compositional characterization, e.g., (Barraza et al., 2017), preferably segregated by size of fully respirable aerosols, e.g., (Tagle et al., 2018). This equipment can be implemented in the same 3 Monitoring Stations where atmospheric pollutants such as particulate matter 2.5 are currently measured in Temuco.

On the other hand, black carbon monitoring efforts by municipalities are considered extremely relevant, because they can enjoy greater budgetary autonomy than ministerial state bodies when executing the investment.

4. Conclusions and Recommendations

4.1.1. Conclusions

In conclusion, this report shows that carbon neutrality has originated in 2008 when a handful economies, cities and corporations made first commitments to this principle. Since then, carbon neutrality commitments have developed to such an extent that greenwashing has become the main issue. It can be considered as a rare phenomenon that the UN decides to phase out its Climate Neutral Now Initiative and replace it by the Race to Zero and Race to Resilience.

The problem is that commitments alone do not diminish the atmospheric CO2 concentration which continues to rise by 2ppm every year and has now overtaken the 420ppm mark, sensibly higher than the levels of the past million years.

The biggest challenge for cities to become carbon-neutral is the density challenge. The particularity of cities is to be dense places of habitat, which may heavily conflict with the land area required for carbon neutrality. The solution presented in the monitoring sections of the report proposes that cities should produce the basic electricity requirements for Decent Living Standards, quantified as 5MWh/person/year (equalling 570W/person) locally and satisfy the remaining energy needs by production outside their territory. For most APEC cities, this will mean planning PV panels (net area values) between 15m2/person and 25m2/person, to be set up within the city territory, depending on the irradiance of the place where the city is located. Some highly densely populated cities such as Manila will have difficulties to meet this principle. A less stringent requirement is formulated in the principle that the net percentage of land area used for PV generation should be at least 30% of the total area of the city. This suggestion is taken in analogy of the first of the Five Principles of sustainable neighbourhood planning published by UN Habitat, stating that at least 30% of the urban area should be reserved to build an adequate space for streets and an efficient street network. Cities should combine both above principles with other solutions proposed in the monitoring section. To maintain their energy security and increase disaster resilience, cities should monitor the production of renewable electricity outside their urban area as well as electricity storage. Ideally, cities should also monitor their energy intensity, the share of green economy in the economy of their city, and key parameters of green finance used in their city, such as the green-debt-green-equity ratio.

Another challenge for cities is the collection of relevant data. The requirements for high quality data may include collection at regular time intervals, at least annually; some cities introduce already daily near real-time data collection. Data should be related to the geographic information system (GIS) so that it can be cross-checked by remote or satellite-based data collection which is anonymous and available in large quantity. Australia is the first APEC economy having created an Open Data Cube in 2017, making data available in a user-ready format on open-source software (Python, GitHub). The definition of “city” worldwide is a highly elastic term designating communities between 200 and 50,000 inhabitants and, in some cases, adding minimum density requirements. Data standardization has been achieved in several ISO standards in cooperation with the Council on City Data (WCCD). Unfortunately, all the data collected by WCCD is confidential and proprietary and is being shared only among the WCCD member cities. This does not satisfy the recommendation of the UN on public access of information. Scientific analysis further requires that data should be made available in machine-readable format such as Excel or CSV files. Data collection should also remain cost-effective and affordable for cities. This is best achieved for accounts-based indicators which is the kind of data that is part of an accounting standard requiring sustainability disclosure such as the Global Reporting Initiative GRI or environmental, social and governance (ESG) aspects.

Cities have multiple ways to create green finance for becoming carbon neutral. The most important source of green finance is carbon pricing mechanisms. They reflect the "polluter pays" principle, either by carbon taxes or by emissions trading systems. Unfortunately, as the "carbonomics" section of the report points out, carbon pricing is still a limited phenomenon. The systematic use of carbon pricing would not only correct today's wrong price incentives given to economic agents, but also collect the amount of resources equivalent to 5% global GDP that are necessary for green energy investment to drive the world towards carbon neutrality. Cities could create voluntary carbon markets and use their proceeds to generate local green finance (green equity, green bonds) invested in renewable energy capacity. Two mechanisms to finance energy efficiency without upfront cost are PACE (Property assessment for clean energy) and PAYS (Pay-as-you-save) programs, both being the most impactful pathways to install various types of low-carbon equipment – cooling being one of them – with no upfront cost. Four elements of success for circular smart cities are a viable business case (e.g. Product-as-a-Service, Industrial Symbiosis, Closed Loop, Upcycling and Downcycling), infrastructure (including financial infrastructure), education (including creation of green skills) and a mindset that interiorizes circular economy.

Credit risk guarantees are an instrument used as a tool to de-risk renewable energy projects and make them competitive compared to conventional energies. The theoretical analysis determines factors on which depend the optimal credit guarantee ratio for renewable energy (RE) loans. CRGs can be used to back green bonds, in conjunction with data-driven risk assessment, sustainability linked lending, green finance certification, and regulatory sandboxes experimenting with innovation. The Philippines and in particular the Metropolitan Manila region could benefit from pushing cities to create green equity and emit green bonds backed by credit risk guarantees, and from allowing cities to participate in internationally competitive renewables tendering and concluding power purchase agreements (PPA) for their supply. Credit risk guarantees might be a possible tool allowing cities to cooperate with international financial institutions. The discussion about setting up a regional APEC-wide credit risk guarantee could be held within APEC Energy Working Group and involve cross-fora cooperation as well as the participation of both, cities and international financial institutions.

Sustainability accounting for corporations is divided into two very different approaches. The better-known among them is the investor-oriented environmental, social and governance (ESG) disclosure which requires corporations to disclose how factors from outside affect the enterprise, especially its cash flows (outside-in approach). There is considerable disagreement among ESG rating agencies on how they evaluate the same enterprise. The other approach is the broader inside-out approach incorporated by the Global Reporting Initiative (GRI). It attempts to show how the enterprise affects the environment. As cities are non-profit entities, the GRI approach would in principle better suit them than the ESG approach. Sustainability accounting for cities should either make a link to the SDGs, targets and indicators, or attempt to integrate the 9 planetary boundaries and the 12 basic human needs as is being experimented by the City of Amsterdam integrating the two approaches into a doughnut model.

Sustainability accounting questions basic economic concepts such as the GDP and value-added. An alternative GDP that should be called gross holistic product (GHP) is derived by means of an agent-based presentation and the diversification of the current single-type capital (also called "produced capital") to include three supplementary forms of capital: environmental, human and financial. It is shown that the GDP is not displaying the totality of capital formed by agents, but also that a general sustainability indicator called net holistic surplus (NHS) can be derived in this framework and that this indicator allows defining eight categories of (un)sustainable cities.

The CDP runs the world's largest environmental disclosure system for investors, companies, cities, states, and regions. The unified reporting platform for local governments and councils created in 2019 by CDP together ICLEI - Local Governments for Sustainability, is one of the official platforms of the Global Covenant of Mayors for Climate & Energy (GCoM), C40 Cities Climate Leadership Group, WWF's One Planet City Challenge, as well as the United Nations' Race to Zero and Race to Resilience campaigns. The GCoM has created its Common Reporting Framework in 2018. It contains a mitigation pillar, an adaptation pillar and a more recently introduced energy access and energy poverty pillar.

Three cities or regions are reporting case studies. The city of San Francisco is certainly a pioneer among them, aiming at carbon neutrality by 2040. In the past 30 years, San Francisco managed to double GDP, increase population by 22% and diminish emissions by 41%. The key factors for the success of this pathway are the visionary leadership of the city and the close cooperation of economic stakeholders. Due to heavy wildfires the city declared climate emergency in 2019. This has never been repealed and has helped to fix high ambition targets. The Greater Washington Region Clean Cities Coalition was created in 1993 and is focusing on promoting electrification of transport and capacity building. Due to its actions, 42,250,000 tons of oil equivalent have been saved. The Chilean city of Temuco is facing the challenge of high (74%) dependence on firewood heating. Emissions have increased by 49% between 1990 and 2020. An ambitious program of thermal improvement of homes, replacement of heaters and development of district energy projects has been decided.

4.1.2. Recommendations

This report makes recommendations for further action as stated below:

APEC cities should take an active role in shaping their energy supply and storage by public procurement (internationally competitive tendering) financed through the polluter pays principle (tradable certificates on compliance or voluntary markets, incentive taxes) or by the creation of green equity or the emission of green bonds backed by credit risk guarantees.

APEC should organize online or in-person capacity building for APEC cities on these issues within the framework of the APEC Energy Working Group (EWG) or its sub-groups.

APEC Energy Working Group (EWG), in cooperation with the Government of the Philippines, involving APEC cities and International Financial Institutions, may wish to explore the creation of an APEC-wide Credit Risk Guarantee for renewable electricity.

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Urban Energy Report 2023

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Asia-Pacific Economic Cooperation

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Published for APEC Secretariat
35 Heng Mui Keng Terrace
Singapore 119616
Tel: (65) 68 919 600
Fax: (65) 68 919 690
Email: info@apec.org
Website: www.apec.org

Published: June 2024

APEC#224-RE-04.4

ISBN: 978-981-94-0265-6