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Promoting Carbon Neutrality in North Sulawesi

Vision, Targets, Benchmarking and Monitoring

APEC ENERGY WORKING GROUP
October 2024

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Foreword

Planning for carbon neutrality is one of the most complex tasks of our societies. It requires clear science-led guidance in a holistic approach as well as a deep outreach into society. The Multistakeholder Dialogue (MSD) held in North Sulawesi in February 2024 managed to have both. The deep outreach into society was achieved by gathering local representatives from the North Sulawesi Government and its cities and regencies, development and planning offices, stakeholders from local universities, energy, finance, agriculture, food, and women's organizations. Representatives from the central government (Bappenas and Ministry of Energy and Mineral Resources) were actively involved. The science-led guidance and holistic approach was provided by a host of international experts invited to share their knowledge with the local stakeholders.

I have been particularly honoured to participate in, and preside over, this MSD at one of its critical moments: the adoption of the ambitious 2030 targets. This type of forum and its ambition to set long-term targets has been an innovation for the North Sulawesi Province. They were also a learning ground for the way to discuss and elaborate future-oriented policies. Even though the three adopted 2030 targets (energy intensity, carbon intensity and renewables share) as well as the vision for carbon neutrality and disaster resilience are at present simple suggestions stemming from the stakeholders without legal force, we will spare no efforts to find ways for the North Sulawesi Provincial Government to give them legal force. This step is decisive to start mobilizing investment necessary for carbon neutrality.

For local and regional authorities, especially for peripheral ones like North Sulawesi, it is essential to have top quality information on the evolving global context as well as on their own region. No region wants to be left behind. On this point, the MSD has been able to benefit from the set of reliable global long-term indicators made available by APEC Sustainable Energy Center (APSEC). This has shown that if the world is on track to triple the installed renewable capacity by 2030, North Sulawesi should make efforts not to fall behind. This is the true meaning of global benchmarking. The described 6-dimensional monitoring system could further help guiding our province towards carbon neutrality. Concerning local data, the MSD has shown the lack of granular energy and emissions data of the North Sulawesi Province. We will carefully take note of the suggested ways to improve the data collection of North Sulawesi.

We are looking forward to the next steps to be taken after the successful completion of this project.

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Acknowledgements and Disclaimer

This report has been prepared through a collaborative approach. The main author of this report is Mr. Craig James MENZIES (Global Factor International Consulting S.L., Bilbao, Spain) who has authored all the chapters except the following ones: Section 1.3 has been authored by Hizkia H. D. TASIK (Sam Ratulangi University, Manado, Indonesia) and Steivan DEFILLA (APEC Sustainable Energy Center, Tianjin University, China); Section 2.3 and the corresponding annexes have been authored by Hizkia H. D. TASIK (Sam Ratulangi University, Manado, Indonesia), and Chapters 4 and 5 and the corresponding annexes have been authored by Steivan DEFILLA (APEC Sustainable Energy Center, Tianjin University, China).

The authors of this report wish to express their gratitude to the Government of the North Sulawesi Province in Indonesia, as well as to the representatives of its Cities and Regencies who became members of the Cooperative Network of Sustainable Cities in order to facilitate the preparation and implementation of this project. Special thanks go to Henriette Jacoba ROEROE who has spared no efforts to contact and motivate stakeholders and authorities of the interest to participate in this project.

The authors are grateful to Syaloom Hermina Dailly KOROMPIS, Henriette Jacoba ROEROE and Brury BANGUN for the final reading of the report.

Great appreciation is also addressed to all 102 speakers, experts and participants of the Multi-Stakeholder Dialogue, originating from 10 APEC economies as well as from outside APEC, hybrid online-in-person event held in Manado, North Sulawesi Province, Indonesia, during February 2024, as well as the preparatory Training of Trainers workshop held online on 22 – 23 August 2023. The enthusiasm, commitment, and active and generous participation of all the speakers, experts and participants throughout the event contributed to the high quality and depth of discussions, information exchange and the overall successful outcome of the Multi-Stakeholder Dialogue.

The authors also wish to express their thanks to the eight APEC co-sponsoring economies (Australia; Chile; Hong Kong, China; Indonesia; Japan; the Philippines; Singapore; Thailand) that have supported the project “Data Driven, Carbon Neutral and Disaster Resilient Cities in the APEC region” (EWG 04 2022A), which was critical to this project’s realization and impact.

It is the authors’ hope that the results and recommendations set out in this report will in turn support not only the targeted Province of North Sulawesi in Indonesia, but also any other APEC municipal and regional level governments throughout all APEC economies in their efforts to achieve carbon neutrality and disaster resilience.

The authors are grateful to JI Yucheng for the cover design of this report.

Purposes, Executive Summary and Recommendations

Purposes

- To accelerate the transition of APEC cities and municipalities towards carbon-neutrality, i.e., to contribute to the improvement of CO2 emissions over baseline emission scenarios of the participating cities and municipalities.
- To contribute to improved energy resilience, to the creation of low-carbon APEC communities, to increase renewables' share in the APEC energy mix, and to the overall improvement of APEC energy intensity.
- To strengthen the institutional capacities of urban and regional planners of APEC economies, on how to use Multi-Stakeholder Dialogues (MSD) to elaborate comprehensive visions for carbon neutrality and disaster resilience in APEC cities or provinces.

Key findings chapter 1

This chapter describes the situation of North Sulawesi Province at the extreme north-east of the Indonesian island of Sulawesi; and its structure comprising four cities and eleven regencies with a population of around 2.6 million inhabitants. It is bounded by the Celebes Sea to the north, the Molucca Sea to the east and south, and the province of Gorontalo to the west. The Province is mountainous, with numerous active volcanoes, and rainforest cover in higher regions. It also has coastal lowlands which are narrow, characterised by fertile soils, and with world class coral reefs in offshore and island regions.

The Province is threatened by a number of disaster threats; including both geological disasters (earthquakes, volcanic eruptions and tsunamis), and hydrometeorological disasters (floods, flash floods and landslides). The economy (and human population) of North Sulawesi Province is growing, driven by core sectors such as manufacturing, mining, forestry and tourism.

Currently, energy demand is met largely through fossil fuels, notably electricity from coal-fired power generation plant, and petroleum. The contribution of low-carbon and renewable energy technologies to meeting energy demand in the Province is currently low, but there is significant potential for expanding its role. Hydropower, geothermal energy, solar energy, bioenergy, ocean energy and wind power are of particular interest. Energy demand is expected to continue to grow markedly in future years.

North Sulawesi Province has no electricity interconnection with the rest of Indonesia and needs, therefore, to rely on its own renewable energy resources to manage the transition towards carbon neutrality, whilst progressively reducing the role of fossil fuel fired energy systems. This represents both a major challenge and opportunity for the Province.

Key findings chapter 2

This chapter describes the Training of Trainers as preparatory step to prepare and inform MSD participants about objectives, goals, operating structures and procedures. As a critical preparatory step, an online "Training of Trainers" (hereafter, "ToT") workshop was held, targeted to energy planners, as well as urban and regional planners and climate data managers of APEC economies. It included several sessions with varying dynamics, based around expert presentations, case studies discussion, and interactive moderated workshop sessions (open dialogue, Q&A, and feedback sessions). The ToT workshop used a checklist comprising strengths, weaknesses, opportunities and challenges to elaborate elements of a vision for carbon neutrality and disaster resilience in

APEC cities and provinces. It also focused on local energy and climate data collection, in view of elaborating best practices, success factors and pitfalls.

Key findings chapter 3

The Multistakeholder-Dialogue (MSD) event took place over six days, during 21 – 28 February 2024 and was implemented in a hybrid format with both in-person participation in Manado city (North Sulawesi), and virtually (online) as an event open to all APEC member economies. Firstly, the MSD focused on the development of a comprehensive vision for a data driven, carbon neutral and disaster resilient future. Discussions considered the purpose of the vision, core values of the Province, sustainability challenges and measures to address them, disaster threats and measures to address them, as well as the Province's strengths, weaknesses, opportunities and challenges to address carbon neutrality. Secondly, the MSD focused on the formulation and adoption of key 2030 targets on energy intensity, CO2 emissions intensity and renewable energy. The discussions were wide-ranging and followed as much as possible the principle "think global, act local". They focused first on the global context and evolution towards carbon neutrality, taking account of the UN Sustainable Development Goals (SDG) and the APEC energy goals, followed by the analysis of the Indonesian context, notably the three scenarios (business as usual, unconditional and conditional mitigation) underpinning the Indonesian Nationally Determined Contribution (NDC), and, finally, on the specific energy sector context of North Sulawesi Province, its scope for low-carbon energy uptake and energy intensity improvements; as well as considering the broader regional, economywide and international context for carbon emissions mitigation and the sustainable energy transition. Discussions also centred around renewable energy resource potential, the low-carbon energy workforce training and skills needs, the need for a "just" transition, technical constraints (e.g., power grid stability), governance issues, and official targets and goals. Chapter 3 also details the reasons why the MSD was successful.

Key findings chapter 4

As a global long term benchmarking tool for cities, APSEC computed two global scenarios for the time horizon 2100, comprising 30 variables, allowing cities to compare their own evolution to the global evolution. The Sustainable Energy Scenario (SES) is based upon the observation that, after possible turning points, growth rates of most relevant variables vary linearly in time. Very simple to estimate, the SES not only reflects APEC Leaders 2023 declaration and COP28 calls to triple renewable energy capacity globally by 2030, but it also shows that carbon neutrality is reached by mid-century. In contrast, the unsustainable scenario is based upon multivariate regression as a function of the growth rates of explanatory variables whose trajectories had been calculated beforehand in the SES scenario. The unsustainable scenario shows not only how multivariate models reflect bulk resistance to change, but also that in consequence, carbon neutrality is reached only after 2100. By 2050, the cumulated emissions are at 550Gt for the SES and the double of this amount for the unsustainable scenario. By 2100, cumulated emissions of the unsustainable scenario increase up to three times as high as the SES. For each of the 30 variables the computations show the 2020 – 2030 step as well as the evolution by 2100. For each trajectory, the computed probability as a function of its data is stated.

Key findings chapter 5

Cities can monitor their development towards carbon neutrality by a system of 18 independent indicators defined by APSEC to be collected annually for each city. These indicators monitor six dimensions of development:

- Monitoring local (within city boundary) installed capacity and land area
- Monitoring distant (outside city boundary) installed capacity

- Monitoring energy efficiency
- Monitoring energy security, storage and disaster resilience
- Monitoring the local green economy
- Monitoring local use of green finance

Each dimension is developed according to the same methodology in which per capita renewable energy generation is decomposed into factors that co-determine it. If combined, these indicators generate around 50 key ratios, eight of which have been quantified globally with 2020-2030 steps computed for comparison. A draft questionnaire for collecting the data from cities is shown in Annex 7.

Recommendations for the North Sulawesi Province

- To clearly communicate the adopted *Vision for carbon neutrality and disaster resilience* as well as the 2030 targets on emissions intensity, renewable share and energy intensity to all stakeholders of the province (in Indonesian) and to APEC (in English).
- To work towards formal and binding measures and frameworks at the provincial level in order to attract relevant foreign investors for promoting the agreed targets and the vision.
- To develop a comprehensive MRV methodology and database for monitoring and capturing six dimensions of carbon neutrality as described in Chapter 5 and Annex 7, and to monitor the compatibility of the data with economywide data. The database should be regularly updated and should be open access and machine-readable.
- To enhance the leverage of the provincial government in obtaining data from Indonesian state-owned enterprises and to ensure its publication through the statistics office.
- To provide capacity building and foster critical skills in both, private and public sectors and to prevent the brain drain.
- To establish a task force to regularly monitor, evaluate and report on interim progress towards achieving the 2030 targets and to discuss progress with local stakeholders.
- To continue identifying and mitigating all critical barriers (economic, market, financing, governance) to the timely implementation of renewable energy, energy efficiency and carbon neutral solutions and infrastructure in the North Sulawesi Province.

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1. Introduction and general context

This chapter describes the situation of North Sulawesi Province, which is located at the extreme north-east of the Indonesian island of Sulawesi; and its structure comprising four cities and eleven regencies with a population of around 2.6 million inhabitants. It is bounded by the Celebes Sea to the north, the Molucca Sea to the east and south, and the province of Gorontalo to the west. The Province is mountainous, with numerous active volcanoes, and rainforest cover in higher regions. It also has coastal lowlands which are narrow, characterised by fertile soils, and with world class coral reefs in offshore and island regions.

North Sulawesi Province is threatened by a number of disaster threats; including both geological disasters (earthquakes, volcanic eruptions and tsunamis), and hydrometeorological disasters (floods, flash floods and landslides). The economy and population of North Sulawesi Province are both growing, driven by core sectors such as manufacturing, mining, forestry and tourism.

Currently, energy demand is met largely through fossil fuels, notably electricity from coal-fired power generation plant, and petroleum. The contribution of low-carbon and renewable energy technologies to meeting energy demand in the Province is currently low, but there is significant potential for expanding its role. Hydropower, geothermal energy, solar energy, bioenergy, ocean energy and wind power are of particular interest. Energy demand is expected to continue to grow markedly in future years.

North Sulawesi Province has no electricity interconnection with the rest of Indonesia and needs, therefore, to rely on its own renewable energy resources to manage the transition towards carbon neutrality, whilst progressively reducing the role of fossil fuel fired energy systems. This represents both a major challenge and opportunity for the Province.

1.1 Outline of the APEC Project

The APEC project **Data Driven, Carbon Neutral and Disaster Resilient Cities in the APEC region** (EWG 04 2022A), (hereafter, "the project") has three outputs**.**

The first output is the realization of a Training of Trainer (hereafter, "ToT") workshop, to train urban or provincial planners in APEC economies on how to use a Multi-stakeholder Dialogue (hereafter, "MSD") to elaborate a vision for carbon neutrality and disaster resilience in APEC cities or provinces. Furthermore, the ToT focused on the identification of success factors and pitfalls for collecting local energy and climate data and defining APEC best practices related to data collection. The ToT was undertaken as two half-day online trainings, held in August 2023.

The second output of the project was the realization of an MSD, held in Manado, North Sulawesi Province, Indonesia, during February 2024 to support the Province's objective of defining a vision for carbon neutrality and disaster resilience and setting 2030 targets for energy intensity, renewables share and carbon emissions reductions.

The third output of the project is the present Final Report. This report describes the key learnings from both events of the project (i.e., the ToT and MSD) and aims to support the broader dissemination of the project's impacts, including the results and recommendations of the MSD that allow applying the key learnings to the broader APEC region.

Overall, the project seeks to accelerate the transition of APEC cities and municipalities towards carbon-neutrality, i.e., to contribute to the improvement of CO2 emissions over baseline emission scenarios of the participating cities and municipalities.

In this line, the first overarching objective of the project is to contribute to improved energy resilience, to the creation of low-carbon APEC communities, to the increase of the renewables' share in the APEC energy mix, and to the overall improvement of APEC energy intensity.

The second overarching objective of the project is to strengthen the institutional capacities of urban and regional planners of APEC economies, on how to use an MSD to elaborate comprehensive visions for carbon neutrality and disaster resilience in APEC cities or provinces. In this context, the project strengthens the institutional capacities of urban and regional planners of APEC economies on how to identify success factors and pitfalls for collecting local energy and climate data and defining APEC best practices.

Specifically, this report describes the context within which the MSD was undertaken; its structure, format and objectives; the principal outputs of the MSD process; and key lessons learned and recommendations for the effective use of MSDs in other similar contexts.

Planning for carbon neutrality requires clear science-led guidance in a holistic approach as well as a deep outreach into society. The MSD held in North Sulawesi Province in February 2024 managed to have both. The outreach into society was achieved by gathering local representatives from the North Sulawesi Government and its cities and regencies, development and planning offices, stakeholders from local universities, energy, finance, agriculture, food, and women's organizations. The MSD brought together 102 online and in-person participants from 10 APEC economies (Australia; Chile; China; Hong Kong, China; Indonesia; Korea; the Philippines; Thailand; USA; Viet Nam). The hybrid in-person and online formula demonstrated to be a highly effective way to discuss carbon neutrality and disaster resilience across APEC.

1.2 Global and APEC political frameworks

The political frameworks governing the sustainable energy transition, carbon neutrality and the improved resilience of cities to disasters, have been the subject of significant attention and strengthening in recent times (and during the last two decades in particular). The improvement of political frameworks, at both the global and APEC levels, is driven by several factors. These include, for example, the widespread understanding of the need to accelerate the speed and scale of the energy transition (with focus on scaling up renewables and improving energy intensity), mitigating climate change through decoupling carbon emissions and economic growth, and ensuring that cities and their inhabitants are resilient to disasters (and especially in the face of increasingly severe weather events driven by climate change).

The following is a general summary of the global and APEC political frameworks and objectives governing efforts to scale up renewable energy, improve energy intensity and mitigate carbon emissions. For a more detailed discussion on the APEC political framework and its development over time please see APEC Energy Working Group's (2019) landmark report "APEC Sustainable Urban Development Report – from Models to Results".[1]

In 2015, the global community responded to sustainability deficits by adopting the Sustainable Development Goals, followed by the Paris Agreement under the UNFCCC, which concretizes SDG 13 on climate action. The Paris Agreement is of crucial importance, as it has more than 900 substantive causal links to other SDGs and targets. Earlier in 2015, the Sendai Framework for Disaster Risk Reduction had already been adopted by the UN General Assembly. This Framework is substantially included in SDG 11 on sustainable cities. For the disaster-struck region around the Pacific Rim, this framework is so important that APEC Leaders have adapted it to the APEC context already few months after its adoption by the UN General Assembly. The UN 10Year Framework Program (10YFP) on Sustainable Consumption-Production (SCP) Patterns contains a chapter on sustainable buildings and construction, which directly links to sustainable urbanization. 10YFP is substantively included in SDG 12 on sustainable consumption and production patterns.

Besides the APEC Disaster Risk Reduction Framework, APEC Leaders also adopted five energy goals and repeatedly stressed their importance for APEC. The two aspirational goals include:

- The reduction of energy intensity of APEC between 2005 and 2035 by 45%, and
- The doubling of renewable energy share in APEC's overall energy mix between 2010 and 2030.

Three other energy-related goals have been set, namely rationalizing and phasing out inefficient fossil fuel subsidies, developing low-carbon systems, and enhancing energy security. The APEC Energy Working Group has been charged with the implementation of these goals. The Energy Smart Communities Initiative ESCI has been created in 2010 in order to facilitate the dissemination of technologies that could support the energy goals set by APEC Leaders. In 2011 the knowledge sharing platform (KSP) was added, and in 2013 the best practice award. Other instruments were created in support of sustainable urbanization: The series of Low Carbon Model Towns in 2010, the Cooperative Network of Sustainable Cities (CNSC) in 2014, and in the same year also the APEC Sustainable Energy Center APSEC. This is tasked with pragmatic cooperation on sustainable energy development among APEC economies and to act as think tank of the Chinese National Energy Administration.

At the global level, recent policy developments and objectives to move towards efficient and renewables-based energy systems free of unabated fossil fuels have been driven by international forums set up to tackle climate change. For instance, a landmark commitment was agreed at COP28 (held in November 2023 in the United Arab Emirates) to:

- Triple the world's installed renewable energy generation capacity to at least 11,000GW by 2030, taking into consideration different starting points and specific circumstances.
- Collectively double the global average annual rate of energy efficiency improvements from around 2% to over 4% every year until 2030.
- To put the principle of energy efficiency as the "first fuel" at the core of policymaking, planning, and major investment decisions.[2]

In summary, political frameworks and targets for low-carbon development, renewable energy uptake, energy efficiency improvements and increased disaster resilience are now well established in both the global and APEC contexts. This creates a significant tailwind for efforts to achieve related policy objectives and targets in city contexts, where the majority of the global population now resides and where the achievement of SDGs, resilience to disasters and extreme climatic events, the mitigation of carbon emissions and the sustainable energy transition are critical.

1.3 The Local Context of the North Sulawesi Province

Authored by Hizkia H. D. Tasik and Steivan Defilla

The local context will be described in two parts, first with a focus on the North Sulawesi Province, followed by a focus cities and regencies of North Sulawesi.

North Sulawesi Province, Indonesia, is bounded by the Celebes Sea to the north, the Molucca Sea to the east and south, and the province of Gorontalo to the west.

In terms of its geography, North Sulawesi Province is mountainous, and much of the higher regions include rainforest cover. The province has numerous active volcanoes. It also has coastal lowlands which are narrow, characterised by fertile soils, and with world class coral reefs in offshore and island regions.

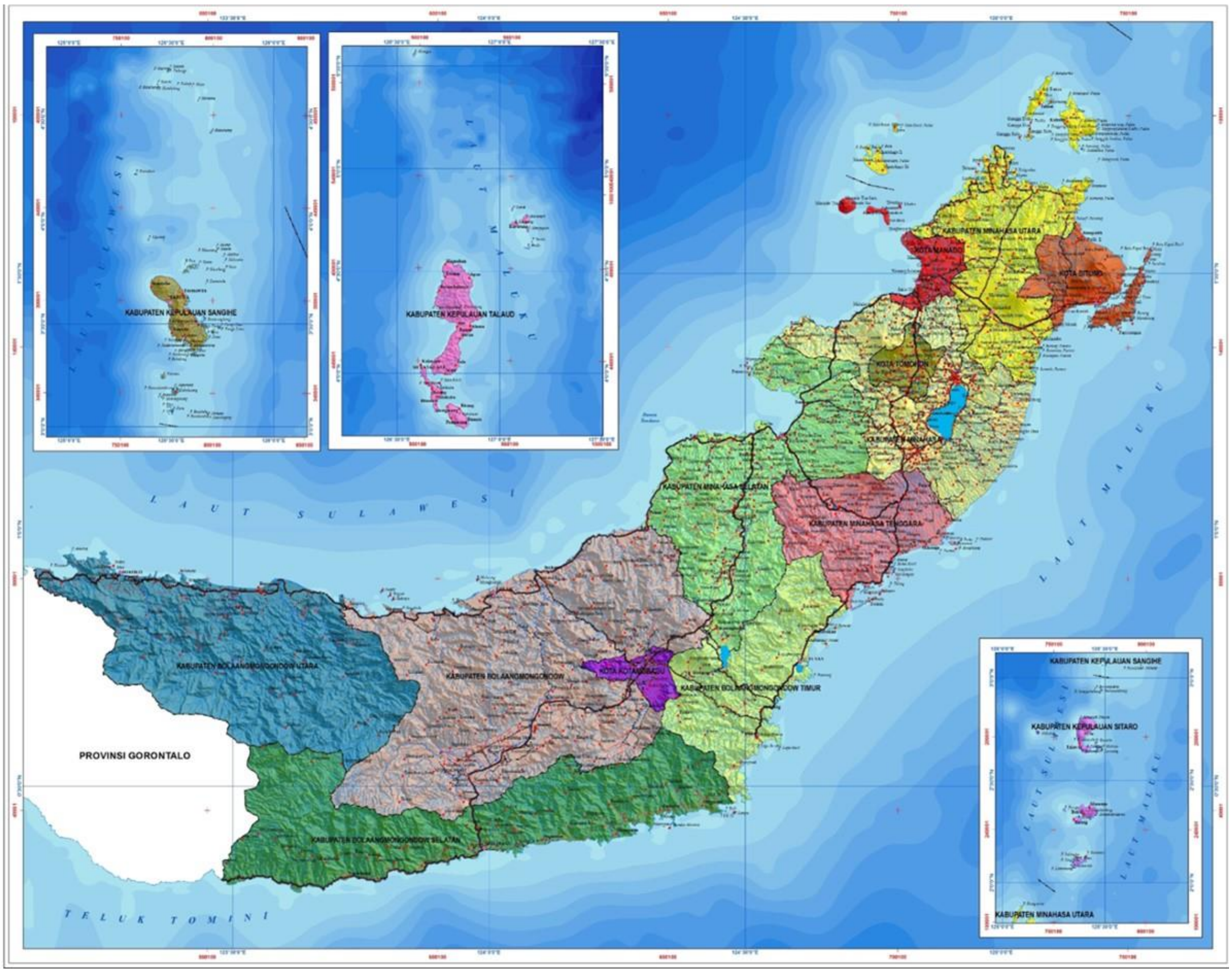


Figure 1: Geography of North Sulawesi.

Source: Peta Tematik Indo (https://petatematikindo.wordpress.com/2013/04/07/administrasi-provinsi-sulawesi-utara/)

North Sulawesi Province is located at the extreme north-east of the Sulawesi Island and comprises four cities and eleven regencies with a population of around 2.6 million inhabitants and is expected to experience steady growth in the period to 2030 and beyond according to Statistics Indonesia (2022). The historical data starts from 2016, while the projection starts from 2023.

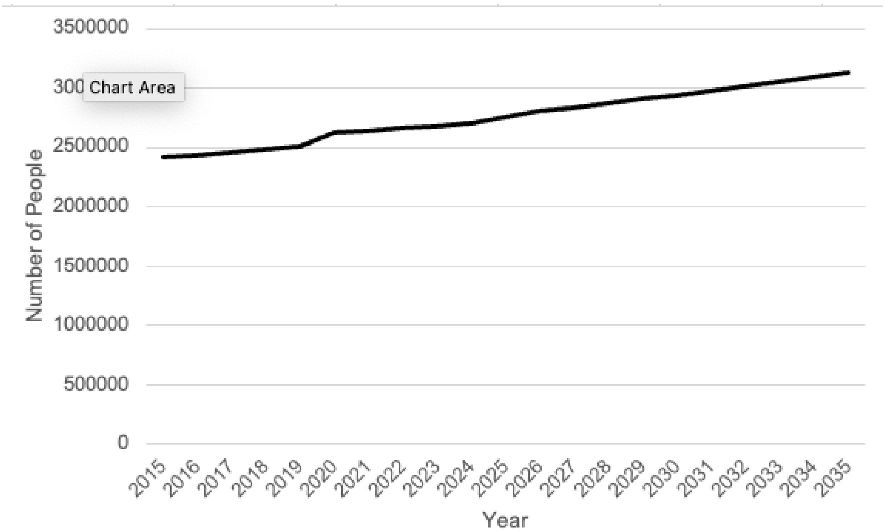


Figure 2: Historical and projected population size of North Sulawesi Province.

Source: Statistics Indonesia (2022)[3]

The GDP of North Sulawesi Province has been growing at a rate of around 5% in the past years attaining IDR96,767,697 Million at constant 2010 prices by 2022. Future projection provided for a growth between 3 to 4%.

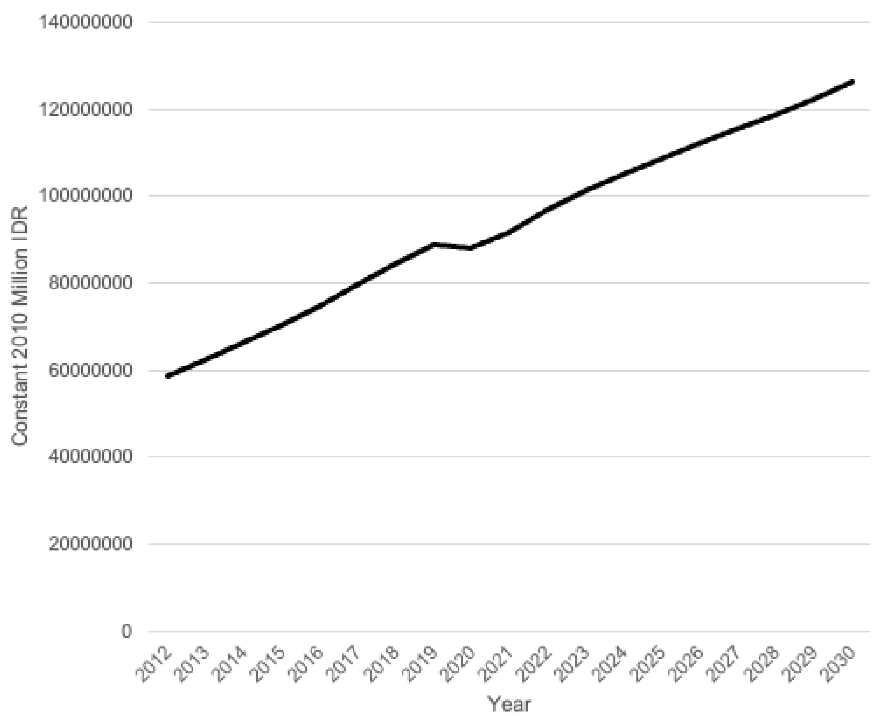


Figure 3: Historical and Projected GRDP of North Sulawesi Province.

Source: Statistics Indonesia (2023)[4]

Concerning the structure of the North Sulawesi economy: North Sulawesi Province produces significant amounts of primary crops, such as rice, coffee and sugarcane; as well as coconuts and nutmeg. The province's economy also depends on mining (gold, iron and sand), manufacturing (in particular, crafts, foods, beverages, coconut and palm oil).

The province's economic growth is partly due to the establishment of a special industrial economic zone (located in Bitung City), as well as generally strong economic activity in core sectors such as manufacturing, mining, forestry and tourism (Likupang tourism special economic zone). Energy demand is expected to continue to grow markedly in future years. The main growth sectors of the province's economy are shown in the table below:

Business Fields	2020	2021	2022	2023
Horticultural Crops	7.67	8.02	7.96	6.99
Livestock	8.05	3.64	5.8	6.89
Agricultural services and Hunting	4.76	4.67	8.68	5.12
Food and Beverage Industry	4.47	8.5	7.31	7.01
Industrial Wood, Articles of Wood and Cork and Woven Goods from Bamboo, rattan and the like	5.57	9.11	7.53	8.14
Chemical, Pharmaceutical and Traditional Medicine	-10.02	6.71	7.96	8.87
Manufacture of Metal Goods, Computers, Electronics, Optical and Electrical Equipment	17.1	-10.61	58.47	-17.65
Construction	6.94	6.97	10.17	5.12
Wholesale and Retail Trade; Repair Cars and Motorcycles	7	7.16	10.26	5.09
River Transport Lake Crossing	-13.87	1.49	11.75	11.93
Provision Eat Drink	-32.94	8.64	33.97	35.27
Financial Intermediary Service	-35.87	18.8	14.58	9.35
Insurance and Pension Funds	-9.62	6.43	9.63	8.57

Table 1: Growth Rate of GRDP by Business Fields (Percent)

Source: Statistics of North Sulawesi

The table above shows the excerpt of the growth rate of GRDP of North Sulawesi Province by business fields. The business fields listed in the table are the ones with growth rate of more than 5%. More information about the GRDP by Business Fields of North Sulawesi can be found in the Statistics of North Sulawesi. Concerning the energy-related development, the data sources of the North Sulawesi Province show that the number of electricity customers from 2010 to 2021 has been constantly rising. This is to be interpreted in light of SDG target 7.1, stating that access to modern energy forms is a key goal for sustainability. It is estimated that the electrification rate of households in North Sulawesi amounts at present to 99.36 %[5].

Year	ELECTRIFIED HOUSHOLD (PLN)	ELECTRIFIED HOUSHOLD (NON-PLN)	NUMBER OF HOUSEHOLD	ELECTRIFICATION RATE (%)
2015	542.385	8.786	618.132	89,17
2016	561.443	8.786	624.489	91,31

2017	587,894	8,786	631,026	94.56
2018	610.339	8.786	635.204	97,47
2019	646.347	8.786	655.199	99,99
2020	676.471	4.862	681.401	99,99
2021	705.896	4.862	710.829	99,99
2022	730.426	4.862	735.288	99,99

Table 2: Historical Electrified Households, Number of Households, and Electrification Rate

Source: Ministry of Energy and Mineral Resources (https://gatrik.esdm.go.id/frontend/download_index?kode_category=statistik)

Electricity consumption of North Sulawesi has been elaborated by the authors in cooperation with PT PLN (Persero), the State Electricity Company. The trend shows a 6.21% growth during the past years, whereby the total electricity consumption attains 1966.05GWh by 2022.

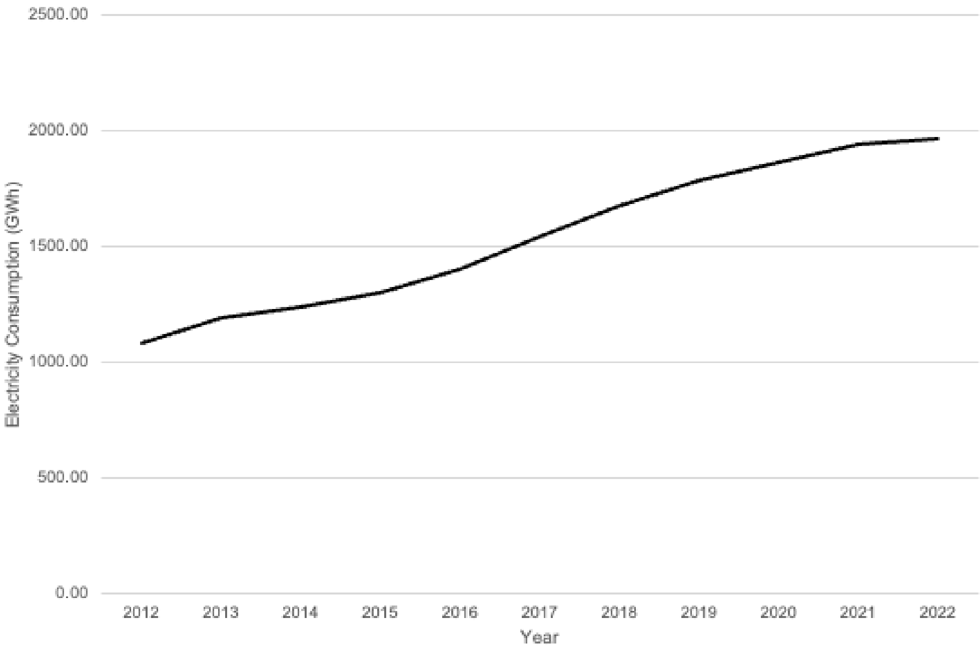


Figure 4: Historical Final Electricity Consumption of North Sulawesi Province.

Source: PLN Statistics

Final energy consumption of the North Sulawesi Province is not shown in the available statistics. For this reason, the authors have estimated the final energy consumption of North Sulawesi by using the electricity consumption of North Sulawesi and the share of electricity in final energy consumption for Indonesia as published by the IEA. The result is shown in the table below. According to this estimation, final energy consumption of North Sulawesi has been approximately steady (decrease by 0.2% per year) in the last decade, attaining now 11,292,481.17GWh per year by 2022.

Year	Final Energy Consumption (GWh)
2012	11673719.26
2013	11158878.88
2014	11102762.28
2015	11093207.23
2016	10724297.22
2017	11640855.94
2018	11400058.43
2019	12457214.59
2020	11909170.59
2021	12019479.99
2022	11292481.17

Table 3: Historical North Sulawesi Final Energy Consumption

Source: Authors' Calculation and IEA (https://www.iea.org/data-and-statistics/data-tools/energy-statistics-data-browser?country=INDONESIA&fuel=Energy%20consumption&indicator=TotElecCons)

The resulting per capita energy consumption of North Sulawesi has been calculated by the authors from the above-mentioned final energy consumption and the population data. The per capita final energy consumption has been growing since 2016 but has then been severely affected by the COVID-19 pandemic. This illustrates the vulnerability of the province facing disasters such as a global pandemic.

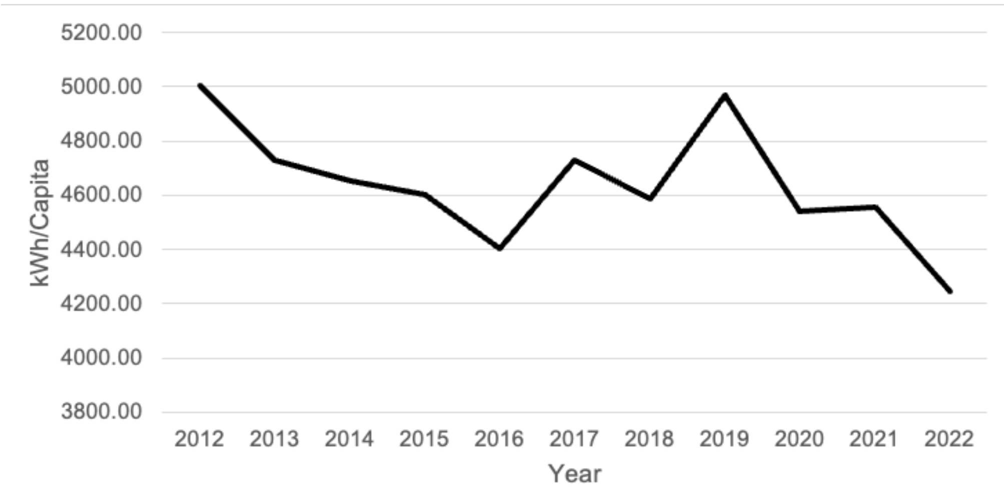


Figure 5: Per capita final energy consumption of North Sulawesi Province.

Source: Statistics of North Sulawesi[6]

The resulting per capita energy consumption between 4400kWh/person and 5000kWh/person should be interpreted in line with other per capita consumption data from developing of emerging economies. The per capita energy consumption of North Sulawesi is between 15.84GJ/person and 18GJ/person and is, therefore, at the upper bound of the energy needs of Decent Living Standards

(DLS, see figure below) that describe energy consumption of developing and emerging economies. The DLS has been proposed by Rao, N. D. and Min (2018)[7], and Millward-Hopkins and others (2020)[8]. They pointed out that the energy needs of DLS vary globally only within a narrow bandwidth of between 13 GJ/person and 18.4GJ/person. Activity levels (mostly mobility levels) and energy intensities (mostly thermal comfort and water heating in residential buildings) make roughly equal contributions to the overall range of DLE values. To suggest a planning figure for North Sulawesi (as well as for other APEC cities), it is proposed to define DLS by means of a rounded value of 18GJ/year/person, corresponding to 5MWh/year/person, or 570W/person (see also section 5.1 further down).

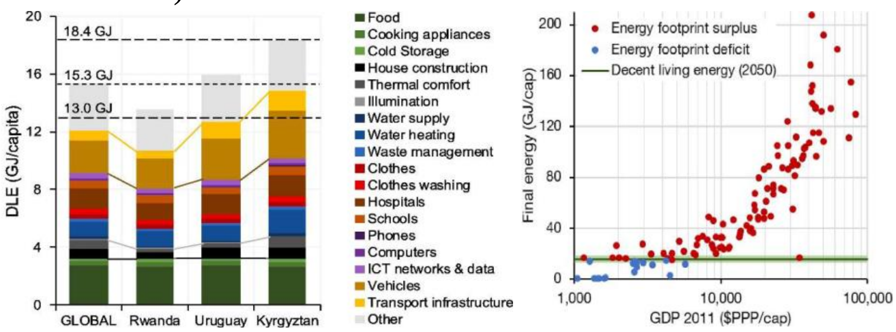


Figure 6: Energy needs of Decent Living Standards

Source: Millward-Hopkins and others[9]

The following cross-section analysis of North Sulawesi by component cities and regencies has been made using the data published on the “dataportalforcities”[10], filtered for North Sulawesi cities and regencies. This platform shows data for “2017” for population, energy consumption and emissions. However, when comparing and cross-checking energy data of this platform with the estimates of final energy consumption made by the authors presented above, it turned out that the “dataportalforcities” showed only about half the amount of final energy consumption estimated above by the authors, pointing to a major data discrepancy. A similar discrepancy was found also on population data. The analysis revealed that the population shown in the “dataportalforcities” for North Sulawesi in 2017 corresponded almost exactly to the North Sulawesi population of the year 2010 as given in the official population statistics published by Statistics Indonesia (2022). On the basis of these two results, it was decided to use the data from the “dataportalforcities” for the cross-section analysis, but to interpret them for the year 2010 and not for the year 2017. The cross-section analysis below reflects these findings. It was further decided to add GDP data of the year 2010 to complete the analysis.

The comparison of the population by the two sources is shown in the figure below.

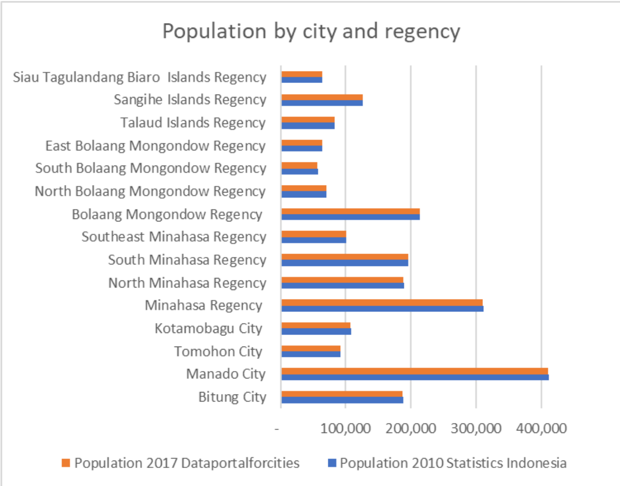


Figure 7: Population by city and regency, two data sources compared

https://dataportalforcities.org/southeast-asia and Statistics Indonesia (2022)[11]

The particularity of the population distribution (2010) is that cities are not the most populous entities. While Manado city, the capital of North Sulawesi, ranks top, the other cities follow in ranks 6, 8 and 10 out of 15, after some regencies. The other particularity is that the three groups of islands are in ranks 7, 11 and 12, which are not at the lowest ranks. This points to the rural character of the traditional North Sulawesi province. The 2010 population is used mainly to compute the per capita values of GDP, energy and emissions.

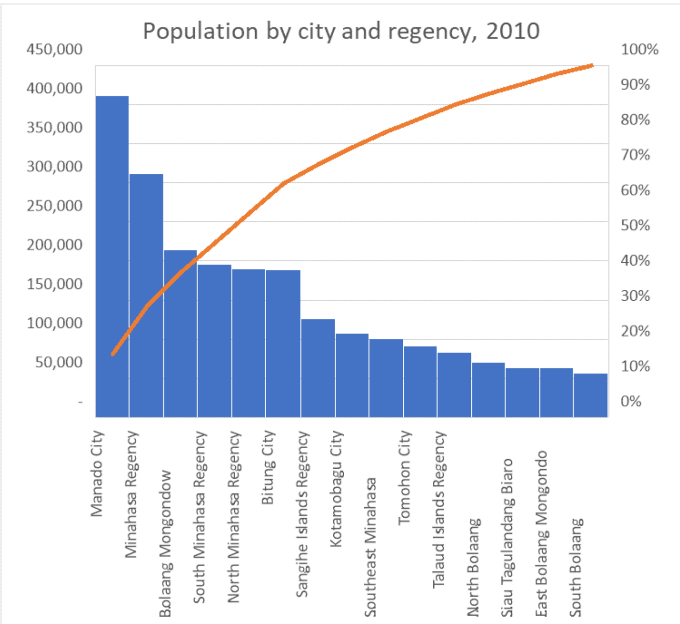


Figure 8: Population by city and regency 2010

Source: Statistics Indonesia (2022)[12]

The cross-section analysis of GDP by city and regency confirms that Manado, the capital city, is clearly number 1, with other cities following in ranks 3, 9 and 10. The islands are in ranks 8, 12 and 14, not really the lowest ranks.

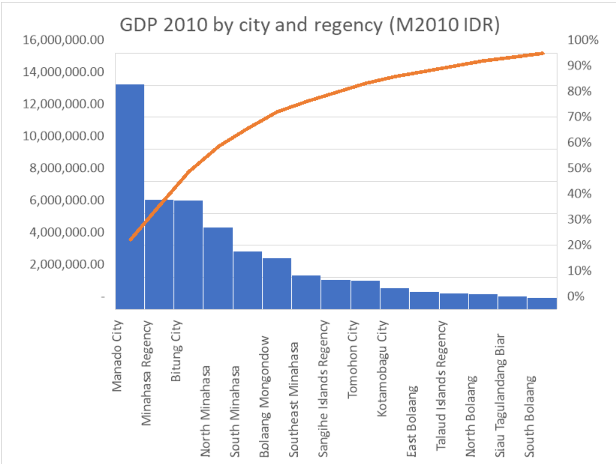


Figure 9: 2010 GDP by city and regency in millions constant 2010 IDR

Source: Statistics Indonesia (2022)[13]

Per capita GDP by city and regency shows that Manado, the capital city, is on rank 2, behind Bitung city, although their distance is small. Tomohon city is on rank 6, whereas Kotamobagu city occupies the last rank. The islands occupy ranks 10, 12 and 14. The disparity between the highest and lowest per capita income of the region is approximately a factor 3.5.

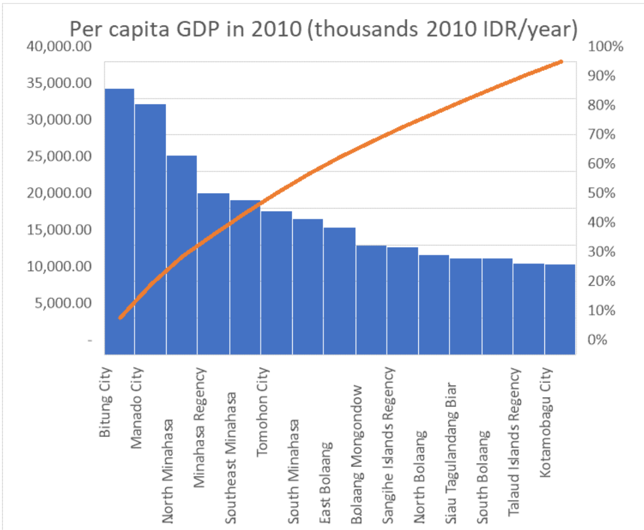


Figure 10: Per capita 2010 GDP by city and regency in thousand constant 2010 IDR.

Source: Statistics Indonesia (2022)[14]

Final energy consumption by city and regency shows a strong disparity. It seems that in 2010, final energy consumption of Manado was much higher than in the other cities or regencies. Bitung city is on rank 2, Kotamobagu city and Tomohon city are on ranks 6 and 7, respectively. Note that the source “dataportalforcities” does not give energy consumption of the regency of South Minahasa nor of the three island regencies, and that this source attributes the data to the year 2017, whereas the authors find the data correspond to the year 2010 (see above).

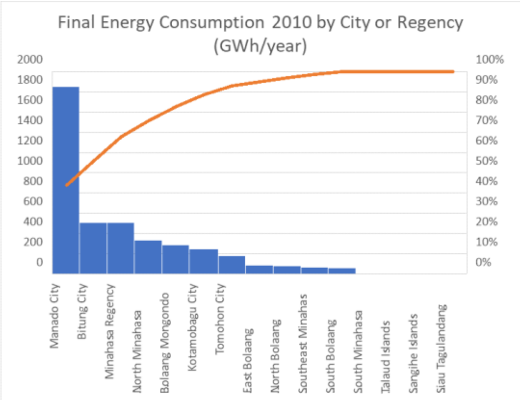


Figure 11: Final energy consumption 2010 by city or regency

Source: dataportalforcities.com[15]

Per capita final energy consumption partially confirms the strong position of the capital city Manado. As expected, the other three cities follow on ranks 2 to 4. Again, the source of this data (dataportalforcities) does not give any information on the three island regencies nor on South Minahasa. The average per capita energy consumption of the North Sulawesi province is at 2343kWh/person/year, which is just about half the level of the final energy consumption as estimated above by the authors. For this reason, the authors interpret the data of this source as describing the year 2010 instead of the year 2017.

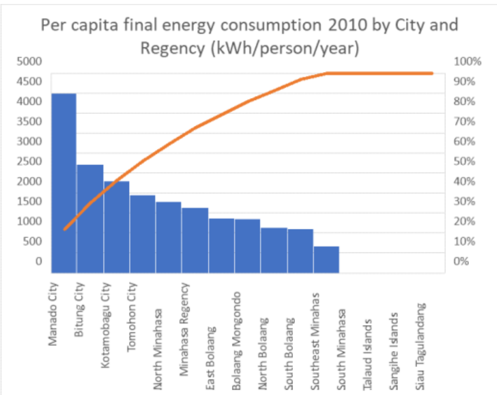


Figure 12: Per capita Final energy consumption 2010 by city and regency in kWh/person/year

Source: Authors' calculation based upon dataportalforcities.com[16]

Final energy intensity of GDP by city and regency has been calculated by the authors from the above data on final energy and GDP. Average final energy intensity of the GDP for North Sulawesi is at 0.061kWh/thousand 2010 IDR, just half the energy intensity estimated by the authors for the year 2021 (0.131kWh/thousand 2010 IDR). For this reason, the data of this source are interpreted to refer to the year 2010 and not to the year 2017. Kotamobagu city has the highest energy intensity, followed by Manado city and Tomohon city. Bitung is on rank 7. The first rank of Kotamobagu is caused by the relatively low volume of economic activity as shown further above (lowest per capita GDP) rather than by high energy use. The source gives no information on the three island regencies nor on South Minahasa.

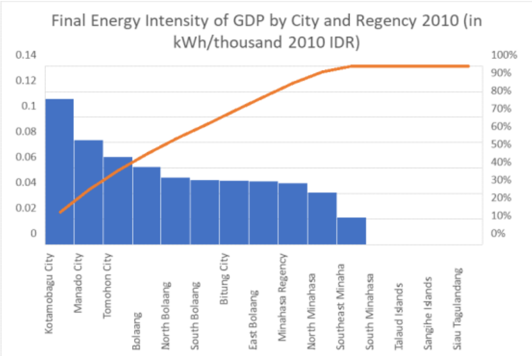


Figure 13: Final energy intensity of GDP 2010 by city and regency in kWh/1000 2010 IDR

Source: Authors' calculation based upon dataportalforcities.com[17]

The cross-section analysis of emissions by city and regency mirrors the analysis of final energy consumption presented further above, showing that the emissions of Manado are much higher than those of other cities or regencies. Again, Bitung city is on rank 2, Kotamobagu city and Tomohon city are on ranks 6 and 7, respectively. These emissions of the shown 11 cities and regencies total 535,000tCO2e, which is about half of what the authors found for 2021. For this reason, also the emissions data of this source are to be interpreted as referring to the year 2010 rather than to the year 2017.

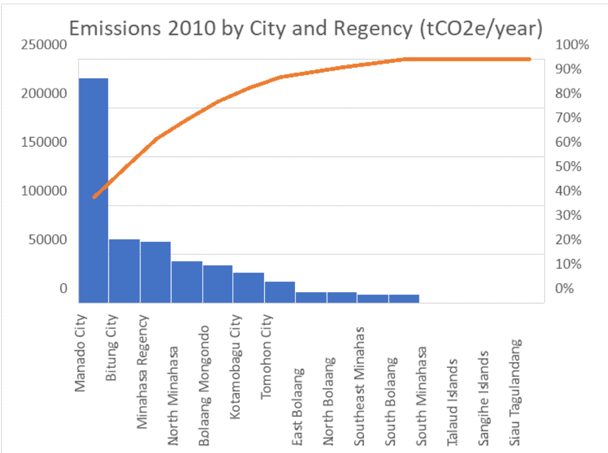


Figure 14: Emissions 2010 by city and regency in tCO2/year

Source: dataportalforcities.com[18]

The identity of ranks of cities and regencies between final energy and emissions can be used to calculate the emissions intensity of final energy consumption by city and regency. It shows a set of values around 120t/GWh or 120g/kWh, with little disparity among the cities and provinces. This is further evidence to interpret the data of this source as referring to the year 2010 rather than to the year 2017.

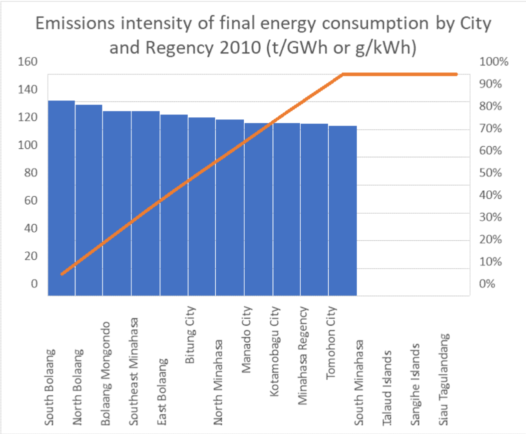


Figure 15: Emissions intensity of Final energy consumption 2010 by city and regency in t/GWh or g/kWh

Source: Authors' calculation based upon dataportalforcities.com[19]

Per capita emissions by city and regency 2010 neatly mirror per capita final energy consumption as presented further above. Manado ranks first, followed by the three other cities. The source gives no information on the three island regencies nor on South Minahasa. According to this source, per capita emissions are in average 297kg/person/year. This is just little more than half the per capita emissions the authors estimated for 2021 (573kg/person/year) for North Sulawesi. The coherence is again established by interpreting the figures of the dataportalforcities as referring to the year 2010 rather than to 2017.

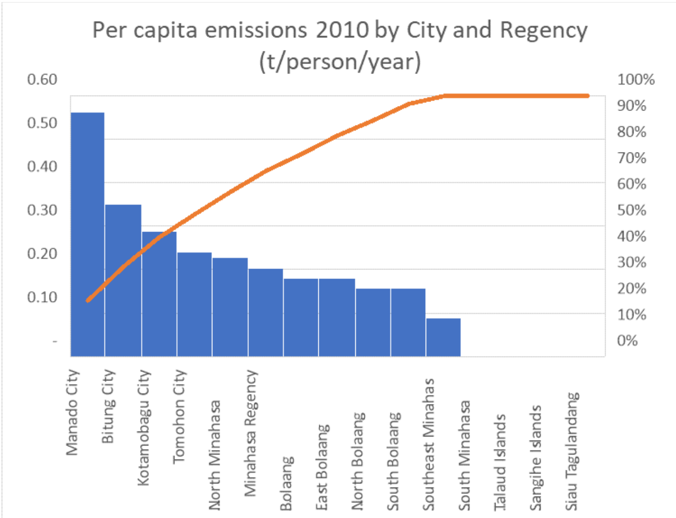


Figure 16: Per capita emissions 2010 by city and regency in tCO2/person/year

Source: Authors' calculation based upon dataportalforcities.com[20]

To conclude the cross-sectoral analysis by city and regency, the emissions intensity has been calculated by the authors. The rank order consistently mirrors the rank order of the energy intensity calculated further above. The average emissions of around 7g/thousand 2010 IDR shown in figure below is again approximately half as high as the quantity of emissions computed by the authors for the year 2020 (15.2g/thousand 2010 IDR). To be coherent, the figure below should be interpreted to refer to the year 2010 instead of the year 2017.

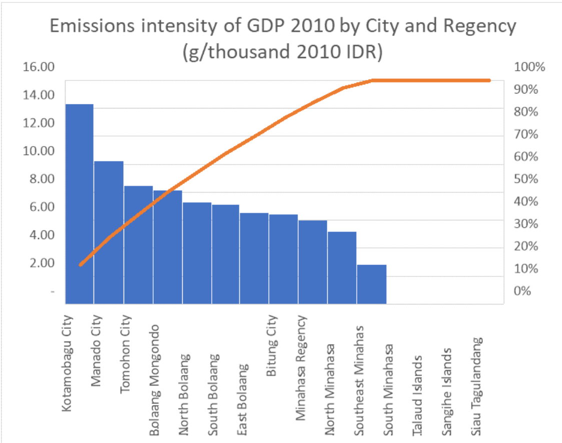


Figure 17: Emissions intensity of GDP 2010 by city and regency in g/thousand 2010 IDR

Source: Authors' calculation based upon dataportalforcities.com[21]

The discussion now continues with disaster threats. Due to its specific geographical and climatological conditions, the Province is threatened by a number of disaster threats. These can be grouped into two main categories. Firstly, geological disasters, which include earthquakes, volcanic eruptions and tsunamis. And secondly, hydrometeorological disasters, which include floods, flash floods and landslides. To mitigate the disasters, it is important to do disaster management based on disaster cadastral map. Unfortunately, there is no such map officially available in the province. It is recommended that such maps should be created.

Plans to meet growing demand focus in particular on the development of rural areas and special economic zones, considered to be regional development priorities in the work program of the North Sulawesi Provincial government for the 2020-2024 period. Additional capacity for this scenario is planned for the 2022-2024 range and adjusts to the 2021-2030 RUPTL (Electricity Business Plan).[22]

Currently, energy demand is met largely through fossil fuels, and in particular from electricity for coal-fired power generation plant, and petroleum. Regrettably, this study revealed that the PLN statistics failed to distinguish between the various sources of energy consumed. Consequently, it is imperative to implement this kind of data separation along energy sources.

Information on renewable energy was scarce and difficult to obtain. PT Pertamina (Persero) and PT PLN (Persero), two state-owned enterprises, possess detailed renewable energy data; however, these details are not publicly accessible. Consequently, the data was personally collected from various other sources, including from the Ministry of Energy and Natural Resources.

The contribution of low-carbon and renewable energy technologies to meeting energy demand in the Province is currently low, but there is significant potential for expanding its role. Hydropower, solar energy, bioenergy, geothermal energy, ocean energy and wind power are of particular interest.

The North Sulawesi Province has no electricity interconnection with the rest of Indonesia and needs, therefore, to rely on its own renewable energy resources to manage the transition towards carbon neutrality. Given its geographic characteristics, and limited electricity grid interconnection capacity with neighbouring provinces in Sulawesi, the North Sulawesi Province must be considered as an isolated grid system until this basic situation changes. Amongst other considerations, this means that if the Province is to move towards a low-carbon future it is critical that its energy system incorporate substantial levels of low-carbon and renewable energy and power generation capacity, whilst at the same time progressively reducing the role of fossil fuel fired energy systems.

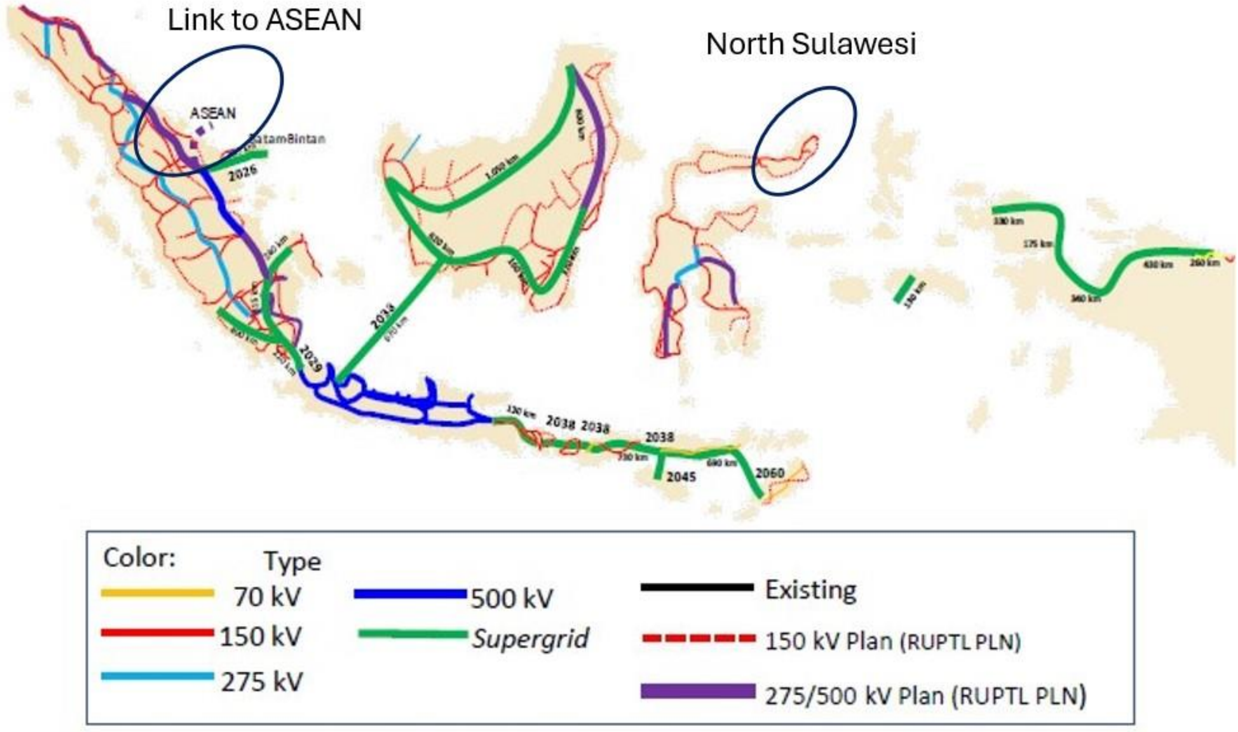


Figure 18: Electricity Map of Indonesia

Source: Dedi Rustandi, BAPPENAS

The above map illustrates the two difficulties of North Sulawesi to develop towards carbon neutrality: Firstly, the Sulawesi Island is not (yet) interconnected with the other Indonesian islands, and secondly, Indonesia is not (yet) interconnected to ASEAN and the rest of the Asian continent. The first issue is most serious for North Sulawesi as no plans exist (yet) to interconnect Sulawesi Island to the rest of Indonesia. The consequence for planning for carbon neutrality are that the Sulawesi Island may have to rely entirely on itself to provide the locally used electricity. The second issue of interconnecting Indonesia to ASEAN is likely to be handled in the forthcoming future. It will open new perspectives on electricity generation and electricity trade in Southeast Asia. In the longer term, the situation might change even more if an interconnector linking Indonesia to Australia will be built, opening the way to large scale electricity exchanges. See Chapter 5, in particular Section 5.2, on the implications of archipelagos for monitoring the transition towards carbon neutrality.

The above implies that local renewable energy systems of all types and sized will be required to address local demand, as they may represent a lower cost option than interconnecting North Sulawesi to its neighbouring islands.

In terms of current official plans, according to PLN's RUPTL of 2021-2030, the Sulawesi region, including North Sulawesi, will receive an additional capacity of 783.09MW. The addition will mostly come from renewables power plants of 397.09MW (51%), while the remaining 386MW (49%) will come from fossil-fuelled power plants. For the isolated system of Talaud, the 2x3MW Talaud coal-fired power plant, located in North Sulawesi province, will be fuelled by biomass from the year 2022.[23]

The North Sulawesi (NS) Province, together with its neighbouring province, namely Gorontalo (GO), are part of the same power system, SulutGo, and are characterized by a high average generation cost (IDR1,918/kWh, compared to an average of 1,119 for Indonesia as a whole). The high average generation cost of SulutGo is driven by a large use of diesel. The extensive potential for RE in the NS and GO provinces and the regulatory framework which is beneficial for areas with higher generation costs are two enabling factors for a larger deployment of RE in the short to medium term. In the long term, the regional plan, RUED, sets targets for 2050 for the use of RE, gas and coal in the two provinces. The ambitions of the two provinces are influenced by their different potentials: North Sulawesi expects a higher RE deployment (46% in 2025 and 49% in 2050) than the overall Indonesian target of 41% RE in 2050 while Gorontalo falls short expecting 15.5% in 2025 and 35% in 2050.[24]

A power interconnection between North Sulawesi Province and Central Sulawesi (via Tolitoli) is currently being planned. The power demand in North Sulawesi settled around 1.6TWh in 2018, around three times larger than the one in Gorontalo, equal to 0.5TWh (PT PLN Persero 2019). The largest load centre in the area is in Manado, followed by Gorontalo and accordingly the southern part of North Sulawesi, Kotamobagu.

The island archipelago of Sangihe, north of Manado, is also part of the system, but is not connected to the neighbouring Sulawesi Island, and is fuelled entirely by diesel engines. A plan to switch to gas engines is in the pipeline, based on the latest PLN plan. The electrification rate is relatively high compared to other parts of the economy, with Gorontalo (91.83% electrified as of May 2019) on the way to reaching the level of North Sulawesi (98.76%).

2. Training of Trainers as preparation for the MSD

This chapter describes the Training of Trainers ("ToT") as an important step to prepare and inform MSD participants about the objectives, goals, operating structures and procedures of the MSD. An online ToT workshop was held in August 2023, and which was targeted to energy planners, as well as urban and regional planners and climate data managers of APEC economies. The ToT included several sessions with varying dynamics, based around expert presentations, case studies discussion, and interactive moderated workshop sessions (open dialogue, Q&A, and feedback sessions).

The ToT workshop focused on the MSD approach to elaborate a vision for carbon neutrality and disaster resilience in APEC cities and provinces; as well as local energy and climate data collection, including best practices, success factors and pitfalls. Discussions also centred on sustainability challenges, disaster threats, and measures to address both.

2.1 Training of Trainers

A tailored program of ToT targeted to energy planners, as well as urban and regional planners and climate data managers of APEC economies was realized. Whilst the ToT workshop was open for attendance by a wide range of stakeholders within APEC economies, attendance was particularly encouraged by the participants in the MSD in North Sulawesi Province.

The ToT workshop was held virtually and over two half-days (specifically, on 22 and 23 August 2023). The ToT workshop focused on two core topics. Firstly, it trained the use of a Multi-Stakeholder Dialogue to elaborate a vision for carbon neutrality and disaster resilience in APEC cities and provinces. Secondly, the ToT workshop focused on local energy and climate data collection, including best practices, success factors and pitfalls.

The ToT workshop included several sessions with varying dynamics, based around expert presentations, case studies discussion, and interactive moderated workshop sessions (open dialogue, Q&A, and feedback sessions). The ToT workshop brought together 67 registered participants from 10 APEC economies (Canada; Chile; China; Hong Kong, China; Indonesia; Korea; the Philippines; Thailand; USA; Viet Nam) and two APEC Research Institutions (APSEC and APERC). The team of internationally known speakers included Michael Shank (Carbon Neutral Cities Alliance), Jaewon Peter Chun (World Smart Cities Foundation), Jinlei Feng (IRENA), Madelaine Alfelor (UCLG-ASPA, Ambassador), Patricia McCarney (World Council on City Data), Vincent Vinarao (Quezon City), Arif Wibowo (ICLEI), Hanah Paik (CDP), Egi Suarga (WRI), and Elvira Gelindon (APEC Energy Research Center).

Participants in the ToT workshops learned about international best practices and practical solutions for effective and comprehensive long-term planning for carbon neutrality, disaster resilience, and robust data collection and management.

For instance, discussions centred on topics such as the core values of transparency, creativity, innovative development and structural reforms in carbon neutrality visions. Discussions also considered effective means to address core challenges around disaster resilience and sustainability (including, for instance, the implementation of comprehensive disaster resilience strategies; understanding of current and potential future urban risks; mapping levels of urban disaster resilience, etc.). Expert speakers (such as Madelaine Alfelor, Ambassador of the United Cities

Local Governments -Asia Pacific) addressed these issues and their implications for long-term sustainability planning (see figure below).

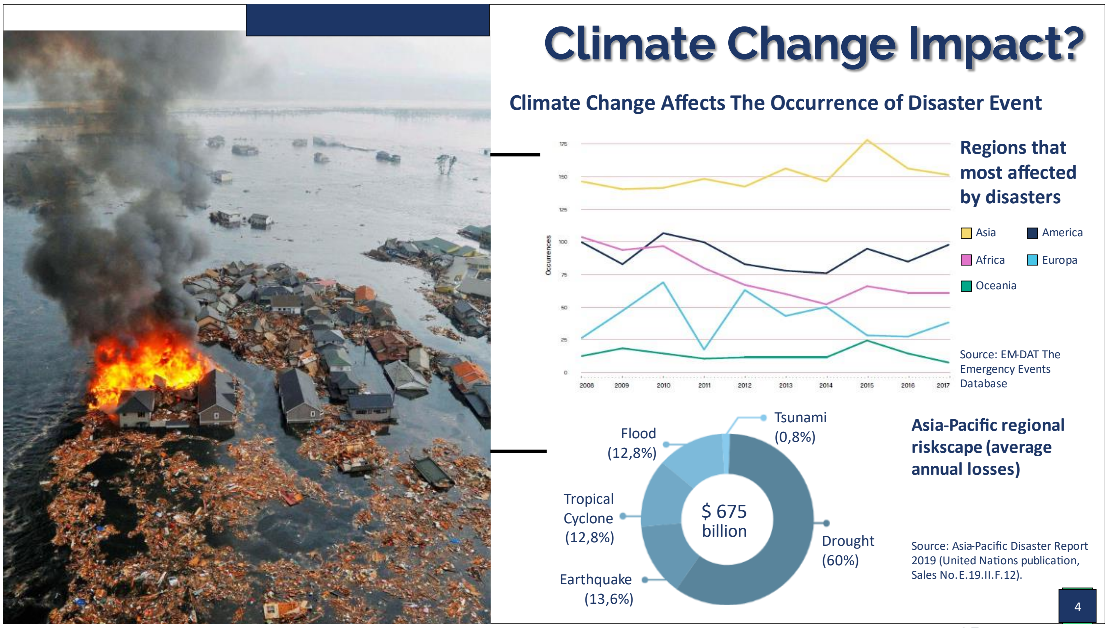


Figure 19: Presentation on Climate Action Plans and Resilience[25]

The sessions also centred on opportunities to identify and mobilize measures to address sustainability targets and disaster resilience. Particular attention was paid to carbon neutrality, and ways in which governments and planning authorities can address carbon neutrality, and identify and capitalize on opportunities to reach carbon neutrality (e.g., tapping into sustainable financing opportunities, promoting data completeness and consistency, etc.).

In a similar vein, the ToT workshop considered the core challenges posed by carbon neutrality, and the options to adequately address those challenges. Some of the main challenges considered include, for example, the existence of informal economies in cities where fuel data is not easily accessible; limited transparency within some energy transition plans; and actual (real) baseline datasets can be patchy, lack transparency and may be difficult to obtain.

The ToT workshop was designed to give participants an introduction and background understanding of the potential of MSD forums, as a vehicle for detailed and productive, interactive discussions, and a forum for effective and consensual decision making for low-carbon development, energy transition and carbon emissions mitigation. Participants were introduced to how MSD forums are organized and implemented, and their myriad benefits. For instance, expert speaker presentations, such as that of Dr Michael Shank of the Carbon Neutral Cities Alliance, focused on opportunities and best practices approaches to mobilize transformative climate action in cities. This included sharing lessons learned on how MSDs focused on developing city-level visions for carbon neutrality and disaster resilience have been successfully executed in the international context.

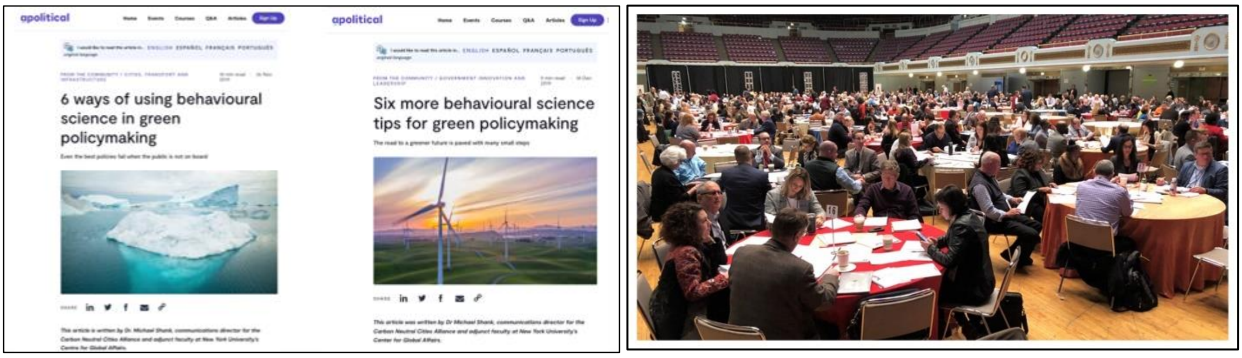


Figure 20: Presentation on the potential and use of MSDs for low-carbon development planning

In relation to the uptake of renewable energy and improving energy intensity, the ToT workshop focused on the specific role of cities as well as the opportunities and challenges that cities encounter. For instance, IRENA (Mr Jinlei Feng) delivered an expert speaker presentation on the roles of cities in the energy transition and policies for power, transport and buildings, and which focused on the need for holistic approaches and the importance of multi-stakeholder interactions.

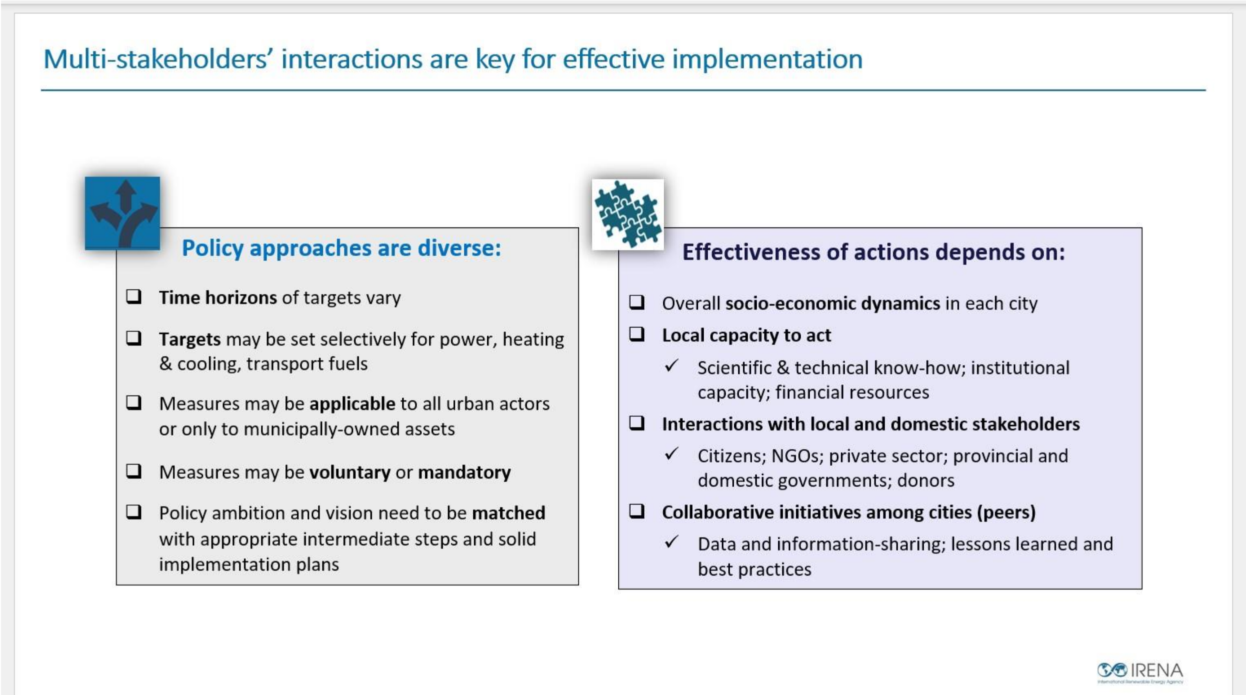


Figure 21: Presentation by IRENA on the roles of cities in the energy transition

2.2 Development of a vision from a checklist of points

As mentioned above, a key focus and output of the ToT workshop was the development of a comprehensive vision for carbon neutrality and disaster resilience in APEC cities and provinces. The vision was prepared based on a predefined Checklist guide, and via a moderated and open discussion within which ToT workshop participants made direct contributions to the contents of the vision.

2.2.1 Checklist for defining a local vision for carbon neutrality and disaster resilience

The Checklist for defining a local vision for carbon neutrality and disaster resilience was prepared by APSEC in cooperation with Members of the Cooperative Network of Sustainable Cities (CNSC) and defines the critical components that should be included within visions for carbon neutrality and disaster resilience in APEC cities and provinces. If elaborated according to the checklist, the vision will contain the following parts.

An introduction to the entity (i.e., the city or region of focus) based upon the overarching purposes (if they exist) or the core values of the entity (if they can be identified and defined).

A part containing the three to five biggest sustainability challenges that the entity faces, and the relevant measures to address them.

A part describing the three to five biggest disaster treats to the entity, and the relevant measures to address them, taken from the UNDRR Disaster Resilience Scorecard for cities, Essential 9.[26]

A slightly modified SWOT analysis for the entity as related to achieving carbon neutrality, and showing the entity's strengths, weaknesses, opportunities and challenges in this situation.

The checklist was approved by the CNSC in December 2022.

"Vision" designates a negotiated document of minimum 500 words (approx. one page); it can be longer and may contain visual materials, provided that stakeholders agree on its content. The Vision should be inspiring, energizing, hopeful, positive, clear, allow for tough decisions, guide decision-making and allocation of resources, and create consistency. Members are encouraged to elaborate the Vision in the local language as well as in English.

The Vision should state:

- The **Member's overarching purpose** if it exists and can be described in one sentence.
- The **Member's 3 to 5 core values** if they exist and can be expressed around keywords arranged in order of decreasing importance. Core values are values to be preserved in the very long run, even beyond mid-century.
- The **Member's 3 to 5 biggest current sustainability challenges** (in order of decreasing importance).
- The **Member's 3 to 5 most important measures addressing sustainability** (in order of decreasing importance).
- The **Member's 3 to 5 biggest current disaster threats** (in order of decreasing importance).
- The **Member's 3 to 5 most important measures improving disaster resilience**. On this point, the following questions may give some guidance:
    - Is there an **early warning system**, and does it reach 100% of the threatened population?
    - Are there **emergency response plans** that integrate professionals as well as community organizations?
    - Have **staffing needs** been defined, and is there sufficient staff to support the disaster response duties?

  - Have **equipment and supply needs** been defined for disaster situations, and is there sufficient equipment (shelter able to withstand disasters, rescue equipment, medical supplies, food and water supplies, fuel, batteries, clothing, bedding) for those situations?
  - Is there **sufficient solidarity (co-ordination, cooperation and interoperability) in emergency situations with neighbouring cities**?
  - Is there sufficient **training for emergency situations**? Is it efficient and is it sufficiently well embedded in local sports or cultural events?
- **How the Member would react if it became certain that by mid-century the use of carbon-emitting fuels would be impossible without fully neutralizing their emissions**. To answer this question and bearing in mind Sustainable Development Goals (e.g., universal access to electricity and to clean cooking fuels, per capita installed renewable electricity capacity, broadband internet, mobile phones), the Member will specially identify:
  - The Member's strengths (3 – 5) to deal with this task.
  - The Member's weaknesses (3 – 5) in this task.
  - The opportunities (3 – 5) arising for the Member from this task.
  - The challenges (3 – 5) the Member would address to face this task.
- **Whether the MSD should become a regular consultative body**.

2.3 Preparing the data collection

This part of the ToT focused on the issue of data and its collection, to facilitate energy and emissions target setting in a meaningful way. The training considered the various opportunities and best practices, as well as challenges and common pitfalls, in data collection and sourcing. It was designed to provide ToT participants with a clear understanding of these topics, also in the context of data collection for 2030 target setting within the (then forthcoming) project MSD. The overall goal was to provide ToT (and MSD) participants with the necessary background understanding of the importance of data for robust and meaningful target setting, and to give them the tools to be able to replicate best practices in data collection in their regions and municipalities located throughout the APEC region.

As mentioned above, an essential step in the process of developing 2030 targets for energy intensity, renewables share and emissions intensity for the North Sulawesi Province and ahead of the MSD taking place involved the collection and analysis of key background (energy and emissions) data for the Province. Such data is required to define historical trends and baseline scenarios for energy demand, renewables share, and emissions. Coordinated efforts to collect data were made during the six months prior to the MSD. For detailed discussion on the specific methodology employed, please see Annex 3. The approach involved a detailed review of all central and provincial level databases, as available, and discussions and submission of data requests to key institutions with responsibility for data collection and management. The data collection process encountered several important challenges, particularly regarding accessing relevant and updating data at the provincial level. In several instances, relevant energy and emissions data was only available at the central or regional levels.

The challenges encountered in data collection for North Sulawesi Province are somewhat typical for the Asia-Pacific region as a whole and as regards accessing comprehensive, transparent, updated, and complete data on energy and emissions at regional, municipal and provincial levels. This is also the specific case in Indonesia, as was outlined in a presentation delivered by World Resources Institute (Indonesia), see below. Some of the key challenges are summarised as follows.

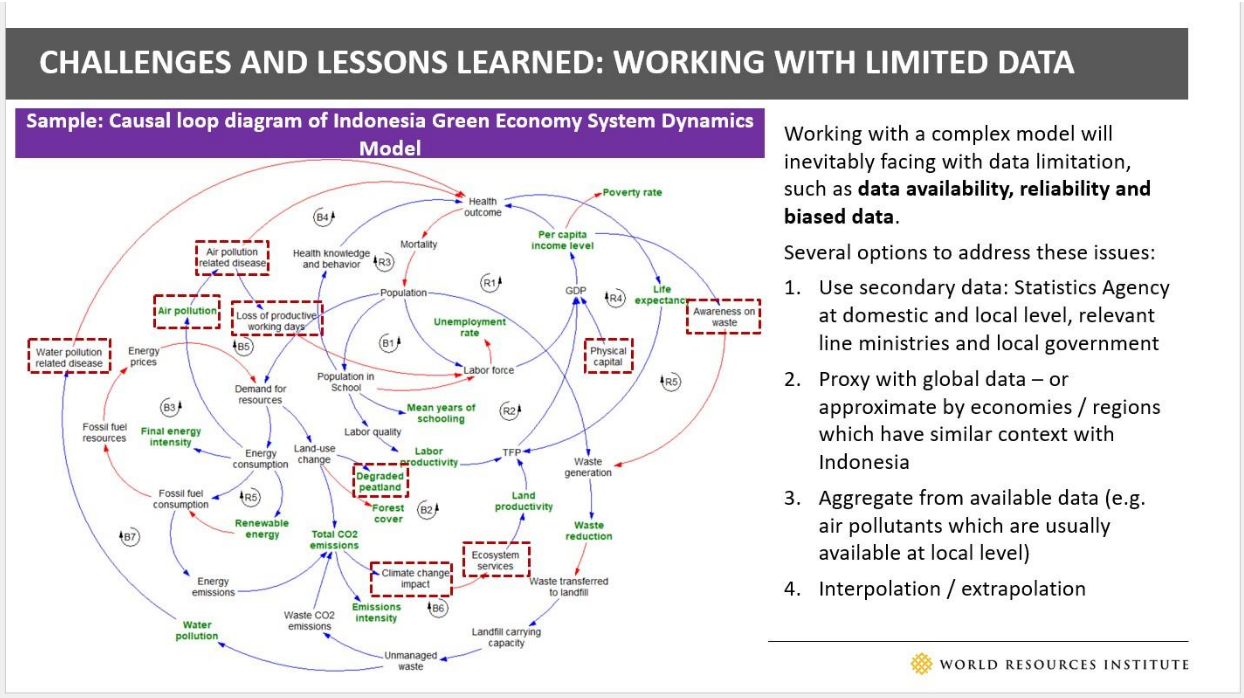


Figure 22: Presentation by World Resources Institute, Indonesia, on data collection

As a general trend and with only few exceptions, city level governments and related authorities do not publish data and information on energy indicators (e.g., demand, installed generation capacities, energy intensity, renewables share, carbon emissions, etc.) and other relevant thematic data (e.g., telecommunications data). Typically, city governments are under no legal obligation to collect and publish such data, and often lack internal resources and necessary tools or knowledge to undertake standardised data collection processes for energy and emissions at city levels. For instance, in 2021, some 38% of cities reporting through CDP-ICLEI Track did not report a community-wide emissions inventory.

Efforts are being made, however, to promote, facilitate and encourage the collection of energy and emissions data at city and municipal levels in the Asia-Pacific region. The Carbon Disclosure Project (CDP), for example, is a major driver of efforts to scale up the collection of standardised data at city and municipal levels. The CDP has developed a city-level questionnaire, that includes the collection of sector-specific data and GHG emissions inventory data for cities. In 2022, the questionnaire (see figure below) Figure 23was redeveloped to reduce the reporting effort of jurisdictions, focusing on the most important data points for climate action. The questionnaire is comprised of five modules or sections across the areas of governance, assessment, targets, planning and actions. Cities new to reporting can start by reporting what they have available and then add more data in subsequent years of reporting. The questionnaire has also been aligned with international standards and frameworks such as TCFD, GCoM CRF, RTZ/RTR, SDGs, SBTs, and several others.

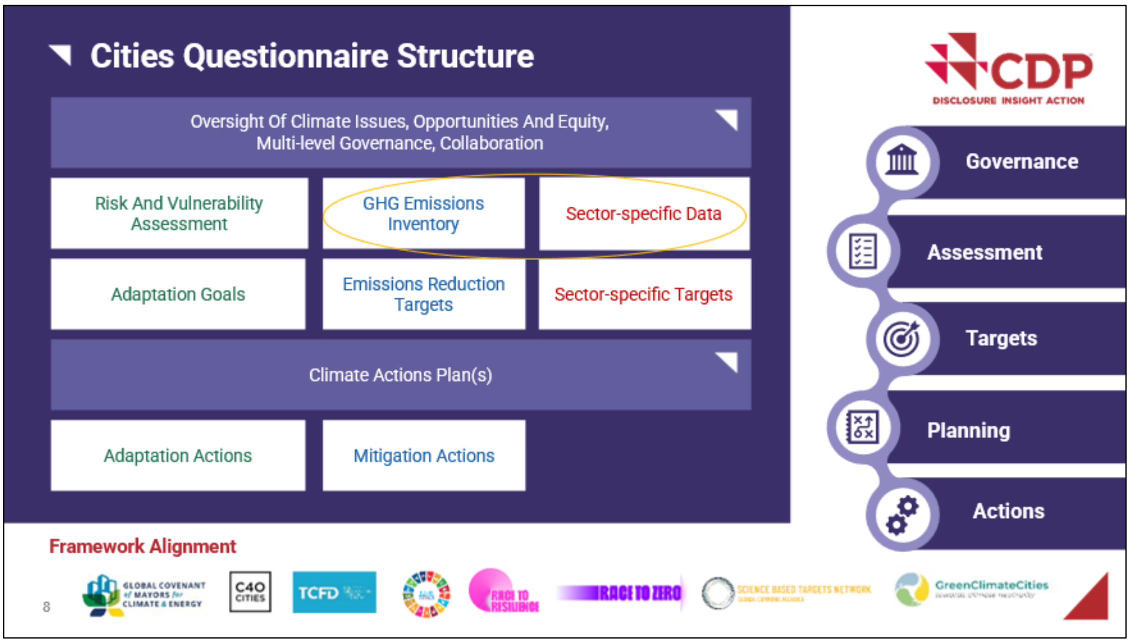


Figure 23: Presentation by CDP on its standardised data collection methodology

A detailed presentation was also delivered by ICLEI (Indonesia) regarding energy and emissions data collection and access. ICLEI and the CDP have an ongoing productive partnership that includes a comprehensive local government climate change adaptation and mitigation action reporting system named CCR (Climate Carbon Registry), operated via a user-friendly web-based platform, accessible to local governments. Through this platform, governmental entities are empowered to report their commitments aimed at attaining sustainable development objectives. These commitments encompass various aspects, including climate change adaptation and mitigation endeavors. The resulting platform, known as the CDP-ICLEI Track, integrates with the support infrastructure developed by ICLEI, known as ICLEI-TAP (Transformative Actions Program). Lessons learned from the reporting to CDP-ICLEI Track is shown in the figure below.

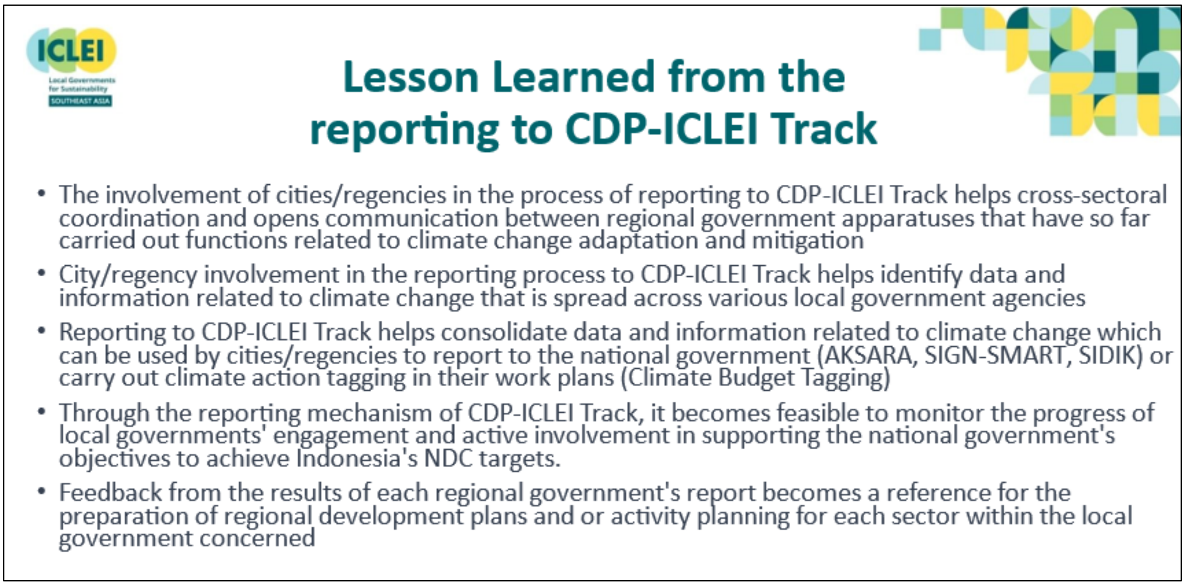


Figure 24: Presentation by ICLEI Indonesia

It is important to underline, however, that despite initiatives such as the CDP's City Questionnaire, several important issues continue to hinder access to relevant and updated energy and emissions data.

In particular, all data provided by cities is done so on a voluntary basis, and cities are not obliged to make publicly available such data. This has the effect of stymying access to such data, which means that specific data requests must be made to the city government each time data is being used. This process is relatively inefficient in terms of effort and timing. Addressing this issue would yield significant advantages to city, municipal and provincial level efforts to understand energy transition and carbon neutrality opportunities and to set meaningful and realistic targets. Through developing and maintaining a robust and comprehensive GHG emissions inventory, cities would be well placed to establish a baseline, set reduction targets, prioritize climate actions, and track progress.

It is important to also underline that, where cities do report emissions and energy data, it is often rather outdated. Data can typically be 3 – 4 years outdated by the time it is published. This can affect the ability to undertake rigorous analyses, to fully understand the current energy and emissions profiles of a city and to prepare meaningful targets.

City, municipal and provincial level governments often encounter difficulties in consolidating data and information related to climate change as it scattered among various agencies within local government. Furthermore, if the authority for the collection of energy data lies with other higher (e.g., regional or central level) government authorities, city governments can be blocked or disincentivized to collect energy and emissions data in a comprehensive way. In this context, it is recommended that central and local interests to achieve climate change targets be increasingly interlinked and coordinated.

Energy and emissions data collection experiences from other city contexts were considered, to highlight approaches used and lessons learned, such as that of Quezon City (the Philippines).

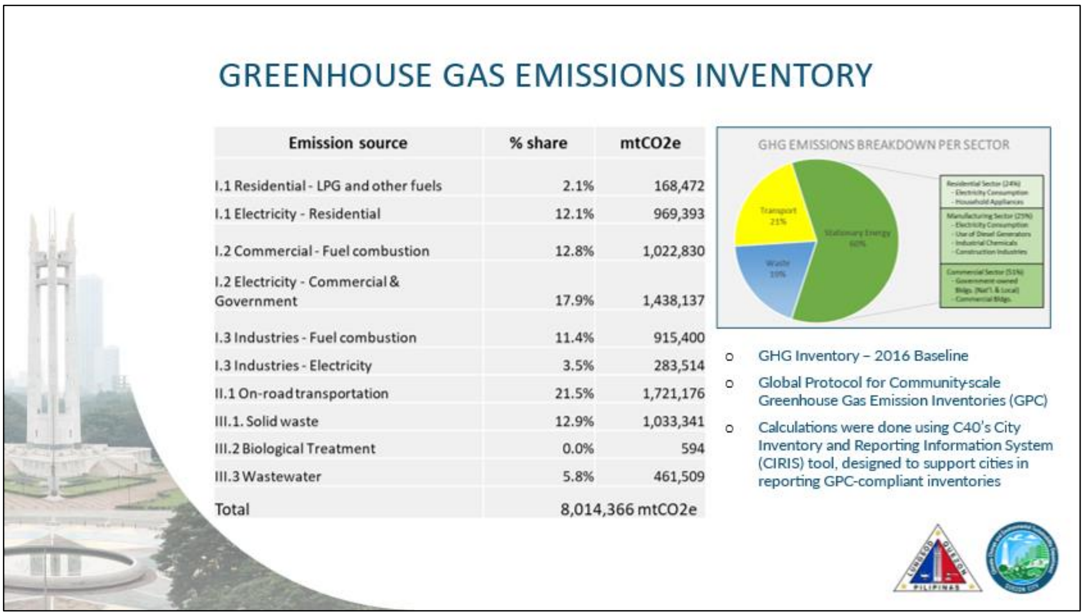


Figure 25: Greenhouse gas emissions inventory of Quezon City, the Philippines

One positive note is that, in recent years, there is an expansion in the number and level of sophistication of GHG emissions monitoring tools, datasets and approaches. These can support and facilitate cities in their efforts to develop inventories. For instance, by providing them with data to address current inventory data gaps; or for instances wherein cities are unable to collect the data themselves. Many energy and emissions data collection and management tools and datasets are developing and evolving rapidly. It is recommended that city, municipal and provincial governments within Asian Pacific economies keep a close track on the evolution of such tools, datasets and approaches, and incorporate them into the ongoing work of government and related relevant institutions.

During the process of defining a data collection methodology and overall process, city, municipal and provincial governments should bear in mind several factors. These include the degree of alignment with relevant geographic boundaries, alignment between a data collection tool's data and the inventory boundary, the most appropriate data / inventory accounting period, sectoral coverage, and the frequency of data collection and update processes. The ToT focused on available methodologies for measuring progress and performance against sustainable development criteria in urban contexts; for instance, lessons learned and key recommendations from the World Council on City Data.

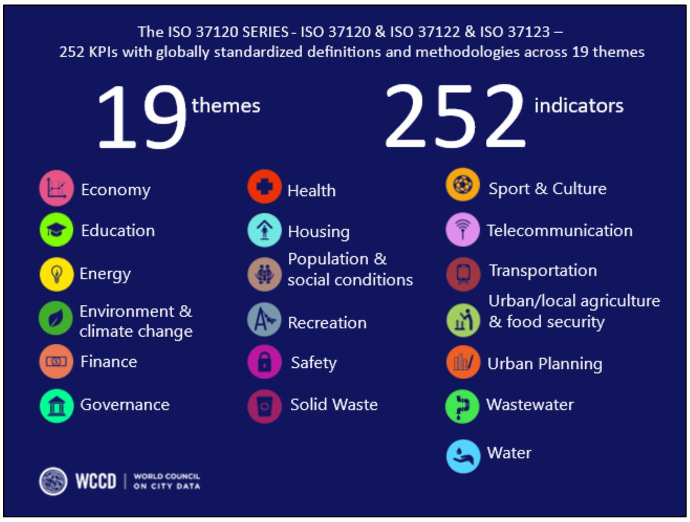


Figure 26: Definitions and methodologies for tracking progress to meet SDGs in cities

Furthermore, in the process of evaluating whether a given data collection and management methodology or tool is appropriate for a given city or province, governments and relevant institutions should also consider whether the methodology or tool also includes additional climate action planning functionalities, whether the data can be downloaded and exported in a meaningful format, and in a straightforward way; and whether the data can be readily shared across different platforms (for instance, those platforms used in other government departments or working groups).

A separate but no less important challenges to adequate data collection at city, municipal and provincial levels is that many jurisdictions do not have climate change working group to assist in assessing climate risk and vulnerability, measuring community-wide emissions and developing climate action plans. Consequently, it is strongly recommended that inclusive climate change working groups be established and made operational in cities, municipalities and provinces to assist them in developing and implementing climate action plans based on scientifically proven methods and comprehensive data.

3. Multi-Stakeholder Dialogue on carbon neutrality and disaster resilience in North Sulawesi

The Multistakeholder Dialogue (MSD) event took place over six days, during 21 – 28 February 2024 and was implemented in a hybrid format with both in-person participation in Manado city (North Sulawesi), and virtually (online) as an event open to all APEC member economies. The first MSD session focused on the development of a comprehensive vision for a data driven, carbon neutral and disaster resilient future. Discussions considered the purpose of the vision, core values of the Province, sustainability challenges and measures to address them, disaster threats and measures to address them, as well as the Province's strengths, weaknesses, opportunities and challenges to address carbon neutrality. Key themes included the optimal balance between ambition and achievability, constraints related to data and information availability, human and institutional capacities for implementation, access to adequate funding support, governance approaches and the need for awareness raising. Secondly, the MSD session focused on the formulation and adoption of key 2030 targets on energy intensity, CO2 emissions intensity and renewable energy. The discussions were wide-ranging and followed as much as possible the principle "think global, act local". They focused first on the global context and evolution towards carbon neutrality, taking account of the UN Sustainable Development Goals (SDG) and the APEC energy goals, followed by the analysis of the Indonesian context, notably the three scenarios (business as usual, unconditional and conditional mitigation) underpinning the Indonesian Nationally Determined Contribution (NDC), and, finally, on the specific energy sector context of North Sulawesi Province, its scope for low-carbon energy uptake and energy intensity improvements; as well as considering the broader regional, Indonesian and international context for carbon emissions mitigation and the sustainable energy transition. Discussions also centred around renewable energy resource potential, the low-carbon energy workforce training and skills needs, the need for a "just" transition, technical constraints (e.g., power grid stability), governance issues, and official targets and goals. Chapter 3 also details the reasons why the MSD was successful.

3.1 How to hold an MSD: The Dos and Don'ts of MSD guided planning

Planning for carbon neutrality requires clear science-led guidance in a holistic approach as well as a deep outreach into society. The MSD held in North Sulawesi Province in February 2024 managed to have both. The outreach into society was achieved by gathering local representatives from the North Sulawesi Government and its cities and regencies, development and planning offices, stakeholders from local universities, energy, finance, agriculture, food, and women's organizations. The MSD brought together 102 online and in-person participants from 10 APEC economies (Australia; Chile; China; Hong Kong, China; Indonesia; Korea; the Philippines; Thailand; USA; Viet Nam). The hybrid in-person and online formula demonstrated to be a highly effective way to discuss carbon neutrality and disaster resilience across APEC.

The science-led guidance and holistic approach was provided by professor Defilla of APSEC, seconded by a host of international experts, including from Global Factor Consulting International (Spain), EMSD of Hong Kong, China, the Metropolitan Manila Planning Authority, Victoria State (Australia), the City of Temuco (Chile), the Carbon Neutral Cities Alliance, the Environmental and Climate Change Research Institute of the Philippines, the World Smart Cities Forum, Hong Kong University, the Imperial College London, the International Institute for Applied System Analysis (IIASA) and the International Energy Agency (IEA).

During its 6-day event, the MSD first discussed and adopted a detailed 10-page vision for carbon neutrality and disaster resilience that paved the way for MSD participants to understand the main factors governing a disaster resilient transition towards carbon neutrality. Thereafter, the MSD discussed and adopted specific targets for the North Sulawesi Province. For the period between 2021 and 2030, energy intensity of the North Sulawesi Province is set to decrease by 2% and emissions intensity by 38%, whereas renewables share is set to increase from 27% to 52% (medium target) or to 60% (high target), respectively.

The MSD event took place over two sessions, during 21 – 28 February 2024. The MSD event was implemented in a hybrid format. Participation in the MSD was both in-person in Manado (North Sulawesi, Indonesia), and virtually (online via Zoom platform) as an event open to all APEC member economies.

The MSD was held under the guidance of the Focal Point of the target province of North Sulawesi, Indonesia. Initially, this was the Provincial Secretary of North Sulawesi Province who delegated the guidance to the other senior representatives of the Province.

The event was structured around two sessions of three consecutive days each:

- The first session (MSD1) took place on 21 – 23 February 2024 and focused on the **development of a comprehensive vision for a data driven, carbon neutral and disaster resilient future.**
- The second session (MSD2) took place on 26 – 28 February 2024 and focused on the **formulation and adoption of key 2030 targets on energy intensity, GHG emissions intensity and renewable energy.**

Figure 27: MSD participants in Manado, North Sulawesi Province, Indonesia (February 2024)

The MSD format included presentations from international experts covering a wide range of topics on low-carbon development, energy transition and resilience to disasters. Presentations from international experts were followed by moderated discussions, opportunities for Q&A and feedback. For a full list of presentations by international experts, please refer to Annex 4.

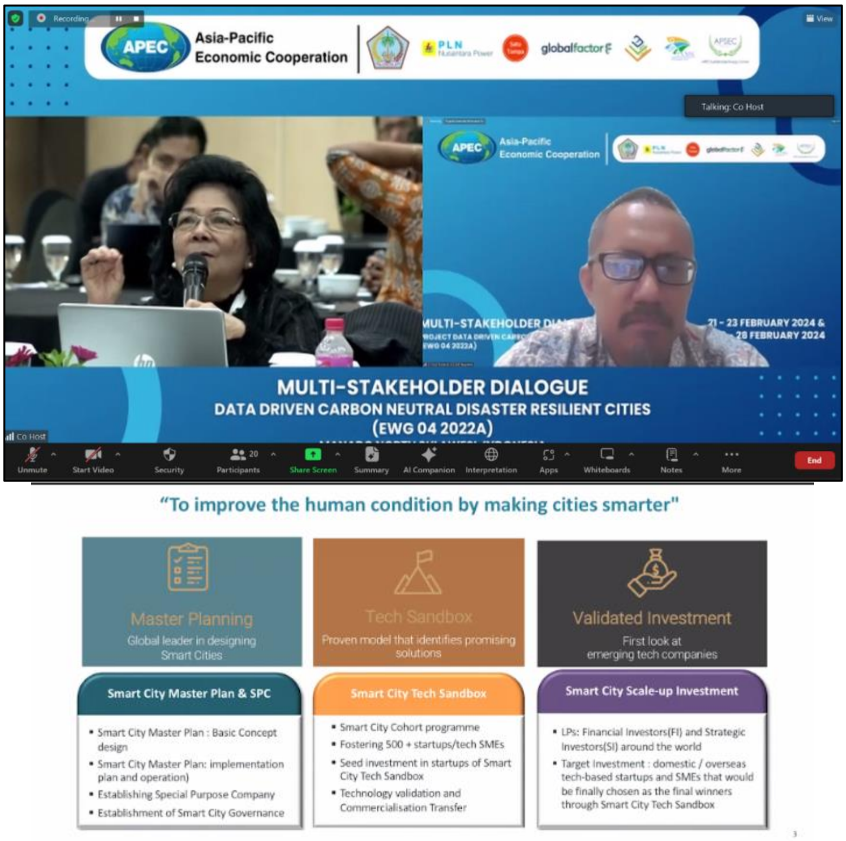


Figure 28: International expert speakers' presentations and moderated discussion

The MSD format also included deeper discussions on the vision and 2030 targets for North Sulawesi Province, via detailed presentations on draft vision texts and draft proposed 2030 targets, followed by first and second structure readings and moderated negotiations.

Appropriate expert stakeholders from the areas of **energy planning, urban or regional planning, climate data management and disaster resilience** were requested for nomination. Nominations of qualified female participants were particularly encouraged. A full list of MSD participants is shown in Annex 5.

The format of the MSD sessions was designed to promote high levels of participant interaction, the effective sharing and discussion of views, and to contribute to a high quality and comprehensive low-carbon development vision.

The overall success of the MSD was contingent on the adequate and timely preparation of both the MSD and the participants within it. The MSD facilitated procedural transparency, the sharing of concerns, issues, opportunities, data and key information, etc. It has improved the visibility of workstreams among government departments and workgroups; and helped bridged information gaps. To be productive, the MSD process requires a degree of commitment and engagement of the MSD participants, working within an atmosphere of trust and openness, and wherein participants contribute in an open way, understanding that their views and inputs will be heard and considered.

During the Multistakeholder event, the Cooperative Network of Sustainable Cities (CNSC) formalized the membership of Kotamobagu City and the Bolaang Mongondow Regency as two new members from North Sulawesi.

The following subsections outline the various discussions that were held within the MSD, describing the full range of issues and topics that were raised, discussed, negotiated and finalized by MSD participants during the MSD.

3.2 Why a vision and how it was developed

This subsection focuses on the discussions related to the development of a vision for low-carbon development and disaster resilience in North Sulawesi Province. The subsection is split into two parts: firstly, the focus is on the global context for developing visions for carbon neutrality and disaster resilience. This is then followed by the discussions on developing the vision for carbon neutrality and disaster resilience in North Sulawesi Province.

3.2.1 The global context for developing visions for carbon neutrality and disaster resilience

In order to provide MSD participants with a general background context on lessons learned and best practices internationally in the use of MSD forums and community assemblies for mobilising action on climate change, low-carbon energy transition, carbon emissions mitigation and disaster resilience, as well as recommendations on how to maximise the impact of the present MSD, several presentations were delivered by expert speakers during the MSD sessions. Some of the main points underlined within those presentations are summarised below.

The importance of communication of climate change and disaster resilience planning, citizen engagement and optimal ways to encourage behavioural changes were discussed as core elements of successful long-term decarbonization vision development and implementation. For example, the Carbon Neutral Cities Alliance shared various case studies and recommendations on these topics (see figure below).

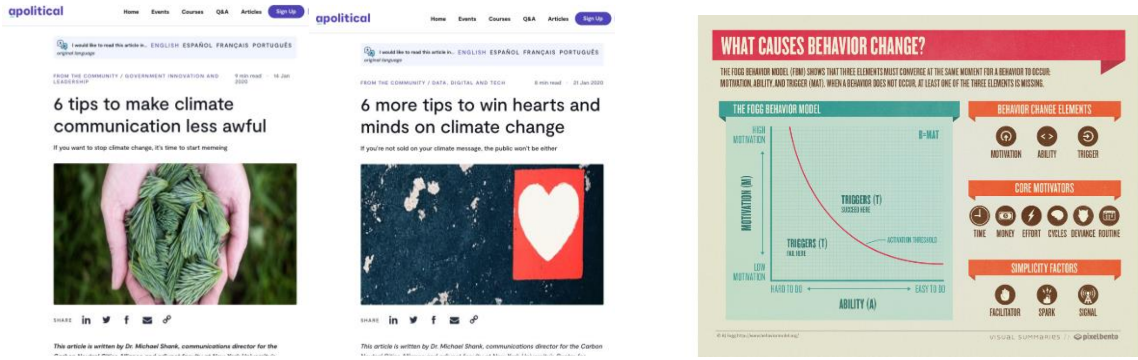


Figure 29: Presentation on mobilizing transformative climate action in cities

The importance of engaging effectively with a wide range of city stakeholders was also underlined. For instance, the experience of the Metro Manila government in developing its "Greenprint 2030", a low-carbon development vision, was presented by the Metropolitan Manila Development

Authority. The presentation focused on stakeholder engagement approaches used (see figure below), the vision that was prepared, and how the vision is being communicated to the wider Metro Manila community.

Figure 30: Stakeholder engagement during the development of Metro Manila's low-carbon vision

A case study outlining the experience of the State of Victoria, Australia, in achieving its renewable energy target and broader energy transition objectives was also presented by Solar Victoria (Government of Victoria State). In addition to describing the overall strategic approach of the government to promoting the uptake of solar energy systems among households and businesses in the State, observations were shared on the catalysing effect of decentralisation of energy generation, specifically to encourage further steps of citizens and businesses to reduce their carbon footprints. It was shown that, based on stakeholder self-reported behavioural patterns, many stakeholders that install decentralised solar PV generation systems on the homes or business buildings, are also then more likely to take additional actions such as switching from a conventional vehicle to a low- or zero-emissions alternative, or to replace electrical equipment with low efficiency ratings. Such examples were held up as a clear example of how setting targets in one key headline topic can in fact create momentum in additional related areas. Such "easy wins" and positive additional impacts should not be overlooked, but rather encouraged.

Figure 31: The experience of Victoria State, Australia, in encouraging energy transition actions

Discussions also focused on the specific context of North Sulawesi Province, Indonesia, and its energy transition progress to date and opportunity for the future. Fransiscus Maindoka Head of the Energy and Mineral Resources Agency of North Sulawesi Province Government, set out the specific context of the Province's economic and social development vision and mission, and how the use of low-carbon and renewable energy systems plays a critical role within both (for example, see figure below).

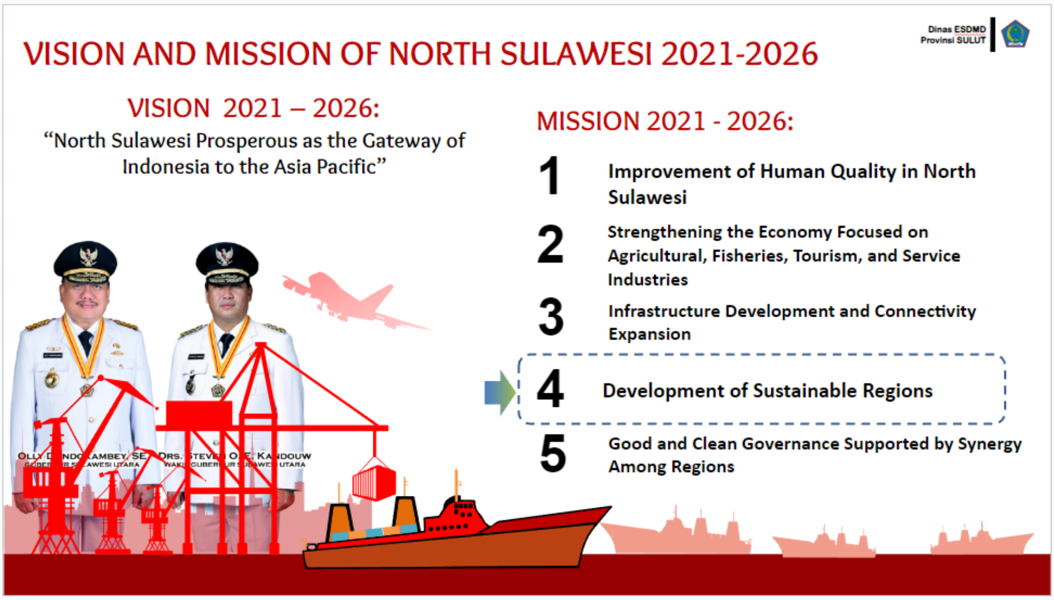


Figure 32: North Sulawesi Province low-carbon and energy transition vision

Some of the central tenets of North Sulawesi Province's mission to develop sustainable regions includes the increased use of renewable energy sources; the encouragement of disaster mitigation efforts and climate change adaptation; and improving the overall quality of settlement environments.

3.2.2 Discussions on the vision for North Sulawesi Province

The session initiated with a series of short introductory statements by key stakeholders of North Sulawesi Province regarding the current starting point for a vision for low-carbon development and disaster resilience.

Discussions then focused in on the purpose, the strengths, weaknesses, challenges and opportunities of North Sulawesi to become carbon neutral. The main discussion points are summarised as follows.

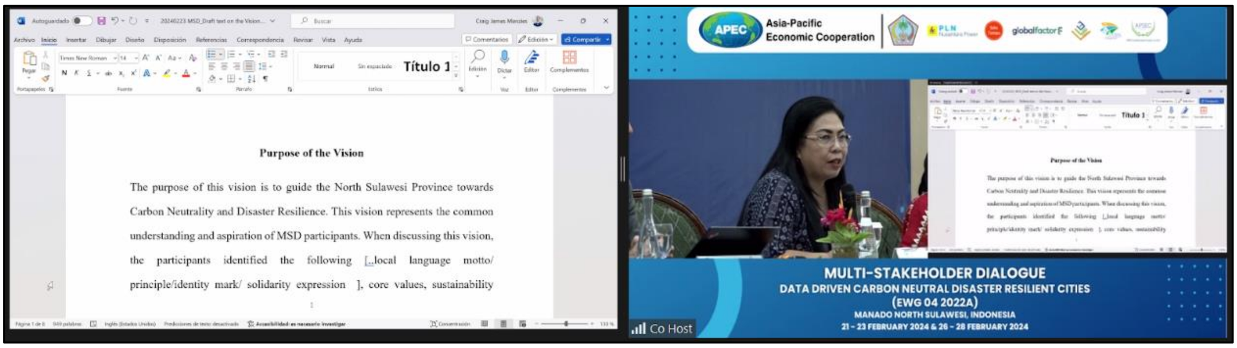


Figure 33: Introductory statements and presentation of the draft vision for carbon neutrality and disaster resilience

Strengths of North Sulawesi Province related to a vision for low-carbon development and disaster resilience

North Sulawesi Province is in a strong starting position to be able to take up a comprehensive vision. One district of North Sulawesi Province, namely North Minahasa district, has recently launched a climate action plan, developed in collaboration with expert teams from IPB and Brawijaya universities.[27] Furthermore, North Minahasa District is a member of the Global Covenant of Mayors (GCoM), and therefore something of a pioneer district within the North Sulawesi Province in terms of carbon neutrality planning and action. Furthermore, the North Minahasa Regency has ***set up a master plan*** for CO2 emissions mitigation in the district.

In the North Sulawesi Province, Regional Regulation No. 8 of 2022 has been launched, which governs the General Plan for Energy in North Sulawesi (RUED). This will continue with a governor's regulation related to the province’s energy mix, incorporating generation and infrastructure development potential as outlined in existing plans.

Regarding the vision of disaster resilience connected to the energy sector, the Marine and Fisheries Agency of North Sulawesi Province government ***has aligned its policies*** with those of the Ministry of Marine Affairs and Fisheries. These policies encompass five key areas within the economic domain, which are then implemented at the regional level. These areas include: 1. Expanding conservation areas, 2. Implementing sustainable fishing practices, 3. Promoting environmentally friendly fish farming, 4. Responsible management of small islands, and 5. Plastic waste management. These policies are cascaded to the local level to foster synergy. The North Sulawesi Provincial Government has also established spatial management and legal documents for this purpose in the previous year.

North Sulawesi Province government ***has designated zones for new renewable energy management***, with some areas such as in the Lembeh Strait, which can harness currents, and in island regions utilizing waves for renewable energy generation. Additionally, efforts related to blue carbon economy were conducted last year, focusing on coastal ecosystems, including mangroves, coral reefs, and seagrasses, which contribute significantly to carbon absorption in the sea. However, it was noted that Indonesia lacks standardized methods for blue carbon calculation.

The ***importance of data*** in facilitating smooth operations was emphasised as a key issue to be addressed within a low-carbon development vision. It was highlighted that cities in North Sulawesi Province have a significant role, where over 120MW of geothermal energy is installed. Tomohon City, for example, has leveraged geothermal energy in collaboration with small businesses involved in palm sugar production.

Discussion also focused on the ***CO2 mitigation plan for the energy sector*** in North Minahasa Regency, highlighting that current CO2 equivalent emissions stand 168,000 tons. The Regency's target for 2030 is to achieve a 6.93% reduction. Additionally, the regency has developed a vulnerability map identifying villages susceptible to disasters and have programs in place to prevent floods and landslides.

In terms of ***CO2 mitigation priority actions***, there is certain focus on mangrove planting and rehabilitation along the North Minahasa Regency's extensive coastline. It is planned to allocate 4,000 hectares of land for mangroves, aiming to reduce greenhouse gas emissions by 18%. In terms of adaptation to the impacts of climate change, improvements to the drainage system in North Minahasa are crucial.

Weaknesses of North Sulawesi Province related to a vision for low-carbon development and disaster resilience

Several weaknesses and critical challenges exist regarding the development of a comprehensive vision for low-carbon development and disaster resilience. These include, for instance, the issue of ***data scarcity*** in North Sulawesi. Whilst a single centralised "One Data Portal" is in place currently in the region, there are significant gaps in terms of data input and the degree of completeness of data collected. There are ***challenges in sourcing data***, particularly from PT Pertamina for fuel usage data, for example due to the lack of representation of PT Pertamina in North Minahasa. Despite encouraging participation, certain key sector companies have to date not participated in data sharing and disclosure, prompting the use of proxy data from other regions for planning purposes. It is considered that there is a need for ***increased support and collaboration*** from institutions like APEC to ensure more professional and accurate results in achieving carbon neutrality.

Discussions also centred on challenges such as ***data quality, privacy, limited resources, and capacity***, while also recognizing opportunities for evidence-based decision-making, innovation, and efficiency. The importance of city's carbon footprint, energy use, and disaster risk strategy were each underlined as important for developing effective plans for carbon neutrality and disaster resilience. This requires certain datasets that need to be collected and analysed efficiently and accurately, and in a way that safeguards transparency of data.

MSD participants also set out their views on the **opportunity** for North Sulawesi Province to ensure low carbon development and disaster resilience. Some of the key opportunities mentioned included the Environmental Agency's central role in providing data for the Greenhouse Gases Inventory Program, building on the work it has been undertaking in collaboration with central

Indonesian government since 2022. There is an opportunity to ***better manage*** the data collection and analysis.

Aan opportunity also exists for North Sulawesi Province to capitalize on ***strategic research collaboration***, particularly as regards disaster early warning systems, and international cooperation in sustainable energy development. Collaborations may involve cities and districts in green finance to accelerate innovation and cost reduction.

It was mentioned that North Sulawesi Province aims to become a pilot case for such low carbon development, with a focus on trade and other initiatives in North Minahasa Regency during 2024. North Minahasa has the largest coral reef and mangrove areas in North Sulawesi Province and is ***well-positioned for these endeavours***.

Lastly, a clear opportunity exists to ***involve the community***, in the Province's low carbon and disaster resilient future.

Concerns regarding facilitating low carbon development

The MSD participants raised various concerns regarding the practicalities of moving to a low carbon development trajectory in North Sulawesi Province. For instance, concerns were raised regarding ***citizen participation in waste separation and recycling***. Specifically, whilst many citizens separate their waste at home, it often gets mixed together again by waste collectors, rendering the effort futile.

Other MSD participants commented that while society is just beginning the journey towards carbon neutrality and disaster resilience, the ***government must take the lead in initiating this strategy for the region***. Currently, there is a low level of understanding of carbon neutrality among the community, and efforts to educate and raise awareness are just beginning. The challenge lies in changing ***traditional energy usage habits and lifestyle practices***. It was suggested that the use of ***language that aligns with the basic needs and priorities of the communities***, such as health, cost-effectiveness, and security, can be an effective way to communicate low-carbon goals and benefits.

Discussions were held regarding climate change communication and overcoming challenges associated with distress and the planning fallacy, and how to regain trust in communication efforts. The need for effective and strategic communication strategies that address societal perceptions, emotions, and challenges in conveying complex issues like climate change were underlined. Clarifying these concepts can provide valuable insights into developing more impactful communication approaches and fostering trust and engagement among stakeholders. Oftentimes, communities may have high hopes and expectations that are not met, leading to disappointment and distrust in local government. To address this, ***cities can set out achievable activities*** with varying time commitments to accommodate busy schedules and ensure that everyone can participate in climate action efforts.

The importance of ***building trust*** *between communities and local government* through transparent communication, realistic goal-setting, and empowering experiences that encourage ongoing engagement in climate action initiatives, was also underlined.

First Round of detailed discussions on the Draft Text on the Carbon Neutrality Vision for North Sulawesi Province

The Province's 3 to 5 most important measures improving disaster resilience.
It was proposed that these measures include comprehensive disaster resilience strategies; understanding of current (and potential future) urban risks; mapping levels of urban disaster resilience; and consolidated/coordinated commitment and collaboration of involved parties. MSD participants provided wide-ranging feedback, including the following points.

- A ***vulnerability map*** is needed for the Province, to map risks and exposure.
- The significance of ***stakeholder engagement*** in improving disaster resilience was emphasised. It was suggested that the broader spectrum of stakeholders involved in disaster resilience efforts indicates progress in this area, and stakeholder engagement is recommended to be included as a crucial aspect of government efforts to deal with disaster resilience.
- The importance of ***incorporating drills and training*** into resilience strategies for disasters was also underlined. Guidelines (e.g., similar to fire drills in schools) could be scaled up and expanded to ensure people are prepared for various disaster scenarios. Proper guidance and training are seen as essential components to minimize casualties and improve overall disaster resilience.
- ***The importance of involving the media*** in efforts to minimize carbon emissions and prepare for disasters was also discussed by MSD participants. It is understood that the media can play a crucial role in informing the public and promoting positive action towards climate protection. Efforts could be made to engage various media channels extensively to educate communities about disaster drills and guidelines.
- There is a need to explore ***strategies for engaging media outlets effectively*** to ensure that information reaches the community and fosters awareness and action regarding disaster resilience initiatives. For instance, ***different measurement tools should be utilized*** for assessing disaster resilience at the domestic, local and global levels, as what works at the economy-wide level may not be suitable for the regional level. Therefore, identifying appropriate tools tailored to the region, such as North Sulawesi, is essential.
- The importance of ***documenting the collective commitment of all stakeholders***, including active involvement of the media for effective communication of relevant information, was also underlined. There is a need to ensure that media outlets play a vital role in disseminating information to the community, thereby fostering awareness and engagement in disaster resilience efforts.
- The importance of ***engaging as many people as possible in disaster resilience efforts*** was mentioned. Drawing parallels to initiatives by the Corruption Eradication Commission (KPK), which educates students and the wider community about anti-corruption measures, it was suggested that a similar approach for disaster resilience education. For instance, the idea of ***involving high school students*** was presented and the power of education to raise awareness and foster active participation was emphasized. Proposals were made highlighting the work of disaster management agencies such as BNPB/BPBD (Indonesian and local disaster management agency) and emphasizing the integration of disaster resilience into daily routines and practices. This approach aims to emphasize the

importance of continuous engagement and action in building resilience within communities.

The figure below shows the draft vision text, under discussion with MSD participants. The draft vision text (shown on the left, and which was presented on the main large screen within the MSD event) was discussed and revised in real-time, based on comments raised and suggestions provided by MSD participants.

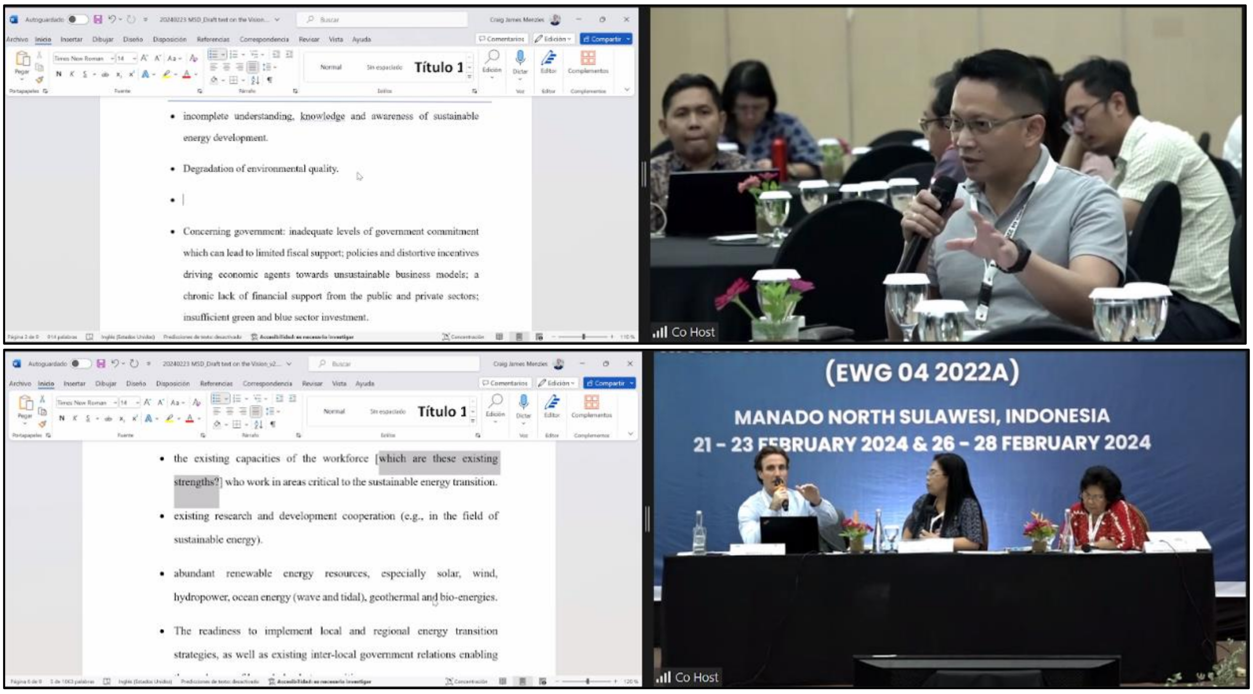


Figure 34: Interactive and moderated discussions on the draft Vision text

The Strengths of Province to address Carbon Neutrality

It was proposed that these strengths include increasing the capacities of the workforce (workers, professionals throughout the value chain) who will work in the sustainable energy sector; stronger research and development cooperation, for example in the field of sustainable energy. In the energy transition, and implementation of strategies with local and geographical contexts, as well as increasing inter-local government relations that enable the exchange of knowledge between cities. MSD participants provided the following feedback and reflections on these proposals.

- The ***collaborative efforts and knowledge exchange among local governments*** as a strength in addressing disaster resilience in North Sulawesi Province.
- Questions were raised on whether the sentence or narration includes the community explicitly or implicitly. They wanted to ensure that the ***involvement of the community*** is clearly stated in the document.
- It was proposed that the interpretation of "***stronger research and development cooperation***" be expanded to include various stakeholders such as academia, universities, and the private sector. Additionally, it was suggested that a further point be incorporated on the availability of natural renewable resources as a strength in the document.
- Proposals were made to consider weaknesses alongside strengths in the discussion. It was pointed out that while the community could be considered a strength, it could also be a weakness due to a lack of awareness among stakeholders, including the people, including

importance of taking a ***comprehensive approach*** to understanding both strengths and weaknesses to address the issues effectively.

The Province's Weaknesses to Address Carbon Neutrality

It was proposed that these weaknesses include a lack of access to clean and GHG emission-free technology; limited government regulations and concrete efforts to reduce the use of high-GHG emission energy systems and fuels; a lack of incentives for producers that are successful in reducing their GHG emissions; a lack of accuracy and validation of climate time series data; there are still different definitions of collected climate data (non-uniform definitions).

- It was highlighted that ***the lack of incentives for businesses*** that make efforts to reduce greenhouse gas emissions in North Sulawesi. For instance, while companies invest significant funds to upgrade their systems to reduce emissions, there is no monetary reward or incentive from the government. This lack of incentive is identified as a weakness in the region.
- It was mentioned that the Environmental Agency conducted greenhouse gas emission inventories for the 2022 time series, but there are two sectors for which no data was reported. This lack of data affects the accuracy of the greenhouse gas emission inventory. It was noted that while economy-wide time series data includes agriculture and waste sectors, ***the absence of data*** from other sectors poses a challenge for future reporting.

The Province's Opportunities to Address Carbon Neutrality

It was proposed that these opportunities include sustainable financing opportunities have enabled cities to enjoy benefits and incentives in collecting data; increasing the number of economy-wide guidelines to ensure data completeness and consistency for future aggregation/disaggregation; improved alignment and collaboration among organizations working on carbon neutrality; higher priority on GHG emissions neutrality at the local level within the APEC Energy Working Group, and the increasing need to cooperate among APEC economies to create a single climate and energy data system at the regional level. MSD participants offered the following comments and reflections on the proposals.

- There is a need to encourage the private sector to ***allocate more of their Corporate Social Responsibility*** (CSR) funds towards environmental aspects. There is hope that, in the future, the private sector will provide more support for initiatives related to carbon neutrality and disaster resilience in cities. There is also a need to support North Sulawesi to secure funding at both economy-wide and international levels for initiatives related to carbon neutrality and disaster resilience.
- It was mentioned that focusing on ***opportunities related to economic growth in the province*** should be linked to the potential for investment in low-carbon energy and climate change mitigation solutions, which could lead to increased economic activity and cost savings through energy and resource efficiency. Transitioning toward carbon neutrality presents significant opportunities for economic growth in the province. Economic growth opportunities could be explicitly included within the opportunities section of the Vision under discussion. Additionally, the potential for green finance to drive the economy was highlighted, presenting opportunities created by carbon neutrality.

The Challenges to the Province posed by Carbon Neutrality

The following points were mentioned as key challenges: air pollution will increase and become a major cause of human health problems and damage to society; many cities have informal economies where fuel data is not easily accessible; a lack of GHG emissions data from the industrial sector; limited transparency within some energy transition plans; actual baseline data (e.g. from around 20 years ago) can be difficult to obtain; and a lack of adequate consultative bodies on GHG emissions neutrality. MSD participants shared the following reflections.

- It was pointed out that a weakness in the ***lack of an economy-wide agency's support*** to address carbon neutrality. It is unclear whether there are government agencies at the economy-wide or regional level in Indonesia tasked with addressing carbon neutrality, identifying this as a weakness in addressing the issue effectively.
- Concerns were raised about the ***fragmented handling of data related to carbon neutrality across various sectors***, each managed by different institutions. The need for comprehensive data was emphasized, suggesting that a development planning agency should oversee this task. However, the absence of such coordination was noted, and it was suggested that the provincial government should regulate and assign the Regional Development Planning Agency (Bappeda) to address this issue.
- It was also suggested that while each agency has its own data, there ***lacks a centralized entity responsible for analysing the overall progress in carbon neutrality planning***.
- It was mentioned that all government agencies are involved in producing the long-term planning of Indonesia for 2025/2045. The importance of ***incorporating these ideas into the planning process*** was emphasized, especially in terms of action plans and program activities related to carbon neutrality and disaster resilience.
- A ***phased approach to transformation*** was suggested to be used: strengthening the foundation, accelerating the transformation, and expanding initiatives, aiming for Indonesia's golden age in 2045. The importance of aligning these plans with Sustainable Development Goals (SDGs) and ensuring that actions are planned and implemented by 2030, with the first five years being crucial.
- It was mentioned that there is ***the significant challenge of transitioning away from fossil infrastructure*** like power plants and internal combustion engines, while simultaneously adopting renewable energy sources and electric vehicles. This challenge could be included among the key considerations for achieving carbon neutrality.
- The ***importance of addressing the society mindset*** surrounding the transition from fossil fuels to green energy was underscored; for instance, changing people's perceptions, particularly regarding electric vehicles, is crucial for successful implementation.

Discussion of the draft text of the carbon neutrality vision for the North Sulawesi Province by MSD participants.

The following issues were raised and discussed regarding the draft text of the carbon neutrality vision.

- The significance of ***emphasizing macro aspects concerning North Sulawesi's involvement in carbon-neutral disaster resilience***.
- A vision statement should be incorporated into the Vision text, with something along the lines of "becoming a carbon-neutral and disaster-resilient" and suggests ***adding a target***, such as aiming to achieve carbon neutrality and disaster resilience by the years 2040 or 2045. Suggestions were made to include key text in the local language like "Mapalus", which is the philosophy of life for the people of Minahasa, North Sulawesi, in the general sense of mutual cooperation. This approach aims to ***enhance community understanding*** of the planned actions.

- ***The need to formulate the vision both qualitatively and quantitatively***, was mentioned, suggesting the inclusion of a timeframe such as "by the year of..." to achieve the vision, and it was noted that planning timelines related to climate change issues, are typically of the range of 2030, 2045, or 2060.
- Conversations were also held concerning the ***similarity*** between "carbon neutral" and "Net Zero emission," mentioning that at the 2021 climate change conference in Glasgow, President Joko Widodo set a target for Indonesia to achieve zero emissions by 2060. It was clarified that the focus of the vision and the overall APEC project is on ***carbon neutrality***. While closely related, there are some important differences between carbon neutrality and Net Zero emissions. The current project specifically emphasizes achieving carbon neutrality.
- It was mentioned that in statutory regulations, core values are principles, and it was suggested that the simple, yet significant words ***"responsibility" and "sustainability" be incorporated as a core value***. A further core value for inclusion could be "quick response," emphasizing the importance of swift responses to disasters, particularly in cities closely connected to disaster management or the disaster departments in each city in North Sulawesi.
- It was suggested that ***core values be condensed into single words***.
- It was mentioned that there is a need to highlight the potential in North Sulawesi, specifically mentioning the 40% contribution from renewable energy to the energy mix.
- It was pointed out that the declining environmental quality is a significant challenge for the province and suggests including it in the text, and this challenge with the need for ***green and blue investments***.

Challenges

The issue of ***poverty as a challenge*** was underlined and suggested to be linked to the positive aspects of transitioning towards carbon neutrality. Low carbon transitions can boost economic growth, create jobs, and help save money and energy. The potential of energy transition to contribute to poverty alleviation and this can be framed in the context of economic development. The importance of addressing ***poverty alongside environmental concerns*** and the need to consider the impact on those still on the poverty line in discussions about environmental issues.

One solution could involve ***intensive socialization***, advocating for a change in the quality of life through introducing a positive lifestyle.

It was mentioned that many remote islands and areas facing poverty have abundant natural resources. Using the example of islands with abundant fisheries but lacking cold storage and electricity, it was suggested building small power systems to support such areas. The ***grid system may not be feasible*** for these remote locations, making small electric systems more suitable to harness the abundant natural resources in those areas.

An additional point could be incorporated to the vision on increasing healthiness to the sustainable challenges, emphasizing the ***interconnectedness of poverty and health***. For instance, poverty significantly influences people's health and suggests considering the importance of carbon neutrality for the health of the people.

The importance of considering the dimensions of ***social and economic justice in the transition towards carbon neutrality*** was mentioned. Economic transitions should account for their impact on various sectors, including vulnerable groups or those dependent on traditional sectors affected by policy changes. There is a need to address the connection between poverty and the economy in a way that ensures justice across society. It was pointed out that the topics of ***social justice and quality of life*** mentioned are not challenges but should be placed elsewhere in the discussion.

Several challenges were discussed in relation to transitioning to renewable energy and zero-carbon infrastructure. For instance, the ***need for capacity building to support workers affected by the shift*** was considered, such as those in petrol stations who may lose their jobs as electric vehicles become more prevalent. While renewable energy creates new job opportunities, there are economic and industry-related hurdles to overcome. The complexity of the transition and the need to address misconceptions about renewable energy being expensive or luxurious were stated.

A ***lack of law enforcement is considered to be a challenge***, despite having guidance from laws, there is sometimes a lack of enforcement. It is important to address this challenge in the context of moving towards carbon neutrality and disaster resilience.

An important issue is the ***chronic lack of financial support***. With some minor exceptions, such as green and blue SUKUK, securities issued by the government for investment in the green and blue sectors, have been recently issued. These initiatives are aimed at supporting carbon-neutral sustainability and marine sustainability, indicating that the financial situation is not necessarily chronic.

It was proposed that "coal power plants" be removed in the first bullet point of the draft text, as Indonesia's economywide energy plan (RUEN) indicates a ***continued reliance on coal***, albeit with efforts to reduce their numbers and improve production cleanliness. It was questioned whether the term "phasing out" accurately reflects this policy, emphasizing the need to align statements with existing regulations to avoid contradictions. MSD participants agreed on the ***need for clarity and alignment with existing regulations to ensure consistency in statements***.

Some MSD participants emphasized the need for a more technical and specific explanation of the "polluter pays" principle, suggesting a focus on methods, standards, and datasets to ensure uniformity and clarity for practical application in regional areas. The need for concrete guidelines to implement the principle effectively were mentioned.

It was suggested that ***detailed measurement rules, regulations, or standards***, should be included in the action plan rather than the vision document. The vision document may not need to delve into detailed measurement rules, regulations, or standards, and ***technical details*** like the implementation of the polluter pays principle, such as a carbon tax, emissions trading system, or voluntary carbon markets, are better suited for the action plan stage rather than the vision document.

It was suggested that the ***shortage of groundwater*** be considered for inclusion as a potential disaster threat, citing a journal that mentions a predicted water shortage by 2050. Furthermore, vulnerability to coastal abrasion is an important issue worthy of attention. It was proposed that the National Disaster Management Authority (BNPB) be consulted to confirm its classification as a disaster. Abrasion or tidal waves that usually occur on beaches are included in the disaster category. Some MSD participants also suggested including ***technological disasters*** in the discussion, encompassing issues related to construction, buildings, bridges, and communication systems like cell phones.

The importance of considering ***technological failure in disaster resilience efforts***, was mentioned, citing the delayed response and communication issues during the Palu disaster. For instance, the need to address technological failures to ensure timely and effective rescue efforts. A separate category could be included, specifically for technological disasters. This separate category would encompass events related to technological failures and could include various incidents such as communication breakdowns and other technology-related challenges.

It was also suggested that the ***issue of water shortage*** be included, particularly the lack of drinking water and clean water, within the sustainability challenges. Given the global significance of this problem, as it is linked to climate change and warming, it is an essential aspect to address in the context of sustainability challenges.

There was a proposed to include a map and code of conduct showing different vulnerability levels in the preparation of comprehensive disaster vulnerability maps (bullet number three). For instance, creating a ***code of conduct*** that could be included in a booklet or pocketbook as part of the action plan.

The importance of following the ***spatial plan to mitigate the impact of disasters*** *was mentioned*. The spatial planning plan regulates various spatial structures, including infrastructure, settlements, disaster-prone areas, and forests, with the aim of maintaining carbon production. Adhering to spatial planning helps define what is permitted and what is not allowed, contributing to reducing the impact of disasters.

There was a suggestion to ***streamline the language for better clarity and fluency***. An improvement could be, for example, "disaster resilience strategies as well as mapping and establishment of a code of conduct." A "***drills and simulations***" point could be included regarding disaster resilience strategies.

Carbon Neutrality Vision

It was emphasized that there is a need to ***simplify the understanding of carbon neutrality***. For instance, carbon neutrality means ensuring that GHG emissions produced are offset or absorbed by corresponding actions. The key is achieving a balance between GHG production and absorption to achieve carbon neutrality.

It was suggested that ***focusing on carbon neutrality rather than discussing standard operating procedures (SOP) for disaster management***, would be beneficial, as the latter is already covered by the Regional Disaster Management Agency (BPBD) standard SOP for all regions. Information could be incorporated on the importance of using digital facilities or tools in the context of disaster resilience strategies and mapping. There was a proposal to implement ***communication tools***, such as ancient communication radios using shortwave or AM frequencies, stored in a box with batteries. This could be implemented in various cities and districts in North Sulawesi to ensure communication during disasters, especially when cellular networks are down. The importance of determining and standardizing communication tools across North Sulawesi before implementation was emphasized.

It was suggested to limit the discussion of disaster threats to natural disasters, as the focus is on carbon neutrality. It was proposed addressing technological aspects in the weaknesses section. The National Disaster Management Authority clarified that, according to the law, disasters are categorized into ***natural and non-natural disasters.*** Natural disasters include floods, landslides, and volcanic eruptions, while non-natural disasters encompass technological failures, social disasters like riots and terrorism. ***Carbon neutrality is not currently classified under these categories***, and there are no specific guidelines or contingency plans for managing carbon neutrality-related issues.

The issue of distinguishing between hydropower and ocean waves as renewable energy resources was raised and suggested including both in the discussion. It was recommended to ***add wave energy to the discussion*** on renewable energy resources, given its unique characteristics and potential importance.

Furthermore, information could be included regarding the ***existing skills and capacities*** in North Sulawesi Province related to sustainable energy transition. These could range from technical skills in solar installation to IT, financial analysis, and business establishment skills. On this issue, it was mentioned that many workers from outside of North Sulawesi are currently employed in the transition energy industry in the province. It was suggested that the region should focus on ***encouraging local talent***, potentially by establishing specialized universities or programs to develop skills related to geothermal energy.

The existing capacities of the workforce in critical areas related to sustainable energy transition are suitable, and efforts are being made through formal and informal education, such as at the University of Manado (UNIMA), Manado Polytechnic University, and the Geothermal Excellence Center (Lahendong Geothermal Education Park) in Tomohon. Having a workforce with existing capacities could be viewed as both a strength and a weakness. It was explained that the strength lies in the potential to retrain these individuals quickly for sustainable energy roles. However, the weakness is the current lack of training and the need for intervention to prepare them for such roles.

It was emphasized that ***detailed regulations on various aspects related to achieving net zero emissions and carbon neutrality are lacking***, both at the regional and economy-wide levels. There is a need for more specific regulations to address various aspects, such as the use of solar panels and other renewable energy sources in homes. Specifically, there are existing regulations, including bans on burning rubbish and regulations regarding the use of solar panels, including recent regulations from the Ministry of Energy and Mineral Resources. Nevertheless, the issue (challenge) lies in ***law enforcement***, such as insufficient waste transportation, inadequate facilities, and mixed waste collection. It was suggested that the government should focus on providing complete and adequate facilities before enforcing laws more strictly.

It was acknowledged that Indonesia has a ***significant reliance on coal*** for its energy needs, which is expected to persist for decades. The central government's policy objective is of phasing down, rather than completely phasing out, coal-fired power plants starting from 2021. While the challenge of eliminating coal entirely is recognized, there is a focus on reducing its role within the energy sector, potentially through the implementation of carbon capture and storage technologies. Completely eliminating coal from the energy mix is deemed to be a considerably more difficult task. There is a target for achieving Net Zero power sector emissions by 2060. This entails reducing the use of coal, mitigating CO_2 emissions from coal power plants, and increasing the role of carbon capture technologies.

MSD participants mentioned the importance of using the terms "phasing in" and "phasing out" to convey the mindset of eventually transitioning away from fossil fuels. For instance, while the government aims to reduce coal usage, it's crucial to have the long-term goal of completely phasing out fossil energy. Without this mindset, achieving such a transition could take decades.

Figure 35: Group photo at the closure of Session 1 of the MSD

A comprehensive vision to guide the North Sulawesi Province towards carbon neutrality and disaster resilience was developed in a collaborative way and was approved with broad support of MSD participants (see Annex 1).

3.3 Developing the 2030 targets

This subsection focuses on the main discussions and agreements reached during the second 3-day block of the MSD.

3.3.1 Global context and long-term scenarios until 2100

In order to place the MSD discussions on 2030 targets in an initial general context, to understand the prevailing best practices and standard approaches to target definition in the international context, this MSD block included various presentations from internationally renowned experts. Presentations focused on long-term target setting and the rapidly evolving global context for targets for emissions mitigation, energy transition and disaster resilience.

For instance, a comprehensive overview of the current global CO2 emissions, population growth, and energy consumption trends and projected evolution in the period to 2100 was presented by the APEC Sustainable Energy Center with the purpose of allowing a kind of benchmarking of set targets by cities. Thus, each target set by a city could be compared to the global baseline scenario. This allows cities to know whether they set ambitious targets or, on the contrary, fall behind global evolution.

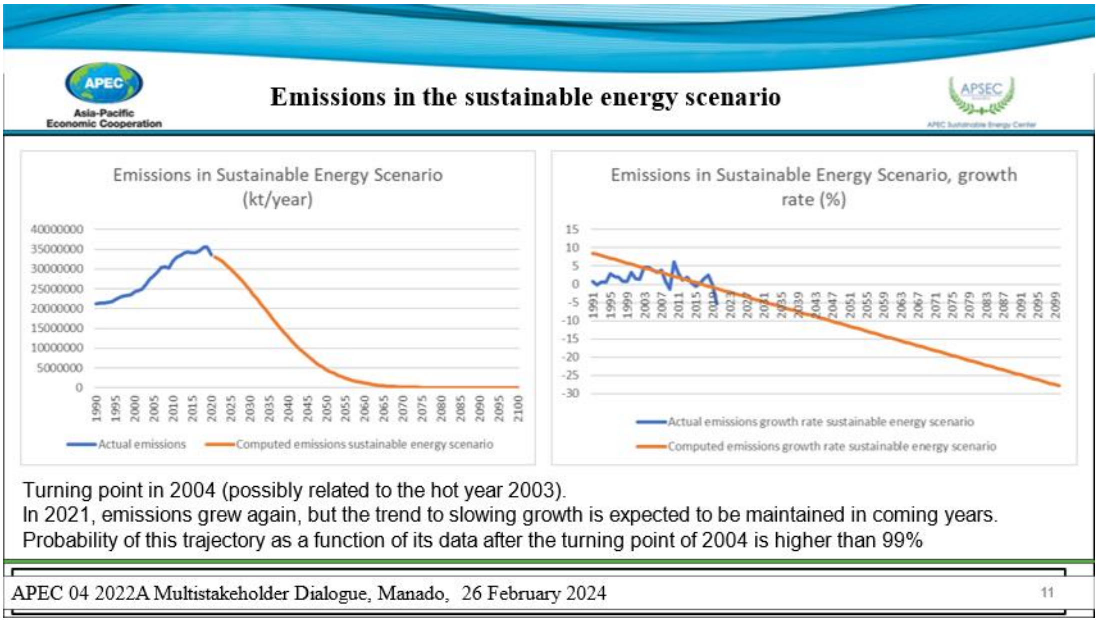


Figure 36: Excerpt from discussions on long-term emissions and their growth rate

Furthermore, the APSEC presentation focused on the specific role of renewable energy within the overall energy mix, at the global level, within a long-term sustainable energy scenario as well as an unsustainable scenario (see figure below).

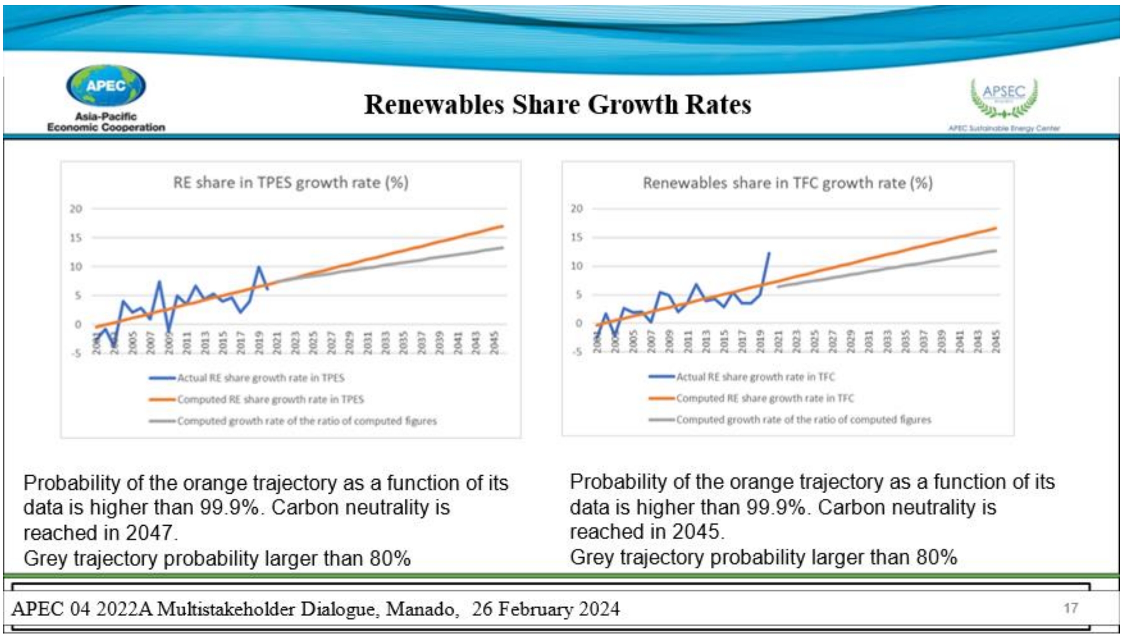


Figure 37: Excerpt from discussions on growth rates of long-term renewable energy shares

For a comprehensive discussion on long-term (until 2100) scenarios for carbon neutrality and the sustainable energy transition, the reader is referred to Chapter 4 of this report. Furthermore, that chapter sets out the robust framework for benchmarking for local communities, in their processes of defining long-term carbon neutrality and renewable energy scenarios.

Other international institutions, such as the International Energy Agency, also delivered detailed presentations and discussion on targets and goals central to the low-carbon energy transition globally. For instance, setting out the need to double the rate of progress in energy efficiency. The International Energy Agency set out the scale of the challenge for accelerating energy efficiency improvements (see figure below), the benefits of doing so, historical performance of energy efficiency improvements, and the required action at sectoral levels to achieve a doubling of energy efficiency.

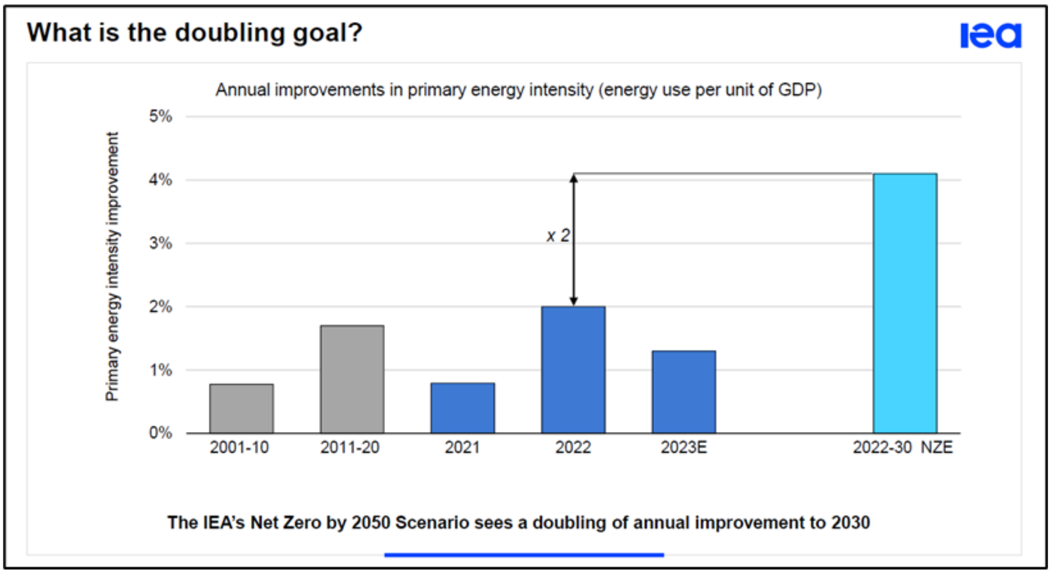
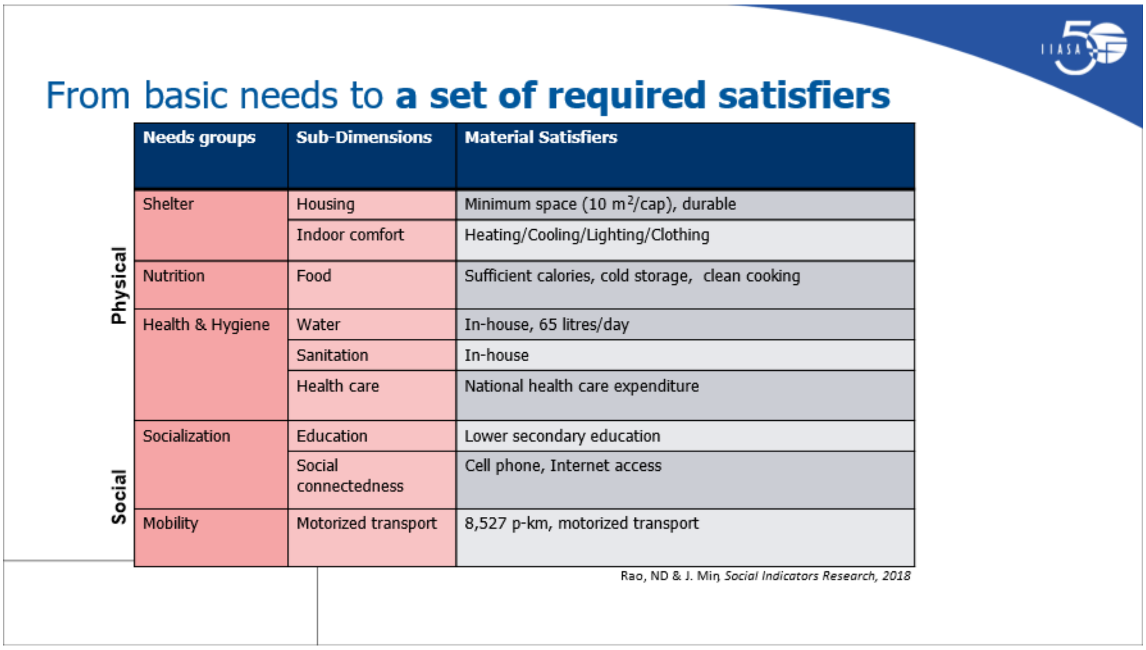


Figure 38: The need to accelerate energy efficiency progress, in the mid-term

Presentations were also delivered by international experts related to the energy needs for achieving decent, safe and sustainable living standards, with a look towards energy needs of individuals, communities, regions and economies, in the context of project economic growth. For example, IIASA presented research findings related to typical energy, resources and service needs for decent living standards, as well as an overview of regional variations in energy needs and use.



	Needs groups	Sub-Dimensions	Material Satisfiers
Physical	Shelter	Housing	Minimum space (10 m^2/cap), durable
		Indoor comfort	Heating/Cooling/Lighting/Clothing
	Nutrition	Food	Sufficient calories, cold storage, clean cooking
	Health & Hygiene	Water	In-house, 65 litres/day
		Sanitation	In-house
		Health care	National health care expenditure
Social	Socialization	Education	Lower secondary education
		Social connectedness	Cell phone, Internet access
	Mobility	Motorized transport	8,527 p-km, motorized transport

Figure 39: Physical and social needs for achieving decent living standards

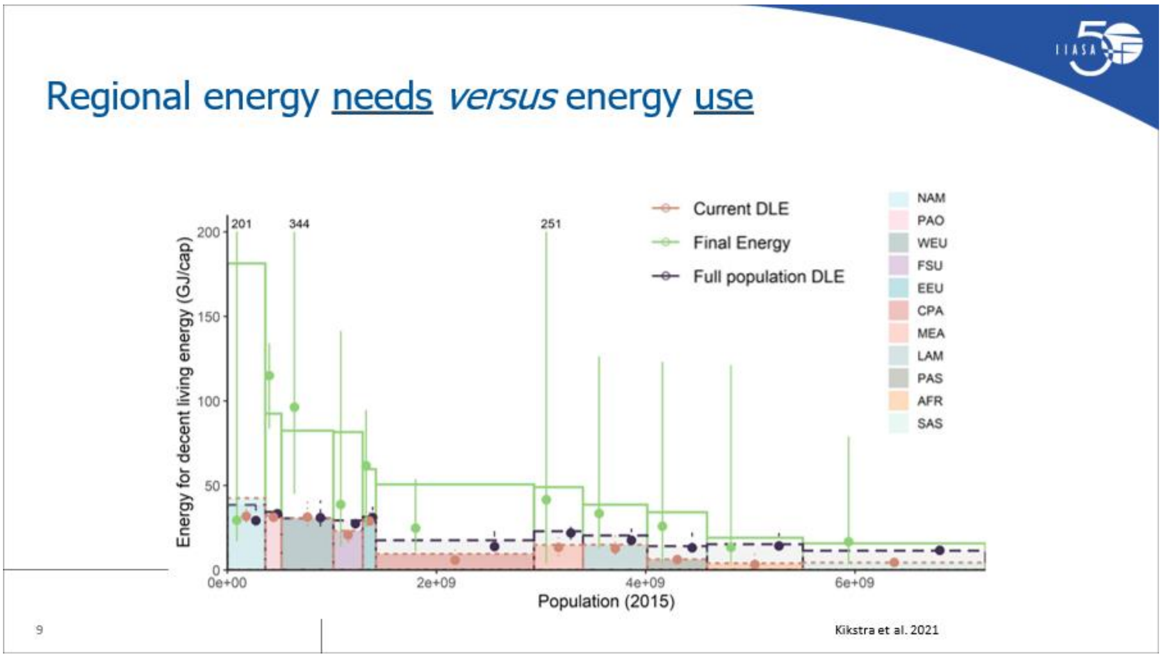


Figure 40: Regional variations in energy needs and use

Discussions on achieving decent living standards globally were also contextualised in terms of the evolution of global CO2 emissions in the long term, and the critical need to balance achieving decent living standards for all whilst progressing towards carbon emissions neutrality (e.g., see figure below).

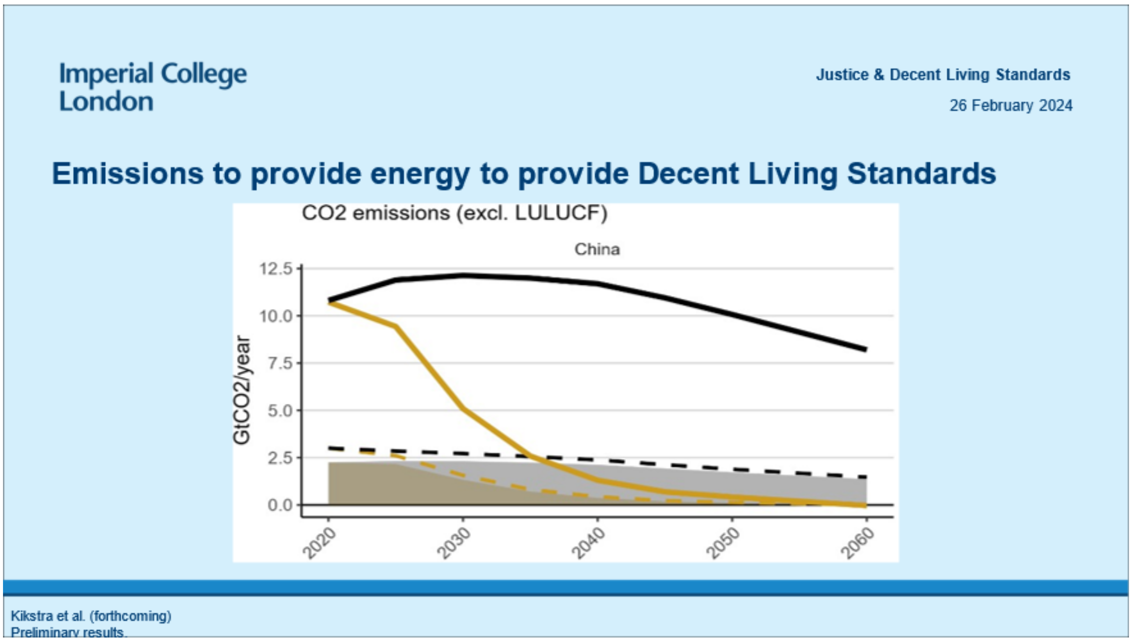


Figure 41: Balancing CO2 emissions reductions and energy needs for decent living standards

3.3.2 The Indonesian context

The MSD considered the general Indonesian context of CO2 emissions and energy consumption, energy intensity and renewables share, and their respective historical and projected future evolution over time. This provided a useful economywide level context to the following discussions at the North Sulawesi Province level.

The discussion of the Indonesian context was led by the APEC Sustainable Energy Center (Professor Steivan Defilla), wherein data was presented firstly on the evolution of primary energy intensity in Indonesia. MSD participants learned that primary energy intensity in Indonesia fell from 5.4 megajoules per dollar of GDP (in constant 2017 PPP) in 2000, to 3.1 megajoules per dollar of GDP (in constant 2017 PPP) in 2020. Efforts to diminish energy intensity in Indonesia have been promoted, for example, through agreements such as that of APEC Leaders in 2011 to diminish aggregate energy intensity by 45% between 2005 and 2035. This is equivalent to a 1.5% decrease per year. APEC is on track to meet this objective.

Key information and data from Indonesia's 2022 Enhanced Nationally Determined Contribution to mitigating climate change was also presented, to provide MSD participants with a detailed understanding of how emissions are forecast to evolve in the period to 2030 at sectoral levels in Indonesia. See figures below.

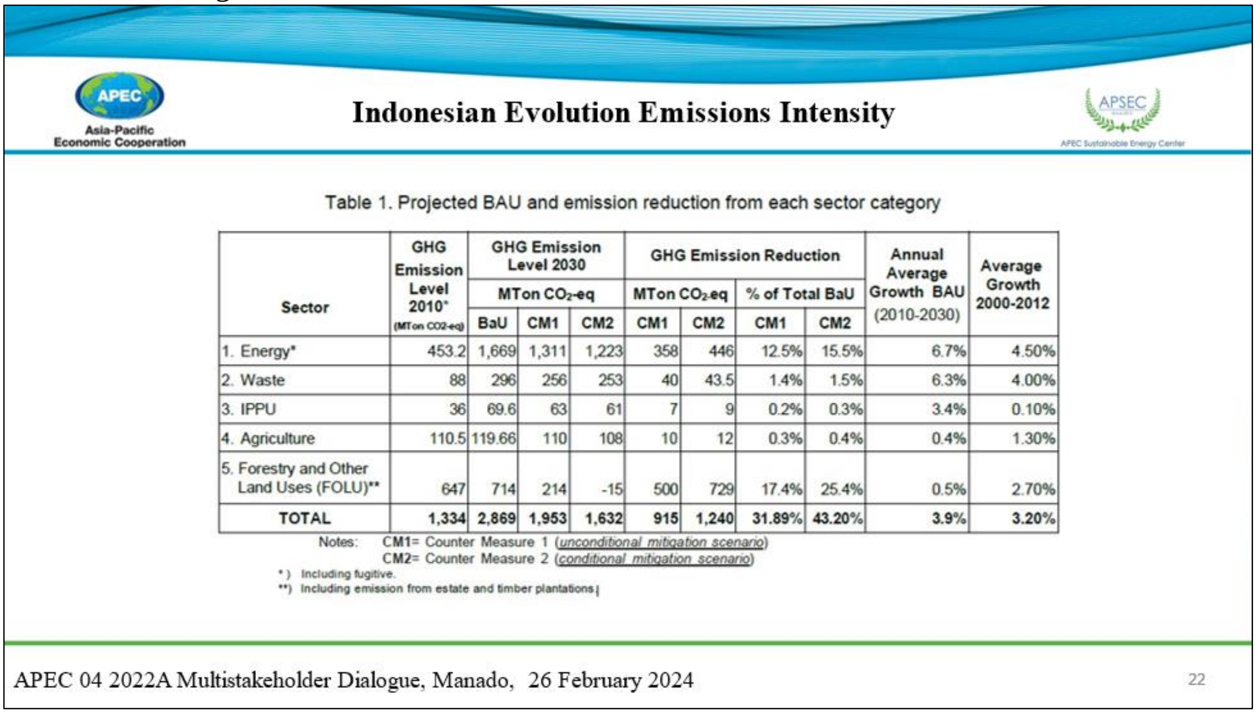
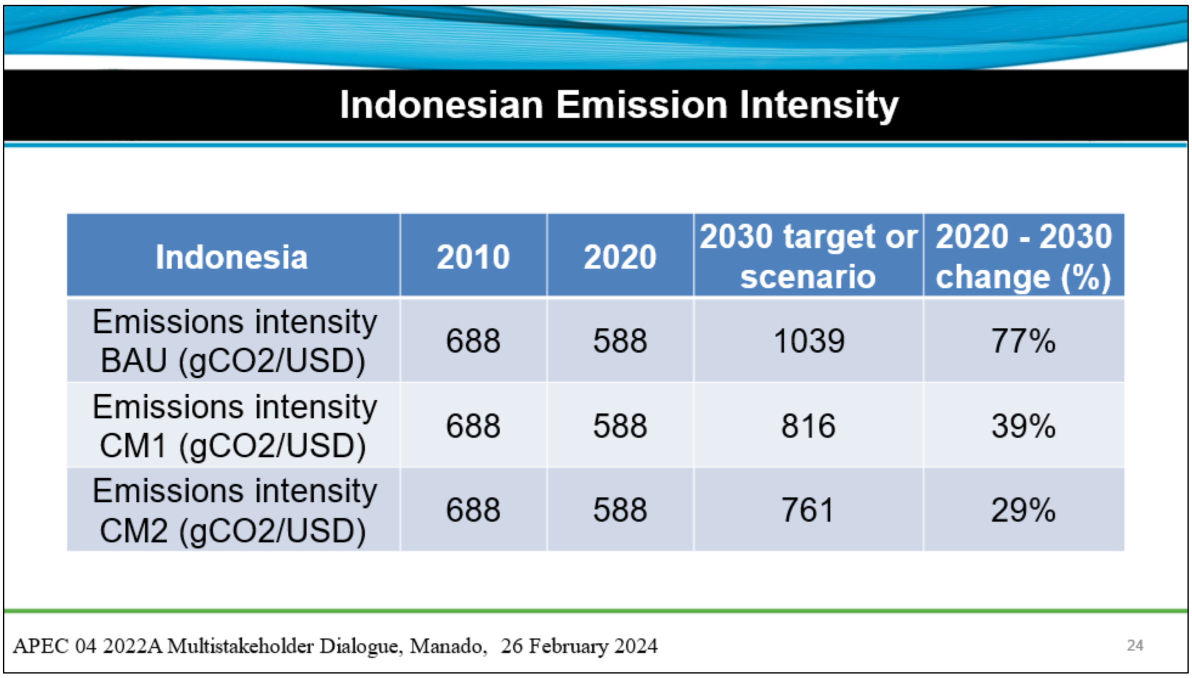


Table 1. Projected BAU and emission reduction from each sector category

Sector	GHG Emission Level 2010* (MTon CO2-eq)	GHG Emission Level 2030			GHG Emission Reduction				Annual Average Growth BAU (2010-2030)	Average Growth 2000-2012
		MTon CO_2-eq			MTon CO_2-eq		% of Total BaU			
		BaU	CM1	CM2	CM1	CM2	CM1	CM2		
1. Energy*	453.2	1,669	1,311	1,223	358	446	12.5%	15.5%	6.7%	4.50%
2. Waste	88	296	256	253	40	43.5	1.4%	1.5%	6.3%	4.00%
3. IPPU	36	69.6	63	61	7	9	0.2%	0.3%	3.4%	0.10%
4. Agriculture	110.5	119.66	110	108	10	12	0.3%	0.4%	0.4%	1.30%
5. Forestry and Other Land Uses (FOLU)**	647	714	214	-15	500	729	17.4%	25.4%	0.5%	2.70%
TOTAL	**1,334**	**2,869**	**1,953**	**1,632**	**915**	**1,240**	**31.89%**	**43.20%**	**3.9%**	**3.20%**

Notes: CM1= Counter Measure 1 (*unconditional mitigation scenario*)
CM2= Counter Measure 2 (*conditional mitigation scenario*)
*) Including fugitive.
**) Including emission from estate and timber plantations

Figure 42: Historical and projected evolution of emissions in Indonesia



Indonesian Emission Intensity

Indonesia	2010	2020	2030 target or scenario	2020 - 2030 change (%)
Emissions intensity BAU (gCO2/USD)	688	588	1039	77%
Emissions intensity CM1 (gCO2/USD)	688	588	816	39%
Emissions intensity CM2 (gCO2/USD)	688	588	761	29%

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Figure 43: Summary of emissions intensity in 2010, 2020 and 2030 (projected) in Indonesia

MSD participants were also briefed regarding the renewable energy share (as a percentage of total final energy consumption) in Indonesia. The share of renewables has actually declined from 45.6% to 22.0% in the period from 2000 to 2020. This is broadly due to the significant increase in overall final energy consumption in Indonesia during that period, and new renewable energy capacity installations not having kept pace during that period. The importance of scaling up the deployment of renewable energy capacity in Indonesia was outlined.

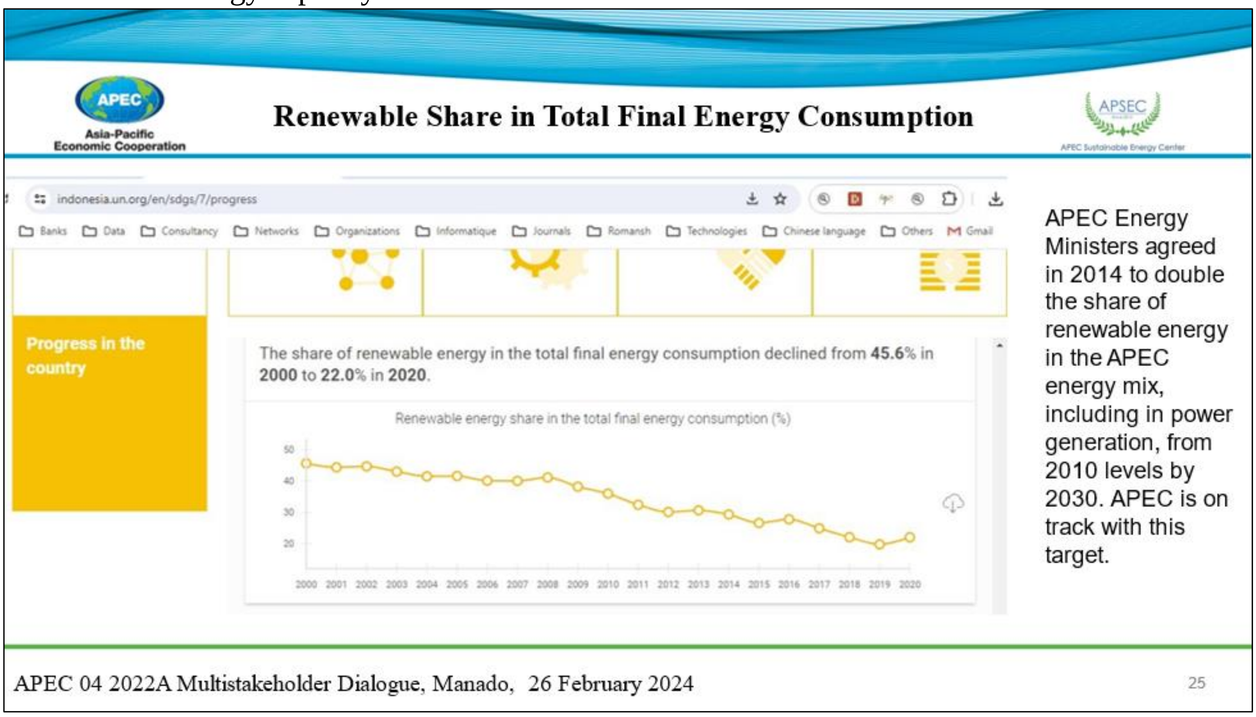

Figure 44: Renewable energy share in Indonesia's total final energy consumption

3.3.3 The North Sulawesi Context

The MSD sessions focussing on developing 2030 targets for North Sulawesi Province also included several comprehensive presentations on the province energy and emissions context, to set the scene for detailed moderated discussions and debate on specific 2030 targets.

In this sense, presentations were delivered by key energy sector institutions and players, such as PT PLN Nusantara Power UPDK Minahasa, PT Pertamina Geothermal Energy (PGE) and Vena Energy Likupang. They focused on issues around energy infrastructure (e.g., electricity transmission and distribution systems) and limitations, and the distribution and scale of renewable energy resources (both in terms of resource potential, and current projects and installed capacities). For example, see figure below, which is an excerpt from the Ministry of Energy and Mineral Resources' presentation on the North Sulawesi Province context; and the following figure, which is an excerpt of the presentation delivered by PT Pertamina Geothermal Energy (PGE), the main geothermal energy player working in the province.

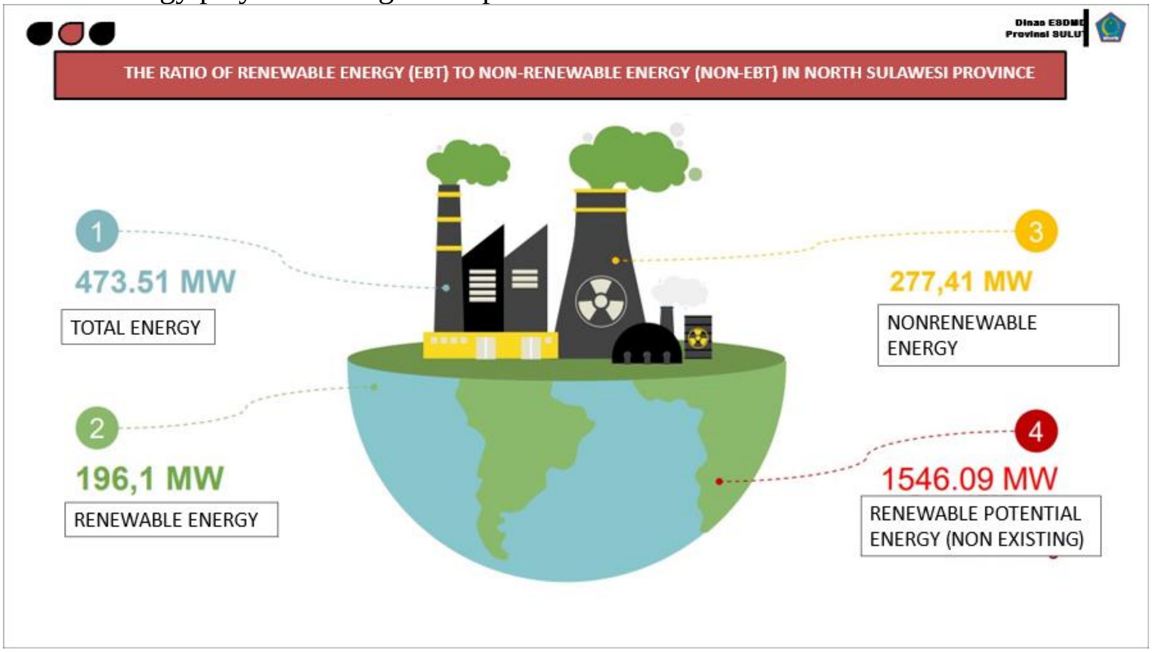

Figure 45: Renewable energy with the energy mix of North Sulawesi Province

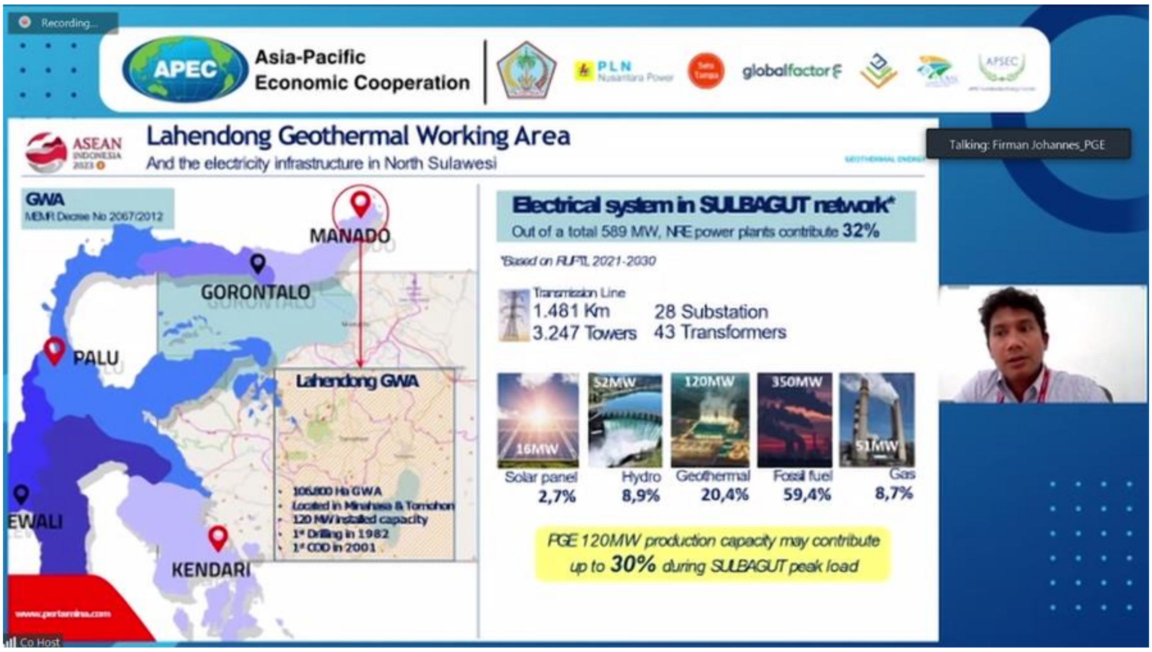

Figure 46: North Sulawesi Province's energy sector, energy mix, and "energy island" status

3.3.4 Moderated discussions with MSD participants

The following is a general summary of the various issues, topics, proposals and recommendations that were raised and discussed by the MSD participants during the second block of MSD discussions (i.e., on 2030 targets).

The issue of data availability was considered by MSD participants, with a general consensus that current publicly available data is insufficiently complete, patchy, and can lack transparency sometimes. Data collection activities can be prohibitively time consuming and challenging. This hinders the veracity of data analysis and target setting.

There were suggestions to establish a dedicated institution to facilitate easy access to data, suggesting a move beyond reliance on BPS. Cities and regencies can play a central role in managing energy and emission data, with large potential for collaborative efforts to address the issue and enhance data accessibility.

In situations where certain data is challenging to collect, existing institutions in the Province rely on qualitative discussions with experts, aiming to gather predictions. The mention of a data forum in North Sulawesi was made, suggesting collaboration to enhance data collection methods and facilitate bringing the information to the provincial level for further action.

There is a need to ***define the methodology and structure of a platform for carbon neutrality and energy in the Province***. Concerns were expressed regarding the cost associated with existing online platforms and the possibility of creating a local platform for measuring and accessing data without additional expenses was mentioned.

It was observed that there is a slightly increasing population size in North Sulawesi, alongside a significant rise in total energy demand, nearly doubling over the past 10-20 years, with expectations of continued growth. In this context of significantly increased per capita demand for energy, there is an increasing importance of energy efficiency and improved energy intensity.

The importance of aligning North Sulawesi's targets with the economy-wide targets was emphasized, and suggestions were tabled to simulate provincial targets based on the economy-wide goal, using Minahasa Utara as an example where emissions reduction capacities are known across various sectors. The ***need to ensure that Enhanced EDC targets are adjusted*** to be in line with the economy-wide targets was mentioned, thereby avoiding significant disparities with the province. The government has committed to a 32% reduction in greenhouse gas (GHG) emissions by the year 2030, consisting of 12% from the energy sector, 0.2% from waste, 0.3% from agriculture, and 17.4% from forestry and other sectors.

MSD discussions also focused on the theme of a "just" and fair energy transition, with participants expressing feedback that, despite a 2030 target being in effect, it is observable that in the region, there hasn't been noticeable advancement towards target achievement. Concerns were raised regarding the policy objective of ensuring that "no one is left behind" emphasizing the importance of this goal within the efforts towards carbon neutrality. It was mentioned that, to date, concerns have been raised by NGOs and CSOs regarding the lack of concrete programs related to community-based renewable energy development. In response to the criticism, adjustments have been made in the Just Energy Transition Partnership's Comprehensive Investment and Policy Plan (CIPP), introducing options for such programs, particularly in areas without electricity access. The patent house will include a dedicated program for these communities. Another consideration is expanding networks to uncovered areas, allowing communities to benefit from sustainable energy. Regarding potential projects, it was mentioned that there is some ***uncertainty about feasible renewable energy projects***.

Recent dialogues organized by LPM Universitas Indonesia were mentioned, providing an avenue for discussions on how local governments can engage in the energy transition. The JETP website serves as a platform to engage media and the public, enabling them to monitor the progress of JETP activities.

The topic of ***renewable energy job growth compared to traditional fossil fuel sectors*** was mentioned, including the challenges in training and developing the workforce, especially in isolated provinces and island communities. There is potential for renewable energy projects to create more jobs in the long term, but it was highlighted that there is a need for adequate training and capacity development to facilitate the energy transition effectively. In this sense, focus is placed on the importance of accessibility to affordable photovoltaic panels, which can be produced locally or imported from low-wage economies. The famous example of the Barefoot Colleges[28] was mentioned, which successfully trained extremely poor individuals living in very remote areas in installing and maintaining solar panels. This was possible in India as soon as India started to produce low-cost PV panels. Regarding the ratio of job creation in renewable energy compared to traditional fossil fuel sectors, it was mentioned that a factor of 6 to 1 is reported in the IEA roadmap, indicating that ***renewable energy can potentially create more jobs than are lost during the transition***. However, the specific employment impact may vary depending on the region and the type of green industry present.

APSEC expressed interest as regards obtaining more specific data on the green sectors worldwide, including green sector employment and value creation. Green sectors are defined in so-called green sector taxonomies which include all industries that produce critical equipment such as transformers, electrolysis systems, batteries, and other components integral to renewable energy infrastructure. There is a ***need for data that specifically focuses on the new sectors emerging within the renewable energy industry***, rather than general data that includes all industries. It was mentioned that IRENA is actively gathering data on employment in the renewable energy sector worldwide, but that this data does not include the corresponding value-added of the green sector. The methodology of monitoring the six dimensions of carbon neutrality, including the economic and the financial dimension is explained in detail in Chapter 5; the draft questionnaire for data gathering is and Annex 7.

The issue of the ***role for provincial and city-level governments to unlock finance for energy efficiency investments*** was considered. The challenge of influencing large financial institutions which are often global, or multinational was mentioned, and the importance of accessing information on unlocking finance, highlighting the need for sharing existing financial mechanisms and building capacity among financial institutions and consumers.

It was mentioned that there is an overall ***lack of awareness among financial institutions about available products and risks,*** leading to higher perceived risks and costs. In this sense, addressing information gaps and building skills at the provincial level should be prioritized. To this end, it was underlined that reports and roadmaps are available for Indonesia at the central level, which offer insights into gaps and potential solutions in energy efficiency financing.

It was highlighted that collaborative efforts of the North Sulawesi government have been made with regard to training and capacity building, particularly the women's organization ***Tim Penggerak Kesejahteraan Keluarga (PKK), in promoting energy efficiency***. For example, capacity-building sessions were conducted by the energy ministry for Tim Penggerak PKK members, primarily women at provincial and regency levels. These sessions focused on applying energy efficiency principles, especially concerning household appliances. Furthermore, training modules provided by the IEA in Jakarta have been implemented at the city and regency levels, demonstrating an effective approach to empower mothers in energy efficiency practices. The significant impact of these efforts within the province were emphasized.

Policy-related training sessions have also been conducted in Jakarta that are aimed towards policymakers to help them set up energy efficiency programs and policies. Additionally, financial training sessions on energy efficiency have been conducted by the OECD, held in Jogjakarta last year. Furthermore, online courses are available for energy efficiency training. Such training is important, especially for consumers, providing an example of the energy-efficient rice cooker, which is widely used in Indonesia.

It was mentioned that the Ministry of Energy and Mineral Resources (ESDM) organizes energy-saving awareness campaigns specifically targeting women from 15 districts and cities. They also conducted awareness programs in high schools to emphasize the importance of conservation and energy efficiency, including educating students about vampire energy.

It was mentioned that one of the traditional strengths of North Sulawesi Province is that ***the province has a high renewable rate***. And this rate has been declining in the recent decade because more fossil fuels have been used than renewables. And this trend is actually contrary with the global trend where renewable energy shares are still very low but growing at a consistent rate. And now concerning the problem supply for island is correct. In this modern technological era, the easiest way to electrify a given community or small-scale system is to develop a solar PV led system, with storage system capacity.

A **summary presentation was provided on the proposed 2030 energy intensity target**, followed feedback and comments from the MSD participants, as summarised here.

The issue of the ***methodology and data simulation for target achievement***, specifically in reducing greenhouse gas emissions was discussed, with emphasis on the relevance of Presidential Decree No. 98 Year 2021 as a key reference point for setting emission reduction targets. Notably, the National Determined Contribution (NDC) outlined in this regulation has been revised to form the Enhanced NDC Contribution. It is important to incorporate this regulation into consideration for emission reduction planning.

It was clarified that the information provided in the summary presentation on the proposed 2030 energy intensity target is currently based on statistical methods. However, future versions will seek to incorporate additional information, aligning with the multi-faceted approach. ***This approach may involve different versions, such as statistical methodologies and those incorporating more comprehensive data, pending further discussion.***

As regards Presidential Decree No. 98 Year 2021, it is noted that it does not provide a breakdown of these targets at the provincial level, leaving uncertainty about whether they apply uniformly or differ for each province.

Target

Feedback was provided by MSD participants regarding the provincial targets in the Economywide Long-Term Planning for 2045, known as Indonesia Emas. It was highlighted that each province has specific targets, with 45 main indicators, two of which are being discussed in the meeting: the predicted percentage of GHG emission and the renewable energy share. For their province, the 2045 target for GHG emission is 41%, while the renewable energy share is still pending calculation at the central level. Furthermore, it was suggested ***the possibility of adopting or proposing the calculated renewable energy share from the provincial level to the central level***. The long-term planning aspect was underlined, but it was emphasized that there is a need for mid-term plans. Separate meetings could be held every five years, allowing for the adoption of mid-term plans derived from these discussions.

It was noted that the final target for 2045 has already been established by the central government. Nevertheless, during forthcoming multi-stakeholder dialogues in North Sulawesi Province, they could propose a mechanism for determining targets every five years. This approach would allow the inclusion of mid-term planning considerations for the North Sulawesi Government. The ***benefits of having mid-term targets instead of exclusively focusing on long-term objectives*** was emphasized, including that shorter-term targets make it easier to manage, maintain, and evaluate progress over five-year intervals. This approach allows for adjustments and improvements in the subsequent five-year periods, eventually leading to the achievement of the long-term target set by the government for 2045.

Lastly, it was noted that the 2030 targets are part of the Sustainable Development Goals (SDGs), which serve as a global framework to work towards common objectives. It was proposed that, just as SDGs are broken down into economy-wide goals, breaking them down further into provincial goals simplifies the process of achieving both short-term and long-term targets.

Challenges

During discussions around 2030 targets, concerns were raised about the lack of awareness or understanding in sectors like entertainment, industry, and services regarding the adoption of green practices, such as utilizing renewable energy sources. The ***importance of accurate and accessible data*** was stressed, noting challenges in data sharing among agencies. Some examples of positive changes in waste management practices over the years were cited, emphasizing the need to strengthen and sustain government regulations to address issues like electronic waste.

The significance of research and development in reducing emissions was mentioned, acknowledging the associated costs. The need for continued efforts in maintaining North Sulawesi's current environmental standards, urging a focus on carbon neutrality was mentioned, linked to the importance of ***government commitment and leadership examples*** in inspiring community practices. The ***issue of waste management and the burning of waste*** was discussed, with particular regard to the lack of reinforcement and a need for better waste management technology, emphasizing the current reliance on traditional methods that contribute to air pollution.

Discussions also centred on the challenge faced by, e.g., Vena Energy, in ***disposing of used solar panels***. This highlights the broader issue of managing electronic waste, especially concerning specialized materials like solar panels. This underscores the importance of finding sustainable and responsible solutions for the disposal of materials associated with renewable energy technologies. Emphasis was placed on the ***need for recycling technology***, especially concerning electronic waste like solar panels, specifically the importance of developing effective recycling technology and adopting better waste management practices to address the growing concerns associated with electronic waste.

MSD participants commented on the ***challenge of different methodologies*** in counting greenhouse gas (GHG) emissions, particularly in the energy sector. For instance, the IPCC 2006 methodology is adopted in their guidebook. The counting involves two types of energy: mobile sources (e.g., vehicles) and immovable sources (e.g., power plants). The data used is sourced from Pertamina for mobile sources and various automatic generation data for immovable sources. Concerns were expressed regarding potential discrepancies in data when comparing different sources: the Indonesian target in Presidential Regulation No. 98 of 2021 as 834 million tonnes of CO2 equivalent, emphasizing the need for social justice in setting regional targets. Proposals were heard regarding using percentage figures rather than absolute numbers to avoid potential discrepancies and ensure fairness across regions in Indonesia.

MSD participants asked a number of questions related to the calculation methodology used for setting the ***target for energy intensity for 2030*** and whether it was based on a time and data series regression approach (only). A point was also made on whether the ***future possible intervention by the local government*** to accelerate the realization of the target was taken into consideration in establishing the target.

Clarifications were provided regarding ***energy intensity***, emphasizing that targets can be expressed both in numerical and percentage terms. It was highlighted ***the importance of considering both aspects***, with the first two lines of the table presenting both the proposed 2030 target and the change in percentage compared to the baseline year. Discussion on the achievability and acceptability of the proposed numerical target was encouraged.

Proposals were heard to structure the data for comparison between global, central, and provincial levels, focusing on essential data points to adopt the targets. Specifically, ***using the latest government proposal for updated Nationally Determined Contributions (NDCs)*** from September 2023 to calculate emission intensity for Indonesia.

It was mentioned that ***there is no specific target for energy intensity at the provincial level*** and that the central planning only focuses on decreasing percentages for greenhouse gas (GHG) emissions without specifying numerical targets. A need for clarity on the energy intensity target at the provincial level was expressed, highlighting the importance of this meeting's conclusion in contributing to the province's data calculation.

A **summary presentation was provided on the proposed 2030 carbon intensity target**, followed feedback and comments from the MSD participants, as summarised here.

Questions were tabled regarding the formula used for the calculation of GHG emission intensity. It was mentioned that in their General Regional Energy Plan (RUED), there is an emission projection, but it differs from the calculation being discussed. Clarification was requested on the parameters utilized to compile the GHG emission intensity in the current calculation. It was explained that for the years 2012 and 2021, calculations were not made but rather ***data was obtained from a source in the Governor's Office*** and the team was not informed about the specific calculation methodology used. However, for the 2030 target, a rigorous analysis was made, considering regulations, and treating the data to mimic actual conditions.

Concern was expressed about the different projections for greenhouse gas emissions in North Sulawesi, outlined in Regional Regulation No. 8 on General Regional Energy Plans. The projections, calculated based on modelling from the Long-range Energy Alternatives Planning System (LEAP), are categorized by sectors such as industry, transportation, household, commercial, and others, with a total projection extending up to 2050. ***It was acknowledged that a challenge exists in comparing these projections due to differences in calculation methodologies.*** To address this, it was suggested to undertake an international, APEC, economy-wide, and local comparison to facilitate a comprehensive assessment.

It was emphasized that there is a ***need to clarify whether the emissions being discussed are solely from the energy sector or encompass all sectors,*** including agriculture, forestry, and other land uses. In particular, the challenge of predicting emissions from forestry, particularly in the context of forest fires. It was suggested that a need exists to reach a consensus on the components considered in emissions data to ensure consistency in future evaluations and emphasized the significance of understanding the central government's focus on reducing emissions, particularly in the forestry sector.

The ***importance of identifying emission reduction criteria*** was underscored, starting with a consistent baseline (e.g., 2020) and defining standardized units for effective communication. This includes the need for mutual agreement on terminology and units used in discussing greenhouse gas emissions, pointing out the discrepancy between Gg (gigagrams) and tons of CO2 equivalent, including a need for *clarity and uniformity in these fundamental aspects of emissions data analysis*. There is a ***need for standardization in measurement units***, and consistent standards. There is a challenge of adapting to various international and organizational standards and a need to commit to converting data to a format compatible with North Sulawesi's practices.

Discussion of the Renewable energy potential of North Sulawesi

MSD participants considered best practices in North Sulawesi, particularly the direct use of geothermal, which is understood to be a world class resource. In North Sulawesi, the ***direct use of geothermal energy is employed in the production of brown sugar from sugar palm at Masarang.*** This involves a collaboration between PT Pertamina Geothermal Energy Area Lahendong Tomohon and local private companies, utilizing geothermal heat directly for cooking enau or aren (*Arenga pinnata*) palm tree sap sugar, which is then exported internationally.

It was highlighted that the renewable energy share in electricity production for 2023 was 41%, which ***is a combined figure when considering both renewable and non-renewable power plants.*** This includes data from various sources, such as fuel consumption by the community, data from Pertamina (Indonesian Oil Company), and BPH Migas (Oil and Natural Gas Downstream Regulatory Agency). The overall renewable energy mix for North Sulawesi province is calculated at 30.32%. However, when focusing solely on electricity generation, the direct comparison between renewable and non-renewable sources has reached 41%.

Specific questions were tabled regarding whether the Energy and Mineral Resources Department has a baseline for energy intensity data, and if there are discussions or plans for 2030 regarding energy intensity. It was commented that, in areas without an Energy and Mineral Resources Department, such as North Minahasa, obtaining data from stakeholders like Pertamina about fuel use, especially fossil fuels, is challenging. It was suggested that the Energy and Mineral Resources Department of North Sulawesi could facilitate the acquisition of such data.

It was mentioned that the term "energy intensity" is somewhat new for the provincial government, and in the RUED terminology, they typically refer to "net zero emissions." Further discussions are needed on these terms.

Information was shared on specific projects in the Province related to the ***direct use of geothermal energy*** in collaboration with PT Pertamina Geothermal Energy (PGE) Area Lahendong in Tomohon. Three projects are currently underway: 1) Palm Sugar Production: Collaborative efforts with the private sector (PT Masarang) involve using geothermal energy for making palm sugar, which is then exported overseas. 2) Crop Drying Equipment: The geothermal energy is utilized for crop drying equipment, benefiting local farmers for drying various agricultural products such as coffee, corn, and cloves. 3) Tourist Attraction (LaoLao): PT PGE is contributing to tourism development in Tomohon City by constructing a tourist attraction named LaoLao. It serves as a bathing place utilizing warm water from geothermal sources, also serving as part of their corporate social responsibility (CSR) initiatives for the city.

Background information was provided on the Regional Regulation No. 8 of 2022, which includes projections of energy intensity for the region from 2021 to 2050. The regulation incorporates indicators such as GDP and energy requirements to derive energy intensity values. Annual projections are outlined for the years 2021, 2025, and from 2040 to 2050. These projections were developed using LEAP (Low Emission Analysis Platform) modelling in 2022, aligning with the publication of the regional regulation.

A **summary presentation was provided on the proposed 2030 renewable energy share target**, followed feedback and comments from the MSD participants, as summarised here.

MSD participants emphasized ***the importance of consistency in establishing baselines for various indicators***. They highlighted the need for a uniform baseline across all indicators, ensuring clarity and comprehension. Specifically, recommendations were heard to align the baseline with the same starting point used for other indicators, like the 41% renewable share in 2023.

It was clarified that the ***data on renewable shares in North Sulawesi Province is specifically related to power plants***, and the introduction of coal-fired power plants (PLTU) could impact the overall renewable share, and the increasing contribution of geothermal energy in Lahendong is influencing the trend upward. It was suggested to seek clarification from PLN (Perusahaan Listrik

Negara), the state electricity company, especially concerning the impact of PLTU construction on the renewable share.

Information was provided that the coal power plants Amurang I and Amurang II ***can operate with a combination of coal and biomass, not solely relying on coal***. The approach of combining coal and biomass in the power plants, was discussed, aligning with the flexibility discussed in the presentation.

Certain criticism was expressed regarding the Just Energy Transition Partnership (JETP), in that a comprehensive investment and policy plan approved at the G20, promised Indonesia funds for renewable energy, which have not been realized. It was highlighted that some ***discrepancies exist in data and the efficacy of methods like cofiring were questioned***, which it is argued only reduces emissions by 1 to 3 percent while requiring costly equipment. The importance of setting standards to avoid being misled in future negotiations was mentioned, and for clearer thinking on renewable energy strategies was urged.

It was proposed to ***examine the methodology and merge available data from stakeholders to gain a clearer understanding***, whilst acknowledging the influence of single large power stations on the renewable share, emphasizing the uncertainty, it is encouraged that a formulation that accounts for uncertainties related to potential large investments be developed.

Some MSD participants considered that the ***current target appears overly ambitious***, considering the impact of the pandemic on (stalling) renewable energy shares. In other words, progress was stymied due to the pandemic-related disruptions. A more moderate approach was proposed, possibly aiming for a 49% target by 2030, which aligns with achievements from the pre-pandemic period in 2017. Suggestions were heard to ***consider a moderate scenario aligned with the RUPTL (Electricity Supply Business Plan)***. The IPP processes were highlighted, including plans for a solar power plant (PLTS) on Lake Tondano, and the potential for transferring renewable power to meet demand in Central Sulawesi once interconnection is established.

Questions were tabled to the main large scale energy companies (e.g., PLN and Vena Energy) in the Province specifically regarding their opinions on what might be an achievable realistic renewable energy level in 2030 (for instance, on whether they consider that the target of 59% by 2030 makes sense, and would be achievable). The key energy companies suggested using RUPTL as a performance indicator for success, and it was mentioned that RUPTL may face technical and non-technical obstacles and suggests setting targets based on RUPTL from 2021 to 2030 for North Sulawesi. It was acknowledged that demand is higher in Central Sulawesi, and the numbers are aligned with RUPTL, considering ongoing developments in transmission lines. Furthermore, the importance of aligning renewable energy targets with existing regulations, planning, and partnerships, such as the Just Energy Transition Partnership, PLN, local government development plans, and the Ministry of Energy and Mineral Resources. The inherent difficulties in defining specific numerical targets without considering these factors were mentioned.

As regards specific target levels for renewable energy share, the Energy and Mineral Resources Department of North Sulawesi Province mentioned that based on Regional Regulation no. 8 of 2022, projecting a renewable energy mix of 38% in 2025 and 67% in 2050: and the need to increase the renewable energy mix to align with RUED targets, anticipating slightly over 38% in 2030.

A second and final reading was made of the MSD-Draft text on 2030 targets on energy intensity, GHG emissions intensity and renewables share for the North Sulawesi Province. The following is a summary of the main discussion and feedback points, as well as key decisions taken by the MSD Focal Point.

The need to ***distinguish between the numerator and denominator units*** when measuring emission intensity was commented upon; specifically, it was suggested that grams and kWh be used for the numerator, as they are familiar quantities, and the need for clarity regarding the base year for constant currency calculations was also highlighted. It was confirmed that ***information on the base year used for calculations*** would be provided, as well as the possibility of transforming measurement units if needed and indicates that the targets for North Sulawesi Province will be expressed in different units.

It was suggested that the RPJMN be referenced, specifically for the numbers regarding the 2030 targets mentioned in the draft text. It was also recommended that the RUKN be consulted to ***ensure that the figures for renewable energy shares align with economywide numbers***. By doing so, potential issues when communicating these targets to the economy-wide level can be avoided.

A question was raised concerning the feasibility of adding another column to the document, describing ***the units used by both APEC/APSEC and Indonesia***. This addition would facilitate communication and understanding when sharing the document with central authorities or other provinces. It was confirmed that the ***table could be adjusted to accommodate different sets of units***.

MSD participants emphasized the ***importance of adhering to clear data standards to avoid confusion***. Suggestions were presented regarding using the concept of data standards and adhering to the economy-widely agreed-upon units for emissions terminology, which are tons of CO2 equivalent/IDR for greenhouse emissions and TCO2 equivalent for potential reduction in greenhouse gas emissions. It was recommended that these standards for the official government document be followed to allow easy comparisons with other datasets within Indonesia.

Discussion was held on how energy intensity is expressed in official documents in Indonesia. It was confirmed that ***there is currently no standard unit for expressing energy intensity in official documents in Indonesia***. The determination of a data standard for energy intensity involves submission by the data guardian to BPS, followed by discussion with all economy-wide data forums at the end of the year. A proposal was made around ***calculating the target and expressing it in both units*** to accommodate any future standardization efforts.

A **discrepancy was raised** ***regarding the reference year for constant prices in GDP calculations***. It was noted that while the text mentions GDP constant prices for 2015, it is understood that Indonesia previously used 2010 as the reference year and it was agreed that this point be confirmed with the Central Bureau of Statistics to ensure accuracy regarding the reference year for constant prices used in Indonesia.

A certain degree of ***scepticism was expressed about the feasibility of achieving a 50% renewable energy target for 2050***. The basis for this doubt lay in that while renewable energy in North Sulawesi increases linearly, fossil energy, particularly coal, increases exponentially. The question of how the 50% target can be achieved if coal energy in North Sulawesi is on the rise was tabled, and it was suggested that while increased energy availability may benefit North Sulawesi and Gorontalo, the renewable energy target does not align with the current energy consumption trend.

It was reaffirmed that the renewable energy targets set in regional energy plans, such as the Regional General Energy Plan (RUPTL), are formulated considering the prevailing context of a strong coal sector and increasing energy demand, while also aiming to ***phase out coal in the long term***. It was pointed out that the target of 38% by 2025 in the regional plan is somewhat lower, and projecting between 38% in 2025 and 67% in 2050 suggests that the renewable share by 2030 will likely be less than 50%.

MSD participants also engaged in discussed around ***the complexity of the power sector in Sulawesi***, emphasizing the need to consider power plants serving nickel smelters, which operate independently of the power grid. For instance, the importance of checking with relevant authorities to ascertain the capacity of these power plants and future developments was mentioned, particularly in light of regulations permitting coal power plants for mineral value addition. It was suggested that ***valuable lessons can be learnt from Bali's renewable energy transition*** and furthermore key numbers can be used from existing regulations and collaborating with smelters to understand total capacity and push for renewable energy utilization.

The ***significant potential for renewable energy***, including geothermal, water, wind, and solar, was underlined, totalling more than 1,000MW. However, some concern was expressed about the infrequency of the economywide electricity supply plan (RUPTN), which is updated only once every 10 years, potentially leaving certain regions behind. A better approach would be to update the plan every 5 years to ensure that opportunities for renewable energy potential can be appropriately adjusted and utilized.

It was mentioned that it would be instructive to compare the proposed targets with the figures specified in regional regulation no. 8 of 2022 concerning General Regional Energy Plans (RUED). This ***comparison would help identify any differences*** between the proposed targets and the ones outlined in the RUED. The specific mentioned ***regulation is effective at the regional level and specifies a target of 38% by 2025.*** However, there is no target set for 2030 within the regulation.

A suggestion was made to incorporate a range of targets to account for uncertainties, such as the impact of large-scale generation projects coming online (or not) at certain key dates, with a higher and lower end to accommodate different scenarios. There was general agreement on following this approach.

It was suggested that ***different scenarios,*** such as high ambition and moderate ambition, be considered within the targets to account for potential developments like the interconnection between North Sulawesi and Central Sulawesi. It was highlighted that the significant amount of renewable energy required to support nickel smelters in Central Sulawesi, emphasizing the need for comprehensive planning and consideration of various scenarios.

The issue of system ***interconnection with other provinces*** was mentioned, as just one of the many factors that will influence North Sulawesi Province's ability to achieve higher or lower levels of renewable energy shares. The importance of conducting a solid technical analysis to determine the target was emphasized, considering various factors that may impact renewable energy development. It was proposed that the Regional General Energy Plan (RUED) be quoted in the target plan for North Sulawesi Province and setting the renewable share target for 2030 at 38%, with a range from 30% to 50% to encompass different scenarios. In particular, suggestions were made to use the numbers from the RUED, which indicate a renewable share target of 38% by 2025 and 67% by 2050. He recommended avoiding the use of the number 50% unless it's based on modelling results. The need for clarity on whether the 38% target includes captive power plants was mentioned and urged conducting modelling exercises to determine accurate targets. It was proposed that a ***working group be established*** involving government, universities, and relevant agencies to ensure solid numbers based on proper modelling.

The ***challenge in obtaining emission intensity data*** was highlighted, and this lack of transparency resulted in most MSD participants refraining from expressing agreement or disagreement with the data presented as draft 2030 targets. The importance of traceability of data was emphasized and it was suggested that the specific parameters used for calculations be included in the 2030 target document to facilitate validation in the future. It is anticipated that evaluation discussions may occur in 2030. It was confirmed with the National Energy Council that the renewable share in 2030 is forecast to be 50% in Indonesia.

Figure 47: Second and final reading of the proposed 2030 targets

Expressions of gratitude were made by the MSD Focal Point for the opportunity and support provided by APEC and the MSD forum to ***discuss sustainable energy in North Sulawesi***. The challenges in collecting and analysing data were underscored, and the importance of research and collaboration among government departments and stakeholders was emphasized. The ***strategic significance of the baseline study for North Sulawesi's future*** was confirmed, and MSD participants were invited to share any additional data or analysis to inform the province's action plan for reducing carbon emissions.

The MSD Focal Point confirmed the North Sulawesi Province Government’s support for the removal of the low target, and opting for a high target of 60% and proposing a medium target of 52%. This adjustment aligns with the official target outlined in the Regional General Energy Plan (RUED) for North Sulawesi Province, based on consultations with the National Energy Commission.

The adopted targets incorporate all the comments and concerns raised above in an acceptable manner. The adopted targets for 2030 are summarized in the table below, together with the expected global evolution during the 2020 – 2030 period (in the last column). In summary, the

MSD agreed to diminish final energy of the North Sulawesi Province by 2% (compared to -15% on global average), diminish emissions intensity by 36% (compared to -43% and +9% on global average, respectively, in the sustainable energy scenario or in the unsustainable scenario), and set two targets for the renewables share in final energy, namely 60% (or multiplication by 2.2) as high target and 53% (or multiplication by 1.96) as medium target (compared to multiplication by 2.4 on global average).

North Sulawesi Targets	2021 Value	2030 Target	Units	2021 to 2030 Variation	Global 2020 to 2030 Evolution
Final energy intensity	0.131	0.128	kWh/thousand constant 2010 IDR	-2%	-15%
Emissions intensity	14	9	gCO2/thousand constant 2010 IDR	-36%	-43% (SES) +9%(UnS)
Renewables share in final energy (high target)	27	60	Percent	Multiply by 2.2	Multiply by 2.4
Renewables share in final energy (medium target)	27	53	Percent	Multiply by 1.96	Multiply by 2.4

Figure 48: Overview of the 2030 targets and comparison with global evolution

The integral text summarizing the discussion and adoption of the targets by the MSD is reproduced in Annex 2. Participants were asked to confirm their approval of the proposed targets, by raising their hands if they agreed, and overwhelming support was shown. By adopting these targets, the MSD recommended the North Sulawesi Province authorities to give them legal force.

Figure 49: MSD participants' vote regarding the approval of the 2030 targets

As final point on the MSD agenda, options to maintain the MSD to become a permanent body at the provincial level were discussed. The following aspects were underscored:

- ***The importance of implementing the agreements*** reached in the forum and ensuring their adoption at the provincial level in North Sulawesi. Coordination meetings could be organized at the provincial level to design regional regulations or, if necessary, governor's regulations to establish legal frameworks for the province. The ***urgency of taking action considering the approaching deadline of 2030*** was stressed and the potential transition to a new regime.
- ***The significance of establishing regulatory frameworks*** for clean energy in Indonesian provinces was mentioned, citing examples from Bali, Central Java, East Java, and Jakarta. North Sulawesi should follow suit by initiating a governor's decree, which could eventually lead to the formulation of local regulations involving the parliament.
- ***The importance of disseminating the results of the Multi-Stakeholder Dialogue (MSD)*** starting from the provincial level and extending down to cities, regencies, and relevant agencies was commented on.
- A suggestion was shared regarding ***making the Vision on carbon neutrality and disaster resilience of North Sulawesi*** an official reference for various levels of government. It was proposed that a governor's decree be prepared to use the document as a reference for short-term, mid-term, and long-term planning. The principle of integrating the document into the frameworks of regencies and cities was supported by the MSD. Support may be required in this endeavour, and any support that APEC could provide would be appreciated.
- ***The importance of conducting separate studies*** at the district or regency level was mentioned, as the targets outlined in the document reflect provincial-level data and may not accurately represent the specific circumstances and challenges faced by individual districts or regencies. Furthermore, the ***importance of involving key stakeholders in discussions***, including PLN, the ESDM, and the central government, in discussions about creating a regulatory framework.
- It was proposed that ***a small task force be formed and mobilised to continue overseeing the progress*** of the initiatives discussed during the event. This task force would be responsible for following up with the governor and monitoring progress over the next six years.
- The ***importance of translating the vision into bilingual*** or Bahasa language to reach the local community effectively was also discussed. This recommendation has already been implemented since the MSD. Both, the Vision for carbon neutrality and disaster resilience as well as the Text on 2030 targets are now available in both languages, English and Bahasa. It was stressed that the above-mentioned task should involve all stakeholders for discussing the progress with them.

3.4 Lessons and Recommendations from the MSD

Several conclusions can be made regarding the process of developing both 2030 targets and a vision for low-carbon development and disaster resilience for the North Sulawesi Province.

Firstly, the authors consider that **the successful realization of an MSD for the purpose outlined is contingent on its adequate and timely preparation**. The use of a dedicated Training the Trainers workshop, prior to the MSD event, was constructive in terms of preparing MSD participants around the objectives, format, structure, possible outcomes and best practices. The ToT workshop was a necessary step in the process of building momentum, capacity and enthusiasm for undertaking the MSD event.

Secondly, there are strong indications that MSD event made several further tangible positive contributions, beyond the preparation of the vision and 2030 targets. Drawing on the findings of stakeholder feedback and further reflections, it is considered that **the MSD contributed to procedural transparency; sharing of concerns, issues, opportunities, data, information, improving visibility of workstreams among government departments and workgroups and bridging information gaps.** Trust appears to have been enhanced between actors / participants, and a broad consensus has been strengthened in relation to North Sulawesi Provinces future and ambition to become a carbon neutral and resilient place to live.

Thirdly, it is concluded that the MSD process of reaching agreements and approval on key outputs (such as 2030 targets) is not always straightforward. **The process requires a degree of commitment, engagement and implication among the MSD participants, and it is important to actively build an atmosphere of trust and openness, and to structure the MSD around a format that encourages participants to actively engage and contribute in an open way, in which all actors consider that their inputs will be heard and considered**. Furthermore, it is important that MSD participants engage with a willingness to learn from other participants.

The fourth key conclusion relates to the availability, level of completeness, transparency and reliability of key data and information on energy, renewables, carbon emissions and economic activity in North Sulawesi Province. **During the process of developing proposals on 2030 targets, several challenges were encountered related to data, and specifically regarding the limited level of data that was publicly available**. Furthermore, the historical time series of available data was often limited and patchy. For obvious reasons, this situation complicates the process of developing robust data analyses and forward forecasts, critical for developing future targets and comparing them. **One practical step that would significantly improve the ability of North Sulawesi Province to accurately monitor the decarbonization of its energy sector, would be to ensure that all energy sector (private sector) players, including key entities such as PLN and Pertamina, share important energy data within a publicly administered database**. Data could be provided and used in an anonymised way, thereby ensuring that all privacy and confidentiality issues are protected. Such an approach is widely adopted in other geographical settings, is straightforward to implement, and can yield many benefits (in terms of governance, public policy effectiveness, and sector efficiency).

A fifth conclusion of the MSD process held in North Sulawesi Province concerns the topic of energy and carbon emissions scenario benchmarking. This is an important step that allows government and policy makers to consider probable scenarios of how carbon emissions and energy sector dynamics are likely to develop over a designated time horizon. Without a clear understanding of possible scenarios, it is difficult to discern reasonable targets for carbon emissions mitigation, or energy sector decarbonization, efficiency, etc. **Oftentimes, a clear methodology and approach for developing local energy scenarios is lacking, and governing bodies lack the skills and resources to be able to undertake such work on a regular and structure basis**. In Chapter 4 of this report (below), an easy to calculate methodology yielding high probability scenarios is developed and applied for global long-term scenarios until 2100. This can be widely used by cities, local and provincial governments in the future.

The sixth and final conclusion of the MSD event is **the requirement to ensure that a robust and wholistic framework for monitoring the transition towards carbon neutrality is established and operated in the province.** Chapter 5 below develops this type of monitoring framework in six dimensions: (1) local on-site installed capacity in cities, (2) distant (outside city boundary) installed capacity, (3) energy efficiency, (4) energy security, storage and disaster resilience, (5) the local green economy, and (6) the local use of green finance. A draft questionnaire for collecting data is shown in Annex 7. The use of such a monitoring framework will allow the North Sulawesi Province government and others to track and measure performance against a suite of indicators. This in turn allows government to clearly identify progress, changes, and to ascertain how the province is performing over time in terms of meeting its 2030 targets for energy intensity, emissions intensity and renewables share for the North Sulawesi Province.

4. Global 2100 Scenarios for Benchmarking Local Communities

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As a global long term benchmarking tool for cities, APSEC computed two global scenarios for the time horizon 2100, comprising 30 variables, allowing cities to compare their own evolution to the global evolution. The Sustainable Energy Scenario (SES) is based upon the observation that, after possible turning points, growth rates of most relevant variables vary linearly in time. Very simple to estimate, the SES not only reflects APEC Leaders 2023 declaration and COP28 calls to triple renewable energy capacity globally by 2030, but it also shows that carbon neutrality is reached by mid-century. In contrast, the unsustainable scenario is based upon multivariate regression as a function of the growth rates of explanatory variables whose trajectories had been calculated beforehand in the SES scenario. The unsustainable scenario shows not only how multivariate models reflect bulk resistance to change, but also that in consequence, carbon neutrality is reached only after 2100. By 2050, the cumulated emissions are at 550Gt for the SES and the double of this amount for the unsustainable scenario. By 2100, cumulated emissions of the unsustainable scenario increase up to three times as high as the SES. For each of the 30 variables the computations show the 2020 – 2030 step as well as the evolution by 2100. For each trajectory, the computed probability as a function of its data is stated.

4.1 Variables Common to Both Scenarios

The two scenarios have a broad common basis making them in fact identical, except for the emissions they cause and, implicitly, for the energy system they correspond to. The description will therefore be made firstly for the common basis of both scenarios, then for the unsustainable scenario, followed by the sustainable energy scenario (SES).

Before outlining the scenarios in detail, a point of consideration should be made on the nature of transitions in general. In systems theory, a transition is usually a process in which a system evolves from one equilibrium state to another equilibrium state. As described further down for the case of global population, the interaction between the decrease of the death rate and the delayed decrease of the birth rate yields a resulting global population following what many authors call a logistic or S-shaped Verhulst curve in which the growth pattern first follows exponential growth, then a portion of approximate linear growth, followed by decelerated growth during which the absolute annual growth numbers diminish. If the approximated linear portion is left out as it is an approximation, the most important single point during this evolution is the turning point at which growth turns to deceleration. The data used for the present scenarios were not found to fit the logistic model. It remains questionable whether the logistic function can apply to phenomena like population at all given that population in some economies has started to decline, a phenomenon that would not be compatible with the logistic curve. Nonetheless, turning points were detected for some variables: global population (1963), global CO_2 emissions (2004), total final energy consumption TFC (1980), and renewable energy employment (2016). The present analysis takes note of these turning points and uses a simplified version of the logistic model, namely a model characterized by linearly variable growth rates in time, which fits the data much better.

Another point is the meaning of “fits the data much better”. The focus of the scenarios in this analysis is on the long term. Short term fluctuations, albeit interesting for short term explanations, are of secondary interest for a long-term analysis. Models explaining short term fluctuations have more explanatory variables and may have a higher R^2 than long term trend models, but the existence of more explanatory variables poses a priori constraints on the model that may fail to reflect the historically evidenced amount of long-term structural change evidenced after the turning point or, on the contrary, it may reflect structural inertia. This is very clearly illustrated in the two emissions scenarios which are differentiated only by the type of model used to create them. See the methodology explained in section 4.4 further down.

Global population (both scenarios)

Population is considered as the single most important variable for monitoring sustainable development. SDG indicator 11.a.1 reads[29]:

11.a.1 Number of countries [sic] *that have national* [sic] *urban policies or regional development plans that (a) respond to population dynamics; (b) ensure balanced territorial development; and (c) increase local fiscal space*

The global population has been undergoing a demographic transition since the beginning of the industrial age. In 1770, average global life expectancy at birth was 28.5 years[30], having grown to 71 years by 2021. A recent analysis and discussion of the global population dynamics can be found in Hrytsiuk (2022)[31]. Looking at the World Bank data, which is available for the years since 1960, the turning point with the highest annual growth rate of global population was in 1963 (2.13%). Since then, the growth rate has been continuously decreasing, attaining 0.8% in 2022. The deceleration has recently increased. Based on the 1963 – 2022 trend, the global population will peak in 2070. Based on the 2013 to 2022 trend, the global population would peak in 2041. Based on the 2017 – 2022 trend, the global population would peak in 2034.

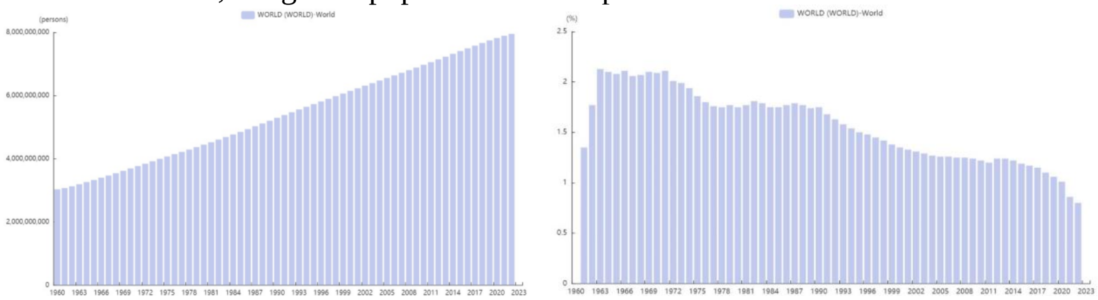


Figure 50: Global population and annual growth rate

Source: APSEC based on World Bank data

It would be fair to say that the absolute growth of global population has peaked in the period 1990 – 2013 (see figure below). Since 2013, a significant change has happed in the fact that absolute growth numbers markedly decreased. The linear part of the logistic curve seems over.

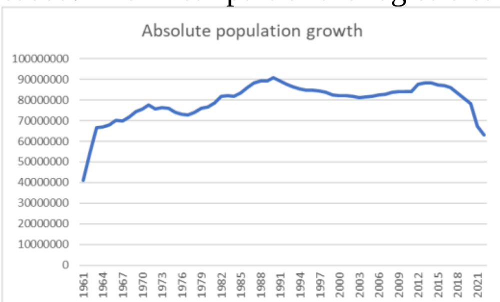


Figure 51: Global population absolute growth

Source: APSEC based on World Bank data

The retained population scenario as well as the underlying growth rate are shown in the figures below. In our analysis, global population is expected to peak in 2070 at a level just over 10 billion, after which it will start declining. The computed probability of this trajectory as a function of its data after the turning point is higher than 99.9%. As for the growth rate, is shows a decreasing trend oscillating around the trendline in generation-long movements of around 30 years each. In this interpretation, the low growth rates observed since 2013 are interpreted as part of a generational wave which is expected to return to the trendline after a half-generation of 15 years (i.e., around 2030).

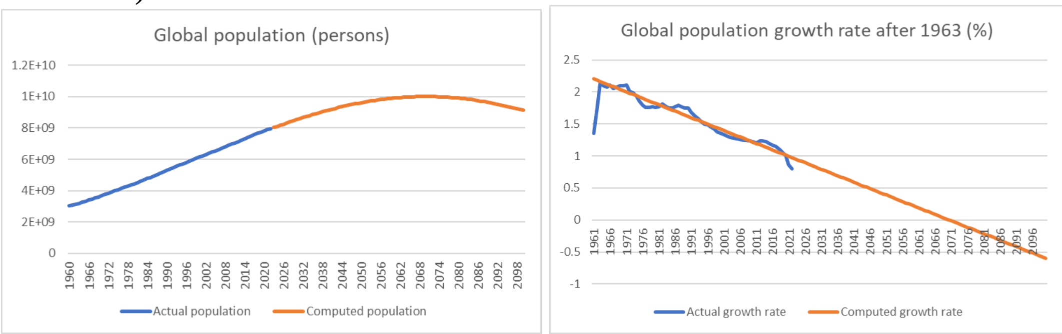


Figure 52: Global population (actual and computed) and growth ratio (actual and computed)

Source: APSEC based on World Bank data

The above population scenario is common to both, the unsustainable scenario as well as the sustainable energy scenario. This scenario should not be misinterpreted to mean that the maximum population is attained everywhere at the same time. There are regions in which the population peak has already been attained, and other regions where it will be attained later than 2070, and regions where the population is in decline already now.

Global Gross Domestic Product GDP (both scenarios)

Global GDP in constant 2015 USD has been growing steadily since time immemorial. Watching the diagram below on the left with bare eyes, one could easily conclude that the growth rate is exponential. A closer look at the growth rate itself shows another picture. On one hand the growth rate is impacted by single global black swan events such as both oil crises of 1975 and 1982, the financial crisis of 2008 and of course COVID-19 in 2020. On the other side, the growth rate seems slightly declining over the period. The APEC Sustainable Urban Development Report (2019)[32] has pointed out that the 2008 financial crisis has diminished the average global growth rate of the period before (1990 – 2007) and after (2008 – 2017) the crisis, and that this was not only the case for global GDP, but also for APEC GDP. The COVID-19 crisis stands out insofar as the contraction has been bigger than for any event recorded since the 1960s.

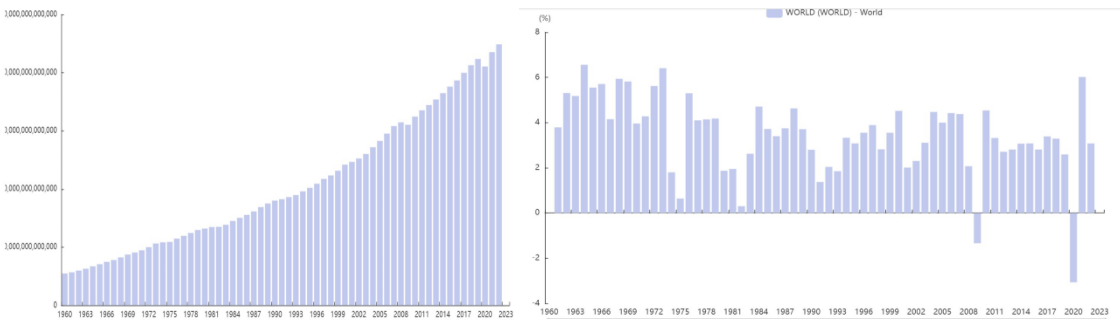


Figure 53: Global GDP at 2015 constant prices and growth rate

Source: APSEC based on World Bank data

Data analysis helps clarifying the conclusion to be drawn concerning the growth rate. The growth rate of GDP has in fact been constantly decreasing since the 1960s. The single global black swan events mentioned above have contributed to the decrease, but the decrease is also imputable to bulk data. The average growth rates of the 1960s were between 4% and 6% per year, whereas the average growth rates of the 2010s are around 3%. Compared to the relatively stable phenomenon of population growth described further above, economic growth is more chaotic. In the economy, growth cycles are visible, but they are of different length and amplitude. APEC Integrated Urban Planning Report (2021)[33] identified the so-called Juglar or investment cycle as the most regular one, having duration of between 7 and 11 years. The figure above on the right-hand side shows traces of the Juglar cycle as well as its irregularity and the presence of other short term cycles. As a result of the long-term decline of growth rates, the long-term GDP scenario points to a flattening of GDP growth and a peak in 2080, ten years after the population peak. The computed probability of this trajectory as a function of its data is higher than 99.8%. This is not the result of any specific policy or governmental action, but simply the consequence of intrinsic long-term trends of the system. The figure below on the left gives the GDP in actual data and its trajectory until the end of the century. On the right, the declining growth rate is shown as the main cause of the flattening of the GDP over time.

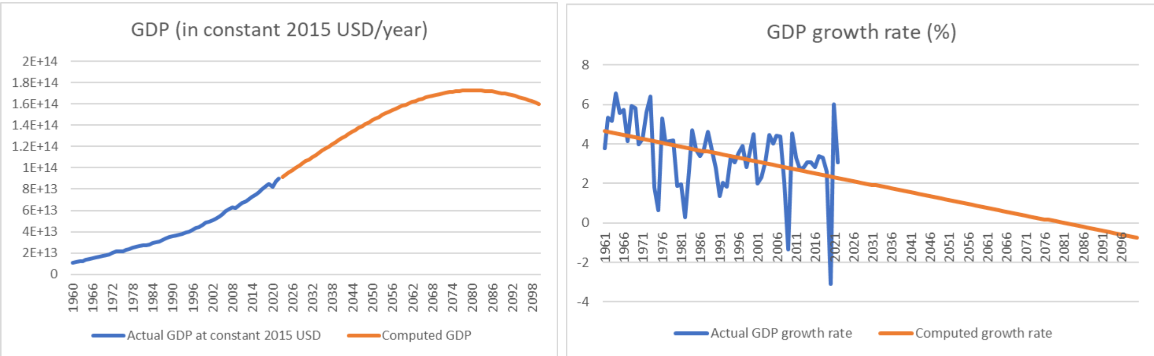


Figure 54: GDP actual and scenario (left) and growth rate up to the end of the century (right)

Source: APSEC based on World Bank data

A note to conclude the discussion on the GDP just to remind that GDP is taken at constant 2015 prices. The way the components of global GDP are deflated and converted to a single currency, 2015 USD in the present case, is of course of prime importance. It is not excluded that the long-term decrease of GDP growth rates shown in the data above is in reality nothing but a bias in the way the purchasing power parities (PPPs) are calculated. The methodology applied to calculate PPPs is not robust enough to exclude this type of bias.

Per capita global GDP (both scenarios)

The per capita GDP in 2015 purchasing power parities and its annual growth rate are shown in the figures below. As with the global GDP, per capita GDP also is growing. The growth rates also reflect the global black swan events that affect GDP.

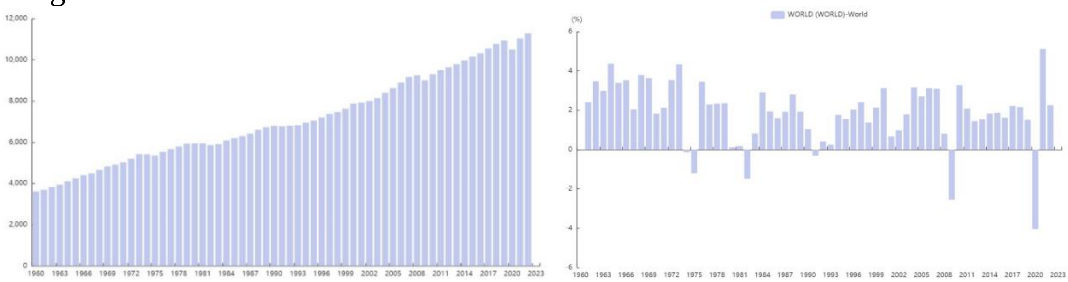


Figure 55: Per capita global GDP in 2015 PPP and annual growth rates

Source: APSEC based on World Bank data

The average growth rate of global per capita GDP 2015 PPP between 1960 and 2022 is 1.87%. Looking at the 1990-based multiannual growth rate, it has been around 1.6% in the last decade, except for the COVID-19-year 2020 for which it was slightly lower, i.e., 1.4% (see figure below).

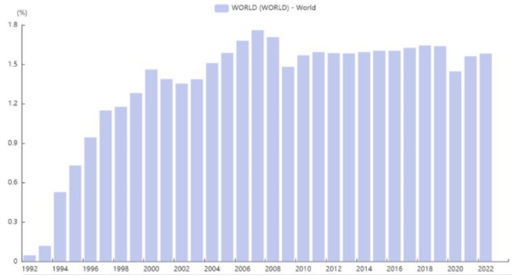


Figure 56: 1990-based multiannual growth rate of per capita global GDP in 2015 PPP

Source: APSEC based on World Bank data

The analysis and scenario computation of the per capita global GDP in constant 2015 USD show much the same pattern and explanatory factors as was the case for global GDP. Per capita GDP is expected to peak in 2085, just five years after the GDP peak. The computed probability of this trajectory as a function of its data is higher than 90%. For the case of per capita GDP, the computation of the scenario can be made by two different methods which normally yield different results. The first method involves analysing and computing the scenario of the per capita GDP as a single series. The result of this method is shown in the orange trajectory in the figure below on the left. The second method involves taking the ratio of the individual scenario computations made for GDP and for population, respectively, from the current period until the end of the century. This is ratio of computed scenario figures is shown in the grey trajectory in the figure below on the left. The computed probability of the grey trajectory is higher than 99.8% and is therefore preferred over the orange trajectory. The ratio of computed figures shows a peak in 2091, just six years after the peak of the orange trajectory. There is a remarkably high degree of congruence between the two methods, achieved despite the far future horizon of 80 years. Recall that population and GDP as well as per capita GDP are all part of the common scenario used later to compute the unsustainable scenario and the sustainable energy scenario. Per capita GDP at constant 2025 USD might suffer from the same type of bias as the GDP at constant 2015 USD mentioned above.

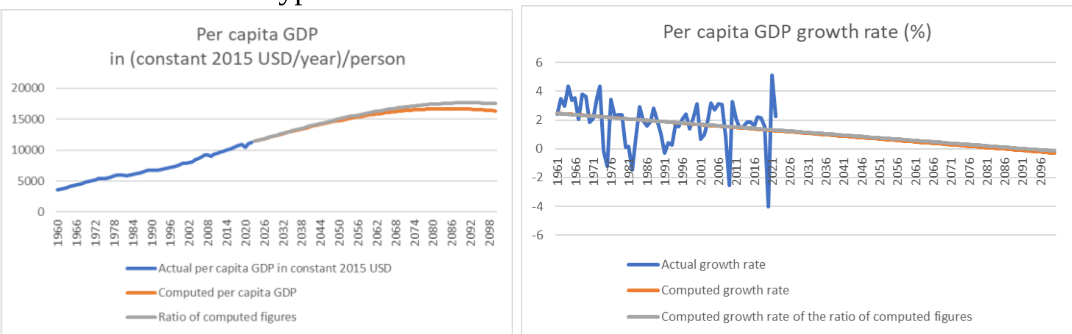


Figure 57: Per capita global GDP (actual and scenario) until 2100, as well as growth rate

Source: APSEC based on World Bank data

Global Total Primary Energy Supply TPES (both scenarios)

Global total primary energy supply (TPES) has been steadily increasing – except for the COVID-19-year 2020. The annual growth rate is influenced black swan events such as those identified further above as having impacted global GDP. But TPES is also impacted by other, less important global events that had less impact on global GDP. Among these are events such as the collapse of the Soviet Union in 1991, possibly the Asian financial crisis which might have had an impact in 1999, and an unidentified event in the years 2015 and 2016.

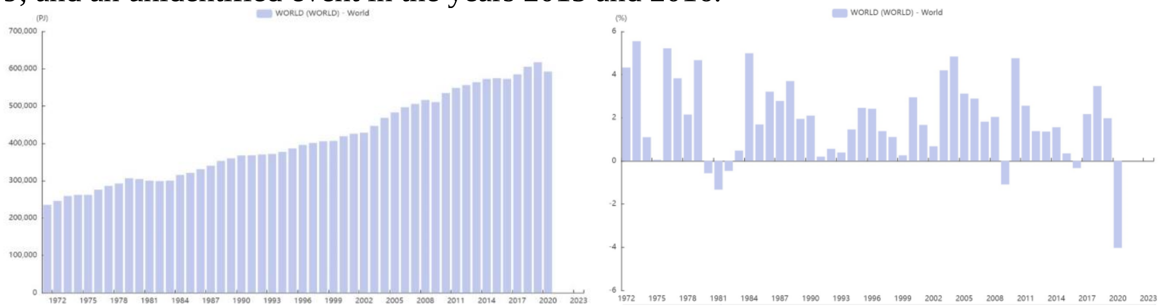


Figure 58: Global total primary energy supply TPES and TPES annual growth rate

Source: APSEC based on IEA data

As far as the structural evolution of global TPES is concerned, the scenario shows a flattening in the years 2050 leading to a peak in 2059 at a level of 208,988,896GWh followed by a decline (figure below, left). The computed probability of this trajectory as a function of its data is higher than 80%. The growth rate is shown in the figure on the right.

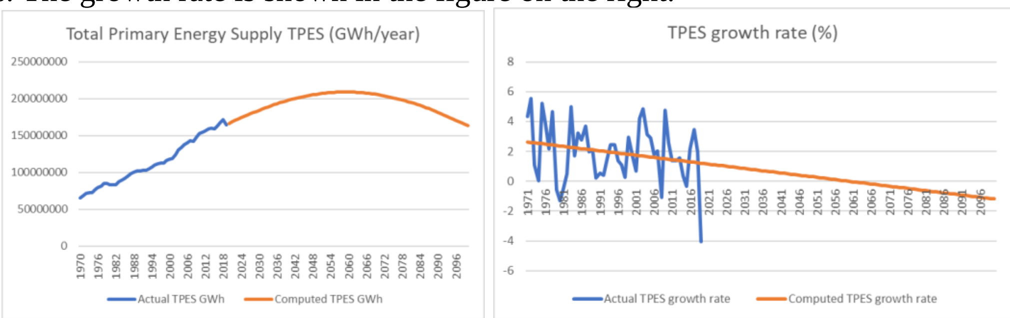


Figure 59: Global TPES scenario and TPES annual growth rate until the end of the century

Source: APSEC based on IEA data

Per capita global Total Primary Energy Supply (both scenarios)

Per capita global TPES has been growing at low rates with irregular patterns over the past decades. Per capita TPES is impacted by the same events as TPES itself but grows slower than TPES due to the still growing population.

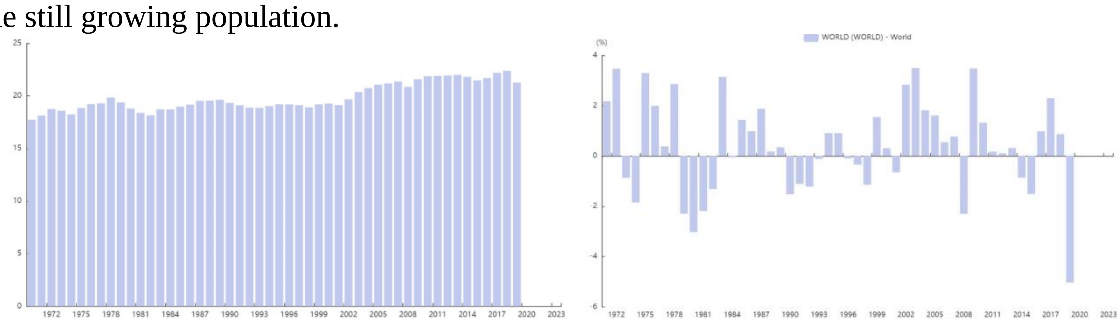


Figure 60: Global per capita TPES and annual growth rate

Source: APSEC based on IEA data

For per capita TPES, it is again possible to calculate the scenario in two methods. The first method consists of making the computation of per capita TPES as a single series, described above and shown in orange in the figure below, whereas the second method consists of taking the ratio between the scenario figures of TPES and population computed above, which is shown in grey in the figure below. The computed scenario shown in orange in the figures below has a computed probability which is too low to be retained. The retained alternative scenario peaks in 2037 at 21.6MWh/person per year, corresponding to a little less than 2.5kW/person. The computed probability of this alternative grey trajectory as a function of its data is higher than 80%. There is still a high convergence between the two methods. Until the end of the century the retained alternative scenario provides for a slight contraction of per capita TPES to attain 17MWh/person, corresponding to about 2kW/person. However, the computed 2037 peak is still a little lower than the peak of 22.4MWh/person reached in 2018. This multi-peak trajectory reflects the fact that per capita TPES is quasi-stationary. Given the long analysis period, there is practically no change in per capita TPES over the 21st century. The growth rate of per capita TPES might decline from at present 0.6% growth per year to a -0.7% contraction per year at the end of the century (see figure below on the right).

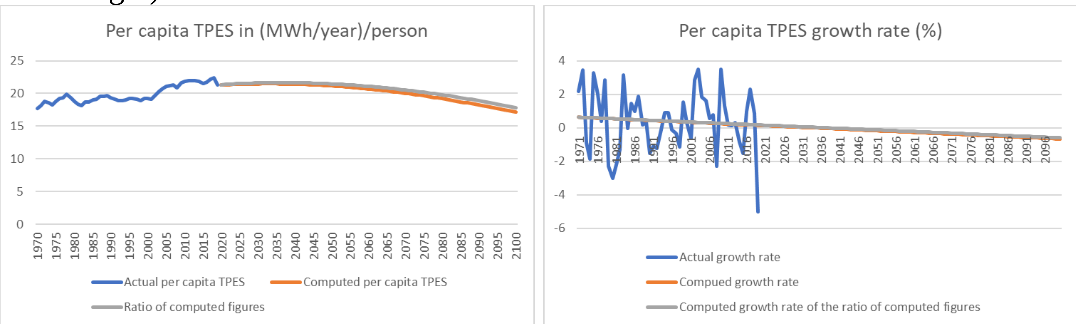


Figure 61: Global per capita TPES scenario and per capita TPES annual growth rate

Source: APSEC based on IEA data

The above might surprise many of those who are engaged in planning future energy infrastructures in the developing and emerging world. In these places, entire cities are being built from scratch, requiring energy in sufficient quantities. Locally, the energy requirement might, therefore, be heavily on the rise. For this reason, and as half of the mid-century buildings are still to be set up by 2050, global TPES is peaking only in 2059. However, the fact that both, per capita TPES (as well as per capita GDP discussed further above) have grown less than 2% per year in the 30 past years since the 1990s and that their growth rates are expected to further decline, can comfort the conclusion that the world is now in the epoch in which per capita TPES is quasi-stationary.

Global Energy intensity TPES/GDP (both scenarios)

Global energy intensity is known to be on a declining trend and reached 4.63MJ/USD in 2020 (latest available data). These trends confirm the existing path of development. SDG 7.3 postulates to double, by 2030, the global rate of improvement in energy efficiency. SDG indicator 7.3.1 explicitly defines energy efficiency as energy intensity measured in terms of primary energy and GDP. If the rate of improvement has been 1.3% per year during the base period 2000 to 2010, then this rate should, according to the postulate of SDG7.3.1, in average increase to 2.6% per year in the period 2020 to 2030[34].

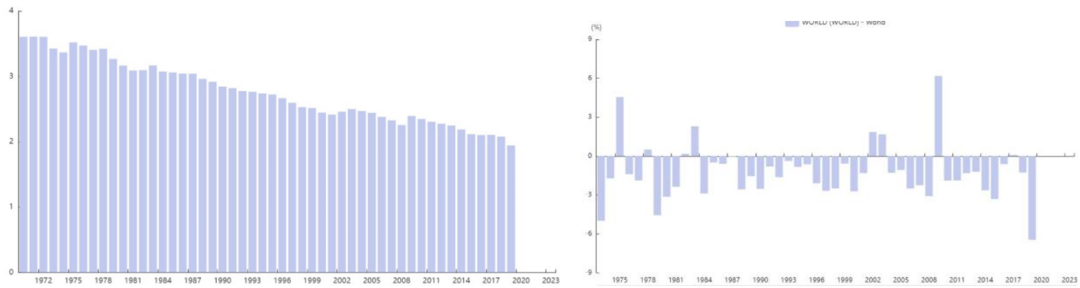


Figure 62: Primary energy intensity of GDP and growth rate

Source: APSEC based on IEA data

The scenario computation for primary energy intensity is showing a decrease but accompanied by high volatility of the indicator. The computation quality of this scenario (shown in orange in the figures below) is too low to be retained. In fact, energy intensity is the quotient of two volatile quantities, TPES and GDP, which makes the quotient difficult to predict. The figures also show (in grey) the alternative scenario computed on the basis of the more likely ratio of the computed figures (TPES and GDP). The computed probability of this trajectory as a function of its data is higher than 80%. The grey trajectory shows a floor level at around 1kWh/USD. This trajectory is shown in grey in the figure below and is more likely, but also more pessimistic, than the orange trajectory. The TPES/GDP ratio cannot decrease infinitely. The grey trajectory will move away from the doubling of the growth rate of efficiency postulated by SDG7.3.1. It moves towards a zero-growth rate of efficiency by the end of the century. Primary energy intensity is measured in (kWh/year)/(USD/year), simplifying to kWh/USD. This global scenario should not be misinterpreted to exclude that in some regions and at some periods, energy efficiency may improve (i.e. come down) faster than global average, thereby satisfying SDG7.3.1. regionally and at certain periods.

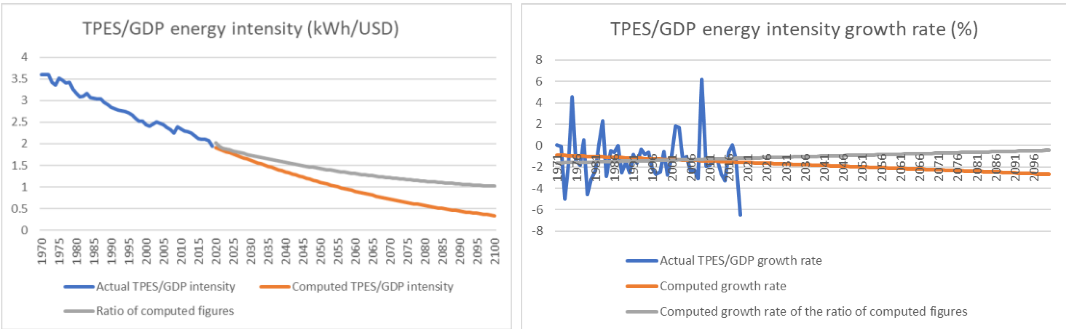


Figure 63: TPES/GDP energy intensity scenario and annual (negative) growth rate

Source: APSEC based on IEA data

Global Total Final Energy Consumption TFC (both scenarios)

Global total final energy consumption is experiencing a pattern and growth rate as shown in the figure below.

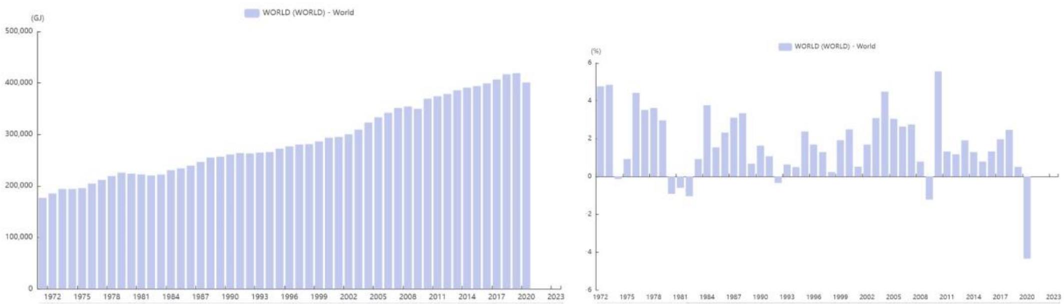


Figure 64: Total final energy consumption TFC and growth rate

Source: APSEC based on IEA data

The scenario computed for total final energy consumption (TFC) shows that TFC is still rising, but the growth rate is steadily diminishing, leading to a flattening after 2040 and a peak in 2057, with a computed probability as a function of its data being higher than 80%. The peak of TFC is happening just two years earlier than the peak of TPES. A decline is expected to follow thereafter. The figures below show the scenario and the associated growth rate.

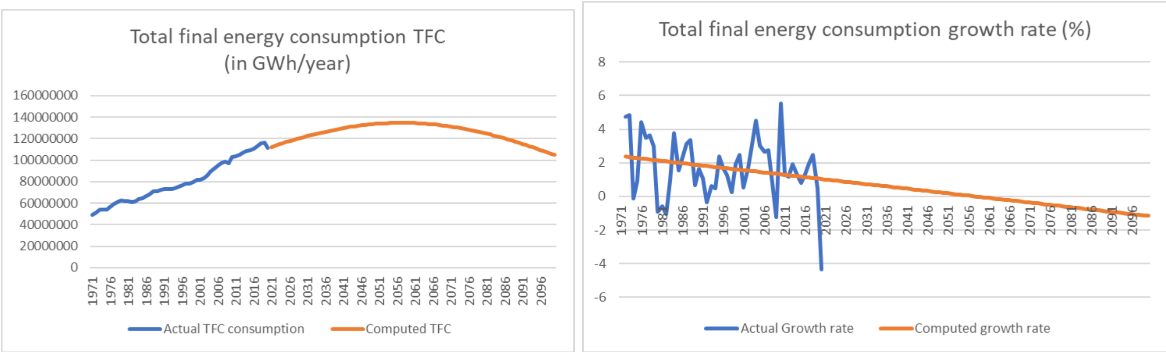


Figure 65: Total final energy consumption scenario and growth rate

Source: APSEC based on IEA data

Per capita Total Final Energy consumption (both scenarios)
Per capita TFC has just peaked in 2018 at 15MWh per person per year and is now starting a slow downward path to attain between 11 and 12MWh per person per year by the end of the century. The probability of the orange trajectory is too low to be retained. The scenario has, therefore, also been calculated by the ratio of its components, shown in grey in the figures below. The computed probability of this alternative grey trajectory as a function of its data is higher than 80%.

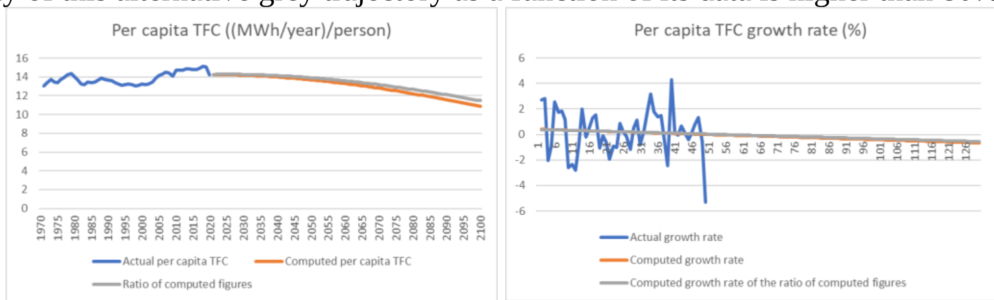


Figure 66: Per capita TFC scenario and annual growth rate

Source: APSEC based on IEA and World Bank data

Total global final energy intensity TFC/GDP (both scenarios)
Total final energy intensity (TFC/GDP) has been declining since the beginning of measurements in the 1970s. To determine the growth rate, the turning point of 1980 must be taken into consideration. Global final energy intensity divides into two periods: one before the turning point of 1980, with the two oil crises (1973 and 1979) and a multiplication of the oil price by a factor of altogether 18, and one after the turning point. The orange trajectory shown in the figure below reflects the trajectory after the turning point. The probability of this trajectory as a function of its data is greater than 80%. The alternative method of computing the trajectory by the quotient of its elements, shown in grey, is also computed with a probability of higher than 80%. At equal probabilities, the alternative grey scenario is retained here as it fits the context better than the orange one. Like in the case of primary energy intensity shown above, the scenario of final energy intensity shows that the improvement of final energy intensity is not coming closer to the trajectory postulated by SDG 7.3, but on the contrary, moving away towards an improvement rate just above zero (i.e., towards a slight deterioration) by end of the century. The TFC/GDP ratio attains a floor level of around 0.7kWh/USD as it cannot decline infinitely. The final energy intensity is measured in (kWh/year)/(USD/year), simplifying to kWh/USD.

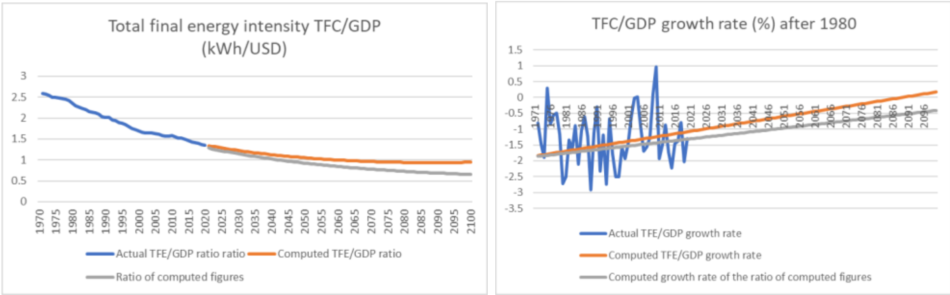


Figure 67: TFC energy intensity scenarios and annual growth rate

Source: APSEC based on IEA and World Bank data

All the scenarios computed up to now are common to both scenarios, the unsustainable scenario as well as the sustainable energy scenario.

4.2 Unsustainable Scenario

Global CO2 Emissions (unsustainable scenario)

Hereafter starts the description of the unsustainable scenario, which is primarily characterized by the emissions it generates. The data used for this scenario is World Bank data whose original provider is Climatewatch[35]. This data describes CO2 emissions originating from energy combustion processes from all sectors, excluding land use change and forestry (LUCF). As a notice of interpretation, it should be stressed that this data does not include CO2 emissions from agricultural livestock and human metabolism. APEC Green Finance Report (2023) has pointed out that CO2 emissions from agricultural livestock and human metabolism can be said to be at least 1t CO2 per year, of which less than one third is from human metabolism and more than two thirds from agricultural livestock[36]. These CO2 emissions are not comprised in the data series below, neither are the emissions of all other greenhouse gases. CO2 emissions show an annual growth, which may be flattening out, not only due to the one-time decrease caused by COVID19 in 2020, but also due to structural change.

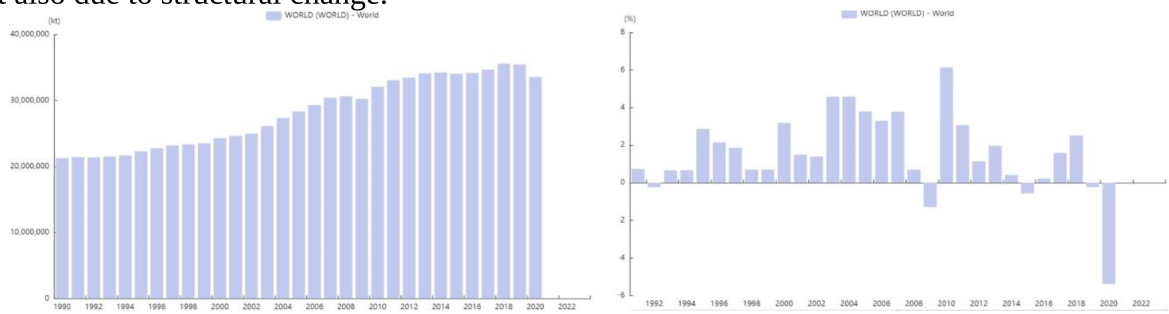


Figure 68: CO2 emissions and growth rate

Source: APSEC based on World Bank/Climatewatch data

For CO2 emissions, two scenarios have been computed, an unsustainable scenario in which the growth rate of CO2 future emissions is computed in multivariate analysis as a function of the growth rates of TPES, GDP and renewable electricity generation, and a sustainable energy scenario in which future CO2 emissions are computed as a function of their data after the turning point of 2004.

The unsustainable scenario for CO2 emissions is shown in the figure below on the left and its growth rates on the right. The growth rates of CO2 emissions have been calculated in multivariate

regression with the growth rates of TPES, GDP and renewable electricity generation as explanatory variables. For growth rates of TPES, GDP and renewable electricity generation, acceptable scenarios up to the end of the century have been computed beforehand (for TPES and GDP they have already been presented above, for renewable electricity generation it is presented further down).
Global emissions in the unsustainable scenario are at present already flattening and will peak in 2030 at 36.6Gt/year, after which they will be declining steadily and reach 3.7Gt/year by end of the century, failing to reach carbon neutrality even after an 80year horizon.

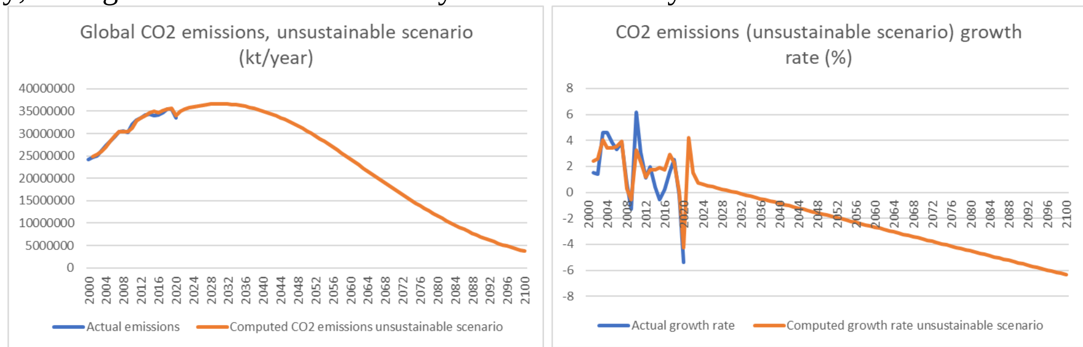


Figure 69: CO2 emissions in the unsustainable scenario and annual growth rate

Source: APSEC based on World Bank/Climatewatch data

As the figures show, the computation manages to explain a considerable amount of variability of the emissions. As expected, the slope coefficients for TPES and GDP growth rates are positive (meaning they contribute positively to emissions growth rate), whereas the slope coefficient of renewable electricity growth rate is negative. The fact that the latter has the smallest probability is important to note. Renewable electricity has been a marginal phenomenon during the period to which the data set refers to (2001 – 2019). Even though this is expected to change rapidly in the future under strong growth of the role of renewable electricity, this is barely seen in the statistics yet.

Explanatory variable	Slope coefficient	t Stat	Probability
TPES growth rate	0.28906891	2.192329098	> 95%
GDP growth rate	0.89986247	4.73909879	>99.9%
RE generation growth rate	-0.20599242	-1.852284073	>90%

Table 4: Statistics of the unsustainable model; explained variable is CO2 emissions growth rate

Source: APSEC

Per capita CO2 emissions (unsustainable scenario)
Per capita CO2 emissions peaked in 2013 and started the decline, contrary to the total CO2 emissions shown above.

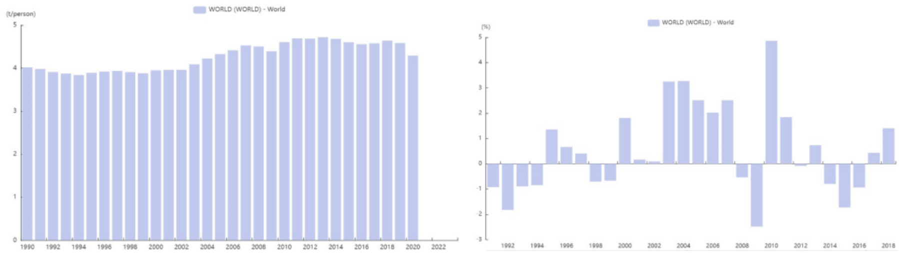


Figure 70: Per capita CO2 emissions and growth rate

Source: World Bank/Climatewatch data processed by APSEC

The unsustainable scenario for per capita CO2 emissions shows a continuous decline. The all-time peak of 4.72t/person has been attained in 2013. The decline is, however, way too slow to reach carbon neutrality by the end of the century. The figures show the trajectory computed on the basis of the multivariate analysis of emissions made above divided by population in orange (left) and its growth rate (right), which is by definition identical to the alternative grey trajectory computed from the quotient of its components (emissions and population, respectively). The figures show that the multivariate analysis captures short term fluctuations of the per capita emissions. The computed probability of these trajectories on the basis of their data is >90%.

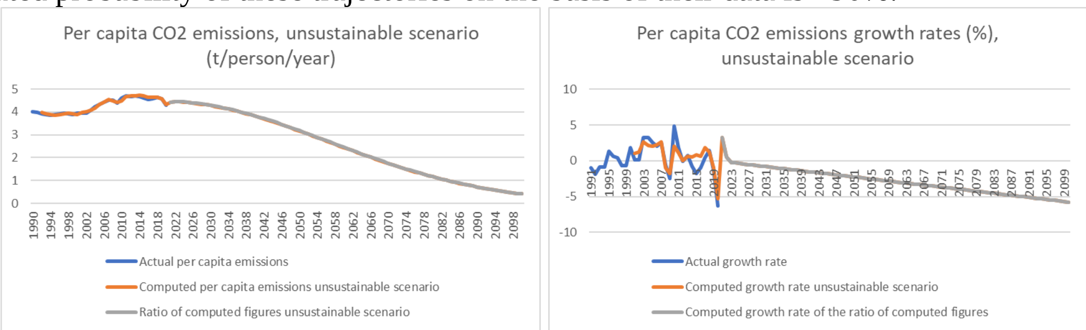


Figure 71: Per capita CO2 emissions and annual growth rate in the unsustainable scenario

Source: APSEC based on World Bank/Climatewatch data

The two above emissions scenarios, together with the cumulated emissions after 2021, shown further down, are the only ones that are specific to the unsustainable scenario.

4.3 Sustainable Energy Scenario (SES)

Global installed renewable energy capacity (sustainable energy scenario)
Global installed renewable energy capacity is part of the sustainable energy scenario.

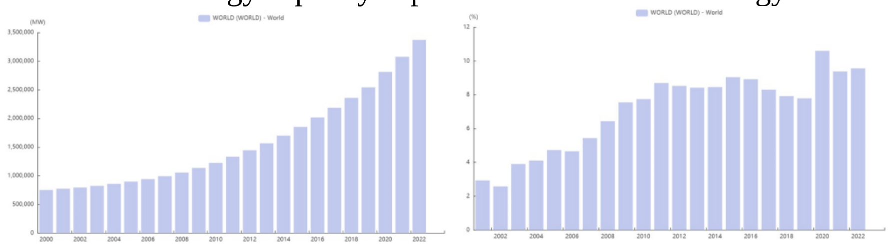


Figure 72: Installed renewable energy capacity and growth rate

Source: APSEC based on IRENA data

The installed renewable energy is on a strong growth path. The scenario is shown in the figure on the left below, and the growth rate in the figure on the right. The computed probability of this trajectory as a function of its data is higher than 99.9%.

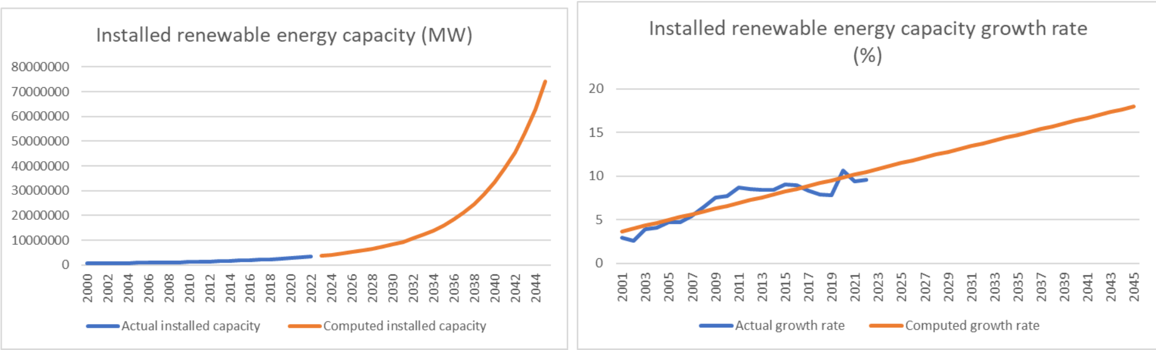


Figure 73: Installed renewable energy capacity and annual growth rate

Source: APSEC based on IRENA data

The 2023 APEC Leaders declaration encourages efforts to triple renewable energy capacity globally through existing targets and policies by 2030[37]. COP28 also declared tripling renewable capacity by 2030 as a key objective[38]. The global scenario above shows that the world is actually on the path of tripling installed renewable energy capacity during the period 2020 – 2030.

Per capita global installed renewable energy capacity (sustainable energy scenario)

Per capita global installed renewable energy capacity is on a strong growth path, but due to population growth, it is expectedly a little less strong than the total installed renewable energy capacity.

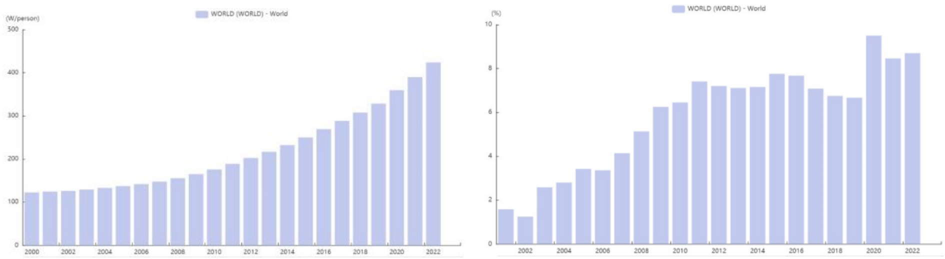


Figure 74: Per capita installed renewable energy capacity and annual growth rate

Source: APSEC based on World Bank/Climatewatch data

The scenario of per capita installed renewable energy capacity is shown in the figures below. The trajectory corresponding to the direct computation is shown in orange in the figure on the left. The computed probability of this trajectory as a function of its data is higher than 99.9%. The alternative scenario, computed as the ratio of its components (installed renewable energy capacity and population respectively) is shown in grey. Its computed probability as a function of its data is higher than 99.9%. The two are not identical, but the difference is too small to be visible in this chart. The corresponding growth rate is shown in the figure on the right below.

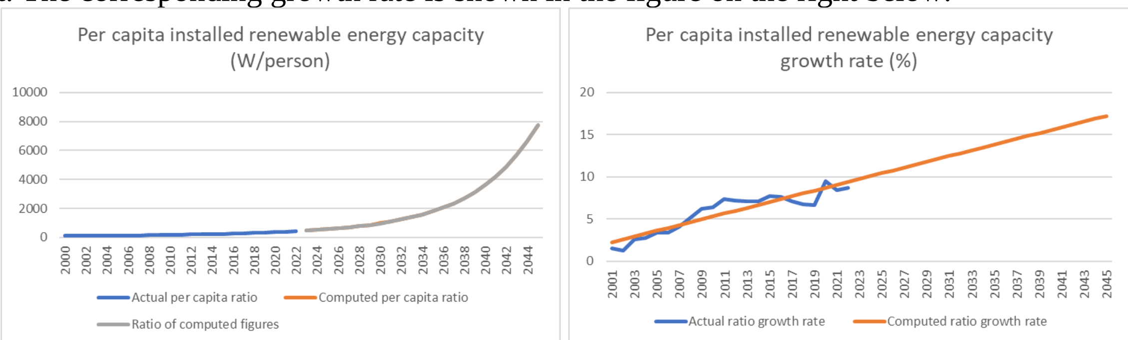


Figure 75: Installed per capita renewable energy capacity and annual growth rate

Source: APSEC based on IRENA and World Bank data

Global renewable energy generation (sustainable energy scenario)

Global renewable energy generation is part of the sustainable energy scenario. Renewable energy generation as measured by IRENA data is on a strong growth path. To be precise, this data measure renewable electricity generation. Except for the years 2001 and 2003, growth rates have been between 3% and 8%.

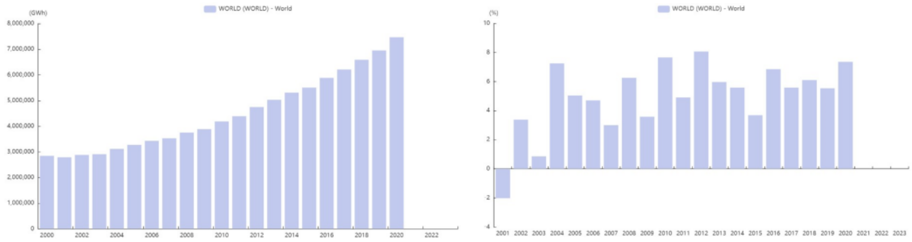


Figure 76: Renewable energy generation and growth rate

Source: APSEC based on IRENA data

The scenario computation made until 2050 reflects this strong growth. The computed probability of this trajectory as a function of its data is higher than 99%.

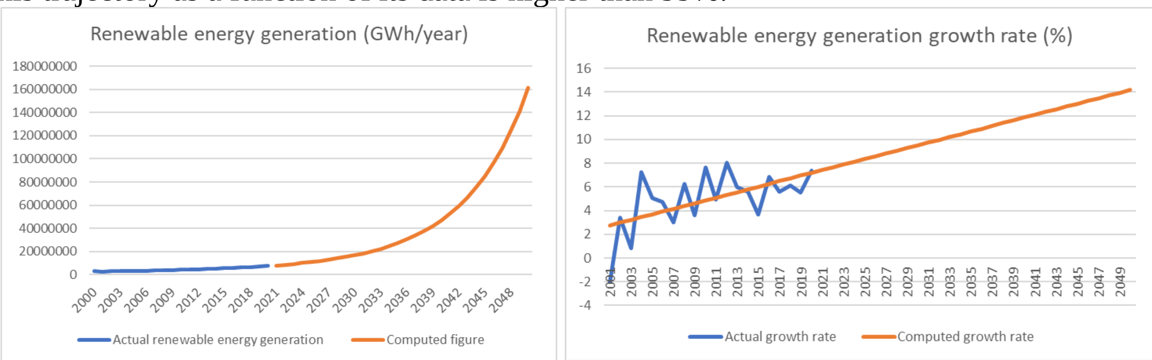


Figure 77: Renewable energy generation scenario and growth rate

Source: APSEC based on IRENA data

Global renewable energy share in TPES (sustainable energy scenario)

The renewable energy share in primary energy supply TPES is expected to grow, driven by the growth of renewable energy just shown above. The scenario computation of the ratio of renewable energy over TPES reflects this picture. According to the Sustainable Energy Scenario, the share of renewable energy in TPES reaches 100% in 2047. The computed probability of this trajectory as a function of its data is higher than 99.8%. This trajectory is shown in the orange in the left figure below. The corresponding growth rate is shown in the figure on the right. This scenario has also been computed by the alternative method, by taking the quotient of the figures, shown in grey in both figures below. In this computation, the share of renewable energy in TPES reaches 100% in 2052. The computed probability of this trajectory as a function of its data is higher than 80%. Due to its higher computed probability, the orange trajectory will be retained.

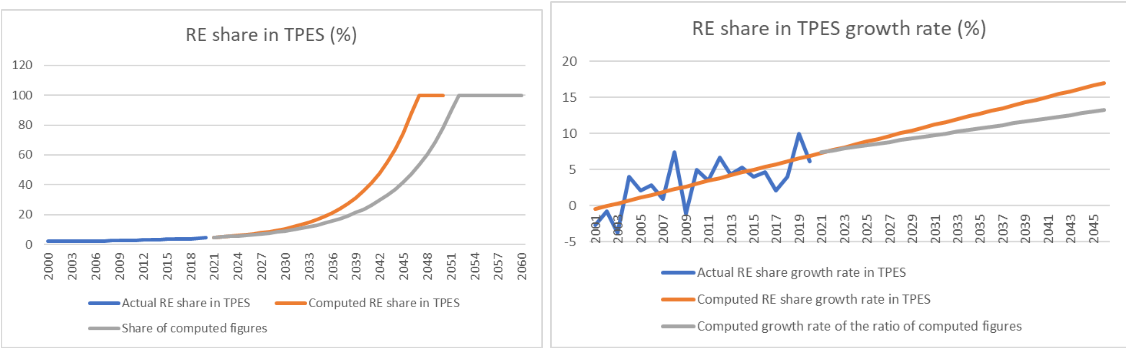


Figure 78: Renewable energy share in TPES

Source: APSEC based on IRENA data (RE) and IEA data (TPES)

The scenario above illustrates the disruptive potential of renewable energy. Once the share of 100% is attained, carbon neutrality is achieved.

Global renewable energy (RE) share in TFC (sustainable energy scenario)
The renewable energy share in total final energy consumption TFC is expectedly growing, similar to the renewables share in primary energy just described above. For the RE share in TFC, there are two divergent data sets expressing two different things. The IEA maintains a dataset related to the tracking of SDG7. This dataset shows the renewables share (%) in TFC where renewables include all forms of renewable energy except traditional biomass. This dataset is shown in the figure below on the left. On the other hand, IRENA publishes a complete data set on renewable electricity. From this IRENA dataset, the renewables share in TFC can also be calculated by using the IEA data on TFC. This is shown in the figure below on the right. Presumably the main difference between the two relates to non-electricity renewables. Given the interest of electricity as a product and the high degree of technological and social modernization that electricity creates, this study only uses the data on renewable electricity to calculate the shares of renewables in TFC. This has also been done in the scenario above computing the renewables share in TPES.

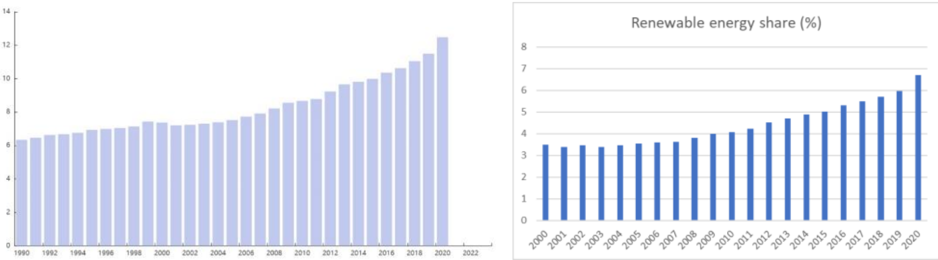


Figure 79: Renewable energy share in TFC according to IEA data (l) and IRENA and IEA data (r)

Source: APSEC based on IEA and IRENA data

The scenario of the renewables share in total final energy consumption is shown in the orange trajectory in the figure below on the left. According to this scenario, the share of renewables in TFC will reach 100% by 2045. The computed probability of this trajectory as a function of its data is higher than 99.9%. As with the case of the renewables share in TPES computed above, it is also possible to compute the alternative scenario by taking the share of computed figures from its components (renewables and TFC, respectively). The corresponding trajectory is shown in grey in the figures below. The computed probability of this trajectory as a function of its data is higher than 80%. Due to its higher computed probability, the orange trajectory will be retained.

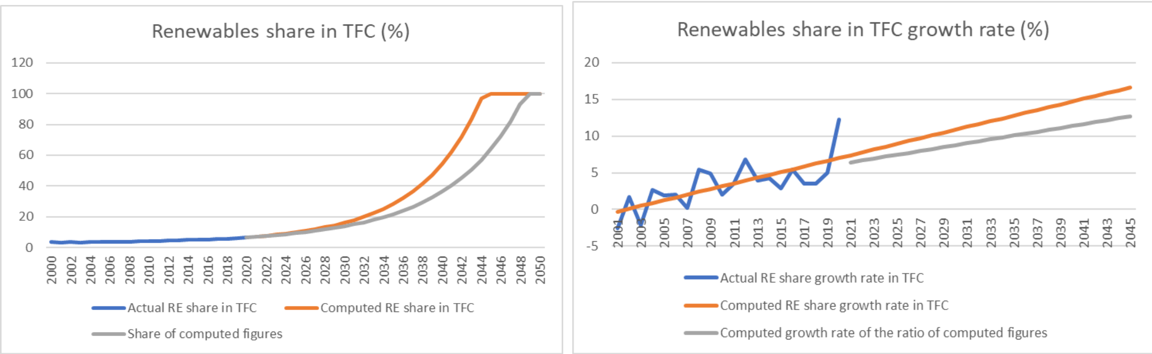


Figure 80: Renewable energy share in total final energy consumption TFC

Source: APSEC based on IRENA data (RE) and IEA data (TFC)

Global CO2 emissions in the Sustainable Energy Scenario

The global CO2 emissions of the Sustainable Energy Scenario are computed in the same way as has been done earlier with global population scenario. For global CO2 emissions, the turning point is in 2004, hence the Sustainable Energy Scenario uses data from 2004 and subsequent years. The turning point of 2004 may be related to the very hot and anormal year 2003 in several parts of the world, entailing as consequence an increased public perception of climate change[39]. The figures below show the emissions in the Sustainable Energy Scenario. This scenario attains carbon neutrality by mid-century. The computed probability of this trajectory as a function of its data is higher than 99%.

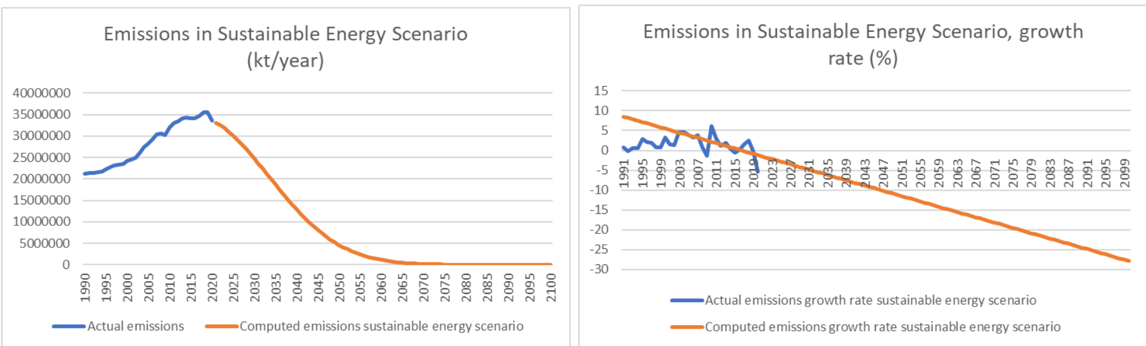


Figure 81: CO2 emissions of the sustainable energy scenario

Source: APSEC using IRENA (RE), IEA (TPES) and World Bank/Climatewatch (CO2) data

Per capita global CO2 emissions (Sustainable Energy Scenario)

The per capita CO2 emissions and the corresponding emissions intensity of GDP of the Sustainable Energy Scenario are shown in the figures below, together with the growth rate. The orange trajectory shows the computation by using per capita emissions data, whereas the grey alternative trajectory shows the ratio of the computations made for emissions and for population, respectively. The two are not identical but strongly coincide. The computations reflect the carbon neutrality trajectory of CO2 emissions in the Sustainable Energy Scenario described above. The computed probability of the orange as well as the grey trajectories as a function of their respective data is >99%.

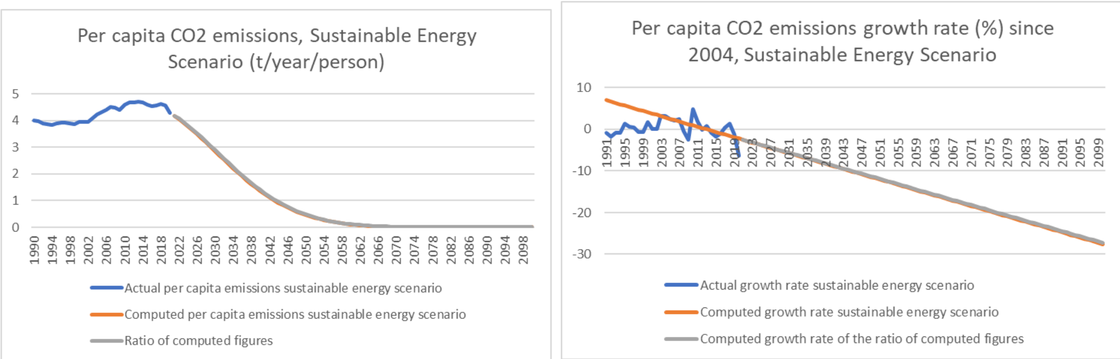


Figure 82: Per capita CO2 emissions of the sustainable energy scenario

Source: APSEC using World Bank/Climatewatch (CO2) and World Bank (population) data

Global CO2 emissions intensity of GDP (Sustainable Energy Scenario)

Global CO2 emissions intensity of GDP of the Sustainable Energy Scenario and the growth rates are shown in the figures below. The probabilities of both, the orange and the alternative grey scenarios as a function of their data after the turning point of 2004 is higher than 99%. As the alternative grey scenario fits better with the context, it is the alternative grey scenario that will be retained. Emissions intensity of GDP is measured in (g/year)/(USD/year) which simplifies to g/USD.

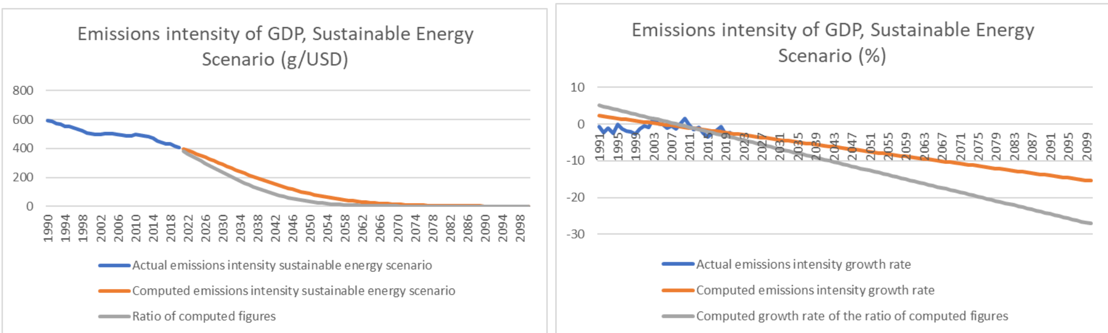
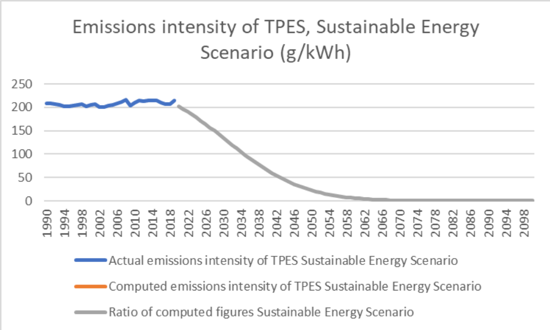


Figure 83: CO2 emissions intensity of the sustainable energy scenario

Source: APSEC using World Bank/Climatewatch (CO2) and World Bank (GDP) data

Global CO2 emissions intensity of TPES (Sustainable Energy Scenario)

Decarbonization of energy is one of the main tasks of the energy transition. This is measured in the CO2 emissions intensity of TPES (total primary energy supply). There is probably no other indicator that better illustrates the energy transition (or the absence of the energy transition, depending on the case). The emissions intensity has been almost stationary in the past decades. The computed trajectory for the Sustainable Energy Scenario until the end of the century has too low probability to be retained. The alternative trajectory, shown in grey in the figure below, is calculated by dividing CO2 emissions by TPES. It has a calculated probability as a function of its data greater than 80%. Carbon neutrality is attained by mid-century.



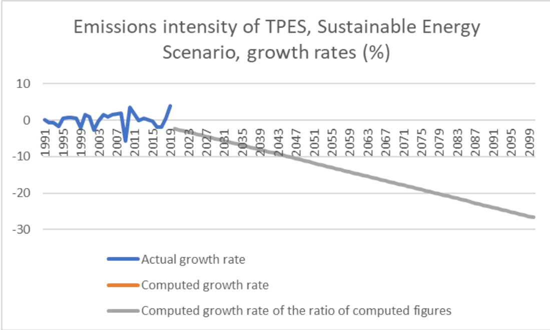


Figure 84: CO2 emissions intensity of TPES in the sustainable energy scenario and growth rate

Source: APSEC using World Bank/Climatewatch (CO2) and IEA (TPES) data

Comparison of cumulative carbon emissions of both scenarios

It might be interesting to compare the cumulative carbon emissions of both scenarios (unsustainable scenario and Sustainable Energy Scenario) among themselves. This comparison is shown in the figure below for the period after 2021.

The Sustainable Energy Scenario has cumulated emissions of 550Gt by 2050 and 584Gt by 2100. Compared to that, the unsustainable scenario has cumulated emissions of 1050Gt by 2050 and 1810 Gt by 2100 and still growing emissions after 2100.

It would be fair to say that the unsustainable scenario causes almost twice the cumulative emissions of the sustainable energy scenario by 2050, and more than three times the cumulative emissions of the sustainable energy scenario by 2100. It is beyond the scope of this report to analyse how many degrees of global temperature increase each of these two scenarios will create, and whether the Sustainable Energy Scenario still lies within the 1.5° target.

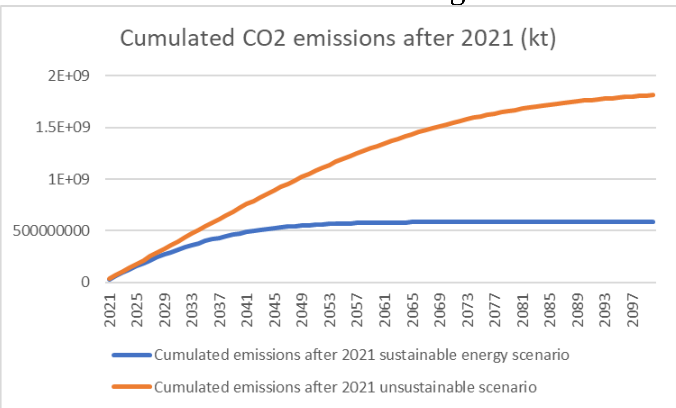


Figure 85: Cumulated CO2 emissions after 2021 of both scenarios

Source: APSEC

To summarize, the above scenarios and their key metrics are shown in the table below. The 2020 – 2030 step show is destined for cities to allow monitoring their own progress during this decade. The departure position of cities is so diverse that the relative change as expressed in the second column below is much better suited for monitoring each city's development than absolute figures. Further scenario computations destined to allow cities monitoring their pathway on the Sustainable Energy Scenario are presented in sections 5.1 to 5.6.

Series	2020 – 2030 step	Evolution by 2100	Probability of trajectory
Global Population (both scenarios)	9% increase	Peak in 2070 at 10 billion	>99.9%; turning point 1963
Global GDP at constant 2015 USD (both scenarios)	29% increase	Peak in 2080	>99.8% (possible bias from PPP)
Per capita GDP (both scenarios)	18% increase	Peak in 2091 at USD17,650/person	>99.8% (alternative)
Total Primary Energy Supply TPES (both scenarios)	10.6% increase	Peak in 2059 at 210,000TWh	>80%
Per capita TPES (both scenarios)	1.5% increase	Quasi-stationary during the century, peaks in 2018 (22.4MWh/person) and 2037;	>80% (alternative)
TPES/GDP (both scenarios)	-14% (decrease)	Floor at 1kWh/USD	>80% (alternative)
Total Final Energy Consumption TFC (both scenarios)	+9%	Peak in 2057 at 135000TWh	>80%; turning point 1980
Per capita TFC (both scenarios)	stationary	Peak in 2018 at 15.1 MWh/person/year, slow decrease to 11 – 12MWh/person/year	>80% (alternative)
TFC/GDP (both scenarios)	-15% (decrease)	Floor at 0.7kWh/USD	>80% (alternative)
CO2 emissions (unsustainable scenario)	9% increase	Peak in 2030 at 36.6Gt/year; carbon neutrality after 2100	>90% (multivariate analysis)
Per capita CO2 emissions (unsustainable scenario)	stationary	Peak in 2013 at 4.72t/year/person; carbon neutrality after 2100	>90% (alternative)
Installed renewable generation capacity (sustainable energy scenario)	Multiply by 3	Strong growth until carbon neutrality (mid-century)	>99.9%
Per capita installed RE capacity (sustainable energy scenario)	Multiply by 2.7	Strong growth until carbon neutrality (mid-century); 2kW/person in 2036	>99.9%
Renewable energy generation (sustainable energy scenario)	Multiply by 2.25	Strong growth until carbon neutrality (mid-century)	>99%
Renewable energy share in TPES	Multiply by 2.375	100% in 2047	>99.8%

(sustainable energy scenario)			
Renewable energy share in TFC (sustainable energy scenario)	Multiply by 2.4	100% in 2045	>99.9%
CO2 emissions (sustainable energy scenario)	-26% (decrease)	Carbon neutrality by mid-century	>99%; turning point in 2004
Per capita CO2 emissions (sustainable energy scenario)	-33% (decrease)	Carbon neutrality by mid-century	>99%
CO2 intensity of GDP (sustainable energy scenario)	-43% (decrease)	Carbon neutrality by mid-century	>99% (alternative)
CO2/TPES intensity (sustainable energy scenario)	-33% (decrease)	Carbon neutrality by mid-century	>80% (alternative)
Cumulated CO2 emissions after 2021 (sustainable energy scenario)	-	550Gt (2050) 584Gt (2100)	>99% (after 2004)
Cumulated CO2 emissions after 2021 (unsustainable scenario)	-	1050Gt (2050) 1810Gt (2100) and still growing	>90% (multivariate analysis)

Table 5: Overview of the scenarios

Source: APSEC

4.4 Methodology and Interpretation of the Scenarios

For computing the scenarios, a great number of models have been tested and mostly found not to apply to the data sets. The basic expectation was that a transition such as the energy transition or the demographic transition should be characterized by the famous logistic or Verhulst model.

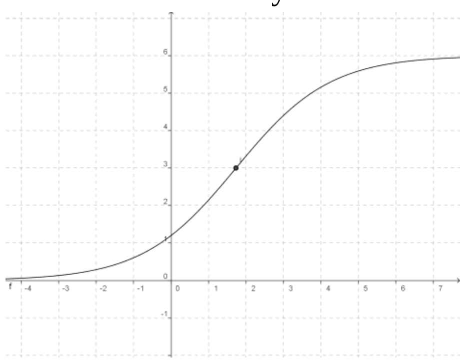


Figure 86: Logistic or Verhulst curve with turning point

Source: Wikimedia Commons[40]

As it seems, however, the logistic curve was not the best fit for the socio-economic variables used in the long-term scenarios. Take the population as example: The logistic curve, if applied to population, cannot explain that the population could be decreasing in the future under the impact of ageing societies. In agreement with the logistic model, some of the analysed variables had, however, turning points. The portion after the turning point could best be described by a model whose growth rate varies linearly as a function of time, hence the structure ($\dot{y} = at + b$). If written in form of a differential equation, this model would be written as:

$$\frac{dy/dt}{y} = \dot{y} = at + b, \text{ transforming to } y'(t) - aty(t) - by(t) = 0,$$

which in the general case solves to $y(t) = Ce^{(\frac{at^2}{2}+bt)}$, describing the family of all the computed trajectories of both scenarios.

Due to its high non-linearity, this family of trajectories is capable of reflecting a large amount of long-term flexibility believed to exist within socio-economic systems where, a priori, nothing remains constant in the long run. For the variables common to both scenarios as well as for the Sustainable Energy Scenario, this specification allows for desired flexibility to describe structural change. Coefficients a and b of each variable have been estimated by linear regressions. The value for the initial condition has been set equal to the latest available data point for each series. For estimating e.g. future CO2-emissions in the Sustainable Energy Scenario, it was necessary to consider the data after the turning point of emissions that took place in 2004 (visible by bare eye), after which emissions were estimated by the above linear equation.

For the unsustainable scenario, the growth rates of CO2 emissions have been computed by multivariate regression as a function of the growth rates of three explanatory variables (growth rates of TPES, GDP, and RE, respectively) whose trajectories had been calculated beforehand using the above model. The multivariate dependence introduces a constraint forcing the growth rate of CO2 emissions to be tied to the growth rates of three explanatory variables, which limits the variability of the CO2 emissions. These constraints may reflect some kind of structural inertia existing at certain times within some human societies.

The probability of each trajectory has been calculated by frequentist interpretation of the term (1 – p-value) of the regression. With the chosen specification, the p-values of the constant and the coefficient of each regression have been consistently found to be very close to each other. The worse of both probabilities is the one at which the model would fail to withstand the null hypothesis and should be rejected. In this way of doing, the computed probability only takes account of the type I error which is the sampling error or, in our case, the error of having a limited number of observations, see figure and reference below for the meaning of type I and type II errors.

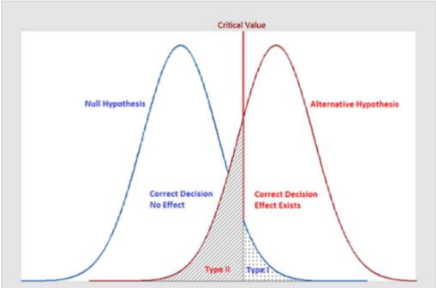


Figure 87: Type I and Type II errors

Source: Statistics by Jim[41]

No type II errors have been considered in calculating the probabilities. One of the type II errors is the influence of the scenario on people's behaviour.

Interpretation

The interpretation of these scenarios should reflect the method by which they have been estimated. Looking first at the computations of the trajectories common to both scenarios as well as the trajectories of the sustainable energy scenario, they use only time (and a constant) as explanatory variable. They have been computed by a model whose growth rate varies linearly as a function of time from the data series taken after a possible turning point. How does this relate to policies? It is not sufficient to put this in relation to policies alone. Such scenario is a type of business-as-usual scenario that should be interpreted in relation to the following three factors:

- Engineers develop new innovative energy technologies at the same speed as before,
- Agents adapt mindsets, management methods and behaviours at the same speed as before,
- Authorities improve regulations and public policies at the same speed as before.

Taking population as example, the diminishing population growth rate since 1963 is the result of new medical technologies (increasing life expectancy), changing reproductive behaviour of the population, and new family planning regulations by authorities.

Similarly, the diminishing growth rate of GDP is the result of waves of new technologies, changes of enterprise management methods and improved public policies by authorities. Furthermore, the diminution of the CO2-emissions growth rates observed since the turning point in 2004 can be explained by explained by new mindsets occurring after the record hot year 2003.

The increasing growth rate of installed renewable electricity capacity could be explained by the result of technological developments (learning curves for PV and wind that diminish prices), higher awareness by agents (renewables become fashionable and mainstream) and specific regulatory interventions by authorities (diminishing fossil fuel subsidies, introducing feed-in tariffs and international competitive auctions for renewables).

Note that any global emissions scenario that provides for carbon neutrality later than mid-century requires a hypothetic, arbitrary, not yet visible future turning point of the growth rate of renewable electricity somewhen between now and mid-century and assumes thereby that the growth rate of renewable electricity flattens after that turning point and delays carbon neutrality.

Two evolutions are implicit in the Sustainable Energy Scenario as data on these two were not easily available.

The first is the phase out of fossil fuel subsidies. Recall that global fossil fuel subsidies in 2004 were six times as high as global support for renewables, and that this ratio has dropped to four in 2017[42]. The Sustainable Energy Scenario assumes that the shift away from fossil energies going over to renewables will be sufficiently rapid to avoid being the main obstacle to renewables deployment. Public support to renewables can happen either through regulations and public procurement (internationally competitive tendering) which can be shown to be by far the best way to proceed, or less favourably, through open or hidden subsidies transferring risk and ownership to the government. APEC Green Finance Report (2023)[43] lists regulations which would allow equilibrating the balance between support for fossil fuels and for renewables.

The second is energy investments, a key variable according to the IEA Net Zero by 2050 Roadmap[44]. The Sustainable Energy Scenario requires tripling of installed renewable electricity capacity by 2030, whereas the IEA Roadmap requires energy investments to jump from USD2 trillion to USD5 trillion annually by 2030. The two are not far from each other.

Looking now at the unsustainable scenario, the growth rates of emissions are still computed as in the variable growth rate model, but with other variables instead of time as explanatory factors. This was possible as the future trajectories of explanatory variables had already been calculated beforehand. Since these factors and the coefficients are fix until the end of the time horizon, they represent a restriction which considerably diminishes the possibility of the explained variable (emissions growth rate) to evolve according to other dynamics, including its proper dynamics. Even though growth rates of two explanatory variables (TPES and population) are diminishing, the growth rate of renewable electricity (having a negative coefficient) is being outweighed by the positive coefficients of TPES and GDP. It is, therefore, not a surprise that emissions in the unsustainable scenario remain high if calculated by this method. This method can be interpreted as reflecting socio-economic inertia to change.

To conclude the note on interpretation, it should be restated that this method produces scenarios, not forecasts, because human behaviour is not predictable. The greatest uncertainty of these scenarios occurs if world leaders openly refuse the sustainability agenda. Should this happen, high-probability scenarios computed as a function of their data would no longer be happening according to calculated scenarios.

5. Key indicators for monitoring carbon neutrality pathways

Authored by Steivan DEFILLA

Cities can monitor their development towards carbon neutrality by a system of 18 independent indicators defined by APSEC to be collected annually for each city. These indicators monitor six categories of development:

- Monitoring local (within city boundary) installed capacity and land area
- Monitoring distant (outside city boundary) installed capacity
- Monitoring energy efficiency
- Monitoring energy security, storage and disaster resilience
- Monitoring the local green economy
- Monitoring local use of green finance

Each category is developed according to the same methodology in which per capita renewable energy generation is decomposed into factors that co-determine it. If combined, these indicators generate around 50 key ratios, eight of which have been quantified globally with 2020-2030 steps computed for comparison. A draft questionnaire for collecting the data in cities is shown in Annex 7.

5.1 Monitoring Local Installed Renewable Capacity and Area

This section discusses ways to monitor the development of the Sustainable Energy Scenario within the city. It is about monitoring the local (i.e., within city boundaries) renewable energy generation by means of monitoring the installed renewable energy capacity and associated land area as they are important to determine renewable energy generation. The complement, addressed in the next section, is monitoring renewable energy generation by means of monitoring the distant (i.e., outside city boundaries) renewable installed capacity which tracks the evolution of installed renewable generation capacity taking place outside the city or municipal borders having a grid interconnection to the city or the municipality (the equivalent of scope 2).

Photovoltaic electricity

The local renewable generation (or more precisely: per capita renewable generation) is decomposed into the factors specified in the equation below. This creates coherence between the different indicators specified in the equation and explained further down. It also allows to determine one unknown term of the equation in case all other terms are known. As PV has in average the largest potential within cities, the below monitoring focuses on photovoltaic energy.

$$\frac{LREgeneration}{LPopulation} = \frac{LREgeneration}{LREcapacity} \times \frac{LREcapacity}{LPVnetarea} \times \frac{LPVnetarea}{LPVgrossarea} \times \frac{LPVgrossarea}{LPopulation} \quad (1)$$

The terms designate the following quantities:

- LREgeneration: Local renewable electricity generation (in GWh/year), comprising electricity generation from solar, wind, hydropower, ocean energies, biomass, geothermal and waste(water)-to-electricity.
- LPopulation: Local resident population (in persons at midyear)
- LREcapacity: Local installed renewable electricity capacity (in MW)
- LPVnetarea: Net local PV area used directly and exclusively for PV (in m2)
- LPVgrossarea: Gross local land area used directly or indirectly for PV (in m2)

The first factor, LREgeneration/LREcapacity, is expressed as (GWh/year)/MW which, after simplification and bearing in mind that one GWh/year converts to 0.114MW, becomes a dimensionless percentage. It shows the average utilization of local capacity during a year. This factor has been described in the APEC Urban Energy Report 2023[45]. For the PV technology, the KWh/year/KWp ratio is the same as the LREgeneration/LREcapacity factor.
The second factor, LREcapacity/LPVnetarea, is the technical factor determining the ratio between capacity and net PV area. It is measured in KW/m2 or KWp/m2. It is the inverse of the area/capacity factor of 5.3m2/kWp used in APEC Urban Energy Report 2023 in the section explaining the density challenge. Numerically, the inverse has the value of 0.189kWp/m2. This factor may improve with technical progress of PV panels.
The third factor LPVnetarea/LPVgrossarea describes how much gross land area (in m2) the city will affect to install a PV panels (in m2), i.e., the translation of the technical or net PV area into land or gross area zone planning. Without mixed use, this factor takes the value of 1 as the totality of PV will be installed on dedicated and exclusively used land. As land zone planning within the city will always involve mixed use, this factor will usually take values between 1 and 0, depending on the mixing rate.
Note that cities have several ways to install PV:

- Rooftop PV. In this case the PV area will be mixed with other area types such as residential, economic, industrial or government area.
- Covering streets and parking areas. According to the Five Principles for sustainable neighbourhood planning published by UNHABITAT (2015)[46], a sustainable city should have 30% of its area dedicated to streets. Streets and parking areas have large potential to be covered at least partially by PV panels. If cities plan to cover parking areas and streets, these will gradually become mixed areas for transport and energy generation. The designs chosen to cover streets can consider other important factors such as offering increased shading, thereby favouring the cooling of city centres.
- Cities located near the seaside or nearby important inland waters can plan for installing floating PV. Also in this case, preference should be given to mixed use combining floating PV with fish, seaweed, algae, and shrimps farming. High value-added products such as pearl culture, oysters can be explored. Furthermore, biodiversity can be enhanced in artificial coral reefs with development of aquaponic (circular) systems growing plants, fish and bacteria, producing minerals and proteins for the pharmaceutical industry, combined with a local research and development campus.

The fourth factor specifies the LPVgrossarea/Lpopulation in m2/person, whereby the LPVgrossarea is the gross amount of land on which PV panels are planned, including the non-dedicated or mixed land use zones.

The above equation also contains further ratios which become evident only by crossing out the one or the other quantity. By crossing out LPVgrossarea, it is possible to obtain the LPVnetarea/person, expressed in m2/person, discussed in APEC Urban Energy Report 2023[47].

$$\frac{LREgeneration}{LPopulation} = \frac{LREgeneration}{LREcapacity} \times \frac{LREcapacity}{LPVnetarea} \times \frac{LPVnetarea}{LPopulation} \qquad (2)$$

By crossing out LPVnetarea instead, it is possible to obtain the LREcapacity/LPVgrossarea ratio, measured in MW/m2. This indicates the density of LREcapacity as it appears in the land planning of the city.

$$\frac{LREgeneration}{LPopulation} = \frac{LREgeneration}{LREcapacity} \times \frac{LREcapacity}{LPVgrossarea} \times \frac{LPVgrossarea}{LPopulation} \qquad (3)$$

Crossing out LREcapacity from equation (1) yields the LREgeneration/LPVnetarea ratio, measured in (GWh/year)/m2, showing the area-specific efficiency of use of the LPVnetarea to generate electricity.

$$\frac{LREgeneration}{LPopulation} = \frac{LREgeneration}{LPVnetarea} \times \frac{LPVnetarea}{LPVgrossarea} \times \frac{LPVgrossarea}{LPopulation} \qquad (4)$$

Equation (2) can be simplified by crossing out LPVnetarea. This yields the LREcapacity/LPopulation ratio (in MW/person) which is the indicator monitored in SDG7.b.1, *Installed renewable energy-generating capacity in developing countries* [sic] (in watts per capita). It is, however, suggested here to monitor this indicator in cities of any development level.

$$\frac{LREgeneration}{LPopulation} = \frac{LREgeneration}{LREcapacity} \times \frac{LREcapacity}{LPopulation} \qquad (5)$$

No new ratio is obtained by crossing out LREcapacity from equation (2) instead, as the LREgeneration/LPVnetarea ratio has already been obtained in equation (4).

$$\frac{LREgeneration}{LPopulation} = \frac{LREgeneration}{LPVnetarea} \times \frac{LPVnetarea}{LPopulation} \qquad (6)$$

Crossing out LPVgrossarea from equation (3) yields the ratio LREcapacity/LPopulation which has already been obtained in equation (5) above.

$$\frac{LREgeneration}{LPopulation} = \frac{LREgeneration}{LREcapacity} \times \frac{LREcapacity}{LPopulation} \qquad (7)$$

Crossing out LREcapacity from equation (3) yields the ratio LREgeneration/LPVgrossarea, measured in (GW/year)/m2, describing the local renewable electricity generation per local gross area affected directly or indirectly to the generation of PV electricity. This is an interesting ratio for cities to monitor as it shows them how much PV electricity is generated annually in all their relevant areas as marked in their urban planning.

$$\frac{LREgeneration}{LPopulation} = \frac{LREgeneration}{LPVgrossarea} \times \frac{LPVgrossarea}{LPopulation} \qquad (8)$$

Crossing out LPVgrossarea from equation (4) yields the ratio LPVnetarea/LPopulation, measured in m2/person. It designates the net area of PV production per person as it has been described in the APEC Urban Energy Report 2023 in the section on the density challenge of cities.

$$\frac{LREgeneration}{LPopulation} = \frac{LREgeneration}{LPVnetarea} \times \frac{LPVnetarea}{LPopulation} \qquad (9)$$

Crossing out LPVnetarea from equation (4) yields the ratio LREgeneration/LPVgrossarea already received in equation (8).

$$\frac{LREgeneration}{LPopulation} = \frac{LREgeneration}{LPVgrossarea} \times \frac{LPVgrossarea}{LPopulation} \qquad (10)$$

As has been pointed out in the APEC Urban Energy Report 2023 in the section on the density challenge of cities, cities will rarely have the possibility to cover all their energy needs from renewable sources originating from within their territory. With the use of the above analytic elements, it can now be shown how cities can handle this challenge. The major difficulty is to reconcile the high density needed for economic development with the area needs for the Sustainable Energy Scenario described in the section on the density challenge of cities.

A key concept to handle the density challenge of cities is Decent Living Standard (DLS). This concept was originally proposed by Rao, N. D. and Min (2018)[48], and its energy needs have been calculated by Millward-Hopkins and others (2020)[49], pointing out that the energy needs of DLS vary globally only within a narrow bandwidth of between 13GJ/person and 18.4GJ/person. Activity levels (mostly mobility levels) and energy intensities (mostly thermal comfort and water heating in residential buildings) make roughly equal contributions to the overall range of DLE values. To suggest a planning figure for APEC cities, it is proposed to define DLS by means of a rounded value of 18GJ/year/person, corresponding to 5MWh/year/person, or 570W/person.

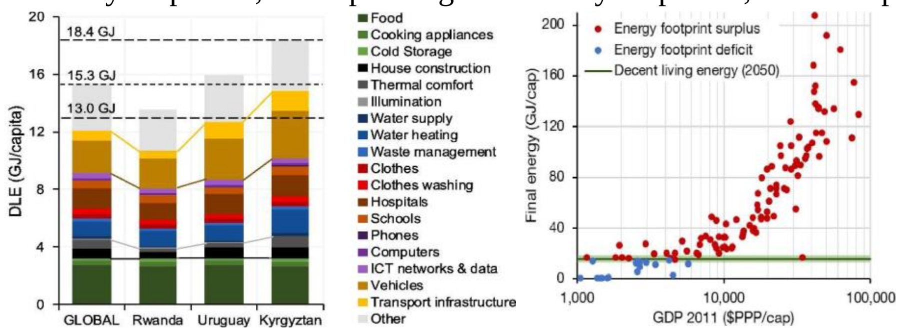


Figure 88: Energy needs of Decent Living Standards

Source: Millward-Hopkins and others[50]

Contrary to DLS which varies within a relatively narrow bandwidth across all economies, total final energy varies enormously across economies, as illustrated by the figure above (right) which shows also that most global economies have a final energy consumption above their DLS levels.

The first planning principle formulated here states that, facing a variety of population density, cities should attempt to provide the basic energy needs covering a Decent Living Standard for their inhabitants by means of renewable energy produced locally within 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 (see table below). The precise amount of irradiance of the city can be found by searching for the city in the online global solar atlas https://globalsolaratlas.info/map?c=11.523088,8.173828,3

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	kWh/day/kWp
Yearly totals kWh/kWp	731	877	1023	1169	1315	1461	1607	1736	1753	1899	2045	2192	2338	kWh/year/kWp
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	PV (m2/person)

Table 6: Per capita net PV area for covering energy needs of DLS as a function of irradiance

Source: APSEC

For the four cities below, whose density challenge was described in the APEC Urban Energy Report 2023 – Driving Cities Through the Low Carbon Transition[51], satisfying the energy needs of DLS by local PV generation would require the percentage of land area shown in the last column of the table below. Cities such as Hong Kong, China and Singapore could satisfy this principle, whereas Manila City and Metro Manila would still have problems satisfying it.

TFC/person (MWh/person)	City	Pop density (pers/km2)	Pop density (pers/ha)	PVOUT (kWh/kWp)	Required per capita PV area for DLS (m2/person)	Required PV area for DLS (m2/ha)	Percentage of land area required for PV in DLS case (%)
7.000	Manila City	43064	431	1376	19.26	8301	83
7.000	Metro Manila	22000	220	1376	19.26	4237	42
9.951	Hong Kong, China	6400	64	1159	22.86	1463	15
21.740	Singapore	8592	86	1287	20.59	1771	18

Table 7: Comparison between four cities for covering energy needs of DLS

Source: APSEC

For extremely densely populated cities such as Manila City and Metro Manila, a second less constraining principle should be formulated, stating 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. In the Sustainable Energy Scenario, streets gradually become mixed space for transport and energy.

The development of building-integrated PV (BIPV) opens totally new horizons. Cities will be able to use vertical surfaces for electricity production. The most interesting are PV windows whose prototypes are now being tested. Obviously, the quantity of energy harvested from a vertical surface is in average less than for horizontal or slightly inclined surfaces. Vertical surfaces should be multiplied by a coefficient between 0 and 1 and added to horizontal ones. Replacing traditional windows with PV windows will not only increase the PV electricity production, but also diminish the need for cooling inside buildings as PV windows may act as sun blinds.

The above explanations are focusing on photovoltaic electricity. This does not exclude that cities should also develop other sources of electricity. To evaluate what would be appropriate monitoring indicators for these other renewable energies, these will be briefly touched upon below.

Wind energy

On global average, wind energy is somehow complementary to solar energy. Whereas solar energy is abundant in the equator region and scarce in the extreme north or south, wind energy is scarce in the equator region and abundant in the extreme north or south. Among the APEC economies having onshore or offshore regions with more than average potential are Australia; Canada; Chile; China; New Zealand; Russia and the United States. Other APEC economies such as Korea and Japan have predominantly offshore wind resources. The figure below compares the wind densities in W/m2 at 200m height in Northeast Asia and the Equator region. As can be seen, wind resources are much less abundant around the equator than elsewhere due to the so-called Intertropical

Convergence Zone (ITCZ). Furthermore, in the off-equator regions, they are less abundant onshore than offshore.

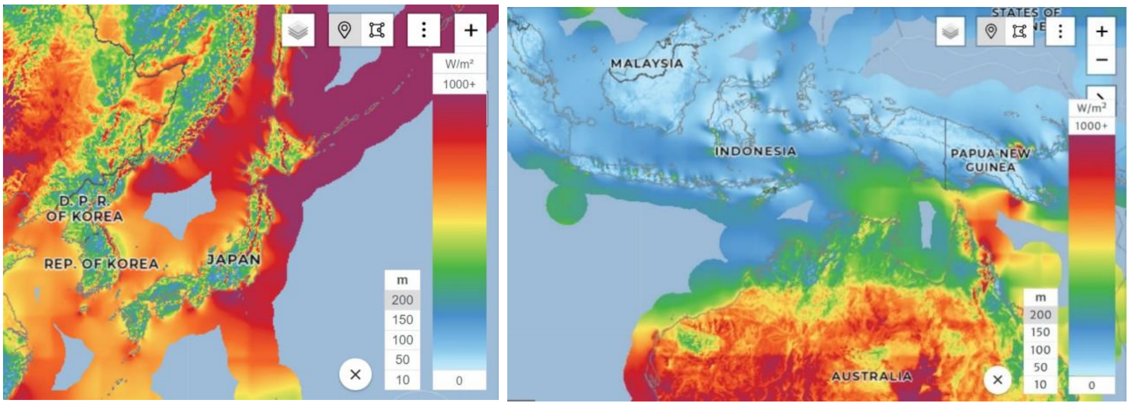


Figure 89: Comparison of wind energy densities at 200m height of Northeast Asia and Equator

Source: Global Wind Atlas[52]

Wind energy is one of the energy resources that can be harvested in cities. However, as the resource is much more abundant at 200m height than on ground level, this means for cities that wind energy should ideally be combined with high-rise buildings. While the big wind parks found in the open areas or offshore are mostly composed by horizontal axis wind turbines, the urban application of wind energy is still under research and development, but the vertical axis wind turbines are mostly favoured and better adapted to the urban landscape. Many high-rise buildings have no flat rooftop and are not very well suited for PV rooftop. They could, however, be suitable for vertical axis wind turbines to be installed. The figure below shows the most common designs of vertical axis wind turbines that are in principle suitable for high-rise buildings.

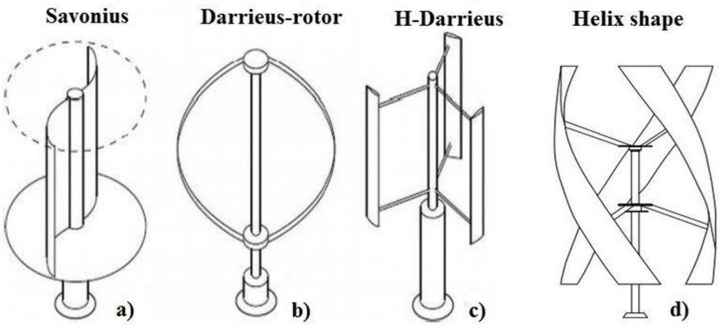


Figure 90: Four of the most common vertical axis wind turbines for urban environments

Source: Castellani and others[53]

Research on building-integrated wind (BIW) is a cutting-edge domain. While two decades ago, the assessments concerning BIW were in majority still negative[54], this has changed recently. Kowk and Hu (2023)[55] show that urban wind, including stand-alone systems standing near buildings, installations on retrofitted buildings as well as building-integrated wind systems have a considerable potential ahead. The designs of urban/building-based wind energy systems comprise building integrated vertical axis wind turbines, power windows, wind-induced vibration-based wind energy harvesters, double skin and other innovative building façade systems, wind source exploration, as well as the potential application of Artificial Intelligence (AI) and Machine Learning (ML) in the context of wind engineering and wind energy systems.

The Bahrain World Trade Center (BWTC) is the flagship example of a building with an integrated wind energy system (3 × 250 kW) contributing 1,100 to 1,300MWh/year or 11 to 15% of the building’s electricity needs, followed by the Strata (SE1) building in London, where three wind turbines provide 8% of the building’s electricity, and the Pearl River Tower in Guangzhou whose wind turbines integrated in its four wind tunnels located at 104 and 205m height, respectively, produce 5% of its electricity.

Figure 91: Bahrain World Trade Center, Strata SE1 London and Pearl River Tower Guangzhou

Sources: Wikimedia, aeccafe.com and blogspot

One of the lesser-known high-rise buildings incorporating building-integrated wind turbines is the Shanghai Tower, the highest tower of Shanghai. At its top it has 200 wind turbines providing more than 1 million kWh or electric energy per year, corresponding to the DLS energy needs of 200 persons. At the height of 580 meters, the wind speeds are 8-10m/s. The wind turbines of the Shanghai Tower are well integrated into the building making them invisible except for the informed public.

Figure 92: Shanghai Tower (left) and its installed wind turbines (right)

Source: The Tower Info[56]

The efficient use of building-integrated wind energy is dependent on characteristics such as roof shape, building height, urban configuration, and the use of corner geometry and other architectural features and fittings in the building's design.

Of particular interest for future urban planning are ideas that combine PV with wind, as shown in the figure below. These should, however, be optimized by rounding the angles so as to better use the wind power without diminishing the use of PV power.

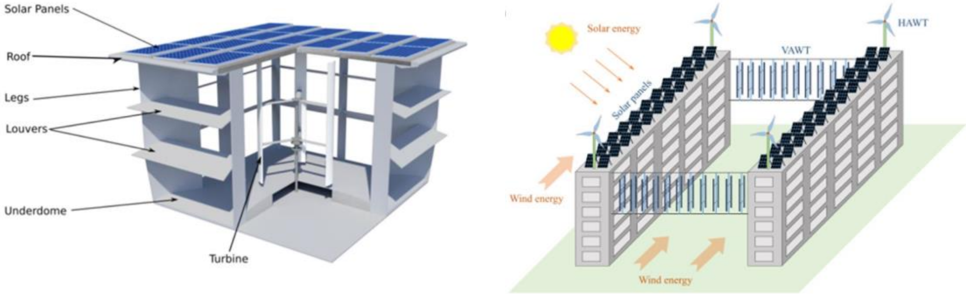


Figure 93: Combining urban PV with urban wind energy

Source: Kowk and Hu (2023)[57]

For urban planning of APEC cities, it is difficult to state the expected role of wind energy. Based upon the above-mentioned examples and the expected technical progress in measuring and harvesting the wind potential, any role between 2% and 20% of total final energy consumption could be feasible, depending highly on the energy density of the wind resource prevailing at the city location and on the degree the urban landscape and building design is being optimized to harvest wind energy.

Wastewater-to-energy

The energy potential of wastewater depends on where the water comes from, residences or industry. Theoretical calculations as well as empirical measurements allowed to determine the energy density of wastewater at the order of magnitude of 107J/m3 of wastewater, i.e., around five times the energy consumed to treat the wastewater[58]. This is approximately the same potential energy as in a hydropower plant with 1000 meters height difference. A mix of domestic with industrial wastewater usually yields up to twice the energy of pure residential wastewater. Given the high water-intensity of modern urban life, this potential is considerable. It is fully renewable as it is part of the waste recycling process.

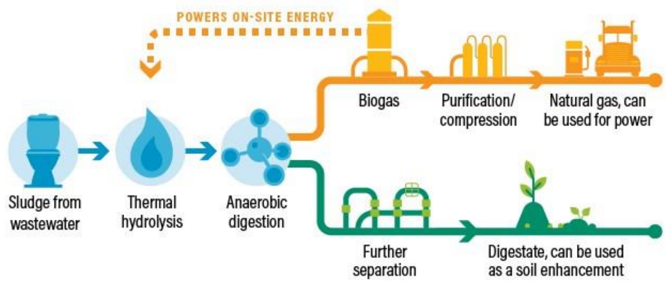


Figure 94: Wastewater-to-energy scheme

Source: World Resources Institute[59]

For urban planning purposes, if we assume 200m3 water per year per capita and 20% efficiency to convert it to electricity, then the energetic resource is 200*107*0.2 J/capita/year = 12.67W/capita, which is about 2.5% of DLS needs. This is truly not very much, but it should not be forgotten that the main purpose of wastewater treatment is to produce environmentally friendly water, not to produce energy. The fact that electricity can be produced and sold into municipal grids adds to the commercial viability of wastewater treatment.

Waste-to-energy
The practice of treatment of municipal waste in APEC is evolving. While the APEC Guidebook for the Development of Sustainable Cities Focusing on Resource Circulation and Waste Management published in 2018[60] focused on landfill a solution, its successor, the APEC Initiative for Realizing Sustainable Cities Focusing on Improvement of Resource Circulation and Waste Management (2022)[61] presents incineration and energy recovery as options.

Municipal solid waste has a net dry calorific value (NCVdry) between 6.2 and 23.7MJ/kg, mostly lower than dry wood pellets (20MJ/kg) or heating oil (45MJ/kg). Assume municipal solid waste production of 1kg/capita/day, and an energy content 10MJ/kg, hence the maximum recoverable energy from MSW is at 10MJ/person/day, equivalent to 116W/person or about 22% of the energy needs of Decent Living Standards (DLS). If, however, 90% of waste is recycled and incineration is only used for 10% non-recyclable waste, the energy yield equals only 1MJ/person/day or 11.574W/capita, about 2.2% of the DLS need. In this case, waste incineration is still making a positive energy contribution, but the main benefit lies in the 90% recycling rate.

As will be explained in the section on monitoring energy security further down, cities produce a part of their electricity supply on their own territory to improve their energy security. Energy security should become a greater focus in the attention of cities.

5.2 Monitoring Distant Installed Renewable Energy Capacity

The preceding section has shown how cities can monitor the development of the Sustainable Energy Scenario within city borders. The electricity not produced within the border is imported from the surrounding hinterland, equivalent to scope 2 for the emissions. This section discusses ways to monitor the development of the Sustainable Energy Scenario outside the city.

Cities have since time immemorial been dependent on their hinterland. This dependency is not going to disappear with the development of the Sustainable Energy Scenario. It is, however, going to take a new focus in which electricity dependence is playing a major role, motivating cities to monitor their electricity security. To guarantee secure distant energy supply in the Sustainable Energy Scenario, the decisive infrastructures are:

- the distant renewable energy generation sites
- the capacity of transmission lines and associated infrastructures such as transformer stations linking them to cities
- the legal framework under which this is happening.

Like in the preceding section, the monitoring system is based upon a basic equation which links per capita distant renewable electricity generation to the terms which influence it.

$$\frac{DPPAREgeneration}{LPopulation} = \frac{DPPAREgeneration}{DPPAREcapacity} \times \frac{DPPAREcapacity}{DREcapacity} \times \frac{DREcapacity}{LTRMcapacity} \times \frac{LTRMcapacity}{LPopulation} \quad (1)$$

The terms designate the following quantities:

- DPPAREgeneration — Distant (i.e., located outside city borders) renewable electricity generation contracted by power purchase agreement (PPA) or similar (in GWh/year) of all the areas to which the city is interconnected by a synchronous (AC) or asynchronous (DC) grid link
- LPopulation — Local resident population of the city (in persons at midyear)
- DPPAREcapacity — Distant (i.e., located outside city borders) installed renewable electricity capacity of those producers with whom the city has a PPA or similar agreement, and to whom the city is interconnected by a synchronous (AC) or asynchronous (DC) grid link (in MW)
- DREcapacity — Distant (i.e., located outside city borders) installed renewable electricity capacity of all producers to whom the city is interconnected by a synchronous (AC) or asynchronous (DC) grid link (in MW)
- LTRMcapacity — Local transmission capacity comprising the sum of the local transmission capacity of all entry points to the city (in MW)

The distant PPA contracted renewable electricity generation, DPPAREgeneration, relates to the electricity generation of all producers who are under (PPA) or similar market-based contract with the city and hence connected to the city by synchronous (AC) or asynchronous (DC) connections. For more information on PPAs see the APEC Green Finance Report – unlocking the Urban Energy Transition[62]. The focus on PPA contracted or similar market-based renewable energy is necessary to satisfy the above-mentioned requirement of the satisfactory legal infrastructure. This will be explained further down. The choice to include AC as well as DC interconnections is justified for the APEC context in which many economies are composed of archipelagos comprising a great number of islands which, if they are interconnected, can be so only by DC links. Current technologies allow laying subsea high voltage DC cables until a sea depth of approximately 800m. Note that the reference population LPopulation is always the local resident population of the city, not the population of the surrounding economy. The interest of this monitoring is focusing on the city, not on the surrounding economy.

The distant installed renewable electricity capacity of all producers with whom the city has a PPA, DPPAREcapacity, is the capacity of those producers with whom the city has PPA contracts and are, therefore, supplying distant renewable electricity as defined by the term DPPAREgeneration. The same remark concerning PPA as well as AC and DC link applies.

The DRAcapacity is the installed renewable electricity capacity of the whole area which is interconnected to cities either by AC or by DC links.

LTRMcapacity stands for the power of all transmission capacity that is at the entry of the city. Note that this indicator does not distinguish between average load and peak load. Transmission and transformer capacities must, however, be designed for peak load, which can be the double or triple or higher than the average load. Local grid operators know this factor well and can integrate it into the monitoring. Neither does this indicator consider how many interconnectors are placed at the entry of the city. In this monitoring system, a city being interconnected by one line is considered the same as a city that is interconnected by two lines having half the capacity of the single interconnector each. These are the limits of this simplified methodology which is designed to be applied by city personnel who not necessarily specialized in electrical engineering.

At this point, an important remark needs to be made. Monitoring electricity security by cities is quite a novelty. Electricity security is at present monitored by economy-wide operating electricity enterprises. This is due to the complexity of the electricity system. The simplified methodology specified in this section can at best consider the conditional electricity security of the monitored city facing a disaster, given that all other cities are running in the secure range (i.e., are not threatened by the same disaster). This conditional electricity security concept is not identical with holistic or systemic electricity security concept applying to the whole economy, as the latter can only be monitored by the whole economy and not by the city. The conditional electricity concept as outlined above will usually show higher electricity security for the city than the holistic or systemic electricity security concept as it considers that a disaster only touches the monitoring city and not the neighbouring cities or regions. The solar-scarce winter months should, however, be dealt with at economywide level.

The first term of equation (1) above is the DPPAREgeneration/DPPAREcapacity ratio. It is measured in (GWh/year)/MW which, after simplification and bearing in mind that one GWh/year converts to 0.114MW, becomes a dimensionless percentage. This ratio gives the percentage of the average utilization of distant capacity of PPA-contracted producers during a year. For the PV technology, the KWh/year/KWp ratio is the same as the LREgeneration/LREcapacity factor. In the case of distant production, this factor mixes all available renewable electricity technologies. At global level, which determines the context, this factor as well as its trend can be determined. The figure below shows the past evolution as well as the scenario computed directly (in orange) and as a ratio of computed figures (grey). The computed probability of the orange trajectory as a function of its data is greater than 80%, the computed probability of the grey trajectory as a function of its data is greater than 99%. By mid-century, the average utilization of renewable capacity is expected to decline from today 30% towards 10%, mostly through the expected increasing relative weight of solar PV in the renewable energy mix. Cities can compute the average utilization rate of their PPA-contracted producers directly to monitor their distant renewable generation.

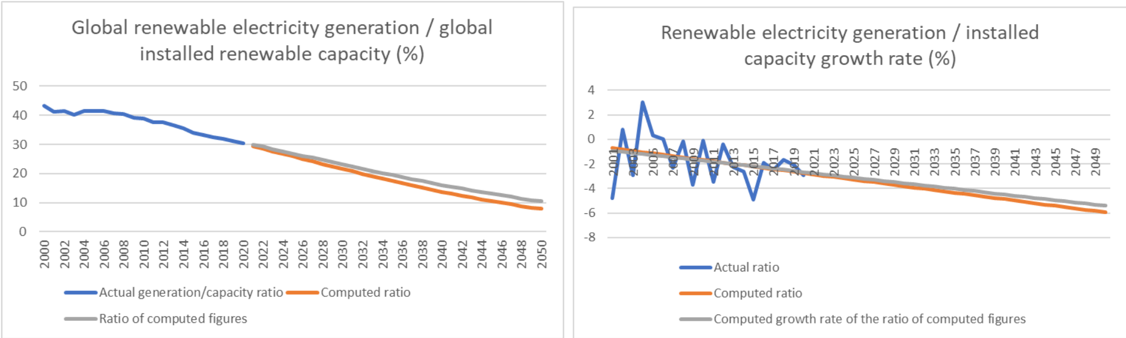


Figure 95: Global renewable energy generation/installed capacity ratio and growth rate

Source: APSEC based on IRENA data

The reason why the monitoring presented in this section only considers PPA-contracted or similar market-based production is that empirical research on the effect of counting the offsetting of CO2-emissions by Renewable Energy Certificates (RECs) shows that RECs are not likely to bring about real emissions reductions nor real renewable energy capacity additions in the years 2015 – 2030, based upon enterprises data of the period 2015 – 2019 (see figure below). For more information on RECs, see the APEC Green Finance Report (2023)[63]. The blue sector shows the emissions reductions made on-site (equivalent to scope 1 or within the city borders), the inner yellow circle shows the total emissions reductions made by all market-based mechanisms outside the location of the enterprise, equivalent of scope 2 for emissions, mainly by using PPA and similar market-based mechanisms, and RECs. The outer circle subdivides the reductions made by market-based mechanisms into PPA or similar market-based mechanisms on one hand, and RECs on the other.

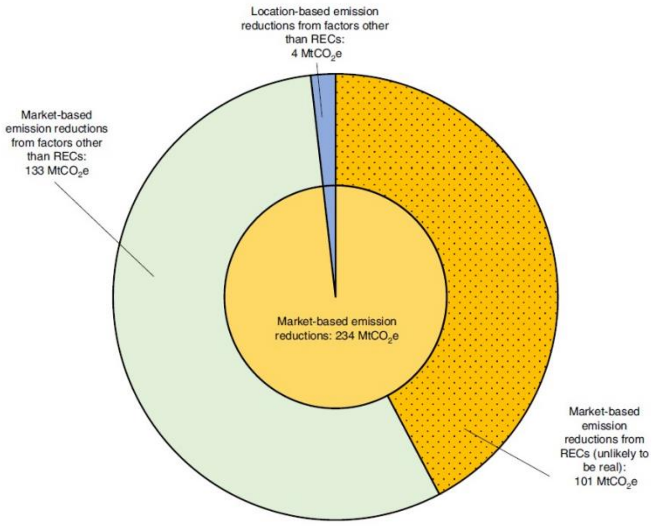


Figure 96: Estimated cumulative scope 2 emission reduction from RECS and PPAs

Source: Bjorn and others (2022)[64]

The global framework for RECS and emissions certificates has been re-negotiated and made more precise at COP26 held in November 2021 in Glasgow. For a succinct description of the new rules see APEC Green Finance Report (2023)[65]. In case future research demonstrates that the new rules avoid the problems of unreal CO2-reductions and RE capacity additions caused by RECs as described in Bjorn and others (2022), the term DPPAREgeneration could be re-interpreted to mean distant renewable energy generation contracted by PPA and other market-based mechanisms as well as by RECs, and similar for the term DPPAREcapacity.

The second ratio of equation (1), DPPAREcapacity/DREcapacity, shows the percentage of installed renewable electricity capacity with which the city has a PPA or similar market-based agreement in total distant installed renewable energy capacity. It is measured as MW/MW simplifying to a dimensionless percentage. For the city, this shows how much renewable capacity is available in its network. This indicator will be nearly 100% in an area of a city on an island without hinterland. It shows the need to build more interconnection between the hinterland of the city and not yet connected neighbouring areas. The indicator will be a low percentage in the case of a city having a large grid-connected hinterland.

The third ratio of equation (1), DREcapacity/LTRMcapacity, shows the ratio of distant renewable capacity to the transmission capacity at the city border. It is measured as MW/MW, simplifying to a dimensionless number. In the case of a city located on an island without hinterland, this number will be only slightly higher than 1. For a city in a highly interconnected hinterland, this number will be much greater than one.

The fourth factor of equation (1), LTRMcapacity/LPopulation, shows the installed local transmission capacity per person living in the city. It is measured in MW/person. It can be interpreted in relation to the per capita distant renewable energy consumption of the city, that is the part of consumption not satisfied by local production as described in the section on the density challenge of cities. As many cities have at present practically no local renewable electricity production, the local transmission capacity at the entry of cities is able to transmit the total electricity consumption of the city. In practice, however, the per capita transmission capacity at the entry of a city is a multiple of the average per capita energy consumption. As stated earlier, transmission systems are among those part of the electricity system that are designed for peak load, not for average load. When interpreting the need to expand the existing transmission capacity at the entry of cities, the peak consumption expected in the Sustainable Energy Scenario should be taken as benchmark.

The above equation contains also hidden ratios which appear when terms are crossed out. Crossing out LTRMcapacity yields DREcapacity/LPopulation, the total per capita installed distant renewable electricity capacity of the interconnected electricity grid in which the city is located. It is expressed as MW/person. This is the complement of the LREcapacity/person described in the previous section which shows the per capita local installed RE capacity.

$$\frac{DPPAREgeneration}{LPopulation} = \frac{DPPAREgeneration}{DPPAREcapacity} \times \frac{DPPAREcapacity}{DREcapacity} \times \frac{DREcapacity}{LPopulation} \qquad (2)$$

Crossing out DREcapacity of equation (1) yields the DPPAREcapacity/LTRMcapacity, the ratio of contracted renewable capacity per local transmission capacity. This is expressed in MW/MW, simplifying to a dimensionless number. It shows the adequacy of transmission capacity at the entry points of the city compared to the distant installed capacity with whom the city has contracts. At present, the ratio is expected to be smaller than 1, as cities are not yet systematically contracting distant renewable energy, a fact that makes the corresponding numerator smaller than the denominator. With growing sustainability, this ratio is expected to approach 1 or even become larger than 1 for all cities having to cover a part of their electricity consumption by distant capacity (that is the normal case).

$$\frac{DPPAREgeneration}{LPopulation} = \frac{DPPAREgeneration}{DPPAREcapacity} \times \frac{DPPAREcapacity}{LTRMcapacity} \times \frac{LTRMcapacity}{LPopulation} \qquad (3)$$

Crossing out DPPAREcapacity of equation (1) yields the ratio DPPAREgeneration/DREcapacity. This shows the relation of distant contracted generation over total distant renewable capacity, measured in (GWh/year)/MW. This simplifies to a dimensionless number which, for a city in an almost isolated island without hinterland is close to 1, showing that more DREcapacity should be built or connected by improving the connection of the hinterland with neighbouring grids. For a city situated in a large, interconnected network, this ratio is much smaller than 1, showing to the city that distant renewable capacity might be available for contracts.

$$\frac{DPPAREgeneration}{LPopulation} = \frac{DPPAREgeneration}{DREcapacity} \times \frac{DREcapacity}{LTRMcapacity} \times \frac{LTRMcapacity}{LPopulation} \qquad (4)$$

Simplifying equation (2) by crossing out DREcapacity yields the ratio DPPAREcapacity/LPopulation. This is measured in MW/person and is a key ratio for cities who satisfy most of their electricity consumption by distant capacity (that is the normal case). Under present circumstances when cities have not yet contracted a lot of distant renewable capacity, the ratio will be small compared to per capita TFC. As the Sustainable Energy Scenario materializes, the ratio for most cities should outgrow per capita TFC.

$$\frac{DPPAREgeneration}{LPopulation} = \frac{DPPAREgeneration}{DPPAREcapacity} \times \frac{DPPAREcapacity}{LPopulation} \qquad (5)$$

Simplifying equation (2) by crossing out DPPAREcapacity yields the ratio DPPAREgeneration/DREcapacity, which is the ratio of contracted distant production over distant installed renewable energy capacity. It is measured as (GWh/year)/MW which simplifies to a simple percentage. In present times this percentage is expected to be small for normal cities, it will grow faster for those cities who contract more new renewable energy than capacity growth which is added by the surrounding interconnected grid. Conversely, it will grow slower for those cities who expand their contracted distant renewable energy less rapidly than the speed of surrounding grid to add new capacity.

$$\frac{DPPAREgeneration}{LPopulation} = \frac{DPPAREgeneration}{DREcapacity} \times \frac{DREcapacity}{LPopulation} \qquad (6)$$

Simplifying equation (3) by crossing out LTRMcapacity yields the ratio DPPAREcapacity/LPopulation, which is not new as it was already found in equation (5).

$$\frac{DPPAREgeneration}{LPopulation} = \frac{DPPAREgeneration}{DPPAREcapacity} \times \frac{DPPAREcapacity}{LPopulation} \qquad (7)$$

Simplifying equation (3) by crossing out DPPAREcapacity yields the ratio DPPAREgeneration/LTRMcapacity, expressed in (GWh/year)/MW which simplifies to a dimensionless percentage showing whether the transmission capacity at the entry of the city is adequate for importing the contracted distant generation. At present times this ratio is small if cities have not yet contracted distant renewable production in large quantities. With the Sustainable Energy Scenario being realized, this ratio is expected to grow to a value less than 1.

$$\frac{DPPAREgeneration}{LPopulation} = \frac{DPPAREgeneration}{LTRMcapacity} \times \frac{LTRMcapacity}{LPopulation} \quad (8)$$

Simplifying equation (4) by crossing out LTRMcapacity yields the ratio DREcapacity/LPopulation which is not new as it was already found in equation (2).

$$\frac{DPPAREgeneration}{LPopulation} = \frac{DPPAREgeneration}{DREcapacity} \times \frac{DREcapacity}{LPopulation} \quad (9)$$

Simplifying equation (4) by crossing out DREcapacity yields the ratio DPPAREgeneration/LTRMcapacity which is not new as it has been found in equation (8).

$$\frac{DPPAREgeneration}{LPopulation} = \frac{DPPAREgeneration}{LTRMcapacity} \times \frac{LTRMcapacity}{LPopulation} \quad (10)$$

Hydropower

Hydropower is among the traditional renewable energy sources that are produced outside the territories of cities. The hydropower potential depends on precipitations, accelerated glacier melting and on the topography which determines whether precipitations can be channelled to produce energy. In the Sustainable Energy Scenario, hydropower may become part of storage. Cities do not have the possibilities to produce hydropower on their territory. The collection of rainwater, also called grey water, may at best represent a contribution to the local water supply. Hong Kong, China is known to have a grey water collection and distribution network.

After the discussion of the basic monitoring principles, it is now possible to consider an example of an APEC city sourcing its renewable energy abroad. This can be illustrated by the case of Singapore having started to import renewable electricity from Laos through Thailand and Malaysia in June 2022[66]. The first contract was a 100MW contract. To qualify as distant PPA contracted renewable energy (DPPAREgeneration), it should be certified that the producing power plant is one or more renewable energy producers in Laos, and that double counting the production is excluded, meaning that the totality of renewable electricity sold by all those power plants delivering this contract at each hour of the year to all its customers is less or equal than the renewable installed capacity. Normally this is satisfied by a system of guarantees of origin (GO) for renewable energy, also known as Energy Attribute or Green Certificates, as described in the APEC Green Finance Report (2023)[67].

For monitoring purposes in the present monitoring system, the 100MW, corresponding to 876.6GWh/year, should be taken in the per capita version, which for a local population of Singapore of 5,685,807 persons (2020) becomes 0.018kW/person or 154kWh/year/person. This is the left-hand side of all above equations for this particular contract. This figure can be compared to the total per capita energy consumption (per capita TFC) of 21.74MWh/year/person of Singapore, i.e., 0.7%. If Singapore decides to satisfy the energy requirements for Decent Living Standards of 5MWh/year/person by local renewable energy generation, the required distant renewable energy generation (at present TFC) will be 16.74MWh/year/person, which is roughly 109 times the amount of the first contract from Laos. Singapore is planning a direct link to Australia[68]. This would greatly widen the possibilities of Singapore to become carbon neutral.
The other ratios of the monitoring system can be relatively easily determined by the monitoring city. The first ratio of equation (1), the DPPAREgeneration/DPPARE capacity ratio, can easily be determined by the importing city in the framework of a monitoring as suggested here by enquiring the installed capacity (DPPAREcapacity) of the power plants producing the electricity of the mentioned contract. As mentioned above, the monitoring of the installed renewable capacity by a system of Green Certificates is necessary to avoid double counting.

The second ratio of equation (1), DPPAREcapacity/DREcapacity includes in its denominator the totality of installed renewable electricity that is located in a network interconnected to Singapore. For the moment, this includes renewable electricity generation installed in Malaysia, Thailand and Laos. Future interconnectors are in discussion with Sumatra in Indonesia. Sumatra has two electricity grids which are normally operated separately[69].

The third ratio of equation (1), DREcapacity/LTRMcapacity, puts the DRE capacity in relation to the local transmission grid at the entry of Singapore. This figure is known to the Singapore electric market operators.

The fourth factor of equation (1), LTRMcapacity/LPopulation, evaluates the per capita transmission capacity that is available for import. This can be calculated from the above by dividing by the local population.

All the other ratios can be computed if all the numerator and denominator terms of equation (1) are known.

5.3 Monitoring Energy Efficiency

The monitoring system outlined in the preceding sections would not be complete without mentioning the role of energy efficiency. APEC Leaders have adopted an aspirational energy efficiency target in 2011 requesting to reduce aggregate APEC energy intensity by 45% by 2035[70]. SDG7.3 calls for doubling the speed of energy intensity improvement, and the associated indicator SDG7.3.1 precises that energy intensity should be measured in terms of primary energy and GDP. This can be integrated into the monitoring system by considering the following equation:

$$\frac{APPAREgeneration}{LPopulation} = \frac{APPAREgeneration}{LTPES} \times \frac{LTPES}{LGDP} \times \frac{LGDP}{LPopulation} \qquad (1)$$

The terms designate the following quantities:

- APPAREgeneration — Accessible (= Local + Distant) renewable electricity generation contracted by power purchase agreement (PPA) or similar and interconnected by a synchronous (AC) or asynchronous (DC) grid link, (in GWh/year)
- LPopulation — Local resident population (in persons at midyear)
- LTPES — Local total primary energy supply (in GWh/year)
- LGDP — Local GDP (in constant local currency unit (LCU/year) or constant USD/year; to simplify, to simplify, only constant USD/year are mentioned in the text below)

The first ratio on the right-hand side is the share of accessible (= Local + Distant) renewable electricity generation contracted by power purchase agreement (PPA) over the local total primary energy supply. It is measured in (GWh/year)/(GWh/year) which simplifies to a dimensionless percentage. The share of renewable energy in TPES is included in the sustainable energy scenario presented in section 4.3. To make the numerator and denominator of the first ratio comparable among each other, both terms include energy produced locally as well as imports.

The second term on the right-hand side is the energy intensity of GDP as defined in SDG indicator 7.3.1, measured in (GWh/year)/(constant USD/year), which simplifies to GWh/constant USD. The energy intensity of GDP is among the indicators used in both scenarios, the sustainable energy scenario and the unsustainable scenario, described in sections 4.1 to 4.3.

The third term is the local per capita GDP, measured in (constant USD/year)/person. Per capita GDP is also among the indicators used in both scenarios described in sections 4.1 to 4.3.

The following new ratios can be found by crossing out specific terms from equation (1). By crossing out LGDP, the new ratio LTPES/LPopulation is found, measured in (GWh/year)/person (see equation 2). This is a meaningful indicator stating the per capita total energy supply and is also among the indicators used in both scenarios described in sections 4.1 to 4.3.

$$\frac{APPAREgeneration}{LPopulation} = \frac{APPAREgeneration}{LTPES} \times \frac{LTPES}{LPopulation} \qquad (2)$$

By crossing out LTPES from equation (1), the ratio APPAREgeneration/LGDP is found. It is measured in (GWh/year)/(constant USD/year), simplifying to GWh/constant USD. This is the renewable energy intensity of GDP. It is distinct from the traditional energy intensity of the GDP as it specifically focuses on locally generated renewable energy in its numerator.

$$\frac{APPAREgeneration}{LPopulation} = \frac{APPAREgeneration}{LGDP} \times \frac{LGDP}{LPopulation} \qquad (3)$$

Contrary to the energy intensity of GDP which has been declining for decades, the renewable energy intensity of GDP is expected to grow rapidly as the growth rate of renewable energy generation is higher than the growth rate of the GDP. Compared to global installed renewable energy capacity, which will triple between 2020 and 2030, the tripling of global renewable energy intensity will occur only in 2035, due to GDP growth. The figure below shows the scenario for global renewable energy intensity of GDP and the growth rate up to 2035. The computed probability of this scenario as a function of the data is greater than 99%.

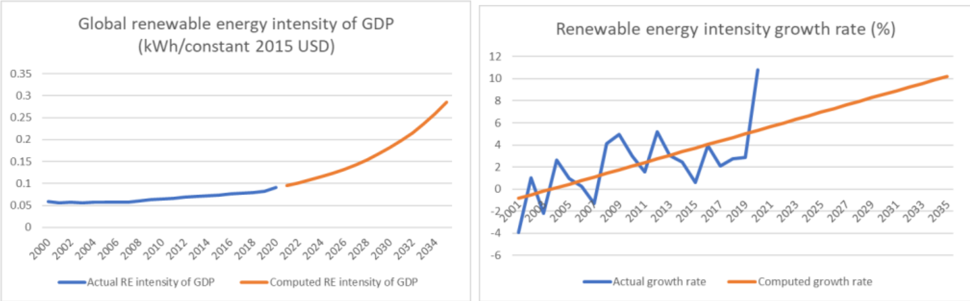


Figure 97: Global renewable energy intensity scenario up to 2035 (l) and growth rate (r)

Source: APSEC based on IRENA and World Bank data

Energy efficiency is crucial for cities in developed economies whose per capita energy consumption is far above the energy consumption of Decent Living Standards. Unless cities of developed economies make strong energy efficiency efforts in the present and next decade, their energy security cannot be improved during the energy transition as they continue to rely on energy produced outside their territories. Conversely, the cities of developing economies need to make less effort in the area of energy efficiency as long as they expand renewable energy as stated in the renewable energy scenario.

5.4 Monitoring Energy Security, Storage and Disaster Resilience

The energy transition is known to increase dependency on intermittent energy sources such as solar and wind energy. This raises the question of how to maintain energy security during and after the energy transition. In any case, energy security should be monitored during and after the energy transition. Climate change is causing more frequent and heavier disasters, especially in the APEC region and the Ring of Fire, see APEC Sustainable Energy Report – Combining Disaster Resilience with Sustainability[71]. The improvement of energy security is also achieved by making the energy system more disaster resilient.

If energy security of the electricity sector is the absence of blackouts or brownouts, then energy security can be improved by diminishing the causes of electricity shortages leading to brownouts or blackouts. These causes are basically threefold:

- insufficient local electricity generation compared to local consumption,
- insufficient transmission and transformer capacity compared to import needs,
- insufficient storage to cover daily and annual or irregular fluctuations caused by disasters.

As the question of adequacy of local generation has been addressed in section 5.1 and the question of transmission in section 5.2 above, the present section will only focus on storage. For monitoring storage, the following equation is proposed:

$$\frac{APPAREgeneration}{LPopulation} = \frac{APPAREgeneration}{AREstorage} \times \frac{AREstorage}{Totalstorage} \times \frac{Totalstorage}{LTFC} \times \frac{LTFC}{LPopulation} \quad (1)$$

The terms have the following meaning:

- APPAREgeneration — Accessible (= local + distant) renewable electricity generation (in GWh/year) contracted by power purchase agreement (PPA) or similar and interconnected by a synchronous (AC) or asynchronous (DC) grid link
- LPopulation — Local resident population (in persons at midyear)
- AREstorage — Accessible (= local + distant) renewable electricity storage (in GWh) contracted by agreement and interconnected by a synchronous (AC) or asynchronous (DC) grid link
- Totalstorage — Total (renewable + other) accessible energy storage (in GWh)
- LTFC — Local total final energy consumption (in GWh/year)

Linking this section with the two preceding ones, accessible renewable electricity generation is the sum of local and distant renewable annual generation: APPAREgeneration = LREgeneration + DPPAREgeneration.

The first ratio, APPAREgeneration/AREstorage, designates how much accessible generation (GWh/year) the city can use in relation to the amount of accessible storage (GWh). The interpretation for "accessible" generation is the "sum of local plus distant, contracted by PPA and connected within a grid", either in a synchronous grid or by DC lines. As APEC has several archipelago-economies, the fact to include grids connected by DC lines as belonging to the same grid for purposes of assessing security of supply is a natural choice. After simplification, the dimension of this ratio is 1/year or $year^{-1}$, meaning the frequency how many times per year the RE generation will fill up the electricity-related storage in average if it is an operational storage which is regularly drawn down. If, e.g., the storage is a day-night storage whose volume comprises 1/365 of the generation, the indicator will show a value close to 365/year, meaning that storage is filled 365times per year. In case of a strategic storage that is not drawn down regularly, this number indicates the equivalent theoretical frequency.

The second term, AREstorage/total storage, shows how big the accessible renewable storage is compared to the total energy storage including all energy forms. This is a dimensionless percentage (GWh/GWh) which shows the relative weight of the renewable electricity storage in the total energy storage.

The third term, Totalstorage/LTFC, indicates how much the total accessible storage (renewables and others combined) is in relation to local total final energy consumption of the city. The dimension of this term is GWh/(GWh/year), simplifying to year. It shows how many years of LTFC can be covered by means of the total accessible storage.

The last term, LTFC/Lpopulation, is the per capita local total final energy consumption, measured in GWh/year/person. Its global tendency has been briefly described in section 4.1 above.

The above equation (1) contains hidden ratios which are evidenced if individual terms of the equation are crossed out. Crossing out LTFC yields the ratio Totalstorage/LPopulation, measured in GWh/person. Note that the numerator is storage of all energy forms, not only renewables. This includes strategic storage of fossil fuels which have been created in several economies to enhance energy security. This will be discussed further down.

$$\frac{APPAREgeneration}{LPopulation} = \frac{APPAREgeneration}{AREstorage} \times \frac{AREstorage}{Totalstorage} \times \frac{Totalstorage}{LPopulation} \quad (2)$$

Crossing out Totalstorage from equation (1) yields the ratio AREstorage/LTFC, measured in GWh/(GWh/year) which simplifies to year. This shows the number of years of LTFC that can be satisfied by accessible renewable energy storage. This is the most meaningful ratio describing the energy security of a city in the Sustainable Energy Scenario. At present, with almost no AREstorage existing, this ratio is very small (around 0.001 years or less, for average cities). With the Sustainable Energy Scenario being implemented and energy security being maintained, this ratio should increase to, possibly 0.1 to 0.3 years. Local and central economic decision makers are invited to reflect how high this ratio should be for cities as well as for economies, so as to feel a comfortable energy security level in the Sustainable Energy Scenario allowing to bridge the supply gaps of seasonally conditioned energy scarcity.

$$\frac{APPAREgeneration}{LPopulation} = \frac{APPAREgeneration}{AREstorage} \times \frac{AREstorage}{LTFC} \times \frac{LTFC}{LPopulation} \quad (3)$$

Crossing out AREstorage from equation (1) yields the ratio APPAREgeneration/Totalstorage, measured in (GWh/year)/GWh, which simplifies to 1/year or $year^{-1}$. It shows the frequency of how many times per year the accessible renewable energy generation fills up the total storage if total storage is regularly drawn down. In case total storage contains a large part of strategic storage which is not regularly drawn down, the frequency shows the theoretical equivalent. If an interconnected grid has limited APPAREgeneration compared to its total accessible storage, this ratio is below 1 (e.g., 0.1/year, meaning that APPAREgeneration needs 10 years to fill up the total accessible storage). If APPAREgeneration multiplies by several orders of magnitude as it will do in the Sustainable Energy Scenario, this ratio would rapidly grow.

$$\frac{APPAREgeneration}{LPopulation} = \frac{APPAREgeneration}{Totalstorage} \times \frac{Totalstorage}{LTFC} \times \frac{LTFC}{LPopulation} \quad (4)$$

Crossing out Totalstorage from equation (2) yields the ratio AREstorage/LPopulation, the per capita accessible storage of the city, measured in GWh/person. This can be compared to the per capita LTFC of the city, as well as to the left-hand term of the equations, APPAREgeneration/LPopulation. As present, APPAREgeneration/AREstorage is much larger than 1 for interconnected grids, hence AREstorage/LPopulation is much smaller than APPAREgeneration/LPopulation. With the implementation of the Sustainable Energy Scenario, APPAREGeneration/LPopulation is expected to grow strongly. The two right-hand terms of the equation below will undoubtedly dramatically change. Energy security of the Sustainable Energy Scenario requires the term APPAREgeneration/AREstorage not to decrease, but on the contrary, to increase during the process.

$$\frac{APPAREgeneration}{LPopulation} = \frac{APPAREgeneration}{AREstorage} \times \frac{AREstorage}{LPopulation} \quad (5)$$

Crossing out AREstorage from equation (2) yields the ratio APPAREgeneration/Totalstorage, measured in (GWh/year)/GWh, which simplifies to 1/year or year^{-1}. This is not new as it was already described in equation (4) above.

$$\frac{APPAREgeneration}{LPopulation} = \frac{APPAREgeneration}{Totalstorage} \times \frac{Totalstorage}{LPopulation} \quad (6)$$

Crossing out LTFC from equation (3) yields the ratio APPAREstorage/LPopulation already found in equation (5) above.

$$\frac{APPAREgeneration}{LPopulation} = \frac{APPAREgeneration}{AREstorage} \times \frac{AREstorage}{LPopulation} \quad (7)$$

Crossing out AREstorage from equation (3) yields the ratio APPAREgeneration/LTFC, describing the accessible renewable energy generation of an interconnected grid per unit of local TFC of the city in question. It is measured in (GWh/year)/(GWh/year), simplifying to a dimensionless percentage. This shows how many times the accessible generation of the interconnected grid can satisfy the LTFC of the city in question. For a city on an island, this ratio will be close to zero. For a city in a large, interconnected grid, this ratio may be above 1 at present, but it is rapidly growing if APPAREgeneration grows in the Sustainable Energy Scenario.

$$\frac{APPAREgeneration}{LPopulation} = \frac{APPAREgeneration}{LTFC} \times \frac{LTFC}{LPopulation} \quad (8)$$

Crossing out LTFC from equation (4) yields the ratio Totalstorage/LPopulation already found in equation (2) above.

$$\frac{APPAREgeneration}{LPopulation} = \frac{APPAREgeneration}{Totalstorage} \times \frac{Totalstorage}{LPopulation} \quad (9)$$

Crossing out Totalstorage from equation (4) yields the ratio APPAREgeneration/LTFC already found in equation (8) above.

$$\frac{APPAREgeneration}{LPopulation} = \frac{APPAREgeneration}{LTFC} \times \frac{LTFC}{LPopulation} \quad (10)$$

After having set out the elements above, it is possible to discuss the energy security more in detail. The Disaster Resilience Scorecard for Cities[72] suggests that cities should measure the loss of electric power in a disaster through the electrical energy loss factor which measures how many percentage days of a city are in lost during a disaster. As an example, a 3-day loss of service for 50% of user accounts in a city results in an electrical energy loss factor of 3x50=150 percentage days. Decentralized generation as well as storage are among the key factors to diminish the loss caused by disasters. Loss of percentage days can be interpreted as insufficient generation and storage that is still accessible during disasters.

Evaluating the existing amount of accessible renewable electricity storage reveals one of the ways the energetic transition progresses. An IRENA 2017[73] report states that global electricity-related storage in the year of the report (2017) was around 4.67TWh of which pumped hydropower made up around 96%. IRENA also points to the problem of reliable statistics which are rare and often express the storage in power terms (GW) instead in energy terms (GWh). Half the global storage power (GW) is concentrated in three APEC economies China; Japan; and the US.

Besides the existing pumped hydro storage, the potential PSH is also of interest. The potential for pumped storage in the APEC region has been analysed in the APEC Workshop on the Use of Pumped Storage Hydropower (PSH) to Enable Greater Renewable Energy Use and Reliable Electricity Supply, whose results are published in the report of the same title (2022)[74].

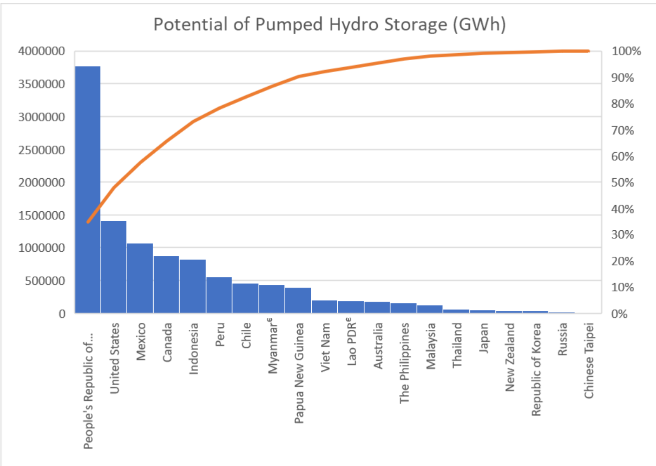


Figure 98: Potential Pumped Hydro Storage (PHS) of APEC economies

Source: APSEC using APEC Workshop on PSH data[75]

Adding the potential pumped hydropower storage (PSH) identified in the APEC region, which for hydrological purposes also includes Laos and Myanmar, adds around 10,850TWh, corresponding to more than 2300 times today's global PSH capacity, of further storage in the APEC region.

Under the simplifying hypothesis that all electricity storage is considered as renewable, the theoretical global APPAREgeneration/AREstorage ratio for 2017 is 1330/year, showing that the global storage capacity is renewed in average more than three times a day and has a capacity of 6.6hours of global renewable electricity generation. If the PSH potential of APEC was fully used, the overall PSH storage capacity would reach more than a year of annual consumption. The geographic distribution of PSH would, however, be unequal.

The mentioned IRENA report also states that all the other forms of electricity-related storage, comprising thermal, electro-chemical and electro-mechanical storage, will inevitably grow muti-fold in the next decades following the growth of renewable energy generation. Given the small size of all these storage forms, they can be considered as operational storage. If cities are addressing the problem of energy security and providing sufficient storage on their territory, they should aim at an APPAREgeneration/AREstorage ratio of around 50/year, corresponding broadly speaking to weekly storage capacity, and then further extend the ratio according to their specific needs to around 4/year.

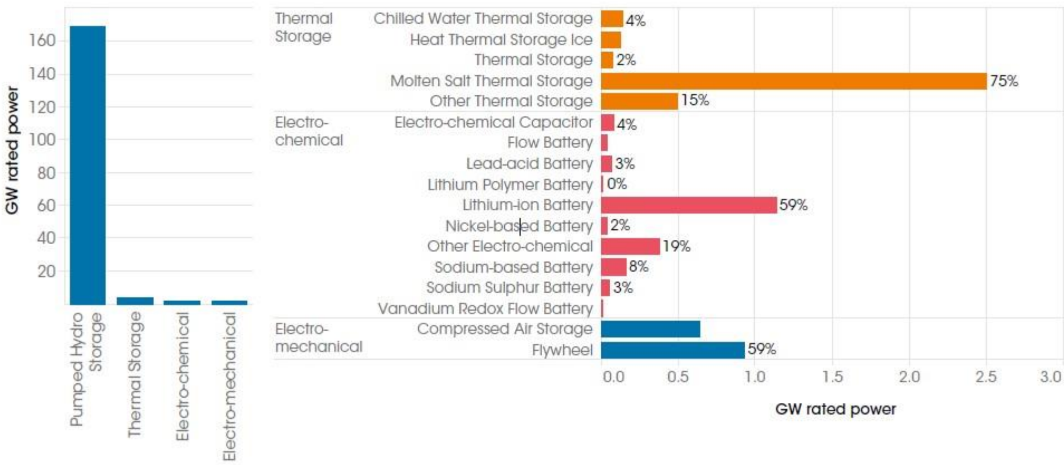


Figure 99: Global operational energy storage power capacity by technology (2017)

Source: IRENA[76]

One way to increase storage of renewable energy is to build a certain proportion of concentrated solar power (CSP) plants into an electricity grid. The diagram above mentions molten salt thermal storage as a form of storage having already the highest power share in 2017. Molten salt is the storage medium of choice used in CSP. CSP is less area-intensive than photovoltaic electricity and can provide electricity as well as hot water and industrial steam, hence cities can plan to install CSP close to their industrial zones. Molten salt is cheap, presents no toxicity and is used in a temperature span between 170°C and 560°C and can be stored and used at atmospheric pressure.

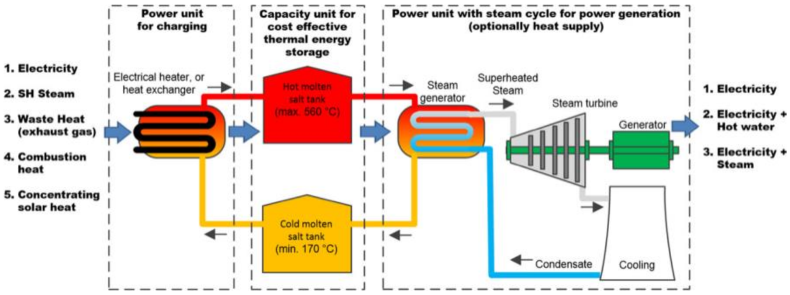


Figure 100: Concentrated Solar Power (CSP) using molten salt as storage medium

Source: Bauer and others[77]

To increase the supply of storage, ways should be found to favour the creation of independent storage enterprises. The root problem of favouring independent storage in cities (and elsewhere) is the difficulty of defining a viable business model for storage. If storage should become an independent profit-generating activity, its source of income should be the time-volatility of electricity prices, i.e., the price differentials of electricity between different periods of time. If electricity is cheap during the second part of the night, electricity stores should be filled during these hours. They should be emptied during the hours of the day when electricity prices are high. For this business model to become reality, electricity storing enterprises of any size should be able to get grid access and negotiating powers on the wholesale market where prices show the required volatility. In some APEC economies, this condition may not be fulfilled yet in the electricity market legislation.

An easy way for cities to increase battery energy storage is to reuse end-of-life EV batteries. For mobile applications such as EVs, batteries must be changed once their charging capacity falls below a certain threshold of e.g., 60% of the original nominal capacity. At this stage, these batteries can, however, still contribute to storage in fix applications, fixed in racks. In June 2019, a team lead by APSEC researchers had elaborated a corresponding project and earned the second prize in a startup-competition. But finally, the project was suspended as access to the wholesale electricity market was too difficult to obtain.

Figure 101: Second life for EV Car Batteries

Source: APSEC

Another means to improve storage is the creation of a storage market. Markets pay a premium for storage (as well as for other services such as insurance, financial costs etc.) when they are in a situation called contango. In a contango situation, spot prices are lower than expected future prices. As the maturity of futures contracts nears, their price will gradually come down to the spot price. The inverse situation occurs after e.g. an unexpected supply disruption suddenly causes spot prices to rise, turning the market to change to the situation called backwardation, in which spot prices are temporarily above expected future prices, and in which the prices of futures contracts will gradually approach the spot price from below. In backwardation, the premium for storage is negative.

Figure 102: Contango and backwardation

Source: Sabrina Jiang © Investopedia 2020[78]

It should be mentioned here that hydrogen is a way to store electricity. Hydrogen has the characteristic to be neither an energy resource nor a final energy product. Contrary to hydrogen, electricity will be the most wanted type of final energy after the energy transition. In this context, green hydrogen produced from renewable electricity is likely to receive an increasing role in the future.

The relative weight of electricity-related accessible storage in the total accessible storage is another indicator for cities to monitor. Since the 1970s, energy security discussion and analysis has been strongly dominated by oil, with storage being at the centre of the measures to increase energy security. The International Energy Program, the basic agreement creating the International Energy Agency in 1973, states as a norm for each IEA member to have oil storage corresponding to 90 days of net oil imports[79]. This energy security standard is still in force and closely monitored among IEA members.

For the energy transition, oil is going to lose importance as basic energy source. In the Sustainable Energy Scenario, oil is replaced by renewable electricity by mid-century. The phase-in of renewables, coupled with the phase-out of oil, should also be reflected in the evolution of the relative weight of electricity-related accessible storage in total accessible storage. While in 2017, this ratio was less than 1% at global level, it should attain 100% by mid-century. Intermediary milestones should be fixed for five-year periods. As the definition of the term specifies, accessible storage does not need to be located on the city territory, but it needs to be accessible by the city. It is not a problem if several cities consider the same storage facility situated outside their territories as accessible for each of them. Usually a disaster, for which a given accessible storage is designed to be used, does not hit more than one city at a time. Storage facilities should be designed as multi-disaster-resilient infrastructures and comprise a mix between different types of storage, see the figure below.

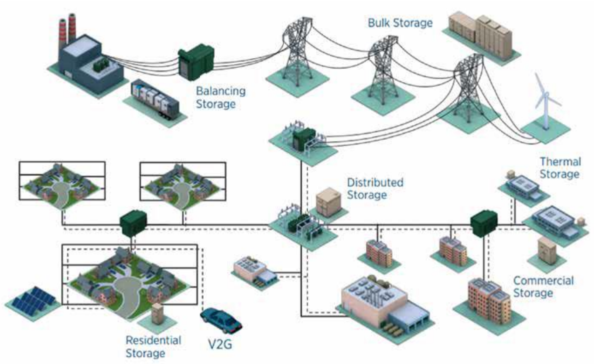


Figure 103: Different types of storage accessible to a city

Source: IRENA (2017)[80]

The Totalstorage/LTFC ratio is important, as it defines the overall storage comprising all technologies: pumped hydropower, thermal storage, electrochemical storage and electro-mechanical storage. The storage requirement may be defined by the central authorities of each economy. If total storage is at 90 days of total final consumption, this ratio shows 0.25years. The relatively high level of stocks required is conditioned by the oil industry and the impossibility for average consumers to produce oil. As solar PV will be disseminated within cities and much more widely accessible to average consumers than oil production, this basic energy security ratio could gradually be lowered, depending on climatic conditions and the degree of supply diversification. In economies having strong seasonal variations of demand, this ratio should still allow for storage to overcome the energy-scarce season. For winter months, sufficient wind potential should be installed, complementing solar energy. In these regions, seasonal underground heat storage combined with reversible heat pumps is a highly recommended way of assuring the availability of heat for the city throughout the cold season. City-level energy storage in both forms, thermal as well as electrochemical, needs to receive high priority, including in urban planning. Many cities realize geological underground heat storage. Different types exist: Tank thermal energy storage (TTES), pit thermal energy storage (PTES), aquifer thermal energy storage (ATES), borehole thermal storage (BTES), latent heat storage (LHS), and thermochemical heat storage (THS).

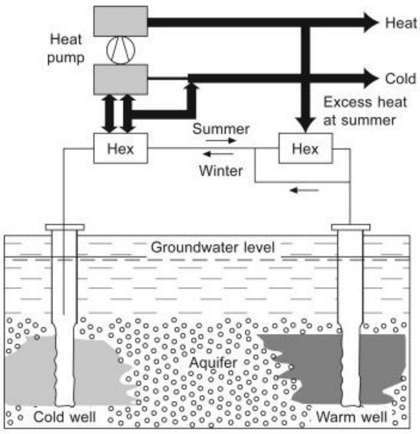


Figure 104: Aquifer thermal energy storage (ATES)

Source: Luisa F. Cabeza[81]

In APEC, all the cities or municipalities having thermal energy storage projects are in Canada and China; all of them are of the borehole or aquifer energy storage types.

Project location	Year of initial operation	Refer ence	Project scale	Main heat source	Back-up heating devices
BTES					
Okotoks, CA	2007	[47]	52 houses	Solar thermal	Gas boiler
Harbin, CN	2008	[48]	One house	Solar thermal	GSHP
Shanghai, CN	2012	[50]	One greenhouse	Solar thermal	None
Tianjin, CN	2013	[52]	270 houses	Solar thermal	GSHP
Ontario, CA[a]	2017	[55]	One greenhouse	Solar thermal	None
ATES					
Scarborough, CA	1984	[57]	One community	Waste heat	HP

Abbreviations: GSHP: Ground source heat pump, HP: Heat pump

Table 8: Thermal Energy Storage in APEC
Source: Tianrun Yang[82]

The availability of district heating and district cooling should become the rule in cities. Combined with reversible heat pumps and underground heat or cold storage, they are the most energy efficient and emissions-poor way to provide space heating and cooling in the Sustainable Energy Scenario.

5.5 Monitoring the Local Green Economy

The preceding sections described a way for cities to monitor the electricity generation and energy security aspects of the Sustainable Energy Scenario. The present section outlines a way for cities to monitor the economic aspects of the Sustainable Energy Scenario. This will again be made on the basis of an equation, similar to the preceding sections. The relevant equation is:

$$\frac{LREgeneration}{LPopulation} = \frac{LREgeneration}{LGreenVA} \times \frac{LGreenVA}{LGreenEmpl} \times \frac{LGreenEmpl}{LGDP} \times \frac{LGDP}{LPopulation} \quad (1)$$

The terms have the following meaning:

- LREgeneration   Local renewable electricity generation (in GWh/year)
- LPopulation   Local resident population (in persons at midyear)
- LGreenVA   Value-added of the local green sector (in constant local currency unit LCU/year or constant USD/year; to simplify, only constant USD/year are mentioned in the text below), where “green” is defined by the applicable taxonomy of green activities of the city.

- LGreenEmpl — Employment force of the local green sector (in full time equivalents), where "green" is defined by the applicable taxonomy of green activities of the city
- LGDP — Local Gross Domestic Product (in constant local currency unit LCU/year or constant USD/year; to simplify, only constant USD/year are mentioned in the text below)

The problem of monitoring the economic dimension of the Sustainable Energy Scenario is in the still low awareness that such a dimension exists. Consequently, the benefitting industries and the economic benefits are still vaguely defined. There is a discrepancy between identifying green activities or industries and green jobs. For this reason, the choice made in the above equations is to rely on the taxonomies elaborated for the financial dimension described in the next section, where so-called taxonomies of green activities or industries have contributed to define the green industry sector by way of the classification of industries as applicable in the jurisdiction. In this line of thought, green jobs are defined as all those jobs created by green activities or industries.

The concept of green jobs has been forged by the International Labour Organisation (ILO) in 2016. For the ILO, green jobs can be defined either through production of environmental goods or services (i.e., the industry in which the job exists; the ILO gives the examples of green buildings or clean transportation; in the figure below they are the dark green jobs), or through jobs that are based upon green production processes and technologies as they exist in any industry (the ILO gives as examples jobs that reduce water consumption or improve recycling systems; in the figure below they are light green jobs). To be qualified as green job in the sense of the ILO, however, a job must above all be decent, as required in SDG8. For the ILO, green jobs are all those jobs that fall in the dashed area.

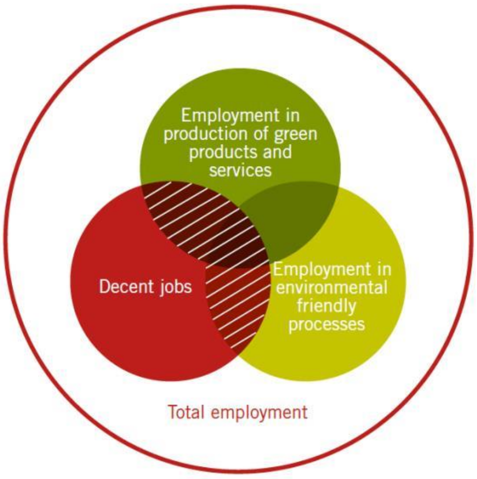


Figure 105: Green jobs definition of the International Labour Organization

Source: ILO[83]

The ILO gives supplementary description to the meaning of green jobs. Green jobs can help to:

- Improve energy and raw materials efficiency
- Limit greenhouse gas emissions
- Minimize waste and pollution
- Protect and restore ecosystems
- Support adaptation to the effects of climate change

Remarkable in the above definition is the prevalence of focus on energy efficiency and the absence of focus on renewable energies. Green buildings and clean transportation refer to energy consumption much more than to energy production.

Neither does ILO reflect the green jobs definition in any of its statistical data bases. The ILO is custodian for a large number of SDG-relevant data, but green jobs are not among them[84]:

- SDG indicator 1.1.1 - Working poverty rate (percentage of employed living below USD1.90 PPP) (%)
- SDG indicator 1.3.1 - Proportion of population covered by social protection floors/systems (%)
- SDG indicator 5.5.2 - Proportion of women in senior and middle management positions (%)
- SDG indicator 5.5.2 - Proportion of women in managerial positions (%)
- SDG indicator 8.2.1 - Annual growth rate of output per worker (GDP constant 2017 international USD at PPP) (%)
- SDG indicator 8.2.1 - Annual growth rate of output per worker (GDP constant 2015 USD) (%)
- SDG indicator 8.3.1 - Proportion of informal employment in total employment by sex and sector (%)
- SDG indicator 8.5.1 - Average hourly earnings of employees by sex (Local currency)
- SDG indicator 8.5.2 - Unemployment rate (%)
- SDG indicator 8.5.2 - Unemployment rate by disability status (%)
- SDG indicator 8.6.1 - Proportion of youth (aged 15-24 years) not in education, employment or training (%)
- SDG indicator 8.7.1 - Proportion of children engaged in economic activity and household chores (%)
- SDG indicator 8.7.1 - Proportion of children engaged in economic activity (%)
- SDG indicator 8.8.1 - Non-fatal occupational injuries per 100,000 workers
- SDG indicator 8.8.1 - Fatal occupational injuries per 100,000 workers
- SDG indicator 8.8.2 - Level of compliance with labour rights (freedom of association and collective bargaining) based on ILO textual sources and economywide legislation
- SDG indicator 9.2.2 - Manufacturing employment as a proportion of total employment (%)
- SDG indicator 10.4.1 - Labour income share as a percent of GDP (%)

IRENA maintains the statistic of employment in the renewable energy sector. This is the narrowest possible definition of the green sector. The value-added of the renewable sector is, however, not available. Furthermore, the data is only published at global level. It will be used to describe the global context further down.

The first ratio of equation (1) measures the relation between local renewable electricity generation and value added of the local green sector, expressed in (GWh/year)/(constant USD/year) which simplifies to GWh/constant USD. In jurisdictions which define the green sector narrowly (e.g., China), this ratio might be close to showing the output per value-added of the renewable energy sector and hence be comparable to an inverted GWh price. In jurisdictions which define the green sector widely, the resulting ratio might be lower than in the narrowly defined case. The idea of this ratio is, indeed, to grasp the participation of the city in industrial and economic activities of the whole green economy sector, comprising not only electricity generation in the narrow sense, but also the production of all equipment that is associated with the Sustainable Energy Scenario, such as PV cells, wind turbines, batteries, heat pumps, electrolysers, fuel cells, and the equipment to run the electricity transmission and distribution network, such as transmission poles and lines, transformers, as well as all the control equipment necessary to keep electricity grids stable.

The second ratio of equation (1) measures the value-added per employee of the local green sector, measured in (constant USD/year)/person. This ratio is sometimes also called value-added productivity per employee. Value-added comprises wages, taxes and profits. The value-added productivity comprises the average wage but is greater than the latter. Ideally, numerator and denominator refer to the same set of local industries and enterprises. If data is not available, proxies may be chosen.

The third ratio of equation (1) shows green employment per local GDP, measured in employees/(constant USD/year). This indicator shows the size of the green employment in the local GDP.

The fourth ratio of equation (1) is the per capita local GDP, measured in (constant USD/year)/person.

Equation (1) has several hidden ratios which are revealed only when crossing out individual terms of equation (1). Crossing out LGDP yields the ratio LGreenEmpl/LPopulation, which simplifies to a dimensionless percentage showing the percentage of local population employed in the green sector.

$$\frac{LREgeneration}{LPopulation} = \frac{LREgeneration}{LGreenVA} \times \frac{LGreenVA}{LGreenEmpl} \times \frac{LGreenEmpl}{LPopulation} \qquad (2)$$

Crossing out LGreenEmpl from equation (1) yields the LGreenVA/LGDP ratio, which simplifies to a dimensionless percentage showing the share of the green economy in the local economy, by value-added.

$$\frac{LREgeneration}{LPopulation} = \frac{LREgeneration}{LGreenVA} \times \frac{LGreenVA}{LGDP} \times \frac{LGDP}{LPopulation} \qquad (3)$$

Crossing out LGreenVA from equation (1) yields the LREgeneration/LGreenEmpl ratio, measured in (GWh/year)/employee.

$$\frac{LREgeneration}{LPopulation} = \frac{LREgeneration}{LGreenEmpl} \times \frac{LGreenEmpl}{LGDP} \times \frac{LGDP}{LPopulation} \qquad (4)$$

All the three newly presented ratios above are highly relevant for assessing the role of the green sector in the local economy. Crossing out LGreenEmpl from equation (2) yields the LGreenVA/LPopulation ratio, measured in (constant USD/year)/person, showing the per capita value-added of the local green sector.

$$\frac{LREgeneration}{LPopulation} = \frac{LREgeneration}{LGreenVA} \times \frac{LGreenVA}{LPopulation} \qquad (5)$$

Crossing out LGreenVA from equation (2) yields the ratio LREgeneration/LGreenEmpl, measured in (GWh/year)/employee, which is not new as it has been found in equation (4) already.

$$\frac{LREgeneration}{LPopulation} = \frac{LREgeneration}{LGreenEmpl} \times \frac{LGreenEmpl}{LPopulation} \qquad (6)$$

Crossing out LGDP from equation (3) yields the ratio LGreenVA/LPopulation, measured in (constant USD/year)/person. This has already been presented in equation (5) above.

$$\frac{LREgeneration}{LPopulation} = \frac{LREgeneration}{LGreenVA} \times \frac{LGreenVA}{LPopulation} \qquad (7)$$

Crossing out LGreenVA from equation (3) yields the ratio LREgeneration/LGDP, measured in (GWh/year)/(constant USD/year), simplifying to GWh/constant USD. This is somewhat complementary to the first ratio of equation (1) above. Whereas the first ratio of equation (1) has the value-added of the local green sector in the denominator, this new ratio below has the local GDP in the denominator, bearing in mind that the local GDP is the value-added of all local sectors taken together.

$$\frac{LREgeneration}{LPopulation} = \frac{LREgeneration}{LGDP} \times \frac{LGDP}{LPopulation} \qquad (8)$$

Crossing out LGDP from equation (4) yields the ratio LGreenEmpl/LPopulation, measured as dimensionless percentage, which has already been found in equation (2).

$$\frac{LREgeneration}{LPopulation} = \frac{LREgeneration}{LGreenEmpl} \times \frac{LGreenEmpl}{LPopulation} \qquad (9)$$

Crossing out LGreenEmpl from equation (4) yields the ratio LREgeneration/LGDP, which is not new as it has already been found in equation (8).

$$\frac{LREgeneration}{LPopulation} = \frac{LREgeneration}{LGDP} \times \frac{LGDP}{LPopulation} \qquad (10)$$

After the presentation of the ratios, the discussion can take place. It will mostly focus on the global context. The first ratio of equation (1) describes the local renewable electricity generation per value-added of the local green sector. For the value-added of the green sector, the value-added of the manufacturing industry as proposed by SDG 9.2.1 is taken as a proxy, in spite of its shortcomings. The mismatch between value-added of the manufacturing sector and value-added of the green sector is visible in the results. Renewable energy generation will grow much faster than manufacturing value-added. As a result, the ratio reflects basically the growth of renewable energy generation. The computed probability of the trend as a function of its data is higher than 98%. For cities, it should not be too difficult to identify their green sectors as well as their value-added.

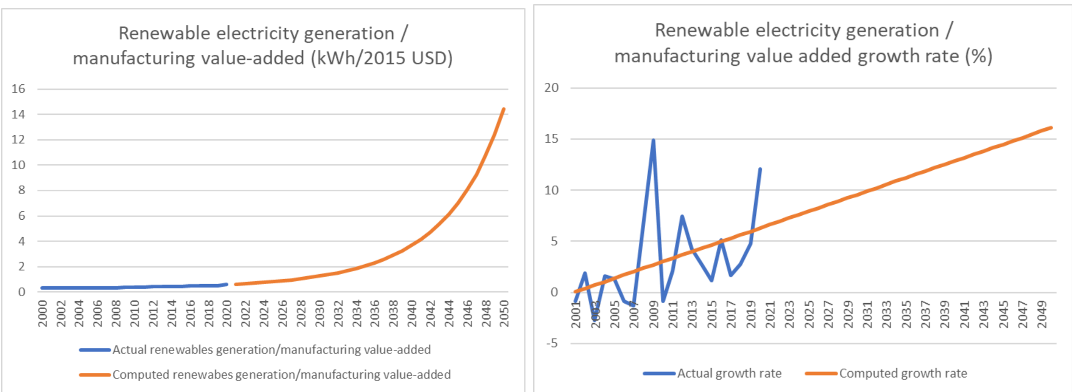


Figure 106: Renewable energy generation / manufacturing value-added (global level)

Source: APSEC based upon IRENA and World Bank data

The second ratio of equation (1) shows the value-added per employee of the green sector. The numerator is the value-added of the global manufacturing sector taken as proxy for the green sector. The denominator is the employment of the renewable energy sector according to IRENA data. With this choice, a same kind of mismatch as in the case just mentioned is visible in the results. Manufacturing value-added per renewable energy employee is neither reflecting a meaningful amount nor a meaningful trend as the denominator grows much faster than the numerator which is not the correct aggregate for the denominator to be compared with.

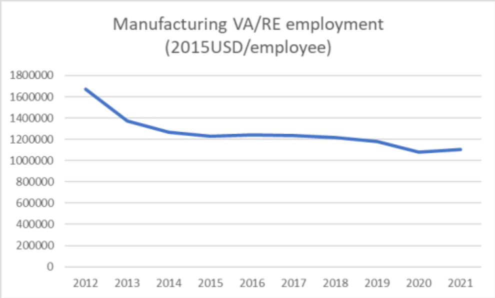


Figure 107: Manufacturing value-added per renewable energy employee (global level)

Source: APSEC based upon World Bank and IRENA data

As value-added per employee, also called employment productivity, is an important indicator, it is available for the APEC economies in general. The figure below shows how value-added per employee has evolved in each APEC economy for the past three decades. The figure for 2023 is based upon an estimation. The top ranks are now held by Singapore; the United States; Hong Kong, China; and Chinese Taipei. It is remarkable that the two city-economies of APEC are among the top ranked. In Japan, employment productivity has stagnated since 2015. Mexico is the only reporting APEC economy where employment productivity has not grown for the past 30 years.
At present, no data is being collected to show the below figure for the green sectors of any APEC economy, nor for the green sectors of any other economy, region or city.

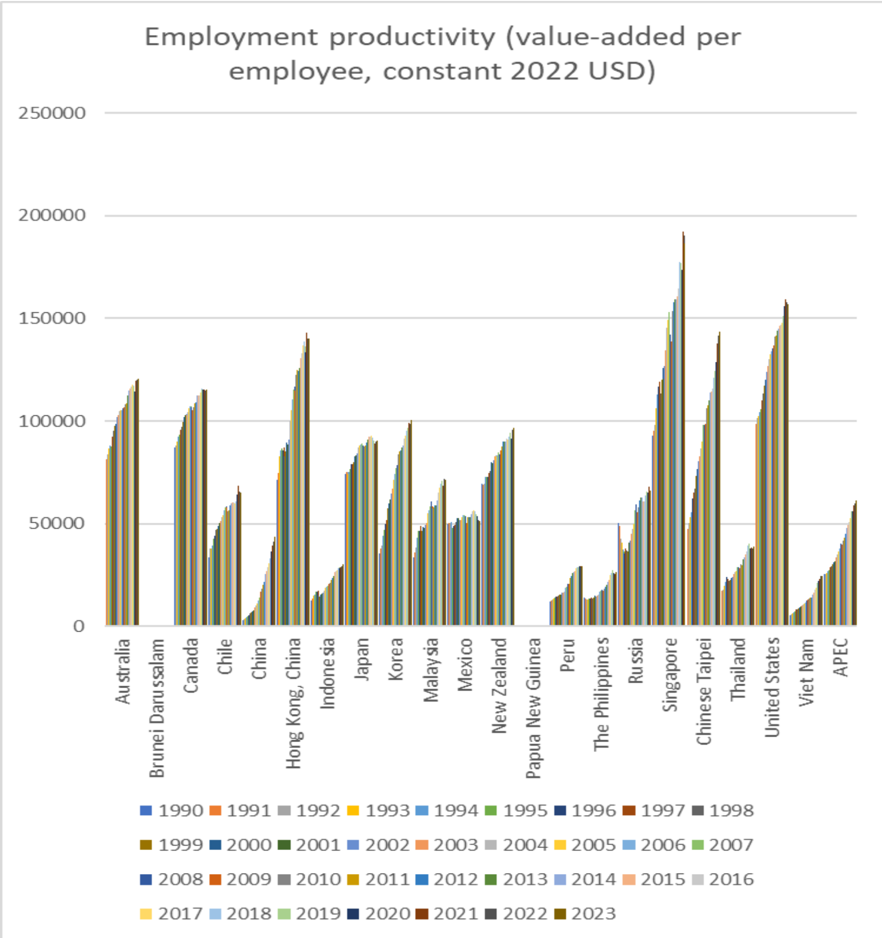


Figure 108: Value-added per employee in APEC economies (2023 is estimated)

Source: APSEC based on StatsAPEC data

The scenario of employment productivity for aggregated APEC until mid-century is shown in the figure below. The computed probability of this trend as a function of its data is higher than 80%.

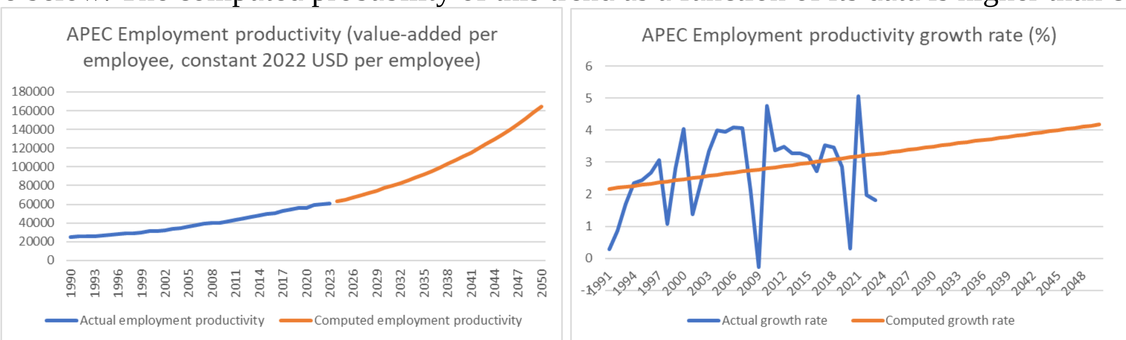


Figure 109: APEC employment productivity 1990 – 2050 and growth rate

Source: APSEC based on StatsAPEC data

The third ratio of equation (1) displays the number of local green sector employees in relation to the local GDP. For this, the IRENA employment data of the global renewable electricity generating sector are used (left). The analysis of the growth rate shows a turning point in 2016 after which its growth is more regular.

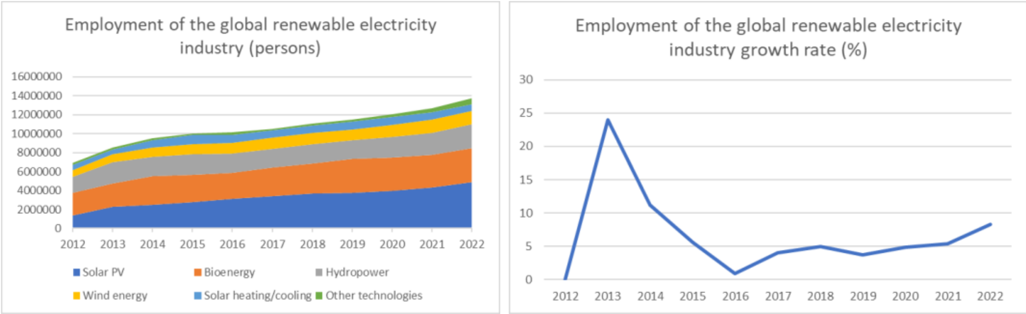


Figure 110: Global renewable electricity employment (left), growth rate (right)

Source: APSEC on the basis of IRENA[85] and World Bank data

A scenario has been calculated for the period after the turning point 2016 – 2030 (left in the figure below), with a computed probability as a function of its data of higher than 98%. The right hand shows the growth rate.

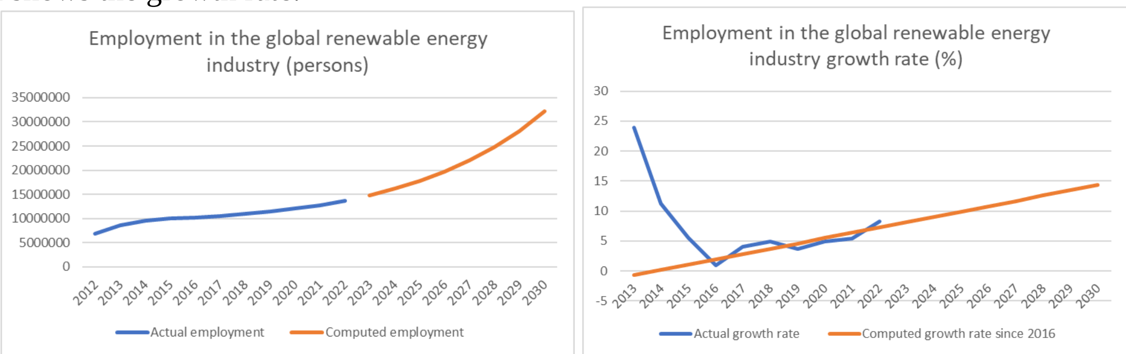


Figure 111: Scenario of the global renewable electricity employment (left) and growth rate (right)

Source: APSEC on the basis of IRENA[86] data

The right-hand figure below shows the renewable electricity employment/GDP ratio and its 2016 – 2030 scenario, computed with a probability as a function of its data of higher than 80%. The growth rate is on the left.

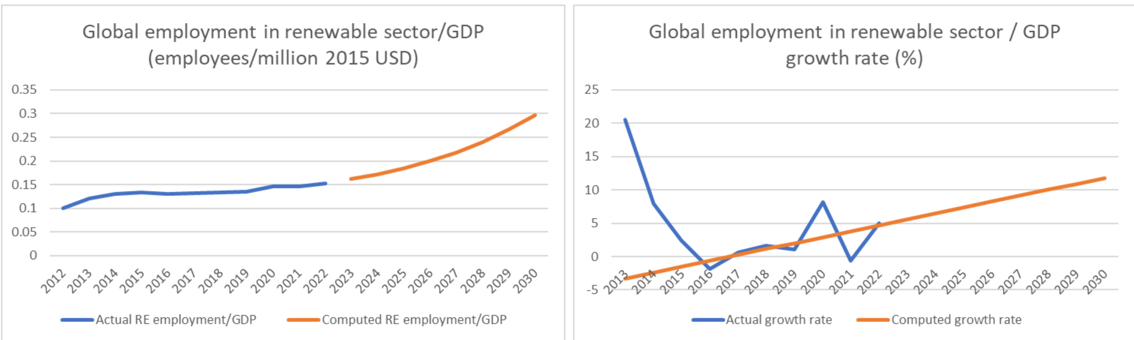


Figure 112: Global renewable electricity employment/GDP (left) and growth rate (right)

Source: APSEC on the basis of IRENA[87] and World Bank data

The IRENA data on employment of the renewable electricity sector reflects the employment of a core subsector of the green economy. The renewable electricity sector is the narrowest possible definition of the green sector. What is shown here is that the renewable electricity sector can be used as a proxy for the green economy, even though it may be multiple times smaller in terms of employment than the green sector itself. This will be further illustrated hereafter.

Equations (4), (6), and (9) use the ratio LREgeneration/LGreenEmpl. Measuring this ratio as LREgeneration/LREEmpl, the local renewable electricity generation per local employee of the renewable electricity sector, compares the numerator with exactly the corresponding denominator. The global context of this comparison is depicted in the figure below which shows that the global per employee annual generation is presently at (0.6GWh/year)/employee and could slightly decline to around (0.5GWh/year)/employee by 2030. The computed probability of this (orange coloured) scenario is less than the computed probability of the alternative (grey coloured) scenario which has a calculated probability as a function of its data of greater than 99%. Therefore, the alternative grey scenario is retained.

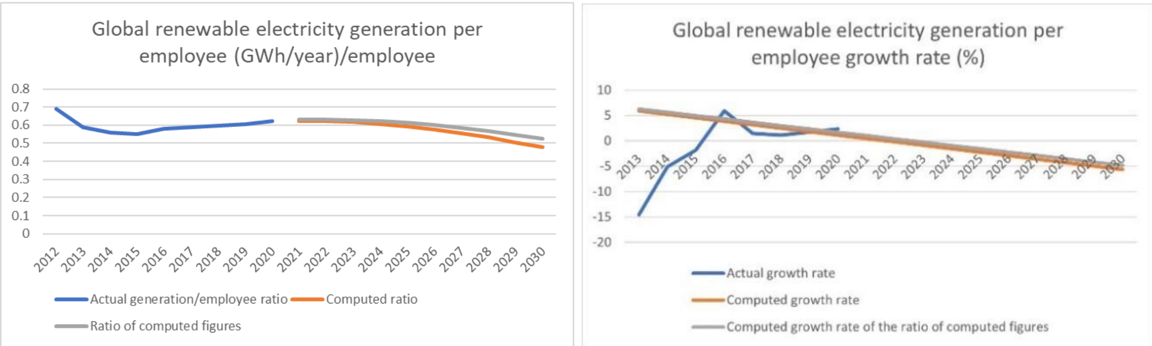


Figure 113: Global renewable electricity generation per employee

Source: APSEC based on IRENA[88] data

Equations (2), (6) and (9) use the employment share of the green sector in total employment. If the renewable electricity sector is chosen as a proxy for the green sector, the contextual global level evolution presents itself like in the figure below. Compared to 2012, the number of per capita employees in the global renewable electricity sector is quadrupling by 2030. The computed probability of this scenario as a function of its data for the period 2016 – 2030 is higher than 99%.

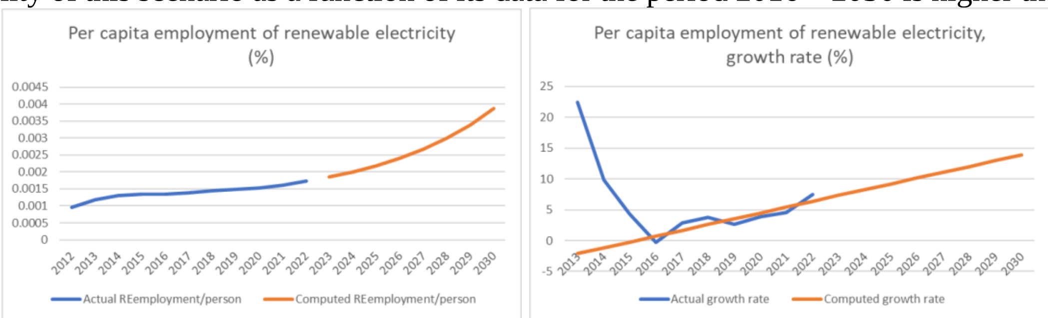


Figure 114: Global per capita employment in the renewable electricity sector and growth rate

Source: APSEC based on IRENA[89] and World Bank data

Equation (3) uses the LGreenVA/LGDP ratio. As mentioned earlier, the value-added of the green sectors of cities are not yet regularly computed. Neither is the value-added of the renewable electricity sectors of cities known yet. This data will be collected gradually once cities are convinced that they have an interest in knowing the contribution of the green economy. Even though the manufacturing value-added is not a proxy for the value-added of the green sector, it might still be interesting to show how the manufacturing share in GDP is evolving. The figure below shows that the global manufacturing share in GDP has the tendency to slowly decline. Since the 1990s when it was at 18%, it is now approaching 16% and might decline further at a slow rate. Note, however, that the calculated probability of this future decline scenario based on its data is too low to be retained as a scenario. For the energy transition, this means that there is a (low) probability that the value-added of manufacturing green energy equipment will happen at the expense of capacities that presently are manufacturing fossil energy equipment. Cities where the share of fossil industries is large, might be made aware that the energy transition has the two aspects of decommissioning and withdrawing fossil-based capacities and at the same time building up the green energy sector.

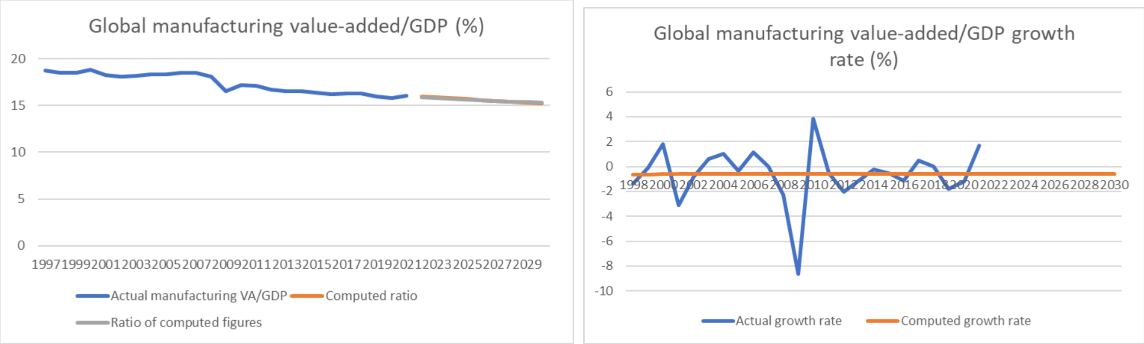


Figure 115: Global manufacturing value-added share in GDP (left) and growth rate (right)

Source: APSEC based on World Bank data

5.6 Monitoring the Local Use of Green Finance

Providing sufficient financing for the renewable energy sector is one of the main tasks allowing to implement the Sustainable Energy Scenario. Cities should, therefore, monitor the development of green finance issued by themselves. They should include green finance investments made by their resident enterprises to the extent this information becomes publicly available due to reporting requirements.

For systematizing the monitoring purposes, it is again proposed to use an equation as specified below:

$$\frac{APPAREgeneration}{LPopulation} = \frac{APPAREgeneration}{APPAREcapacity} \times \frac{APPAREcapacity}{LGreenDebt} \times \frac{LGreenDebt}{LGreenEquity} \times \frac{LGreenEquity}{LPopulation} \quad (1)$$

The terms designate the following quantities:

- APPAREgeneration — Accessible (= Local + Distant) renewable electricity generation contracted by power purchase agreement (PPA) or similar and interconnected by a synchronous (AC) or asynchronous (DC) grid link, (in GWh/year)
- LPopulation — Local resident population of the city (in persons at midyear)
- APPAREcapacity — Accessible (= Local + Distant) installed renewable electricity capacity of those producers with whom the city has a PPA or similar agreement, and with whom the city is interconnected by a synchronous (AC) or asynchronous (DC) grid link (in MW), where APPAREcapacity = LRE capacity + DPPARE capacity

- LGreenDebt — Amount of local green debt (assets) held by the city and its resident green performance disclosing enterprises, at the end of the year (in constant local currency unit LCU or constant USD; to simplify, only constant USD are mentioned in the text below), where "green" is defined by the applicable taxonomy of green activities, and "debt" means all senior debt forms, in particular green bonds and green loans
- LGreenEquity — Amount of local green equity assets held by the city and its green performance disclosing residents (enterprises) located in the city, at the end of the year (in constant local currency unit LCU or constant USD; to simplify, only constant USD are mentioned in the text below), where "green" is defined by the applicable taxonomy of green activities, and "equity" includes all junior debt forms, in particular equity, guarantees (including credit risk guarantees) and grants (e.g., assets received).

The main monitored quantity, at the left hand of the equation (1), is the per capita local plus distant renewable electricity generation accessible to the city. The monitoring is done through monitoring the installed renewable capacity of those producers who supply the city. The motivation for monitoring through the installed capacity has been explained above in the section on monitoring distant production. Renewable producers should emit some kind of guarantee of origin for the production each hour during the year. The reasons for requiring a PPA or similar agreement and an AC or DC interconnection has also been explained in the same section on monitoring distant production.

Investments in renewable energies are either financed by green debt (bonds, loans) or by green equity. "Green" is defined by the relevant taxonomy of green industries and activities of the economy in which the city is located. The three types of green securities (equity, bonds, loans) have been described in the APEC Green Finance Report (2023)[90].

The APEC Green Finance Report also discussed the most important taxonomies already existing, which are the China Taxonomy[91], the EU Taxonomy[92], as well as the Common Ground Taxonomy (CGT)[93] that is comparing the two to understand their communalities and differences. The figure below shows that at the upper level, both taxonomies are relatively similar. Differences exist, however, at granular level.

EU Objectives[14]	China Objectives[15]
Climate change mitigation	Climate change response
Climate change adaptation	
The sustainable use and protection of water and marine resources	Environmental improvement (pollution control and ecological conservation)
The protection and restoration of biodiversity and ecosystems	
The transition to a circular economy	More efficient resource utilization (circular economy, waste recycling and pollution prevention)
Pollution prevention and control	

Table 9: EU Taxonomy compared to the China Taxonomy

Source: International Platform on Sustainable Finance: Common Ground Taxonomy[94]

Several APEC economies have already elaborated, or are in the process of elaborating, a green taxonomy, as described in the APEC Green Finance Report (2023). Differences in the definition of “green” may mean that “green” in a city of a given APEC economy does not have exactly the same scope as “green” of a city of another APEC economy in terms of included or excluded industries. Annex 3 shows the list of green industries as defined by China in its taxonomy dated 2021.

The fundamental principle of finance for any enterprise, no matter in what industry the enterprise is active, is to seek a basic cushion of initial finance in form of equity. During the growth phase, equity is increased, but also supplemented by debt finance to match the rapid growth of the enterprise. Equity does not have to be reimbursed and is ready to support risks, whereas debts must be reimbursed. For this reason, equity is sometimes considered to have “junior” status, whereas to debt (bonds and loans) are considered to have “senior” status. This will be further discussed below.

The first ratio of equation (1), APPAREgeneration/APPAREcapacity, describes the available PPA contracted generation per available capacity of those PPA contracted producers. It is measured in (GWh/year)/MW. After simplification, as one GWh/year simplifies to 0.114MW, it becomes a dimensionless percentage. Both, the numerator and the denominator, are each the sum of the corresponding local and distant terms described in the sections on monitoring through local capacity and monitoring through distant capacity, respectively. Their significance is basically comparable to what was described in the monitoring through distant capacity. This ratio gives the percentage of the average utilization of accessible (= distant + local) capacity of PPA-contracted producers during a year. In the case of accessible production, this factor mixes all available renewable electricity technologies as shown for the distant production. This factor is declining at global level, as shown further above.

The second ratio of equation (1), APPAREcapacity/LGreenDebt, shows the accessible PPA contracted renewable energy capacity per amount of local green debt held by cities and its green performance disclosing entities. It is measured in MW/constant USD. If a city expands its accessible PPA contracted renewable energy capacity in its hinterland and is financing this expansion by green debt (in practice: green bonds), this ratio will follow the trajectory of an inverse price of installed capacity. As the price per MW installed capacity will fall, this ratio will increase in consequence, in case green debt is fully used to finance the expansion.

The third ratio of equation (1), LGreenDebt/LGreenEquity, is measured in USD/USD, which simplifies to a simple percentage. It reflects the famous debt-to-equity (D/E) ratio computed specifically for the local green sector of the city. The D/E ratio designates the ratio between senior and junior debt, where senior is defined as low-risk debt that has to be reimbursed in priority, whereas junior debt is the high-risk debt which does not need to be reimbursed. The role of the D/E ratio will be discussed further down.

The fourth ratio of equation (1), LGreenEquity/LPopulation, in constant USD/person, shows the amount of per capita local green equity held by the city and its local green performance disclosing residents (persons and enterprises). This indicator is often named as critical for financing the Sustainable Energy Scenario. As the IEA Roadmap to Net Zero by 2050 for the Global Energy Sector[95] shows, developing and emerging economies do not manage to raise sufficient green equity to provide for the basic level of finance to kick-start or accelerate the energy transition. This will be discussed further down.

Equation (1) has hidden ratios which appear only by crossing out specific terms. Crossing out LGreenEquity yields the ratio LGreenDebt/LPopulation, measured in constant USD/person. This per capita green debt should be monitored to avoid reaching unsustainably high levels compared to the local per capita GDP.

$$\frac{APPAREgeneration}{LPopulation} = \frac{APPAREgeneration}{APPAREcapacity} \times \frac{APPAREcapacity}{LGreenDebt} \times \frac{LGreenDebt}{LPopulation} \quad (2)$$

Crossing out LGreenDebt from equation (1) yields the ratio APPAREcapacity/LGreenEquity, measured in MW/constant USD, showing the amount of accessible PPA-contracted renewable energy capacity by local green equity. It is a complement to the similar ratio shown in equation (1) relating the accessible PPA capacity to the local green equity.

$$\frac{APPAREgeneration}{LPopulation} = \frac{APPAREgeneration}{APPAREcapacity} \times \frac{APPAREcapacity}{LGreenEquity} \times \frac{LGreenEquity}{LPopulation} \quad (3)$$

Crossing out APPAREcapacity yields the ratio APPAREgeneration/LGreenDebt, measured in (GWh/year)/constant USD, the complement of the APPAREcapacity/LGreenDebt found in equation (1).

$$\frac{APPAREgeneration}{LPopulation} = \frac{APPAREgeneration}{LGreenDebt} \times \frac{LGreenDebt}{LGreenEquity} \times \frac{LGreenEquity}{LPopulation} \quad (4)$$

Crossing out LGreenDebt from equation (2) yields the APPAREcapacity/LPopulation, measured in (MW/person), which is similar to the DPPAREcapacity/LPopulation described in the Monitoring through distant generation section above, with the difference that APPAREcapacity is the sum of DPPAREcapacity and LCapacity.

$$\frac{APPAREgeneration}{LPopulation} = \frac{APPAREgeneration}{APPAREcapacity} \times \frac{APPAREcapacity}{LPopulation} \quad (5)$$

Crossing out APPAREcapacity from equation (2) yields the ratio APPAREgeneration/LGreenDebt, measured in (GWh/year)/constant USD.

$$\frac{APPAREgeneration}{LPopulation} = \frac{APPAREgeneration}{LGreenDebt} \times \frac{LGreenDebt}{LPopulation} \quad (6)$$

Crossing out LGreenEquity from equation (3) yields the ratio APPAREcapacity/LPopulation which is not new as it was found in equation (5) above.

$$\frac{APPAREgeneration}{LPopulation} = \frac{APPAREgeneration}{APPAREcapacity} \times \frac{APPAREcapacity}{LPopulation} \quad (7)$$

Crossing out APPAREcapacity from equation (3) yields the ratio APPAREgeneration/LGreenEquity, measured in (GWh/year)/constant USD. This ratio is the complement to APPAREcapacity/LGreenEquity found in equation (3) above. The newly found ratio relates local green equity to renewable generation, whereas the former ratio, found in equation (3), relates it renewable capacity.

$$\frac{APPAREgeneration}{LPopulation} = \frac{APPAREgeneration}{LGreenEquity} \times \frac{LGreenEquity}{LPopulation} \quad (8)$$

Crossing out LGreenEquity from equation (4) yields the ratio LGreenDebt/LPopulation which is not new as it has already been found in equation (2) above.

$$\frac{APPAREgeneration}{LPopulation} = \frac{APPAREgeneration}{LGreenDebt} \times \frac{LGreenDebt}{LPopulation} \quad (9)$$

Crossing out LGreenDebt from equation (4) yields the ratio APPAREgeneration/LGreenEquity, which is not new as it has already been found in equation (8) above.

$$\frac{APPAREgeneration}{LPopulation} = \frac{APPAREgeneration}{LGreenEquity} \times \frac{LGreenEquity}{LPopulation} \quad (10)$$

After the presentation of the different equations for monitoring through green finance, it is now possible to discuss the role of these ratios for the Sustainable Energy Scenario. The importance of finance to attain the SDGs has been recognized since their negotiation and adoption in 2015. The 2015 Addis Ababa Action Agenda (AAAA), which is the financing arm of the UN 2030 Agenda for Sustainable Development, was adopted in 2015 by the UN General Assembly together with the Sustainable Development Goals themselves. The AAAA contained the pledge to mobilize USD100 billion of annual investment through market-based initiatives, partnerships and leveraging development banks. SDG13.a states the same figure. COP26 in Glasgow (2021) discussed ways to attain the USD100 billion target. These figures are far from stating the totality of the financing gap. The financing gap has been stated by both, the IEA and the IRENA in their landmark publications. Both organizations arrive at relatively similar figures.

The IEA Roadmap to Net Zero by 2050 for the Global Energy Sector[96] mentions that a jump from USD2.2 trillion (or 2.5% global GDP) to USD5 trillion (or 4.5 % global GDP) annually should take place during the present decade, and overall annual energy investment will then be kept at this comparatively higher level until 2050, but due to economic growth its share in global GDP will fall back to 2.5% by 2050.

The 1.5°C Scenario of the IRENA, outlined in its World Energy Transition Outlook WETO (see the IRENA contribution in the APEC Green Finance Report APEC Green Finance Report – unlocking the Urban Energy Transition)[97], demands an annual global investment of about 5% of global GDP. This is within the current capacity of global financial markets, which reached a volume of some USD200 trillion in 2019.

Municipal green bonds have been used by cities since about 2014[98]. On 11 January 2019, S&P launched a specific Green Municipal Bond Index[99]. The global volume of annually emitted municipal green bonds has stagnated in recent years around a level of about USD10 billion annually, as seen in the figure below. The role of multilateral development banks in the green bond market has recently been overtaken by financial and non-financial (e.g., property) corporate issuers. Note also the steadily rising part of sovereign emitters.

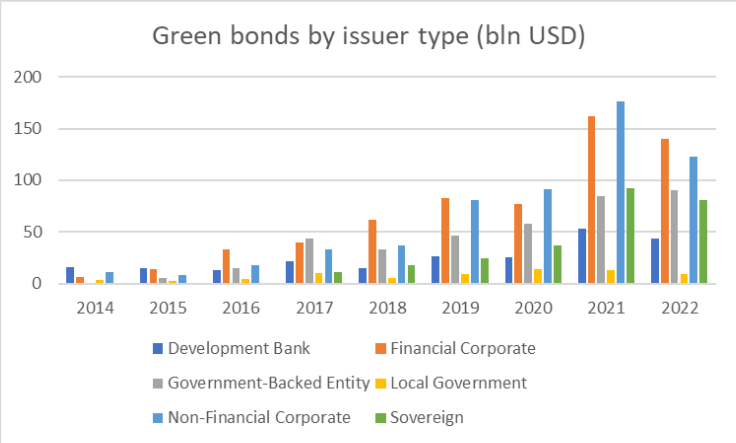


Figure 116: Annually issued green bonds by issuer category

Source: Climatebonds[100]

China has been active in promoting the use of green finance at provincial level. The Provincial Green Finance Index has been computed in 2020, showing a ranking of all Chinese provinces with respect to the use of green finance[101]. The evaluation shows a considerable disparity among Chinese provinces. Empirical research on the nexus between green finance and energy poverty eradication furthermore shows that in those provinces where some conditions are fulfilled, green finance accelerates the energy poverty eradication[102]. Chen and others (2021)[103] analysed the impact of green finance on carbon emissions of Chinese provinces. They found a double effect, direct and indirect, mostly through the development of scientific and technological innovation, and highlighted the disparities between the western and the eastern Chinese regions, depending on whether or not there is provincial policy support for green pathways. More specifically for Chinese cities, Xu and Li (2023)[104] show that green bonds significantly decrease carbon emissions of Chinese cities, that they improve green innovation of the green bond issuing cities, and that environmental legislation is a positive factor in cities' emissions mitigation, and that the effect is stronger in developed cities. A recent report by the World Economic Forum (2023) [105] lists all economies and jurisdictions who are known to have issued green municipal bonds, among these are: Australia; Canada; China; Hong Kong, China; Japan; Mexico; Peru; USA (for domestic and foreign investors) and Chinese Taipei (for foreign investors only). Particular examples are Toronto and San Francisco. Toronto has raised nearly USD1 billion through issuing green bonds.

As the above WEF survey shows, green bonds have been mainly issued by developed economies. In particular, no city in a Southeast Asian economy has issued green bonds yet. If green finance is to provide a significant source to finance the energy transition in developing economies, this could in particular be done by empowering cities of these economies to issue green finance securities. This empowerment should not only comprise the purely technical aspect of preparing the issuance of green finance securities, but also the necessary accompanying policies axed on the three following axes:

- development of scientific and technical innovation,
- local environmental policy, and
- public participation.

More importantly, cities are at the heart of promoting not only the issuance of green bonds (which have to be reimbursed), but also green equity (which does not have to be reimbursed). The IEA Roadmap 2050[106] has revealed the comparative lack of both, equity and public finance, in the new energy sector. Cities in developing APEC economies should, therefore, be privileged subjects who will create the local conditions for channelling more equity and more public funds towards green energy investments. A monitoring activity of the Sustainable Energy Scenario in cities of developing APEC economies could help increasing the focused type of policy support that is needed for the energy transition. The critical indicator to monitor in this regard is the debt-equity (D/E) ratio mentioned in the above equations.

For the general debt-to-equity ratio, investment advisors give an ideal value of 2.0 (i.e., 200%), meaning that the ideal industry would hold twice as much debt as equity[107]. Higher ratios show higher risk level of the enterprise or the sector. For the average industry in the US in the period 2012 to 2022, this ratio is at only 83%[108], showing a relatively safe level. Specific industries can have significantly different debt-to-equity ratios which are calculated year by year for listed enterprises. The 139 listed electricity, gas and sanitary services enterprises of the US had a debt-to-equity ratio of 2.01 in 2021, see table below.

Electricity, gas, sanitation	**2021**	**2020**	**2019**	**2018**	**2017**
Debt to equity ratio	2.01	2.02	1.93	1.75	1.72
Number of enterprises	139	142	152	172	200

Table 10: Debt-to-equity ratio of the US listed electricity, gas and sanitation enterprises

Source: ReadyRatios, SEC[109]

The ideal D/E for an average industry is around 200% (or 2.0), which, by coincidence, is close to the D/E ratio of the US electricity sector (see table above). Higher D/E ratios show higher risk of the sector. During growth, it is sometimes necessary for an industry to go through phases of higher risk higher D/E ratio. An increase of the D/E ratio diminishes also the return on assets (ROA) as debts have to be honoured and reimbursed. Conversely, a higher D/E ratio increases the return on equity (ROE) as the company bears higher risk which must be honoured by paying higher cost on new equity, as the self-explaining example below shows.

At present, no data is being collected to show the below figure for the green sectors of any APEC economy, nor for the green sectors of any other economy, region or city.

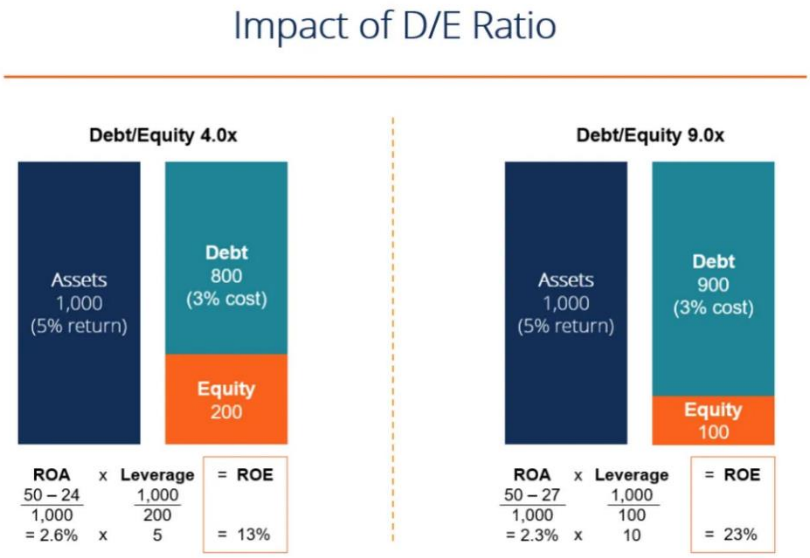


Figure 117: D/E ratio impacts return on assets (ROA) and return on equity (ROE)

Source: Corporate Finance Institute[110]

The examples above are based upon the assumption that assets have regular returns that can be forecasted. To achieve regular returns on renewable electricity investments, the instrument of choice is the power purchase agreement (PPA). A PPA or similar arrangement can ensure that an investment has regular long-term income.

As the APEC Green Finance Report (2023)[111] has shown, to close the SDG financing gap, innovative financing mechanisms and instruments should be used. One of them is the catalytic effect of equity. This effect consists of using so-called junior finance, especially grants, equity, and guarantees (including the Credit Risk Guarantees) to attract so-called senior finance (debts and bonds, which must be honoured and reimbursed). The D/E ratio is at the heart of the catalytic effect of equity. One way to use the catalytic effect of equity occurs when provinces or cities (including in less developed economies) provide junior finance, especially equity in a framework of public-private partnerships, together with de-risking instruments such as credit risk guarantees, to attract senior finance such as debts and bonds. The catalytic effect of equity describes the ratio of senior (private) debt attracted by a provider or consortium of providers of junior (public) debt.

An example of catalytic finance is mentioned in the APEC Green Finance Report (2023), see the contribution of the Green Climate Fund (GCF). The GCF has supported the Shandong Green Development Fund (SGDF). This project is part of the Beijing – Tianjin – Hebei area where the GCF provided catalytic funding for leveraging Private International Commercial (PIC) investors. Through catalytic funding of USD1.5 billion public funds, a sum of USD12 billion private funds has been leveraged, resulting in a catalytic factor of eight. A catalytic factor of this level is a remarkable result, which is not often attained. If public funds can be used as seed funds in this type of project to attract private funds in a scalable way to finance the Sustainable Energy Scenario, this achievement could contribute to the closing of the finance gap by means of a catalytic effect of public equity.

To conclude this description on monitoring, the figure below summarizes the six different monitoring dimensions described above. Local per capita renewable electricity generation is monitored 1) by local installed renewable electricity capacity, net PV area, gross PV area and 2) by local green sector value-added, local green sector employment and local GDP. Distant per capita renewable electricity generation is monitored by distant per capita renewable electricity capacity that is accessible and contracted by PPA, distant renewable energy capacity as well as by local transmission capacity. Total (local + distant) accessible per capita renewable electricity generation is monitored 1) by energy efficiency defined as ratio between local total primary energy supply and local GDP, 2) by accessible renewable energy storage, total energy storage, and local total final energy consumption, 3) by total (local + distant) installed capacity, local green debt and local green equity. Annex 7 outlines a draft questionnaire to cities allowing them to collect the 18 required independent data series.

$$\frac{DPPAREgeneration}{LPopulation} = \frac{DPPAREgeneration}{DPPAREcapacity} \times \frac{DPPAREcapacity}{DREcapacity} \times \frac{DREcapacity}{LTRMcapacity} \times \frac{LTRMcapacity}{LPopulation}$$

$$\frac{LREgeneration}{LPopulation} = \frac{LREgeneration}{LREcapacity} \times \frac{LREcapacity}{LPVnetarea} \times \frac{LPVnetarea}{LPVgrossarea} \times \frac{LPVgrossarea}{LPopulation}$$

$$\frac{LREgeneration}{LPopulation} = \frac{LREgeneration}{LGreenVA} \times \frac{LGreenVA}{LGreenEmpl} \times \frac{LGreenEmpl}{LGDP} \times \frac{LGDP}{LPopulation}$$

$$\frac{APPAREgeneration}{LPopulation} = \frac{APPAREgeneration}{LTPES} \times \frac{LTPES}{LGDP} \times \frac{LGDP}{LPopulation}$$

$$\frac{APPAREgeneration}{LPopulation} = \frac{APPAREgeneration}{AREstorage} \times \frac{AREstorage}{Totalstorage} \times \frac{Totalstorage}{LTFC} \times \frac{LTFC}{LPopulation}$$

$$\frac{APPAREgeneration}{LPopulation} = \frac{APPAREgeneration}{APPAREcapacity} \times \frac{APPAREcapacity}{LGreenDebt} \times \frac{LGreenDebt}{LGreenEquity} \times \frac{LGreenEquity}{LPopulation}$$

Figure 118: Synopsis of the six dimensions of per capita renewable energy monitoring

Source: APSEC

Some of the above ratios have been quantified and forecast at global level as part of the Sustainable Energy Scenario. The trajectories computed in the monitoring sections above are all part of the Sustainable Energy Scenario. They are summarized in the table below. The 2020 – 2030 step is designed to help cities monitor their pathway along the Sustainable Energy Scenario during the present decade. Given the great variety of departing situations among cities in 2020, the relative 2020 – 2030 step is better suited as monitoring indicator than absolute values.

Series	**2020 – 2030 step**	**Evolution by 2100**	**Probability of trajectory**
Renewable electricity generation/installed RE capacity (%)	-24% (decrease)	10% by 2050	>99% (alternative scenario)
Global renewable electricity intensity of GDP (kWh/constant 2015 USD)	Multiply by 2	1kWh renewable electricity / constant 2015 USD in 2046	>99%
Renewable electricity generation/manufacturing value-added (proxy), in kWh/constant 2015 USD	Multiply by 2.18	Strong growth	>98%
APEC employment value-added/employee, in constant USD/employee	Multiply by 1.3	USD160,000 /employee	>80%

Global employment in renewable electricity generation (proxy), (employees)	Multiply by 2.7	2 million employees in 2050	>98%
Global employment in RE generation (proxy) / GDP, (employees/million USD)	Multiply by 2	10 employees / million USD	>80%
Renewable electricity generation per employee in RE generation (proxy), (GWh/employee)	-16%	0.5GWh/employee in 2030	>99%
Per capita renewable employment (proxy) (employees/person)	Multiply by 2.5	Strong growth	>99%

Table 11: Summary of the globally quantified monitoring indicators

Source: APSEC

6. Conclusions

The present Final Report summarizes the APEC Project “Data Driven Carbon Neutral Disaster Resilient Cities”. The project has three outputs:

- A Training of Trainers held virtually in August 2023 to familiarize the planning officers of the North Sulawesi Province with the challenges of planning towards carbon neutrality with the involvement of local stakeholders.
- A 6-day Multistakeholder Dialogue (MSD) held in hybrid virtual-on-site mode in February 2024 in Manado, the Capital of the North Sulawesi Province, with the objectives of elaborating a long-term vision and setting three 2030 targets for the Province.
- The present Final Report which describes the process and lessons learnt in detail.

If there is one expression to best characterize the planning for carbon neutrality by cities and local planning authorities, it is the famous “think global act local”. Experience gained from the present project shows that preferably all local planners have constantly to draw all their inspiration from the global level. The main objective pursued with carbon neutrality is to mitigate global climate change by phasing out fossil fuels and replacing them by renewable energies.

One of the lessons learnt and confirmed through this project has been that the local level stakeholders do not easily understand the causalities and determinants of global climate change. They are much better equipped to analyse and address the impact of climate change in terms of local disasters. Anticipating this lesson, the present project mentions both, carbon neutrality and disaster resilience in its title.

A second lesson confirmed through this project is that we cannot manage what we cannot measure. The data scarcity of cities and local communities in terms of energy and climate data can be a real obstacle to set targets that can be monitored. Even though this lesson was known already before the start of the project, the collection of relevant data by means of surveys can be impeded by proprietary issues preventing data to be collected for local planning purposes.

In the case of North Sulawesi, the non-electricity energetic data are property of the local fossil fuel supplier. To overcome this proprietary issue and to receive relevant data at regional and local level, it may be necessary to create or strengthen the statistics legislation allowing collecting relevant data at all levels.

In the concrete case of North Sulawesi, the proprietary data issue prevents the dissemination of official data on final energy consumption. North Sulawesi final energy consumption has been estimated as a proxy, using the electricity consumption of North Sulawesi and the electricity share in total energy of Indonesia published by the IEA. The resulting per capita energy consumption is 4,969kWh/capita in 2019, the last pre-COVID-19 year. The local government should receive greater leverage for accessing the relevant data produced and owned by state-owned companies.

The Multistakeholder Dialogue (MSD) has proven to be an efficient tool to reach out to local stakeholders and involve them into discussions of a complex nature. This being understood that use of scientific data and expertise is also needed. It is, therefore, important to combine both these elements when planning carbon neutrality. The MSD successfully managed to combine both these elements and adopted a long-term Vision for carbon neutrality and disaster resilience as well as three targets for 2030. The MSD agreed to diminish final energy of the North Sulawesi Province by 2% (compared to -15% on global average), diminish emissions intensity by 36% (compared to -43% and +9% on global average, respectively, in the sustainable energy scenario or in the unsustainable scenario), and set two targets for the renewables share in final energy, namely 60% (or multiplication by 2.2) as high target and 53% (or multiplication by 1.96) as medium target (compared to multiplication by 2.4 on global average).

Local governments need to provide mechanisms for attracting international investors that bring about the energy transition towards carbon neutrality. This should become a key competence of those authorities in charge of foreign investment. The North Sulawesi Province could plan to hold an investor roundtable in February 2025, one year after the MSD was held.

Annex 1 – Vision for low-carbon development and disaster resilience in North Sulawesi Province

The North Sulawesi Province, Indonesia

A Vision for Carbon Neutrality and Disaster Resilience

From 21st – 23rd February 2024, the North Sulawesi Province, assisted by international and domestic partners acting within the framework of the APEC Project EWG 04 2022A, "Data Driven Carbon Neutral Disaster Resilient Cities", convened a Multistakeholder Dialogue (MSD) to Manado, Indonesia, which was also made available online to all APEC participants, to discuss a Vision for Carbon Neutrality and Disaster Resilience for the North Sulawesi Province. The MSD acted as consultative body chaired by Mrs. Syaloom H. D. Korompis (North Sulawesi Province Government) and comprised representatives from the North Sulawesi Government and its cities and regencies, development and planning offices (forestry, environment, disaster resilience, transportation, public works and settlements, statistics) and local stakeholders from universities, energy (PLN, PGE, Vena), telecommunication, finance, agriculture, food, and women's organizations. The MSD adopted the Vision for Carbon Neutrality and Disaster Resilience as stated hereafter and transmits it hereby to the North Sulawesi Province Government for decision on appropriate further actions it may take in view of giving it official status.

Purpose of the Vision

The purpose of this Vision is to guide the North Sulawesi Province towards Carbon Neutrality and Disaster Resilience. The Vision should be inspiring, energizing, hopeful, positive, clear, allow for tough decisions, guide decision-making and allocation of resources and create consistency. This Vision represents the common understanding and aspiration of MSD participants. The participants identified the following core values, sustainability challenges and measures addressing them, disaster threats and measures to improve disaster resilience.

Vision

Our Vision is to become a carbon neutral and disaster resilient province.

The **core values** of the North Sulawesi Province include Mapalus[1], sustainability, responsibility, transparency, innovative development, collaboration, political commitment, structural reforms and consistency.

[1] Mapalus is a traditional management related to knowledge transfer deeply embedded in the lives of families in Minahasa, Indonesia. Mapalus derives from two words which are "Ma" (each other) and "Palus" (helping).

Among the **sustainability challenges** currently encountered in the North Sulawesi Province, the most significant ones are:

- incomplete understanding, knowledge and awareness of sustainable energy development.
- Degradation of environmental quality and protection of natural resources and capital.
- Chronic poverty, health and wellbeing, and unsustainable lifestyles.
- Lack of social justice and lack of quality of life.
- Depletion of fresh and safe drinking water resources.
- Concerning government: inadequate levels of government commitment which can lead to limited fiscal support; policies and distortive incentives driving economic agents towards unsustainable business models.
- A lack of financial support from the public and private sectors; insufficient green and blue sector investment.
- Limited enforcement of rules.

Among the **measures addressing sustainability challenges**, the most important ones are:

- Using the polluter pays principle to pay for the introduction of the circular economy in all areas.
- international cooperation towards sustainable energy development and technology transfer.
- upskilling and capacity building to ensure mastering of new technologies.
- mobilization of green finance to accelerate innovation and scale up investment.
- adequate funding levels for public-private partnerships models.

The most important **disaster threats** facing the North Sulawesi Province are:

- at present, hydrometeorological disasters, in particular, floods, flash floods and landslides; in the future there is a risk of sea level rise, tropical windstorms, whirlwinds, droughts, extremes temperatures, forest fires and land erosion (including in coastal zones).
- geological disasters such as earthquakes, volcanic eruptions and

tsunamis.

- Technological disasters, including failures and outages of critical technology, infrastructure and systems.

The most important **measures to improve disaster resilience** of North Sulawesi Province are:

- better understanding of current and future disaster risks.
- disaster response plans, including early warning systems reaching all vulnerable population segments, technology support systems, and regular disaster response drills.
- preparation of comprehensive disaster vulnerability maps showing different vulnerability levels.
- disaster resilience strategies, as well as the establishment of codes of conduct for different levels of disaster resilience.
- stakeholder engagement in specialized voluntary or professional emergency response organizations.
- law enforcement on spatial planning, at the domestic, provincial, regency

and city levels.

- leadership commitment to disaster resilience.
- collaboration of stakeholders, including an appropriate and active role of the media for communication of relevant information.
- integration of disaster resilience as a lifestyle and community movement.

The participants discussed how their Province should react if it became certain that by mid-century the use of carbon-emitting fuels would be impossible without fully neutralizing their emissions. To answer this question and bearing in mind Sustainable Development Goals, participants specially identified the following strengths, weaknesses, opportunities and challenges of carbon neutrality of their Province:

The most important **strengths** driving the North Sulawesi Province towards carbon neutrality are:

- the increasing numbers of the workforce that work in areas critical to the sustainable energy transition.
- existing research and development cooperation (e.g., in the field of

sustainable energy).

- abundant renewable energy resources, especially solar, wind, hydropower, ocean energy (wave and tidal), geothermal and bio-energies.
- The readiness to implement local and regional energy transition strategies, as well as existing inter-local government relations enabling the exchange of knowledge between cities.

The most important **weaknesses** limiting the ability of the North Sulawesi Province to address carbon neutrality are:

- a lack of access to clean and emission-free technology.
- limited regulations and lack of law enforcement of certain regulations.
- limited public-sector driven efforts to reduce the use of high emission energy systems and fuels.
- a lack of incentives for producers that are willing to reduce their emissions.
- a lack of climate and energy data.

- the practice of using different definitions of energy and climate data (non-uniform definitions).
- limited awareness of low-carbon investment opportunities among the local private sector.

The most important **opportunities** arising from carbon neutrality for the North Sulawesi Province are:

- new green finance tools and sustainable financing opportunities created by the international community or by locals.
- higher GDP growth rates and higher job creation rates due to the introduction of carbon neutrality policies.
- improved collection, management and consistency of climate and energy data.
- improved coherence and completeness of decisions thanks to better energy and climate data.
- more environmentally friendly behavior induced by decentralized solar energy systems: reduced household waste, higher recycling rates,

reduced water consumption, increased use of public transport.

- domestic policies guiding towards carbon neutrality.
- improved alignment and collaboration among organizations working on carbon neutrality.
- higher prioritization of carbon neutrality at the local level.
- improving cooperation with other provinces and APEC economies to create a single climate and energy data system at the regional level.

The most important **challenges** posed by carbon neutrality to the North Sulawesi Province are:

- the challenge of both, phasing out fossil fuel infrastructure (coal power plants, internal combustion engines) and phasing in zero-carbon infrastructure (renewable electricity generation, electric vehicles and their charging infrastructure).
- the challenge of achieving a just energy transition.
- converting informal economies and integrating them into a formal low-carbon economy.

- lack of timely and publicly available emissions data, particularly from the industrial and the energy sector.
- lack of independent advice and analysis concerning carbon neutrality.
- lack of a designated government entity responsible for monitoring the progress towards carbon neutrality.

Participants also discussed whether the MSD should become a regular consultative body of their Province.

Annex 2 – 2030 targets on energy intensity, emissions intensity and renewables share

The North Sulawesi Province, Indonesia

2030 targets on energy intensity, emissions intensity and renewables share for the North Sulawesi Province

From 26th – 28th February 2024, the North Sulawesi Province, assisted by international and domestic partners acting within the framework of the APEC Project EWG 04 2022A, "Data Driven Carbon Neutral Disaster Resilient Cities", convened a Multistakeholder Dialogue (MSD) to Manado, Indonesia, which was also made available online to all APEC participants, to discuss 2030 targets on energy intensity, emissions intensity and renewables share for the North Sulawesi Province. The MSD acted as consultative body chaired by Mrs. Syaloom H. D. Korompis and Dr. Fransiscus Engelbert Manumpil (North Sulawesi Province Government) and comprised representatives from the North Sulawesi Government and its cities and regencies, development and planning offices and local stakeholders from universities, energy, telecommunication, finance, agriculture, food, and women's organizations. The MSD adopted the text on the three 2030 targets as stated hereafter and transmits it hereby to the North Sulawesi Province Government for a decision on appropriate further actions it may take in view of giving it official status.

The MSD first took note of the global evolution having taken place since 2010 in the areas of primary energy intensity (SDG 7.3.1.), final energy intensity, emissions intensity (understood for this purpose as CO2 emissions from energy activity), and renewables share in total final energy (SDG 7.2.1.). The analysis has been presented by Professor Steivan Defilla, APEC Sustainable Energy Center.

The MSD also took note that the UN SDGs contain the target 7.3 of doubling the speed of energy intensity, calling for stronger energy efficiency policies as measured in SDG indicator 7.3.1., and that, furthermore, APEC Leaders agreed in 2011 to diminish aggregate energy intensity by 45% between 2005 and 2035, and that APEC is on track to meet this objective which translates to 1.5% linear decrease of energy intensity per year.

The MSD furthermore took note that both, energy intensity as well as emissions intensity at global level have been steadily decreasing since the 1960s, and that global renewables share increased from 4% to 7% (2010 to 2020) and is expected to increase to 16% in 2030 (>99.9% probability of the trajectory as a function of its data, calculated by APSEC).

World	2010	2020	2030 scenario	2020 - 2030 change (%)
SDG 7.3.1. Primary energy intensity (kWh/ constant 2015 USD)	2.349	2.028	1.737	-14%
Final energy intensity (kWh/ constant 2015 USD)	1.581	1.356	1.147	-15%
Emissions intensity (gCO2/ constant 2015 USD), sustainable energy scenario	494	408	233	-43%
Emissions intensity (gCO2/ constant 2015 USD), unsustainable scenario	494	408	345	-15%
SDG 7.2.1. Renewables share in TFC (%)	4%	7%	16%	9%

The MSD also took note of the specific evolution having taken place since 2010 in Indonesia, in the areas of primary energy intensity (SDG 7.3.1.), final energy intensity, CO2 emissions from energy (BAU, unconditional mitigation scenario CM1 and conditional mitigation scenario CM2), GDP, the corresponding CO2 emissions intensity (BAU, CM1, CM2) and the renewables share in total final energy (SDG 7.2.1.). This analysis has been presented by Prof Steivan Defilla, APSEC.

Indonesia	2010	2020	2030 target or scenario	2020 - 2030 change (%)
SDG 7.3.1. Primary energy intensity (kWh/constant 2017 PPP USD)[1]	1.18	0.87	0.74	-15%
CO2 emissions from energy (million tons) (BAU)[2]	453	606	1669	175%
CO2 emissions from energy (million tons) (CM1)	453	606	1311	116%
CO2 emissions from energy (million tons) (CM2)	453	606	1223	102%
GDP Indonesia (in billion constant 2015 USD)[3]	658	1030	1607	56%
Emissions intensity BAU (gCO2/USD)	688	588	1039	77%
Emissions intensity CM1 (gCO2/USD)	688	588	816	39%
Emissions intensity CM2 (gCO2/USD)	688	588	761	29%
7.2.1. Renewables share in TFC (%)[4]	36%	22%		

[1] Data source: https://indonesia.un.org/en/sdgs/7/progress, MJ converted to kWh; 2030 estimated as 85% of 2020 value.
[2] Data source: 2010: Enhanced NDC from Indonesia; 2020 emissions: Our World in Data Indonesia Country Profile https://ourworldindata.org/co2/country/indonesia
[3] Data source: World Bank. 2030 Scenario by APSEC using World Bank Data
[4] Data source: https://indonesia.un.org/en/sdgs/7/progress

Concerning Indonesia, the MSD noted that primary energy intensity was decreasing as it does in the rest of the world, that the updated NDC submitted by Indonesia provides for 175% (BAU), 116% (CM1) and 102% (CM2) increase in the 2020 – 2030 period, that GDP for 2030 was forecast to increase by 56% (2020 – 2030), and that the resulting emissions intensity increase was 77% (BAU), 39% (CM1), 29% (CM2), respectively, and that the renewables share had decreased from 36% to 22% (2010-2020), contrary to the rest of the world where it increased. The MSD noted that while past energy and emissions intensities in Indonesia both steadily declined, projected future emissions intensities seemed to strongly increase in all scenarios, pointing to a decreasing future level of energy efficiency.

The MSD took note of the specific evolution of the North Sulawesi Province since 2012 or 2014, respectively, in the areas of final energy intensity, emissions intensity and renewables share in total final energy (SDG 7.2.1.). This analysis has been presented by Dr. Hizkia Tasik from Sam Ratulangi University. MSD decided to consider the renewable electricity share targets adopted by the Regional General Energy Plan (RUED): 38% by 2025, 52% by 2030 and 67% by 2050. MSD also took note of the RUPTL renewables electricity share target of 50% by 2030 for the whole of the Sulawesi Island (all six provinces together).

As data on total final energy consumption (TFC) of North Sulawesi is not available, it has been estimated based on the North Sulawesi electricity consumption and the electricity share of TFC of Indonesia given by the IEA[5]. The MSD had agreed on a 2% reduction of final energy intensity by 2030.

North Sulawesi	2012	2021	2030 target	2020 - 2030 change (%)
Final energy intensity (kWh/thousand constant 2010 IDR)	0.199	0.131	0.128	-2%
Emissions intensity (gCO2/thousand constant 2010 IDR)	26	14	9	-38%
SDG 7.2.1. Renewables share in TFC (%) original proposal	47%	27%	59%	32%
SDG 7.2.1. Renewables share in TFC (%) high target	47%	27%	60%	33%
SDG 7.2.1. Renewables share in TFC (%) medium target	47%	27%	52%	25%
Remarks concerning renewable electricity share	(2014)	41% (2023)	50% (Sulawesi)	

[5] https://www.iea.org/countries/indonesia/energy-mix

Based on the information and trends shown in the above tables, and after discussion of these aspects in the MSD, the MSD decided to adopt the following 2030 targets for the North Sulawesi Province:

Final energy intensity:	0.128 kWh/ thousand constant 2010 IDR equivalent to 128 kWh/million constant 2010 IDR.
Emissions intensity:	9 gCO_2/thousand constant 2010 IDR equivalent to 0.009 tCO_2/million constant 2010 IDR.
Renewables share in TFC:	60% (high target) 52% (medium target)

Annex 3 – Methodology for 2030 target definition

The 2030 targets include energy intensity (in kWh/million constant 2010 IDR), emission intensity (in tCO2/million constant 2010 IDR), and renewable shares (in percentage). The energy intensity is derived from the ratio of final energy consumption in kilowatt hours to gross domestic product in million constant 2020 Indonesian Rupiahs. The emission intensity is derived from the ratio of total carbon dioxide emitted from the energy sector in tonnes of carbon dioxide equivalent to gross domestic product in million constant 2020 Indonesian Rupiahs. Meanwhile, the renewable shares are calculated by dividing all electricity generated from renewable sources by total electricity generated multiplied by one hundred percent.

The data used to calculate the 2030 targets for North Sulawesi Province comes from various sources. All the data used is at the provincial level. The North Sulawesi energy consumption data from 2012 to 2022 was obtained from Indonesian State Electricity Company (PLN). The North Sulawesi emission data available was from 2012 to 2016, and 2019. The data was obtained from the Ministry of Environment and Forestry. The North Sulawesi renewable share data from 2014 to 2022 was obtained from the Ministry of Energy and Mineral Resources. The actual data (2012 – 2022 period) and the forecasted data (2023 – 2030 period) of energy intensity are shown in Figure 119, while the actual data (2012 – 2022 period) and the forecasted data (2023 – 2030 period) of emission intensity are shown in Figure 120.

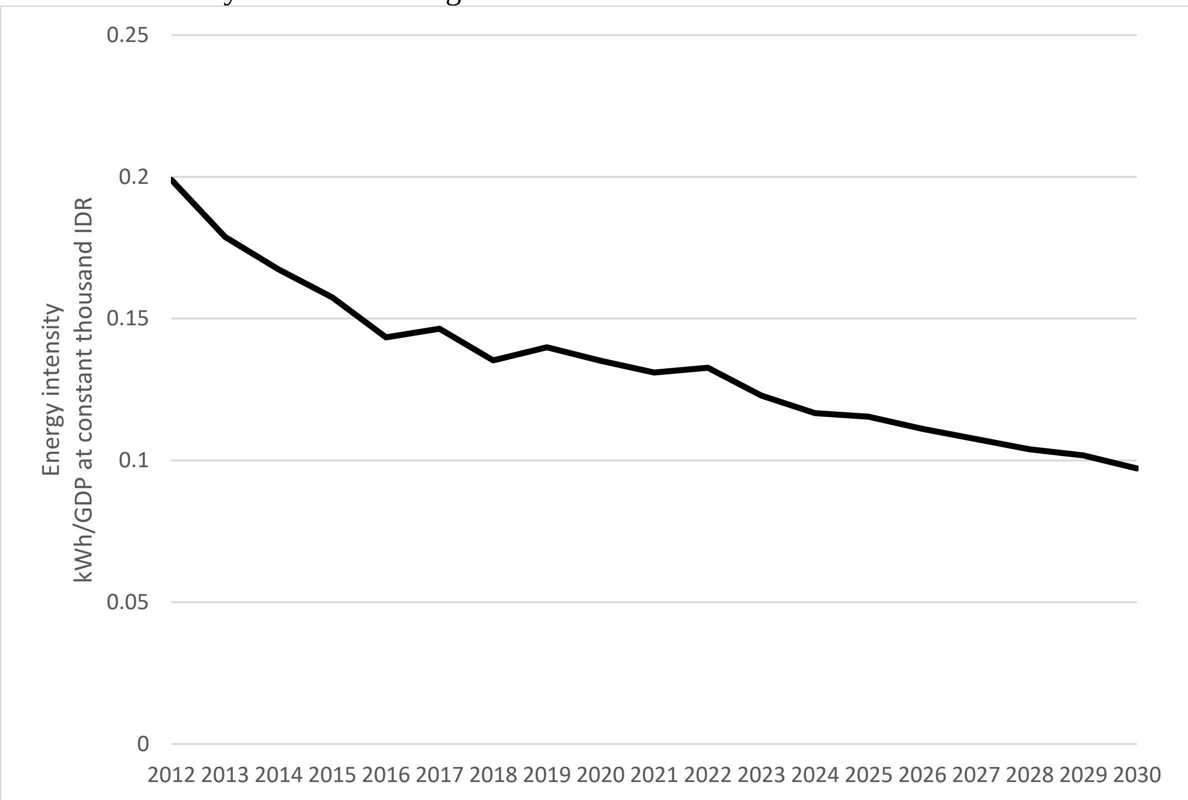


Figure 119: North Sulawesi energy intensity (2012 – 2030)

The energy intensity of 2023 – 2030 period is forecasted using Cross Section Regression Model with $p<0.05$. The data was obtained from Indonesian State Electricity Company (PLN).

Unlike the series of energy consumption data and renewable shares data that were adequate for a forecast, the emission data was missing from 2017 to 2018, and from 2020 to 2022 which enforced the need to fill the missing years. The data for the missing years were calculated by taking a 3-year moving average of the past data right before the missing year. After completing the data for all the necessary years, the 2030 targets calculation can be executed using exponential smoothing forecast model.

To calculate the 2030 targets, a forecast for each series of data required was taken. The forecast was made for the final energy consumption, emission, and renewable shares based on the actual data available. The forecast was established based on the pattern of the past data. Shortly speaking, the model chosen to project the future data was the one that was able to mimic the patterns of the past data. For that reason, all the available models were used to predict the past data which then were compared to the actual past data. The model that produced values closest to the actual data was chosen.

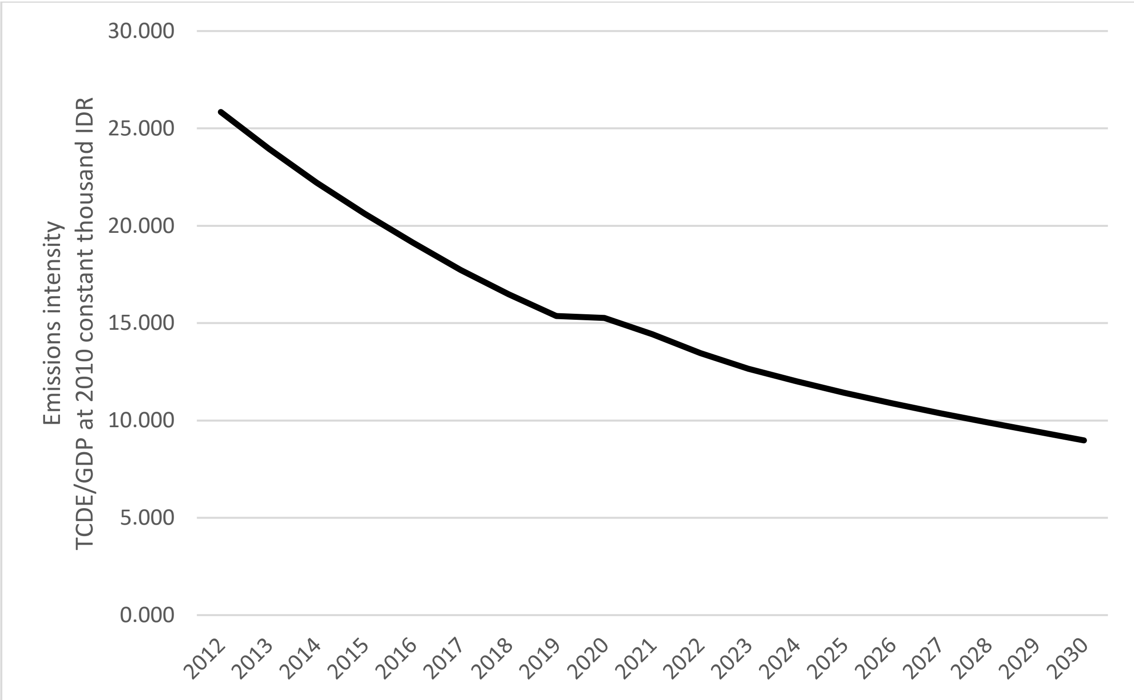


Figure 120: North Sulawesi Province emissions intensity

Note: The emissions intensity of 2023 – 2030 period is forecasted using Cross Section Regression Model with $p<0.05$. The data was obtained from the Ministry of Environment and Forestry, Republic of Indonesia.

Based on the distribution of the actual data, there were several assumptions needed to make the forecast. Firstly, with respect to the energy consumption and the emission models, it is assumed that there is a linear relationship between the year and the energy consumption, as well as between the year and the emission. This assumption can only be made when the actual data conveys a linear relationship between both variables. It is also assumed that the use of a 3-year moving average is sufficient to fill the gap of the actual data of emission which is the missing data.

The moving average formula used is $A_f = \frac{A_{f-3}+A_{f-2}+A_{f-1}}{3}$, where A_{f-3}, A_{f-2} and A_{f-1} are the data of the $f-3$, $f-2$, and $f-1$ respectively, while f is the year of the forecasted data A_f. Additionally, the periods of the missing data are short, namely, 2-year period of 2017 - 2018, and 3-year period of 2020 - 2022. Using a 2-year moving average may not be sufficient since the period of the missing data is longer than the number of years used for the moving average calculation. A 2-year moving average may also be insufficient to capture the variations of the past data. On the other hand, using a 4-year period or longer period may capture too many variations of the past data which may not be necessary as the A_{f-4} data may be too far to mimic the A_f data. Secondly, with respect to the renewable shares model, the relationship between the year and the renewable shares data conveys a non-linearity. Instead, it appears to be an exponential relationship. Therefore, to make the forecast, it is assumed that the relationship between both variables is exponential.

That said, the model used to forecast the final energy consumption values for the 2023 – 2030 period, and the emission values for the same period is a cross-section regression model of $y_i = \beta_0 + \beta_1 x_{1i} + \varepsilon$, where y_i is the energy consumption or emission, x_{1i} is the year, β_0 is the intercept, and $\beta_1$is the coefficient. To forecast the GDP values for the same period, the cross-section regression model was also applied. On the other hand, the model used to forecast the renewable shares values for the 2023 – 2030 period is an exponential smoothing model. The exponential smoothing forecast model of $y_{t+1|t} = \beta_0 yt + \beta_0(1 - \beta_{0_{yt}} - 1 + \beta_0(1 - \beta_0)^2 yt - 2 + \cdots$ allows the model to bind larger weights to more current observations than to ones from the distant past, where $0 \leq \beta_0 \leq 1$ is the smoothing parameter. The one-step-ahead forecast for time $t + 1$ is the weighted average of all observations in the series $y_1, \dots, y_t$. In this case, the forecasts are calculated using weighted averages, where the weights decrease exponentially as observations come from further in the past. The rate at which the weights decrease is controlled by the parameter β_0. The smallest weights are linked with the oldest observations. The actual data (2012 – 2022 period) and the forecasted data (2023 – 2030 period) of renewable shares are shown in Figure 121.

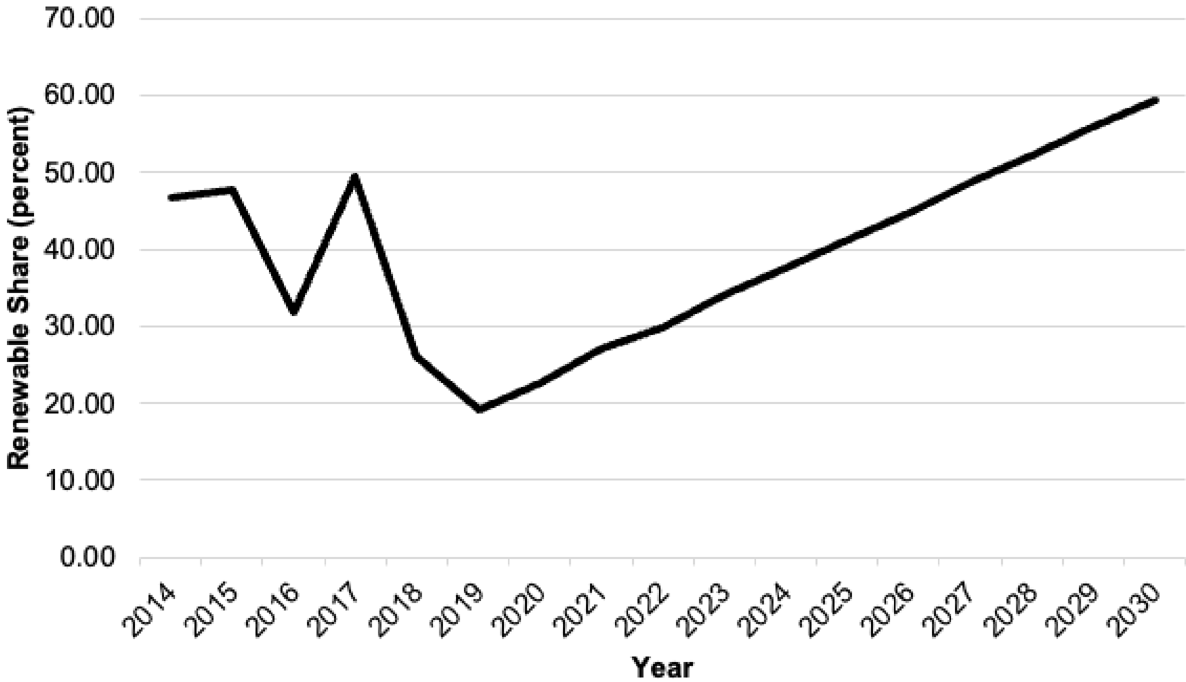


Figure 121: North Sulawesi Province renewable energy share.

Applying the models using the provided data is simple. For the moving average calculation, if there is missing data and the period of missing data is 3 years, one is suggested to use a 3-year moving average. However, one must make sure that the past actual data is sufficient to forecast the missing data. By sufficiently, the past actual data must be available for the past 3 years prior to the forecasted year. For the cross-section regression, one can use any statistical packages to run a regression of energy consumption variable with respect to year variable, as well as a regression of emissions variable with respect to year variable.

On the other hand, one can use any statistical package or spreadsheet software to use the exponential smoothing forecast model when the software features the exponential forecast model. When the feature is not available, one can use the forecast model above as the formula to be inserted in the cell of the spreadsheet software.

After using the forecast models suitable for each series of data, energy intensity, emission intensity, and renewable shares for the 2023- 2030 period can then be calculated. The 2030 energy intensity target is 97.17kWh/million constant 2010 IDR. It is equivalent to 0.097kWh/thousand constant 2010 IDR. Meanwhile, the 2030 emissions intensity target is 0.009t CO_2/million constant 2010 IDR, which is equivalent to 9g CO_2/thousand constant 2010 IDR. The 2030 renewable shares target is 59.45 percent. To provide more rooms to reach the renewable shares target, the forecasted 59.45 percent proposed forecasted target is accompanied by two other targets proposed in the MSD. The first one being the medium target of 52 percent and the second one being the high target of 60 percent.

Annex 4 – MSD Agenda

ANNEX I

AGENDA (DRAFT)

MSD Session 1 (Day 1)

21st February 2024, 08:30–17:00 (Beijing, Manila, Manado Indonesia, GMT+8)

08:00 – 08:30	Registration of participants and connectivity test for online speakers		
	Welcome remarks		
08:30 – 09:00 (30 min)	Welcome remarks by Fransiscus Maindoka, North Sulawesi Province Government Chrisnawan Anditya, Representative of the Ministry of Energy and Mineral Resources MEMR Steivan Defilla, APEC Sustainable Energy Center Craig Menzies, Global Factor. Overview of the MSD Session 1 objectives and programme		
09:00 – 09:15	**Group photo**		
09:15 – 10:30 (75 min.)	Adoption of the MSD programme Agenda Introducing the MSD: Purpose, procedural approach, housekeeping rule and expected outcomes Session moderated by Wydia Masengi (N. Sulawesi Province Gov), assisted by Global Factor		
10:30 – 10:45	**Coffee break**		
10:45 – 11:15 (30 min.)	Summary of the outcomes of the Training of Trainer event (August 2023) & Presentation of the draft text of a carbon neutrality vision for North Sulawesi Province Session moderated by Craig James Menzies (Global Factor)		
11:15 – 11:30 (15 min.)	Initial feed-back by the North Sulawesi Province Government on the Draft text of the Vision		
11:30 – 12:15 (45 min.)	Stakeholder Short Introductory Statements concerning the vision (3 minutes each)/MSD participants Session moderated by Wydia Masengi (N. Sulawesi Province Gov), assisted by Global Factor		
12:15 – 13:30	**Lunch break**		
13:30 – 15:30 (120 min.)	**Title of presentation**	**Organization**	**Speaker and time zone**
	Climate Smart Philippines	Environmental and Climate Change Research Institute	Glenn Banaguas (GMT+8)
	Hong Kong, China 2050 vision and planning for low-carbon development	Government of Hong Kong, China	Lee Ho Fung (GMT+7)
	Solar energy planning and community engagement in Victoria State, Australia	Department of Energy, Environment and Climate Action, Government of Victoria State (Australia)	Stan Krpan (GMT +10)
	Q&A and open discussion with participants. Moderated by Joseph Viandrito (Global Factor)		
15:30 – 15:45	**Coffee break**		
15:45 – 16:45 (60 min.)	General comments by stakeholders on the draft text of the carbon neutrality vision Moderated by Joseph Viandrito, Global Factor		
16:45 – 17:00 (15 min)	Closure of the MSD Session 1, Day 1 and Group photo		
	Group photo		
	End of Day 1		

1

MSD Session 1 (Day 2)

22st February 2024, 08:30–17:00 (Beijing, Manila, Manado Indonesia, GMT+8)

08:00 – 08:30	Registration of participants and connectivity test for online speakers		
08:30 – 08:45 (15 min.)	Welcome and introductory remarks from the moderator Overview of the objectives and agenda of day 2 of MSD session 1: Discussion of a comprehensive vision for a data driven, carbon neutral and disaster resilient future		
08:45 – 09:00	**Group photo**		
09:00 – 10:30 (90 min).	**Title of presentation**	**Organization**	**Speaker and time zone**
	The Communal town plan 2020 – 2024 of Temuco City, Chile	Environment Department of Temuco City Municipal Government, Chile	Patricio Figueroa Espindola (GMT -4)
	Practical approaches to the use of Multi-Stakeholder Dialogue and ensuring successful outcomes	Carbon Neutral Cities Alliance	Michael Shank (GMT -6)
	Q&A and interactive and open discussion with participants Moderated by Craig James Menzies, Global Factor		
10:30 – 10:45	**Coffee break**		
10:45 – 12:30 (120 min.)	First detailed discussion on the first five points of the draft text on the carbon neutrality vision for North Sulawesi Province / MSD participants • The Province's overarching purpose • The Province's 3 to 5 core values • The Province's 3 to 5 biggest current sustainability challenges • The Province's 3 to 5 most important measures addressing sustainability • The Province's 3 to 5 biggest current disaster threats Chaired by Syaloom H. D. Korompis, North Sulawesi Province Government, assisted by Global Factor		
12:30 – 13:30	**Lunch break**		
13:30 – 15:00 (90 min.)	**Title of presentation**	**Organization**	**Speaker and time zone**
	Long-term planning for energy sector decarbonization in Indonesia	National Planning and Development Agency, Government of Indonesia	Dr. Dedi Rustandi (GMT +7)
	Metro Manila Greenpoint 2030	Metropolitan Manila Development Agency	Ms Shiela Gail Satura (GMT +7)
15:00 – 15:15	**Coffee break**		
15:15 – 17:00 (105 min.)	First detailed discussion of the second five points of the draft text on the carbon neutrality vision for North Sulawesi Province / MSD participants • The Province's 3 to 5 most important measures improving disaster resilience • The Strengths of Province to address Carbon Neutrality • The Province's weaknesses to address Carbon Neutrality • The opportunities for the Province arising from Carbon Neutrality • The challenges to the Province posed by Carbon Neutrality Chaired by Syaloom H. D. Korompis, North Sulawesi Province Government, assisted by Global Factor		
Group photo			
End of Day 2			

MSD Session 1 (Day 3)

23rd February 2024, 08:30–17:00 (Beijing, Manila, Manado Indonesia, GMT+8)

08:00 – 08:30	Registration of participants and connectivity test for online speakers
08:30 – 08:45 (15 min.)	Introductory remarks from the moderator Overview of the objectives and agenda of Day 3 of MSD session 1: Discussion of a comprehensive vision for a data driven, carbon neutral and disaster resilient future
08:45 – 09:00	**Group photo**
09:00 – 10:15 (75 min)	Second and final detailed discussion of the first five points of draft text of the carbon neutrality vision for North Sulawesi Province / MSD participants • The Province's overarching purpose • The Province's 3 to 5 core values • The Province's 3 to 5 biggest current sustainability challenges • The Province's 3 to 5 most important measures addressing sustainability • The Province's 3 to 5 biggest current disaster threats Chaired by Syaloom H. D. Korompis, North Sulawesi Province Government, assisted by Global Factor
10:15 – 10:30	**Coffee break**
10:30 – 11:30 (60 min.)	Second and final detailed discussion of the second five points of the draft text of the carbon neutrality vision for the North Sulawesi Province / MSD participants • The Province's 3 to 5 most important measures improving disaster resilience • The Strengths of Province to address Carbon Neutrality • The Province's weaknesses to address Carbon Neutrality • The opportunities for the Province arising from Carbon Neutrality • The challenges to the Province posed by Carbon Neutrality Chaired by Syaloom H. D. Korompis, North Sulawesi Province Government, assisted by Global Factor
11:30 – 13:30	**Prayer & Lunch**
13:30 – 15:30 (120 min.)	Adoption by the MSD of the text of a comprehensive vision for a data driven, carbon neutral and disaster resilient future for the North Sulawesi Province Stakeholder remarks Chaired by Syaloom H. D. Korompis, North Sulawesi Province Government, assisted by Global Factor
15:30 – 15:45	**Coffee break**
15:45 – 17:00 (75 min.)	Additional time available for further discussion of the vision (if required). Closure of the MSD Session 1: Summary of sessions, outcomes and agreements. Overview of the MSD Session 2. (Craig Menzies, Global Factor) Group Photo
Group photo	
End of Day 3	

MSD Session 2 (Day 1)

26th February 2024, 08:30–17:00 (Beijing, Manila, Manado Indonesia, GMT+8)

<table>
<tr><td>08:00 – 08:30</td><td colspan="3">Registration of participants and connectivity test for online speakers</td></tr>
<tr><td>08:30 – 09:00
(30 min.)</td><td colspan="3">Opening address by Joune Ganda, Regent of North Minahasa Regency
Syaloom H. D. Korompis, North Sulawesi Province Government
Adoption of the MSD 2 Session Agenda & Overview of the MSD Session 2 objectives, programme and housekeeping rules (Craig James Menzies, Global Factor)</td></tr>
<tr><td colspan="4">Group photo</td></tr>
<tr><td rowspan="5">09:00 – 10:45
(120 min.)</td><td>Title of presentation</td><td>Organization</td><td>Speaker and time zone</td></tr>
<tr><td>Technological solutions for carbon neutral and climate resilient cities</td><td>World Smart Cities Foundation</td><td>Jaewon Peter Chun (GMT -6)</td></tr>
<tr><td>Energy needs of decent living standards</td><td>IIASA</td><td>Dr Jihoon Min (GMT-7)</td></tr>
<tr><td>Technological solutions and public planning for sustainable transportation in Hong Kong, China</td><td>Hong Kong University</td><td>John Ure (GMT +7)</td></tr>
<tr><td colspan="3">Q&A and interactive and open discussion with participants, moderated by Joseph Viandrito, Global Factor</td></tr>
<tr><td>10:45</td><td colspan="3">Signature of the CNSC Declaration by Dr Arsipan Nani, Mayor of Kotamobagu</td></tr>
<tr><td>10:45 – 11:00</td><td colspan="3">Coffee break</td></tr>
<tr><td>11:00 – 11:15</td><td>The Dynamic Global Context of the 21st Century</td><td>APEC Sustainable Energy Center</td><td>Prof. Steivan Defilla (GMT+8)</td></tr>
<tr><td>11:15 – 12:00</td><td colspan="3">Stakeholder Short Introductory Statements on the proposed 2030 targets (3 minutes each)/MSD participants
Chaired by by Syaloom H. D. Korompis, North Sulawesi Province Government, assisted by Global Factor</td></tr>
<tr><td>12:00 – 13:00</td><td colspan="3">Lunch break</td></tr>
<tr><td>13:00 – 14:00
(60 min.)</td><td colspan="3">Expert speaker presentation: North Sulawesi, trends in the local population, GDP, energy, emissions, and renewable energy
Summary presentation of the draft text on 2030 targets on energy intensity, GHG emissions intensity and renewables share for the North Sulawesi Province
Dr Hizkia Tasik (Sam Ratulangi University)</td></tr>
<tr><td>14:00 – 14:15
(15 min.)</td><td colspan="3">Initial feed-back by the North Sulawesi Province Government on the draft text on 2030 targets on energy intensity, GHG emissions and renewables share for the North Sulawesi Province</td></tr>
<tr><td>14:15 – 14:30</td><td colspan="3">Coffee break</td></tr>
<tr><td rowspan="4">14:30 – 17:15
(45 min.)</td><td>Just Energy Transition Partnership (JETP)</td><td>ICRES</td><td>Paul Butarbutar</td></tr>
<tr><td>Energy needs of decent living standards, from a climate planning perspective</td><td>Imperial College London</td><td>Dr Jarmo Kikastra (GMT +0)</td></tr>
<tr><td>Carbon Neutrality Planning and Monitoring for Local and Regional Governments</td><td>APEC Sustainable Energy Center</td><td>Prof. Steivan Defilla (GMS+8)</td></tr>
<tr><td>Doubling global progress on energy efficiency</td><td>IEA Southeast Asia Energy Efficiency Policy Analyst</td><td>Natalie Kauf (GMT+1)</td></tr>
<tr><td>17:15 – 17:30
(15 min.)</td><td colspan="3">Closure of the MSD Session 2, Day 1
Group Photo</td></tr>
<tr><td colspan="4">Group photo</td></tr>
</table>

MSD Session 2 (Day 2)

27th February 2024, 08:30–17:00 (Beijing, Manila, Manado Indonesia, GMT+8)

08:00 – 08:30 (30 min.)	Registration of participants and connectivity test for online speakers		
08:30 – 09:00 (30 min.)	Overview of the objectives and Agenda of Day 2 of MSD Session 2: Discussion of the text on 2030 targets on energy intensity, GHG emissions intensity and renewables share for the North Sulawesi Province Craig James Menzies, Global Factor Group photo		
Group photo			
09:00 – 10:00 (60 min.)	Detailed discussion of the proposed energy intensity target: Presentation of the proposed 2030 energy intensity target / Dr Hizkia Tasik (Sam Ratulangi University) Detailed discussion of the proposed energy intensity target / MSD participants Chaired by Syaloom H. D. Korompis, North Sulawesi Province Government, assisted by Global Factor		
10:00 – 10:15	**Coffee break**		
10:15 – 11:15 (60 min.)	Detailed discussion of the proposed carbon intensity target: Presentation of the proposed 2030 carbon intensity target / Dr Hizkia Tasik (Sam Ratulangi University) Detailed discussion of the proposed carbon intensity target / MSD participants Chaired by Syaloom H. D. Korompis, North Sulawesi Province Government, assisted by Global Factor		
11:15 – 12:00	**Title of presentation**	**Organization**	**Speaker and time zone**
	Renewable energy potential of North Sulawesi	North Sulawesi Province	Mrs. Widya Masengi
12:00 – 13:00	**Lunch break**		
13:00 – 15:15 (135 min.)	**Title of presentation**	**Organization**	**Speaker and time zone**
	The Role of Renewable Energy for Security, Energy Security and Disaster Resilience	Republic of Indonesia Defense University (RIDU)	Dr. Drs. Tatar Bonar Silitonga, M.Si
	Solar and wind energy in North Sulawesi	Vena Energy Indonesia	Mr. Daddy Krishananto, Operation & Maintenance Manager
	Geothermal energy in North Sulawesi	PT PGE Tbk Area Lahendong	Mr. Firman Johannes Simanullang, Assistant Manager Production
	Hydropower in North Sulawesi	PLTA Tonsealama PLN	Mr. Aminudin Wahib, Manager
15:15 – 16:15 (60 min.)	Detailed discussion of the proposed renewables share target: Presentation of the proposed 2030 renewables share target / Dr Hizkia Tasik (Sam Ratulangi University) Detailed discussion of the proposed renewables share target / MSD participants Chaired by Syaloom H. D. Korompis, North Sulawesi Province Government, assisted by Global Factor		
16:15 – 16:30	**Coffee break**		
16:30 – 17:00 (30 min.)	Identification of problems and disagreement gaps for the three targets Chaired by Syaloom H. D. Korompis, North Sulawesi Province Government, assisted by Global Factor		
17:00 – 17:15 (15 min.)	Wrap up of the progress achieved and progress gaps still to be bridged Closure of the MSD Session 2, Day 2 Group Photo		
Group photo			
End of Day 2			

MSD Session 2 (Day 3)

28th February 2024, 08:30–17:00 (Beijing, Manila, Manado Indonesia, GMT+8)

08:00 – 08:30 (30 min.)	Registration of participants and connectivity test for online speakers
08:30 – 09:00 (30 min.)	Overview of the objectives and Agenda of Day 3 of MSD Session 3: Discussion of the text on 2030 targets on energy intensity, GHG emissions intensity and renewables share for the North Sulawesi Province Craig James Menzies, Global Factor Group photo
	Group photo
09:00 – 09:30 (30 min.)	Presentation of possible solutions to the outstanding problems and gaps Craig Menzies / Joseph Viandrito (Global Factor) / Dr Hizkia Tasik (Sam Ratulangi University)
09:30 – 10:30 (60 min.)	Discussion of the proposed solutions to the outstanding problems Chaired by Syaloom H. D. Korompis, North Sulawesi Province Government, assisted by Global Factor
10:30 – 10:45	**Coffee break**
10:45 – 12:00 (75 min.)	Session available for further discussion on outstanding problems of the text on 2030 targets on energy intensity, GHG emissions intensity and renewables share for the North Sulawesi Province, if required. Adoption by the MSD of the text on 2030 targets on energy intensity, GHG emissions intensity and renewables share for the North Sulawesi Province Chaired by Syaloom H. D. Korompis, North Sulawesi Province Government, assisted by Global Factor
12:00 – 13:15	**Lunch break**
13:15 – 14:15 (60 min.)	Session available for further discussions on proposed targets, if required. Adoption by the MSD of the text on 2030 targets on energy intensity, GHG emissions intensity and renewables share for the North Sulawesi Province Information on the possible actions of the North Sulawesi Province Government in view of officializing the text of the carbon neutrality vision and the text of the 2030 targets. Chaired by Syaloom H. D. Korompis, North Sulawesi Province Government, assisted by Global Factor
14:15 – 14:30	**Coffee break**
14:30 – 16:30 (120 min.)	High-level policy consultations and discussion on the use of MSD as a permanent consultative forum for North Sulawesi Province for managing the pathway towards carbon neutrality Chaired by Dr. Fransiscus Engelbert Manumpil, North Sulawesi Province Government, assisted by Global Factor
16:30 – 17:00 (30 min.)	Closure of the MSD Session (Moderated by Mr. Craig Menzies, Global Factor) Closing session address: Paul Butarbutar (Advisory Board Member APEC Sustainable Energy Center) Closing session address: Syaloom H. D. Korompis, North Sulawesi Province Government Group photo
	Group photo
	End of MSD event
After 17:00	Release of both documents (Vision and Targets) to the public. Press conference / media event

Annex 5 – Overview of MSD participants' profile

The following is a short summary of the profile of MSD participants, including their profession group and level of previous experience in local planning processes.

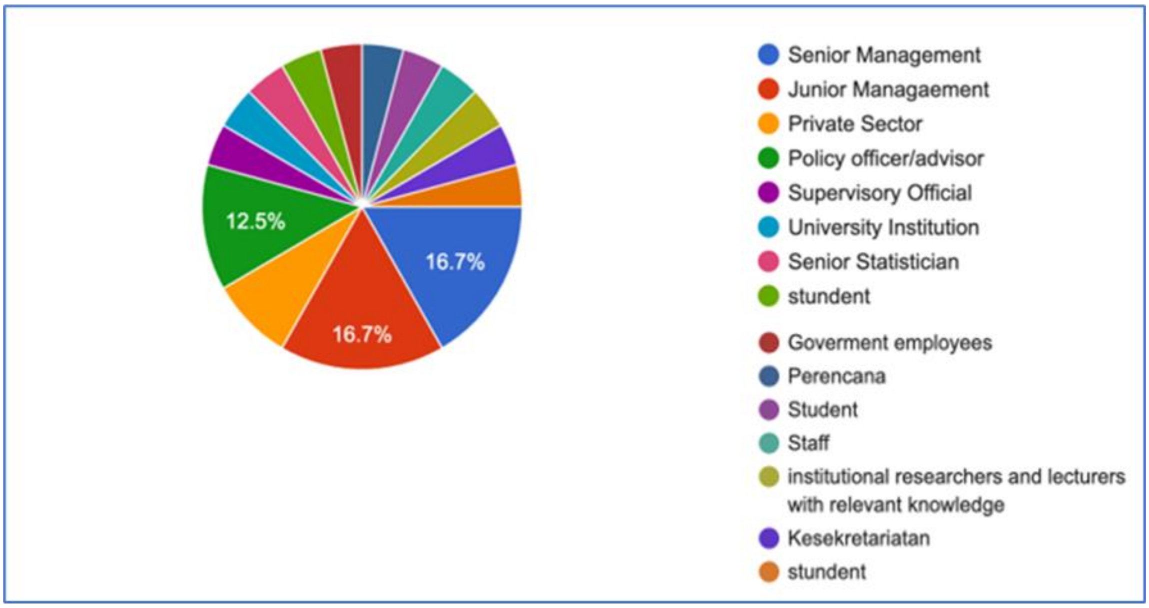


Figure 122: MSD participants' profiles by category

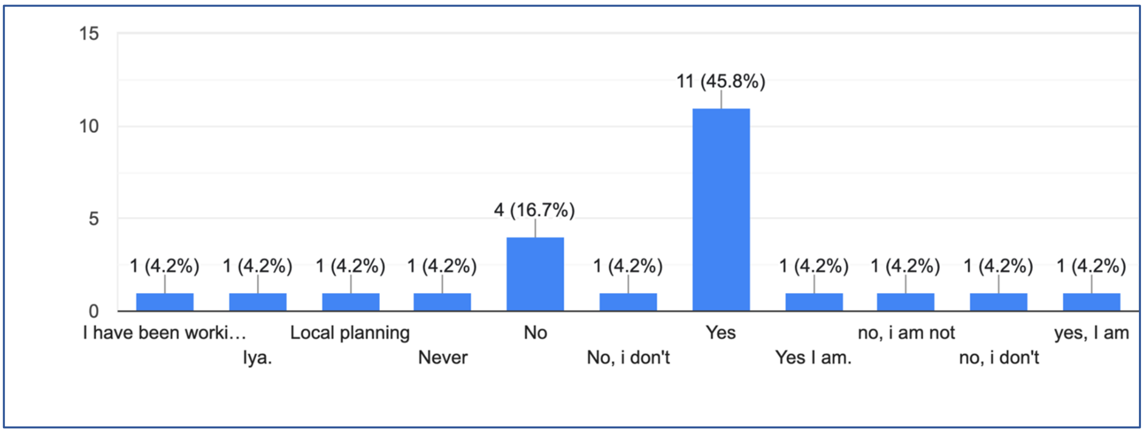


Figure 123: MSD participants' degree of previous involvement in regional or local planning

Most of participants have been involved in regional or local planning at their respective place.

On Topic 1 (the development of a comprehensive vision for a data driven, carbon neutral and disaster resilient future), most of participants prefer to have presentation materials at an Introductory level.

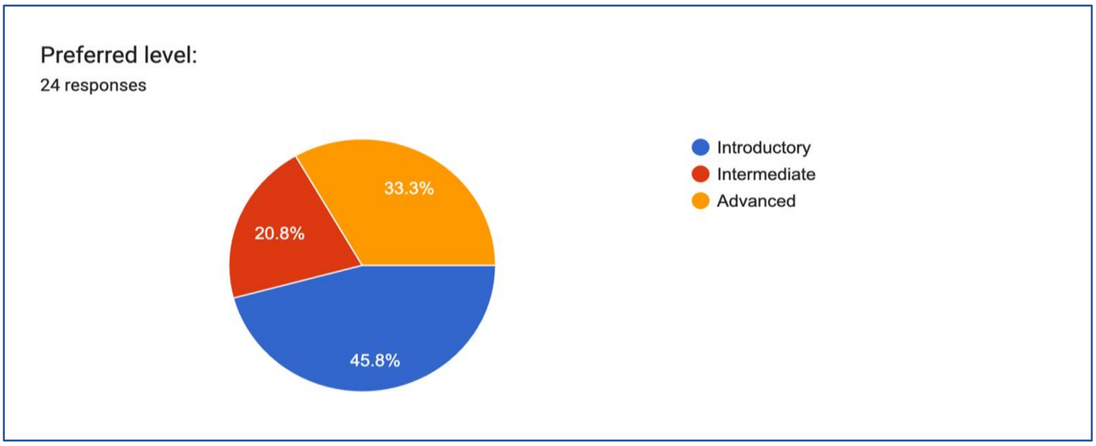


Figure 124: MSD participants' preferred level of detail of presentation materials

On Topic 2 (the formulation and adoption of key 2030 targets on energy intensity, GHG emissions intensity and renewable energy), most of participants prefer to have presentation materials at the Intermediate level.

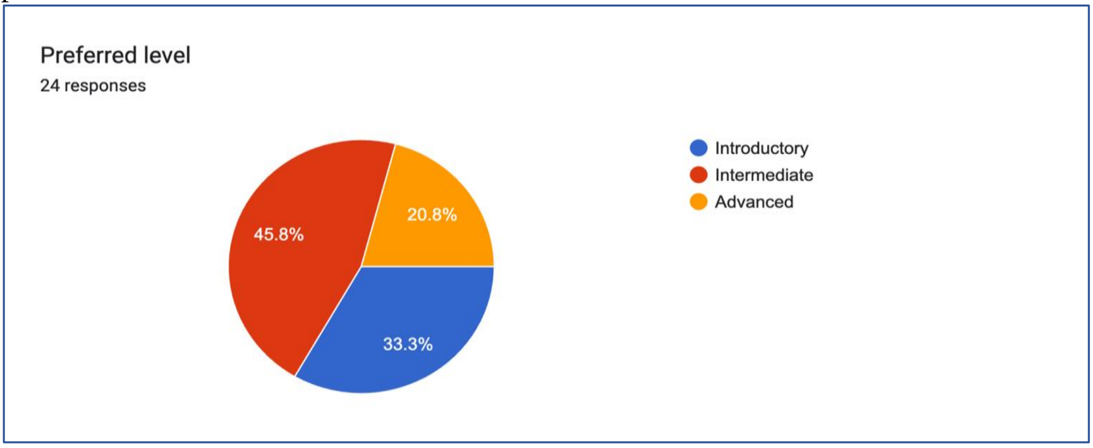


Figure 125: MSD participants' preference on the level of detail of presentation materials related to 2030 targets

Participants are encouraged to describe two topics that they would be interested to learn more about in the next 12 months (Topics 2). The results are as follows:

- Solar panel for green houses
- Carbon capture, renewable energy for household
- Renewable energy on biomass
- Clean Energy
- Disaster resilience
- IPP challenges
- Calculating Energy dan Emission Intensity
- Regional planning
- Renewable energy innovation
- Data analysis
- International economic development
- Train leadership and management
- Economic Development
- Transportation and Logistics carbon

- Geothermal Energy
- Renewable Energy on geothermal energy
- Blue economy
- Future Development in Power Generation Technology
- changes in behaviour and response to the policy of transferring resources from fossil fuels to the newest energy sources
- Transportation
- 2030 targets on energy intensity, emission intensity and renewables share for North Sulawesi Province

Annex 6 – MSD participants' views on the MSD

This section presents the range of feedback that was received from MSD participants related to the MSD structure, format, contents, effectiveness and outputs. Feedback was obtained from MSD participants via an online questionnaire that participants completed in the days immediately following the finalization of the MSD. Feedback was provided anonymously.

- Almost all participants stated that the content was relevant to them

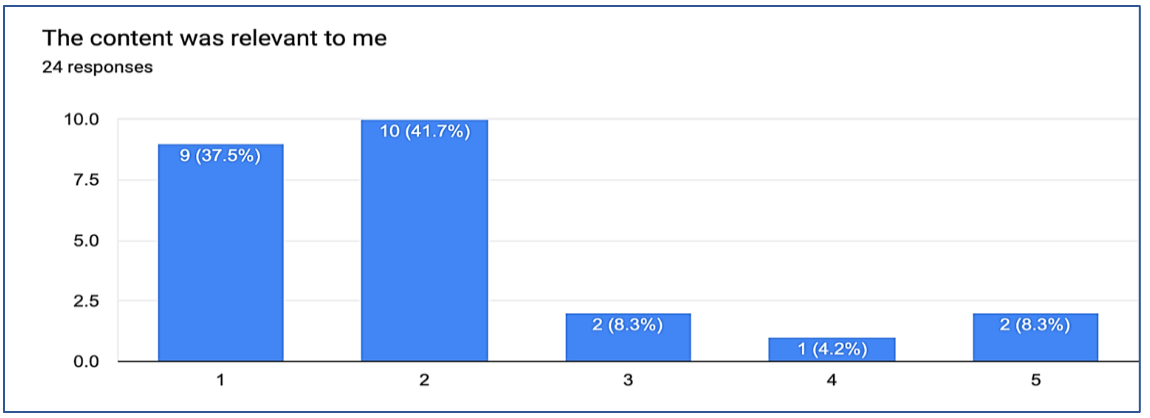


Figure 126: Level of relevance of MSD contents as reported by MSD participants.

Degree of agreement with the statement "The contents were relevant to me" (1 = strongly agree; 5 = strongly disagree).

- Almost all participants stated that the event was applicable to their work

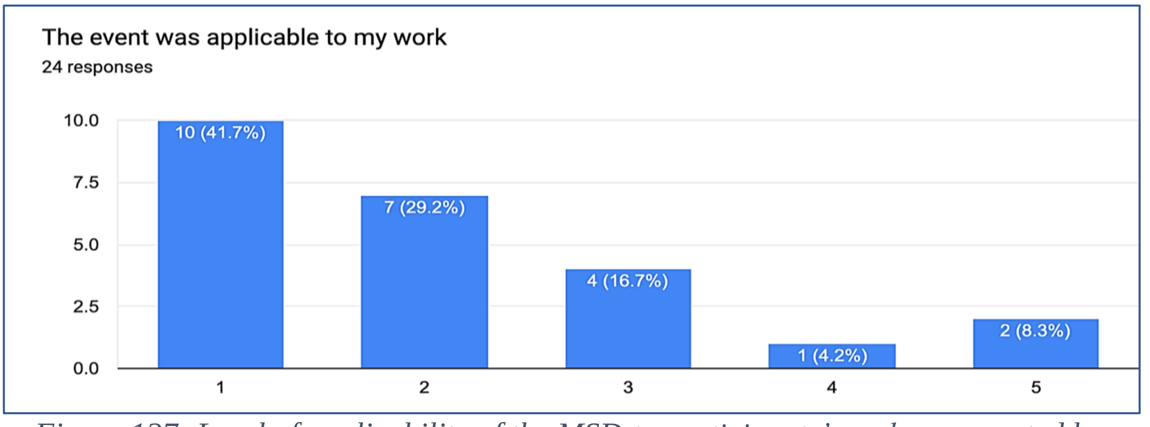


Figure 127: Level of applicability of the MSD to participants' work, as reported by MSD participants.

Degree of agreement with the statement "The event was applicable to my work" (1 = strongly agree; 5 = strongly disagree).

- Almost all participants stated that the content was delivered effectively

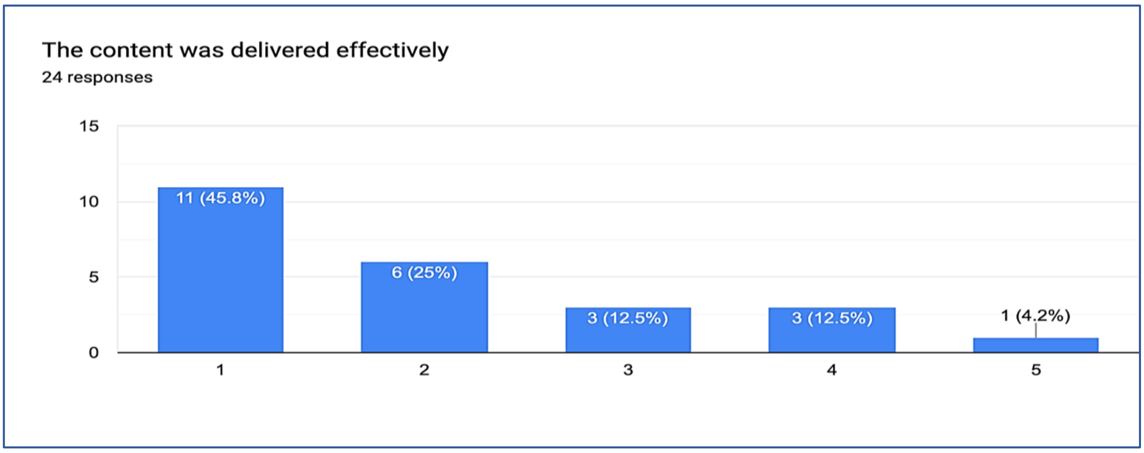


Figure 128: The degree to which the MSD contents were delivered effectively, as reported by MSD participants.

Degree of agreement with the statement "The content was delivered effectively" (1 = strongly agree; 5 = strongly disagree).

- Most of participants stated that the program was well paced.

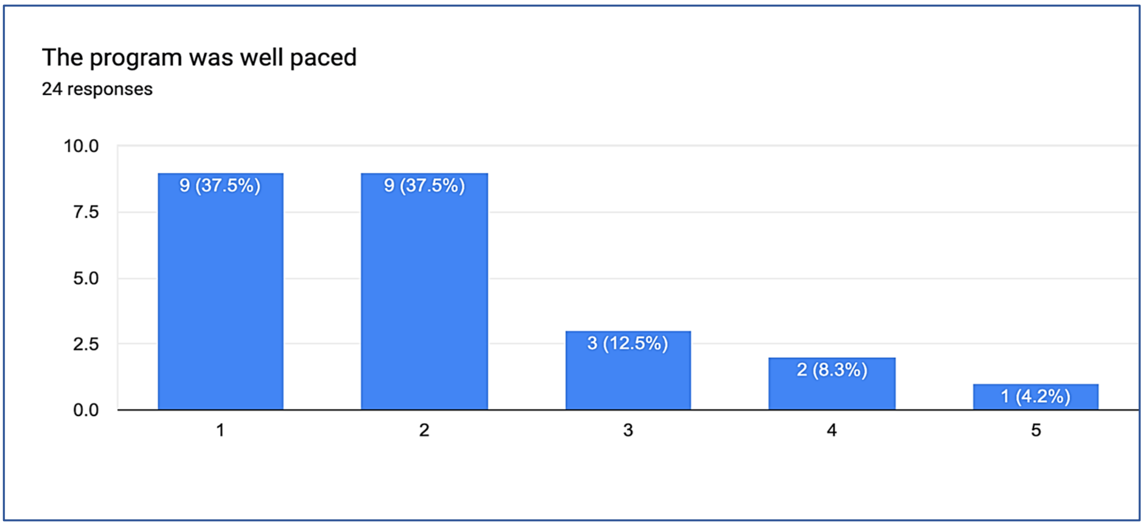


Figure 129: The degree to which the MSD was well paced, as reported by MSD participants.

Degree of agreement with the statement "The program was well paced" (1 = strongly agree; 5 = strongly disagree).

- Most of participants stated that instructors were good communicators

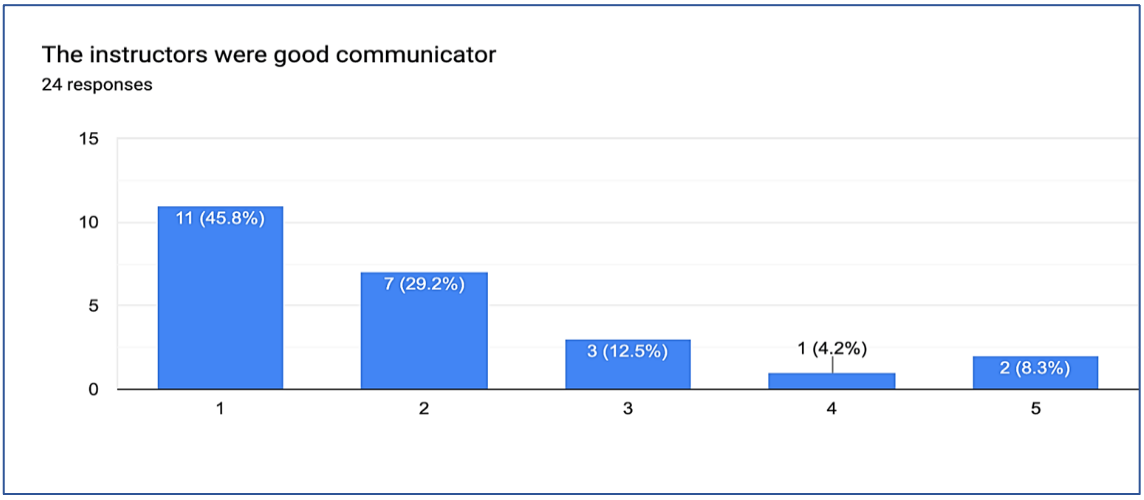


Figure 130: The extent to which the instructors communicated well, as reported by MSD participants.

Degree of agreement with the statement "The instructors were good communicators" (1 = strongly agree; 5 = strongly disagree).

- Most of participants stated that the material was presented in an organized manner

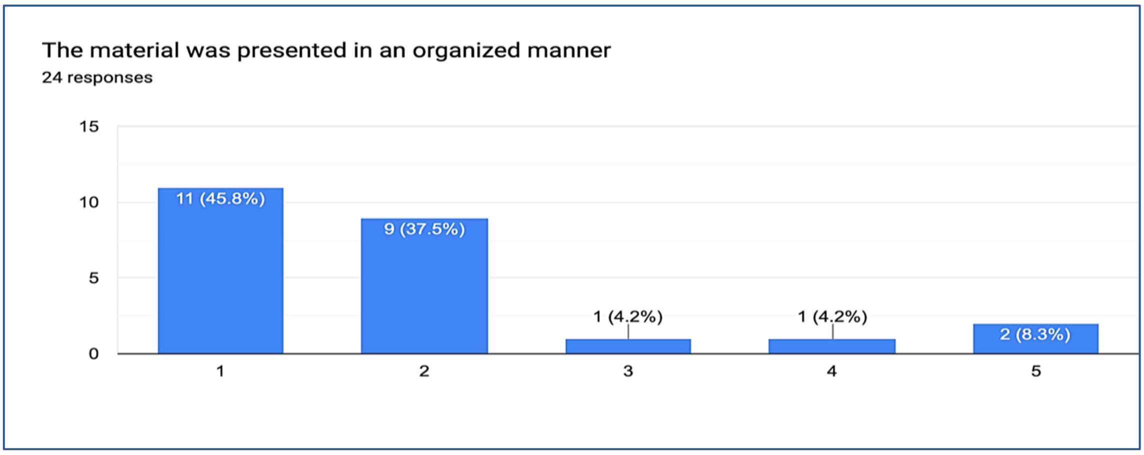


Figure 131: MSD participants' views on whether materials were presented in an organized manner

Degree of agreement with the statement "The material was presented in an organized manner" (1 = strongly agree; 5 = strongly disagree).

- Most of participants stated that the instructors were knowledgeable on the topic

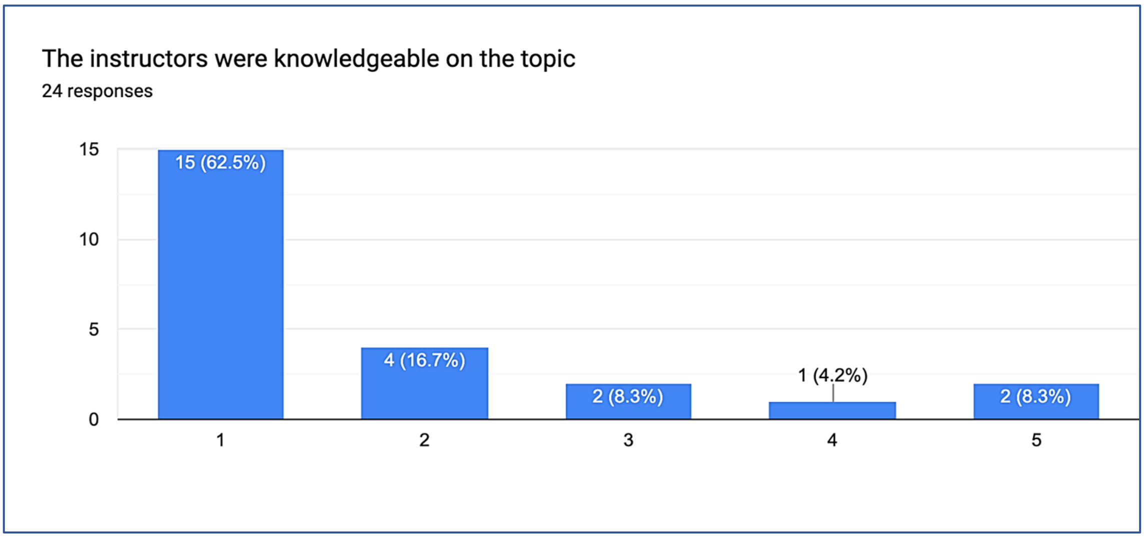


Figure 132: MSD participants' perceptions on the extent to which the instructors were knowledgeable on the topic

Degree of agreement with the statement "The instructors were knowledgeable on the topic" (1 = strongly agree; 5 = strongly disagree).

- Most of participants stated that they would be interested in attending a follow up, more advanced workshop on this same subject.

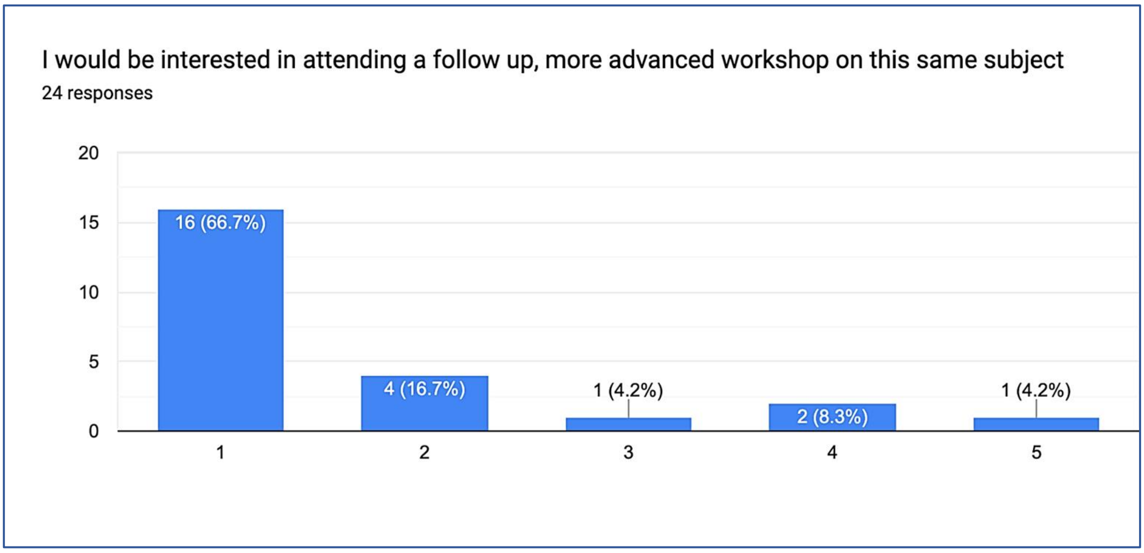


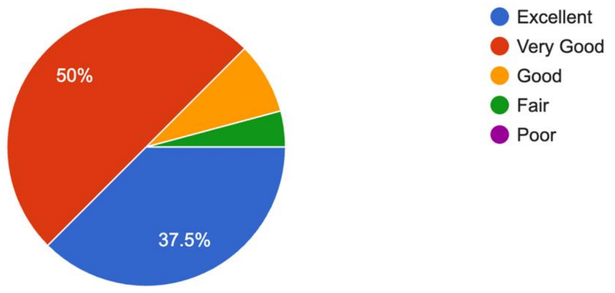
Figure 133: Reported interest of MSD participants to attend follow up workshops

Degree of agreement with the statement "I would be interested in attending a follow up, more advanced workshop on this same subject" (1 = strongly agree; 5 = strongly disagree).

- Most of participants stated that the visual, meeting space, presentations and program overall were very good and excellent.

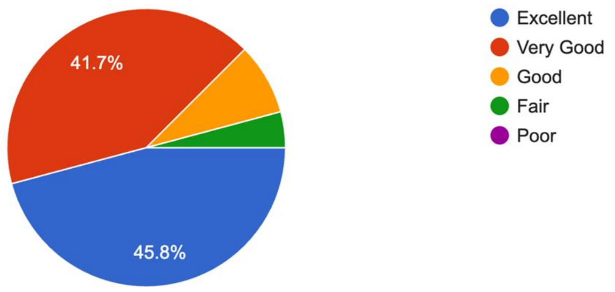
Visuals

24 responses



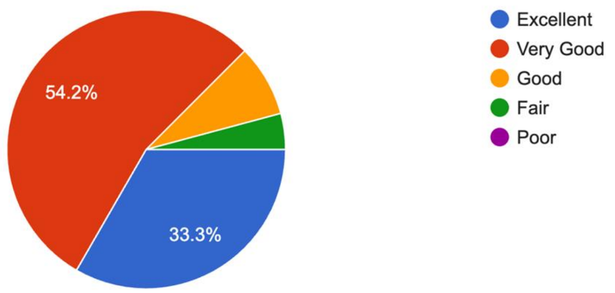
Meeting Space

24 responses



Presentations

24 responses



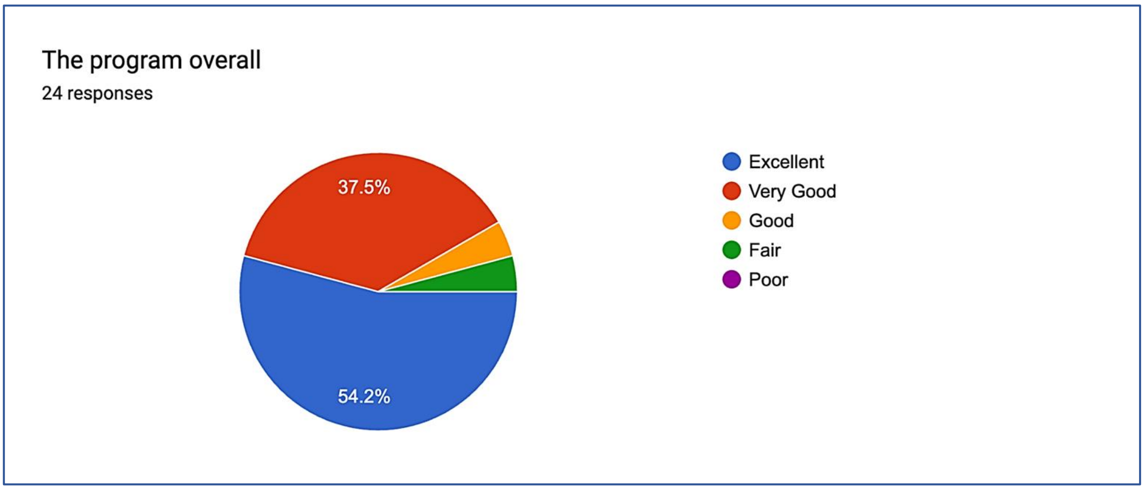


Figure 134: MSD participants' views on the quality of the visuals, meeting space, and the overall program

Suggestions received from MSD participants for future MSDs on low-carbon development, energy transition and disaster resilience

Participants also shared their views to response the questions:

- What did you most appreciate/enjoy/think best about the event?
- Any suggestions for improvement?

Their views are as follows:

- The distribution of the material is extraordinary, but it would be better if the material slides were easier to understand.
- We really appreciate APEC for its contribution on North Sulawesi's disaster resilient and managing renewable energy for the best future.
- I noticed that it would be great if we could communicate more effectively and expected time for our meetings.
- About renewable energy applicable related to carbon neutrality in higher education (university).
- Discussion in material and participants are more professional.
- I'm enjoying this event.
- In the attachment to the MSD invitation letter (general information circular), it is stated that participants attending in person will receive accommodation facilities at the hotel. However, in reality, we did not receive this facility. As a result, those of us who are not from Manado had to undertake a long and tiring journey every day. This has caused us to be frequently late and less able to fully participate in activities as a significant amount of energy is expended in travel. Additionally, the participants are mentioned to receive an allowance of USD105 per person per day. In reality, we did not receive this. If we misunderstood the contents of the attachment, we apologize. In the future, if there are similar events, it would be advisable for the organizing committee to hold a meeting or briefing with participants to clarify such matters.
- The delivery of the material was extraordinary, but it would be nice if the material display slides were easier to understand.

- I hope the next APEC event can be held on my campus, at Sam Ratulangi University.
- The material is diverse and adds to knowledge. For future activities, outdoor activities can be added, especially for longer events, to prevent participants from getting bored. Accommodation can be facilitated, especially for participants from out-of-town.
- For improvement, I think must have a few of the "ice breakers" movement.
- On time, but too long hours, 6 hrs is max for better focus
- All parties have a contribution to efforts to reduce carbon emissions, it is necessary to find a solution globally because this is a common problem... it is very understandable if there are parties who take the initiative to offer solutions by selling products at the end, but if we are committed to finding the best solution, then There should be a policy that can cover this problem and requires collaborative research to find technology or solutions to reduce carbon emissions
- Good rundown. Good refreshments. The moderator is good, and the event organizer is friendly. Suggestions: Insert breaks between the agenda items; show videos related to the topics. Include energizers or icebreakers. Ensure the presenters are more communicative with the audience, especially for an Indonesian audience. Provide accommodation for participants. Double-check names and surnames, especially when MDS certificates are involved.
- It's a really good gathering.
- This event is very important to many multidisciplinary experts for example public health experts, environmental expert and energy experts, economy expert.
- The efficiency of the event. I think it could be better in time management.
- Renewable energy transition & shares.
- Very good topics to follow and the organizers are very professional in organizing the event.

Annex 7 – Draft monitoring questionnaire for cities

The monitoring described in Section 7 requires altogether 18 independent data series plus two dependent data series that are the algebraic sums of independent data series.

INDICATOR DEFINITION	UNIT	2016	2017	2018	2019	2020	2021	2022	2023
Total population: Total population is based on the de facto definition of population, which counts all residents regardless of legal status or citizenship. The values shown are midyear estimates.	persons								
LRE generation: Local renewable electricity generated on the city territory, originating from solar, wind, hydropower (including ocean energies), biomass, geothermal and waste(water)-to energy sources.	GWh								
LRE capacity: Installed renewable electricity capacity on the city territory that generates energy from renewable sources	MW								
LPV net area: Net local photovoltaic (PV) area of the city used directly and exclusively for PV electricity	m2								
LPV gross area: Gross local land area of the city used directly or indirectly for PV	m2								
DPPARE generation: Distant (i.e., located outside city borders) renewable electricity generation contracted by power purchase agreement (PPA) or similar of all the areas to which the city is interconnected by a synchronous (AC) or asynchronous (DC) grid link	GWh/year								
DPPARE capacity: Distant (i.e., located outside city borders) installed renewable electricity capacity of those producers with whom the city has a PPA or similar agreement, and to whom the city is interconnected by a synchronous (AC) or asynchronous (DC) grid link	MW								
DRE capacity: Distant (i.e., located outside city borders) installed renewable electricity capacity of all producers to whom the city is interconnected by a synchronous (AC) or asynchronous (DC) grid link	MW								

LTRM capacity: Local transmission capacity comprising the sum of the local transmission capacity of all entry points to the city	MW								
APPARE generation = LRE generation + DPPARE generation	GWh								
LTPES: Local total primary energy supply, defined as primary energy production in the city + acquisition of primary and secondary energy from outside the city **-** sales of primary and secondary energy to outside regions +/- aviation and marine bunkers +/- stock changes	GWh/year								
LGDP: Local Gross Domestic Product, the sum of gross value added by all resident producers in the economy + any product taxes - any subsidies not included in the value of the products.	Constant local currency units/year or constant USD/year								
ARE storage: Accessible (= local + distant) renewable electricity storage (in GWh) contracted by agreement and interconnected by a synchronous (AC) or asynchronous (DC) grid link	GWh								
Totalstorage: Total (renewable + other) accessible energy storage	GWh								
LTFC: Local total final energy consumption, defined as total energy supply minus transformation and transportation losses (including the own use of the energy sector) before reaching the end consumer. It is also the sum of consumption all end-use sectors and also includes non-energy use.	GWh/year								
LGreenVA: Value-added of the local green sector, where “green” is defined by the applicable taxonomy of green activities of the city.	Constant local currency units/year or constant USD/year								
LGreenEmpl: Employment force of the local green sector, where “green” is defined by the applicable taxonomy of green activities of the city	full time equivalents								

APPAREcapacity = LRE capacity + DPPARE capacity	MW								
LGreenDebt: Amount of local green debt (assets) held by the city and its resident green performance disclosing enterprises, at the end of the year, where "green" is defined by the applicable taxonomy of green activities, and "debt" means all senior debt forms, in particular green bonds and green loans	Constant local currency units or constant USD								
LGreenEquity: Amount of local green equity assets held by the city and its green performance disclosing residents (enterprises) located in the city, at the end of the year, where "green" is defined by the applicable taxonomy of green activities, and "equity" includes all junior debt forms, in particular equity, guarantees (including credit risk guarantees) and grants (e.g., assets received).	Constant local currency units or constant USD								

Table 12: Draft monitoring questionnaire for cities

Annex 8 – China example of a Green Industries Taxonomy

As an example of a definition of the green economy sector, the Chinese Green Bond Endorsed Projects Catalogue (2021 Edition) is shown below in unofficial English translation. The fourth column of the document stating the legally binding conditions has been eliminated from the table below. The original can be found at the following website: http://www.pbc.gov.cn/goutongjiaoliu/113456/113469/4342400/2021091617180089879.pdf

Green Bond Endorsed Projects Catalogue (2021 Edition)

Note: The Green Bond Endorsed Projects Catalogue (2021 Edition) was jointly announced by the People's Bank of China (PBOC), the National Development and Reform Commission (NDRC) and the China Securities Regulatory Commission (CSRC) on 21 April 2021.

1. Projects to be included in this catalogue shall meet the requirements listed in the Explanatory notes of the Green Industry Guidance Catalogue (2019 Edition) and the corresponding "Instructions/Conditions" of this catalogue.
2. Projects to be included in this catalogue shall comply with relevant safety, environmental protection and quality regulations and policies.
3. Policy documents and standard specifications referred to in this Catalogue are the latest version and within the validity period.
4. The English version of the catalogue may only be used as a reference. In case a different interpretation of the translated information arises, the original Chinese shall prevail.

Sector		Program
1. Energy Saving and Environmental Protection Industry		
1.1 Energy Efficiency Improvement	1.1.1 Manufacturing of Energy Efficient Equipment	1.1.1.1 Manufacturing of Energy-saving Boilers
		1.1.1.2 Manufacturing of Energy-saving Furnace/Kiln
		1.1.1.3 Manufacturing of Energy-saving Pumps and Vacuum Equipment
		1.1.1.4 Manufacturing of Energy-saving Gas Compression Equipment
		1.1.1.5 Manufacturing of Energy-saving Hydraulic and Pneumatic Pressure Equipment
		1.1.1.6 Manufacturing of Energy-saving Blowers and Fans
		1.1.1.7 Manufacturing of High-efficient Generators and Generator Sets
		1.1.1.8 Manufacturing of Energy-saving Motors
		1.1.1.9 Manufacturing of Energy-saving Transformers, Rectifiers, Inductors, and Electric Welding Machines
		1.1.1.10 Manufacturing of Residual Heat, Pressure and Gas Exploitation Facilities
		1.1.1.11 Manufacturing of High-efficient and Energy-saving Household Appliances
		1.1.1.12 Manufacturing of High-efficient and Energy-saving Commercial Appliances
		1.1.1.13 Manufacturing of High-efficient Lighting Products and Systems
		1.1.1.14 Manufacturing of Energy Measuring, Monitoring, and Controlling Equipment
	1.1.2 Industrial Energy Saving Retrofit	1.1.2.1 Energy-saving Transformation and Energy Efficiency Improvement of Boilers (Furnaces/Kiln)
		1.1.2.2 Energy Efficiency Improvement of Motor System
		1.1.2.3 Utilization of Residual Heat and Pressure
		1.1.2.4 Optimization of Energy System
1.2 Sustainable Buildings	1.2.1 Green Building Materials	1.2.1.1 Manufacturing of Green Building Materials
1.3 Pollution Prevention	1.3.1 Manufacturing of Advanced Environment al	1.3.1.1 Equipment Manufacturing for Water Pollution Prevention and Control
		1.3.1.2 Equipment Manufacturing for Air Pollution Prevention and Control

	Protection Facilities	1.3.1.3 Equipment Manufacturing for Soil Pollution Control and Remediation
		1.3.1.4 Equipment Manufacturing for Solid Waste Treatment and Disposal
		1.3.1.5 Equipment Manufacturing for Shock-absorption and Noise-reduction
		1.3.1.6 Equipment Manufacturing for Prevention and Treatment of Radioactive Contamination
		1.3.1.7 Manufacturing of Medicament and Materials for Environmental Pollution Treatment
		1.3.1.8 Manufacturing of Environmental Monitoring Instruments and Emergency treatment Equipment
	1.3.2 Treatment of Sewage Water	1.3.2.1 Protection and Control of High-quality Water and Underground Water Environment
		1.3.2.2 Treatment and Control of Water Pollution in Major River and Sea Area
		1.3.2.3 Remediation and Treatment of Urban Black and Malodorous Water
		1.3.2.4 Prevention and Treatment of Ship and Port Pollution
	1.3.3 Treatment and Control of Air Pollution	1.3.3.1 Treatment and Control of Traffic Vehicles Pollution
		1.3.3.2 Comprehensive Treatment and Control of Urban Dust Pollution
		1.3.3.3 Treatment and Control of Food and Beverage Fume Pollution
	1.3.4 Treatment and Control of Soil and Other Pollution	1.3.4.1 Treatment and Control of Construction Land Pollution
		1.3.4.2 Treatment and Control of Deserts Pollution
		1.3.4.3 Treatment and Control of Agricultural Land Pollution
		1.3.4.4 Treatment and Control of Noise Pollution
		1.3.4.5 Treatment and Control of Odor Pollution
	1.3.5 Comprehensive Improvement of Agricultural and Rural Environment	1.3.5.1 Prevention and Control of Non-point Source Pollution in Agriculture, Forestry, and Prata culture
		1.3.5.2 Improvement of Rural Living Environment
1.4 Water Conservation and Unconventional	1.4.1 Unconventional Water Resources	1.4.1.1 Desalination of Seawater and Brackish Water
		1.4.1.2 Rainwater Collection, Treatment, and Utilization

Water Resources Utilization	Utilization	
1.5 Comprehensive Utilization of Resources	1.5.1 Manufacturing of Resources Recycling Facilities	1.5.1.1Manufacturing of Equipment for Comprehensive Utilization of Mineral Resources
		1.5.1.2 Manufacturing of Equipment for Comprehensive Utilization of Industrial Solid Waste
		1.5.1.3 Manufacturing of Equipment for Harmless Utilization of Construction and Transportation Waste
		1.5.1.4 Manufacturing of Equipment for the Recycling and Harmless Treatment of Food Waste
		1.5.1.5 Manufacturing of Re-manufacturing Equipment for Automobile Components, Electromechanical Products
		1.5.1.6 Manufacturing of Facilities for Resources Recycle and Reuse
		1.5.1.7 Manufacturing of Facilities for the Use of Unconventional Water Resources
		1.5.1.8 Manufacturing of Facilities for the Recycling and Harmless Treatment of Agricultural and Forestry Residues
	1.5.2 Comprehensive Utilization of Solid Waste	1.5.2.1 Comprehensive Utilization of Mineral Resources
		1.5.2.2 Recycling of Waste and Discarded Resources
		1.5.2.3 Remanufacturing of Automobile Components and Electromechanical Products
	1.5.3 Comprehensive Utilization of Biomass Resources	1.5.3.1 Comprehensive Utilization of Urban and Rural Household Waste
		1.5.3.2 Recycling and Utilization of Agricultural Waste Resources
		1.5.3.3 Comprehensive Utilization of Sludge from Urban Sewage Treatment Plants
1.6 Green Transportation	1.6.1 Manufacturing of New Energy Vehicles and Green Ships	1.6.1.1 Manufacturing of Key Components of New Energy Vehicles and its Industrialization
		1.6.1.2 Manufacturing of Facilities for Charging, Battery Replacement, and Hydrogenation
		1.6.1.3 Manufacturing of Green Ships
2. Clean Production Industry		
2.1 Pollution Prevention and Treatment	2.1.1 Pollution Prevention and	2.1.1.1 Industrial Desulfurization, Denitrification and Dust Removal Transformation

	Control	2.1.1.2 Integrated Treatment of Volatile Organic Compounds
		2.1.1.3 Transformation of Ultra-Low Emission of Steel Enterprises
	2.1.2 Treatment of Sewage Water in Production	2.1.2.1 Wastewater Treatment of Major Industries
		2.1.2.2 Centralized Treatment of Wastewater in Industrial-Intensive Zones
	2.1.3 Pollution Treatment in Industrial Parks	2.1.3.1 Promotion of Centralized Treatment of Pollution
		2.1.3.2 Transformation of Major Industries into Cleaner Production
	2.1.4 Non-hazardous Alternatives and Treatment of Hazardous Waste	2.1.4.1 The Production and Usage of Non-hazardous Materials as Alternatives
		2.1.4.2 Management and Disposal of Hazardous Waste
		2.1.4.3 Transport of Hazardous Waste
2.2 Green Agriculture	2.2.1 Comprehensive Management in Agriculture and Rural Environment	2.2.1.1 Effective, Low-Toxicity and Low-Residue Pesticide Production and Alternatives
		2.2.1.2 Treatment of Livestock and Poultry Husbandry Waste and Pollution
		2.2.1.3 Recycling of Waste Agricultural Film
2.3 Comprehensive Utilization of Resources	2.3.1 Comprehensive Utilization of Solid Waste	2.3.1.1 Harmless Treatment, Disposal and Comprehensive Utilization of Industrial Solid Waste
		2.3.1.2 Treatment of Historical Tailings
		2.3.1.3 Recycling and Treatment of Packaging Waste
	2.3.2 Comprehensive Utilization of Resources in Industrial Parks	2.3.2.1 Cross-Industry Collaboration and Resources Circulation
		2.3.2.2 Energy Efficiency Improvement
2.4 Water Saving and Efficient Use of Non-conventional Water Resources	2.4.1 Industrial Water Saving	2.4.1.1 Water Saving and Efficient Use of Water During Production
3. Clean Energy Industry		
3.1 Energy Efficiency Improvement	3.1.1 Energy Saving in Power Facilities	3.1.1.1 Production of Smart Grid Products and Equipment
		3.1.1.2 Construction and Operation of Smart Grids
3.2 Clean	3.2.1	3.2.1.1 Production of Wind Generators

Energy	Production of New Energy Equipment and Clean Energy Equipment	3.2.1.2 Production of Solar Generators
		3.2.1.3 Production of Biomass Energy Utilization Equipment
		3.2.1.4 Production of Hydro-power Generators and Pumped Storage Equipment
		3.2.1.5 Production of Nuclear Power Equipment
		3.2.1.6 Production of Gas Turbine Equipment
		3.2.1.7 Production of Fuel Cell Equipment
		3.2.1.8 Production of Geothermal Energy Utilization Equipment
		3.2.1.9 Production of Marine Energy Utilization Equipment
	3.2.2 Construction and Operation of Renewable Energy Facilities	3.2.2.1 Construction and Operation of Wind Power Facilities
		3.2.2.2 Construction and Operation of Solar Energy Utilization Facilities
		3.2.2.3 Construction and Operation of Biomass Energy Utilization Facilities
		3.2.2.4 Construction and Operation of Large-Scale Hydropower Facilities
		3.2.2.5 Construction and Operation of Nuclear Power Plants
		3.2.2.6 Construction and Operation of Geothermal Energy Utilization Facilities
		3.2.2.7 Construction and Operation of Marine Energy Utilization Facilities
		3.2.2.8 Construction and Operation of Hydrogen Energy Utilization Facilities
		3.2.2.9 Construction and Operation of Heat Pump Facilities
	3.2.3 Efficient Operation of Clean Energy	3.2.3.1 Construction and Operation of Multi-energy Complementary Projects
		3.2.3.2 Operation and Construction of Energy Efficient Storage Facilities
		3.2.3.3 Construction and Operation of Natural Gas Transmission, Storage, and Peak Load Regulation Facilities
		3.2.3.4 Construction and Operation of Distributed Energy Resources (Ders) Projects
		3.2.3.5 Construction and Operation of Pumped-Storage Power Stations
		3.2.3.6 Construction and Operation of Carbon Dioxide Capture, Utilization and Storage (CCUS) Projects
4. Ecology and Environment-related sector		
4.1 Ecological Agriculture	4.1.1 Conservation of Agricultural Resources	4.1.1.1 Modern Agriculture, Seed Industry and the Protection of Animals, Plants and Germ plasm Resources
		4.1.1.2 The Management of Crop Protection

		Areas and Protection Zones
		4.1.1.3 Protection of Forest Genetic Resources
		4.1.1.4 The Management and Protection of Marine Ranching
		4.1.1.5 Pest Prevention and Control
		4.1.1.6 Comprehensive Rural Land Reform
	4.1.2 Comprehensive Management in Agriculture and Rural Environment	4.1.2.1 Control and Prevention of Crop Diseases and Insect Pests
	4.1.3 Supply of Green Agricultural Products	4.1.3.1 Green Organic Agriculture
		4.1.3.2 Green Animal Husbandry
		4.1.3.3 Green Fishery
4.2 Ecological Protection and Construction	4.2.1 Conservation and Restoration of Natural Ecosystems	4.2.1.1 Protection of Natural Forest Resources
		4.2.1.2 Protection of Animal and Plant Resources
		4.2.1.3 Construction and Operation of Nature Reserves
		4.2.1.4. Construction, Maintenance and Operation of Ecological Function Areas
		4.2.1.5 Projects of Turning Farmlands Back to Forests or Grasslands and Restoring Grazing Lands to Grasslands
		4.2.1.6 Protection and Restoration of Rivers, Lakes and Wetlands
		4.2.1.7 Protection and Restoration of National Ecological Security Barriers
		4.2.1.8 Comprehensive Treatment of Key Ecological Areas
		4.2.1.9 Ecological Restoration of Degraded Mining Areas
		4.2.1.10 Comprehensive Treatment of Desertification, Rocky Desertification and Soil Erosion
		4.2.1.11 Drought and Flood Management for Water-Related Ecosystem
		4.2.1.12 Management and Restoration of Groundwater Overdrawn Zones
		4.2.1.13 Comprehensive Management of Coal Mining Subsidence Areas
		4.2.1.14 Comprehensive Management of Sea Areas, Coastal Zones and Islands
	4.2.2 Supply of Ecological Products	4.2.2.1 Forest Resources Cultivation Industry
		4.2.2.2 Under-forest Economy of Planting and Animal Farming Industry
		4.2.2.3 Carbon Sequestration Forest, Tree and

		Grass Planting and Seedlings, and Ornamental Flowers
		4.2.2.4 Forest Recreation and Health Rehabilitation Industry
		4.2.2.5 Protective Operation of National Parks, World's Heritages, National Scenic Spots and Historic Interest Areas, National Forest Parks, National Geo-Parks, and National Wetland Parks
5. Sustainable Upgrade of Infrastructure		
5.1 Energy Efficiency Improvement	5.1.1 Energy Efficiency and Energy Use in Urban Power Facilities	5.1.1.1 Operation and Upgrade of Cleaning construction of Urban Central Heating Systems
		5.1.1.2 Operation and Upgrade of Urban Power Facilities into Smart Power Facilities
		5.1.1.3 Construction and Operation of Integrated Power System in Urban and Rural Areas
5.2 Sustainable Buildings	5.2.1 Energy-Saving Buildings and Green Buildings	5.2.1.1 Construction of Ultra-Low Energy Consumption Buildings
		5.2.1.2 Green Buildings
		5.2.1.3 Application of Renewable Energy in Buildings
		5.2.1.4 Prefabricated Buildings
		5.2.1.5 Energy Conservation and Environmental-friendly Renovation of Existing Buildings
		5.2.1.6 Green Warehousing Logistics
5.3 Pollution Prevention	5.3.1 Urban Environmental Infrastructure	5.3.1.1 Construction and Operation of Facilities for Sewage Treatment, Recycling, and Sludge Treatment and Disposal
		5.3.1.2 Construction and Operation of Garbage Treatment Facilities
		5.3.1.3 Inspection, Upgrade, Construction and Renovation of Urban Sewage Collection System
		5.3.1.4 Construction and Operation of Environment Monitoring System
		5.3.1.5 Inspection and Rectification of Sewage Pollution Discharge Outlets to Rivers and Standardization of Sewage Discharge
5.4 Water Saving and Non-conventional Water Resources	5.4.1 Water Saving	5.4.1.1 Construction and Operation of Leakage Control in District Measurement of Urban Water Supply Pipeline Network
	5.4.2 "Sponge" City for Flood Prevention	5.4.2.1 Construction and Operation of Sponge Buildings and Communities
		5.4.2.2 Construction and Operation of Sponge Roads and Squares
		5.4.2.3 Construction and Operation of Sponge Parks and Greenspace
		5.4.2.4 Construction, Operation and Renovation

		of Up-to-standard Urban Drainage Facilities
		5.4.2.5 Restoration of the Natural Ecology of Urban Water Bodies
		5.5.1.1 Construction and Operation of Electronic Toll Collection (ETC) System
		5.5.1.2 Construction and Operation of Multimodal Container Transportation System
		5.5.1.3 Construction and Operation of Smart Transportation
		5.5.1.4 Construction and Operation of None-motorized Transportation System
		5.5.1.5 Construction and Operation of Public Transportation System in Urban and Rural Areas
		5.5.1.6 Construction and Operation of Facilities for Shared Transport
		5.5.1.7 Construction and Operation of Drop and Pull Transport System
	5.5.2 Railway Transport	5.5.2.1 Construction and Operation of Rail Freight Transport and the Environmental-Friendly Transformation of Railways
	5.5.3 Waterway and Air Transport	5.5.3.1 Construction of Power Supply Facilities at Ports, Docks and Airport Bridges
	5.5.4 Clean Energy Vehicle Facilities	5.5.4.1 Construction and Operation of Charging, Battery Replacement, Hydrogen Refuelling and Gas Refuelling Facilities
5.6 Ecological Protection and Construction	5.6.1 Urban Ecological Protection and Construction	5.6.1.1 Construction, Maintenance and Operation of Parklands
		5.6.1.2 Construction, Maintenance and Operation of Greenway Systems
		5.6.1.3 Construction, Maintenance and Operation of Green Space Attachments
		5.6.1.4 Construction and Maintenance of Road Greening
		5.6.1.5 Construction, Maintenance and Operation of Regional Greenspace
		5.6.1.6 Construction and Maintenance of Vertical Greening
6. Green Services		
6.1 Consultancy	6.1.1 Green Consulting Technical Services	6.1.1.1 Green Industry Project Survey Services
		6.1.1.2 Green Industry Project Design Services
		6.1.1.3 Technical Consultancy for Green Industry Projects
		6.1.1.4 Clean Production Audit Services
6.2 Operation	6.2.1 Green Operation	6.2.1.1 Construction of Power Management System

Management Services	Management Services	6.2.1.2 Energy Performance Contracting Services
		6.2.1.3 Power Demand-side Management Services
	6.2.2 Environmental Rights Transaction Services	6.2.2.1 Provision of Services for Energy-use Rights Transactions
		6.2.2.2 Provision of Services for Water-use Rights Transactions
		6.2.2.3 Pollutant Discharge Permit and Transaction Services
		6.2.2.4 Carbon Emission Trading Services
		6.2.2.5 Renewable Energy Certificate (Green Tags) Trading Services
6.3 Audit, Inspection and Evaluation of Projects	6.3.1 Audit, Inspection and Evaluation of Projects	6.3.1.1 Energy-Saving Assessment and Energy Audit
		6.3.1.2 Evaluation of Environment Impact
		6.3.1.3 Verification of Carbon Emission
		6.3.1.4 Evaluation of Geological Disaster Hazards
		6.3.1.5 Evaluation of Soil and Water Conservations
6.4 Monitoring and Detection	6.4.1 Monitoring and Detection	6.4.1.1 Building of Online Energy Monitoring System
		6.4.1.2 Monitoring of Polluting Sources g
		6.4.1.3 Monitoring and Evaluation of Environmental Damage
		6.4.1.4 Monitoring and Assessment of Environmental Impact
		6.4.1.5 Environmental Monitoring for Enterprises
		6.4.1.6 Monitoring of Ecological Environment
6.5 Promotion and Certification of Technical Products	6.5.1 Promotion and Certification of Technical Products	6.5.1.1 Promotion and Certification of Energy Saving Products
		6.5.1.2 Promotion and Certification of Low-Carbon Products
		6.5.1.3 Promotion and Certification of Water Saving Products
		6.5.1.4 Promotion and Certification of Environmental Labelling Products
		6.5.1.5 Promotion and Certification of Organic Food
		6.5.1.6 Promotion and Certification of Green Food
		6.5.1.7 Assertion and Promotion of Products with Comprehensive Utilization of Resources
		6.5.1.8 Promotion and Certification of Green Building Materials

Table 13: Green Bond Endorsed Projects Catalogue (2021 Edition). Source: PBC.

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Promoting Carbon Neutrality in North Sulawesi

Asia-Pacific Economic Cooperation

Vision, Targets, Benchmarking and Monitoring

This report shows how a Multistakeholder-Dialogue (MSD) was used to promote carbon neutrality in Indonesia's North Sulawesi Province: Elaborating a long-term carbon neutrality vision, including on how to improve local disaster resilience, and setting three 2030 targets for energy intensity, carbon intensity and the renewables share.
The target setting was validated by long-term global scenarios describing the dynamic background comprising global population, energy, emissions, and GDP, all impacting upon and benchmarking local communities. Monitoring renewable energy generation has been separated into local generation, distant generation, its impact on energy security and energy efficiency, and the relation to the green sector economy and green finance.

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