Asia-Pacific
Economic Cooperation

APEC

Sustainable Urban Development Report

From Models to Results

ENERGY WORKING GROUP

December 2018

Asia-Pacific
Economic Cooperation

APEC Sustainable Urban Development Report –

From Models to Results

APEC Energy Working Group

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Foreword

APEC Sustainable Energy Center (APSEC) is pleased to present the APEC Sustainable Urban Development Report – From Models to Results.

In June 2016, the APEC High-Level Urbanization Forum took place in Ningbo, Zhejiang Province. It was the first large-scale high-level event under the APEC framework focusing on urbanization. In the Ningbo Initiative, Member economies affirmed the importance of promoting sound, sustainable and people-oriented urbanization among Asia-Pacific economies within an Asia-Pacific Urbanization Partnership, which had been endorsed by APEC Economic Leaders in Beijing in November 2014.

Member economies also reaffirmed their commitment and cooperation in eight key areas, including boosting inclusiveness and dynamic development of cities, improving urban infrastructure, building smart cities, developing green cities, encouraging urban regeneration and retrofit, driving innovative urban development, advocating good urban governance, and boosting APEC cooperation on sustainable urban development.

With this report, APSEC contributes to the relevant discussion on sustainable urban development, focusing on synergies to both, sustainable energy development and disaster risk reduction.

This report is the work of the APEC Sustainable Energy Center. It does not necessarily reflect the views or policies of the APEC Energy Working Group or individual member economies. Nevertheless, we do hope that it will serve as a useful basis for analytical discussion both within and among APEC member economies for the enhancement of sustainable urban development.

APEC Sustainable Energy Center

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Purposes, Key Findings and Recommendations

Purposes

- to note urbanization trends of APEC economies and the important role cities play to ensure economic growth,
- to identify the most evident sustainability gaps of APEC cities and the great number of instruments that have already been developed that could be used to address these gaps, and
- to outline elements of a cooperative strategy for scaling up APEC sustainable urbanization by targeted focus on energy technologies that synergize resilience with better economic performance, social inclusiveness and less environmental impact.

Key Findings

The high speed, with which urbanization has been taking place in the last decades in some APEC economies, is a phenomenon related to rapid industrialization. China has been massively affected by this phenomenon. Within one generation, China has developed from a predominantly agricultural economy, with three quarters of population being agricultural at the end of the 1980s, to a predominantly urban economy with almost 60% of urban population. Today, China has the largest urban population worldwide (758 million). Seven countries, among them the three APEC economies China, Indonesia and the United States, are expected to experience half the global increase of urban population by 2050. From the 12 biggest cities worldwide (2015), six are APEC cities (Tokyo, Shanghai, Mexico City, Beijing, Osaka, New York).

Cities are engines of economic growth. Among the big world regions, China is the economy where the contribution of cities to economic growth is largest (94%). APEC has higher per capita GDP than the world average, and higher per capita GDP growth than the world. APEC has also been slightly less affected by the financial crisis than the world. Contemporary urbanization trends are fully in line with the urbanization trends of early industrialization. At the beginning of industrialization, cities usually grow fast. After some time, population growth of cities slows down, but economic growth continues. Economic growth is limited by cost of land. This requires buildings to rise higher and higher to maintain competitiveness. More than 90% of the supertall buildings (>300m height) being constructed, planned or envisioned worldwide are in APEC cities. Competitiveness of cities also requires cities to keep urban transport fluid. Building new lanes for mass transit is not necessarily the best solution, as additional lanes may increase congestion (Braess' paradox). Constructing underground transport systems (or sky trains) may be more efficient, as a railway line has the capacity of 15 motorway lanes. Car sharing has also proven to be useful. Each shared car may remove up to 15 private cars from the streets. For achieving inclusive economic growth, there should be a size hierarchy of cities (generalized rank size rule). Medium-sized and small cities represent a significant way for diminishing unequal income distribution.

An important sustainability deficit of modern cities is the lack of circularity. In all APEC sub-regions, the collection rate of urban municipal waste is, however, above world average. An important deficit of urbanization is also the lack of disaster resilience. Between 1998 and 2017, climate-related and geophysical disasters killed 1.3 million people worldwide and left a further 4.4 billion injured, homeless, displaced or in need of emergency assistance. While most fatalities were due to geophysical events, earthquakes and tsunamis, 91% of all disasters were

caused by floods, storms, droughts, heatwaves and other extreme weather events. APEC cities are particularly exposed to disasters. Of the 100 cities worldwide with the greatest exposure to natural hazards, 21 are in the Philippines, 16 in China, and 11 in Japan. Disasters such as floods also affect capital cities of APEC economies. Floods can be exacerbated by land subsidence. APEC cities most affected by land subsidence are Jakarta, Bangkok, Ho Chi Minh City, Manila and Mexico City. In some districts of Jakarta, the soil sinks at rates between 20 and 28 centimetres per year. Total per capita primary energy supply in APEC (3.8kW) is significantly higher than in world average (2.5kW). Also per capita CO_2 emissions of APEC are higher (7.8 tons per year) than in global average (4.5 tons per year). As for the decoupling path between GDP and emissions, APEC lags two years behind the world average. During the period 1990 – 2014, APEC per capita GDP has doubled, and per capita emissions increased by 50%, whereas for world average, per capita GDP increased by 60% and per capita emissions increased by only 20%. Emissions intensity in APEC decreases at about 1% per year, at the same speed as world average, but absolute emissions are still increasing in both, APEC and in the world. By the middle of the century, emissions should approach zero. The danger of slum formation seems to be less acute in APEC cities than in cities of other world regions. Nonetheless, some APEC cities (Bandung, Manila, Mexico City, Santiago (Chili), Bangkok, Ho Chi Minh City) are reported to have slums. Slums will not automatically disappear with higher average income levels, but require deliberate policies, especially the provision of essential infrastructures to slum cities. A fundamental, cross-cutting sustainability lack in all APEC cities is the data-poverty, especially for sustainability indicators at local level. A sustainability assessment made by the UN for the Asia Pacific region disposed of data for only 25% of the sustainability targets. For targets of the SDGs on climate action and life below water, no data at all were available.

In 2015, the global community has 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 are 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.

APEC economies have brought responses to the sustainability challenge. China takes the implementation of all SDGs, including the INDC pledges of the Paris Agreement, very seriously. China translated the Sustainable Development Goals into a comprehensive *National Plan on Implementation of the 2030 Agenda for Sustainable Development*, published in September 2016. Implementation progress is further being reviewed in the *Progress Report on the Implementation of the 2030 Agenda for Sustainable Development* released in August 2017. Hong Kong, China, is a member economy of APEC, as well as a city member of C40 Cities Climate Leadership Group and of the Global Covenant of Mayors GCoM. Hong Kong, China has released a Climate Action Plan 2030 in January 2017. Given its comprehensive character, covering mitigation and adaptation, this plan can be considered as best practice. Other cities, e.g. Ha Noi in Viet Nam, have given partial responses to sustainability issues. Considering the initial situation of such cities, these are still noteworthy.

The policy response of the European Union is presented as early sustainability pioneer. The interest of looking at the European Union for sustainable urbanization in APEC is not only the ambitious strategies for 2020, 2030 and, most recently, the vision 2050, providing for at least one carbon neutral city in the EU by 2030 and one hundred diverse cities as zero-carbon labs by 2040, but also the number of initiatives that have originated in Europe fostering cooperation among cities. The EU hosts several of the world's biggest inter-municipal organizations. The United Cities and Local Governments UCLG is the world's biggest inter-municipal organization representing 240'000 local communities, or 70% of the world population. ICLEI Local Governments for Sustainability, headquartered in Bonn, has more than 1500 local members (cities, towns and regions) worldwide, impacting 14% of world population. The C40 Cities Climate Leadership Group, originally created in London, comprises 96 megacities, representing 8% of world population with 25% of the world GDP. C40 has undertaken altogether 10'000 actions to combat climate change. The Covenant of Mayors CoM, which in 2016 became the Global Covenant of Mayors GCoM, is headquartered in Brussels and counts now more than 9100 cities representing 10% of world population. Its aim is to make cities invest for mitigation and adaptation. The World Bank has a cooperation program of 4.5 billion USD over the period 2018 - 2020 with GCoM, allowing for cities to realize ambitious climate action programmes. The particularity of the GCoM and its predecessor, the CoM, is that its action is results-oriented and measurable. The verifiable engagements of the 6200 members of the former CoM amount to cumulative emissions reductions of 27% from 2008 to 2020. GCoM has already 340 member-cities in APEC, accounting for a total of 230 million inhabitants.

Policy instruments are but one type of instruments that support sustainability. Other types of instruments are scientific concepts. Physical and life sciences contribute to the notion of sustainability in three ways, namely, to formulate sustainability as conquest of time (H-indicator), or as struggle against the entropy principle, or as homeostatic regulation. Economic analysis contributes to sustainability by searching for the appropriate game-theoretical framework for analysing sustainable development paths, or by defining internalization of externalities as key principle for making markets more efficient, or by enlarging the System of National Accounts to become the System of Environmental-Economic Accounts. The latter is a measurement system for sustainability which has been adopted by two APEC cities. Other

measurement systems for sustainability are the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC), and the Index System of APEC Low-Carbon Towns LCT-I. Further instruments supporting sustainability are planning tools, especially the Multi Criteria Decision Making (MCDM) which is shown to be particularly well adapted to a political framework such as the SDGs, consisting of several different goals that may conflict with each other. Another tool is E-government, especially its principle of Open Government Data (OGD), which figures among the recommendations of this report. New ICTs in support of sustainable urbanization include big data, artificial intelligence, internet of things, virtual and augmented reality, high performance and quantum computing, and blockchains. Among the instruments that support sustainability are also ISO and IEC standards. This report suggests referring to ISO standard 37151 for smart cities, and to the ISO standards on energy efficiency in buildings (ISO 52000 series).

Finally, a selection of cutting-edge technologies is presented among the instruments supporting sustainability, intended to show technologies that are only just emerging. Plus-energy districts can become the nuclei of sustainable urban housing contributing significantly to their own energy balance. Next generation photovoltaic devices offer cheap, decentralized electricity on any type of surface and at low light intensity. Wastewater-to-electricity diminishes environmental impact of wastewater treatment, as well as subsidy rates, through sale of energy. Fuel-cell vehicles extend the range of electric vehicles. Self-driving cars enhance driving comfort of car users. Photovoltaic roads could show the way towards wireless charging for electric vehicles. Automatized underground freight transport relieves congestion on urban roads and diminishes environmental impact. China recently presented six new projects of this kind.

Recommendations

This report outlines the elements of a cooperative strategy for scaling up APEC sustainable urbanization by targeted focus on energy technologies that synergize resilience with better economic performance, social inclusiveness and less environmental impact. The report basically suggests that the cooperation partners identified in the report should fulfil their roles as outlined in the Conclusion of the report, and thereby implement the strategy.

This strategy identifies altogether 15 different roles and their respective cooperation partners. This relative complexity originates from the complexity of APEC organizational structures. Most importantly, the APEC Energy Working Group EWG is the adopting authority of the strategy, while APEC Sustainable Energy Center APSEC is the executing agency. APEC cities, all of them acting on voluntary basis, are the key cooperation partners for this strategy. The suggested core values of the partners are closely related to sustainable urbanization and can be found in SDG 11.b, asking for a commitment to integrated urban policies and planning. The suggested time frame for the strategy is 2030, like all the overarching political frameworks to which the strategy refers.

Three activities are suggested, all of them have in common results-oriented monitoring; no such monitoring exists in APEC yet:

The first activity is results-oriented monitoring, at city-level, of the implementation of the Sendai Framework for Disaster Risk Reduction DRR by EWG, in cooperation with EPWG.

The second activity is results-oriented monitoring by EWG, at city-level, of the implementation of the INDC as communicated to the UNFCCC.

The third activity is results-oriented monitoring by EWG, at city-level, of the implementation of APEC Leaders' two aspirational goals (diminution by 45% of the energy intensity of the city's GDP by 2035 and doubling the share of renewable energy in the city's energy mix by 2030), and of the three other energy goals, by means of proxies, as detailed in the text.

A proposed exploratory activity for EWG is the implementation of the system of environmental-economic accounting (SEEA) at city level, following examples of two APEC cities. To this activity, EWG could contribute, but not take the leading role. The leader could be the APEC PSU or the FotC Urbanization.

This report is designed to have a decisive and multi-year impact on the discussion on urban sustainability in APEC fora. For overcoming the data shortage at city-level, the report suggests that APSEC should collect relevant statistics directly from cities, through an appropriate city network, and use them for research on urban sustainability. The intention is also to make these statistics publicly available, increasing transparency about achieved results.

EWG as authority over this strategy may analyse the results achieved by cities, compare them to APEC Leaders' energy goals, and report back to the Leaders.

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Chapter 1 – Basic Facts about Urbanization

In some APEC economies, urbanization has been taking place at high speed, a phenomenon which is related to rapid industrialization. China has been massively affected by this phenomenon. Within one generation, it has developed from a predominantly agricultural economy, with three quarters of population being agricultural at the end of the 1980s, to a predominantly urban economy with almost 60% of urban population. Today, China has the largest urban population worldwide (758 million). Seven countries, among them the three APEC economies China, Indonesia and the United States, are expected to experience half the global increase of urban population by 2050. From the 12 biggest cities worldwide (2015), six are APEC cities (Tokyo, Shanghai, Mexico City, Beijing, Osaka, New York). Cities are engines of economic growth. Among the big world regions, China is the region where the contribution of cities to economic growth is largest (94%). APEC has higher per capita GDP than the world average, and higher per capita GDP growth than the world. APEC has also been slightly less affected by the financial crisis than the world. Contemporary urbanization trends are fully in line with the urbanization trends of early industrialization. At the beginning of industrialization, cities usually grow fast. After some time, population growth of cities slows down, but economic growth continues. Economic growth is limited by cost of land. This requires buildings to rise higher and higher to maintain competitiveness. More than 90% of the supertall buildings (>300m height) being constructed, planned or envisioned worldwide are in APEC cities. Competitiveness of cities also requires cities to keep urban transport fluid. Building new lanes for mass transit is not necessarily the best solution, as additional lanes may increase congestion (Braess' paradox). Constructing underground transport systems (or sky trains) may be more efficient, as a railway line has the capacity of 15 motorway lanes. Car sharing has also proven to be useful. Each shared car may remove up to 15 private cars from the streets. For achieving inclusive economic growth, there should be a size hierarchy of cities (generalized rank size rule). Medium-sized and small cities represent a significant way for diminishing unequal income distribution.

1.1. Urbanization Trends and Prospects

1.1.1. Urbanization Trends and Prospects Worldwide

Urbanization designates the process leading to the greater spatial concentration of people and economic activities in urban settlements. Mostly it is caused by migration from rural areas towards cities. It is a global phenomenon and a characteristic of modern civilization. At the global level, the number of people living in cities has been steadily increasing. This process started a long time ago and has accelerated during the past decades.

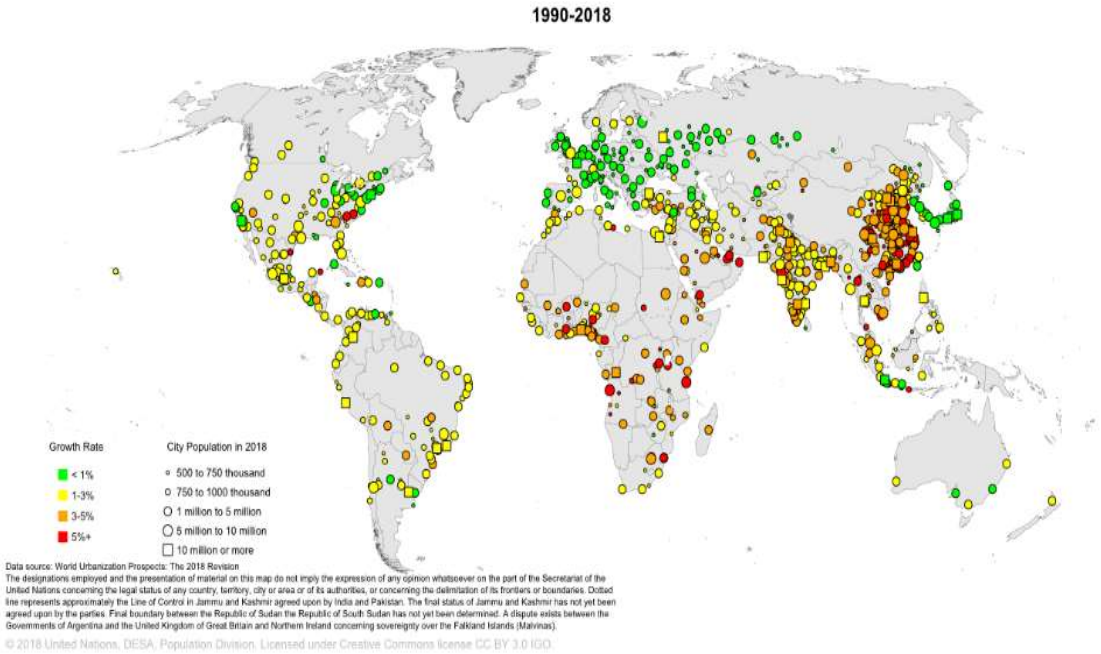

Figure 1: Growth of urban population by size class 1990 – 2018
Source: United Nations, DESA, Population Division, World Urbanization Prospects 2018[1]

In 1950, 30% of the global population lived in cities, whereas 70% lived in rural communities[2]. In 2008, this proportion was half and half. Today the percentage of world population living in cities is 55%. By 2050, two-thirds of global population is expected to live in cities.

In 2018, China has the largest urban population (758 million), followed by India (410 million)[3]. China and India together account for 30% of the global urban population. Adding urban populations of the United States of America (263 million), Brazil (173 million), Indonesia (134 million), Japan (118 million) and Russia (105 million), these seven economies account for 50% of world urban population.

In 2018, the most urbanized world regions are North America (82% of population living in urban areas), Latin America and Caribbean (81%), Europe (74%) and Oceania (68%). In Asia, the percentage of urban population is approaching 50%, while Africa (43% in urban areas) is still mainly rural.

According to UN projections, Asian and African cities will see an unprecedented increase in the urban population and are thereby expected to catch up with proportions of urban population that are observed in developed regions such as North America and Europe. At present, about 1.8 billion people worldwide (or 55%) live in urban areas. This figure is expected to reach 77% by 2050. By that time horizon, the urban population is expected to increase by a further 33% to 2.4 billion.

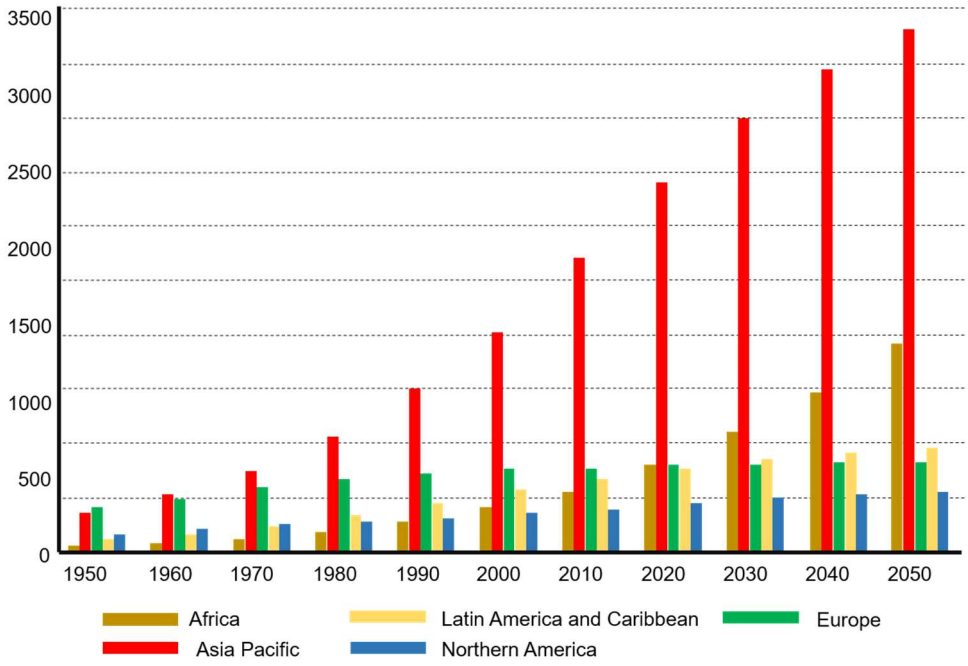

Figure 2: Projected World Urban Population until 2050
Data Source: World Urbanization Prospects 2014, DESA, UN

Nearly 90% of this increase is projected to take place in Asia and Africa[4]. 35% of this growth will take place in only three economies: India (416 million inhabitants), China (255 million), and Nigeria (189 million).

Projections into the future bear necessarily a certain degree of uncertainty. To recall the WUP 2014 revision: In 2014, urban population was projected to grow by 404 million people in India, 292 million in China and 212 million in Nigeria. In other words, 2050 projections for India have been revised upwards, while projections for China and Nigeria have been revised downwards in the 2018 edition.

Seven economies are expected to show half the global increase of urban population by 2050: India, China, Nigeria, Indonesia, the United States of America, Pakistan and the Democratic Republic of Congo.

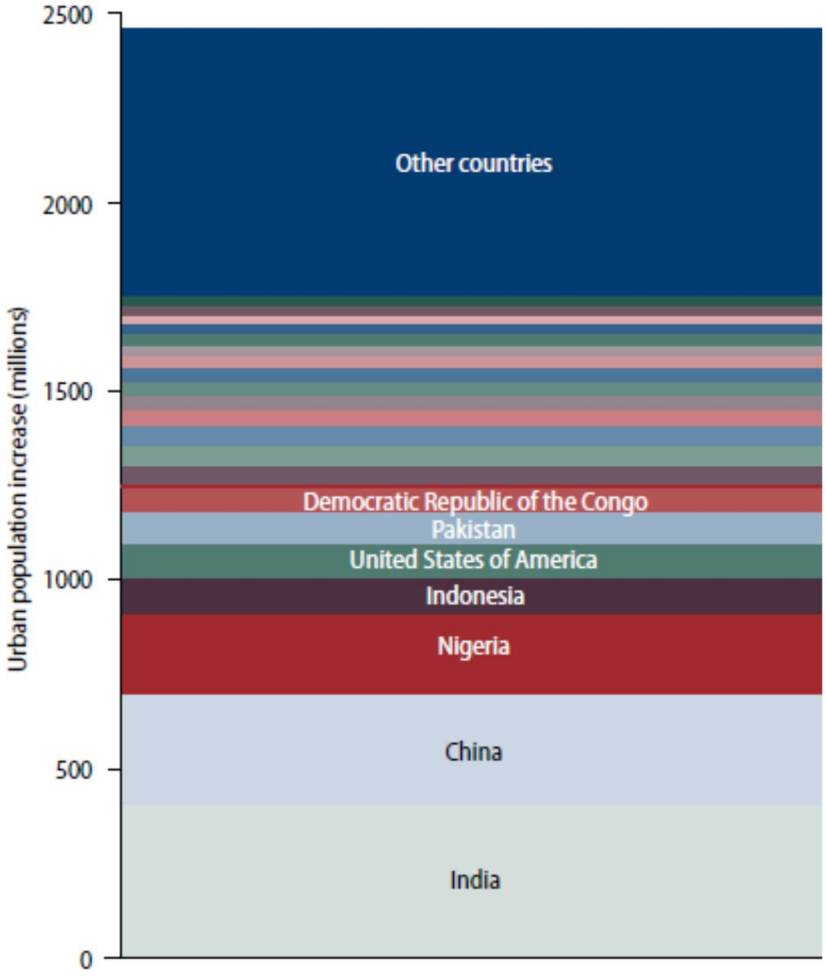

Figure 3: Contribution to urbanization by 2050
Source: World Urbanization Prospects Highlights 2014

The decline of urban population is expected to take place in Japan and Russia, despite an increase in the percentage of urban population. By 2050, Japanese cities may lose altogether 12 million urban dwellers and Russian cities 7 million dwellers.

In 2018, Tokyo is the world's biggest city (37 million inhabitants), followed by Delhi (29 million), Shanghai (26 million), Mexico City and Sao Paolo with each around 22 million inhabitants. Cairo, Mumbai, Beijing and Dhaka all have close to 20 million inhabitants each.

The growth of the world's biggest agglomerations shows diverse patterns. Tokyo and Osaka may soon reach the peak and start declining, whereas Delhi is still strongly growing. Beijing and Shanghai could peak after 2030.

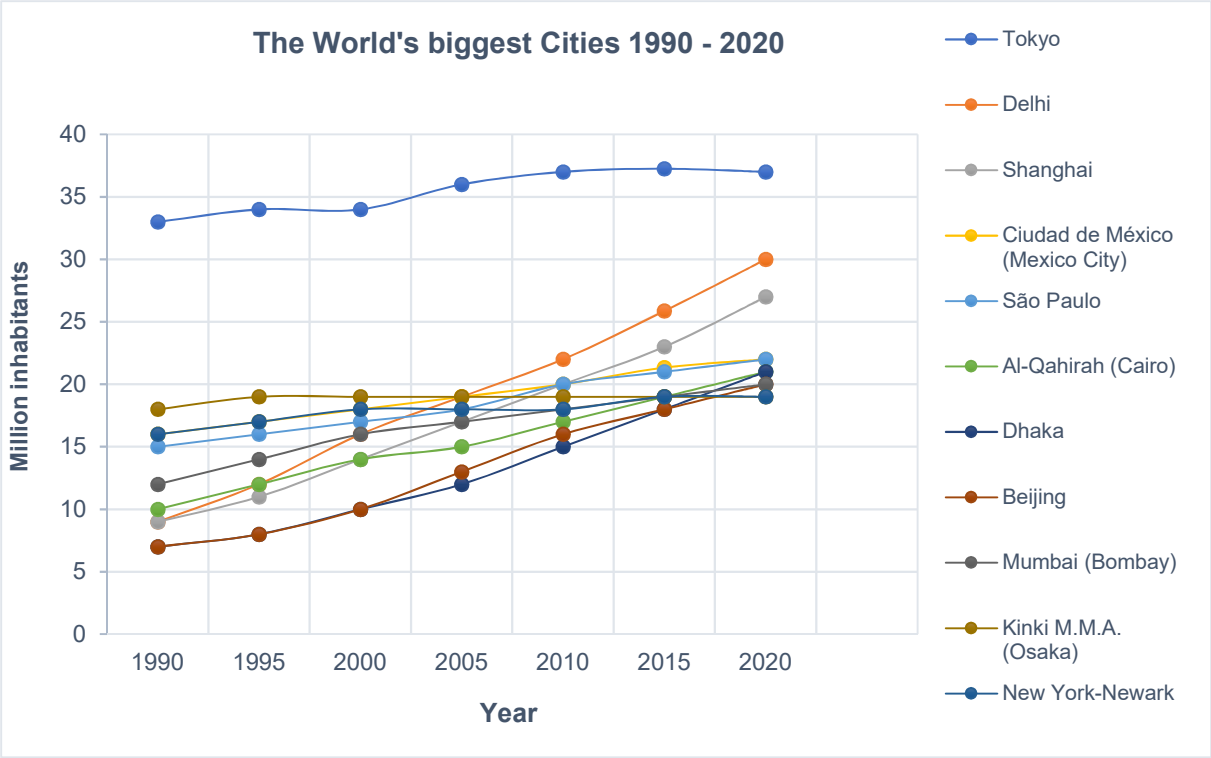

Figure 4: Growth patterns of the world's biggest cities
Data Source: World Urbanization Prospects

By 2030, 43 urban agglomerations worldwide will have at least 10 million inhabitants each, a third more compared to 33 such mega-cities of 2018. Today, close to half the world urban population resides in cities of less than half a million inhabitants.

The annual growth rate of cities varies between continents. European and Northern American cities showed low growth rates since the 1950s, whereas growth in Latin American cities declined smoothly over the past decades. Asian and African cities show irregular variations of growth rates which may reflect the history of major economies of these regions.

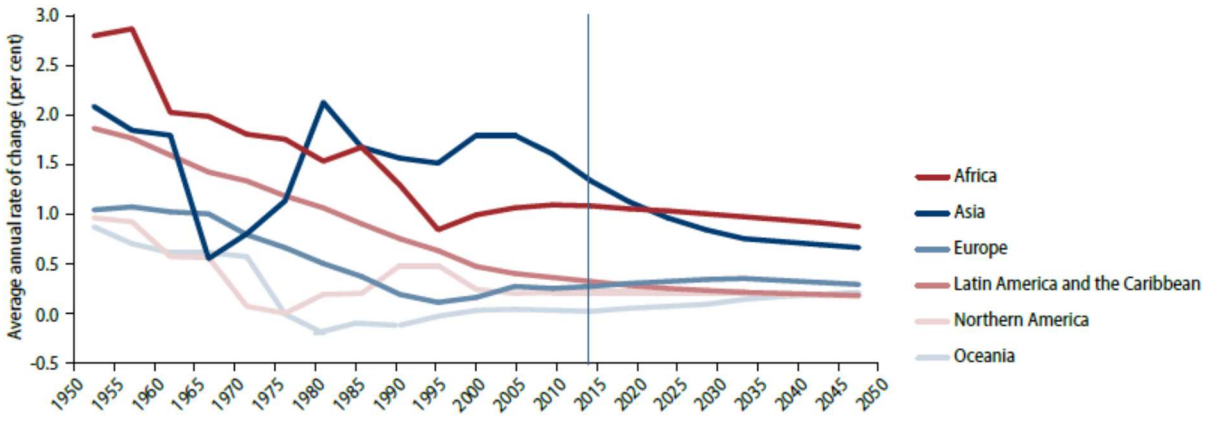

Figure 5: Annual growth rates of urban population by regions
Source: World Urbanization Prospects Highlights 2014

While the world urban population is growing, the world rural population is not yet declining. The global rural population is now close to 3.4 billion and is expected to rise slightly and peak in the coming decade and to start declining to 3.1 billion by 2050[5]. Once rural areas will stop delivering migrants to cities and cities will stop growing, the world will face completely different challenges from today.

Modern cities are places of heavy geographic concentration of population, wealth, and environmental impacts. A population concentrated on less than 5% of the global land mass consumes more than two thirds of global energy and emit over 70% of global greenhouse gases[6].

The growth of cities does not happen everywhere along the same pattern. On most of the continents, the built-up area of cities grows when population grows, whereas in Northern America and Europe, the built-up area of cities grows significantly, even without population growth. The latter points to the problem of urban sprawl, which affects cities in Europe and Northern America more than elsewhere. The figure below, reproducing data points 1975, 1990, 2000 and 2015, shows that even in Asia, Africa and Latin America, where the built-up area of cities grew as a function of population, the built-up area grew much faster than the population. In Asia, the built-up area of cities has more than tripled between 1975 and 2015, while the population in cities only doubled.

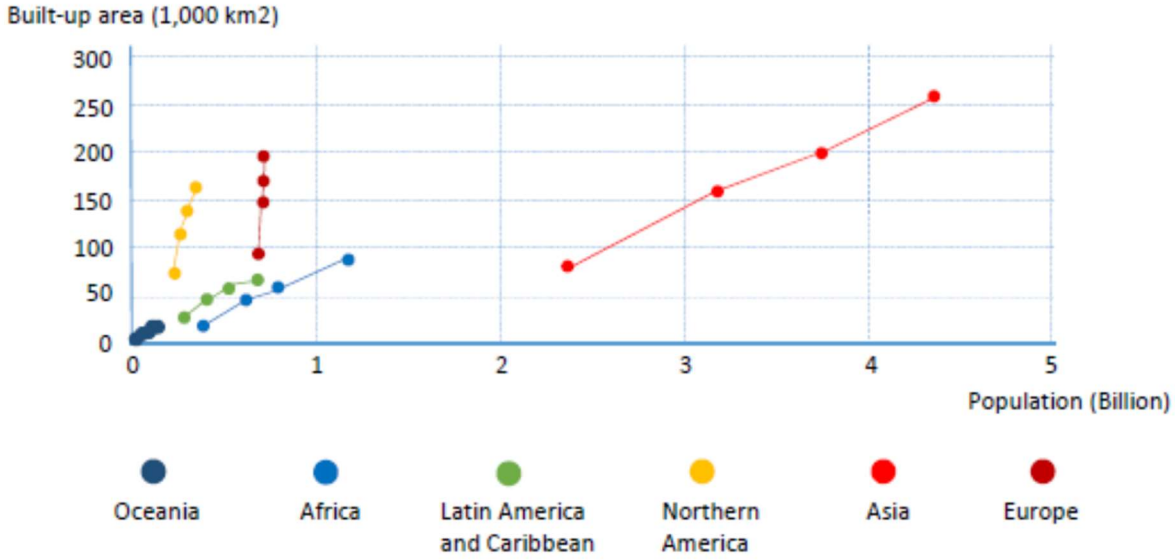

Figure 6: Growth of built-up area as function of population
Source: SDG11 Global Synthesis Report, UN Habitat[7]

Urban sprawl diminishes inclusiveness and energy efficiency of cities. This can be shown by the following comparison[8]. In 1990, the population of Atlanta (2.5 million) was slightly less than the population of Barcelona (2.8 million), but the built-up area of Atlanta (4280km^2) was more than twenty-five times larger than the built-up area of Barcelona (162km^2). This difference has a consecutive effect on the emissions of the transport system of both cities. The per capita CO_2 emissions of the public and private transport systems of Atlanta (7.5 tonnes per year) are more than ten times as high as the corresponding ones of Barcelona (0.7 tonnes). The low population density of Atlanta is seen as a difficulty in implementing an efficient public urban transport system.

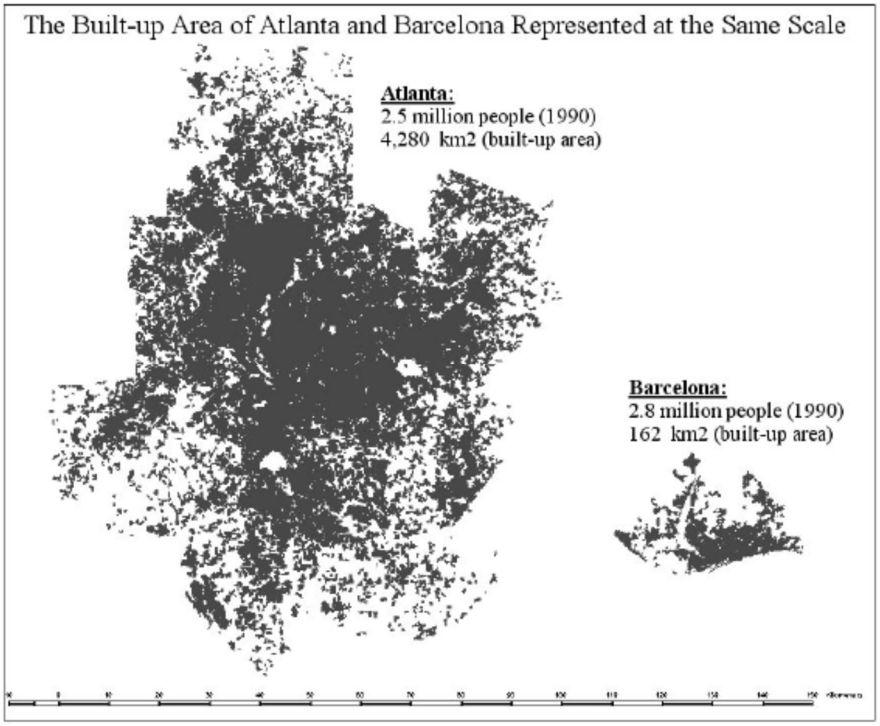

Figure 7: Comparison between Atlanta and Barcelona
Source: Bertaud, A. and Richardson, A.W., 2004. *Transit and Density: Atlanta, the United States and Western Europe*

In all the world regions, cities contribute to economic GDP growth of their region. This contribution is, however, different between one region and another. A projection for 2010 – 2025 can be found in the CityScope by McKinsey[9]. With 94%, the contribution of cities towards economic growth in the China region is expected to be highest among all regions, whereas the contribution of cities in South Asia is expected to be lowest (49%) among all the world regions. Unfortunately, the calculation method of this comparison is not revealed.

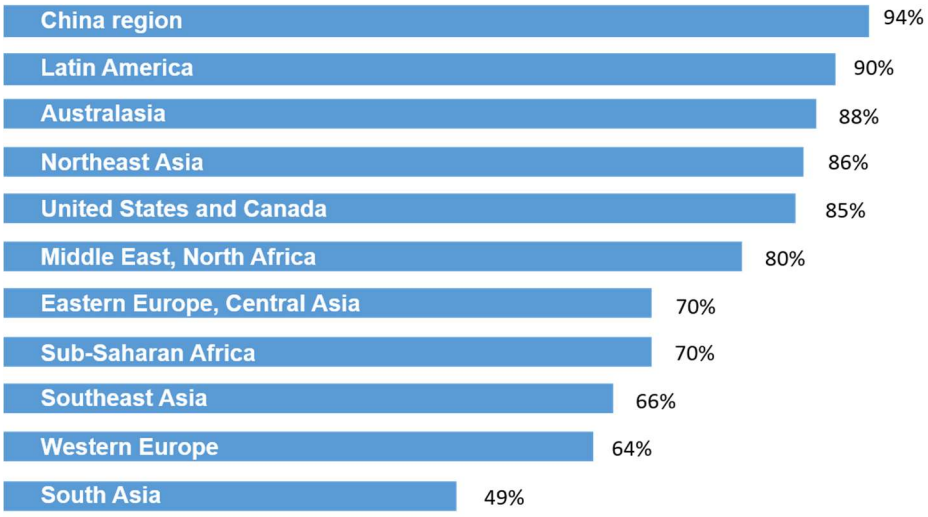

Figure 8: Contribution of cities to their region's total GDP growth 2010 – 2025
Source: McKinsey Global Institute CityScope v2.0 June 2012

Cities not only increase wealth, but also generate municipal solid waste. In OECD countries, the production of municipal solid waste is highest with amounts above 2kg per person per day. In Latin America, Eastern and Central Europe, the Middle East and Northern Africa, and East Asia and Pacific, it is around 1kg per person per day, whereas in Africa and in South Asia it is lowest.

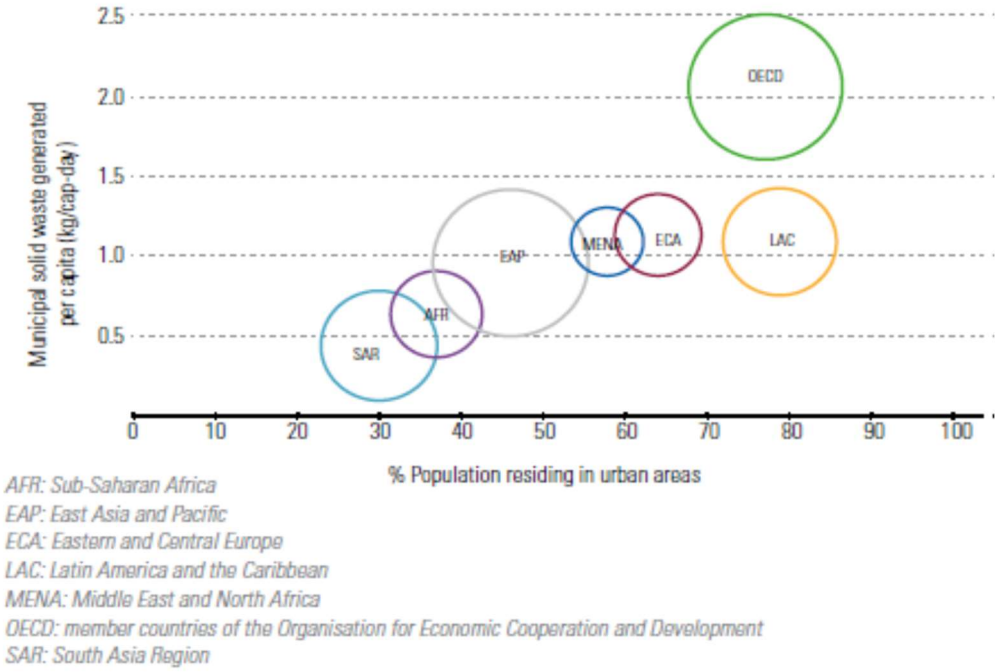

Figure 9: Waste management per capita as function of urbanization
Source: *World Cities Report 2016*, UN Habitat

Cities are not always more disaster resilient than rural areas. The *5th annual Natural Hazards Risk Atlas (NHRA)*[10] assesses the natural hazard exposure of over 1,300 cities, selected for their importance as significant economic and population centres in the coming decade. Of the 100 cities with the greatest exposure to natural hazards, 21 are in the Philippines, 16 in China, 11 in Japan and 8 in Bangladesh. The analysis considers the combined risk posed by tropical storms and cyclones, floods, earthquakes, tsunamis, severe storms, extra-tropical cyclones, wildfires, storm surges, volcanoes and landslides. The Philippines' extreme exposure to a myriad of natural hazards is reflected by the inclusion of 8 of the economy's cities among the ten most at risk globally, including Tuguegarao (2nd), Lucena (3rd), Manila (4th), San Fernando (5th) and Cabanatuan (6th). Among the 10 most exposed cities worldwide, only Port Vila, Vanuatu (1st) and Taipei City, Chinese Taipei (8th) are not located in the Philippines.

At the global level, high exposure of cities to natural hazards correlates with strong population growth. A projection for the time interval 2018 – 2035 has been made for 1800 cities using the Verisk Maplecroft climate change vulnerability index CCVI[11]. Over 95% of the 234 cities considered 'extreme risk' in the climate change vulnerability index are in Africa and Asia. These are predicted to have population growth mostly over 2% per annum. At the other end of the spectrum, 86% of the 292 'low risk' cities are in Europe and the Americas and can mostly expect population growth of less than 2% per annum. Unfortunately, this CCV-Index is of limited scientific validity as its formula is not revealed to the public.

1.1.2. Urbanization Trends and Prospects in APEC

The APEC economies stretch over four continents, and are, therefore, one of the largest and most heterogeneous organizational groupings in the world. All types of economy are present: developed, emerging and developing economies. The percentage of population living in urban areas in selected economies clearly evidences the three categories of economies.

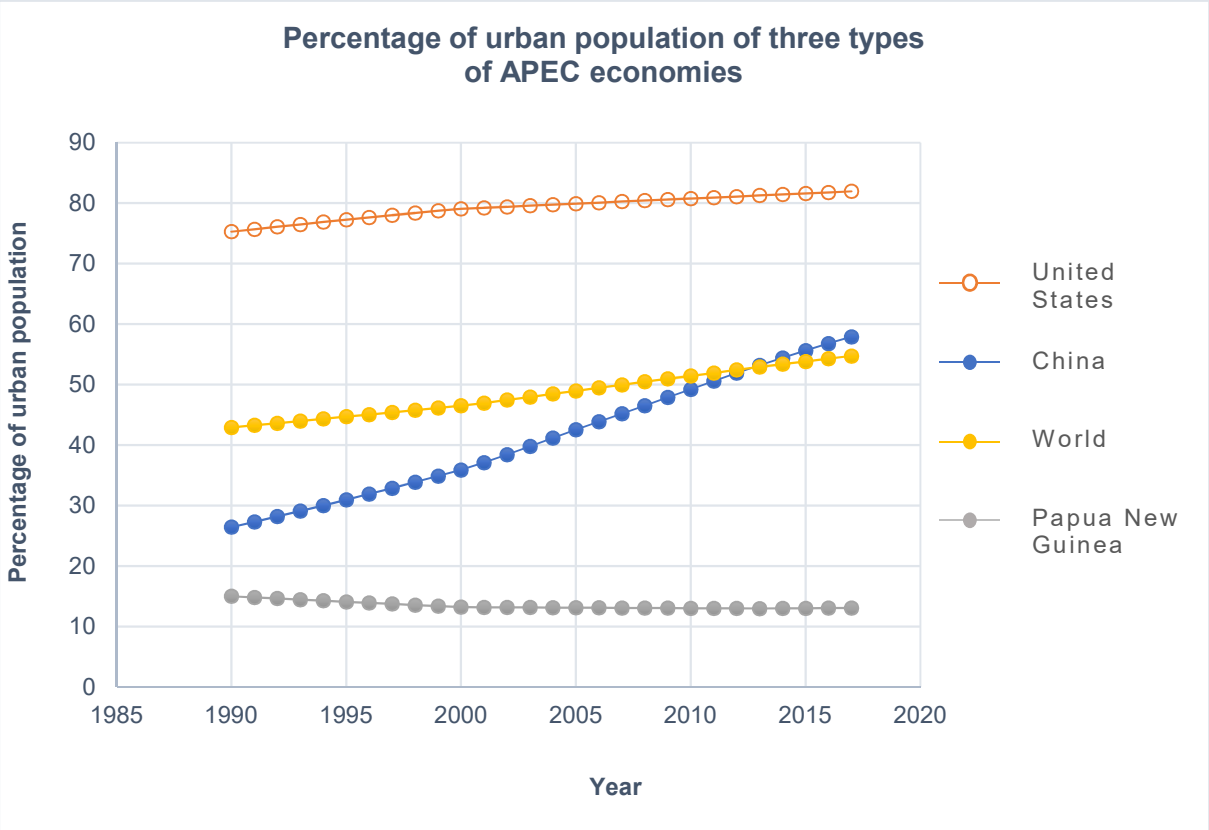

Figure 10: Percentage of urban population in three types of APEC economies
Data source: World Bank Data

Among all three categories of economies, emerging economies show the highest urbanization development rates. For China, the percentage of urban population has practically doubled since 1990. In international comparison, China marked a very high urbanization growth during the period 1990 to 2018 when compared to the world average of the same period.

Within less than one generation, China evolved from a predominantly agricultural to an urban type of society. China has undergone the fastest and most profound change and has evolved more rapidly than Asia, and even more rapidly than East Asia.

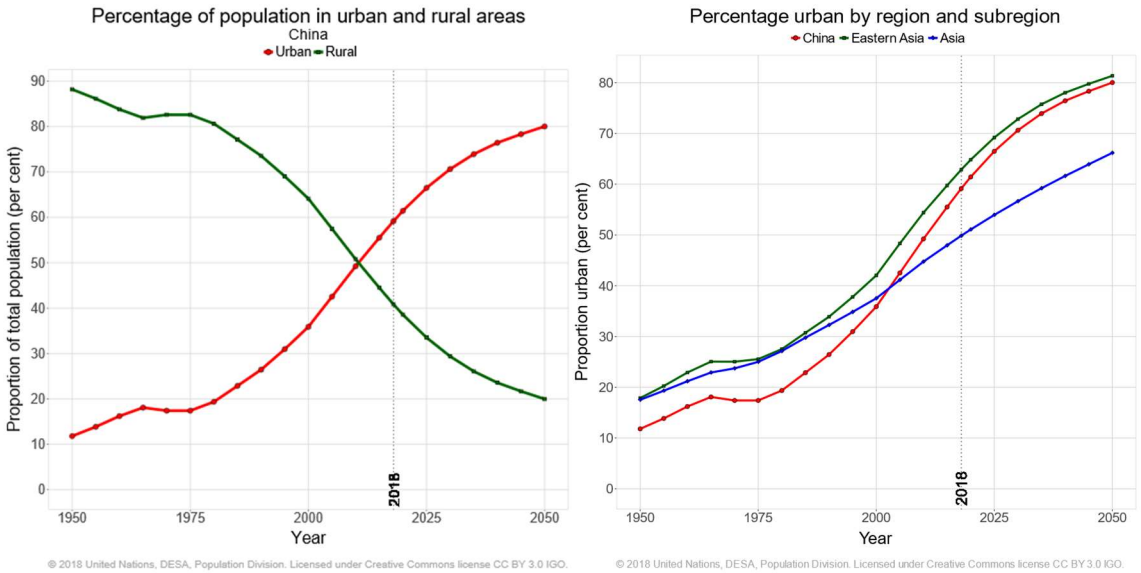

Figure 11: Rural-urban transition in China
Source: United Nations, DESA, Population Division, *World Urbanization Prospects 2018*

For showing the structural diversity that exists within APEC, the region has been divided into two groups: one comprising economies that started with urbanization proportions above 60% in 1990 (starting as urban economies, or “urban starting economies”), and a second group with urbanization proportions of 50% and less in 1990 (starting as rural economies, or “rural starting economies” in short). The evolution of both groups of APEC economies is shown in the two figures below. The first group can be characterized as follows:

- It comprises two city-economies (Singapore and Hongkong, China) showing 100% urban population all the way long.
- Australia, New Zealand and Chile started in 1990 from a proportion of urban population already above 80% and steadily grew until 2017.
- A special case is Japan which shows a post-industrial urbanization starting in 2000, bringing it from a high level of almost 80% to a very high level of over 90% in 2017.
- Very similar urbanization patterns are found in the three economies, the US, Canada and Korea, all three starting below 80% in 1990 with a slow increase to above 80% in 2018.
- A special case, Russia, shows practically no change in the proportion of urban population at 73% since 1990.
- A further group of economies is composed of Mexico, Peru and Brunei Darussalam, all three evolving from similar levels between 65% and 71% in 1990 to attain a level just under 80% in 2017.
- For comparison, the proportion of urban population in world average increased from 43% to 55% during the period 1990 – 2017.

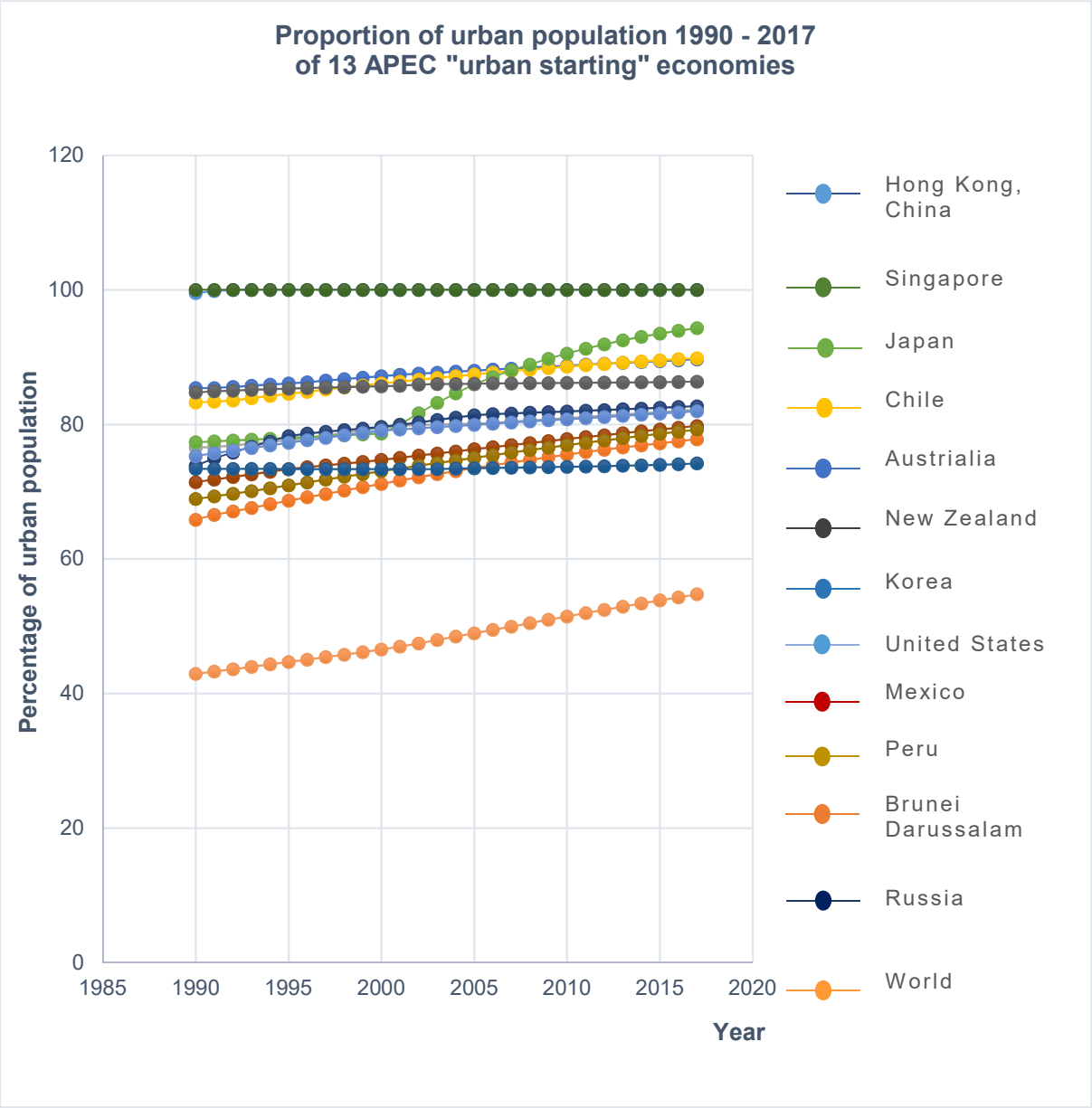

Figure 12: Proportion of urban population of "urban starting economies"
Data source: World Bank World Development Indicators[12]

- The second group comprises seven other APEC economies that had a proportion of urban population of 50% or less in 1990, showing, however, different urbanization paths up to 2017. Thus, rapid urbanization was experienced since 1990 in Malaysia, Indonesia, China, Thailand (since 2000), and Viet Nam, the latter starting from a low level of around 20%. These are the typical emerging economies within APEC.
- The Philippines and Papua New Guinea show that the proportion of urban population has slightly decreased during the period 1990 – 2017.
- APEC database does not have any data on urban population.
- World Bank does not have any data on Chinese Taipei. Hence urban population of Chinese Taipei is absent from these two figures.

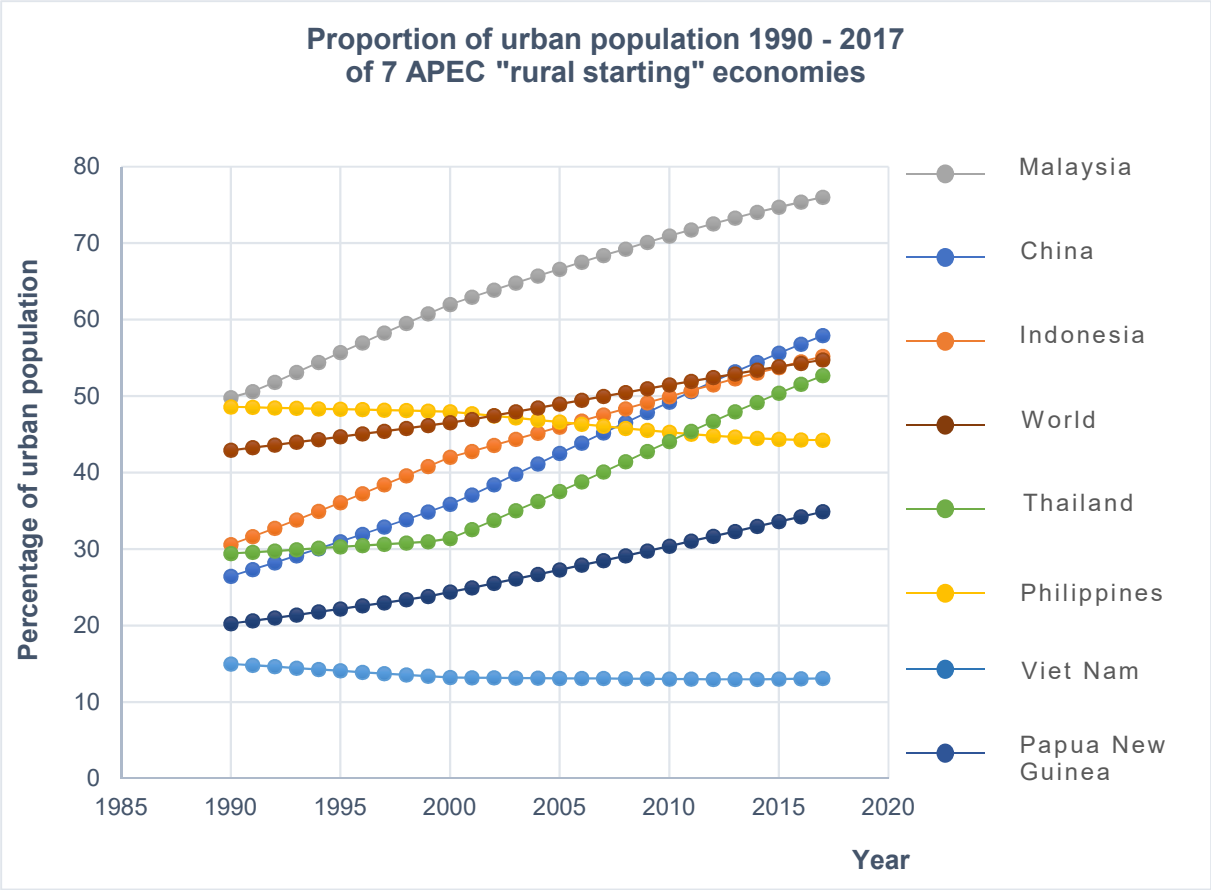

Figure 13: Proportion of urban population of "rural starting economies"
Data source: World Bank World Development Indicators[13]

The above analysis evidences that three APEC economies (Russia, the Philippines, and Papua New Guinea) show stagnating or even decreasing percentages of urban population. As this evolution is contrary to the global trend, it is worthwhile investigating the urban population of these three economies in a longer-term perspective back to 1950. In fact, all three economies had a growing percentage of urban population until 1990, after which they experienced a change of pattern during more than two decades and could possibly be starting to grow the proportion of urban population again in the coming years.

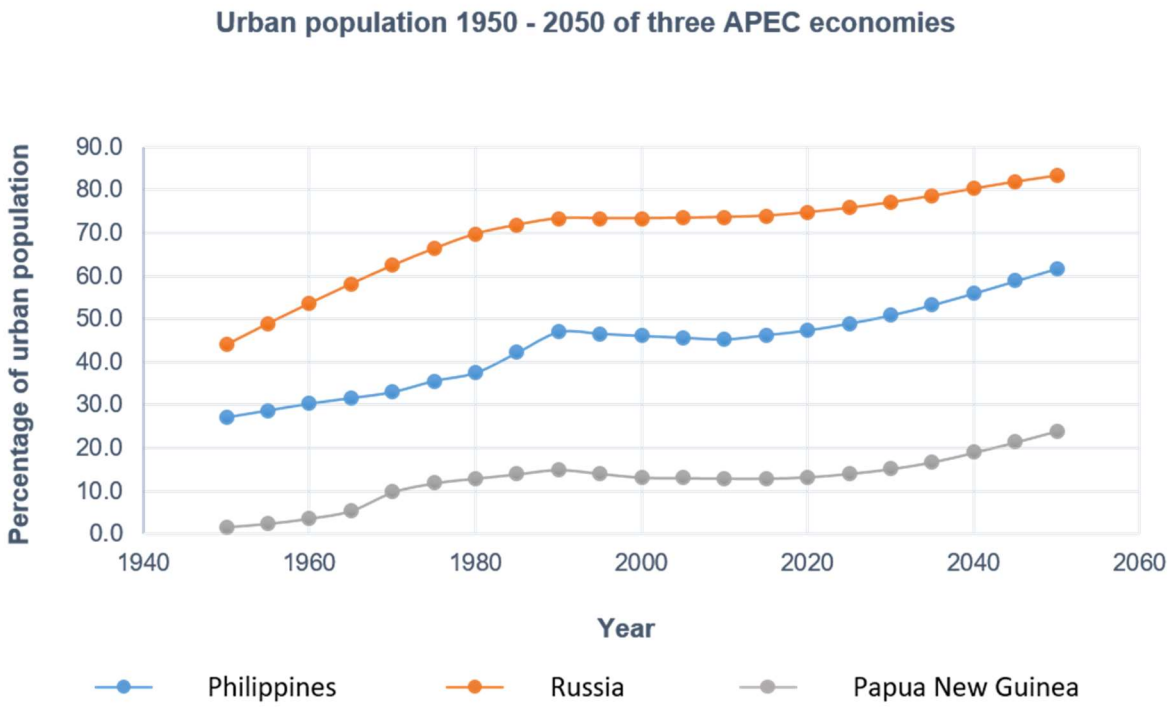

Figure 14: Urban population 1950 – 2050 of three APEC economies
Data source: World Urbanization Prospects[14]

1.1.3. Absence of a Standardized Definition of Urban Population

The above statistics may have a methodological problem that would need to be corrected if rigorous statistical or mathematical modelling was used. The problem is that the concept "city" does not have an internationally standardized meaning. Contrary to, e.g. the definition of "poverty", which has been internationally standardized, the concept of "city" has not. Each economy uses its own definition of what it means by "city". Most economies use a minimum population threshold to define whether an agglomeration is a city or not. It may strike to note how low these thresholds sometimes set at. Four economies consider a "city" to be an agglomeration already at a threshold of just 200 inhabitants, whereas 23 economies (the biggest group) set this threshold to 2000 inhabitants. No economy uses a threshold of more than 50'000 inhabitants for defining a city[15].

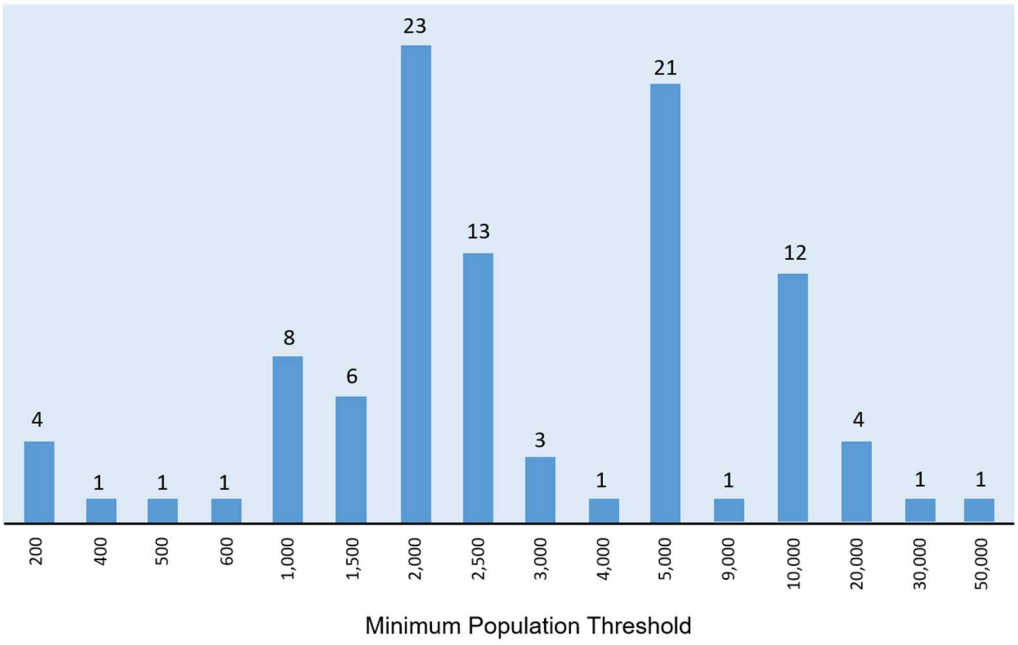

Figure 15: Minimum population threshold for defining a city
Source: contribution by Chandan Deuskar[16]

Besides the minimum threshold, some economies also use minimum population density per square kilometre to qualify a city. The lowest density threshold is used by Germany (150 persons per square km) and highest one by China and the Seychelles (1500 persons/km2).

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

Besides the "city", also the "agglomeration" takes increasing importance. The *World Development Report 2009*[17] uses instead of the "city" a harmonized concept of "agglomeration" which it defines as an area whose core has:

- a population density of over 150 persons per square km
- a population of over 50'000 inhabitants
- and can be reached from outside within 60 minutes travel time

The *World Development Report 2009* defines the percentage of urban population as a function of the above definition of agglomeration. As the *World Development Report 2009* is the first study to have introduced a standardized definition of urban population in the global context, it allows comparing this new standardized definition of urban population with the conventional non-standardized definition of urban population used by the World Bank, by the World Urbanization Prospects of the UN, and by governmental statistics. The discrepancy between harmonized and non-harmonized definitions for a few selected economies and for regions is shown in the figures below.

Using this standardized definition, the percentage of global urban population in the year 2000 would not have been 47%, as shown in the figures above and in all the other data sets, such as World Urbanization Prospect (WUP) data, but 52%, i.e. five percentage points higher. With the harmonized definition of agglomeration, the global 50% urban population threshold was attained before the year 2000 and not in 2008.

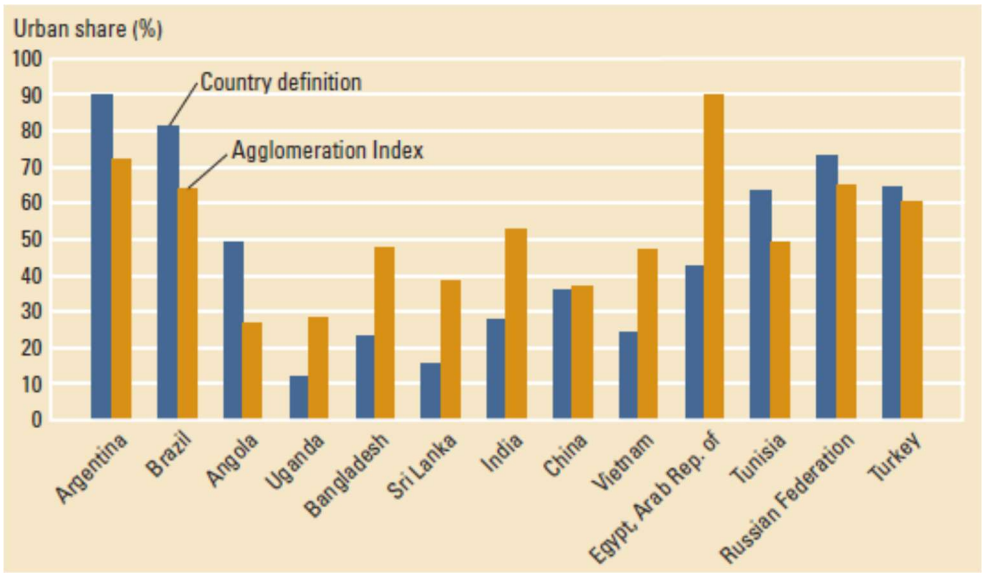

Figure 16: Discrepancy between the harmonized and the non-harmonized definition of city for selected economies
Source: *World Development Report 2009*

In East Asia & Pacific, as well as, in other high-income economies which both are part of the APEC region, the difference between the conventional definition and the harmonized definition of urbanization seems not to be too significant, except for Viet Nam, which, when using the standard definition, seems to have a proportion of its urban population twice as high as what its own statistics show. Also, in South Asia the two statistics differ significantly, the harmonized index showing a much higher proportion of urban population than the conventional one. On the contrary, in Latin America, the harmonized definition gives a 10% lower proportion of urban population than the conventional one.

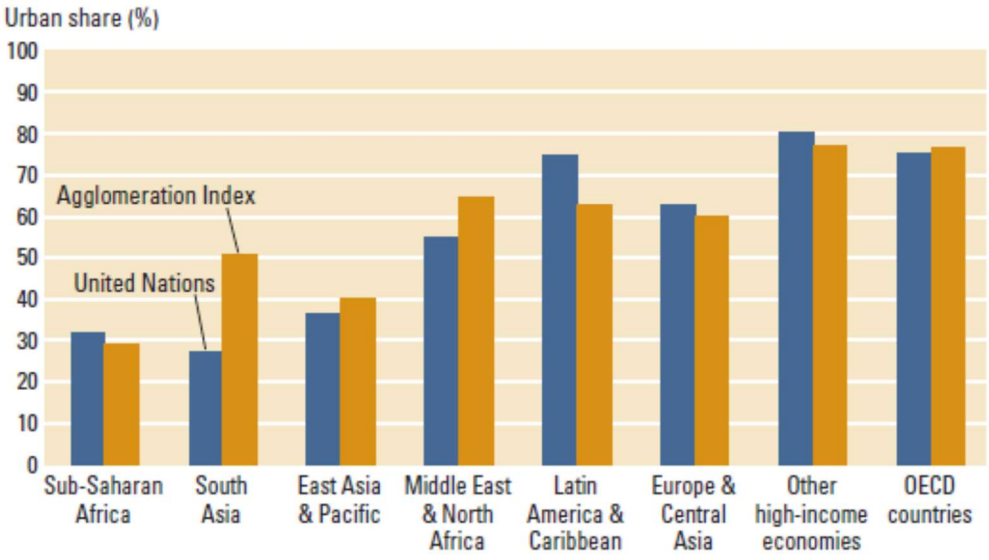

Figure 17: Discrepancy between the harmonized and the non-harmonized definition of urbanization for world regions
Source: *World Development Report 2009*

1.2. Relationship between Urbanization and Economic Growth

1.2.1. Economic Growth in APEC

When comparing per capita GDP in the time frame 1990 – 2016, APEC economies started higher than the world average and grew faster. As was mentioned in the preceding section, the percentage of urban population in APEC economies was higher than world average in 1990.

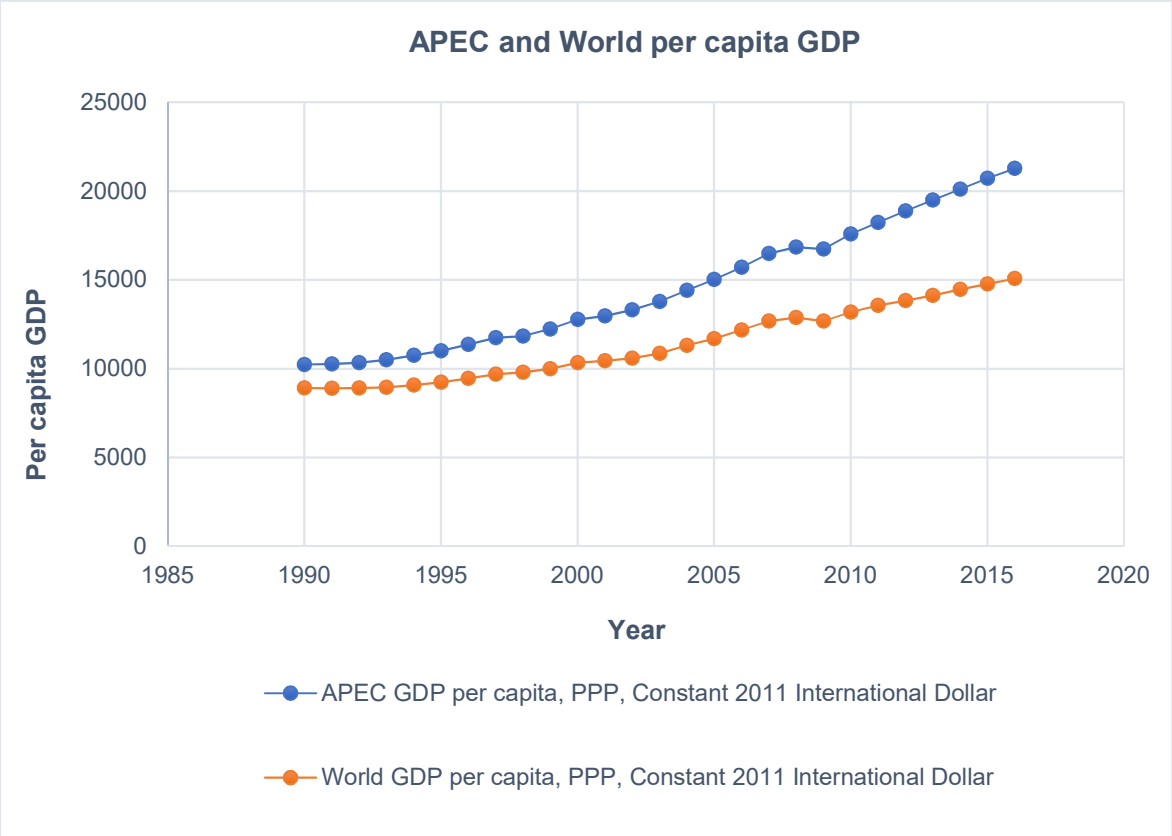

Figure 18: APEC and World per capita GDP PPP, Constant 2011 International Dollar
Data source: Stats APEC

When looking at the mean per capita GDP growth rate, the outstanding performance of China is striking. This can be put in relation, among others, to the above-made observation that China has undergone faster urbanization than any other economy.

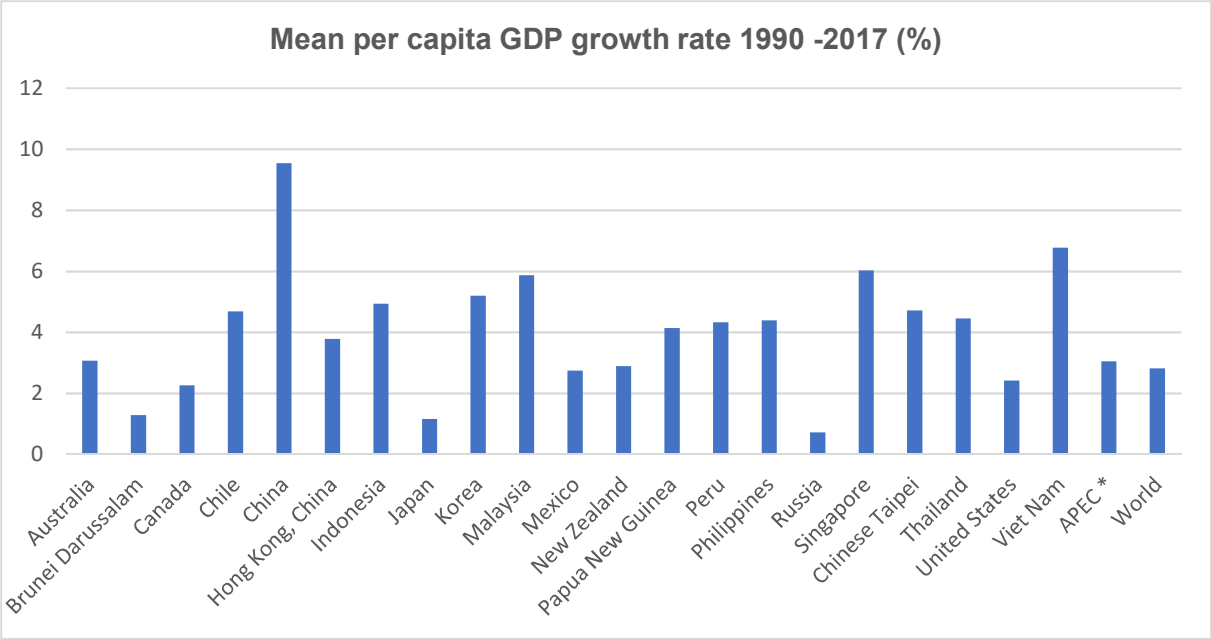

Figure 19: Mean per capita GDP growth rate 1990 – 2017, in percentages
Data source: Stats APEC

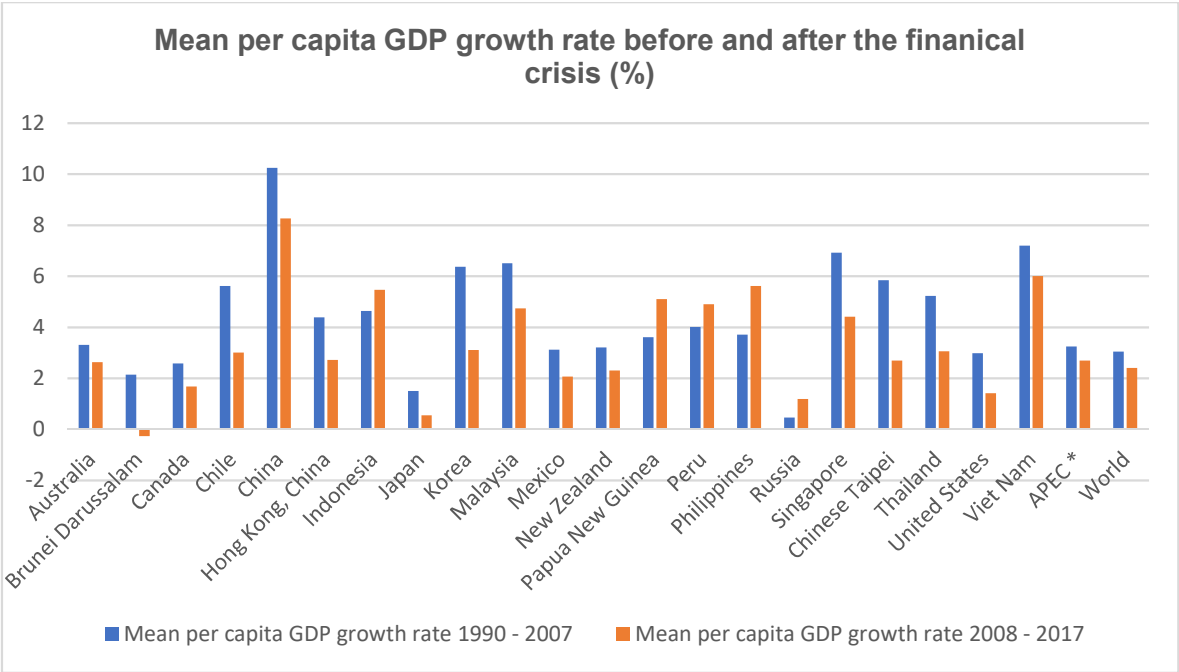

Figure 20: Mean per capita GDP growth rates before and after the financial crisis, in percentages
Data source: Stats APEC

APEC has higher per capita GDP than the world average, and higher per capita GDP growth than the world average. APEC has also been slightly less affected by the financial crisis than the world. But some APEC economies have heavily lost average annual per capita GDP growth since 2008: Korea (-3.3%), Chinese Taipei (-3.2%), Chile (-2.6%), Singapore (-2.5%), Thailand (-2.2%), China (-2.0%), Malaysia (-1.8%), whereas others have gained average

growth since 2008: The Philippines (+1.9%), Papua New Guinea (+1.5%), Peru (+0.9%), Indonesia (+0.8%), Russia (+0.7%). Note that the average per capita GDP growth for the entire APEC region in the above figures has been calculated after correction of an obvious error in APEC statistics, whose per capita GDP growth figure for 2015, reported in the data base as 23%, has been assumed to be a point-error which should read 2.3% instead. The APEC series corrected in this way is marked as APEC * in the above figures.

1.2.2. Urbanization Favouring Economic Growth

The statistics presented in the preceding sections point to some type of relationship between urbanization and economic growth. The relationship between the two is certainly complex. It shows that economic growth favours urbanization in many ways, and urbanization, in turn, has a positive influence on economic growth. In summary, this is a typical hen-and-egg problem which has been the object of several multi-disciplinary reports:

- *Partnerships for the Sustainable Development of Cities in the APEC Region*[18] compiled by the APEC Policy Support Unit (PSU) dates from 2017. It has 14 case studies from different parts of the APEC region and formulates a whole array of specific recommendations to APEC economic leaders. The main idea is to make neighbouring cities cooperate more intensely among themselves towards becoming regional pools of growth and innovation.

- *Urbanization and Growth* that has been prepared by the Commission on Growth and Development of the World Bank in 2009. It evidences that despite numerous partial theories that are explained in detail in that report, there is no general theory that could explain all the essential processes behind urban development and their relationship with the corresponding economic developments.

- A standard work remains certainly the *World Development Report 2009 – Reshaping Human Geography* elaborated by the World Bank. This may well be the hitherto most comprehensive analysis made on economic geography and spatial economy, a subject that is largely relevant for urbanization.

At economy level, there exists a statistical relationship between GDP and the proportion of urban population for the economies of the world. The two variables may not be too well correlated in a linear relationship. Nonetheless, the figure below shows e.g. that only two economies have a per capita income higher than 8’000 USD and an urban population rate below approximately 50% (high income with little urbanization, blue lines). Conversely, only two economies have per capita income lower than about 2’500 USD and an urban population rate of more than 60% (low income with high urban population rate, yellow lines).

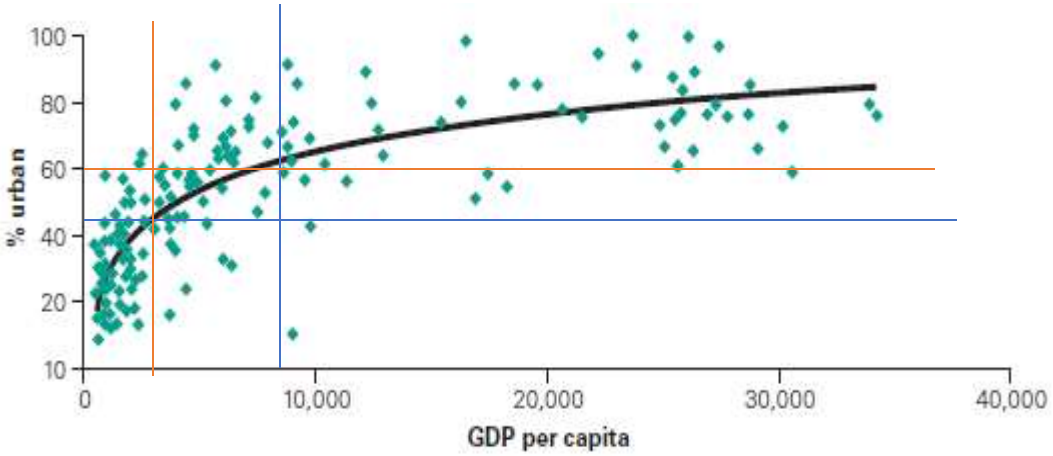

Figure 21: Statistical relationship between urban population and GDP

Source: Patricia Clarke Annez and Robert M. Buckley: Urbanization and Growth: Setting the Context, in: *Commission on Growth and Development: Urbanization and Growth*, The World Bank, 2009.

A similar development can be seen in historic perspective. In many economies, production concentrates in some areas when development levels rise.

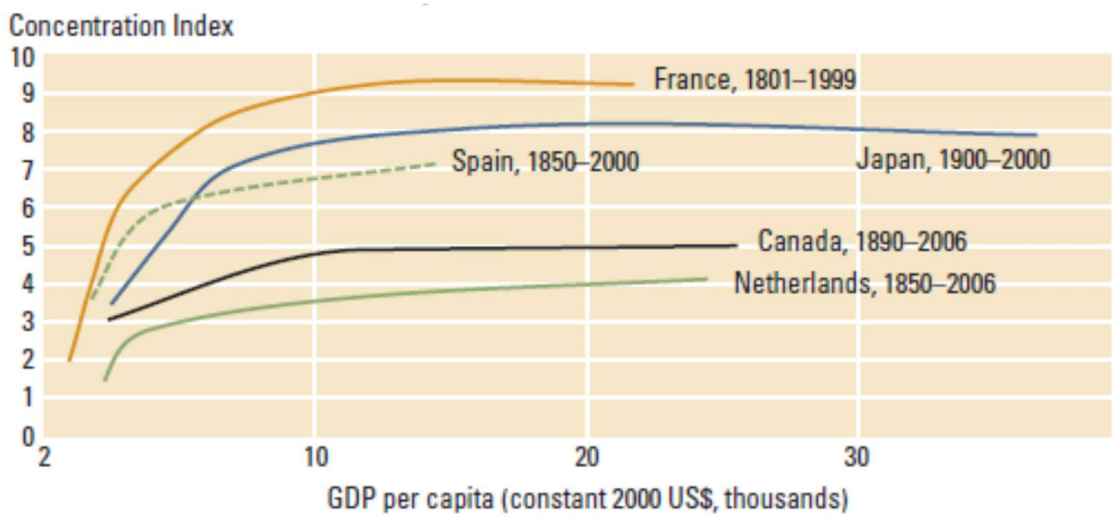

Figure 22: History of concentration process in leading areas of some economies
Source: *World Development Report 2009*

1.2.3. Economic Explanation for Size and Growth of Cities

Urbanization in the early stage has often been associated with hardships for the newly arriving dwellers. In the West African city of Lagos, people speak about living in a pressure cooker. The population is so dense, and the activity is so hectic that people share rooms on a six-hour basis before turning it over to other people. What's more, Lagos is one of the places where crime and insecurity are among the highest in the world. Why then would people go to live and work in Lagos?

This skewed negative image of urbanization has persisted for many years. It is mainly rooted in three misconceptions[19]:

- Rural-urban migration is unmanageable
- Rural-urban migration is unproductive
- Urban growth is driven by pro-urban bias rather than economic fundamentals.

A more profound scrutiny shows that these misconceptions are to some extent contributed by the lack of preparedness of the host cities to address the rural-urban migration. As will be shown hereafter, the size and growth of cities can well be explained by rational arguments. One of them is certainly that cities offer to their dwellers not only economic benefits, but also perspectives they would not have elsewhere. Jane Jacobs, the well-known urbanist, wrote[20]:

"A metropolitan economy, if it's working well, is constantly transforming many poor people into middle-class people, many illiterates into skilled people, many greenhorns into competent citizens. Cities don't lure the middle class. They create it."

The perspective of rural migrants to one day become part of the urban middle class is without any doubt sufficiently attractive to warrant large migration flows. For fulfilling this role, cities must however have a specific array of infrastructures that are typically used by the middle class: schools, hospitals, roads and other networks.

In a nutshell, the question why agglomerations have their actual size at any given time is explained by the equilibrium between their centripetal and centrifugal forces. The main centripetal (or attracting) force is the economy of scale. Producing in bigger units makes the unit price lower. This holds not only for commercial, industrial or service enterprises, but also for cities that produce infrastructures and public services. Most literature suggests that at times of economic growth, centripetal forces of cities are stronger than the centrifugal ones. But there is some lack of understanding of what happens if the population of cities grows even at times when there is less economic drive. The major centrifugal force is the cost of living, which is driven especially by higher land cost due to land scarcity. One of the keys of a successful city planning is to diminish the negative effects of land scarcity by any technology that is available.

The question of whether cities foster economic efficiency has been answered positively in literature[21]. Cities provide large efficiency benefits to their economic agents. Urban planners in rapidly growing cities are, therefore, well advised to improve the functioning of their cities by providing infrastructures and public services. The converse is also true: Restricting urbanization entails losses.

Cities offer increasing economies of scale. Three reasons can be given for that:

- Firstly, a larger city allows for more efficient sharing of infrastructure. Larger cities make it easier to connect to special infrastructures.
- Secondly, a larger city allows for better matching between buyers and vendors, employers and employees, borrowers and lenders.
- Thirdly, a larger city can favour innovation, learning, diffusion and learning by offering higher frequencies of contacts with other actors.

These three factors taken together create an atypical relationship for wages in cities. Normally one would expect that the bigger the labour force, the lower the wages. With an increasing economy of scale, this relationship inverses: increasing labour force tends to

increase the wages. This is the fundamental reason why cities exist. This reason holds as long as the economies of scale hold. Economies of scale are specific for each economic activity.

Besides being determined by wages, the cities' size is also determined by the cost of living. In small and medium size cities, cost of living increases slower than wages. At a certain saturation point, the cost of living can start to increase more rapidly than the wages. Beyond this point, cities become congested and show more and more negative factors for its industries and inhabitants.

The difference between the two curves is the net wage curve. Point B is the optimal size of cities from the workers' perspective as it maximises workers' net wage. As market equilibrium will also depend on labour supply, the market equilibrium will lie at point C. This can be interpreted as the point beyond which workers will decide to move out of the city.

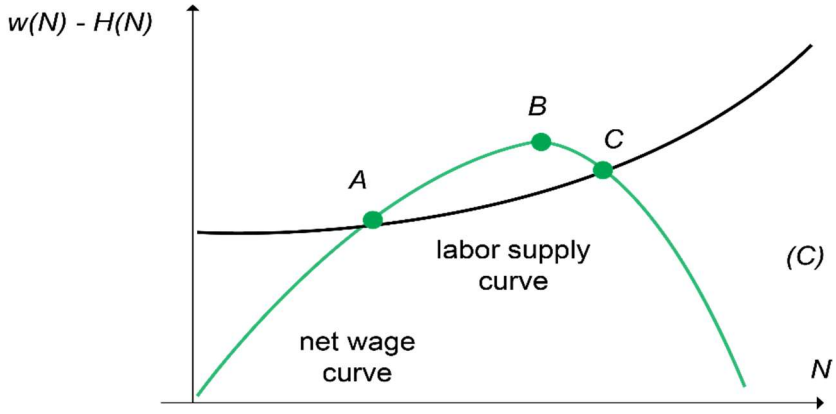

Figure 23, Labour supply (black) and net wage curves of cities as a function of size
Source: Gilles Duranton: Are Cities Engines of Growth and Prosperity for Developing Countries? In *Commission on Growth and Development: Urbanization and Growth*, The World Bank, 2009.

A similar pattern exists for revenue curves and cost curves of enterprises. In a dynamic technological environment, the slopes of these graphs, as well as, their points of intersection change in time. Increasing economy of scale is the main driver for cities to grow. This is specific not only for each economic activity (thus, e.g. restaurants are usually smaller than car factories) but also for each technology used in each activity (meaning that a nuclear power plant is usually larger than a gas-fired power station).

A decisive factor for the existence of economies of scale is upfront investment cost. Whenever the upfront investment is high, the economy of scale is an essential tool to reduce unit cost to market prices or below. In their growth strategies, cities attract activities such as large factories that are dependent on increasing scale.

Some economies of scale are based on physical laws and are, therefore, not the result of regulatory or economic decisions. A simple example is the thermic loss of a heat storage. Thermic loss depends on the ratio between volume and surface of the storage. An efficient thermic storage minimizes surface for a given volume. It is easy to show that this is best satisfied for a storage that has the form of a large sphere. For a given volume, a large sphere minimizes the thermal losses of an energy storage. This natural law, together with other factors such as the abundance of heat sources in cities, predestines large cities to be competitive over small cities for large-scale heat storage. For practical reasons, this would usually be underground storage.

Economy of scale may determine the number of competitive enterprises that are active in one market. There are markets where only one enterprise can be active (so-called natural monopolies). These include all infrastructure markets that have a so-called “last mile” characteristic. As an example, which may illustrate the “last mile”, any consumer will be connected to grids such as the electricity grid or the IT grid by one single entry point, beyond which he takes care himself of the internal distribution within his consumption unit. The advantage of cities is that the effective connection cost for such services is very low due to the physical proximity of clients. Strong regulatory oversight is necessary to oblige natural monopolists to offer these low costs to all urban clients. Low connection costs for clients are an essential locational factor for the city in maintaining the positive effect of economy of scale. Without proper regulation, the cost of the last mile billed to consumers can easily increase due to the lack of competition. This would then mean that connection cost will become a centrifugal force. Economic agents would then experience it as a negative locational factor and start reducing their activity in the city or even leave a city altogether.

All in all, the economies of scale can be characterized along two big categories, internal (if created within the enterprise) or external (created by other enterprises of the city), and further broken down to the categories pecuniary, technological, localization, urbanization, and pure agglomeration effects.

Type of economy of scale				Example
Internal	1. Pecuniary			Being able to purchase intermediate inputs at volume discounts
	Technological		2. Static technological	Falling average costs because of fixed costs of operating a plant
			3. Dynamic technological	Learning to operate a plant more efficiently over time
External or agglomeration	*Localization*	Static	4. “Shopping”	Shoppers are attracted to places where there are many sellers
			5. “Adam Smith” specialization	Outsourcing allows both the upstream input suppliers and downstream firms to profit from productivity gains because of specialization
			6. “Marshall” labor pooling	Workers with industry-specific skills are attracted to a location where there is a greater concentration.[a]
		Dynamic	7. “Marshall-Arrow-Romer” learning by doing	Reductions in costs that arise from repeated and continuous production activity over time and which spill over between firms in the same place
	Urbanization	Static	8. “Jane Jacobs” innovation	The more that different things are done locally, the more opportunity there is for observing and adapting ideas from others
			9. “Marshall” labor pooling	Workers in an industry bring innovations to firms in other industries; similar to no. 6 above, but the benefit arises from the diversity of industries in one location.
			10. “Adam Smith” division of labor	Similar to no. 5 above, the main difference being that the division of labor is made possible by the existence of many different buying industries in the same place
		Dynamic	11. “Romer” endogenous growth	The larger the market, the higher the profit; the more attractive the location to firms, the more jobs there are; the more labor pools there, the larger the market—and so on
	12. “Pure” agglomeration			Spreading fixed costs of infrastructure over more taxpayers; diseconomies arise from congestion and pollution

Table 1: Twelve types of economy of scale
Source: *World Development Report 2009*

The growth of cities is limited by centrifugal forces acting against the advantages of economies of scale. One of the most important limiting factors in cities’ growth is the land. Cities extend their geographic size in order to conquer their neighbourhood. The city of Mexico gives a good example of this process.

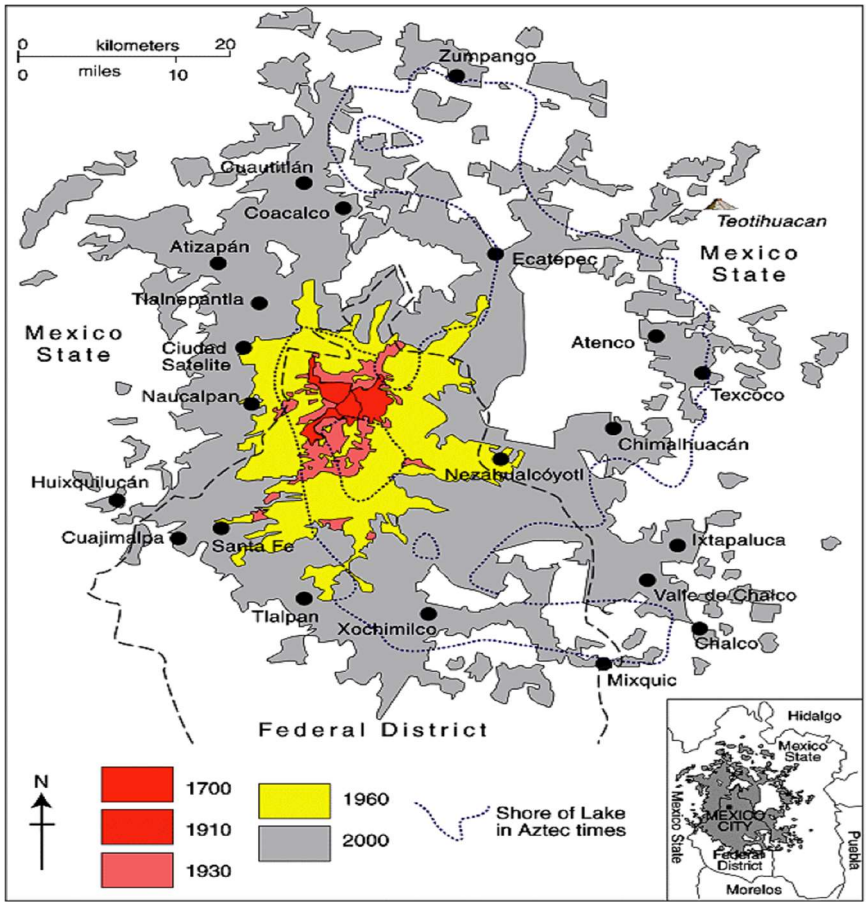

Figure 24: Geographical growth of Mexico
Source: Hungry Cities Partnership HCP[22]

One of the disadvantages of pure geographic expansion is that geographic distances also grow. This has been shown above in the comparison between Atlanta and Barcelona. Pure geographic expansion is certainly not the optimal growth pattern. A more efficient growth pattern implies also the growth of concentration. This growth pattern will develop automatically as land in cities becomes scarce, obliging cities to find appropriate means to “artificially” increase available surface.

Only two examples will be given here on how cities artificially increase their available surface. One is increasing the height of buildings. Each supplementary storey allows for adding a certain percentage of the area of the ground floor in form of economically or socially useable area. The technology of the early 1900s allowed for tall buildings up to 300m, all of them built in the US. In the early 1930s the first supertall buildings (> 300m height) such as the Empire State Building (381m) were constructed. Technological innovation steadily improved. Since 1990, APEC cities play the dominant role in this process. Of the 183 supertall buildings constructed or topped out worldwide since 1990, 143 (i.e. more than three quarters) are in APEC cities[23]. In future, the role of APEC cities will increase even further as of all the 855 supertall buildings currently under construction, proposed or envisioned, 785 (or 91.8%) will be in APEC cities.

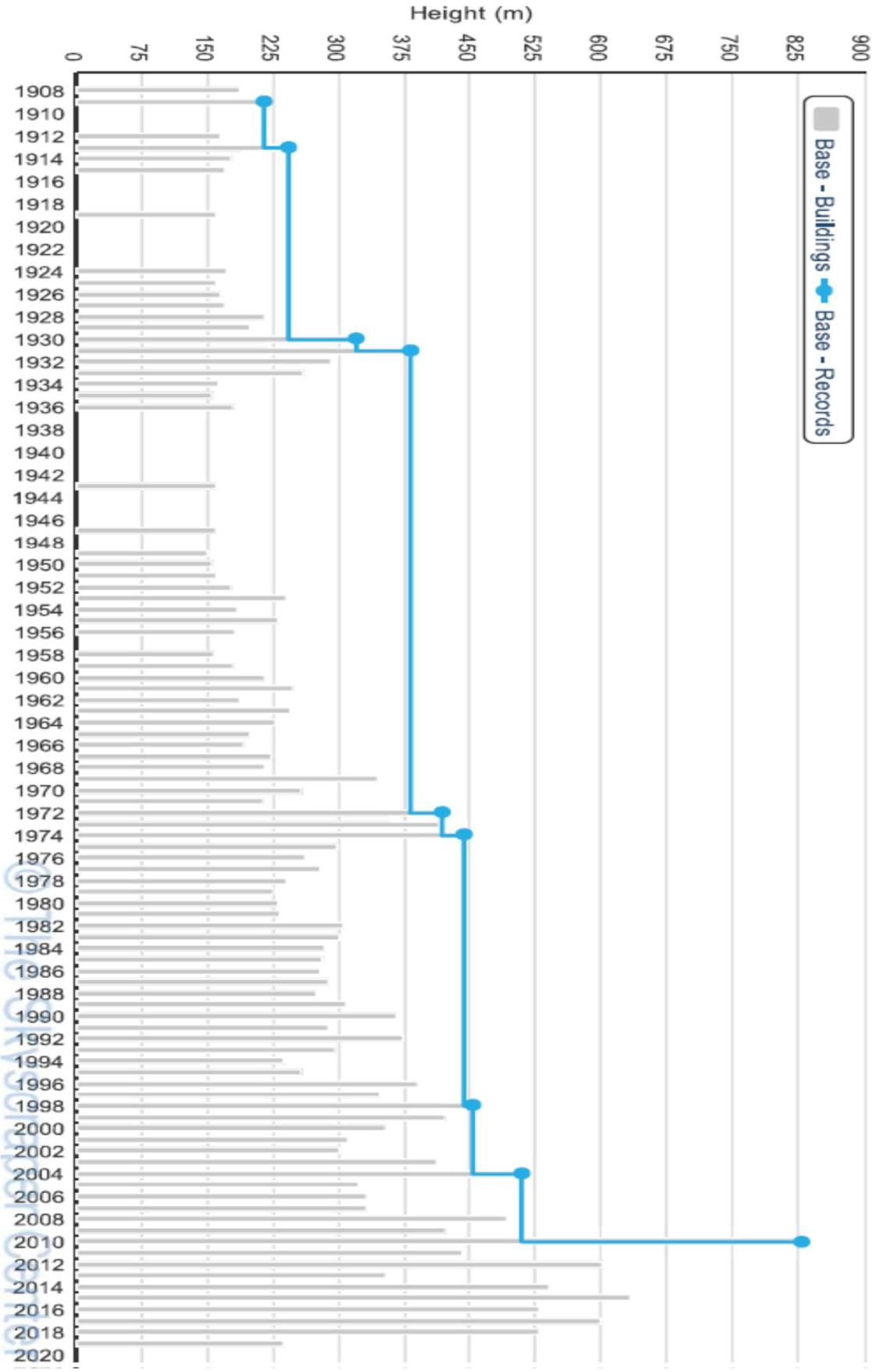

Figure 25: Evolution of the tallest buildings of the world
Source: The Skyscraper Data Base of The Council on Tall Buildings and Urban Habitat[24]

While supertall buildings allow for economies of scale in cities, they also require adequate surrounding infrastructures for the transport of all categories of daily users as well as for the enormous quantities of goods and services that are required to make these buildings perform competitively. Of special importance is, therefore, the monitoring of the performance of such buildings as they may contribute in a substantive way to the sustainable performance of cities. The awards attributed by the Council of Tall Buildings and Urban Habitat include, among many others, the category of performance awards designed to reward excellent performance. Since the inception of this award in 2014, all the attributed performance awards have been attributed to buildings in APEC cities (Jin Mao Tower in Shanghai, International Commerce Centre in Hong Kong, Chifley Tower in Sidney, and Taipei 101 in Taipei). It is not clear why no performance awards have been attributed since 2017.

The geographic size of cities has in some cases entailed an upgrading of the role of the city from the local level to the provincial level or a similar level directly under the central government, as is the case for China, where municipalities like Beijing or Shanghai enjoy special status. Such metropolises have themselves been divided into districts that assume an increasing number of tasks.

In the other example of how cities artificially increase their available surface is by means of urban transport allowing commuting with outskirts. A solution adopted over a long time has been the addition of supplementary lanes to urban transport where it was thought to help decongesting traffic.

Figure 26: Highway junction
Source: Fast Company[25]

As experience shows, however, this has not proven to be the always the case. Well-documented examples have even shown that additional traffic lanes have increased congestion. The reason has been described for the first time in 1968 and is known under the name Braess' (or Braess's) paradox. It will be analysed in more detail in Chapter 4.

Urban transport congestion is a major centrifugal factor, as it increases the economic distance between one point of the city and another and decreases the competitiveness of cities. A broad variety of measures have been taken by cities to alleviate transport congestion. The most important of these measures is shifting passenger transport to underground subway

systems. Some economies such as Thailand are choosing sky train systems instead. As one railway line has the capacity of 15 lanes of car traffic[26], either system allows leap-frogging the transport capacity of urban transport systems, as expressed per square meter, of the urban street surface.

Another, slightly less efficient means to increase the capacity of urban transport has been public road transport. One bus has a capacity of 40 to 50 cars. The well-known conditions for public transport to fulfil the aim of contributing to urban de-congestion is intermodal cooperation. Public transport represents rarely the whole part of a journey. Crucial elements of public transport are the capacity to efficiently handle peak hour demand as well as some basic timetabled service during low-frequency hours in the evenings.

More recently, carsharing has become increasingly popular. It has been calculated that in an average European city such as Bremen in Germany, each shared car has removed in average 15 private cars from the street[27]. This shows that car sharing can represent a contribution towards diminishing urban congestion. Carsharing can be incentivized by several other measures. One factor contributing to increased car sharing rates for e-vehicles is the practice to limit the issue of new number plates for fossil-fuelled cars, as is the case in most large Chinese cities.

In the new transport mix, bicycle and e-bike sharing should not be omitted. The condition for shared transport to contribute in an efficient manner to de-congestion of cities are the availability and technical state of shared vehicles. For the user, the best solution for shared vehicles is the free float type, allowing them to take and leave vehicles at any point as desired.

For electric bikes, either the city cares for setting up charging stations at specific inter-modal points, like in subway or railway stations, in residential areas, in Central Business Districts, or else, the service supplier should provide for battery swap models. Electric bicycles can further be miniaturized to become electric scooters. They can be supplied as shared docked electric scooters. Some models can be folded and hand-carried.

Figure 27: Electric scooters at docking station, Singapore
Source: Singapore Press Holdings Ltd.[28]

An important means to convey the feeling of integration to all the inhabitants of a city is to create ample public built-up open spaces which can be used freely for any kind of activity. In this domain, Eastern and South-Eastern Asia are worldwide leaders in percentage of urbanized open space in the built-up area.

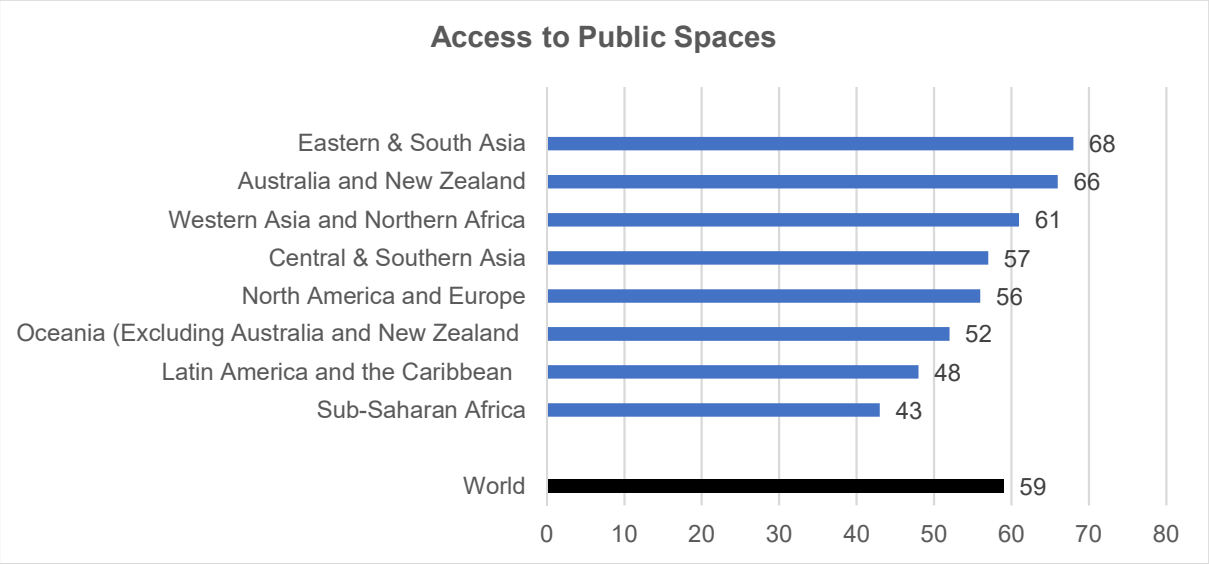

Figure 28: Percentage of urbanized open space in built-up area
Source: *SDG11 Global Synthesis Report*, UN Habitat

1.2.4. Size Hierarchy of Cities within Economies

The question on how cities convey benefits to their host economy in terms of improving the economic performance merits attention, though is not always straightforward to answer. As a general assertion, one may state that it is not beneficial for the development of an economy if the economy has a single very large city called primary city, most often the political capital, whereby all other cities are much smaller and almost without importance as compared to the capital city.

The optimal distribution of size is not a dichotomic one, creating a two-level dichotomy between an urban and a rural type economy, but a continuous spectrum of communities, from rural to villages, small towns, large towns, secondary cities and an urban large city at its centre.

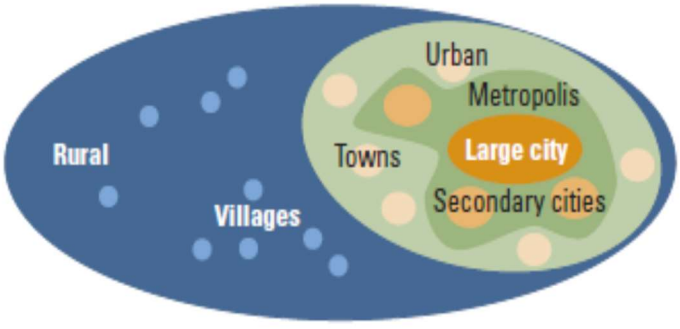

Figure 29: The rural- urban continuum
Source: *World Development Report 2009*

The distribution of cities according to size obeys to two more or less robust regularities:

- The “rank size rule”, discovered in 1913 (A generalization of Zipf’s law, see box 1)
- The “Gibrat’s law”, named after Robert Gibrat (1904 – 1980), stating that the rate of population growth of a city is independent of its size.

The Zipf’s law is named after the American linguist George Kingsley Zipf (1902 – 1950) who, however, was not the first one to have discovered it. Before him, the French stenographer Jean-Baptiste Estoup (1868 – 1950) and the German physicist Felix Auerbach (1856 – 1933) have referred to it.

Zipf’s law establishes a regularity found in natural languages. It states that the frequency of any word is inversely proportional to the rank of that word in the frequency table. This means that the most frequent word in English is twice as frequent as the second most frequent word and three times as frequent as the third most frequent word, and so on. Empirically, the most frequently used word in English is the word “the” (7% of all occurrences), followed by the word “of” (3.5% or just half of 7%) and the word “and” (2.3% of all occurrences).

Zipf’s law is a special case where the power of the rank is exactly -1. This special case can be generalized by taking the power of the rank different from -1. In that more general form, the law describes many economic and social phenomena.

Box 1: Zipf’s law

The rank-size rule, applied to describing the hierarchy of cities, states that the rank r of a city of size S is proportional to S to some negative power. If this negative power equals -1, the law indicates the special case of the Zipf’s law.

Empirically the rank-size rule holds for many economies at many different moments in history. The power is usually not exactly -1. Also, it has often been observed that some of the largest cities do not obey the rule. For the US in 2000, the rank-size rule shows the following graph. The largest city (rank e^0= 1) has a population of just under e^{17}= 24 million inhabitants, the smallest city on this graph (approximately rank e^6= 400) has a population of approximately e^{12}= 160’000 inhabitants.

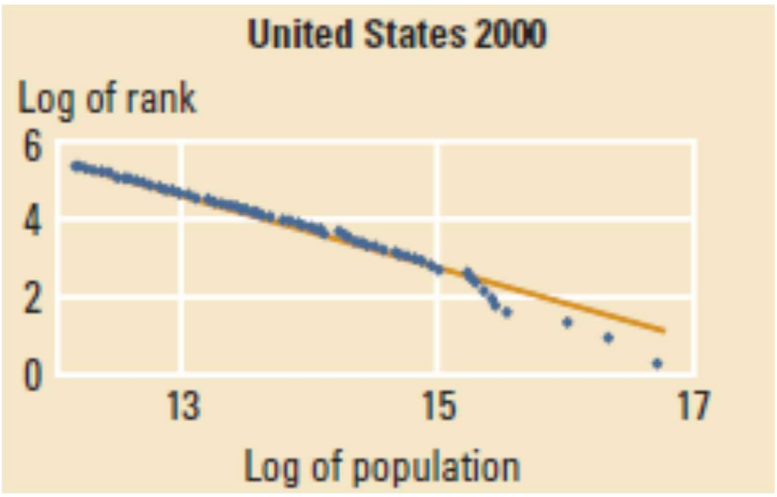

Figure 30: Rank-size rule for the US, 2000
Source: *World Development Report (2009)*

The general shape of the curve remains the same even if the cities grow. Larger and smaller cities are mutually dependent in different regards. Sometimes smaller cities provide commuters to larger cities. The middle-sized towns are the indispensable connective tissue between the rural areas and the large metropolises. They are markets for agricultural and rural products and act as stimulators for non-farm activities. Often, they are centres for postsecondary education and specialized health services.

An example of an over-sized primary city of the APEC region is e.g. Mexico City, which produces on its own about 30% of the Mexican GDP. This kind of urban structure is at the origin of spatial inequality, which increases general inequality given that only a minority of inhabitants can live in the primary city. Inequality is measured by the Gini inequality index. The higher the Gini index, the less equal the income distribution. If the Gini index is zero, there is perfect equality of income, if the Gini index is 100%, there is perfect inequality of income, i.e. all the measured income goes to only one person.

The Gini index of selected APEC economies varies between Chile, Peru and Mexico (ranging from 49% to 43.4%) on the upper end, and Japan and Korea (ranging from 31.5% to 32.3%) on the lower end, with all the other APEC economies in between. Only 15 APEC economies publish the Gini index in the World Bank database.

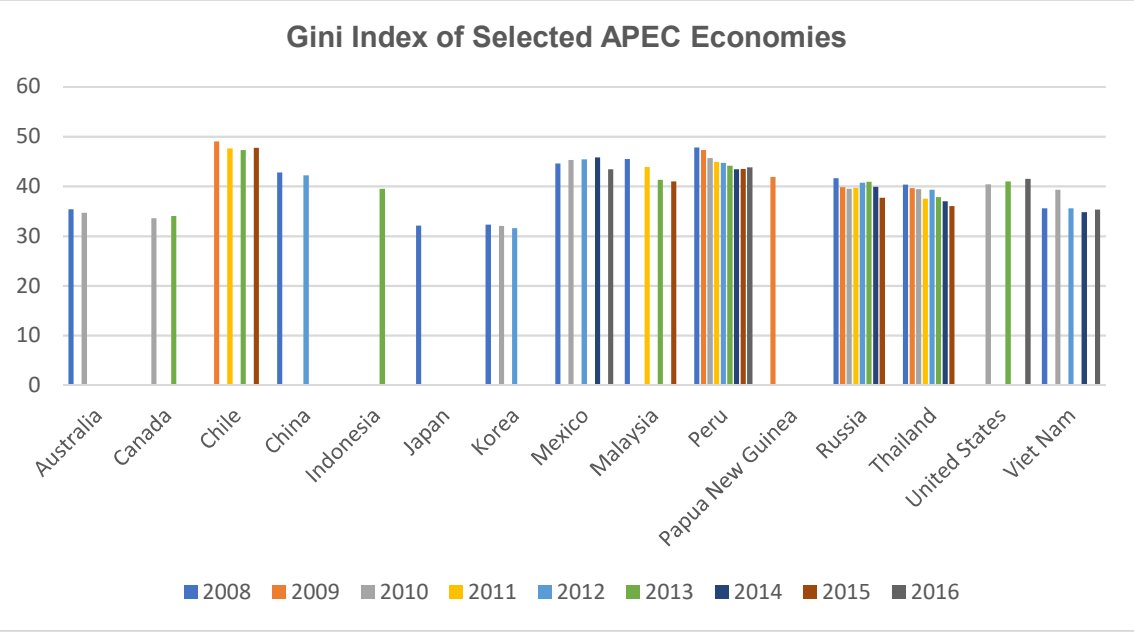

Figure 31: Gini index of selected APEC economies
Data source: World Bank

An interesting indicator is the ratio of urban-rural income gap to urban population share. Two trends are interesting to note: the urban-rural disparity falls between provinces as a function of the urbanization rate of the province, and the urban-rural income gap increases with time when the share of urban population increases. This is well illustrated by China. In 1999, a Chinese province whose urban population share was 50% had a ratio of urban to rural income of 2, whereas a province whose urban population share was 25% had a ratio of urban to rural income of 3. In 2006, the first province may have increased its urban population share

to, say, 60% and hence have a ratio of urban to rural income of 2.5, and the second province may have increased its urban population share to 35% and have a ratio of urban to rural income of 3.5.

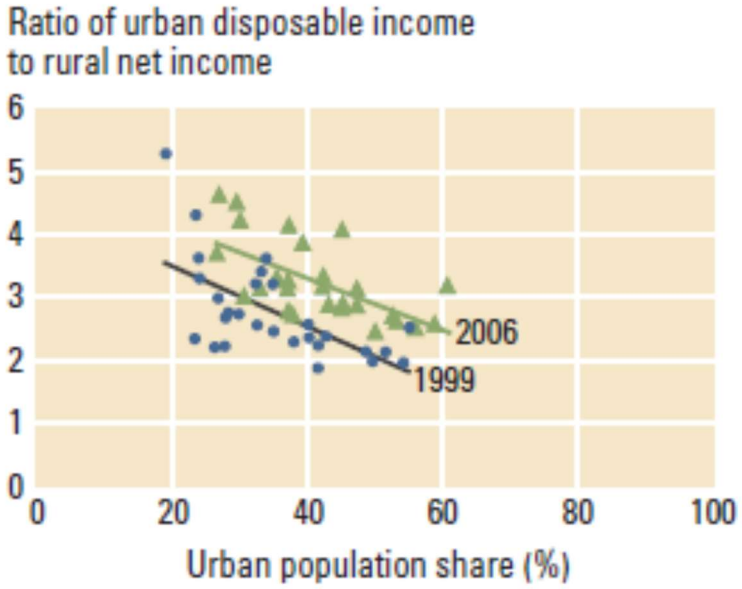

Figure 32: Disparity among provinces in China, 1999 and 2006
Source: *World Development Report 2009*

Disparities between provinces tend to decrease with increasing urbanization. This is also true for basic amenities. Highly urbanized economies show almost no difference between cities and rural areas as for access to basic services like clean water[29] and electricity.

For economies to develop harmoniously, the economic distance between leading and lagging regions is the key factor to look at. Economic distance is the ease or difficulty for goods, services, labour, capital, information and ideas, to travel between two points within the same economy. Distance in this sense is not the Euclidian distance, but the path along a network of roads and infrastructures which is specific for each category, goods, persons, services, information and capital. Historic evolution of all developed economies shows a growth pattern where first the leading regions grow, thereby increasing the regional inequality. If the economic distance between the leading center and the lagging countryside diminishes by increased construction of infrastructure, the lagging regions will then start growing and inter-regional disparities will again level off.

1.2.5. Role of Cities in Regional Integration - the International Dimension

Many big agglomerations have grown to such a size that their economic power is comparable in weight to the economic activity of medium-sized economies. Thus, the urban agglomerations like Tokyo or New York have estimated GDPs (in purchasing power parity) comparable to Canada and Spain. The agglomeration of London has higher GDP than the one of countries like Switzerland or Sweden.

Cities have not only a role in economy-wide development that they may influence favourably, but also a role as international centres. The limiting factor for international development is division created by cultural, religious, language or political factors.

Due to the development of the worldwide internet since the mid-90s of the past century, the impression has grown that we now live in a globalized world without borders. As the figure below shows, contrary to a popular misbelief, the number of land borders has tripled within the last 50 years, reaching now more than 600, as evidenced in the *World Development Report 2009*. Compared to the 21st century, the 19th century was a century with few borders. If all federated states split apart, and if all minorities receive self-determination and some of the remaining 70 dependencies seek independence, the number of borders would further increase in the future.

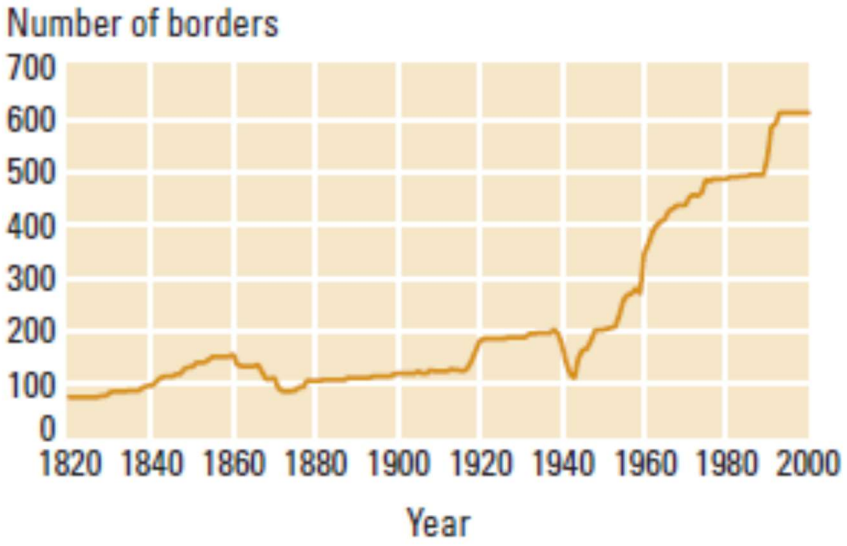

Figure 33: Number of worldwide land borders
Source: *World Development Report 2009*

Borders have many advantages: They enclose people with shared characteristics, provide a sense of place and belonging that may be beneficial for welfare. They create the administrative units for management and government. They may provide security and stability.

For economic growth, borders matter today more than ever before, as an ever-larger part of global GDP originates from international trade. Not all borders have the same height. The height of a border translates to increased economic distance between parties on either side of the border.

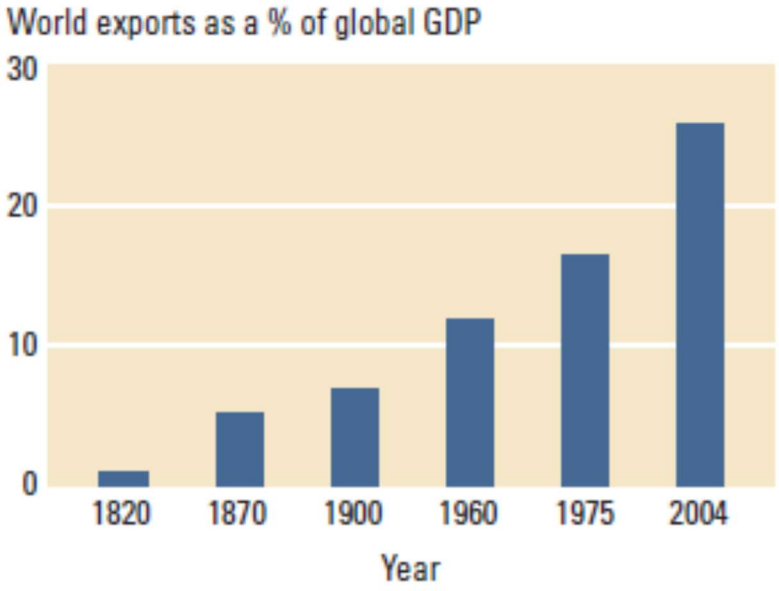

Figure 34: World exports as part of global GDP
Source: *World Development Report 2009*

What has been said above about economies of scale for cities also holds for entire economies. Small economies provide fewer economies of scale than big ones. The small economies have, therefore, a greater interest in diminishing the height of borders than big economies. Priority for them might be deepening regional integration with neighbouring economies.

Cities in smaller economies will benefit from the gradual international opening of their economies and can also contribute to making such opening beneficial to their economy.

Chapter 2 – Sustainability Deficits of Urbanization

An important sustainability deficit of modern cities is the lack of circularity. In all APEC sub-regions, the collection rate of urban municipal waste is, however, above world average. An important deficit of urbanization is also the lack of disaster resilience. Between 1998 and 2017, climate-related and geophysical disasters killed 1.3 million people worldwide and left a further 4.4 billion injured, homeless, displaced or in need of emergency assistance. While most fatalities were due to geophysical events, earthquakes and tsunamis, 91% of all disasters were caused by floods, storms, droughts, heatwaves and other extreme weather events. APEC cities are particularly exposed to disasters. Of the 100 cities worldwide with the greatest exposure to natural hazards, 21 are in the Philippines, 16 in China, and 11 in Japan. Disasters such as floods also affect capital cities of APEC economies. Floods can be exacerbated by land subsidence. APEC cities most affected by land subsidence are Jakarta, Bangkok, Ho Chi Minh City, Manila and Mexico City. In some districts of Jakarta, the soil sinks at rates between 20 and 28 centimetres per year. Total per capita primary energy supply in APEC (3.8kW) is significantly higher than in world average (2.5kW). Also per capita CO_2 emissions of APEC are higher (7.8 tons per year) than in global average (4.5 tons per year). As for the decoupling path between GDP and emissions, APEC lags two years behind the world average. During the period 1990 – 2014, APEC per capita GDP has doubled, and per capita emissions increased by 50%, whereas for world average, per capita GDP increased by 60% and per capita emissions increased by only 20%. Emissions intensity in APEC decreases at about 1% per year, at the same speed as world average, but absolute emissions are still increasing in both, APEC and in the world. By the middle of the century, emissions should approach zero. The danger of slum formation seems to be less acute in APEC cities than in cities of other world regions. Nonetheless, some APEC cities (Bandung, Manila, Mexico City, Santiago (Chili), Bangkok, Ho Chi Minh City) are reported to have slums. Slums will not automatically disappear with higher average income levels, but require deliberate policies, especially the provision of essential infrastructures to slum cities. A fundamental, cross-cutting sustainability lack in all APEC cities is the data-poverty, especially for sustainability indicators at local level. A sustainability assessment made by the UN for the Asia Pacific region disposed of data for only 25% of the sustainability targets. For targets of the SDGs on climate action and life below water, no data at all were available.

2.1. Sustainability Deficits in APEC

2.1.1. General Lack of Circularity in APEC

Lack of circularity is not limited to APEC but is a general problem of all the economies of the world. Still, it is not yet systematically measured. Municipal solid waste collection is the single most measured item related to circularity. Data can be found for major geographic regions, but not yet for APEC. For the world on average, the collection rate is 74%. The highest collection rate is in Australia and New Zealand (94%), followed by North America and Europe (89.6%), Latin America and the Caribbean (80.4%). Eastern and South-Eastern Asia (72%) lies in the middle, whereas the collection rate is lowest in Sub-Saharan Africa (43.4%).

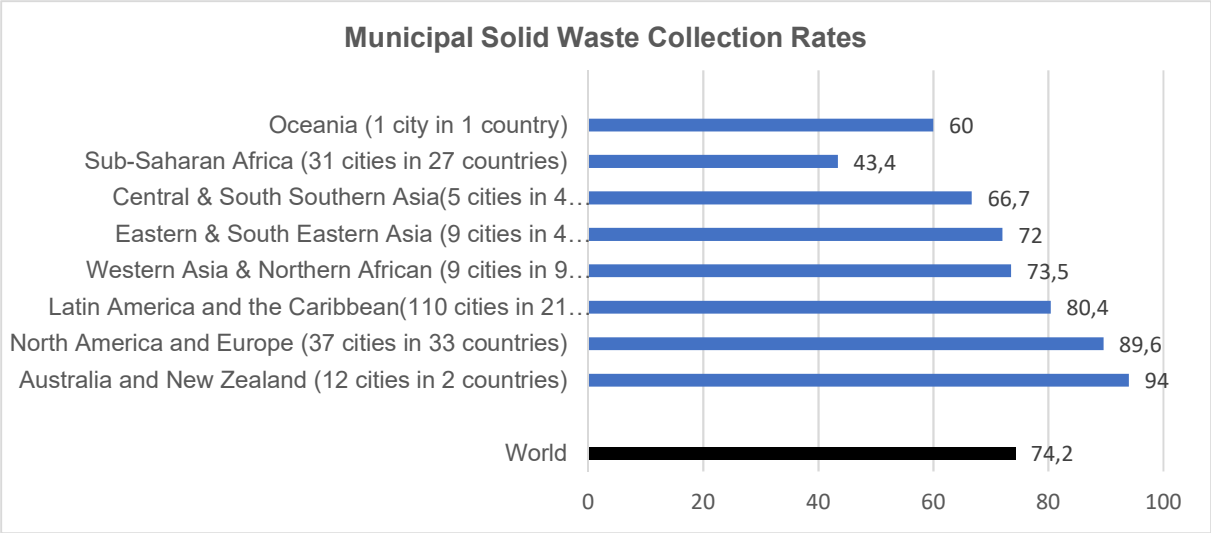

Figure 35: Municipal solid waste collection rates per region
Source: *SDG 11 Global Synthesis Report 2018*, UN Habitat

APEC region has 57% of world GDP, whereas the population accounts for 42%. APEC is, therefore, in the upper half of global wealth. Waste production is normally a function of GDP. Presumably, per capita waste production of the APEC region is also above the world average.

Indicator	APEC relative size in the world (%)
Population	42%
GDP	57%
Global Trade	44%
Megacities > 10 Mio	50%
Cities 5 -10 Mio	53%
Cities 1 – 5 Mio	42%
Cities 0.1 – 1 Mio	49%

Table 2: APEC relative size in the world
Source: *Partnerships for the Sustainable Development of Cities in the APEC Region*

Besides general municipal solid waste, the production of particular types of waste has been estimated. Plastic waste belongs to the long-standing waste products whose dispersion has been noted all over the planet. The problem of plastic waste is more serious as plastic swims on the sea surface and is therefore not disappearing at the bottom of the oceans.

Figure 36: Plastic waste in Indonesia
Source: The Jakarta Post, 11 April 2017[30]

It has been estimated that at current production growth rates, by 2050 the total amount of plastic in oceans, measured in tons, will outweigh the total biomass of fish in the ocean[31],[32]. Microplastic particles have already been found in the human food chain, as has been evidenced by the analysis of human excrements[33].

2.1.2. Insufficient Disaster Resilience in APEC

APEC economies are geographically located around the Pacific Rim, where the different disaster risks are higher than elsewhere. It has been stated in Chapter 1 that eight of the ten most exposed cities of the world are in the Philippines.

The higher regional risk exposure is related on one side to various climate change effects. The Pacific Ocean acts as a source of extreme climate events taking the form of heavy rainfall, extreme wind, and high sea waves. In parallel, periods of high temperature and drought are becoming more probable and cause fires.

On the other side, APEC is also located in the Ring of Fire, exposing the region to a high amount of volcanic and seismic activity which causes earthquakes and tsunamis of extreme magnitude.

The death toll of hydrometeorological disasters is increasing worldwide.

Between 1998 and 2017, climate-related and geophysical disasters killed altogether 1.3 million people (i.e. 65’000 per year in average) and left a further 4.4 billion (i.e. 220 million per year in average) injured, homeless, displaced or in need of emergency assistance. While the majority of fatalities were due to geophysical events, mostly earthquakes and tsunamis, 91% of all disasters were caused by floods, storms, droughts, heatwaves and other extreme weather events[34].

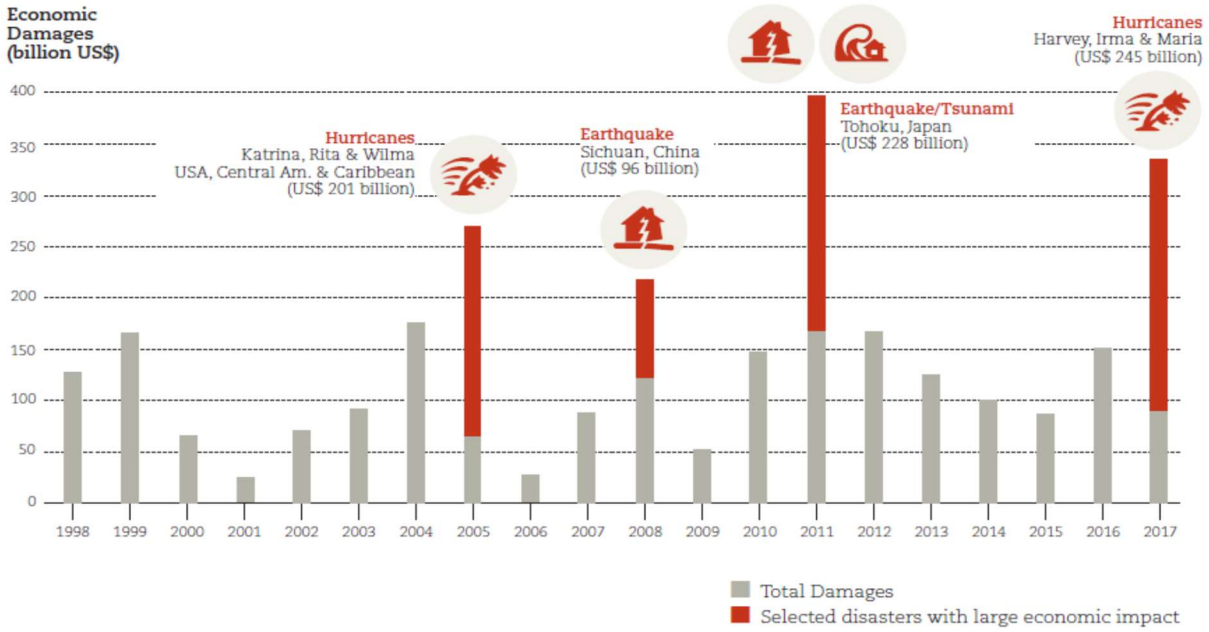

Figure 37: Total reported economic losses per year, with major events highlighted 1998 - 2017
Source: UNISDR, *Economic Losses, Poverty and Disasters 1998 – 2017*

Besides the direct casualties, disasters cause massive amounts of economic losses. The World Bank estimates that APEC has incurred over 100 billion USD annually in related economic losses over the past 10 years[35].

These extreme weather events may affect the big cities and capitals of APEC economies and therefore touch the very heart of economic and social activity.

Figure 38: Flood in Bangkok
Source: The Bangkok Post, 21 October 2011[36]

The 21 October 2011 flood cost the Thai economy 46 billion USD in repairs and rehabilitation. 8 billion USD was spent on Bangkok alone. More than 800 deaths were recorded, and 13 million people were affected by the flooding[37].

Flooding can be exacerbated by land subsidence. Several APEC cities experience land subsidence. Land subsidence is the gradual caving in or lowering of ground due to underground material movement most often caused by the removal of water, oil, natural gas, or mineral resources out of the ground at a rate higher than the natural replenishment rate, by pumping, fracking, or mining activities.

The APEC cities most affected by subsidence are Jakarta, Bangkok, Ho Chi Minh City, Manila, and Mexico City. In some areas of Jakarta, the soil sinks at rates between 20 and 28 centimetres per year[38]. Bangkok has been affected by subsidence since the 1970s. The piezometric level of groundwater in the main aquifer layers has been drawn down by as much as 65 meters[39]. Subsidence of the southern part of Bangkok has occurred at a rate of 12 centimetres per year. Even though measures have been taken now to stabilize the groundwater level, subsidence will continue for some time due to time-lag effects.

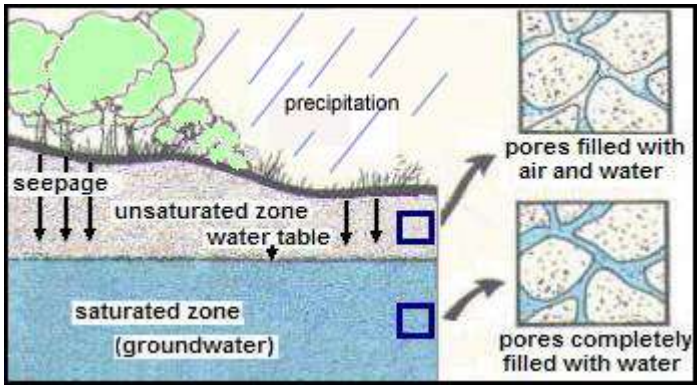

Figure 39: Groundwater
Source: New York State, Department of Environmental Conservation[40]

Land subsidence occurs when large amounts of groundwater have been withdrawn from certain types of rocks, such as fine-grained sediments. The rock compacts because the water is partly responsible for holding the ground up. When the water is withdrawn, the rock falls in on itself, diminishing the storage capacity of the aquifer.

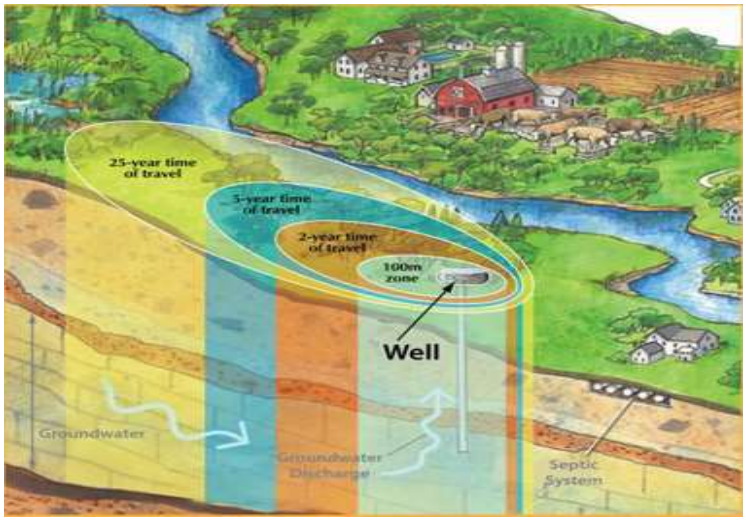

Figure 40: Recharge times of aquifer
Source: New York State, Department of Environmental Conservation

2.1.3. Lack of Decoupling of CO_2 Emissions from Economic Growth

APEC economies lag behind the world in the tendency to decouple CO_2 emissions from economic growth. CO_2 emissions are usually justified either with the need to allow economic GDP growth or with the equity argument to allow a certain quantity of per capita emissions. The basic understanding of the sustainability depends on the interactions between population, GDP, total primary energy supply and energetic CO_2 emissions. These can be shown in an easy-to-remember set of formulae. The APEC region can then be compared against the world. Furthermore, comparisons among economies and, provided data are found, among cities, can be made.

An easy to remember set of formulae

There is an easy way to remember the relationship between per capita CO_2 emissions, energy consumption and per capita GDP:

Emissions per capita = emission intensity of energy X energy intensity of GDP X GDP per capita. This is the basic formula given below. It may indicate that emissions per capita are the result of three other essential aggregates.

Alternatively, as the product of energy intensity of GDP and GDP per capita equals the energy consumption per capita, the equation can be simplified to evidence energy consumption per capita. This is given in alternative 1 evidencing per capita energy consumption.

Furthermore, the emission intensity of energy can be multiplied by the energy intensity of GDP to give emission intensity of GDP. This is alternative 2 evidencing emission intensity of GDP.

$$\frac{emissions}{capita} = \frac{emissions}{energy} \times \frac{energy}{GDP} \times \frac{GDP}{capita}$$ basic formula

$$\frac{emissions}{capita} = \frac{emissions}{energy} \times \frac{energy}{capita}$$ alternative 1, with per capita energy consumption

$$\frac{emissions}{capita} = \frac{emissions}{energy} \times \frac{energy}{GDP} \times \frac{GDP}{capita}$$ basic formula

$$\frac{emissions}{capita} = \frac{emissions}{GDP} \times \frac{GDP}{capita}$$ alternative 2, with emissions intensity of GDP

Box 2: Mathematical relationships between CO_2 emissions, energy, GDP and population

The three per capita indicators are framed in green (environmental constraint), yellow (instrumental variable) or red (desired socio-economic objective), respectively, whereas the three intensities (or structural indicators) are left unframed. Among these, the emission intensity of energy essentially indicates technological choices, energy intensity of GDP indicates economic structure, whereas emissions per GDP indicates on how successful policy has brought about decoupling of GDP from CO_2 emissions; it is a climate policy success indicator.

These relationships hold mathematically if the same numbers are used for each of the variables in the equations, namely CO_2 emissions (more precisely: CO_2 equivalents), capita (population), energy (e.g. total primary energy supply) and GDP (PPP at constant international USD.

This simple framework can be applied to any geographic entity, i.e. country, economy, region, city, or the world. If one bears in mind that GDP is the sum of value-added, they may be applied also to business enterprises.

For APEC economies using 2014 data, the result is shown in the figures below.

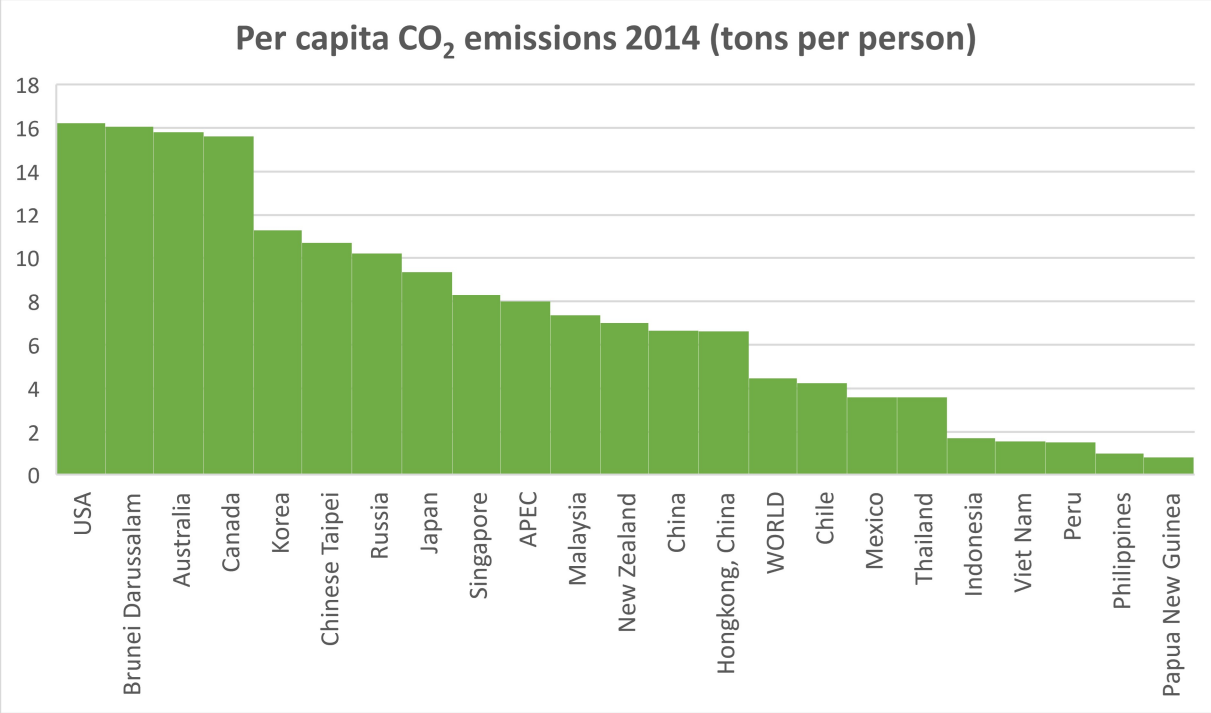

Figure 41: Per capita CO_2 emissions 2014, in tons per person
Source: compiled using APEC, APERC and IEA data

The per capita CO_2 emissions of the APEC region are at 7.8 tons per person per year and are well above world average of around 4.5 tons per person per year.

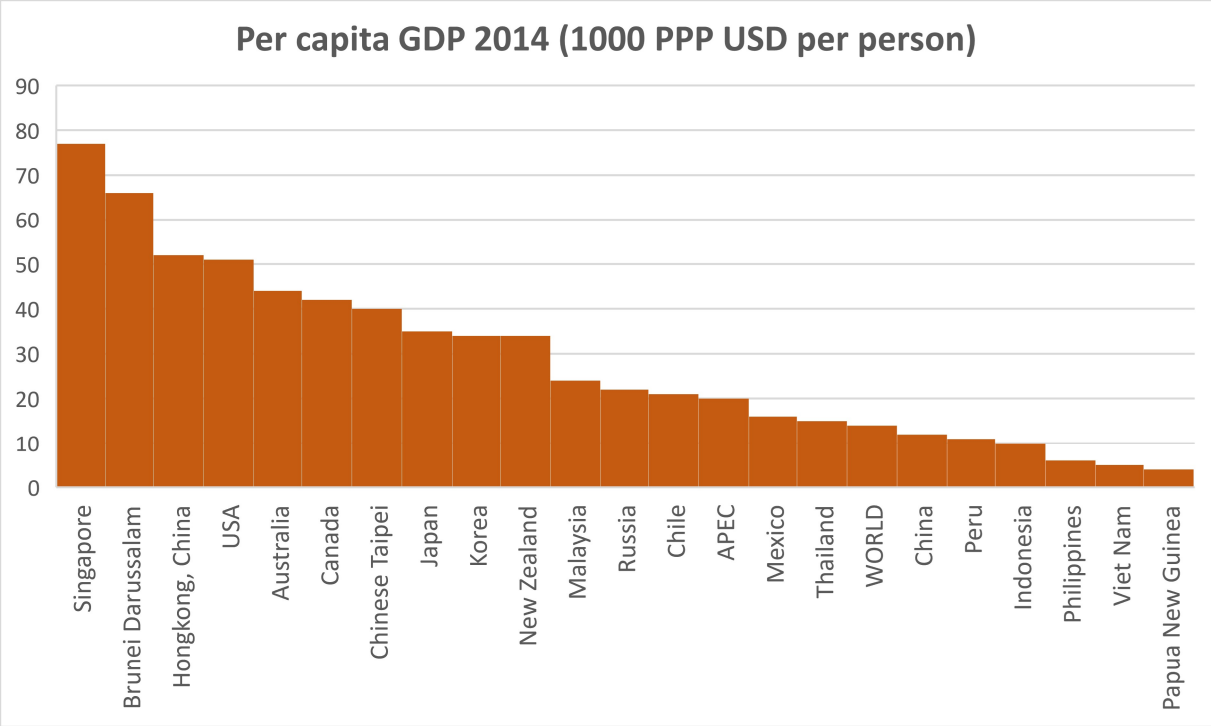

Figure 42: Per capita GDP 2014, in thousands PPP USD 2010 per person
Source: compiled using APEC, APERC and IEA data

Per capita GDP PPP at constant 2010 international USD is higher in APEC economies (around 20'000 constant 2010 international USD per person) than in global average (around 14'000 constant 2010 international USD per person).

The next figure gives per capita total primary energy supply (TPES). Contrary to usual convention stating TPES in tons of oil equivalent per capita per year, the figure below shows per capita TPES in kilowatt (kW) in order to facilitate interpretation. The energy consumption reported in annual statistics is always understood to relate to the reported year, in other words, consumption is an annual energy flow. An energy flow per year is measured in energy/time and is, therefore, an average power. The reader who is not necessarily energy specialist may not have an easy grasp of how much a ton of oil equivalent (TOE) is. It is more likely, instead, that the average reader may know what a Watt is. Watt is used in household appliances like light bulbs, kettles, etc. Furthermore, the Watt is also used in the construction industry, where e.g. the thermal conductivity of a window is expressed in Watt/K. Also, the intensity of solar radiation is measured in Watt/m^2. For transforming the units, 1toe = 10^7kcal and 1kcal = 4.1868kJ, 1W=1J/s, and one year has 3600x24x365.25 seconds.

The long-term (or sustainable) energetic carrying capacity of the planet Earth has been estimated to be around 2kW per person (see the vision of the "2kW society"[41]), meaning that in the long run, planet might not support higher energy consumption than about 2kW per person.

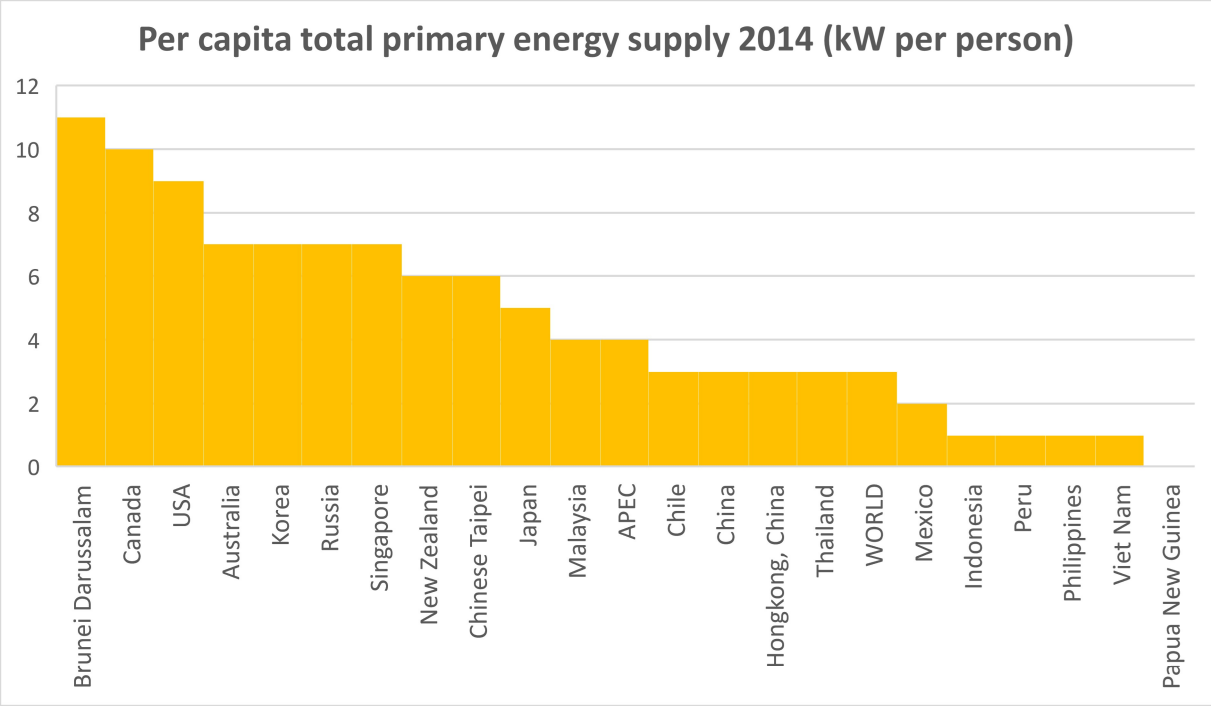

Figure 43: Per capita total primary energy supply 2014, in kW per person
Source: compiled using IEA and EGEDA data

This figure shows that, the per capita global energy consumption is at present not far away from 2kW, the maximum long-term capacity. In APEC, however, per capita consumption is at almost 4kW per person or double the long-term capacity. Remarkable to see that the per capita consumption of Hong Kong, China, is low compared to other cities like Singapore.

Concerning the data, unfortunately, the StatsApec online database does not contain any energy data. Until 2011 APEC Energy Statistics were available in the annual publication "APEC Energy Statistics"[42]. Thereafter, the publication has been made available electronically as pdf book on the website of the APEC Expert Group on Energy Data and Analysis EGEDA[43]. Now energy statistics are also available in the EGEDA data base[44].

The above figure can still be converted further in order to express per capita energy consumption as multiple of the so-called resting metabolic rate (RMR), thereby allowing for a direct comparison to human physiological energy consumption. Thus, in the absence of physical activity, i.e. at sleep, every human being consumes physiological energy at a so-called resting metabolic rate (RMR), comparable to a "base load" of electricity systems. The RMR or "sleeping energy" is dependent on gender, weight, height, and age of the person[45]. If we choose as a sleeping reference person a "sleeping beauty" of female gender with conventionally fixed body height (around 1.60 m) and weight (around 55 kg), this person would consume about 1280 kcal per day. A consumption rate of 1280 kcal per day corresponds to an average power of approximately 60 Watt. With such a reference person, the definition of the RMR can become a kind of "natural measurement unit"[46]. This way expresses the per capita energy consumption as a multiple of the RMR, i.e. a multiple of the minimal physiological energy consumption of the sleeping beauty.

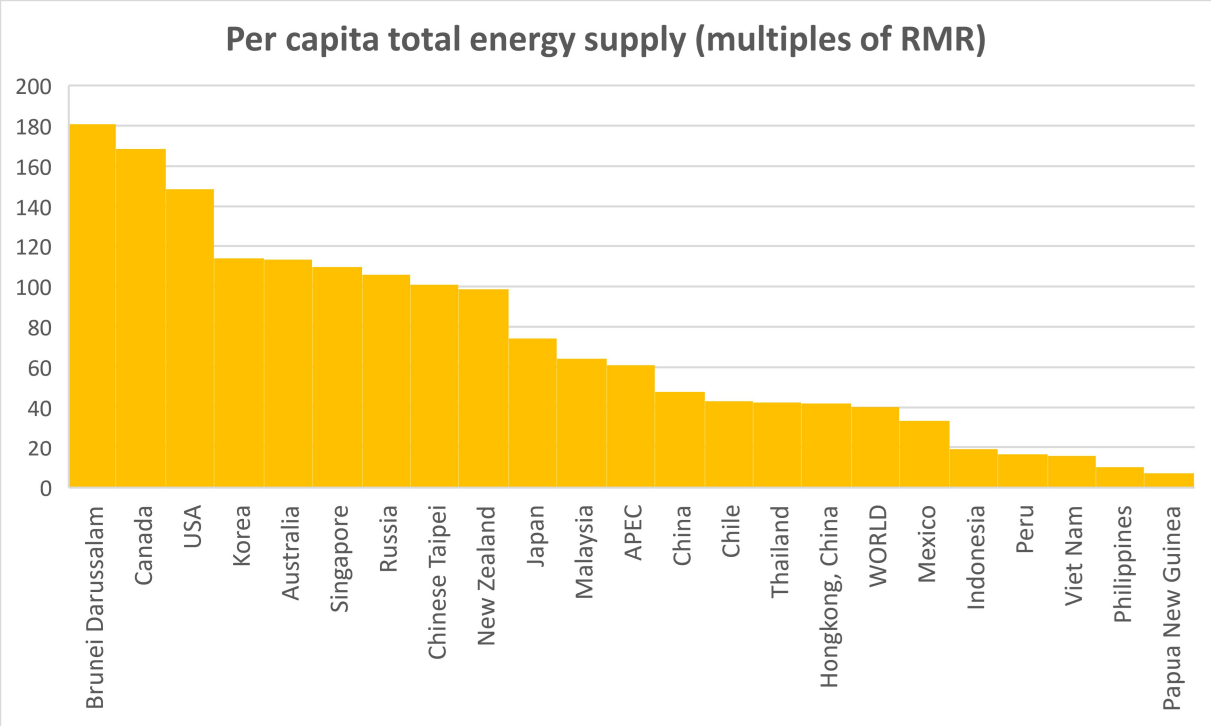

Figure 44: Per capita total primary energy supply, in multiples of RMR
Source: compiled using EGEDA and IEA data

The interpretation is that e.g. in Brunei Darussalam, each inhabitant consumes an equivalent energy corresponding to 180 resting persons, whereas for APEC this factor is about 60 and in world average, it is about 40. The maximum long-term carrying capacity of 2 kW per capita corresponds to about 33 times the resting metabolic rate.

Traditionally, a high energy consumption was interpreted as a sign of progress. This interpretation should be reconsidered in light of the sustainable development discussion. There might well be an optimum level of energy consumption, beyond which energy consumption is being considered as energy inefficiency.

These statistics are sufficiently simple to be collected at the urban level, and sufficiently complete to allow stating progress towards sustainability.

The degree of decoupling between GDP and CO_2 can be shown by means of time series of the above quantities. The evolution of per capita GDP and per capita CO_2 in index form since 1990 shows a GDP-CO_2-decoupling for APEC economies: During the period 1990 to 2014, per capita GDP has doubled, whereas per capita CO_2 emissions have increased only by 50%.

The same data at world level show that per capita GDP at global average has increased by 60%, whereas the per capita CO_2 emissions have increased only by 20%.

This recent trend must still be verified in both cases, APEC and world. It seems that per capita CO_2 emissions have been peaking at world level since about 2011. At APEC, peaking could have started in 2013, but data for subsequent years would be needed to verify this trend.

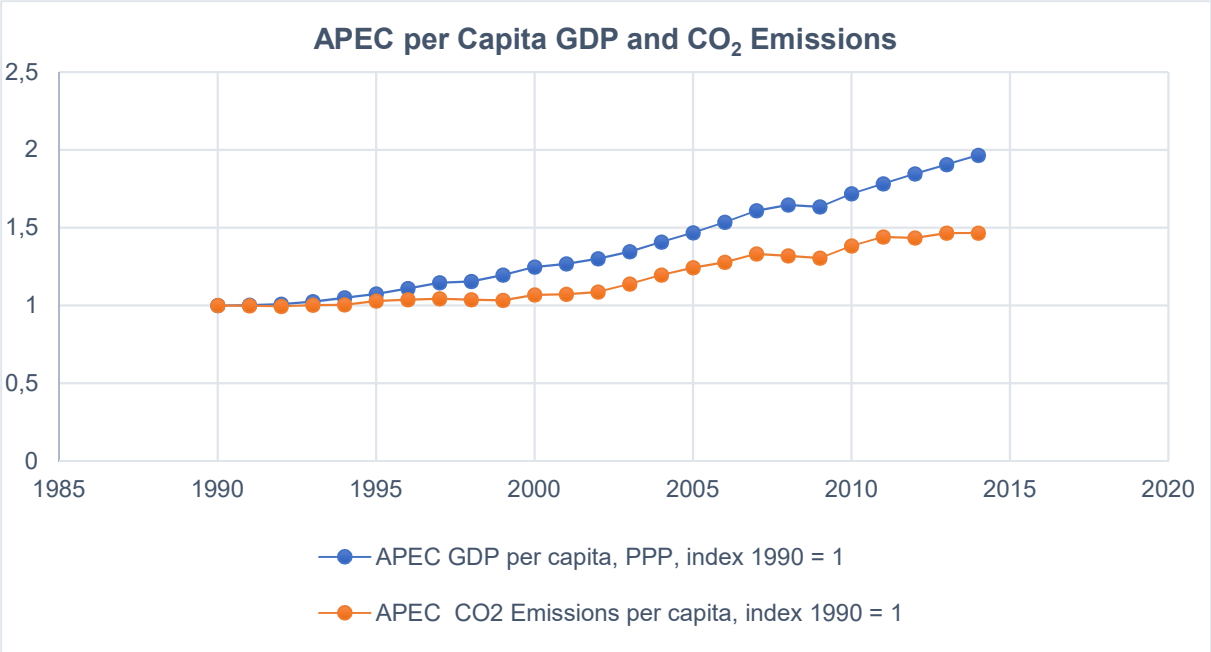

Figure 45: APEC decoupling of per capita GDP from per capita CO_2
Data Source: StatsApec

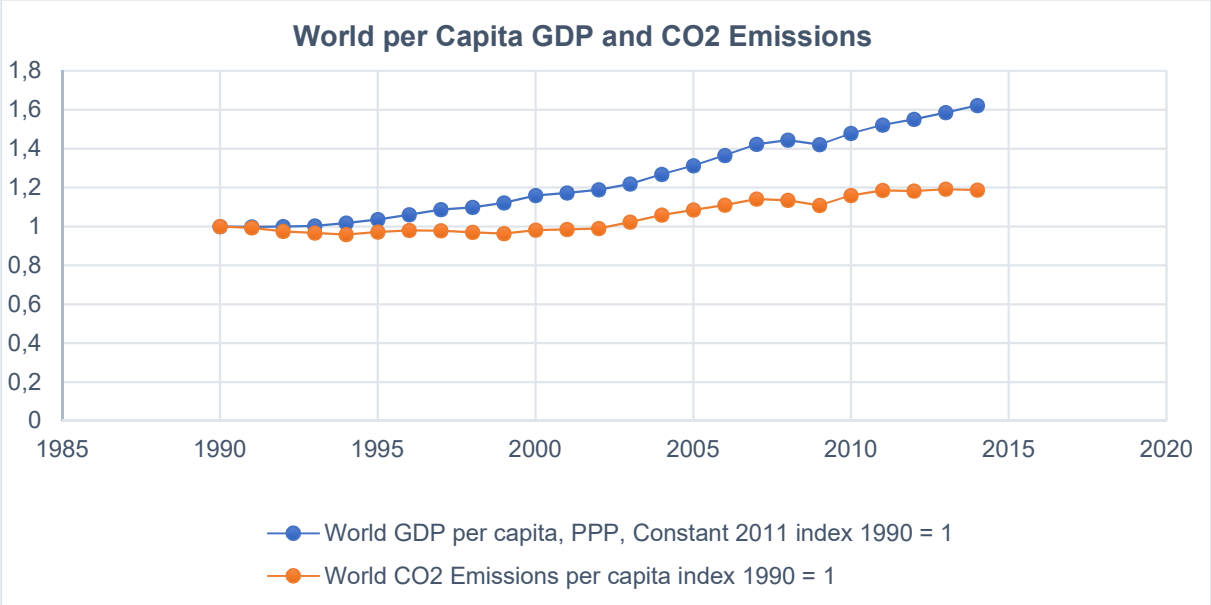

Figure 46: World decoupling of per capita GDP from per capita CO_2
Data source: StatsApec

To complete this analysis, the evolution of the CO_2 intensity of APEC can be compared to the evolution of CO_2 intensity of the world. APEC has higher CO_2 intensity than the world average, but both have been steadily declining since 1990. In the period 1990 to 2014 (24 years), this intensity has decreased from 523 tons to 393 tons per million international 2011 dollars, i.e. by 25% in total, or about 1% per year. In comparison, the aspirational speed desired by APEC Leaders for diminishing energy intensity (see Chapter 3) is 1.5% per year.

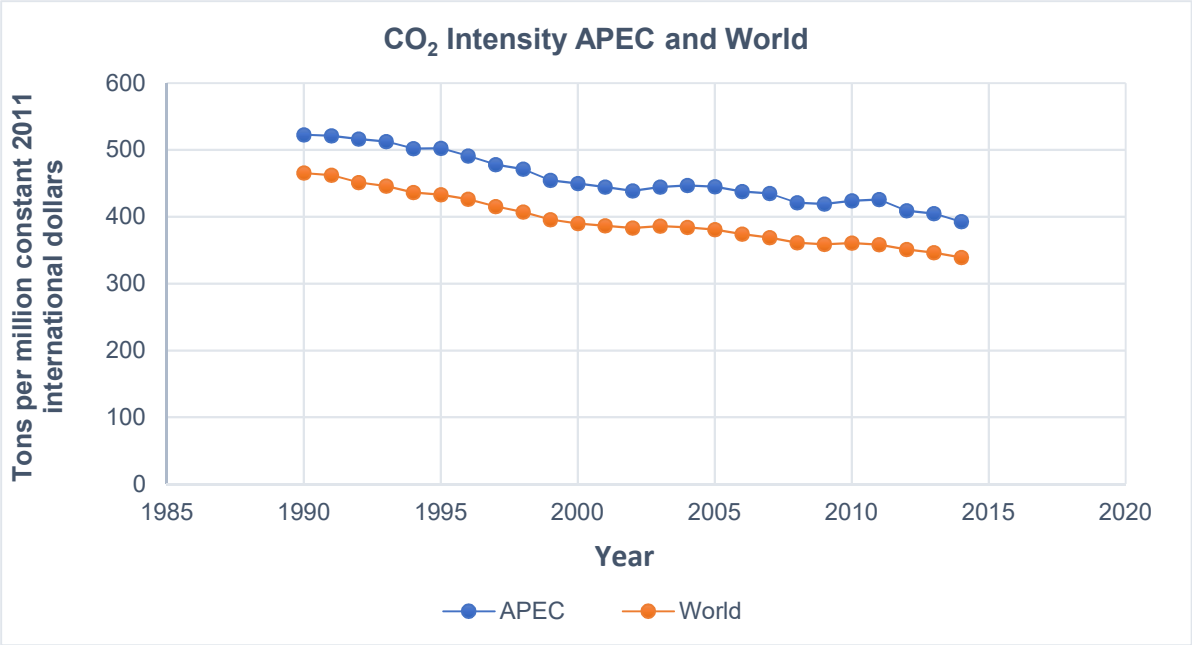

Figure 47: CO_2 intensity of APEC and World
Data source: StatsAPEC

The total CO_2 emissions of APEC and of the World are still growing, albeit at less speed.

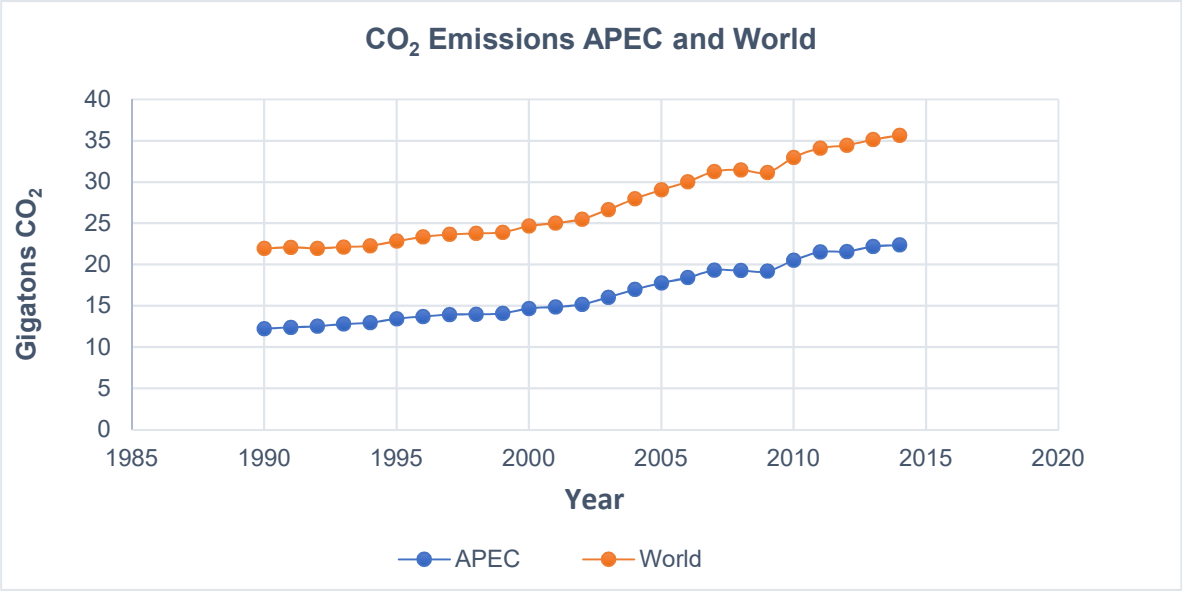

Figure 48: CO_2 Emissions APEC and World
Data source: StatsAPEC

To summarize, there is weak decoupling in both cases, for APEC and for the world. It is called weak decoupling as the trend for both, per capita GDP and per capita CO_2, is still the same (i.e. upward). If the 1.5-degree scenario is to be attained, the decoupling should be strong, so that per capita CO_2 emissions start to decrease at the global level despite per capita GDP growth. In the 1.5-degree scenario the objective should be to phase out CO_2 by the middle of the century (2050).

The Intergovernmental Panel on Climate Change IPCC has released a *Special Report and Summary for Policymakers* in October 2018, focusing on the impact of the 1.5-degree scenario[47]. It states that human activities are estimated to have caused approximately 1.0°C of global warming above pre-industrial levels, with a likely range of 0.8°C to 1.2°C. Estimated anthropogenic global warming is currently increasing at 0.2°C (likely between 0.1°C and 0.3°C) per decade due to past and ongoing emissions (high confidence). Warming over the Arctic is two to three times higher than average. A striking finding is that sea level will continue to rise beyond 2100 even if global warming is limited to 1.5°C in the 21st century (high confidence). Model-based projections of global mean sea level rise (relative to 1986-2005) suggest an indicative range of 0.26 to 0.77 m by 2100 for 1.5°C global warming, 0.1 m (0.04-0.16 m) less than for a global warming of 2°C (medium confidence). An additional rise of 0.1 m in global sea level implies that up to 10 million more people would be exposed to related risks, based on population in the year 2010 and assuming no adaptation (medium confidence). Marine ice sheet instability in Antarctica and/or irreversible loss of the Greenland ice sheet could result in a multi-metre rise in sea level over hundreds to thousands of years. These instabilities could be triggered around 1.5°C to 2°C of global warming (medium confidence).

In other words, starting from the 22nd century, coastal cities around the globe will face major challenges, even if warming is limited to 1.5°C during the 21st century.

2.1.4. Danger of Slum Formation in APEC

While at the global level, the problem with slums is acute, APEC economies might be somewhat better off. Rapid migration towards urban centres may entail the risk of growth of the population residing in slums. Slums are the sign that cities fail to expand infrastructure at the same speed as the arrival of migrants. Slums have characterized all the major European and North American cities during the 19th and early 20th century and can be understood to be a transitional phenomenon of early industrialization.

The good news is that at the global level, when the percentage of urban population increases, the percentage of population in slums tends to decrease.

The bad news is that at the global level, even with 100% urbanization rate, 30% of the population will continue to live in slums, if present trends continue. Empirically, the proportion of urban dwellers living in slums in developing economies has been steadily decreasing from 46.2% in 1990, to 39.4% in 2000, 32.6% in 2010, to 29.7% in 2014[48]. But as the urban population has strongly increased during that time, the relative decrease of slum population still means an absolute increase of slum population from 689 million in 1990 to 880 million in 2014.

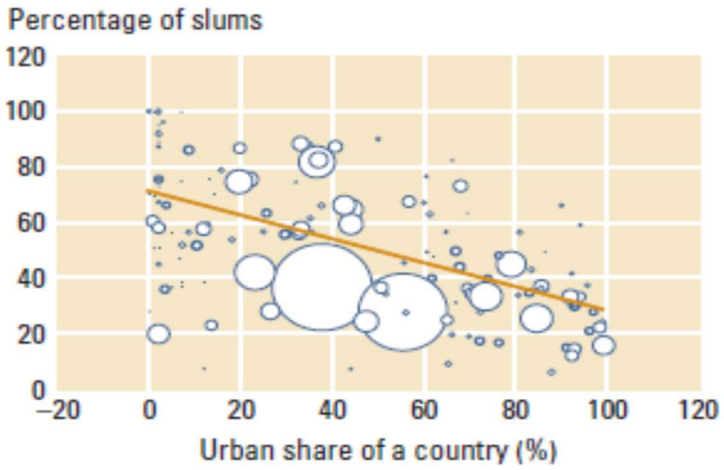

Figure 49: Higher urban share causes diminution of percentage in slums
Source: *World Development Report 2009*

The danger of slum formation can also be understood by looking at the basic characteristics of income distribution. In fact, while the higher development level certainly increases the average income, it does not really change the fundamental shape of the income distribution.

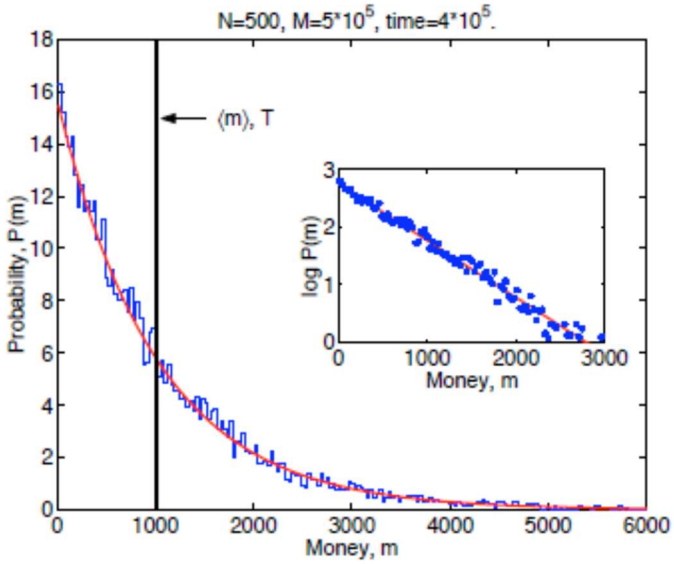

Figure 50: Computer-simulated income distribution
Source: V. Yakovenko, 2013

Theoretically, the income distribution follows a negative-exponential distribution. This has been tested in a computer simulation for a population of 500 individuals that all received the same initial amount of money[49] (vertical line in the figure above). After a sufficiently large number of transactions, the distribution of income stabilized at the equilibrium negative-exponential distribution. The basic property of this income distribution is that the mode of this distribution curve lies at zero income, meaning that the biggest number of inhabitants is in the income class having the smallest income.

Recent theoretical and empirical research[50] verified by data from 67 economies shows that under standard hypotheses (i.e. Arrow-Debreu General Equilibrium Model, together with Rawl's fairness principle[51]), income distribution of the enlarged middle class follows a negative-exponential distribution. It is independent of the income or development level of an economy. In other words, it also holds for the most highly developed economies.

Empirically, the above income distribution does not apply to the two extreme population groups (very poor and very rich). The very poor are often lifted to a minimum wage by some form of governmental policy, so that the largest number of people (i.e. the mode of the distribution curve) is slightly above the zero income. Empirically, also the very rich outnumber the theoretical prediction, as there are more very rich persons (top 3%) than the theory would predict. Empirically, the income of the very rich follows a power law distribution. Some textbooks state that income distribution in general follows a power law described by V. Pareto (1919). While there is a relation between power law and the negative-exponential law, the two are not identical.

The negative-exponential distribution of income makes the existence of slum eradication policies almost mandatory in any local community. Integrated urban planning is to provide public goods such as basic infrastructure to newly arriving migrants. This policy is more efficient than price subsidies or price caps for essential goods. This is in line with statements of APEC Leaders to phase out inefficient fossil fuel subsidies while providing those in need with essential services (see Chapter 3). Price caps or similar instruments diminish the signalling efficiency of prices, hence its market clearing capacity.

APEC economies, compared to the global picture regarding slums, are possibly relatively better off than the world in average. Slum development is reported in Bandung (Indonesia), Manila (the Philippines), Mexico City (Mexico), Santiago (Chile), Bangkok Khlong Toei District (Thailand) and Ho Chi Minh City (Viet Nam). More generally, urban poverty is found in some APEC economies: Indonesia, Mexico, Papua New Guinea, Peru, the Philippines, and Thailand, which are all experiencing increased absolute numbers of urban poor[52].

Data scarcity on urban development affects specially the knowledge about slums.

2.1.5. Lack of Urban Data in Asia-Pacific Region

Data scarcity is a major problem for sustainability analysis. This is even more the case if data at urban level is sought. Data scarcity has been evidenced as a major problem for the analysis of sustainability progress in the Asia-Pacific region. The UN Economic and Social Commission for Asia-Pacific UNESCAP published a progress report in 2017 covering the progress of the Asia Pacific Region towards attaining the 2030 Sustainable Development Goals (SDG)[53]. For a presentation of SDGs see Chapter 3.

Across the board, the assessment of progress contained in this report is limited by data availability. For this reason, only 25 per cent of the official SDG indicators were available to assess progress in Asia and the Pacific. The UNESCAP had to take 57 proxy indicators to cover the 169 targets that are included in the 17 SDGs goals for which insufficient evidence is available.

The most data-poor SDGs are the ones on reduced inequalities (Goal 10), sustainable cities and communities (Goal 11), responsible consumption and production (Goal 12), climate

action (Goal 13), life below water (Goal 14), and peace, justice and strong institutions (Goal 16). On these six goals, less than 15 per cent of the official SDG indicators is available for regional progress assessment. No indicator was available to assess progress on the two SDGs on climate action and life below water for which, therefore, the entire analysis had to be based on proxy indicators.

Looking beyond data scarcity, this analysis may show that the region is fully on track with one goal (Goal 4) only, ascertained, however, by 36% of evidence-based data only. Goal 11 (sustainable cities and communities) is short off track but evidenced by only 13% of evidence-based data. Goal 7 (Affordable and clean energy) is well below track, as is clearly ascertained by 67% of evidence-based data, the most certain result. For Goal 13 (Climate action), zero data is available, but a significant progress gap is identified using proxies. Two goals (Goal 10 and 16) show regress, based on only 9% of evidenced information.

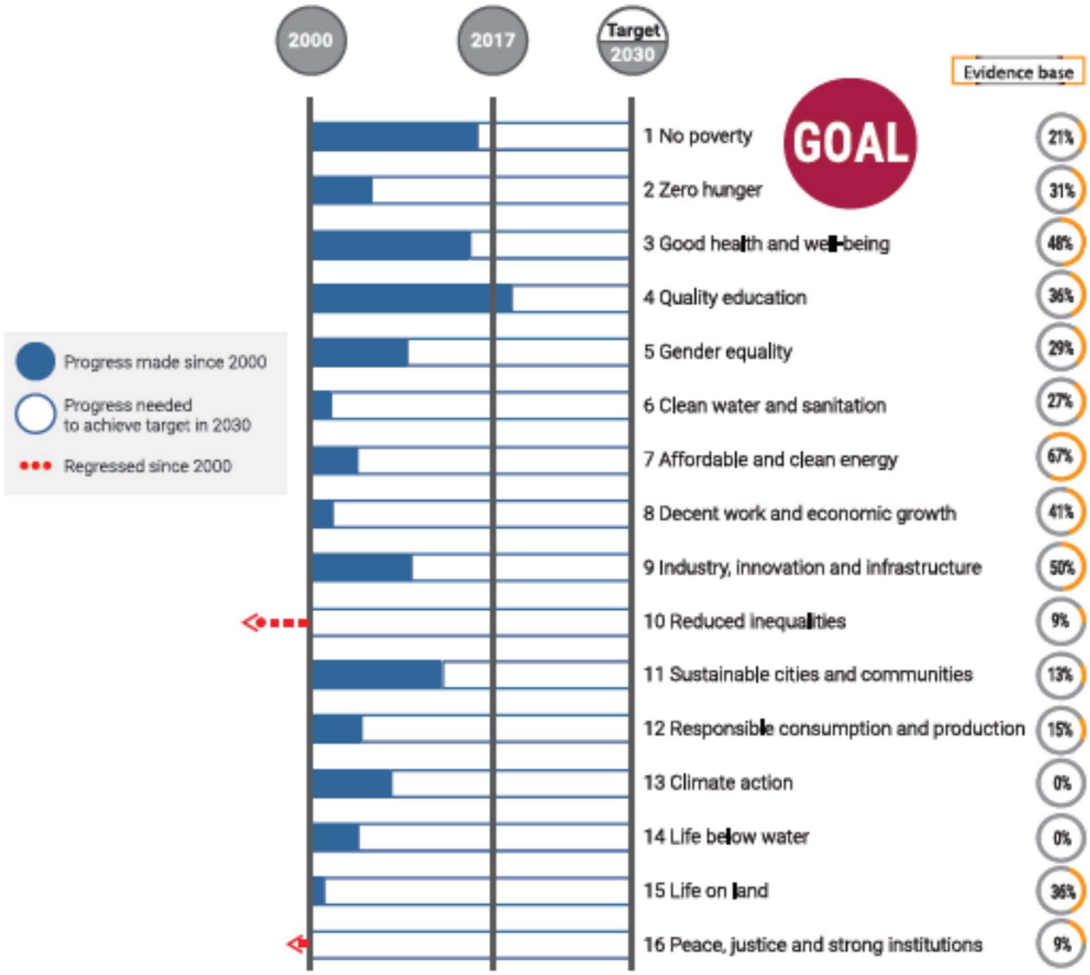

Figure 51: Snapshot of SDG progress by 2017.
Source: UNESCAP *Asia and the Pacific SDG Progress Report 2017*

In a snapshot, the Asia-Pacific region generally needs to accelerate the pace of change and reverse some negative trends if the 2030 SDGs are to be attained. Asia and the Pacific's progress towards implementing the various SDGs on improving environmental stewardship, for instance, has fallen short across the board. Thus, Goal 13, climate action, is unlikely to be met at the current pace of change. Progress towards sustainable cities and communities (Goal 11) was also insufficient.

At the level of targets, out of the 57 targets which are analysed in the UNESCAP progress report, progress is sufficient only for 13 indicators (green), for 37 indicators it is insufficient (yellow), and for 7 indicators it is negative (red), i.e. the development must be reversed.

Figure 52: Dashboard of progress on targets for the Asia-Pacific region as a whole
Source: UNESCAP *Asia and the Pacific SDG Progress Report 2017*

From this picture, one can try to filter out those indicators that are either directly or indirectly relevant to sustainable urbanization. Sustainable urbanization is often approached under a holistic perspective. In this sense, not only targets included in SDG 11, “Making cities and communities sustainable”, are relevant for sustainable urbanization. The table below chooses SDGs 6 to 13 and SDG 15 as directly or indirectly relevant for sustainable urbanization. The following indicators show whether the region is on track (green), needs acceleration (yellow) or needs reversal of development (red); no colour means not assessed due to lack of sufficient data.

Goal	Indicator	2000 (or earliest)	2017	2030	Target value
11	Urban population living in slums (%)	48.0	22.9	6.3	0.0
11	Economic loss from disasters	0.2	0.2	0.1	0.1
11	Annual mean concentration of PM10 /PM 2.5 in cities	68.5 / 26.3			21.0 / 12.0
6	Safely managed drinking water services (% of population)	74.3	79.2	93.4	100
6	Safely managed sanitation services (% of population)	2.5	1.5	1.5	0.0
7	Access to electricity (% of population)	94.3	100	100	100
7	Reliance on clean energy (% of population)	38.7	59.1	81.1	100
7	Renewable energy share (% of total final energy consumption)	19.6	10.5	12.0	25.7
7	Total primary energy supply TPES	5.8	4.9	4.2	2.0
8	Real GDP per capita growth rate (% change per capita per annum)	4.1	1.9	1.3	7.0
8	Real GDP per employed person growth rate (% change per annum)	2.6	1.7	1.6	5.3
8	Youth unemployment rate (% of 15 – 24-year-old labour force)	11.8	12.1	12.1	6.0
8	Unemployment rate (% of >15 years old labour force)	5.8	5.3	4.3	2.6
9	Manufacturing value added	12.8	10.9	10.1	18.1
9	Manufacturing employment	10.6	8.6	9.6	26.6
9	CO2 emission intensity	0.3	0.2	0.2	0.1
9	Research and development expenditure	0.2	0.5	1.1	0.7
9	Medium and high-tech industry value added	21.1	19.3	22.2	30.0
9	% population covered by a least 3G mobile phone network	71.5	98.3	100	100
10	Gini coefficient	36.5	36.1	33.9	28.0
10	Labour share of GDP (%)	47.4	44.2	45.7	55.2
12	Material footprint (kg per USD 2005 GDP)	3.2	3.0	2.8	1.8
12	Domestic material consumption (kg per USD 2005 GDP)	2.9	2.6	2.4	1.1
13	GHG emissions (metric tons of CO2 equivalent per capita)	2.5	3.1	3.7	1.1
13	CO2 emissions per unit of manufacturing value added	0.9	0.4	0.4	0.3
15	Forest area (% of land area)	37.8	37.2	36.1	43.9

Table 3: Performance of the region for indicators related to sustainable urbanization
Source: UNESCAP *Asia and the Pacific SDG Progress Report 2017*

The indicators can be divided into four categories: Firstly, those where the region manages well, e.g. safely managed sanitation services, access to electricity and coverage by at least 3G mobile phone networks. Also, expenditure for research and development is on track.

Secondly, indicators where the region is well progressing, but evolution needs to be accelerated. Among them, two are directly of concern to urbanization, namely diminishing the percentage of urban population living in slums and the economic loss from disasters. In other words, cities need to have stronger policies for eradicating slums and need to become more resilient against extreme weather events such as hurricanes. Further efforts also need to be made to diminish unemployment, increase the labour share in GDP, diminish social inequalities and diminish the material intensity of the economy.

Thirdly, two groups of indicators that show problematic developments: economic growth per capita is insufficient and CO_2 emissions per capita are on the reverse track as they have increased instead of decreasing. This is surprising, as the main justification for increasing CO_2 emissions is precisely economic growth. Where per capita growth is not taking place as expected, the increase of per capita CO_2 emissions is unexpected and requires further analysis. This will be attempted in this section hereafter.

Fourthly, the progress report points out to the fact that the region becomes less equal. The problem of inequality may be exacerbated by suboptimal city-size hierarchy when e.g. one dominant capital city is surrounded by small rural communities without any second or third-tier cities.

The ESCAP Asia and the Pacific SDG Progress Report includes information from all Asia-Pacific countries and is therefore not representative for APEC. The above results include notably Central and South Asia but exclude North, Central and South American APEC economies.

2.2. Sustainability Deficits of Selected APEC Economies

Sustainability scores of Chinese cities have been calculated by UNDP and published in the report UNDP (2016) *China Sustainable Cities Report 2016: Measuring Ecological Input and Human Development*[54]. It analyses the sustainability of 35 medium and large Chinese cities using a combination of two indices, a first one for indicating a desirable output (Urban Human Development Index), and a second one for indicating the corresponding ecological cost (Urban Ecological Input Index).

The Urban Human Development Index (UHDI) indicates the desired output of a city, expressed as a geometric mean of its three components: life expectancy at birth (Life Expectancy Indicator LEI), years of education (Education Indicator EI, equal to the arithmetic means of its two parts, namely mean years of schooling and expected year of schooling), and per capita income (Income Indicator II). Concerning the exact way how the LEI, EI and II are being constructed, see the referenced UNDP report. The Urban Human Development Index applies the Human Development Index (HDI) to the urban context. The HDI is scaled to take values between 0 and 1, where 0 means least developed and 1 means most developed. In 2014, UNDP globally has adopted the convention that HDI below 0.55 indicates low human development, HDI between 0.55 and 0.7 indicates medium, between 0.7 and 0.8 high, and above 0.8 it is very high human development.

The Urban Ecological Input Index (UEII) indicates the different kinds of ecological inputs of a city and is made up of nine ecological indicators, of which three are resource consumption indicators (Urban Resource Consumption Index URCI) and six are pollution output indicators (Urban Pollutant Discharge Index UPDI) to measure the environmental health of a city. The UEII is equal to the arithmetical average of URCI and UPDI. These indicators are selected because they reflect areas over which the local governments have policy influence.

The URCI is equal to the arithmetic mean of its three components: Urban water consumption index UWCI, urban energy consumption index UECI, and urban land consumption index ULCI.

The UPDI includes three indicators, each made up of two components: the urban water pollutant indicator (including chemical oxygen demand COD, which is a measure for organic pollutants in wastewater, and ammonia), the urban air pollutant indicator (SO_2 and NO_x), and an urban solid waste indicator (industrial waste and municipal solid waste). The UPDI is equal to the arithmetic mean of its six mentioned components.

Each component is scaled between 0 and 1, where 0 means least environmental impact and 1 means the highest environmental impact. This allows the UEII to be bounded between 0 and 1.

The process towards improving the sustainability of a city can be pictured as the increase in the output (upper hemisphere), shifting in right direction, and a decrease in inputs (lower hemisphere), shifting in the left direction.

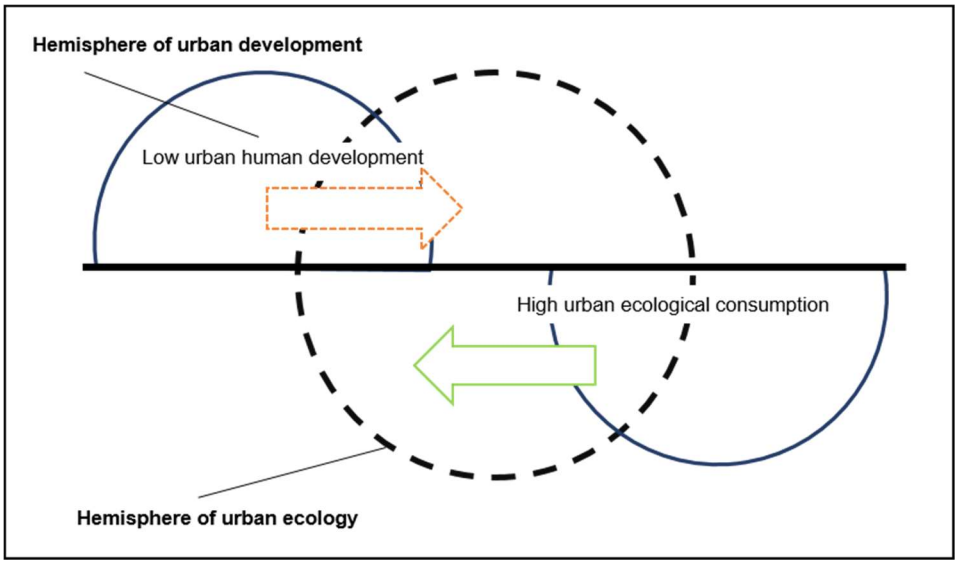

Figure 53: Sustainable development as alignment of two hemispheres
Source: UNDP (2016). *China Sustainable Cities Report 2016: Measuring Ecological Input and Human Development*

This methodology of combining the two indices UHDI and UEII has been applied to evaluate the sustainable development of 35 large and medium sized Chinese cities. The UHDI (desired output) is plotted on the horizontal axis and the UEII (harmful input) on the vertical axis. The higher a city scores on the horizontal axis, the higher its HDI is. Conversely, the higher a city scores on the vertical axis, the higher its environmental impact is. The most sustainable cities are, therefore, those with high output and low environmental impact, i.e. the

ones on the right-hand side below the middle line. Conversely, the least sustainable cities are those with low output in terms of HDI and high environmental impact, i.e. on the left-hand side above the middle line.

The chosen methodology and index normalization method allows comparing a group of cities, in this case 35 Chinese cities, among themselves. From the 35 analysed Chinese cities, eight are relatively less sustainable (upper left quadrant: Taiyuan, Hohhot, Urumqi, Nanning, Lanzhou, Guiyang, Yinchuan, Xining), whereas eight are relatively more sustainable (lower right quadrant: Beijing, Hangzhou, Tianjin, Qingdao, Dalian, Shenyang, Changsha, Jinan). It would be a false interpretation, however, to consider that the cities in the lower right quadrant are sustainable. The problem of this method is that is only allows showing relatively better and relatively worse off cities. This is related to the fact of using the chosen index method.

Quadrant	City	Feature of input/output	Sustainable development level
II	Beijing, Hangzhou, Tianjin, Qingdao, Dalian, Shenyang, Changsha, Jinan	Low input, high output	Sustainable development
I	Chengdu, Chongqing, Xi'an, Zhengzhou, Harbin, Changchun, Kunming, Hefei, Fuzhou, Haikou, Nanchang, Shijiazhuang	Low input, low output	Less sustainable development
III	Shanghai, Guangzhou, Shenzhen, Nanjing, Wuhan, Ningbo, Xiamen,	High input, high output	
IV	Taiyuan, Hohhot, Urumqi, Nanning, Lanzhou, Guiyang, Yinchuan, Xining,	High input, low output	Unsustainable development

Figure 54: Sustainability of Chinese cities

Source: UNDP (2016). *China Sustainable Cities Report 2016: Measuring Ecological Input and Human Development*

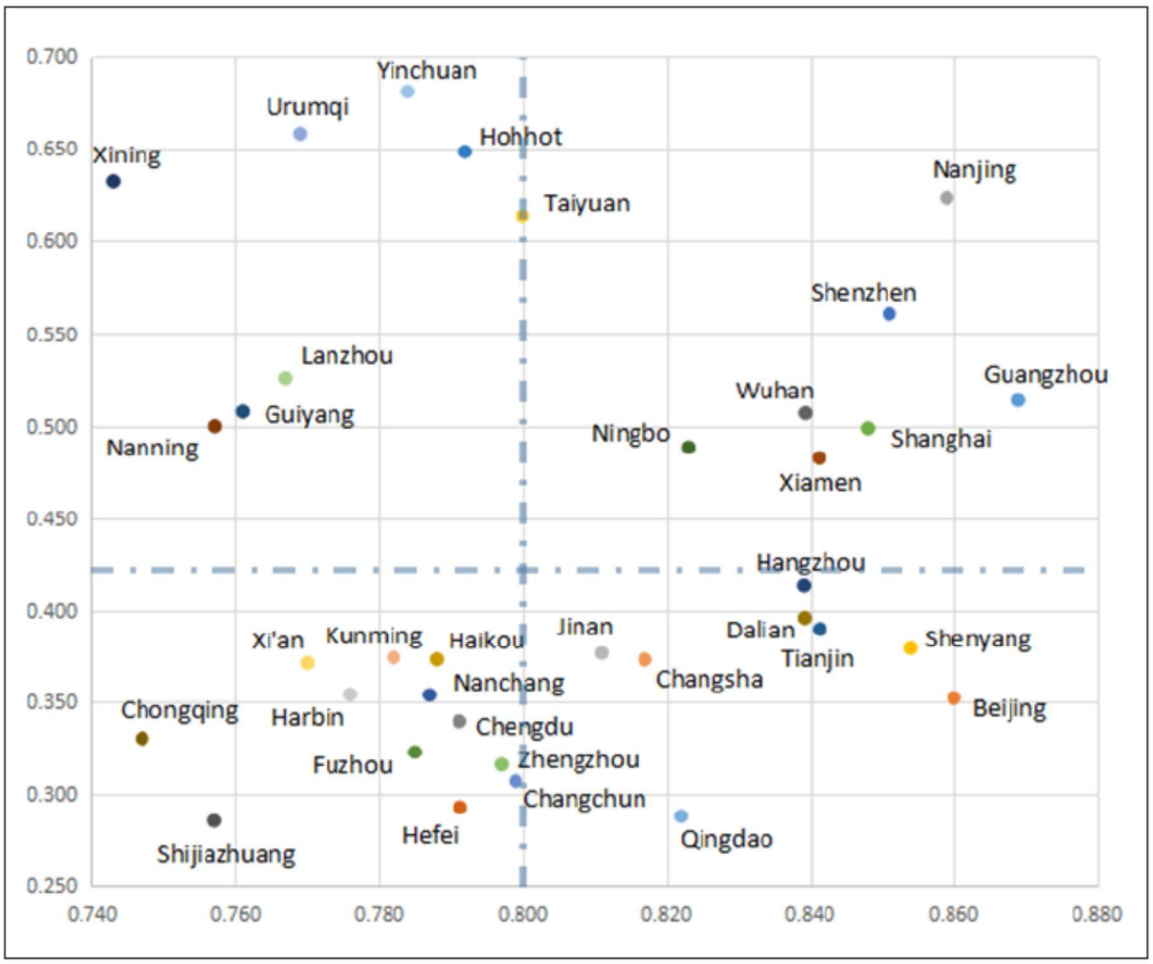

Figure 55: UHDI (horizontal) vs UEII (vertical) plot of 35 large and medium-sized Chinese cities
Source: UNDP (2016). *China Sustainable Cities Report 2016: Measuring Ecological Input and Human Development*

Chapter 3 – Policy Responses

In 2015, the global community has 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. 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 are 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. Individual APEC economies have also brought responses to the sustainability challenge. China translated the Sustainable Development Goals into a comprehensive *National Plan on Implementation of the 2030 Agenda for Sustainable Development*, published in September 2016. Implementation progress is further being reviewed in the *Progress Report on the Implementation of the 2030 Agenda for Sustainable Development* released in August 2017. Hong Kong, China, is a member economy of APEC, as well as a city member of C40 Cities Climate Leadership Group and of the Global Covenant of Mayors GCoM. Hong Kong, China has released a *Climate Action Plan 2030* in January 2017. The European Union is an early sustainability pioneer. The interest of looking at the European Union for sustainable urbanization in APEC is not only the ambitious strategies for 2020, 2030 and, most recently, the vision 2050, providing for at least one carbon neutral city in the EU by 2030 and one hundred diverse cities as zero-carbon labs by 2040, but also the number of initiatives that have originated in Europe fostering cooperation among cities. The EU hosts several of the world's biggest inter-municipal organizations. The United Cities and Local Governments UCLG is the world's biggest inter-municipal organization representing 240'000 local communities, or 70% of the world population. ICLEI Local Governments for Sustainability, headquartered in Bonn, has more than 1500 local members (cities, towns and regions) worldwide, impacting 14% of world population. The C40 Cities Climate Leadership Group, originally created in London, comprises 96 megacities, representing 8% of world population with 25% of the world GDP. C40 has undertaken altogether 10'000 actions to combat climate change. The Covenant of Mayors CoM, which in 2016 became the Global Covenant of Mayors GCoM, is headquartered in Brussels and counts now more than 9100 cities representing 10% of world population. Its aim is to make cities invest for mitigation and adaptation. The World Bank has a cooperation program of 4.5 billion USD over the period 2018 - 2020 with GCoM, allowing for cities to realize ambitious climate action programmes. The particularity of the GCoM and its predecessor, the CoM, is that its action is results-oriented and measurable. The verifiable engagements of the 6200 members of the former CoM amount to cumulative emissions reductions of 27% from 2008 to 2020. GCoM has already 340 member-cities in APEC, accounting for a total of 230 million inhabitants.

3.1. Global Response: 2030 Agenda for Sustainable Development

3.1.1. Sustainable Development Goals (SDGs) as Global Milestone

The SDGs are part of the UN 2030 Agenda for Sustainable Development, which also includes as integral part the Addis Ababa Action Agenda of the Third International Conference on Financing for Development[55]. The latter consists of a new global framework for financing sustainable development and will not be further discussed here.

In September 2015, world leaders met at the UN General Assembly and adopted the 2030 Agenda for Sustainable Development, covering altogether 17 Sustainable Development Goals (SDGs) and 169 associated, more detailed targets. The SDGs replaced the Millennium Development Goals, which had been set in 2000 with the time horizon 2015. The idea of formulating Sustainable Development Goals (SDGs) had originally been incepted by Columbia [56] and discussed during the 2012 United Nations Conference on Sustainable Development (Rio +20).

In 1992 the UN Conference on Environment and Development (UNCED), held in Rio, had defined sustainable development as a set of three pillars (economic viability, social equity and environmental protection) that guarantee balanced sustainable development.

Figure 56: Pictograms of each of the 17 Sustainable Development Goals (SDG)
Source: United Nations[57]

The 2015 SDGs mark a clear progress over the 1992 sustainable development concept in the sense of improved clarity of definition. Furthermore, the 17 goals have been supplemented by 169 specific targets having elements of measurability[58]. Over the next 15 years, countries commit to eradicating all forms of poverty, achieving equity and tackling climate change, while ensuring that no one is left behind. The goal of sustainable development could fundamentally change the traditional development concept of one-sided pursuit of economic growth. Instead, it can promote the concept of sustainable development, meaning inclusive growth with coordinated development of the economy, the society and the environment. The goals of sustainable development, whether in breadth, depth, difficulty or strength, go far beyond the

Millennium Development Goals and portray an ambitious blueprint for global sustainable development.

The SDGs are a success story as they confer broadly negotiated targets to all governments and other stakeholders. Their success bases also on the fact that they integrate a broad array of other specialized international documents, agreements or institutions:

1. Mandate of the Doha Development Round (WTO)
2. World Health Organization Framework Convention on Tobacco Control
3. Doha Declaration on the TRIPS Agreement and Public Health (WTO)
4. Programme of Action of the International Conference on Population and Development and the Beijing Platform for Action and the outcome documents of their review conferences
5. 10-Year Framework of Programmes on Sustainable Consumption and Production
6. Enhanced Integrated Framework for Trade-related Technical Assistance to Least Developed Countries
7. Global Jobs Pact of the International Labour Organization
8. World Trade Organization agreements, the fisheries subsidies negotiations, the Doha Development Agenda and the Hong Kong ministerial mandate
9. Sendai Framework for Disaster Risk Reduction (DRR) 2015-2030
10. United Nations Framework Convention on Climate Change (UNFCCC)
11. Green Climate Fund
12. Intergovernmental Oceanographic Commission Criteria and Guidelines on the Transfer of Marine Technology
13. United Nations Convention on the Law of the Sea (UNCLOS)
14. “The future we want”

When they were finally adopted by the UN General Assembly in September 2015, the SDGs had won the race against other competing projects to steer the global development process until 2030. Compared to “green economy” proposals or the various ideas such as e.g. a General Agreement on Reduction of Emissions (GARE)[59] and similar proposals, the SDGs had the clear advantage of being pluri-dimensional, including the energy-relevant objectives of Sustainable Energy for All (SE4All), but leaving the more difficult questions of emissions reduction to the UNFCCC. Compared to various proposals of an “International Framework for Sustainable Development” discussed in the Rio + 20 cycle, they had the advantage of being goal-driven rather than rule-driven and were, therefore, not in open conflict with the WTO. Compared to simply extending the time-horizon of the Millennium Development Goals, the SDGs had the advantage of addressing also the problems of developed countries. And with respect to the outputs of the 1992 Rio summit, the SDGs had the decisive advantage of being more clearly appreciable or measurable. The decision-makers furthermore managed to integrate the SDGs into the broader 2030 Agenda for Sustainable Development.

The important role of cities in sustainable development has been recognized by the fact that cities have received a specific goal:

Figure 57: United Nations Sustainable Development Goal 11-Sustainable cities and communities
Source: United Nations

This goal postulates to “Make cities and human settlements inclusive, safe, resilient and sustainable” by 2030. Furthermore, the following specific targets have been set:

11.1 By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums

11.2 By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons

11.3 By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries

11.4 Strengthen efforts to protect and safeguard the world’s cultural and natural heritage

11.5 By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations

11.6 By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management

11.7 By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities

11.a Support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning

11.b By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015-2030, holistic disaster risk management at all levels

11.c Support least developed countries, including through financial and technical assistance, in building sustainable and resilient buildings utilizing local materials

Target 11.b refers to the Sendai DRR Framework 2015 – 2030. Target 11.b requires countries to introduce National Urban Policies (NUP). These policies mitigate the negative externalities of urbanization and play a key role for sustainable urbanization.

The SDGs have been translated to local level at the Habitat III Conference held in Quito, Ecuador, in 2016. Traditionally, Habitat Conferences have been held in a twenty-year cycle which started in 1976 in Vancouver (Habitat I), followed by Istanbul (Habitat II) in 1996 and Quito (Habitat III), 2016. The Habitat III Conference adopted the New Urban Agenda (NUA)[60], composed of the Quito Declaration on Sustainable Cities and Human Settlements for All, and an implementation plan.

The Quito Declaration called for a paradigm shift, that will

a) readdress the way we plan, finance, develop, govern, and manage cities and human settlements, recognizing sustainable urban and territorial development as essential to the achievement of sustainable development and prosperity for all;

b) recognize the leading role of governments, as appropriate, in the definition and implementation of inclusive and effective urban policies and legislation for sustainable urban development, and the equally important contributions of sub-national and local governments, as well as civil society and other relevant stakeholders, in a transparent and accountable manner;

c) adopt sustainable, people-centred, age- and gender-responsive and integrated approaches to urban and territorial development by implementing policies, strategies, capacity development, and actions at all levels, based on fundamental drivers of change including:

    i. developing and implementing urban policies at the appropriate level including within multi-stakeholder partnerships, building integrated systems of cities and human settlements, promoting cooperation among all levels of government to enable them to achieve sustainable integrated urban development;
    ii. strengthening urban governance, with sound institutions and mechanisms that empower and include urban stakeholders, as well as appropriate checks and balances, providing predictability and coherence in the urban development plans to enable social inclusion, sustained, inclusive, and sustainable economic growth and environmental protection;
    iii. reinvigorating long-term and integrated urban and territorial planning and design in order to optimize the spatial dimension of the urban form and to deliver the positive outcomes of urbanization;
    iv. supporting effective, innovative, and sustainable financing frameworks and instruments, enabling strengthened municipal finance and local fiscal systems in order to create, sustain, and share the value generated by sustainable urban development in an inclusive manner.

3.1.2. Paris Agreement under the UNFCCC

The Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCC)[61] was adopted in December 2015 and represents another milestone for sustainable development. Almost a quarter of a century – or one generation after the adoption of the basic framework agreement in 1992 – the latter finally was complemented by a specific agreement implementing the detailed manner as to how the international community intended to address climate change at global level. The Paris Agreement under the UNFCCC for the first time fixed the ambitious objective to keep warming well below 2 degrees with efforts to limit warming to 1.5 degrees. It provided for a rich array of voluntary measures (so-called intended nationally determined contributions, INDCs) addressing not only the Parties to the UNFCCC, but also non-Party stakeholders, including civil society, the private sector, financial institutions, cities and other subnational authorities, local communities and indigenous peoples.

The most recent INDCs submitted by APEC economies are listed in the following table.

APEC Economy	INDC
Australia	Reduce GHG emissions by 26 to 28% by 2030 compared to 2005
Brunei Darussalam	Reduce total energy consumption by 63% compared to BAU by 2035; increase renewables share in power generation to 10% by 2035; reduce carbon dioxide emissions from morning peak hour vehicle use by 40% by 2035 compared to BAU; increase the total gazette forest reserves to 55% of total land area by 2035
Canada	Reduce GHG emissions by 30% below 2005 levels by 2030
Chile	Reduce CO2 intensity by 30% below 2007 levels by 2030; Reduce CO2 intensity by 35% to 45% by 2030 conditional to IMF grant
China	Peaking of CO2 emissions by 2030 and best efforts to peak earlier; reduce CO2 intensity by 60% to 65% by 2030 compared to 2005; increase the share of non-fossil fuels in primary energy consumption to around 20% by 2030; increase forest stock volume by around 4.5 billion cubic meters by 2030 compared to 2005
Hong Kong, China	See China
Indonesia	Reduce GHG emissions by 29% by 2030 compared to BAU; reduce GHG emissions by 41% by 2030 conditional on support from international cooperation
Japan	Reduce GHG emissions by 25.4% by 2030 compared to 2005
Korea	Reduce GHG emissions by 37% from BAU level by 2030
Malaysia	Reduce GHG intensity by 35% by 2030 compared to 2005; reduce GHG intensity by 45% by 2030 conditional on climate finance, technology transfer and capacity building
Mexico	Reduce GHG and Short-Lived Climate Pollutants by 25% below BAU by 2030 (i.e. 22% GHG and 51% Black Carbon). Reduce GHG and SLCP by 40% by 2030 conditional to international measures
New Zealand	Reduce GHG emissions by 30% by 2030 compared to 2005

Papua New Guinea	100% renewable electricity by 2030, contingent on funding; reduce deforestation and promoting forest conservation.
Peru	Reduce GHG emissions by 20% compared to BAU by 2030; Reduce GHG emissions by 30% by 2030 subject to availability of international financing
Philippines	Reduce GHG emissions by about 70% by 2030, compared to BAU
Russia	Limit anthropogenic GHG to 70% to 75% by 2030 compared to 1990
Singapore	Reduce emissions intensity by 36% by 2030 compared to 2005, and stabilize emissions with the aim of peaking around 2030
Chinese Taipei	See China
Thailand	Reduce GHG emissions by 20% from BAU level by 2030; 25% reduction subject to access to technology, finance and capacity building
United States	Reduce GHG emissions by 26% to 28% by 2030 compared to 2005
Viet Nam	Reduce GHG emissions by 8% by 2030 compared to BAU; reduce GHG emissions by 25% by 2030 with international support

Table 4: INDCs submitted by APEC economies
Source: UNFCCC[62]

The Paris Agreement is substantially included in SDG 13.2, “Integrate climate change measures into national policies, strategies and planning”, even though the Paris Agreement was concluded two months after the adoption of the SDGs. The target 13.2 is one of the most important targets of the SDG. This is shown by the analysis of the effects of target SDG 13.2 (i.e. the Paris Agreement) on all other SDGs. A recent analysis made by the New Climate Institute identifies altogether 916 causal links between SDG 13.2 (climate mitigation) and all other SDGs. SDG 17 is left out from the analysis as the relationships would be too diffuse.

The figure below lists the different climate mitigation actions (on the left) and shows the relation with each of the remaining 15 SDGs (on the right). Climate mitigating actions electricity and heat have 502 causal links affecting SDGs, followed by transport (102 links), industry (97 links) and buildings (92 links). SDG 8 (growth) is the SDG having the biggest number of causal links (170) with climate mitigation, followed by SDG 9 (industry, 128 links), SDG 11 (sustainable cities, 121 links) and SDG 15 (forests, biodiversity, 99 links).

The above figure does not tell whether the causal links are positive or negative, neither does it inform whether the links are quantitatively strong or, on the contrary, rather weak. The study finds that out of all the 916 described links, 716 (or about three quarters) have the character of synergies, whereas 200 (roughly one quarter) are trade-offs. This information is summarized in the table below. The lines indicate the SDGs and the columns the above-mentioned climate mitigation actions.

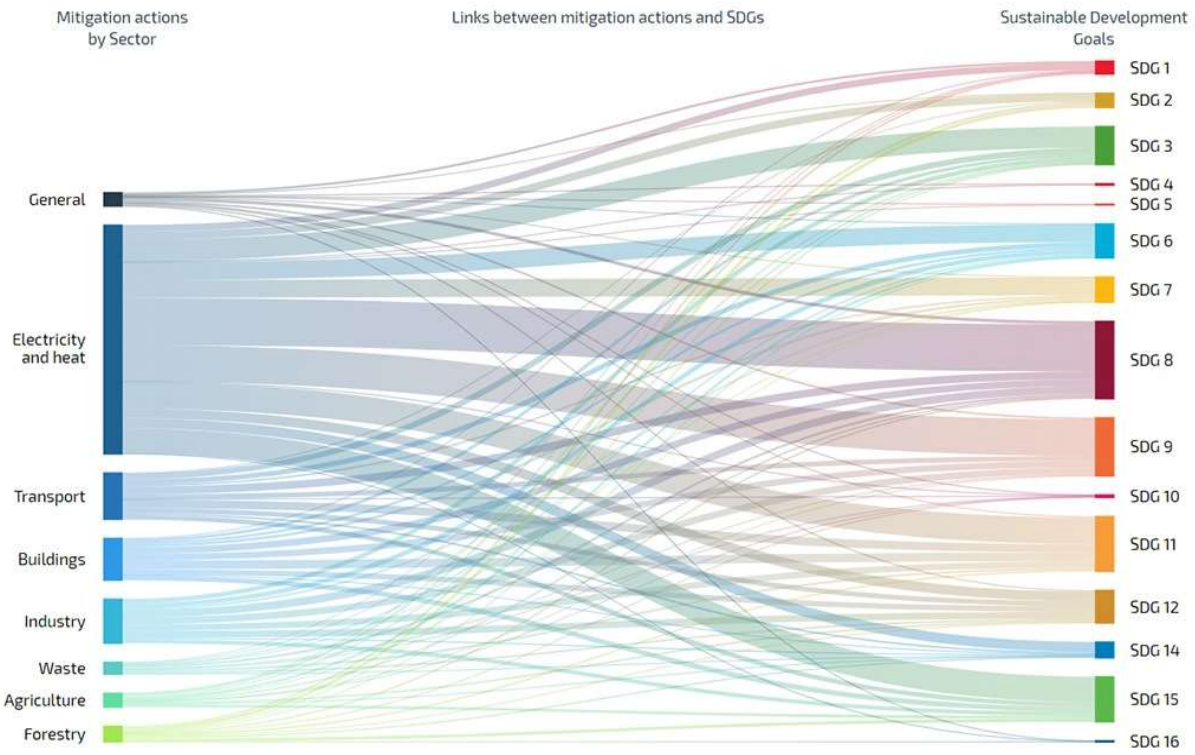

Figure 58: Links between climate mitigation and SDGs
Source: New Climate Institute[63]

Legend: Only negative links | More negative links | Both positive and negative links | More positive links | Only positive links | No links

	Electricity & heat	Transport	Buildings	Waste	Industry	Agriculture	Forestry	General
1. No poverty								
2. Zero hunger								
3. Good health and well-being								
4. Quality education								
5. Gender equality								
6. Clean water and sanitation								
7. Affordable and clean energy								
8. Decent work and economic growth								
9. Industry, Innovation and infrastructure								
10. Reduced inequalities								
11. Sustainable cities and communities								
12. Responsible consumption								
14. Life below water								
15. Life on land								
16. Peace, justice and strong institutions								

Table 5: Positive, mixed and negative effects of climate mitigation on SDGs
Source: New Climate Institute

This analysis between SDGs complements the analysis made in Chapter 1 above, which shows that cities are engines of economic growth. Their host economies cannot realize SDG 8, “promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all”, without the active cooperation of cities.

Cities are leading technological research and innovation hubs; therefore, without cooperation from cities, their economies cannot realize target 9.5., “Enhance scientific research upgrade the technological capabilities of industrial sectors in all countries, in particular in developing countries, including, by 2030, encouraging innovation and substantially increasing the number of research and development workers per 1 million people and public and private research and development spending”.

Cities are poles of inequalities as they have higher economic activity than their surroundings. For the harmonious development of an economy it is particularly important that a harmonious size hierarchy among cities exists (generalized Zipf’s law or rank size rule). In that sense, economies cannot realize SDG 9, “reduce inequality within and among countries”, without the help of the small and medium size cities.

Cities are major producers of waste. Therefore, economies cannot achieve target 12.5, “By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse”, if cities do not actively cooperate.

Cities emit large amounts of CO_2. Their economies, therefore, need the active cooperation of cities to attain SDG 13, “Take urgent action to combat climate change and its impacts.”

3.1.3. Sendai Framework for Disaster Risk Reduction DRR 2015 – 2030

SDG target 11.b makes an explicit reference to the Sendai Framework for Disaster Risk Reduction 2015 – 2030, in short Sendai DRR Framework, another international framework that is substantially included in the SDGs and relevant for sustainable urbanization. Formally, the Sendai Framework was adopted in March 2015 at the World Conference on Disaster Risk Reduction held in Sendai, Japan and endorsed by the UN General Assembly in June 2015. It was preceded by the Hyogo Framework for Action adopted in 2005[64].

The original idea behind the Sendai DRR Framework may have been to shield cities from the increasing risks of climate change events. In fact, the framework is much broader than adaptation to climate change. It is a holistic disaster risk management framework with a particularly broad scope, addressing all types of risks, and having a timetable for measures to be implemented by 2030[65]. The types of risks addressed are:

- Small scale as well as large scale
- Frequent and infrequent
- Sudden and slow onset disasters
- Caused by natural or man-made hazards as well as related environmental, technological and biological hazards and risks.
- Multi-hazard management and disaster risk at all levels and within and across all sectors

It has a twofold goal:

1) to prevent and reduce existing disaster risk through the implementation of integrated and inclusive measures of all kinds (economic, structural, legal, social, health, cultural, educational, environmental, technological, political and institutional)

2) to increase preparedness for response and recovery, and thus strengthen resilience

The Sendai DRR Framework defines resilience as “the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions”. This ability is particularly important for sustainability.

It has four priority areas that are also meant to apply at local level:

Priority 1: Understanding disaster risk.
Priority 2: Strengthening disaster risk governance to manage disaster risk.
Priority 3: Investing in disaster risk reduction for resilience.
Priority 4**:** Enhancing disaster preparedness for effective response and to “Build Back Better” in recovery, rehabilitation and reconstruction.

Based upon information collected during the adoption conference held in Sendai, Japan, in 2015, worldwide disasters of the last 10 years have caused

- Loss of life of 700’000 people
- Injured 1,4 million people
- Made homeless 23 million people
- Affected overall 1,5 billion people causing economic loss of USD 1.3 trillion

The Sendai DRR Framework fits well with the SDGs, with which it has the holistic approach in common. It has seven quantitative targets:

(a) Mortality: Substantially reduce global disaster mortality by 2030, aiming to lower the average per 100,000 global mortality rate in the decade 2020–2030 compared to the period 2005–2015;
(b) People affected: Substantially reduce the number of affected people globally by 2030, aiming to lower the average global figure per 100,000 in the decade 2020–2030 compared to the period 2005–2015;
(c) Economic loss: Reduce direct disaster economic loss in relation to global gross domestic product (GDP) by 2030;
(d) Critical infrastructure and services: Substantially reduce disaster damage to critical infrastructure and disruption of basic services, among them health and educational facilities, including through developing their resilience by 2030;
(e) Disaster risk reduction strategies: Substantially increase the number of countries with national and local disaster risk reduction strategies by 2020;
(f) International cooperation: Substantially enhance international cooperation to developing countries through adequate and sustainable support to complement their national actions for implementation of the present Framework by 2030;

(g) Early warning and risk information and assessment: Substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to people by 2030.

Local communities such as cities and towns are in the lead to address the first five targets (a) to (e), whereas central governments are in the lead for the last two targets (f) and (g).

The first five targets of the Sendai DRR Framework have direct relationships with SDG 1, SDG 11 and SDG 13. These three SDGs are the backbone for sustainability at the local level. The relationship between the Sendai Disaster Risk Framework and these three targets is shown in the figure below, where the five boxes in the middle relate to the first five quantitative targets of the Sendai DRR Framework.

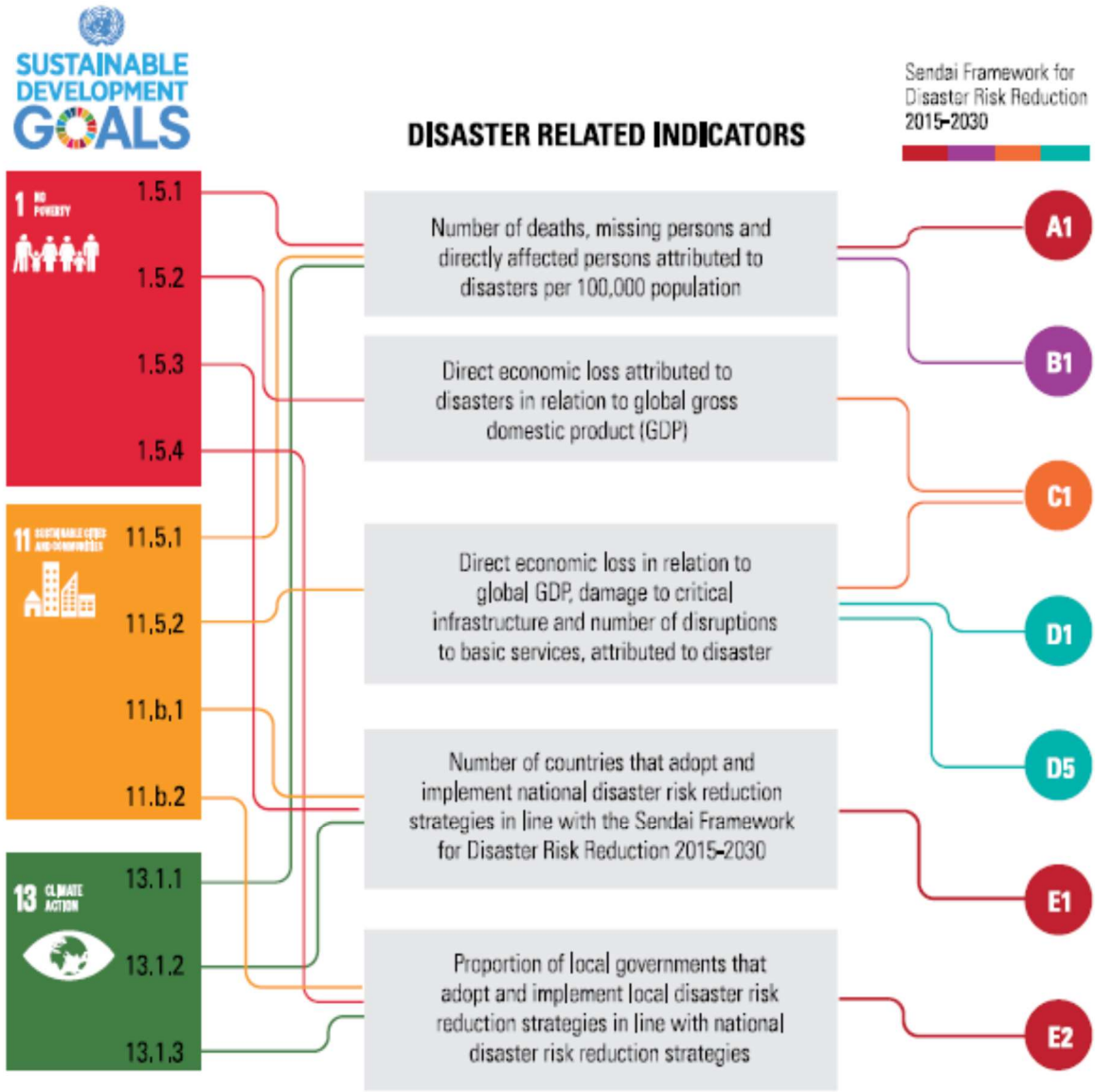

Figure 59: Interlinkages between SDGs and the Sendai DRR Framework
Source: *SDG 11 Synthesis Report*, UN Habitat, 2018

The United Nations Office for Disaster Risk Reduction UNISDR is the UN agency for implementing the Sendai Framework for Disaster Risk Reduction. The Centre for Research on the Epidemiology of Disasters CRED in Belgium maintains a global database on disasters.

For managing disasters, a disaster management cycle includes the following elements:

Figure 60: Disaster Management Cycle
Source: *World Risk Report 2016*[66]

3.1.4. 10YFP on Sustainable Consumption and Production (SCP) Patterns

The 10-Year Framework Program (10YFP) on Sustainable Consumption and Production (SCP) Patterns[67] is substantially included in SDG 12 (sustainable consumption and production patterns) and referenced in SDG 8 (decoupling economic growth from environmental degradation). The 10YFP was adopted by the worlds Heads of States meeting for the Rio+20 Conference in June 2012. The 10YFP is managed by the UNEP and includes six programmes:

- Sustainable Public Procurement
- Consumer Information for SCP
- Sustainable Tourism
- Sustainable Lifestyles and Education
- Sustainable Buildings and Construction
- Sustainable Food Systems

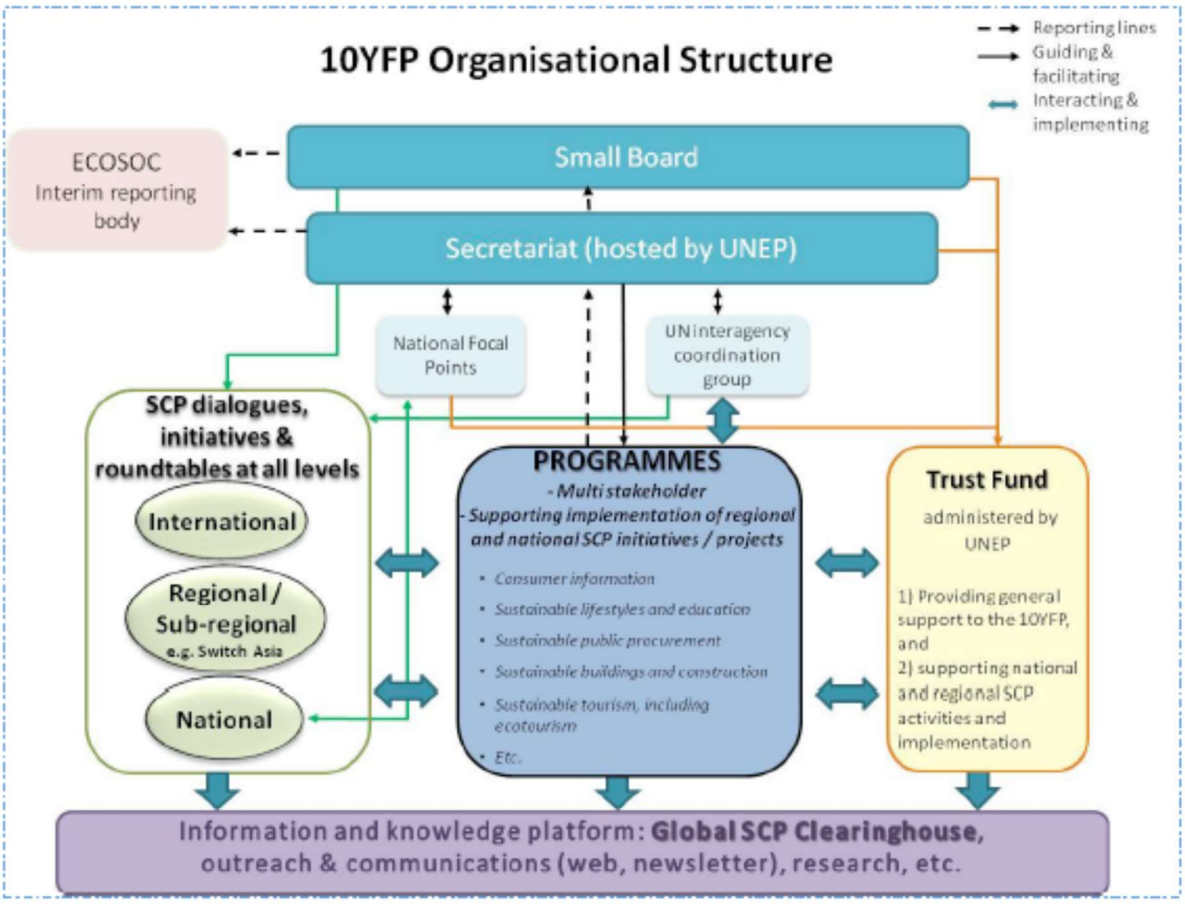

Figure 61: 10YFP Organizational Structure
Source: UNEP

The 10YFP has created the One World Network for enhancing global cooperation towards sustainable consumption and production. The Sustainable Buildings and Construction (SBC)[68] applies a life cycle approach to all stages of the buildings industry, including: development, planning, design, investment, construction, operation, management, promotion and marketing.

The SBC has four program areas:

- Establish, promote, and enable conditions for sustainable building and construction policies
- Support and promote sustainable housing
- Enhance sustainability in the building supply chain
- Reduce climate impact and strengthen climate resilience of the building and construction sector

3.2. Policy Responses of APEC

The APEC vision or mission statement defines APEC by the following words[69]:

> "APEC is the premier Asia-Pacific economic forum. Our primary goal is to support sustainable economic growth and prosperity in the Asia-Pacific region.
>
> We are united in our drive to build a dynamic and harmonious Asia-Pacific community by championing free and open trade and investment, promoting and accelerating regional economic integration, encouraging economic and technical cooperation, enhancing human security, and facilitating a favourable and sustainable business environment. Our initiatives turn policy goals into concrete results and agreements into tangible benefits".

Box 3: APEC vision or mission statement
Source: APEC

In its mode of working, APEC defines Objectives (e.g. Sustainable Development, Equitable Growth, Strengthening Asia-Pacific Community), Initiatives (e.g. the Energy Sustainable Communities Initiative ESCI), and Pillars (e.g. the three pillars Trade and Investment Liberalization, Business Facilitation, and Economic and Technical Cooperation, ECOTECH).

Sustainable development was mentioned among the objectives in the growth strategy enacted in 2010 as a reaction to the 2008 financial crisis.

Figure 62: APEC Objectives, Examples of Initiatives, and APEC Pillars
Source: APEC[70]

Besides the APEC Economic Leaders, also the APEC Ministerial Meetings, the APEC Energy Ministers Meeting, and the Senior Officials Meeting Friends of the Chair (SOM FotC) are subsidiary bodies of APEC that have some role in policy-setting. Annex 1 (at the end of

this report) states important declarations by APEC Economic Leaders and APEC Ministers Meetings since 2014.

3.2.1. APEC Disaster Risk Reduction DRR Framework

Few months after the UN adopted the Sendai Framework for Disaster Risk Reduction 2015 – 2030 (see above), APEC Leaders adopted the APEC Disaster Risk Reduction (DRR) Framework[71], thereby transposing the Sendai Framework to the APEC context. The short time span before transposition to APEC points to high emergency of this task. The Leaders noted in their declaration that the region had the most active tropical cyclone formation of the world in terms of frequency per year and that the phenomenon was exacerbated by climate change and phenomena like El Niño and La Niña. The "new normal" was increasing frequency, magnitude and scope, impacting on a higher interlinked value-chain. As per World Bank estimate, the region has incurred losses of over 100 billion USD per year during the last 10 years. In 2016, the APEC Emergency Preparedness Working Group (EPWG) discussed a disaster risk reduction action plan.

In substance, the APEC DRR Framework has four pillars:

- Prevention and mitigation: identification of vulnerabilities and taking proactive measures to avoid disasters
- Preparedness: multi-sectoral measures to anticipate (early warning), cope with, and recover from disasters
- Response: identification and assessment of impacts immediately after a disaster, such as procurement of relief goods and services, cleaning of bottle-necks in supply chain
- Rehabilitation and build back better: fast tracking rehabilitation

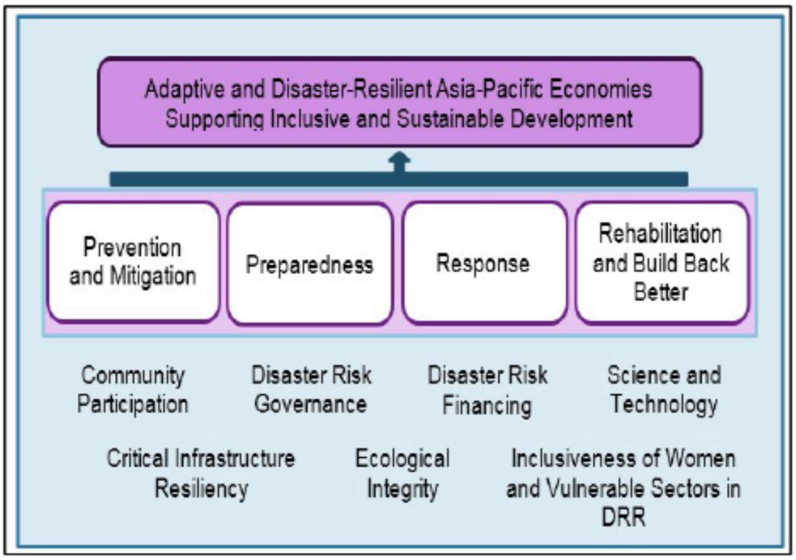

Figure 63: Four pillars of APEC DRR Framework
Source: APEC

The APEC DRR Framework specifically calls for critical infrastructure resiliency and mentions water, energy, transportation, road networks, communication, public health, and financial services as such critical infrastructures.

As the Sendai DRR Framework specifies five quantitative targets, the APEC DRR Framework needs not specify any other targets.

3.2.2. APEC Guidebook for the Development of Sustainable Cities

On 13 May 2017, the second Senior Officials Meeting (SOM) Friends of the Chair on Urbanization held a seminar in Ha Noi, Viet Nam, on urbanization in the APEC region on the theme "Workshop on developing the methodology for measuring and realizing the sustainability of cities in the APEC region".

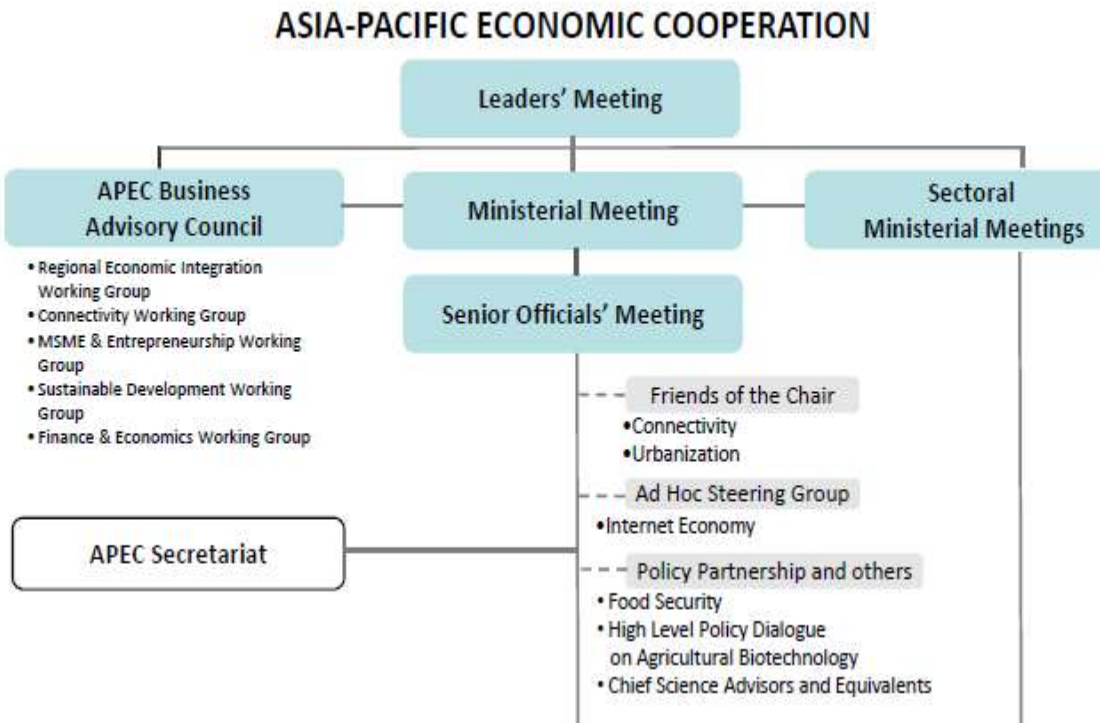

Figure 64: APEC Organization Chart（upper part）
Source: APEC[72]

As a follow-up of the above-mentioned seminar, the SOM Friends of the Chair on Urbanization released the *APEC Guidebook for the Development of Sustainable Cities Focusing on Resource Circulation and Waste Management* in 2018.

The *APEC Guidebook for the Development of Sustainable Cities Focusing on Resource Circulation and Waste Management*[73] identifies seven key sectors for realizing sustainable cities, five of which (except air and soil) are taken from ISO Standard 37151 (see Chapter 4):

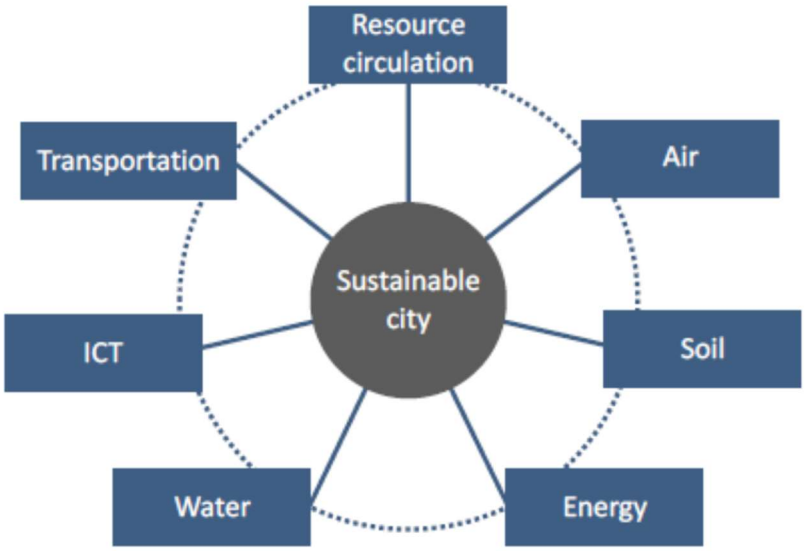

Figure 65: Seven key sectors for realizing sustainable cities
Source: *APEC Guidebook for the Development of Sustainable Cities Focusing on Resource Circulation and Waste Management*

The essential lesson of the Guidebook is to separate waste into five categories:

- Construction waste
- Motor vehicles
- E-waste
- Hazardous waste
- Municipal waste

General principles advocated by the Guidebook are:

- Limit the production of waste
- Sort a maximum waste at the source or at central sorting stations
- Aspire at high collection rate and efficient transport of waste
- Recycle what can be recycled
- Treat hazardous waste separately
- Search for an appropriate waste treatment

The Guidebook considers landfill of non-recyclable waste as a preferred solution due to its low cost. However, while the quantity of waste increasing proportionally to the GDP and the volume of waste to be stored increases rapidly, the long-term storage of waste in landfill becomes impossible. Rain infiltration of landfills causes severe water pollution by so-called leachates (highly odorous black or brown liquid that commonly contains heavy metals, such a lead, and volatile organic compounds or VOCs). Some regions of the world (e.g. the European Union) consider banning landfills altogether after 2025. Solutions must be found that are as cheap as landfill but environmentally friendlier. In the APEC region, some good examples can be found replacing landfill by waste combustion with associated energy production. The example of Guangzhou (see further below) shows that waste incineration of non-recyclable combustible waste, combined with highest standard smoke filtering, could be preferred to landfills.

3.2.3. APEC Energy Working Group EWG

APEC Energy Working Group EWG was established in the same year as APEC in 1990[74].

Within APEC organization structure, it is subordinate to the Sectoral Ministerial Meetings and to the SOM Steering Committee on ECOTECH (SCE), which comprises 15 Working Groups and Task Forces, among them the Energy Working Group.

In the year 2000, the EWG launched the Energy Security Initiative ESI with the objective to prepare the region for potential energy supply disruptions and subsequent impacts on economic activities. ESI covers a broad variety of subjects, such as the Monthly Oil Data Initiative, Maritime security, Real-time emergency information sharing, Oil supply emergency response, Energy investment, Natural gas trade, Nuclear power, Energy efficiency, Renewable energy, Hydrogen, methane hydrates and clean fossil energy.

The EWG Strategic Plan 2014 – 2018 has the following mission statement for the years 2014 – 2018[75]; this will remain unchanged for the period 2019 – 2023:

"Our mission is to build the capacity of APEC members to strengthen domestic and regional energy security and lower the carbon intensity of energy supply and use across the region, facilitated by information and data exchanges, joint research and development, and open trade and investment".

The major goals of the Energy Working Group EWG are[76]:

- Reducing energy intensity: In 2007, APEC Leaders agreed to a regional aspirational goal of reducing energy intensity by at least 25 percent by 2030 (with a 2005 base year). However, given the ever-increasing energy demand across the APEC region, Leaders instructed the Energy Working Group to intensify their analysis for an enhanced energy intensity reduction goal. Following EWG review of this goal, and building upon ongoing energy efficiency and conservation work, APEC Leaders agreed in 2011 to substantially increase the goal to a 45 percent reduction of regional aggregate energy intensity by 2035.

- Doubling renewable energy: At the 2014 APEC Leaders' Meeting, Leaders endorsed a new aspirational goal to double the share of renewable energy in APEC's overall energy mix by 2030 (over 2010 levels) and increase cooperation to achieve it. This goal builds upon ongoing efforts within the Energy Working Group to promote capacity building, best practices, and accelerated development and deployment of renewable energy resources and technologies. The EWG also continues to undertake work on the integration of renewables into the grid and grid-related energy storage.

- Rationalizing and phasing our inefficient fossil fuel subsidies: Annually since 2009, APEC Leaders have committed to rationalize and phase out inefficient fossil-fuel subsidies that encourage wasteful consumption and constrain sustainable economic growth while still providing essential energy services to those in need. They have recognized that inefficient subsidies come at a high cost to governments, and often fail to provide adequate assistance to the poorer vulnerable populations they are intended

to help. In 2011, the Leaders agreed to establish a voluntary reporting mechanism on progress toward this end. APEC's Energy Working Group is working to implement the Leaders' commitment through capacity building and supporting voluntary peer reviews. In 2013, the EWG developed a methodology and adopted Guidelines for conducting voluntary peer reviews of inefficient fossil fuel subsidies.

- Low carbon development: At the 9th APEC Energy Ministers Meeting in June 2010 in Fukui, Japan, Energy Ministers noted the importance of energy efficiency and cleaner energy supplies as a means to address energy security, economic growth, and lower carbon emissions. Recognizing the need to improve low carbon policies and increase technical capacities for sustainable development, the Ministers launched the Low Carbon Model Towns (LCMT) Project and instructed the EWG to assemble a specific LCMT Task Force (LCMT-TF). The Task Force was instructed to develop the concept of the LCMT, conduct feasibility studies for low-carbon communities in urban development plans, and share best practices for making low-carbon communities a reality. LCMT efforts are a vital cross-cutting component of the Energy Smart Communities Initiative (ESCI), combining elements of smart transport, buildings, power grids and jobs. At Fukui, the Ministers also encouraged economies to set individual goals and action plans for introducing low-emission power sources.

- Enhancing energy security: As mentioned above, enhancing domestic and regional energy security is a key component of APEC's energy agenda, and contributes to the region's broader economic, social, and environmental goals. Toward this goal, the EWG established the Energy Security Initiative (ESI), endorsed by APEC Leaders in October 2001, which comprises a series of measures to respond to temporary energy supply disruptions and longer-term challenges facing the region's energy supply.

As for the extent to which each goal is being attained, the status is as follows:

- Reducing energy intensity: EWG claims to be on target for achieving its energy intensity goal[77]. EWG has implemented a number of energy efficiency and conservation projects through ESCI under its pillars of smart buildings, smart transport, smart power grids, and smart jobs and education, together with cross-cutting activities on Low Carbon Model Towns and the APEC Knowledge Sharing Platform. EWG has not yet published an easily accessible progress report demonstrating at what speed the energy intensity goal is being attained. This goal could be implemented at city-level.
- Doubling renewable energy: EWG makes substantive efforts to attain the goal of doubling the share of renewables in APEC's energy mix. EWG is undertaking new projects to explore the roadmap to achieve this goal, while seeking stronger partnerships with international organizations to share lessons learned and best practices and to undertake modelling and demonstrations. As with the energy intensity goal, EWG has not published an easily accessible progress report demonstrating the speed at which the renewables goal is being attained. This goal could be implemented at city-level.
- Rationalizing and phasing our inefficient fossil fuel subsidies: EWG developed a methodology and adopted guidelines for undertaking voluntary peer reviews of inefficient fossil fuel subsidies. APEC Leaders did not set any deadline for this goal.

EWG has not published an easily accessible progress report demonstrating overall progress made on this goal.

- EWG conducts Peer Reviews on Low Carbon Energy Policies (PRLCE) to help promote the development of low carbon energy supply. Together, these and related efforts help provide the best low carbon policies, practices and tools among APEC economies to promote the development of sustainable communities and contribute to the reduction of energy intensity across the region. APEC Leaders did not set a specific low carbon goal for the region. EWG has not published any easily accessible progress report on this goal. This goal could be implemented at city-level.
- The EWG is working to enhance energy security in a number of ways to help economies overcome short-term energy supply disruptions and secure access to reliable, affordable and cleaner energy supply. Efforts include developing emergency response mechanisms and improving timely and reliable data to minimize supply disruptions; phasing out inefficient fossil fuel subsidies that promote wasteful consumption while providing essential energy services; understanding the energy-water nexus and addressing associated challenges; enhancing the security of energy supply networks; promoting energy efficient and sustainable communities; supporting cleaner energy development; and facilitating energy-related trade and investment to sustain economic growth. Capacity building and sharing best practices in these and other areas will help enhance energy security across the APEC region. APEC Leaders did not define any indicator for measuring this goal. EWG has not published any easily accessible progress report on this goal. This goal could be implemented at city-level.

The EWG[78] is composed of policy officials and technical experts from APEC Member Economies who work with experts in other APEC fora, academia, private industry, and regional and international organizations to build the capacity of APEC Member Economies aimed at:

- Strengthening regional and domestic energy security and resilience across the region;
- Lowering the carbon intensity of energy supply and use;
- Promoting the diversification of fuels and sources; and
- Training a gender-inclusive energy workforce.

The EWG is headed by a Lead Shepard from one of the member economies, and an EWG Secretariat which works closely with the APEC Secretariat.

The EWG's Work incorporates guidance from APEC Economic Leaders, Ministers and Energy Ministers and SOM Friends of the Chair to form a solid foundation for APEC energy cooperation.

The EWG cooperates with three organizations and one government external to APEC. Pursuant to the applicable APEC rules and regulations on cooperation with external organizations, these organizations have received guest status at APEC[79]:

- International Energy Agency (IEA)
- World Energy Council (WEC)
- International Copper Association (ICA)
- Mongolia

EWG has granted observer status to the following organizations[80]:

- APEC Business Advisory Council (ABAC)
- ASEAN Secretariat
- Pacific Islands Forum PIF Secretariat
- Pacific Economic Cooperation Council PECC

The Energy Working Group has in total four expert groups and two task forces:

- The Clean Fossil Energy (EGCFE) leads the EWG's work on clean fossil energy, supporting EWG's overall efforts to promote economic growth, energy security and resilience, and environmental sustainability in the APEC region.
- The Energy Data and Analysis (EGEDA) is responsible for providing policy relevant energy information to APEC bodies and the wider community through collecting energy data of the APEC region, managing the operation of the APEC energy database through its coordinating agency, the Energy Statistics and Training Office (ESTO) of the Asia Pacific Energy Research Centre (APERC).
- The Energy Efficiency and Conservation (EGEEC) promotes energy conservation and the application of energy-efficiency practices and technologies through advancing the application of demonstrated energy-efficiency practices and technologies, developing and enhancing trade between APEC Economies in products and services and energy-efficiency practices and technologies, contributing to international efforts to reduce the adverse impacts of energy production and consumption, and improving the analytical, technical, operational and policy capacity for energy efficiency and conservation within APEC Economies.
- The New and Renewable Energy Technologies (EGNRET) has the mission to facilitate an increase in the use of new and renewable energy technologies in the APEC region. The work of EGNRET contains as pillars the APEC 21st Century Renewable Energy Development Initiative, the Energy Smart Communities Initiative (ESCI), the APEC Smart Grid Initiative (ASGI), and the aspirational objective of doubling the share of renewables in the APEC energy mix by 2030.
- The Low Carbon Model Town Task Force (LCMT-TF) is in charge of implementing the APEC Low-Carbon Model Town (LCMT). The LCMT is a multiyear project composed of a series of Low Carbon Model Towns that have the common aim to combine energy-efficient buildings, transport and power systems to create communities that affordably reduce energy use and carbon emissions while creating pleasant living conditions. The towns are currently implementing their low carbon development plans to create green towns in the Asia-Pacific region. In addition, the project is developing low carbon indicators to measure the progress of these green towns The LCMT project is a part of APEC's Energy Smart Communities Initiative (ESCI), and the LCMT Task Force organizes activities under this multiyear project.
- The Energy Resiliency Task Force (ER-TF) has as objectives to implement the Energy Ministers' instructions to promote energy resiliency in the APEC region anchored on the four strategic priority sub-themes identified in the Cebu Declaration, the outcome document of the EMM 12, to wit: 1) Climate-proofing energy infrastructures; 2)

Providing an avenue for cutting-edge energy efficient technologies; 3) Advocating community-based clean energy use in energy poverty-stricken areas; and, 4) Improving energy-related trade and investment in APEC.

Energy Working Group has two research centres[81], the Asia Pacific Energy Research Centre (APERC) and the APEC Sustainable Energy Center (APSEC).

3.2.4. Asia-Pacific Energy Research Centre APERC

The Asia Pacific Energy Research Centre (APERC) was established in July 1996 in Tokyo following the directive of APEC Economic Leaders in the Osaka Action Agenda. The primary objective of APERC is to conduct research to foster understanding among APEC members of regional energy outlook, market developments and policy.

APERC's activities[82] are directed at helping APEC members to address these challenges. The activities include work on the following topics:

(1) Research and analysis, guided by the fourteen principles agreed at the first meeting of Energy Ministers in Australia in 1996. This research includes the Energy Demand and Supply Outlook, released every two to three years, the APEC Energy Overview, released every year, and Energy Policy Reviews compiled on important policy issues.

(2) APEC Cooperative Activities, such as the Peer Review on Energy Efficiency, elaborated in relation to the goal set by APEC Leaders to reduce energy intensity by at least 45% by 2015 as compared to 2005, the Compendium of Energy Efficiency Policies compiled annually, the Cooperative Energy Efficiency Design for Sustainability, made sector by sector for several APEC economies, the Peer Review on Low Carbon Energy Policies, the Low Carbon Model Town project, and the APEC Oil and Gas Security Exercises.

(3) Know-How Transfer Program, consisting of Seminars on Energy Supply and Demand Outlook, and dispatching of IEEJ experts to specific APEC economies to present short courses.

(4) the Energy Data Network Service, i.e. compiling energy statistics for APEC economies.

3.2.5. APEC Sustainable Energy Center APSEC

APEC Sustainable Energy Center (APSEC) was established at the 11th APEC Energy Ministerial Meeting (EMM) in Beijing in 2014. The National Energy Administration (NEA) assigned Tianjin University as responsible for the daily operation and administrative management of APSEC.

The vision of APSEC is to become an internationally renowned think-tank in the field of energy with widespread and far-reaching influence on the sustainable development of Asia Pacific and the globe.

The APSEC mission is twofold:

1) To promote pragmatic cooperation on sustainable energy development among APEC economies;

2) To act as think tank of the National Energy Administration in conducting strategic research and international cooperation in the field of sustainable energy development.

APSEC aims to promote advanced ideas and models of sustainable energy development across the APEC region, and facilitate cooperation among member economies through information exchange, policy dialogue, technology R&D, demonstration and dissemination, and capacity-building in the field of sustainable energy.

APSEC conducts research on low carbon transition path and sustainable development and promotes implementation of two pillar projects: The Cooperative Networks of Sustainable Cities (CNSC) and the Clean Coal Technology Transfer (CCT).

APEC Sustainable Energy Center (APSEC) organizes two annual flagship events, one is on sustainable cities, and the other one is the Asia Pacific Sustainable Energy Development Forum. APSEC regularly provides technical training and output underlining Chinese action in favour of Developing Economies and establishes long-term strategic cooperation with 20 well-known institutions in APEC.

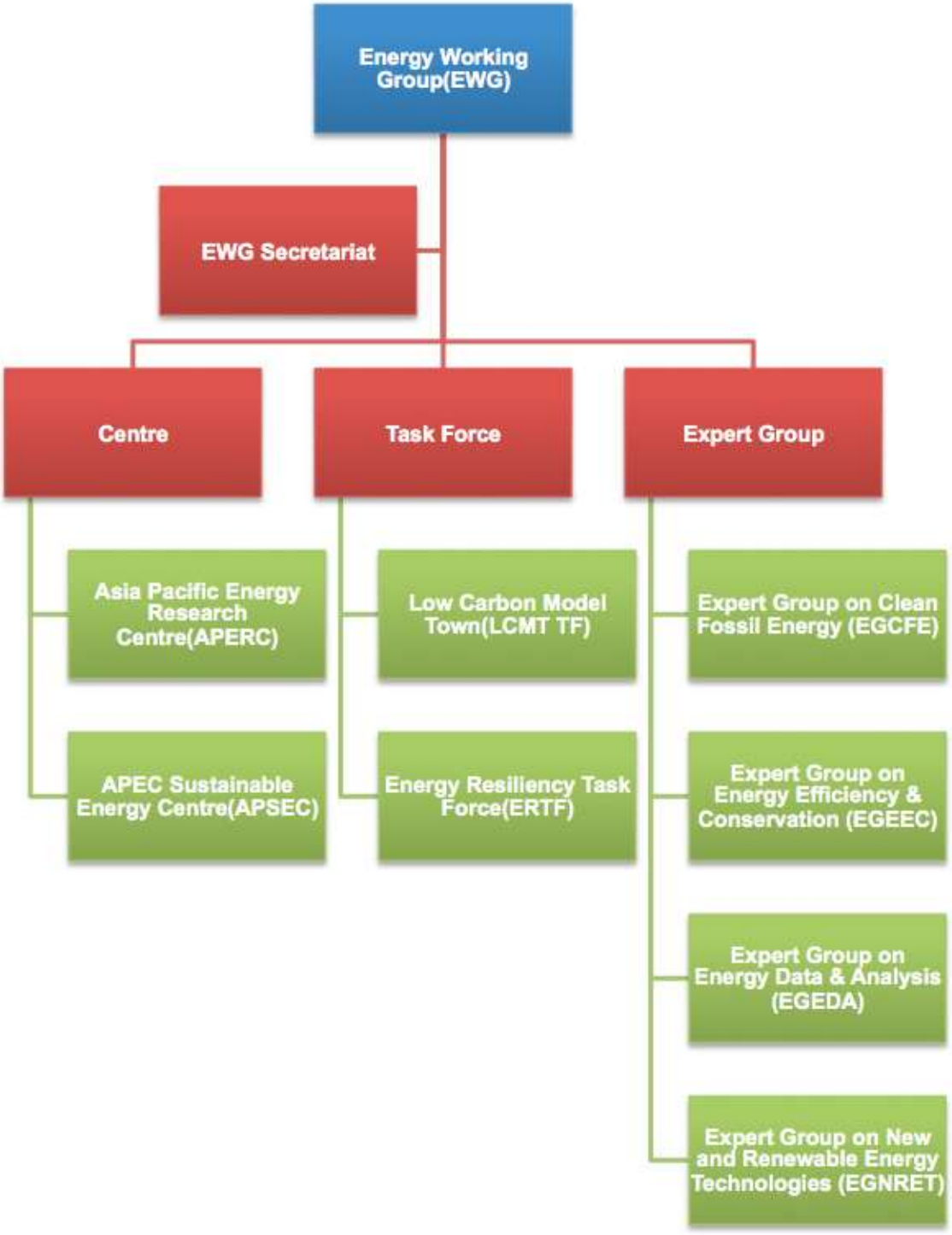

Figure 66: EWG Structure
Source: APEC[83]

The EWG's work program is delivered through EWG Projects and Activities, some of which are described below. Besides these core activities, the Energy Working Group (EWG) is also engaged in a certain number of cross-cutting activities, see Annex 2 at the end of this report.

3.2.6. APEC Energy Smart Communities Initiative (ESCI)

The Energy Smart Communities Initiative (ESCI) was presented at the APEC Economic Leaders' Summit in November 2010 by President Barack Obama and then Japanese Prime Minister Naoto Kan. The 41st meeting of the APEC Energy Working Group in May 2011 added a platform (http://esci-ksp.org/) for information sharing (Knowledge Sharing Platform, KSP) for collecting best practices developed under ESCI. So far, the ESCI-KSP platform has been used for more than 500 types of projects. The Knowledge Sharing Platform KSP is run by the University of Pennsylvania Institute for Urban Research and the Taiwan Institute for Economic Research and is being supported by the National Development Council.

The ESCI has the following goals:

- To demonstrate the practicality of clean energy technologies related to the APEC goal to reduce energy intensity by 45% of 2005 by 2030, and renewable energy doubling goal.

- To provide case studies, policy briefs, research findings, and data on smart transport, smart buildings, smart grid, smart jobs and consumers, and low carbon model towns.

- To serve as a communications resource for the APEC Energy Working Group (EWG) and associated partners. Inform APEC decision-makers about green growth, sustainable development and long-term job creation.

The initiative is subdivided into pillars facilitating the research of projects:

- Smart Transport (ST)
  ST-1: Energy Efficient Urban Transport Network
  ST-2: Energy Efficient Freight Transport Network
  ST-3: Electromobility Survey and Roadmap
  ST-4: Electric Vehicle Demonstrations

- Smart Buildings (SB)
  SB-1: Low Energy Buildings Network
  SB-2: Materials Testing and Ratings Center
  SB-3: Cool Roof Demonstrations
  SB-4: Low Energy Windows Demonstrations

- Smart Grids (SG)
  SG-1: Smart Grid Survey and Roadmap
  SG-2: Smart Grid Test Bed Network

- Smart Jobs & Consumers (SJ)
  SJ-1: Energy Efficiency Training
  SJ-2: Energy Efficiency School Curricula
  SJ-3: Sister Schools Programs

- Industry Zone (In)
  In-1: Industry Overview
  In-2: Enterprise Portfolio
  In-3: New Technology Application

- Low Carbon Model Towns (LCMT)

Besides collecting information on projects, the ESCI-KSP platform (http://esci-ksp.org/) is also used for submitting projects for selection to one of the ESCI Best Practice Awards. In 2013, the 45th meeting of the APEC Energy Working Group added the ESCI Best Practice Award which is given every two years. APEC Energy Working Group selects 10 award-winning projects every two years. So far, the award has been distributed three times (2013, 2015, 2017), with 26 projects from 8 economies receiving the award.

3.2.7. APEC Cooperative Network of Sustainable Cites (CNSC)

The APEC Cooperative Network of Sustainable Cities (CNSC) has been established in response to the 2014 APEC Summit's Beijing Declaration, stating "We support the APEC Urbanization Partnership Initiative, and pledge to establish an APEC sustainable urban cooperation Network", adopted by the APEC Economic Leaders Meeting in 2014. APEC Sustainable Energy Center was designated as the official implementing agency of the Leaders' initiative in the 2015 APEC meeting document.

CNSC aims to seek new drivers for economic growth through urbanization and sustainable urban development, to promote cooperation and exchange of experience in urbanization and sustainable urban development through holding forums and policy dialogues to play the role of the International Friendship City project. It makes full use of existing resources, promotes urbanization research and capacity-building, emphasizes the importance of the eco-city and Intelligent City cooperation project, and explores ways to realize green urbanization and sustainable urban development.

CNSC includes two networks and an annual workshop[84] (http://esci-ksp.org/cnfsc/cnsc/):

- APEC Cooperative Network for Low-carbon and Energy-efficient Cities
- APEC Sustainable Cities Service Network
- APEC Sustainable Cities Workshop, which is held in the first half of each year in conjunction with the APEC Energy Working Group meeting.

The first batch of seven cities has been chosen to become members of the Cooperative Network for Low-carbon and Energy-efficient Cities in 2016:

Australian Capital Territory ACT
Adelaide, Australia
Bitung, Indonesia
Tianjin, China
Turpan, China
Zhenjiang, China
Kunming, China

Simultaneously, ten entities have been selected to become the first members of the Sustainable Cities Service Network.

CNSC's main job is to expand the links between members of the network and APEC through the network, to strengthen the exchanges and cooperation between APEC members and other economies, and to assist members to participate in APEC projects and activities to establish a city image and enhance international visibility. The establishment of an information platform allows members to share APEC information, thus gaining greater autonomy in international cooperation.

Up to now, three annual CNSC workshops have been held. Within China, the CNSC, in cooperation with the National Energy Administration (NEA), also promotes pilot projects for sustainable urbanization. NEA selects projects submitted economywide, then recommends projects to APEC for international bidding on attracting advanced urban development technology, concept, mode and solutions.

During the APEC Economic Leaders' Meetings in 2010 and 2011, Chinese Leaders actively supported the low carbon model town (LCMT) initiative (see next section). At the 20th APEC Economic Leaders' Meetings in 2012, the Chinese National Energy Administration presented the *APEC Low-Carbon Model Town (LCMT) Project China Development Report*. During China's Host Year in 2014, the 22nd APEC Economic Leaders' Meetings was successfully held in Beijing. At that occasion, Yujiapu in Tianjin, China, was chosen to be the first APEC Low Carbon Model Town. In order to promote low carbon model town development in China and sustainable urban development in the APEC region, the NEA implemented the plan of "Low Carbon Model Town Promotion Activities" and selected and reviewed the first batch of 26 Low carbon Town projects in China in August 2014. The first fifteen of these projects are presented below[85].

Project Name	Location	Declaration Time	Recommender
Nucleus Island of Beijing Yanqi Lake International Convention Center	Yangqi Lake, Huairou District, Beijing	2013.6	Beijing Municipal Commission of Development and Reform
Shenzhen International Low-Carbon City	Pingdi Avenue, Longgang District, Shenzhen	2013.7.5	Shenzhen Municipal Commission of Development and Reform
Dongxiang Cross – Strait Low-Carbon Ecological Demonstration Area, Jiangxi Province	Dongxiang Country, Jiangxi	2013.5.30	Jiangsu Municipal Commission of Development and Reform
Songhuajiang Farm	Songhuajiang Farm, Reclamation Area, Heilongjiang	2013.5.22	Heilongjiang Reclamation Administration
Guantang New Town, Zhenjiang City	Zhenjiang, Jiangsu		Jiangsu Energy Administration
Jingneng Gas-fired Cogeneration Project, Beijing City	Future Technology City Park, Changping District, Beijing	2013.6.12	Beijing Municipal Commission of Development Reform
Mentougou New Town, Beijing City	Mentougou District, Beijing	2013.6	Beijing Municipal Commission of Development Reform
Mayang Low-Carbon Ecological Town, Changtai, Fujian	Changtai Country Fujian		China Development Bank
Tongzhou Bay New Town, low carbon demonstration city, Nantong City, Jiangsu Province	Nantong Binhai Park, Nanton, Jiangsu	2013.7	Jiangsu Energy Administration
“Yuansheng. Jin Luo Bay” Project Zhengzhou, Henan	Intersection of Hanghai Road and Zijinshan Road, Zhengzhou, Henan		Henan Municipal Commission of Development and Reform
Qingdao Sino-German Ecological Park	West beach, Jiaozhou Bay, Qingdao, Shandong		China Development Bank
Shagangwang APEC Low-Carbon Model Town	Zhongmou Country, Zhengzhou, Henan	2013.7.19	Henan Municipal Commission of Development and Reform
Low-Carbon Town in Shanshan Village, Dongshan Town, Wuzhong District, Suzhou City Province	Shanshan Village, Dongshan Town, Wuzhong District, Suzhou city, Jiangsu	2013.7.1	Jiangsu Municipal Commission of Development and Reform
Qinghai Zhongguancun High-Technology Industry Base	Pingann Contry , Haidong City Qinghai	2013.11.22	Qinghai Municipal Commission of Development and Reform
Tianjin Yujiapu Economic Area	Tianjin Binhai New Area		Tianjin

Figure 67: The first fifteen sustainable urbanization projects promoted by CNSC
Source: Project Database of APEC Low-Carbon Towns

3.2.8. Low Carbon Model Towns (LCMT)

The APEC 9th energy ministers' meeting in 2010 agreed that cooperation would be needed to promote sustainable energy development in APEC and to support economic growth and development in member economies. It was decided to launch the APEC Low-Carbon Model Town Project (LCMT) to control the growing energy consumption and greenhouse gas emissions in different urban areas of the APEC region, to introduce low-carbon technologies in urban planning, to improve energy efficiency and reduce fossil energy use, and to demonstrate best practices and successful models for advanced low-carbon technologies. The project is one of the priority initiatives under the APEC Energy Cooperation framework. Its main objectives are:

(1) Developing a Low-Carbon Town Concept to provide guidance for the principles and implementation of Low-carbon town design;

(2) To assist in the implementation of concepts in selected Low-Carbon Model Towns through the provision of feasibility studies and policy reviews of these urban development projects.

(3) Share best practices and practical experience in low-carbon urban design with planners and decision makers in the APEC region.

In the APEC Energy Working Group, Japan led the establishment of a Low-carbon demonstration town Task Force and funded its Asia-Pacific Energy Research Centre (APERC) to engage in related work. APERC analysed the concept, guideline, index system and policy of the seven Low-carbon demonstration towns selected by the project phase I. At present, the Low-carbon Model Town (phase two) project has been launched, mainly to promote Low-carbon Model towns. To the present date, seven APEC towns have been involved in an LCMT project as case studies (see also Annex 3 at the end of this report for more details).

Yujiapu/Tianjin
China

Koh Samui
Thailand

Da Nang Viet
Nam

San Borja,
Lima Peru

Bitung, North
Sulawesi Indonesia

Mandaue, Cebu
Philippines

Krasnoyarsk Russia

3.3. Policy Responses of Selected APEC Economies

3.3.1. China

China takes the implementation of all SDGs, including the INDC pledges of the Paris Agreement, very seriously. China has translated the Sustainable Development Goals into a comprehensive *National Plan on Implementation of the 2030 Agenda for Sustainable Development* that was published in September 2016[86]. Implementation progress is further reviewed in the *Progress Report on the Implementation of the 2030 Agenda for Sustainable Development* released in August 2017 by the Ministry of Foreign Affairs[87].

Based upon the analysis of China's achievements of the Millennium Development Goals and the challenges ahead, the plan lays out the guiding thoughts, general principles and approaches as well as specific plans for the implementation of the 17 Sustainable Development Goals (SDG) and their 169 targets.

The implementation of the 2030 Agenda for Sustainable Development by China is in line with the historically significant strategy of reform and opening-up decided by the leadership of the Chinese Communist Party in December 1978. In the period 2000 to 2015 Chinese GDP has increased almost sevenfold, making China the second-largest economy of the world since 2010.

During that period, agricultural output grew steadily, enhancing agricultural productivity and, therefore, a substantial diminution of poverty by over 90%, from 689 million in 1990 to 57 million in 2015.

Under the leadership of the government and with the participation of social sectors, China has gradually developed a comprehensive social security and assistance system. By 2015, more than 500 million urban and rural residents had been covered by basic pension insurance.

Compared with 2005, China's carbon dioxide emission per GDP unit decreased by 33.8% by 2014. Per GDP unit consumption of major resource products like oil, coal and water had also been cut dramatically.

Forest coverage had expanded by 32.78 million hectares, and forest reserves had increased by 2.681 billion cubic meters from that of 2005, achieving "zero growth" in land desertification ahead of schedule.

The biggest challenges for China in the realization of the 2030 Agenda remain the following: how to eradicate poverty, improve people's livelihood, defuse social problems, achieve common prosperity, improve governance system and capability, and achieve coordinated development among different regions, at all levels and in all fields.

The effective implementation of the 2030 Agenda will pave the way for China to complete the building of a moderately prosperous society and achieve the "Two Centennial Goals" specified by Xi Jinping in 2012: First, China will build a "moderately prosperous society" by doubling its 2010 per capita GDP to $10,000 by 2021, when it celebrates the 100th anniversary of the Chinese Communist Party. Second, it will become "fully developed, rich, and powerful" by the 100th anniversary of the People's Republic in 2049. Six guiding principles will govern this implementation:

Innovation-driven development: China will implement the innovation-driven strategy to promote innovations in theory, institution, science and technology and culture to improve the quality and efficiency of development.

Coordinated development: This could be achieved through regional cooperation, urban and rural integration, parallel development of material wealth and spiritual enrichment and integration of economic development with defence, and synchronized advances will be ensured in new industrialization, IT application, urbanization and agricultural modernization, so as to form a balanced and holistic development structure.

Green development: China will adhere to the basic policy of resource conservation and environmental protection, follow a civilized development path that ensures increased levels of production, better living standards, and a sound ecology. China will pursue green development by promoting a green and low-carbon development model and lifestyle, actively addressing the climate change and protecting the ecological system.

Open development: China will adopt an opening-up strategy featuring mutual benefit and win-win results, make great efforts to deepen opening-up, develop a new level of openness within our economy, and promote strategic mutual trust, economic and trade cooperation, and people-to-people exchange, thus realizing win-win cooperation.

Shared development: Sticking to the principle of development of the people, by the people and for the people, China will focus on equal opportunities, ensure basic needs for all, take targeted efforts to advance people's well-being and let the people have a greater sense of benefit as they contribute to and share in development. China will use seven approaches to implement the 2030 Sustainable Development Agenda:

(1) The use of synergy of strategies aims at integrating the 2030 Agenda into China's various mid-and-long term development strategies and creating synergy and complementarity between international agenda and domestic strategies. This means especially integrating the 17 SDGs and 169 targets into China's overall development planning and break down, incorporate, or link them in the specialized sectoral plans. It furthermore means bringing the development objectives of local governments in line with the 2030 Agenda. Based on the Outline of the 13th Five-Year Plan, the 31 provinces, autonomous regions and municipalities directly under the central government in China's mainland have formulated their own five-year plans, and the cities and counties have completed their road maps and annual plans. On the international level, it means pushing multilateral mechanisms to formulate an action plan for the 2030 Agenda to create synergy at international level. China played a leading role in urging the G20 to draw up an action plan on implementation of the 2030 Agenda, while advancing the "Belt and Road" Initiative in a way that will facilitate the implementation of the 2030 Agenda in countries along the two routes.

(2) Institutional guarantee refers to the institutions, mechanisms and policies that will support the implementation of the 2030 Agenda. This means promoting targeted reforms to establish an institutional framework for the implementation of the 2030 Agenda. China will not only enhance the horizontal cross-region and inter-agency coordination, but also establish a vertical implementation mechanism linking the central, local and grassroots levels. China's domestic inter-agency coordination mechanism comprised of 43 government departments has

been established for the implementation of the 2030 Agenda, and its local governments will set up corresponding working mechanisms to ensure smooth implementation.

(3) Social mobilization: The general public's understanding, recognition and participation is key to consistent and effective implementation of the 2030 Agenda. China will implement the 2030 Agenda by the people and for the people and enhance the sense of responsibility in participating in the implementation of the 2030 Agenda. China will make the 2030 Agenda more accessible to the general public and create a good environment for the implementation via newspapers, magazines, radio, TV and internet, as well as publicity campaigns of various forms, including knowledge quiz. China will engage non-governmental groups, the private sector and individuals, especially the youth, in training courses, networking and management activities related to the 2030 Agenda.

(4) Resource input: this aims at fully utilizing the domestic and international markets and resources and giving full play to the institutional and market advantages in the implementation efforts. China will focus on fiscal, taxation and financial reforms and rationally set aside and guarantee government funds for the implementation of the 2030 Agenda. China will innovate in cooperation models and promote cooperation between the government and the social capital and mobilize and guide social resources into sustainable development.

(5) Risk management: Despite being the world's second largest economy and with a modest level of GNI per capita, China is still facing daunting development tasks and its development is far from balanced between different regions and rural and urban areas. The implementation of the 2030 Agenda is a long-term, arduous task, requiring sound risk management mechanisms and capabilities. Targeted efforts are needed. For this purpose, China will maintain economic growth. China will continue its commitment to the general principle of making progress while working to keep performance stable.

(6) International cooperation: China will join the international community in deepening international development cooperation for effective implementation of the 2030 Agenda. China respects the right of other economies to choose their independent development path and advocates increased exchanges and mutual learning among governments, social organizations and stakeholders in the implementation efforts according to the Principle of "Common but Differentiated Responsibilities".

(7) Oversight and review is used to assess achievements, challenges and inadequacies in the process of implementation of the 2030 Agenda, in order to optimize policy options and summarize best practices. China will conduct reviews of its implementation efforts simultaneously with annual assessment of the progress in the 13th Five-Year Plan and corresponding work plans in specific sectors. The inter-agency mechanism has assigned the 169 targets of the 2030 Agenda to specific government agencies, ensuring full accountability for every review task.

The detailed implementation plan of the 17 goals and each of the 169 targets can be found in the *National Plan on Implementation of the 2030 Agenda for Sustainable Development*. The implementation progress has been reported in the *Progress Report on the Implementation of the 2030 Agenda for Sustainable Development* published by the Chinese Ministry of Foreign Affairs in August 2017. The following general conclusions can be taken from that report:

- The economy has registered sound and steady growth
- People's living conditions have been improved
- All-round progress has been made in green development
- Remarkable achievements have been made in deepening international development cooperation

The report analyses the Chinese achievements target by target. Specifically concerning the Sustainable Development Goal 11, "Make cities and human settlements inclusive, safe, resilient and sustainable", the report states:

- China has vigorously promoted government-subsidized housing projects and housing conditions for urban and rural residents have kept improving.
- China has implemented strategy to prioritize public transport development and the sustainable urban transport system has been further strengthened.
- China has put people first and the new-type urbanization has made gratifying progress.
- China has stepped up management of urban and rural waste as well as air pollution control, and adverse per capita environmental impact in cities has been further mitigated.
- China has employed multiple measures, and cities' sustainable development capability and disaster resilience have been further enhanced.
- China has strengthened the planning of scenic spots and protection of cultural heritage, making important contribution to world heritage protection.
- China has enhanced South-South cooperation to help other developing countries build disaster resilient buildings.

On SDG 11.b the *National Plan on Implementation of the 2030 Agenda for Sustainable Development* states:

11. b By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015 – 2030, holistic disaster risk management at all levels. Improve the housing system, vigorously advance revamping of rundown areas and dilapidated houses.	Raise the energy-saving standards for building and promote super low and zero energy consumption buildings. Improve the energy saving capacity for existing building and promote green construction materials and prefabrication. Strengthen natural disaster monitoring and early warning system, as well as disaster- residence capability of engineering projects. Improve the social mobilization for disaster prevention and reduction of build channel for social participation in disaster prevention and reduction. Promote the building of sponge cities and launch low-carbon pilot zones across provinces, cities, industrial parks, and communities, set up experimental zones climate change adaption in cities.

Figure 68: Implementation of SDG 11.b by China
Source: *National Plan on Implementation of the 2030 Agenda for Sustainable Development*

The *Progress Report on Implementation of the 2030 Agenda for Sustainable Development* mentions in the area of resilience:

China has employed multiple measures, and cities' sustainable development capability and disaster resilience have been further enhanced**.** Efforts have been made to promote landscaping, greening and ecological garden construction in urban and rural areas, and push for coordinated urban ecological restoration. Sponge city pilot programs have been launched in 30 cities to alleviate water-logging and improve ecological environment and human settlement in urban areas. Energy efficiency standards and seismic fortification for new construction projects have been improved and mandatory energy-efficiency standards thoroughly applied. The construction of ultra-low and zero energy consumption buildings and the technology of seismic mitigation and isolation has been promoted. The development of prefabrication building has been sped up through such measures as improving top-level design and enhancing standards and regulation. An inter-agency mechanism has been set up to evaluate and label green building materials. Pilot projects for climate resilient city development have been carried out with redoubled efforts on climate-resilient infrastructure. In 2016, the total floor area of energy-efficient building exceeded 15 billion square meters, including 480 million square meters of new green buildings and 114 million square meters of prefabricated building projects. By the end of 2016, the green space in urban built-up areas had amounted to 197,000 hectares, or 36.44% of the total area and the green area in parks reached 64,000 hectares, with a per capita area of 13.45 square meters.

On SDG 13.2 the mentioned *National Plan* states:

13.2 Integrate climate change measures into national policies, strategies and planning	Integrated the implementation of "intended nationally determined contributions" into national strategies and plans, formulate the Work Plan for Greenhouse Gas Emission Control during the 13th Five-Year period, and take climate mitigation actions as driving force for China to shift to a new pattern and advance environmental protection and ecological progress.

Figure 69: Implementation of SDG 13.2 by China
Source: *National Plan on Implementation of the 2030 Agenda for Sustainable Development*

Concerning emissions control policy, the mentioned Progress Report states:

China has strengthened top-level design and improved policies and institutions for low carbon development to put greenhouse gas emissions well under control**.** The "Work Plan for Greenhouse Gas Emissions Control during the 13th Five-Year Plan Period" has been formulated, setting forth eight key areas for controlling greenhouse gas emissions, including low-carbon-driven energy revolution, shaping the low-carbon industry system, promoting low-carbon urbanization, accelerating low-carbon regional development, development and operation of the market for the trading of carbon emission rights, innovations on low carbon technologies, strengthening basic capabilities, and carrying out extensive international cooperation.

3.3.2. Hong Kong, China

Hong Kong, China plays a pivotal role, as it is a member economy of APEC, as well as a city-member of C40 Cities Climate Leadership Group and of the Global Covenant of Mayors GCoM. Hong Kong, China has released a *Climate Action Plan 2030* in January 2017[88]. It has been elaborated under the impulse of the conclusion and rapid entry into force of the Paris Climate Agreement. It contains several dimensions: emissions reductions (absolute as well as of carbon intensity, reflecting the engagements taken by China in the Paris Climate Agreement), measures at supply and demand side on transport and consumption, adaptation measures in infrastructure, city planning, water flows and biodiversity conservation, and increasing resilience.

The CO_2 emissions are targeted as follows:

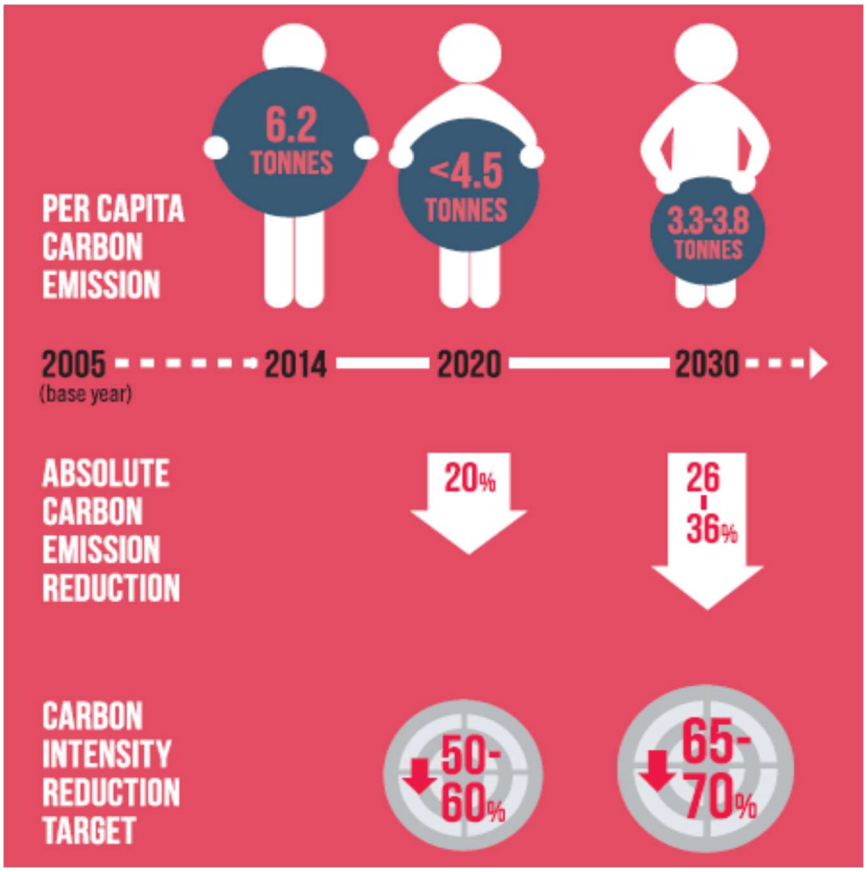

Figure 70: Emissions reductions planned by Hong Kong, China
Source: Hong Kong, China, official website

The Chinese engagement in the Paris Agreement applies to Hong Kong, China. China has agreed to:

- Peak carbon emissions in 2030, making best efforts to peak earlier
- Lower carbon intensity of GDP by 60% to 65% compared to 2005 levels
- Increase the share of non-fossil fuels in primary energy to 20% by 2030
- Increase forest stock volume by 4.5 billion cubic metres above the 2005 level.

China also pledged to proactively defend against climate risks in key areas such as agriculture, forestry, water resources, ecologically vulnerable areas, cities and coastal areas, to strengthen early warning and emergency response systems and disaster prevention and reduction mechanisms.

Hong Kong, China, plans to peak CO_2 emissions already by 2020.

Mitigation will be achieved through energy measures at supply side (substitute part of coal by gas fired electricity, increase renewable electricity) and demand side in the building sector which will contribute to diminish energy intensity by 40% compared to 2005. The savings have been compiled in a separate *Energy Saving Plan for Hong Kong's Built Environment 2015 – 2025*[89]. Hong Kong, China government attaches importance to include citizens in the planning process (4Ts: set Targets and Timeline Together in Transparency), in order to maximize multiple benefits of this strategy for all stakeholders. The measures include showcase of green buildings, new buildings should out-perform the building energy code, auditing and implementation of energy management opportunities, and green procurement.

Energy related measures are also planned in transportation by

- favouring rail transportation as back bone,
- controlling private car growth,
- promoting walking and cycling, and by
- increasing awareness with consumers at large.

Planned adaptation measures comprise measures in

- infrastructure (improved slope safety, increased drainage and flood management, improving the sponge city function, monitoring sea level rise and strengthening coastal protection),
- city planning
- water security (conservation measures by increased use of desalinated water, reclaimed water and recycled grey water, and harvested rainwater), and
- biodiversity conservation (implementing the Biodiversity Strategy and Action Plan (BSAP), enhancing country parks and special areas, promoting sustainable farming and fisheries, and enhancing biodiversity in urban environment).

Electricity is for the time being the largest CO_2 emitter. Special attention is given to mitigating climate change in electricity generation. The plan includes phasing out coal generation (48% in 2015) replacing it by natural gas (60% to 70% in 2030). Renewables shall fully use the presently available 3% - 4% of resources. Off-shore wind farms are planned.

Feed-in tariffs and renewable energy certificates are being explored. Storage options will be studied allowing the share of renewables to grow. Waste to energy options are being tested.

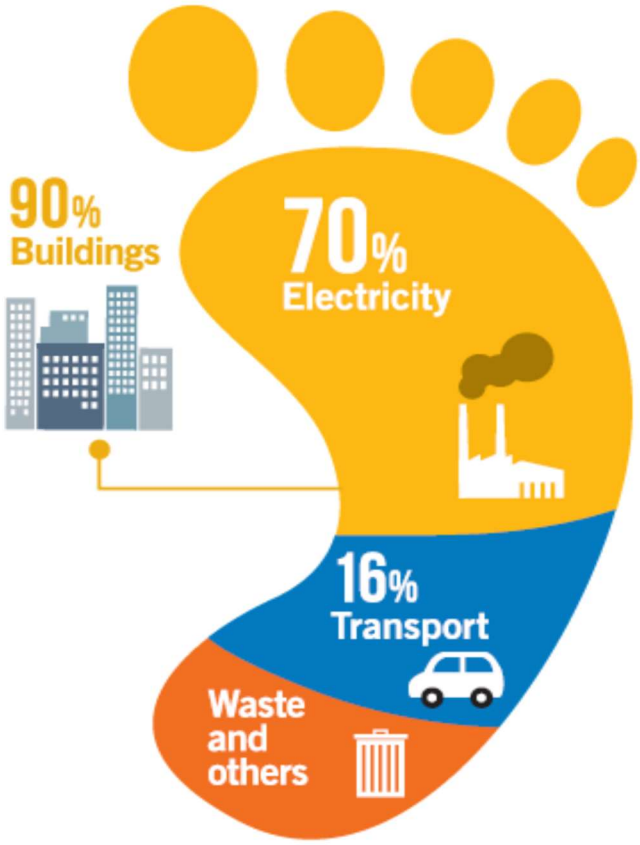

Figure 71: Electricity generation: largest source of emissions
Source: *Hong Kong's Climate Action Plan 2030*

Integrated PV is being considered in the following public infrastructures:

- Roofs and open areas of pumping stations and treatment works
- Reservoirs
- Rock slopes
- Noise barriers
- Roofs of covered footbridges and walkways
- Roofs of public piers
- Lights in parks, public housing

Larger PV options are floating PV or PV integrated in the rock face of an old road quarry. These options require addressing issues of public concern.

Imports of renewable energy from mainland can be an option. The neighbouring Guangdong Province is estimated to have 14 GW of exploitable on-shore and 11 GW of off-shore wind.

Energy efficiency in buildings is considered as an important option as Hong Kong, China buildings use 90% of the city's electricity and are responsible for 60% of overall carbon emissions. The Government studies ways to increase energy efficiency, among others by means of an energy efficiency market. Commercial buildings consume two-thirds of energy consumed by HK buildings.

Figure 72: Possible site for PV: Anderson Road Quarry
Source: *Hong Kong's Climate Action Plan 2030*

The construction industry consumes 40% of materials entering the global economy. The embodied carbon of construction materials represents a major part of the life cycle energy of a building. The Hong Kong Green Building Council HKGBC has created the G-PASS, a labelling and certification scheme to certify environmentally-friendly building materials, products and building services components.

As the increase of the building stock is relatively small, much attention is given to the existing buildings. To manage this, the 4Ts, the partnership between government and the building sector plays a crucial role. It will increase energy savings by means of energy audit, benchmarking, retro-commissioning, retrofitting, by promoting the Green Building Standard, and to encourage "beyond compliance".

Given the climatic conditions of Hong Kong, China, 30% of energy is used in air-conditioning. Most existing commercial buildings use traditional air-cooled air-conditioning. The use of water-cooled air-conditioning is 20% more energy-efficient, even though it requires some freshwater for cooling purposes. Higher energy savings can be achieved by district cooling. District cooling is 35% more efficient than conventional air-cooled air-conditioning. A first pilot project of a district cooling station (DCS) is being put in operation in Kat Tak Development. The government plans to build more district cooling stations in the future. District cooling can be operated with seawater.

A large role in increasing energy efficiency is given to market forces. The Mandatory Energy Efficiency Labelling Scheme (MEELS) relevant information to buyers of energy-consuming equipment. The government continues to tighten standards and to add more products to the scheme.

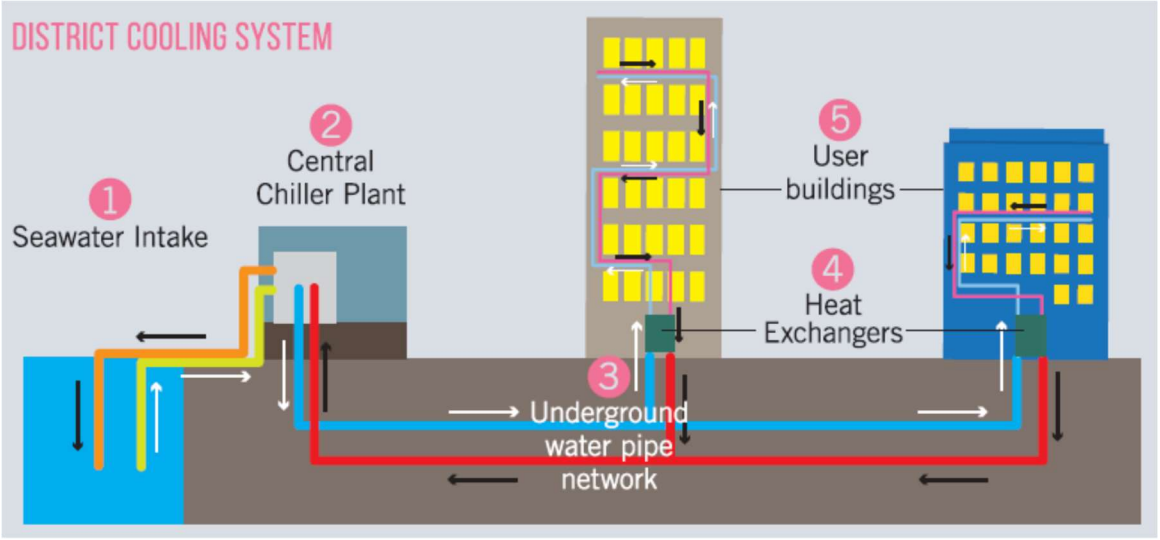

Figure 73: District Cooling System
Source: *Hong Kong's Climate Action Plan 2030*

Transport systems have energy savings potential. Transport systems make up 16% of Hong Kong, China's emissions. 90% of daily passenger trips are made by public transport. This proportion is among the highest in the world. Hong Kong, China's public transport system was ranked first among 84 cities in an international survey published in 2014. In order to do even better, the *Hong Kong 2030+: Towards a Planning Vision and Strategy Transcending 2030*[90] proposes to reshape travel patterns to reduce vehicle based commuting needs through spatial planning. More employment related uses would be planned in new development areas and outside of the main urban area to bring jobs closer to homes. The mentioned report concludes that land requirement until 2046 (4800 ha) will exceed land availability (3600 ha), hence new methods of land management must be found.

The further development of intermodal transport nodes allowing to combine different transport modes is planned. Attention is given to increase accessibility of all systems. Universal access has been started and will continue with 160 projects in the city. Hong Kong, China people walk more than in other cities, mostly for taking transport. Efforts are undertaken to make walking smart, connected, enjoyable, and safe. The system of urban escalators and covered walkways will be further extended. Urban escalators are a unique innovation of Hong Kong, China, and will be further developed.

As part of the transport strategy, cycling tracks will be further extended.

Controlling the extension of the car fleet is one of the objectives of Hong Kong, China's transport policy. In the period 1995 to 2014 the annual growth of the fleet has been at 3%, contrasting with only 0.78% population growth and 1.65% household growth during that period. Since 2014 the fleet growth has surged to 5% per year. This is clearly unsustainable. The government has planned the introduction of electronic road pricing (ERP).

As energy-saving measure, the government has started introducing electric and hybrid vehicles, taxis and buses and double-decked buses.

One of the available modes of transport is waterborne transport. The government expects that the fleet of cross-boundary ferry boats will start to be replaced by more modern vessels made of carbon fibre. By 2030 this process should be well advanced.

The Airport Authority Hong Kong (AAHK) and 53 airport business partners committed to reduce airport-wide carbon intensity at Hong Kong International Airport (HKIA) by 10% for the 2016-2020 period. In the previous 5 years, carbon intensity has been reduced by 25.6%. The HKIA is unique among operators worldwide in setting a carbon reductions target that includes the emissions of a majority of business partners. In 2013, HKIA became the first airport in the Asia-Pacific region to receive the Airport Carbon Accreditation "Optimization" award from Airports Council International.

In the area of climate adaptation, the measures adopted by Hong Kong, China, are detailed in the *Hong Kong Climate Change Report* published in 2015, as well as in the last chapter of *Hong Kong's Climate Action Plan 2030+* published in 2017.

The risks and vulnerabilities of climate change are exposed hereafter.

Climate change makes Hong Kong, China, hotter. The speed of the temperature rise has been increasing. During the period 1985 – 2014, the temperature rose by 0.16°C per decade, whereas during the period 1885 – 2014, the temperature rose only by 0.12°C per decade.

Climate change makes Hong Kong, China wetter with more extreme rainfall. During the period 1885 – 2014, rainfall rose in average by 22 mm per decade. The maximum hourly rainfall rose from 88.4 mm (1886) to 145.5 (2008). However, during the period 1885 – 2014, the number of days without significant rainfall during the summer months (April – September) rose by 5.9 days per century.

During the period 1954 – 2014, the sea level has risen 30 mm/decade. Projections by 2100 show a possible increase by 70 to 90 centimetres. About 15% of the city's total land area lies below sea level already now. The risk of coastal flooding and damage to coastal infrastructure will increase. Future efforts will have to determine the kind of coastal defensive infrastructure necessary to protect the coasts.

Climate change increases the risk of landslides in Hong Kong, China. The increase has been observed until the creation of the Geotechnical Engineering Office (GEO) in 1978, whose activity has greatly reduced landslide fatalities. The stormwater drainage system has diminished the number of flood prone black spots from 121 to 10. Revitalizing water bodies has been a successful measure of flood prevention. However, if heavy storms such as typhoon Morakot (2009) would hit the city, the very large number of landslides would completely overwhelm the capacity of the present system.

Climate change impacts water security. At present, Hong Kong, China, has three sources of water supply: local yield (19%, 2014), seawater for toilet flushing (22%) and imports from Guangdong Province (59%). Water consumption is seasonal with a peak in summer and trough in winter. Water consumption has increased from around 120 litres per capita per day in 2002 to 130 litres in 2014. Supply is planned to diversify with addition of three more types of sources: 1) a first desalination plant is expected to be commissioned in 2020. 2) The use of reclaimed or treated sewage water for toilet flushing is planned from 2022 onwards, 3) Grey water recycling and rainwater harvesting could be implemented in the future. Water saving awareness campaigns have been carried out, whereby participating households were given

flow controllers for taps to help them save water. Flow controllers are being installed in public rental housing estates. For better management of water reservoirs, two of them will be linked by a 2.8 km long water tunnel of 3 m diameter.

Climate change impacts energy systems. Pylons and overhead lines are vulnerable to storms. Efforts have been made since 2012 to phase out overhead lines and place transmission and distribution systems in cable tunnels.

Climate change increases the risk of infectious disease. Dengue fever, malaria and Japanese encephalitis are expected to be among the challenges.

Climate change increases the risk of falling urban trees.

Climate change impacts biodiversity, and this requires setting aside large tracks of land for protection as country parks or special areas, planting native trees, and setting up marine parks. Hong Kong, China, has elaborated a city-level biodiversity strategy and action plan 2016 – 2021 and contributes also to China's *National Biodiversity Strategy and Action Plan*. One of the objectives is to diminish information gaps about vulnerability of wildlife habitats.

Climate change impacts finance in three ways:

- extreme weather events entail interruption of banking business
- the gradual shift to finance mitigation activities such as clean energy infrastructure
- rising insurance activity as risks are rising.

The city government together with HKEx encourage listed companies to disclose their carbon footprint as a result of their business operation.

Besides the above-mentioned, more recent adaptation measures have been proposed in 2017:

- Incorporating urban climatic and air ventilation considerations in urban design for mitigating heat waves
- Rejuvenating the stock of ailing housing infrastructure, enforcing two mandatory schemes for building and window inspections and providing technical and financial assistance to owner of buildings aged 30 or more years
- Creating a debris barrier to protect the important expressway to the airport
- Promoting the Blue-Green Infrastructure (or sponge city) concept, involving constructed wetland, river revitalization, stormwater storage, flood-control schemes.

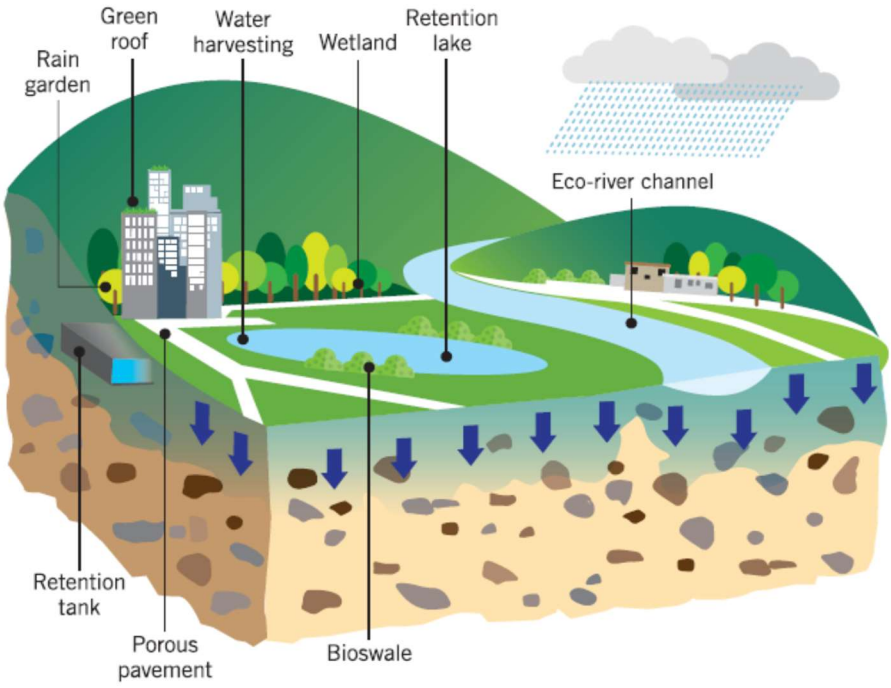

Figure 74: The concept of Blue-Green Infrastructure
Source: *Hong Kong's Climate Action Plan 2030*

- Minimize water leakage through a Water Intelligent Network (WIN) and Automatic Meter Reading (AMR) and mobile apps to enhance consumer awareness
- Better protecting ecosystems by increasing the proportion of indigenous native tree species that are better adapted to local climate than imported species (e.g. Acacia), or native crops such as paddy rice, water chestnut and Chinese arrowhead.
- Formulating an urban forestry management strategy, implementing the concept of place ecology in urban landscape design for public infrastructure projects to achieve multifunctional use. Place ecology refers to the relations and interactions between places through a holistic integration of social, technological, environmental, economics and design of external landscape that contribute to the overall place identity and sustainability of urban environment.
- Urban forestry, sustainable urban agriculture and sustainable fishery and local aquaculture
- Sustainable rooftop landscape for lowering urban temperature, in combination with PV systems

3.4. Policy Responses of Selected APEC Cities

3.4.1. Guangzhou, China

Guangzhou is China's third largest city after Beijing and Shanghai. The city processes approximately 22'600 tons of solid waste per day[91]. Since 2012, Guangzhou has introduced a series of comprehensive waste treatment schemes, engaging the public in decision-making.

The strategy foresees that each community can develop its own approach to household waste collection. Residents participate in the formulation of their community's approach as well as in the implementation through each household's own waste management practices. The strategy contains several common elements:

- Front-end waste sorting, which was deeply rooted in education at all levels as well as in society and in local institutions. This scheme involves market mechanisms to sort out reusable waste such as glasses, bottles, e-waste and used wood, each of which receives a different price. Collectors and street cleaners may receive subsidies. A smart phone app simplifies the process of sorting in each household.

- A waste transfer network, which uses financial compensation to pay for transferred waste from the collection point to the final treatment. Companies are encouraged to develop modern tools such as smart phone apps to disseminate information and incentivize households to separate waste.

- Final treatment, comprising waste-to-energy incineration as option of choice, replacing earlier landfill. Each incinerator produces 210 million kWh of electricity per year, enough to provide electricity to 7000 – 8000 households. Companies may bid to operate the waste treatment facilities. Local resistance against new incineration plants could be overcome by using most advanced incineration technologies (Japan, Denmark), highest emission standards and a participative process involving local opinion committees establishing an information flow between the producers of the incineration technologies and the local population.

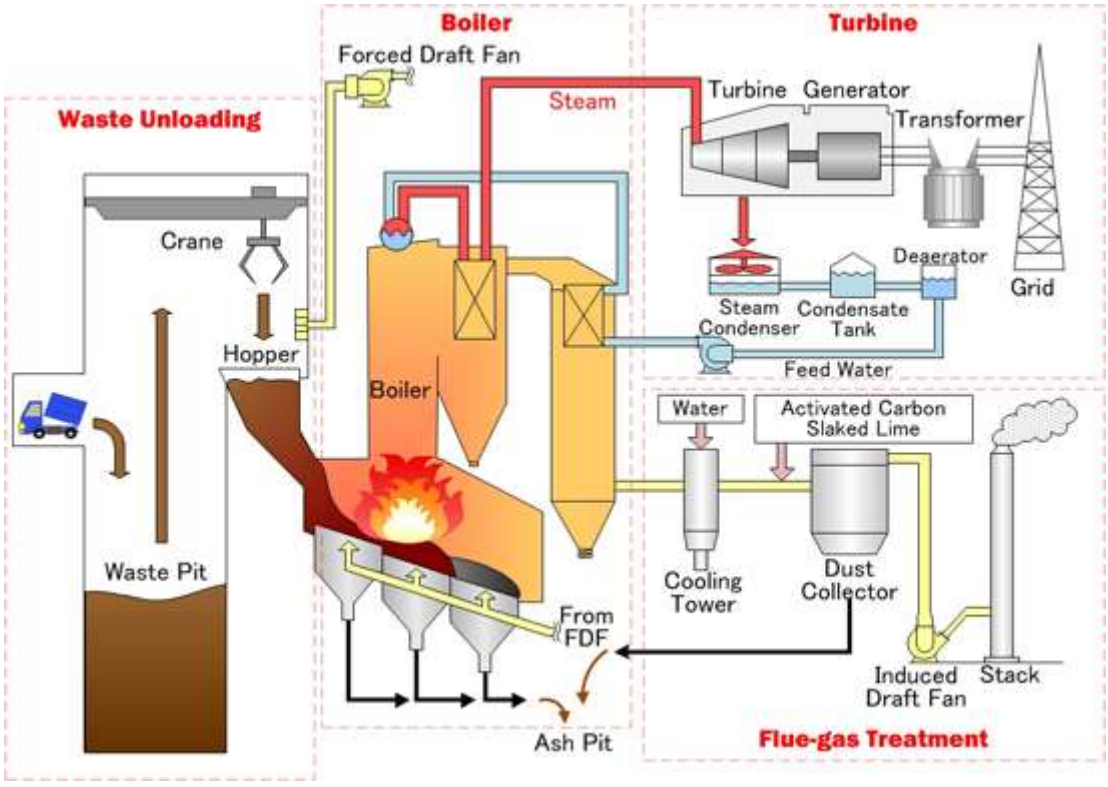

Figure 75: Waste to energy plant
Source: Yokogawa[92]

3.4.2. Ha Noi, Viet Nam

A Green Growth Index has been elaborated for Ha Noi, the capital of Viet Nam, by the International Centre for Environmental Management (ICEM) in 2015 (see ICEM (2015): *Viet Nam Urban Green Growth Action Phase I - Urban Green Growth Index Report*)[93]. This index follows the definition of the Green Growth Index made in 2011 by the Economist Intelligence Unit EIU on Asian cities. The elaboration of this index has been a challenge as official data was often missing. The index has, therefore, been calculated in close cooperation with the different Ministries of Viet Nam, often by using data from unofficial sources. Ha Noi has no superior public transport and lacks in this respect well behind other cities.

Theme	Indicators	Average	Hanoi	Year	Source
1. Energy and CO2	CO2emissions per person (tonnes/person)	4.6	1.9[1]e	2007	(1)
	Energy consumption per US$ GDP (MJ/US$)	6.0	9.5[1]e	2007	(2)
2. Land use and buildings	Population density (persons/km^2)	8,228.8	1,935.1	2009	(3)
	Green spaces per person (m^2/person)	38.6	11.2	2008	(4)
3. Transport	Superior public transport network , covering trams, light rail, subway and BRT (km/km^2)	0.17	0.00		(5)
4. Waste	Share of waste collected and adequately disposed (%)	82.8	95.0[2]	2009	(6)
	Waste generated per person (kg/person/year)	375.2	282.0[2]	2009	(7)
5. Water	Water consumption per person (litres per person per day)	227.6	53.1[3]e	2006	(8)
	Water system leakages (%)	22.2	45.0[4]	2003	(9)
6. Sanitation	Population with access to sanitation (%)	70.1	40.0[5]e	2008	(10)
	Share of wastewater treated (%	59.9	10.0[6]	2008	(11)
7. Air quality	Daily nitrogen dioxide levels (ug/m3)	46.7	20.0	2004	(12)
	Daily sulphur dioxide levels (ug/m3)	22.5	25.0	2004	(13)
	Daily suspended particulate matter levels (ug/m3)	107.8	110.0	2004	(14)

Sources: (1), (2) and (3) EIU estimate. (4) Graduate School for International Development and Cooperation, Hiroshima University. (6) and (7) Hanoi City Environmental Protection Agency. (8) GMSARN International Conference on Sustainable Development. (9) Asian Development Bank. (10) and (11) Hanoi Water Resources University. (12), (13) and (14) Clean Air Initiative.

Figure 76: Components of the Green Growth Index for Ha Noi
Source: ICEM: *Urban Green Growth Index Report*

This index shows the comparatively low level of per capita CO_2 emissions of 1.9 tons per capita per year compared with the average value of all other Asian cities (4.6 tons). Energy intensity is, however, above average. Despite having much lower population density compared to other cities, there is much less green area per person in Ha Noi than in other cities. In terms of waste generation, Ha Noi performs better than average, as it has not only lower per capita waste but also a higher collection and disposal rate than average. Per capita water consumption is only at a quarter of average, but the proportion of leakages of the water system are double the average as almost half the water is leaking. The share of population with access to water is much lower than in average Asian cities, but only 10% of wastewater is being treated. The lower level of the daily NO_2 concentration indicates that Ha Noi has a smaller number of cars than Asian average, whereas the average SO_2 concentration indicates coal consumption in the Asian average.

3.4.3. Green School, Bali, Indonesia

As a rural example of promoting sustainability in APEC economies, the Green School in Bali[94] is combining sustainable rural life with modern technology such as photovoltaic energy. The bamboo construction using locally produced materials is, therefore, a good example of the Sustainable Development target 11c calling for the use of local materials in buildings.

Figure 77: Green School Bali
Source: Trip Advisor[95]

Studying and living in the green environment has also pedagogical advantages. A study on the role of neighbourhood greenspace in children's spatial working memory conducted in the UK in 2018 concludes that children living in greener urban neighbourhoods have better spatial working memory, a conclusion which holds similarly for deprived and non-deprived neighbourhoods[96]. The study calls for these findings to be used to inform policy decision makers on education and urban planning.

Furthermore, the Green School serves also as tourist attraction.

3.5. Policy Responses by the European Union

3.5.1. The European Union as Pioneer Promoting Sustainability

The interest of looking more specifically at Europe is that Europe has been the forerunner of sustainable development. In Europe, two of the three sustainability dimensions, namely the social and economic one, were already well represented in the founding official documents such as the Treaty establishing the European Economic Community (TEEC), concluded in Rome in 1957 ("Treaty of Rome")[97]. The third dimension, the environment, was added to European law in the so-called Single European Act of 1986[98], the first major revision of the Treaty of Rome, paving the way for addressing all three dimensions of sustainability at the EU level several years before the United Nations Conference on Environment and Development (UNCED) took place in Rio in 1992 and defined the basic concept of sustainable development.

The UNCED summit of 1992 adopted the basic toolkit of the Local Agenda 21, which started driving the municipalities all over the world into the direction of higher awareness about sustainable development. Europe spearheaded the dissemination of Local Agenda 21, especially by enhancing horizontal, i.e. inter-municipal, cooperation. Such cooperation was specially favoured by the European Commission to enhance European integration.

Cooperation between municipalities of EU countries for implementing Local Agenda 21 was concretized in a series of conferences on sustainable cities and towns. The first of this conference was held in 1994 in the city of Aalborg in Northern Denmark and adopted the Aalborg Charter[99]. A third conference held ten years later (2004) endorsed the Aalborg Commitments[100] which mark the common European understanding of Local Agenda 21. These commitments were signed by hundreds of local authorities.

Figure 78: The 10 Aalborg Commitments
Source: ICLEI: *The Aalborg Commitments Implementation Guide, 2007*[101]

Besides this cycle of conferences, held every three to four years, the EU also elaborated between 2001 and 2006 a *Thematic Strategy on the Urban Environment*[102]. These processes may explain why Europe has been the continent where the Local Agenda 21 was more popular and better implemented than in the US or in developing countries such as India[103]. In some EU countries, such as e.g. in Sweden, all local communities implemented Local Agenda 21 initiatives[104].

In May 2007 the European Council adopted the Leipzig Charter on Sustainable European Cities[105]. It addresses the need for European cities to modernize infrastructure and become more energy efficient. Especially the building sector for both, existing and new buildings, should become more energy efficient. Improved standards are needed.

3.5.2. EU 20-20-20 Strategy for 2020 and Energy/Climate Targets for 2030

In 2008, the EU discussed and adopted the so-called "20-20-20" strategy and its negotiation mandate for the UNFCCC[106]: By 2020, CO_2 emissions should be reduced by 20%, the share of renewables increased by 20% and the energy efficiency increased by 20%. The EU offered even to reduce CO_2 emissions by 30%, conditional upon equivalent engagement by other big global players such as China and the US in the UNFCCC negotiations. Due to its easily understandable goals, this strategy has paved the way for serving as model not only for the EU member states that formally adopted and ratified them, but also for the climate policies of many European actors of the civil society, namely the Mayors (see below).

Figure 79: "20-20-20 by 2020" strategy of the EU

In 2014 the EU reached a basic political agreement on its 2030 targets[107]. CO_2 emissions should be curbed by 40% compared to 1990 levels. For renewable energy, the discussed goal was a binding target of 27%, whereas for energy savings it was a 27% non-binding target as compared to the business as usual scenario. The emissions trading scheme (ETS) is planned to be reformed and made more effective. In the past, the ETS had practically no effect because too many free certificates circulate in the market so that the resulting CO_2 price was too low.

In November 2016 the Commission published the Clean Energy for All package[108] for discussion to attain the 2030 goals. It is a comprehensive proposal of eight new legislative acts in the climate-energy area with hitherto unprecedentedly broad scope. Its strategic goals are:

- Putting energy efficiency first
- Achieving global leadership in renewable energies
- Providing a fair deal for consumers

Facing early criticism of not fully using synergies between the three objectives, the revised proposal was upgraded and provides, finally, for increasing and strengthening the energy efficiency target to a binding 30% target, mainly by improving the performance of buildings and introducing eco-design requirements for air heating and cooling[109].

As a first of eight legislative acts of the Clean Energy for All package, the new Energy Performance of Buildings Directive came into force on 9 July 2018[110]. Member states have 20 months to transpose it into internal law. The buildings sector is the single largest energy consumer of the EU. The reform of this Directive[111] introduces building automation and control systems as an alternative to physical inspections, encourages the roll-out of the required infrastructure for e-mobility (with a focus on large commercial buildings and excluding public buildings and SMEs), and introduces a smartness indicator to assess the technological readiness of the building to interact with their occupants and the grid to manage themselves efficiently.

Other parts of the package include:

- Renewable Energy
- Energy Efficiency
- Governance
- Electricity Market Design comprising three separate acts: Electricity Regulation, Electricity Directive, and Risk-Preparedness Regulation
- Rules for the Regulator ACER

The package was complemented by further communications:

- Communication on an Ecodesign working plan 2016-2019
- Communication on accelerating clean energy innovation
- Communication on a European strategy on cooperative, intelligent transport systems
- Separate reports on Energy prices and costs in Europe and the implementation of the European Energy Programme for Recovery (EEPR) and the European Energy Efficiency Fund

In sum, the European Union has played a forerunner role in sustainable development policies since the late 1980s. The most recent package of measures for 2030 contain an energy efficiency target which has been strengthened and revised upward from a non-binding 27% to a binding 30% target, but also for renewable energy share which is being increased from 27% to 32% with an upwards revision clause in 2023. The EU aims at keeping and strengthening its leadership role towards sustainable development.

In November 2018, the European Commission presented its vision for a carbon neutral Europe by 2050[112]. The *Final Report of the High-Level Panel of the European Decarbonization Pathways Initiative* has been published at the same date[113]. Discussion in all EU institutions (European Council, the European Parliament, the Committee of the Regions and the Economic and Social Committee), all parliaments, business sector, non-governmental organisations,

cities and communities, as well as citizens - and especially the youth, is to take place, ensuring that the EU can continue to show leadership and hold other international partners to do the same. The EU is to adopt an ambitious strategy in early 2020 and submit it to the UNFCCC as requested under the Paris Agreement. In this vision, cities are the laboratories for transformative and sustainable solutions. Half of the current European Regional Development Fund's envelope will be invested in cities. That amounts to €100 billion, including funding earmarked specifically for sustainable urban development and managed by the cities themselves. For the future Cohesion Policy post-2020, the Commission proposes to create the European Urban Initiative, a new instrument for city cooperation, innovation and capacity-building in key urban priorities like air quality and energy transition.

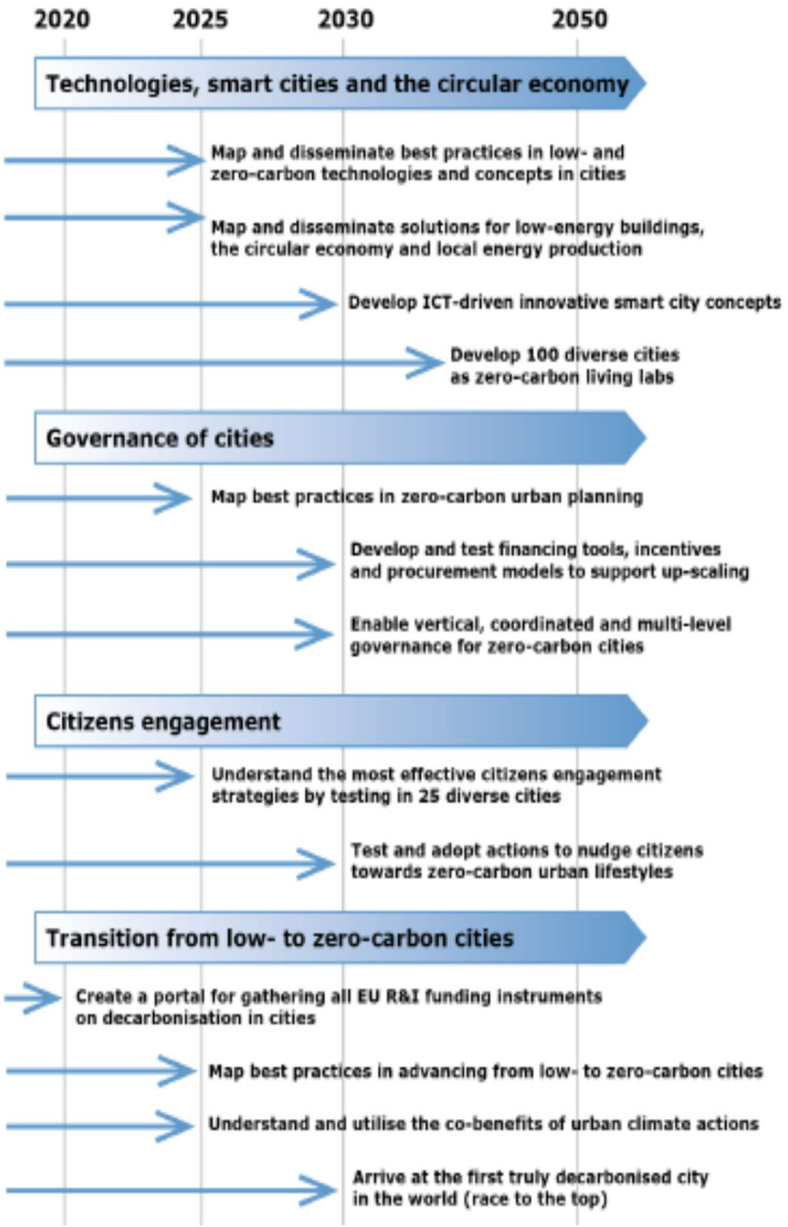

Figure 80: Possible research and innovation pathways for cities
Source: *Final Report of the High-Level Panel of the European Decarbonization Pathways Initiative*

3.5.3. Increasing Role of Horizontal Cooperation among Municipalities

Europe is the birth place or the host area of a certain number of organizations of horizontal cooperation among municipalities which will be presented hereafter.

United Cities and Local Governments UCLG[114] is the world's biggest inter-municipal organization. It is the result of a consolidation and merger process that terminated in 2004, involving three existing organizations:

- International Union of Local Authorities (IULA), created in 1913 in Ghent, Belgium
- United Towns Organizations (UTO. also known as World Federation of Twin Cities WFTC), founded in 1957 in Aix-les-Bains, France[115]
- Metropolis, founded in 1985 in Montreal, Canada[116]

Metropolis, though associated with UCLG by sharing headquarters in Barcelona, Spain, continues acting under its own name. UCLG spearheaded the Global Taskforce of Local and Regional Governments, which pushed for cities to have a seat at the table when the New Urban Agenda (NUA)[117] was negotiated during the Habitat III Conference in Quito, Ecuador, in 2016. The UCLG also hosted the Second World Assembly of Local Leaders on the side-lines of Habitat III. UCLG is today by far the largest organization of sub-national governments in the world, with over 240,000 members (towns, cities, regions and metropolises) as well as 175 local and regional government associations in over 140 UN Member States, de facto representing 5 billion people or 70% of the world's population[118].

ICLEI – Local Governments for Sustainability' is a leading global network of 1,500+ cities, towns and regions, impacting over 14% of the global population, committed to building a sustainable future. Local and regional governments across the ICLEI network work alongside a diverse team of global experts in 22 offices active across 124 countries. ICLEI addresses the local impacts of unprecedented global change, from climate change to urbanization, aiming for urban development to have the least possible impact on global systems and to build communities that are people-centred and equitable. ICLEI makes urban sustainability an inextricable part of development at all levels. Originally created in the years 1989 – 1991 under the name International Council for Local Environmental Initiatives ICLEI, it participated in UNCED and was the driving force for the Local Agenda21 concept[119]. In 2003, ICLEI changed its name and statutes with a broader mandate to address sustainability issues. In 2009 ICLEI moved its headquarters from Toronto to Bonn (Germany).

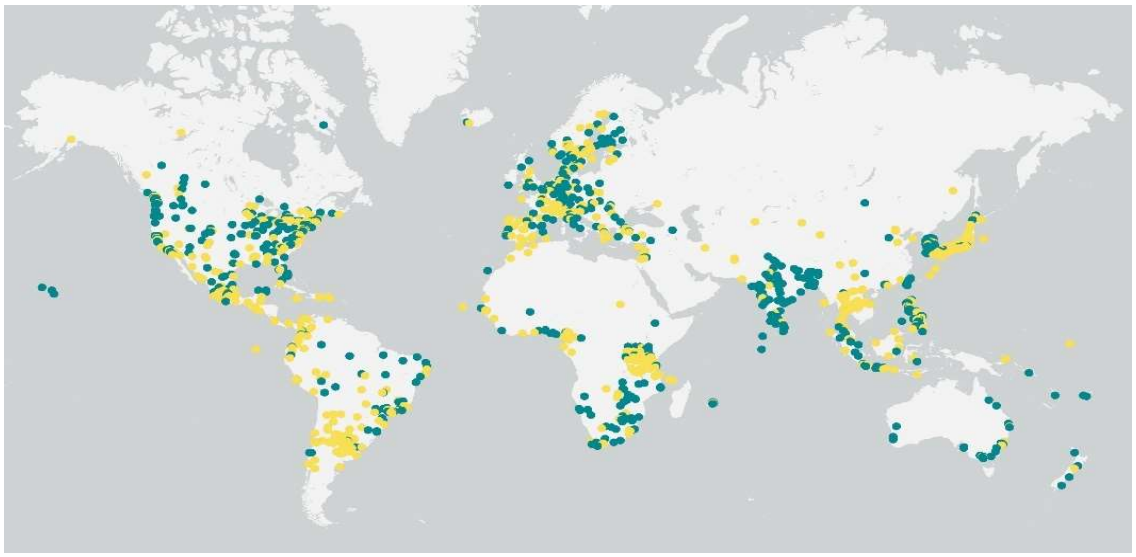

Figure 81: ICLEI member cities
Source: ICLEI[120]

The Cities Alliance – Cities without slums[121] was created in May 1999 as a global partnership by bilateral aid agencies of the US, Canada, Japan, UK and Germany at the World Bank. The philosophy of Cities Alliance is cooperation among complementary partners. For this reason, the organization unites members from six different constituencies: Associations of local authorities (such as Metropolis, UCLG, ICLEI and the Commonwealth Local Government Forum); Governments (currently 13 governments, among them 3 from APEC, i.e. the USA, the Philippines, Chile); NGOs; International Financial Institutions (World Bank, UN Capital Development Fund, UN Habitat as well as UN Environment); Private sector and foundations; Research Centres of Universities. The activity of the Cities Alliance was comprehensively assessed in 2012[122]. The assessment shows that addressing the conditions of slums remains a challenge. One of the problems mentioned in the assessment is the lack of involvement of cities or slum-dwellers themselves. Furthermore, European stakeholders wished to have a higher weight in the decisions of this organization. As a result, this organization moved its headquarters out of the World Bank in 2013 and created a Secretariat in Brussels (Belgium) in the premises of the UN Office for Project Services UNOPS. The Cities Alliance – Cities without Slums and APEC co-authored the publication on Partnerships for the Sustainable Development of Cities in the APEC Region in 2018.

The C40 Cities Climate Leadership Group was created in London in 2005 by the then Mayor Ken Livingstone who convened representatives of 18 megacities to pursue action and cooperation on reducing greenhouse gas emissions. In 2006 Mayor Livingstone invited the Clinton Climate Initiative (CCI) to become its partner. The network had grown to 40 cities, giving the corresponding name to the initiative. From 2008 to 2010 former Mayor of Toronto David Miller took over the C40 chair introducing programmes such as the C40-CCI Climate Positive Development Programme and the Carbon Finance Capacity Building Programme. From 2010 to 2013 former New York Mayor Michael R. Bloomberg chaired the organization, initiating partnerships with the World Bank and ICLEI, and adopting the test version of the Global Protocol for Community-Scale Greenhouse Gases Emission Inventories (GPC) elaborated jointly by the World Resources Institute, the C40 and ICLEI. The GPC will be

presented in detail in Chapter 4. Since 2013, Rio de Janeiro Mayor Eduardo Paes has been chairing the C40.

APEC Economy	**Names of C40 Cities (and number of participated initiatives)**	**Number of cities**	**Total number of cities' initiatives**
Australia	Melbourne (4), Sydney (3)	2	7
Brunei Darussalam	0	0	0
Canada	Montreal (0), Toronto (4), Vancouver (3)	3	7
Chile	Santiago (1)	1	1
China	Beijing (1), Chengdu (0), Dalian (0), Fuzhou (0), Guangzhou (1), Nanjing (1), Qingdao (0), Shanghai (0), Shenzhen (1), Wuhan (3), Zhenjiang (0)	11	7
Hong Kong, China	Hong Kong (3)	1	3
Indonesia	Jakarta (2)	1	2
Japan	Tokyo (3), Yokohama (2)	2	5
Korea	Seoul (2)	1	2
Malaysia	Kuala Lumpur (0)	1	0
Mexico	Guadalajara (0), Mexico City (4)	2	4
New Zealand	Auckland (3)	1	3
Papua New Guinea	0	0	
Peru	Lima (1)	1	1
Philippines	Quezon City (4)	1	4
Russia	Moscow (0, temporarily inactive)	(1)	0
Singapore	Singapore (3)	1	3
Chinese Taipei	0	0	0
Thailand	Bangkok (2, temporarily inactive)	(1)	(2)
United States	Austin (1), Boston (2), Chicago (3), Houston (3), Los Angeles (4), New Orleans (1), New York (4), Philadelphia (1), Portland (0), San Francisco (4), Seattle (3), Washington DC (4)	12	30
Viet Nam	Ha Noi (1), Ho Chi Minh City (3)	2	4
APEC		45	85

Table 6: APEC Cities that are C40 Members
Source: C40 website

Today C40 comprises 96 cities, representing 25% of World GDP and 8% of world population. The C40 accounts for 10'000 actions to combat climate change. The cities are divided into the three categories Megacities, Innovator Cities and Observer Cities.

Cities participate in one or several of five initiatives:

- Energy and Buildings
- Adaptation Implementation
- Transportation and Urban Planning
- Food, Waste and Water
- Air Quality

No C40 city participates in all five initiatives. Some cities participate in four initiatives, some cities do not participate in any initiative.

C40 membership from APEC economies is given in the table above. This table shows that APEC cities make up 45 of the 96 C40 cities, i.e. almost half them. It is difficult to give an estimate of aggregate C40 effect. The total number of initiatives can be used as proxy for overall effect. The total number of initiatives of APEC cities is 85.

The Global Covenant of Mayors for Climate and Energy (GCoM) emerged in 2016 as a new forum for addressing all the issues of sustainable development at local level. This new initiative, based in Brussels, is the consolidation of three existing organizations of sustainable urbanization, namely:

- The Covenant of Mayors created in 2008 by the EU
- The Mayors Adapt, created in 2014 by the EU
- The Compact of Mayors created in 2014 by the UN Secretary General

A first merger happened in 15 October 2015 when the Covenant of Mayors and Mayors Adapt merged into a new Covenant of Mayors for Climate and Energy[123]. The three pillars of the combined Covenant – mitigation, adaptation, and secure, sustainable and affordable energy – were symbolically endorsed on this occasion.

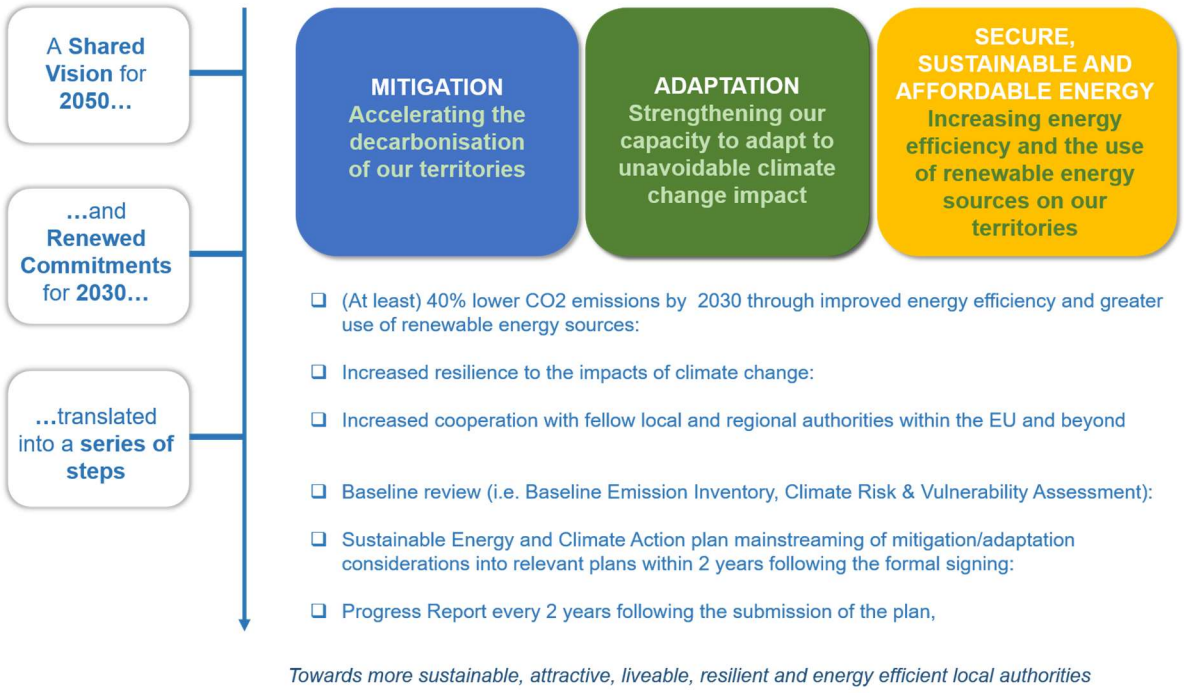

Figure 82: Three pillars of the Covenant of Mayors for Climate and Energy
Source: Covenant of Mayors for Climate and Energy[124]

A second merger occurred on 22 June 2016 in Brussels, when the new Covenant of Mayors for Climate and Energy officially merged with the Compact of Mayors. The Compact of Mayors (or Mayors' Compact)[125] had been launched in 2014 by UN Secretary General Ban Ki-moon and former New York City Mayor Michael Bloomberg, the UN Special Envoy for Cities and Climate Change. The Compact represented a common effort from global city networks C40 Cities Climate Leadership Group (C40), ICLEI, and United Cities and Local Governments (UCLG), as well as UN-Habitat, to unite against climate change. 428 global cities had committed to the Compact of Mayors. Its collective member cities comprised over 376 million people and 5.19% of the global population.

On 21 March 2018 the Global Covenant of Mayors for Climate and Energy opened new headquarters in Brussels[126] in the presence of King Philippe of the Belgians, together with European Commission Vice-President for the Energy Union Maroš Šefčovič and Michael R. Bloomberg, UN Secretary-General's Special Envoy for Cities and Climate Change and Co-Chair of the Global Covenant and other leaders and personalities.

Heralded as the "world's biggest urban climate and energy initiative" by the European Commissioner Miguel Arias Cañete, the signatories of the newly created Global Covenant of Mayors for Climate and Energy commit to implement policies and undertake measures to (i) reduce / limit greenhouse gas emissions, (ii) develop a local GHG emissions inventory, (iii) assess risks and vulnerabilities of the city, (iv) create full climate and energy action plans, and (v) report and track progress toward these objectives. The targets and action plans for mitigation / low emission development must be quantified and consistent with or exceed relevant commitments defined through the relevant UNFCCC Intended Nationally Determined Contribution (INDC).

Between the 4 September 2016 and the 14 September 2018, GCoM membership has increased from 6201 to 9149 cities worldwide, i.e. almost 3000 cities in two years, or 4 cities per day. On 12 December 2017 the Global Covenant of Mayors for Climate and Energy and the World Bank announced a cooperation program of 4.5 billion USD over the period 2018 - 2020 allowing for cities across the world to realize ambitious climate action programmes[127].

The reporting guidelines of GCoM are based on the *Global Protocol for Community-Scale Greenhouse Gases Emission Inventories* (GPC) elaborated by the World Resources Institute, the C40 and ICLEI. It will be presented in detail in Chapter 4.

UN-Habitat and the United Nations Environment Program (UNEP) have established and implemented Sustainable City Planning (SCP) since 1990 to ensure worldwide sustainable local environment and to fully understand the important contribution of urban areas to social and economic development.

For Asia the Sustainable City Planning-Asia (SCP-Asia) carries out this function. SCP-Asia provides sophisticated Environmental Planning and Process Management (EPM) to help cities meet these challenges. Since its inception, the program has been working to integrate environmental issues into urban development decision-making. SCP-Asia provides capacity-building and institutional support to 66 demonstration cities in 10 countries (among them 30 cities in 6 APEC economies) and their government partners. The global program team in Nairobi mainly provides specialized technical support.

Figure 83: Geographic scope of Sustainable City Planning SCP-Asia
Source: UN Habitat Regional Office for Asia and the Pacific, Fukuoka[128]

3.5.4. The Impact of the Covenant of Mayors CoM 2008 - 2016

The European Commission's Joint Research Centre (JRC)[129] made a comprehensive analysis of the Sustainable Energy Action Plans of the city-members of the Covenant of Mayors in 2016. This analysis points out that if all Covenant of Mayors signatories keep their commitment to reduce GHG emissions by 2020, then the cumulative emissions will be reduced by 27%, that is 7% above the 20% target.

The study of the 2008 Covenant of Mayors CoM is of interest to sustainable urbanization of APEC economies as the CoM is a results-based initiative and, hence, its impact can be measured. This is equally valid for its successor, the 2016 GCoM presented above.

The results-based nature is the very consequence of the CoM mandate and of its evaluation method (see next section): The CoM has been created in 2008[130] as a supporting initiative of climate policy. In the EU, cities make up almost three quarters of CO2 emissions. In their commitment, the signatory Mayors mirror their Member state's engagement at local level. In order to fulfil the aim to support their Member state's engagements, the engagements of cities must be quantitative, measurable and verifiable.

The CoM signatories, mayors of towns or cities, committed to the following:

- Prepare a Baseline Emission Inventory;
- Submit a Sustainable Energy Action Plan within the year following the official adhesion to the Covenant of Mayors initiative, and including concrete measures leading to at least 20% reduction of CO_2 emissions by 2020;
- Submit an implementation report at least every second year after submission of their Sustainable Energy Action Plan for evaluation, monitoring and verification purposes.

By 2016, the implementation of the Covenant of Mayors exceeded expectations, partly because it had not only been proposed to cities and towns within the EU, but also worldwide. After eight years of implementation, by 4 September 2016, 6201 local authorities from 54 economies had joined the initiative, representing 213 million inhabitants, of which 15% or about 32 million were outside the EU.

The following analysis was made in 2016 and refers to the original 2008 Covenant of Mayors (CoM). CoM signatories within the EU represent 36% of the EU population. 89% of the signatories representing 21% of the population are Mayors of small and medium-size cities of less than 50'000 inhabitants. Mean size of affiliated cities was 34'350 inhabitants. The CoM is especially popular in three Member states, namely Italy (2953 signatories), Spain (1376 signatories) and Belgium (176 signatories).

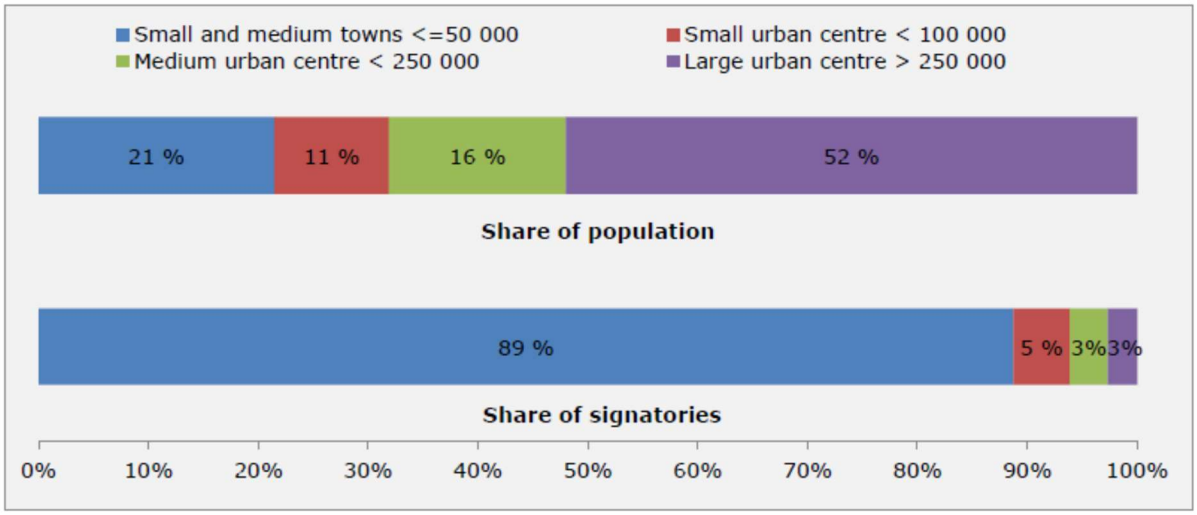

Figure 84: Share of population vs share of signatories of the Covenant of Mayors
Source: JRC Science for Policy Report on the Covenant of Mayors, 2016

The mitigation commitment of the Covenant signatories is mainly related to the emissions associated with energy consumption in sectors which can be influenced by the local authority (housing, services and urban transport), leaving out other emitters which are outside the mandate of the local authority (e.g. highways). 70.5% of the reduction comes from the building sector, 28.3% from the transport sector.

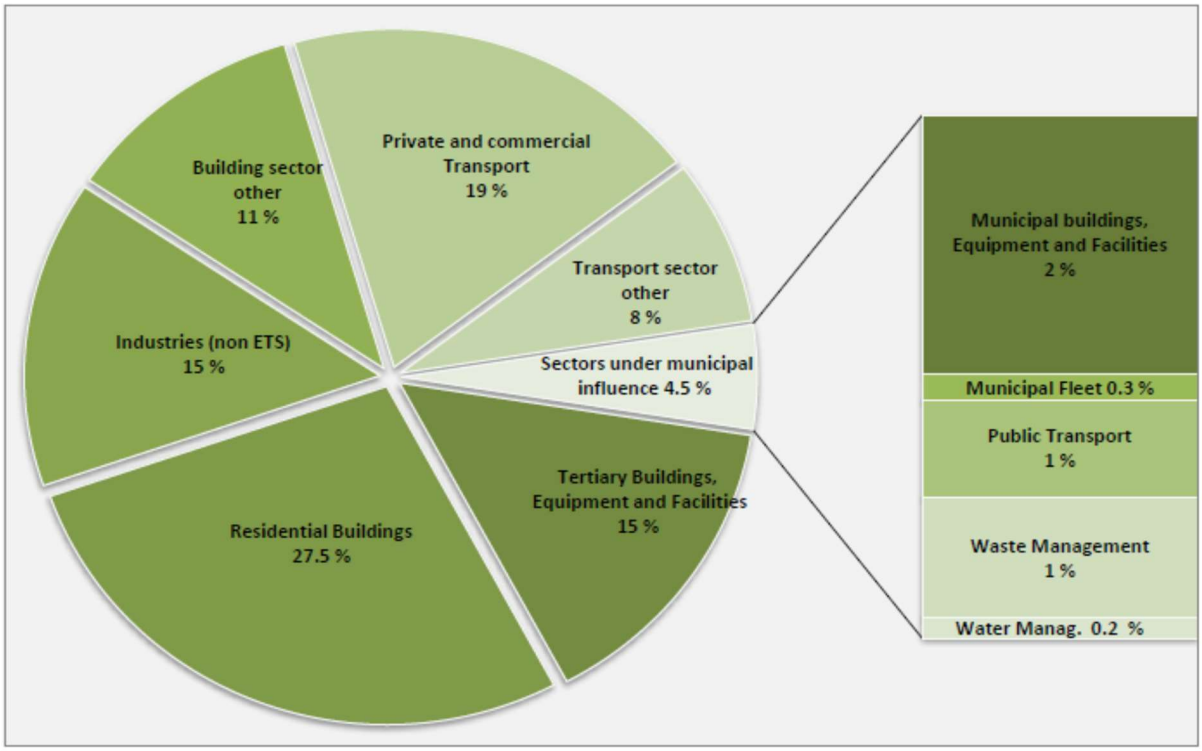

Figure 85: GHG-Reductions of Covenant of Mayors signatories by sector
Source: JRC Report, 2016

The analysis of the first 315 implementation reports (representing 25.5 million inhabitants) reveals that 23% of the cut in emissions had already been achieved in 2014, six years ahead of schedule.

The decrease in GHG emissions between baseline and monitoring years was driven by the following factors:

- GHG emissions due to electricity consumption fell by 17 % from the baseline to monitoring years due to a less-carbon-intensive fuel mix and more efficient electricity generation power plants;
- GHG emissions in buildings from heating and cooling fell by 36 % from the baseline to monitoring years, driven by improved energy efficiency in buildings and consequently lower energy consumption levels, more efficient local heat production from district heating networks, and by increasing shares of renewable resources in decentralized local heating production;
- GHG emissions in the transport sector fell by 7 % from the baseline to monitoring years driven by more efficient vehicles, an increase in the share of biofuels, and the shift towards public transportation and electric mobility.

The most common policies being implemented are:

- Energy management and public procurement;
- Building standards and energy certification labelling for new and existing buildings;
- Awareness-raising and training;
- Financial incentives;
- Third-party financing;
- Urban planning: local authorities establish local mobility plans defining limited traffic zones, low emission zones, designated parking spaces for low-emission vehicles, and free parking for cleaner efficient vehicles. Furthermore, they set road pricing schemas, and integrated ticketing/charging to foster sustainable mobility.

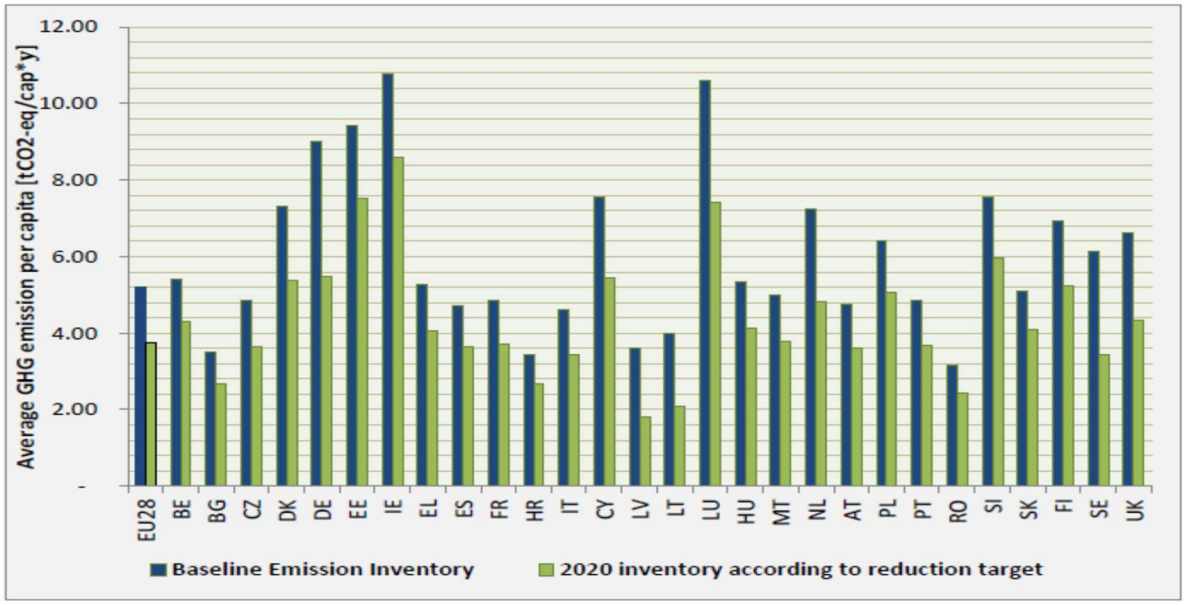

Figure 86: The GHG reduction per Member state committed by the Covenant of Mayors signatories. Source: JRC Report, 2016

3.5.5. Relevance of the GCoM for APEC

The analysis of the first 315 implementation reports (representing 25.5 million inhabitants) reveals that 23% of the cut in emissions had already been achieved in 2014, six years ahead of schedule.

The GCoM is relevant to the process of sustainable urbanization in APEC. Two reasons contribute to this. Firstly, the GCoM is a fast-growing global initiative with growing membership also in APEC economies, and secondly, it is a results-oriented initiative, incentivizing its city-members to formulate measurable goals and to work towards attaining them.

Between the 4 September 2016 and the 14 September 2018, GCoM membership has increased from 6201 to 9149 cities worldwide, i.e. almost 3000 cities in two years or 4 cities per day in average. GCoM is creating regional chapters in North America, Latin America and the Caribbean, Sub-Saharan Africa, Middle East and North Africa, European Union and Western Europe, South Asia, East Asia, South East Asia, Oceania.

In 16 APEC economies, a total of 340 cities totalling a population of 232 million inhabitants have taken the engagement to cooperate under the GCoM. As most of these engagements are quite recent, many cities have not yet completed their report on emissions, hence only population data is available for the moment.

APEC Economy	Number of GCoM Cities	Corresponding Population	Mean City Size
Australia	26	3’482’609	133’946
Brunei Darussalam	0	0	
Canada	29	18’315’411	631’566
Chile	6	9’023’957	1’503’993
China	0	0	
Hong Kong, China	1	7’336’600	7’336’600
Indonesia	18	22’155’018	1’230’834
Japan	14	21’693’924	1’549’566
Korea	8	16’983’057	2’122’882
Malaysia	2	2’700’000	1’350’000
Mexico	23	19’557’129	850’309
New Zealand	6	2’477’502	412’917
Papua New Guinea	0	0	
Peru	3	9’427’052	3’142’350
Philippines	28	10’756’202	384’150
Russia	2	13’307’396	6’653’698
Singapore	0	0	
Chinese Taipei	6	14’508’563	2’418’094
Thailand	15	658’156	43’877
United States	153	59’893’032	391’458
Viet Nam	0	0	
APEC	340	232’275’608	683’164

Table 7: APEC cities having taken engagements under GCoM
Source: Global Covenant of Mayors

The above table shows that the mean size of affiliated APEC cities is around 680’000 persons. This is almost 20 times larger than the average size of cities affiliated to the predecessor (CoM, see above) during the years 2008 – 2016, but is probably still smaller than the average APEC city size and certainly smaller than the average size of C40 members. GCoM remains a voluntary framework that addresses the sustainability needs of medium size cities that do not otherwise have easily access to results-based international cooperation frameworks promoting sustainable urbanization. China, Singapore and Viet Nam have some of their cities engaged in C40 but none in GCoM. Brunei Darussalam and Papua New Guinea do not have any cities in either forum.

The contribution of the GCoM can be expressed in terms of the reported results and compared to the business as usual (BAU) in similar matter as shown above for the CoM. After implementation of measurable and reportable targets, the GCoM members will have contributed significantly to improve sustainable urbanization. The above table shows that no city of mainland China has up to now become a member of the GCoM.

Chapter 4 – Instruments Supporting Policy Responses

Policy instruments are but one type of instruments that support sustainability. Other types of instruments are scientific concepts. Physical and life sciences contribute to the notion of sustainability in three ways, namely, to formulate sustainability as conquest of time (H-indicator), or as struggle against the entropy principle, or as homeostatic regulation. Economic analysis contributes to sustainability by searching for the appropriate game-theoretical framework for analysing sustainable development paths, or by defining internalization of externalities as key principle for making markets more efficient, or by enlarging the System of National Accounts to become the System of Environmental-Economic Accounts. The latter is a measurement system for sustainability which has been adopted by two APEC cities. Other measurement systems for sustainability are the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC), and the Index System of APEC Low-Carbon Towns LCT-I. Further instruments supporting sustainability are planning tools, especially the Multi Criteria Decision Making (MCDM) which is shown to be particularly well adapted to a political framework such as the SDGs, consisting of several different goals that may conflict with each other. Another tool is E-government, especially its principle of Open Government Data (OGD), which figures among the recommendations of this report. New ICTs in support of sustainable urbanization include big data, artificial intelligence, internet of things, virtual and augmented reality, high performance and quantum computing, and blockchains. Among the instruments that support sustainability are also ISO and IEC standards. This report suggests referring to ISO standard 37151 for smart cities, and to the ISO standards on energy efficiency in buildings (ISO 52000 series). Cutting-edge technologies are among the important instruments supporting sustainability. Plus-energy districts can become the nuclei of sustainable urban housing contributing significantly to their own energy balance. Next generation photovoltaic devices offer cheap, decentralized electricity on any type of surface and at low light intensity. Wastewater-to-electricity diminishes environmental impact of wastewater treatment, as well as subsidy rates, through sale of energy. Fuel-cell vehicles extend the range of electric vehicles. Self-driving cars enhance driving comfort of car users. Photovoltaic roads could show the way towards wireless charging for electric vehicles. Automatized underground freight transport relieves congestion on urban roads and diminishes environmental impact. China recently presented six new projects of this kind.

4.1. Scientific Concepts Supporting Sustainability

4.1.1. Physical and Biological Concepts Supporting Sustainability

Physical sciences and life sciences contribute in at least three ways to the discussion of sustainability.

(1) the conquest of time is the result of sustainability, from which a physical sustainability indicator, the “H” indicator, can be derived,
(2) the fight against the entropy principle is the basis for energetic sustainability,
(3) homeostasis of governed biological systems is a type of sustainable process.

(1) The conquest of time is the most basic concept of sustainability, as it is the main result of sustainability. A sustainable system is, above all, a system that lasts in time. The

conquest of time governs all physical systems. Due to a set of fundamental laws, the analysis of physical systems allows looking far into the future for knowing what is likely to happen. Knowledge about the future of the Universe is important to shape people's thoughts about sustainability.

Today, it is still impossible to know with certitude whether the Universe is perennial or not. There is currently no scientific explanation as to why the Universe exists or should be perennial. Speculations about other universes that exist in parallel or are being continuously formed (multiverse speculations) have fuelled the discussion but are often beyond science as they can neither be proven nor disproven.

Looking backwards in history, the Big Bang is usually dated 1.38×10^{10} years before the present. It may be futile to ask the question what was "before", as time could itself have been created at the beginning of the Universe.

For the Universe, a logarithmic time scale might be more appropriate than a linear time scale. A logarithmic time scale converts today's age of the Universe (1.38×10^{10} years) to the exponent of that figure, i.e. 10. When the Universe was 10^{-50} years young (age of the Planck time), this scale would show -50. When it will be aged 10^{100} years old (age of large black holes), this scale indicates 100. With a logarithmic scale, the Universe may last from minus infinity to plus infinity.

Looking forward into the future, the Universe will conquer time if it lasts in time. According to today's knowledge, the Universe can only stop expanding if its internal mass is sufficiently large for gravitational attraction to stop and eventually reverse its expansion. Astronomers are trying to find the missing mass in the Universe which would confirm the hypothesis that the Universe is oscillating. Currently the ascertained mass of the Universe is slightly below the critical mass. If the mass of the Universe is below the critical mass, the Universe will end up expanding forever. In about 10^{100} years it will be a black body filled only with low energy long-wave radiation[131]. Matter will have disappeared; the Universe will be dark, and its temperature will approach the absolute zero.

On the contrary, if the mass of the Universe is above the critical mass, the Universe will stop its expansion, start contracting and eventually become small again to the very small size it had at the time of the Big Bang. From there it could re-start with a new Big Bang. However, even if the Universe started all over again with a new Big Bang, it would lose some of its energy due to bulk resistance[132]. The next "Universe day" would have less energy than the present one. This is he consequence of the entropy principle (see below).

The longest-living known objects of the Universe are big black holes that might exist for 10^{100} years or more. The smaller black holes that have less mass than a threshold equalling approximately the mass of our moon dissipate already now (Hawking radiation)[133] as they are warmer than the universal background radiation (currently 2.7K or -270.45 degrees Celsius). If the universal background radiation cools further down, even the largest black holes having temperatures around 10^{-14}K would eventually dissipate.

It is not known yet why the Universe contains more matter than antimatter, and why the number of protons is about equal to the number of electrons, making the Universe electrically neutral. It is known, however, that protons are the most stable heavy particles. They have a half lifetime of at least 10^{31} years which is more than 10^{20} times as long as the time span since

the Big Bang[134]. The Universe is only at the very beginning of its evolution and it is not the proton decay that will make it disappear any time soon.

Galaxies and clusters of galaxies exist because the Universe is currently in the stellar age. This age is forecast to last for about 10^{14} years, after which the hydrogen, the main stellar fuel, will have been consumed and transformed to heavier elements. At its current age, the Universe has only lived for about one ten-thousandth of its stellar age.

Our solar system is comparatively young as it dates from about 4.6 billion years. If the sun follows a standard model, it has since then steadily increased its size and radiation intensity by about 25%[135],[136]. During the next four billion years this process will continue at the present speed, after which the sun will grow more rapidly and become a red giant, absorbing the planets Mercury and Venus. In about 12 billion years the sun will implode and become a white dwarf.

The life duration of stars depends on their size.

Mass (solar masses)	Time (years)	Spectral type
60	3 million	O3
30	11 million	O7
10	32 million	B4
3	370 million	A5
1.5	3 billion	F5
1	10 billion	G2 (Sun)
0.1	1000s billions	M7

Table 8: Life time of stars as a function of their size
Source: Carlos A. Bertulani[137]

The above table allows introducing the most basic sustainability indicator (“H” indicator). This indicator is the product of the life time of the system multiplied by its size. The size of physical systems is expressed as the energy equivalent of the number of protons contained in the system. The most basic sustainability indicator has, therefore, the dimension of [energy X time]. Such a quantity is called “action”. The indicator says that both, size and duration matter for sustainability. The smallest quantum of action that exists in nature is the famous Planck quantum (0.5×10^{-34}Js or $\hbar/2$). This sustainability indicator is a multiple of that quantum. It would be useful to give it the symbol H.

Below the Planck quantum, nature does not define exact causality, but only statistical probability. Planck quanta are therefore the “causality atoms” of the Universe. The most basic sustainability indicator expresses sustainability as multiple of such “causality atoms”. This is not without philosophical relevance as the fight for conquering time can only take place in systems where ageing and dying have causes.

Applying the sustainability indicator H to stars in the above table shows that the largest stars with 60 times solar mass and life span of only 3 million years have a sustainability indicator of only 1.8% of the sustainability indicator of the sun, whereas the smallest stars with mass 0.1 times that of the sun and life times of 1000s of billions of years have a H indicator of at least 10 times as high as the corresponding indicator of the sun. Therefore, sun is not the most sustainable energy provider of the Universe.

The System of Environmental-Economic Accounting, which will be presented further down, allows to see how the H-indicator can be adapted to measuring sustainability of economies or cities.

(2) The fight against the entropy principle is the basic principle defining energetic sustainability. The entropy principle or second thermodynamic principle states that the entropy of an isolated system will tend towards a maximum. This principle accompanies the first thermodynamic principle which states that the quantity of energy of an isolated system is constant. As the Universe is an isolated system, energy is the natural accounting unit of the Universe as its energy is constant. As the Universe is also a thermodynamic system, its entropy is tending towards a maximum. Entropy increase can show intrinsic ageing of an isolated system. For the Universe, ageing, or entropy increase, materializes itself in increased quantities of radiation being emitted while the quantity of matter diminishes accordingly.

Entropy (usually noted S) is a measure of the spontaneous, irreversible dispersal of thermal energy[138]. Thermal energy, as well as thermal radiation such as sunlight, are forms of waste into which all other "noble" energy forms degrade. Entropy increases until thermal energy is evenly spread in space. The basic process to which entropy increase applies is the heat dispersal of a heat source (temperature T_1) into its surrounding environment (T_2), where $T_1>T_2$. In 1824, the French engineer Sadi Carnot discovered that for this process, the maximum useful energy that can be extracted is not proportional to the temperature difference T_1-T_2, but to the "Carnot factor" $(T_1-T_2)/T_2$, which describes the best possible or ideal technology. In contrast, the maximum energy that can be extracted from purely mechanical, "noble" energy sources such as, e.g. hydropower, is, in an ideal case, proportional to the height difference (h_1-h_2) between a dam (at height h_1) and the hydropower station (at height h_2). Entropy is an energy/temperature ratio, expressed in J/K.

Entropy is a quality inherent in thermal energy. Thermal energy, once dispersed (i.e. cooled), cannot be concentrated (heated up) above the temperature of its source, unless energy with less entropy (or higher quality) is used. Thus, a concentrated solar power (CSP) plant collecting solar energy that arrives at a temperature of 5777K (i.e. the surface temperature of the sun) can at most produce heat at that temperature.

Box 4: Entropy

Contrary to the Universe, the Earth is not an isolated system, but a solar-powered engine receiving highly energetic solar radiation corresponding to the surface temperature of the sun (5777K) and emitting low-energy infrared radiation corresponding to the mean surface temperature of the Earth (288K). The drop of the temperature of the radiation from 5777K to 288K increases entropy of outer space, whereas on the Earth surface, entropy, on the contrary, diminishes by photosynthesis of plants which concentrates energy in form of chemical substances.

The incoming energy (solar radiation) of the Earth energy balance is shown in the figure below on the left (342W per square meter), of which 107W/m^2 are reflected. The ratio between reflected and incoming energy, i.e. 0.312, is called average albedo. The atmosphere receives 67W/m^2 from absorption of sunlight, plus 24W and 78W per square meter, respectively, from thermals and evapotranspiration plus, above all, 350W/m^2 from infrared radiation coming from the soil. In total the atmosphere receives 519W/m^2, and it loses in average the same amount

(165 plus 30 plus 324W/m^2 equals 519W/m^2). This compares to mere 198W/m^2 hitting the soil in form of direct solar radiation, of which 30W/m^2 are reflected. This shows that the atmosphere metabolizes in average about three times more energy than the earth's soil.

The direct solar energy absorbed by soil, 168W/m^2, is only about half of what the surface receives from the atmosphere (324W/m^2, on the right in the figure below), and which forms the greenhouse effect. Radiative forcing, the influence of anthropogenic greenhouse gases, is expressed in W/m^2. The primary effect of radiative forcing is the increase of the absorption by the atmosphere (350W/m^2) at the expense of the atmospheric window (40W/m^2) which "closes" and causes a corresponding increase of the back radiation (324W/m^2). According to the 2007 IPCC synthesis report[139], radiative forcing has been 1.6 (0.6 – 2.4)W/m^2 since the beginning of industrialization in 1750.

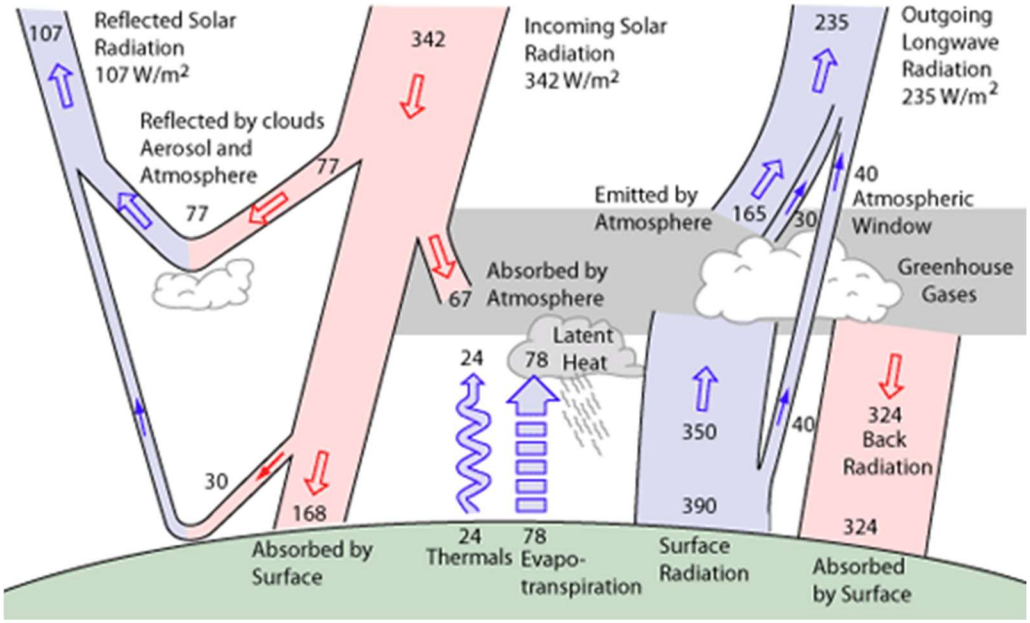

Figure 87: Energy balance of the earth
Source: Kiehl & Trenberth[140]

The greenhouse effect is, therefore, produced by incoming solar light and the atmosphere. Without atmosphere, the average temperature on Earth would be *minus* 19 degrees Celsius, that is 34 degrees lower than with the atmosphere, and no greenhouse effect would exist. The radiative forcing of 1.6 (0.6 – 2.4)W/m^2 noted above is already of the same order of magnitude as the total photosynthesis production of the biosphere, as is shown hereafter.

The above energy balance does not yet account for the energy use by the biosphere and the economy. Locally and during peak production, the highest-yielding green plants produce around 10W/m^2, a figure that drops to 4W/m^2 in all-year average, corresponding to an average efficiency of around 2% of the incoming solar light of 198W/m^2. If this production rate was equally distributed over the whole planet, the total photosynthetic productivity of the earth would be around 2000TW. This theoretical maximum is by far not attained as the climatic conditions do not allow for high yield plants to live everywhere. Marine cyanobacteria account for a large part of Earth's primary photosynthetic productivity as they convert solar energy into biomass-stored chemical energy at the rate of 450TW[141]. Photosynthesis production can be

observed from space. If land-based photosynthesis production is 40TW to 50TW, the average, energy production from the biosphere (oceans + land) could therefore be around 500TW, corresponding to about 1W/m^2.

In comparison, the total world energy consumption of the human society in 2015 has been 18.1TW[142], or 3.6% of the biosphere production. The food energy requirement of the human population of 7.5 billion persons needing 135W (or 2787Kcal per day) in average is of the order of magnitude of 1TW or 0.2% of biosphere production. A rule of thumb says that to guarantee food security, each preceding step of the food chain must have a biomass production of about ten times higher than the succeeding one. Thus, a vegetable food production of 100TW will allow feeding an animal feedstock production of around 10TW which in turn allows to feed a human population requiring 1TW. It would increase food security if all humans were feeding themselves only with vegetables. Conversely, reducing vegetables and lengthening the food chain would decrease food security.

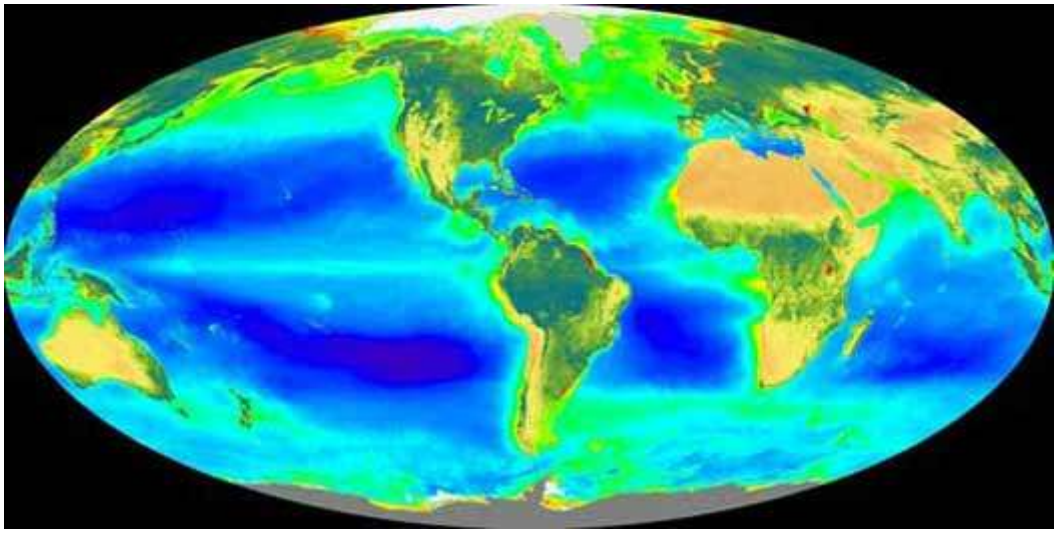

Figure 88: Photosynthesis production seen from space
Source: SeaWiFS Project NASA GSFC and GeoEye, Inc.

The “business model” allowing the Earth to struggle against the entropy principle is the following: From the “income” of 168W/m^2 on Earth’s surface, the Earth retains a tiny profit margin of less than 1W/m^2 for the biosphere, to be distributed among the billions of shareholders that are the living organisms. These distribute it among themselves along the food chains. Living organisms use the greatest part of it to constantly re-build the ageing biomass. A remaining tiny part has been stored in the past in sedimentary rock strata in the earth crust in form of fossil energy. Widespread coastal swamp forests and peat are at the origin of lignite, coal and anthracite which were formed during the Carboniferous and Permian periods (360 – 250 million years ago). This process was only possible before the appearance of white rod Agaricomycetes, a kind of fungi capable to decompose lignite[143], 250 million years ago. Since then, no more coal is produced. The origin of petroleum and natural gas is less certain than the origin of coal. The biogenic school supports the argument the oil originated from sedimentary organic matter which was, like coal, thermally converted to oil and gas, whereas the abiogenic school postulates that oil and gas originated either from mantle

degassing associated with the polymerization of low molecular weight compounds, or from serpentisation in association with Fischer-Tropsch reactions[144].

(3) Homeostasis is a relevant idea for the formulation of the sustainability principle. Homeostasis, often in reference to a living organism, means that an organism has the capacity to react to external influences in such a way that some influenced variables are coming back to the initial level. The most frequently cited example of a homeostatic phenomenon is the regulation of blood temperature in humans at around 37°C. Human body temperature varies in a circadian day-night cycle. The circadian (or daily) cycle is a major cause for jet lag. Industrial thermostats are mimicking biological homeostasis.

Figure 89: Circadian variation of human body temperature
Source: aminoz.com.au

Limiting climate change to 1.5 or 2 degrees is somewhat like homeostatic regulation. Many plant and animal species live only within specific temperature bandwidths. The present increase of ambient average temperature is causing a dramatic loss of biodiversity. In fact, the present mass extinction is the sixth one in history. During the last 500 million years, heavy variations in temperature and acidity of oceans have been a great challenge to life. Five large earlier periods of mass extinction are documented ("the big 5")[145], during which each time many species died out. The best-known mass extinction is probably the one of the dinosaurs 65 million years ago, which eliminated 76% of life on Earth[146]. Before that, four other extinctions have taken place, some with even more dramatic consequences for the biosphere. As the reefs are among the oldest existing biotopes, each extinction can be traced back in their fossil remains.

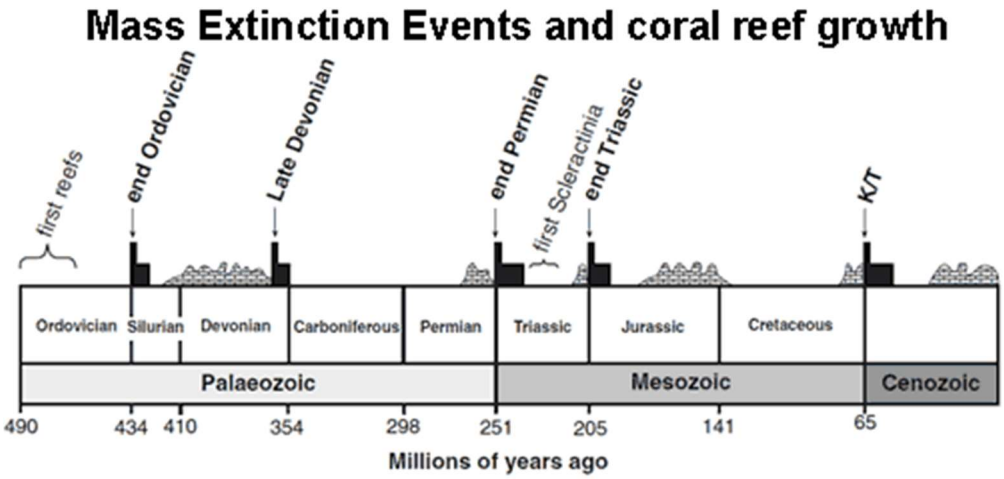

Figure 90: The Five Big Mass Extinction Events
Source: John Cook, *Earth's five mass extinction events*[147]

Mass extinction	**Loss (% of species)**	**Causes**
End Ordovician	86%	Glaciation, low temperatures, falling sea levels, possibly too fast removal of CO_2 by plants
Late Devonian	75%	Not very clear. Possibly caused by volcanic activity
End Permian	96%	Vulcanic eruptions, high methane content and high acidity of oceans, high temperatures
End Triassic	unclear	Asteroid, climate change, flood basalt eruptions
Cretaceous/Tertiary K/T	76%	Volcanic activity, asteroid impact, climate change
Holocene (present day)	Ongoing	Climate change and human impact

Table 9: Periods and causes of mass extinctions

The Earth does not have a homeostatic regulator for temperature. The last 500 million years are shown in the figure below, where the time axis is on a logarithmic scale. The logarithmic scale hides the fact that the present climate change is by far the most rapid ever. Compared to all the past variations of climate, the present climate change is a climate explosion.

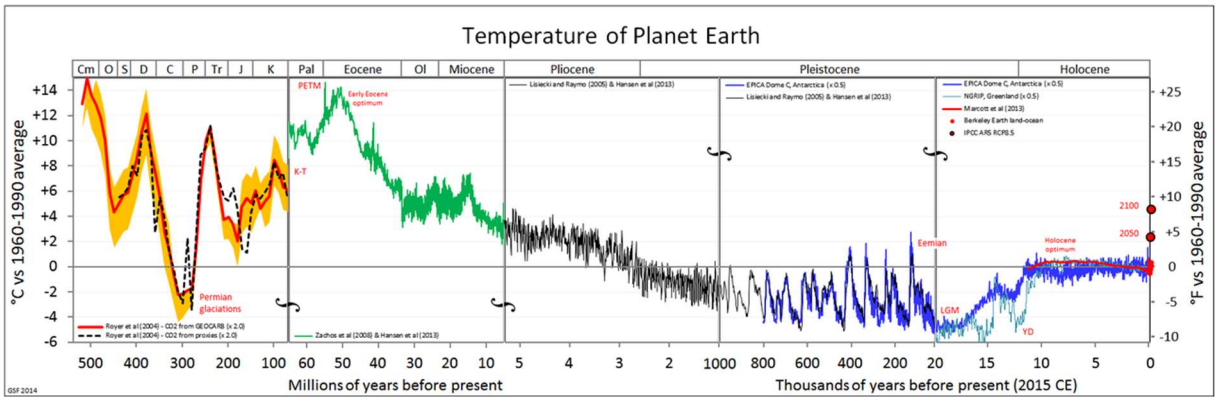

Figure 91: Temperature of Planet Earth
Source: By Glen Fergus; CC BY-SA 3.0[148]

Homeostatic regulation of temperature and other important factors is necessary to limit mass extinctions. Average atmospheric temperature should neither be too high nor too low. Cyanobacteria and plants may have caused mean Earth temperature to gradually decrease over the last 50 million years. They might be at the origin of the first (end Ordovician) mass extinction due to low temperatures. At that time, plants might have removed too much CO_2 from the atmosphere, thereby undercooling the planet. According to present knowledge, plants are the only cause having created oxygen in the atmosphere by removing CO_2. Around 2.8 billion years ago, oxygen started to be produced by cyanobacteria and became a significant component of the atmosphere around 2.45 billion years ago. Before that, the earliest bacteria lived on sulphate as source of energy[149] as sulphur was abundant in the earlies atmosphere. Oxygen may have been lethal for these early bacteria.

4.1.2. Economic Concepts Supporting Sustainability

Economic analysis contributes in three ways to the discussion of sustainable development:

(1) by searching for an appropriate game-theoretic framework for analysing sustainable development paths

(2) by defining internalisation of externalities as key principle for making markets more efficient. Examples of externalities are the Tragedy of Commons and the Braess' Paradox.

(3) by widening the System of National Accounts (SNA) to become the System of Environment-Economic Accounts (SEEA). The SNA's GDP and the SEEA will be presented further down among the measurement methods supporting sustainability;

(1) Economic analysis contributes to the discussion of sustainable development by searching for an appropriate game-theoretic framework for analysing sustainable development paths. Since the mid-18th century, when trade started to develop, economic analysis has focused on how trade can improve wealth and on how an optimum general equilibrium of exchanges can exist. The focus on these topics went so far that the analysis of the link of the economy to natural resources has gone out of mainstream analysis. The role of sustainability economics is to re-introduce the link to natural resources and to become mainstream analysis.

Ever since Adam Smith postulated the existence of an invisible hand in 1776[150], economic thought has been characterized by the idea of finding overall optimum. Since then, several generations of leading economists have shown that a simultaneous or general equilibrium exists for all prices and quantities of all commodities and all players. The rigorous mathematical demonstration was made by Leon Walras in 1874 and 1877[151], and by his disciple Vilfredo Pareto in 1919[152], followed by Arrow-Debreu[153] in 1954. If general equilibrium is such a universal concept, it is interesting to briefly look in what way it relates to sustainability.

General equilibrium is the state when all prices exactly clear the market so that neither surplus nor deficit exists on any market. A false interpretation would be to assume that equilibrium prices are stable in time, or that they are the result of homeostatic mechanisms. Equilibrium prices are just market-clearing, nothing more. In order to be able to fulfil this role, they often vary considerably in time (price volatility). Volatility can be illustrated at the example of the oil price. Over more than 150 years, the quality of the product has barely changed, so that a price series can be expressed in USD and mapped on a graph. It shows two periods of high volatility, a first one when the market was still very little developed, and a second one when geopolitical instabilities started at the beginning of 1970s.

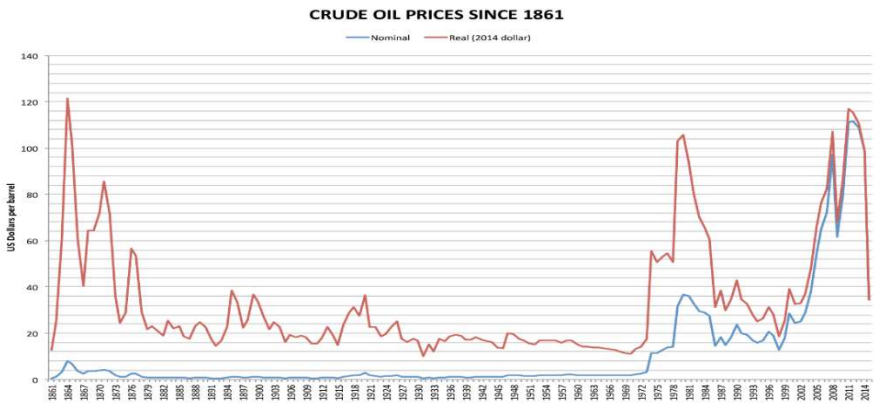

Figure 92: Nominal (blue) and real (red) crude oil prices since 1861
Source: By Jashuah, data from BP workbook of historical data, CC BY-SA 3.0[154]

Prices also vary in space between one specific marketplace and another one. Price differentials between regions can be persistent and can be a source of profit and growth. The following example[155] shows how the complementarity between a city (high price) and its surrounding countryside (low price) yields a profit. This example is, therefore, relevant for spatial economy.

A farmer grows apples in the low-price countryside and sells them on the high-price market in town. As the production cost is lower in the countryside, the farmer can reap a profit B from selling them in town. His value-added or profit will increase (B+B') if he produces apple cakes and sells them in town.

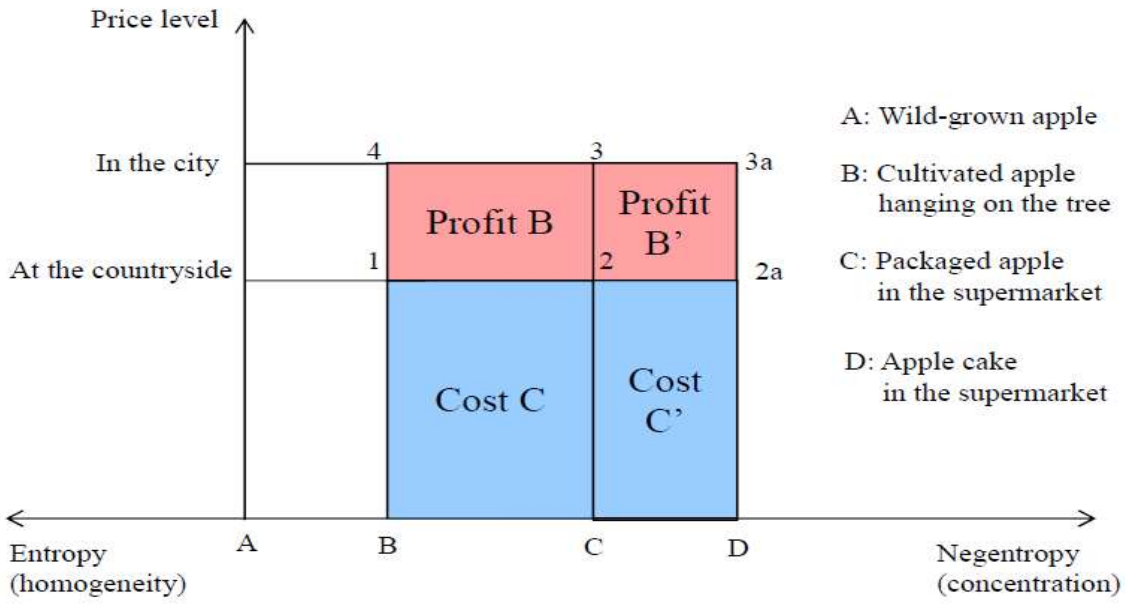

Figure 93: Generating profit from price differential
Source: Defilla WEO 82(2007) p. 221, translated from Russian

The horizontal axis in the figure shows the degree of concentration (negentropy) which increases along the value-chain from point A (wild-grown apple) to B (cultivated apple hanging on the tree), C (packaged apple in the supermarket) and D (apple cake in the supermarket).

Since the middle of the 20th century, economic theory has started expressing almost all its main ideas in terms of game theory, developed by J. v. Neumann since 1928[156]. Two types of games are particularly important in economic analysis: Competitive zero-sum games and (non-)cooperative non-zero-sum games.

In competitive zero-sum games, the sum of gains of players is exactly equal to the sum of losses of players, e.g. in chess, where the gain of one player (+1) equals the loss of the other (-1), unless there is a draw situation ending in a tie (0 for each player). Competitive zero-sum games reflect the above-mentioned focus on exchange economy. They have been widely used in economic analysis. They characterize the so-called Pareto optimality or Pareto efficiency which is a state of allocation of resources in which it is impossible to make anyone better-off without making someone worse-off. It is a triple efficiency:

- Efficiency of distribution of commodities among consumers: It is impossible to increase the utility of one consumer by redistributing goods without reducing the utility of another consumer.
- Efficiency of allocation of production factors among producers: It is impossible to increase the profits of one producer by reallocating the production factors without reducing the profits of another producer.
- Efficiency in the composition of the production mix: the production mix satisfies the tastes of the consumers in the best possible way.

To be Pareto-efficient, markets must be “ideal” and satisfy a certain number of conditions such as: perfect competition (i.e. have an infinitely large number of players), perfect information (no information advantage of sellers over buyers), no cost for entry or exit of any market player, absence of transaction costs, perfect mobility of production factors (capital and labour) between producers, perfect substitution of all products among each other (i.e. every producer produces the same consumer basket of goods), perfect substitution of all firms among each other, and internalization of all external effects (costs and profits). Furthermore, as Pareto efficiency is characterized by a zero-sum game, there is no economic growth and no technological progress.

Box 5: Hypotheses underlying Pareto efficiency

Moreover, Pareto efficiency is a necessary, but not a sufficient condition for describing social welfare. Many attempts[157] have been made to search for the missing function that could complete this framework to become a social welfare framework. Arrow discovered in 1950[158] that the Pareto framework cannot be completed by a social welfare function as the Pareto framework uses ordinal utility or preference functions. For specifying a welfare function that fits into the Pareto framework, it would be necessary to use cardinal utility functions.

The Pareto hypotheses are so restrictive that they can only be applied to specific contexts, but hardly to the global economy. A major progress was made by disaggregating enterprises to allow distinction between categories of producers. This research was made during the middle of the 20th century with the pioneering input-output analysis by Leontief[159],[160] who disaggregated the American economy into 500 branches and introduced the use of matrix representation, linear programming and computers to model the interdependence between these branches.

Non-cooperative games described by John F. Nash in 1950[161] characterize the global economic process better than zero-sum games. In this category of games, each player decides independently of the others and has an equilibrium strategy that is known to the other players, but players only gain if all of them cooperate.

Non-cooperative games can be illustrated by some well-known situations such as the famous prisoners’ dilemma: Two prisoners in separate cells are both sentenced to imprisonment but offered reduction if they betray their fellow by convincing prosecutors of their innocence and of the guilt of the other. If both are, however, found guilty, then the prison term is higher for both. The game-theoretic solution predicts that in this situation selfish behaviour will prevail, entailing that both will betray each other and receive heavier sentences than if they would not betray each other (i.e. cooperate). Cooperation, thought unlikely, would lead for both to have further reduction of both their sentences. The term “non-cooperative” has been chosen to emphasize that cooperation is unlikely as the outcome for any player only improves if all players cooperate. If only one player fails to cooperate, the outcome for all will be bad. All “non-cooperative” games are also “cooperative games” as they always include a special outcome when cooperation among all players takes place. Further down, “non-cooperative” games will be called “cooperative games” as they not only allow for cooperation, but such cooperation also improves the outcome of players.

Box 6: Prisoners Dilemma illustrating non-cooperative games

It would be interesting to find out what type of game “Sustainable Development” is or should be. Games can be characterized according to whether their design allows that no player, one player, many players and/or all players can win, and whether teams are known and fix throughout the game, or known and dynamic, or hidden, or whether no teaming is possible. With all these distinctions there is a considerably large spectrum of possible strategy games. No universal typology of these games has been made yet. Some game practitioners divide strategy games into four basic categories: competitive, cooperative, collaborative and quasi-competitive games[162].

In this typology, competitive games are those games whose design makes it impossible that no player wins, and equally impossible that all players win. Hence, some players must win, and others must lose. Either only one player wins (competitive one-winner games, e.g. chess or monopoly) or more than one player (i.e. one team) wins, and all the others lose. Depending on the type of partnerships and alliances, there are at least eight sub-categories as the figure below shows.

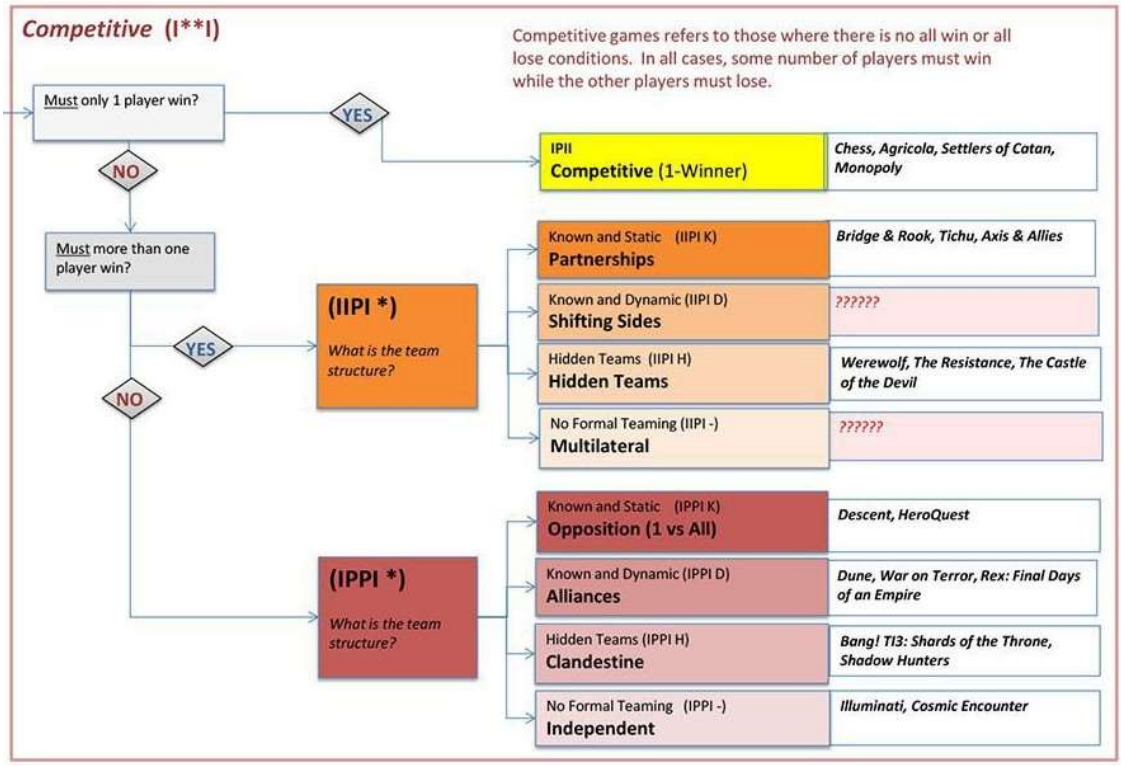

Figure 94: Competitive games
Source: Boardgame geek

The second category, cooperative games, are those games whose design makes it possible that either no player wins or that all players win. If in a cooperative game, players can only either all win or all lose together (prisoners’ dilemma), the game is a true cooperative game in the sense of this typology. The reader should be reminded that, even though games of the prisoners’ dilemma type mark a progress in comparison to competitive games for describing economic behaviour, such non-cooperative games still do not accurately describe actual human behaviour, but only selfish human behaviour under absence of an external authority enforcing rules. In fact, humans show a high degree of cooperative and self-

organizing behaviour, depending on each situation. Cooperative behaviour is exemplified in the numerous bottom-up initiatives aiming at eliminating unsustainable behaviour.

True cooperative games are a sub-category of cooperative games. If the design of a cooperative game is such that it is impossible for a group of players to win, whereas the game allows for no player, one player or all players to win, it is a single winner cooperative game. Cooperative games contain as sub-category also the games whose design allows that either no player, one player, a group of players or all players win. This design is the most open or least restrictive design, in which not the game designer, but only the strategy of the players determines which of the above outcomes will materialize (no player, one player, a group of players or all players win). For this reason, the general term “non-cooperative games” designs also cooperative games.

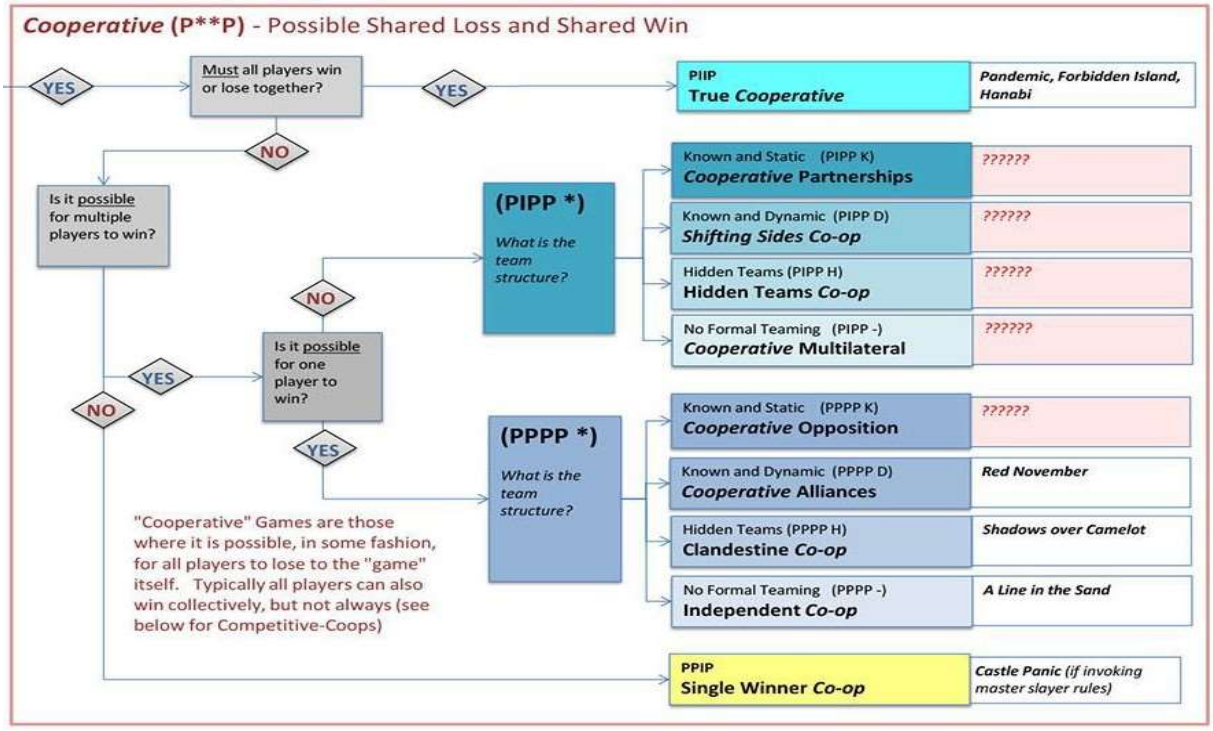

Figure 95: Cooperative games
Source: Boardgame geek

Collaborative games are games whose design allows that no player wins, but not that all players win. Sub-categories of collaborative games are games where multiple (but not all) players may win (containing eight sub-categories of collaborative interaction), or where only one player may win (competitive collaboration games), or where everybody always loses (a kind of Russian roulette, not shown in the figure below).

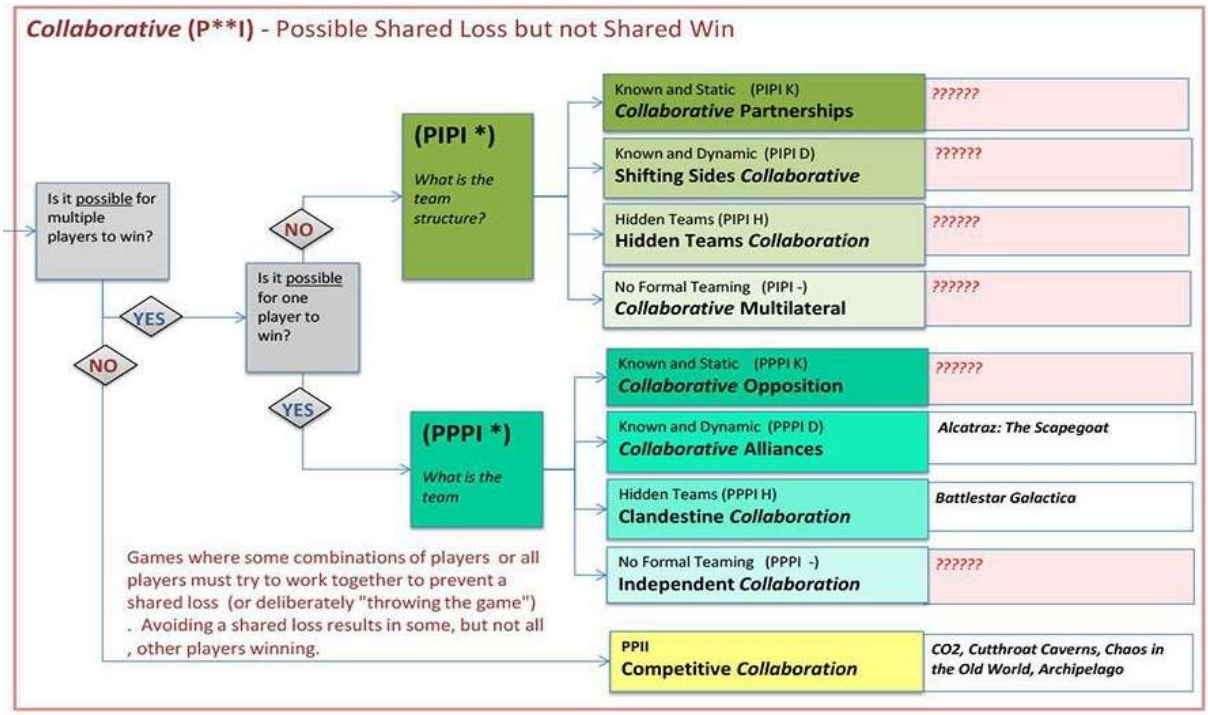

Figure 96: Collaborative games
Source: Boardgame geek

Quasi-competitive games are games, whose design makes it impossible that no player wins, but allows for either a single player, a group of players or all players to win. This category includes as special category the dummy games where everybody always wins (not shown in the figure below).

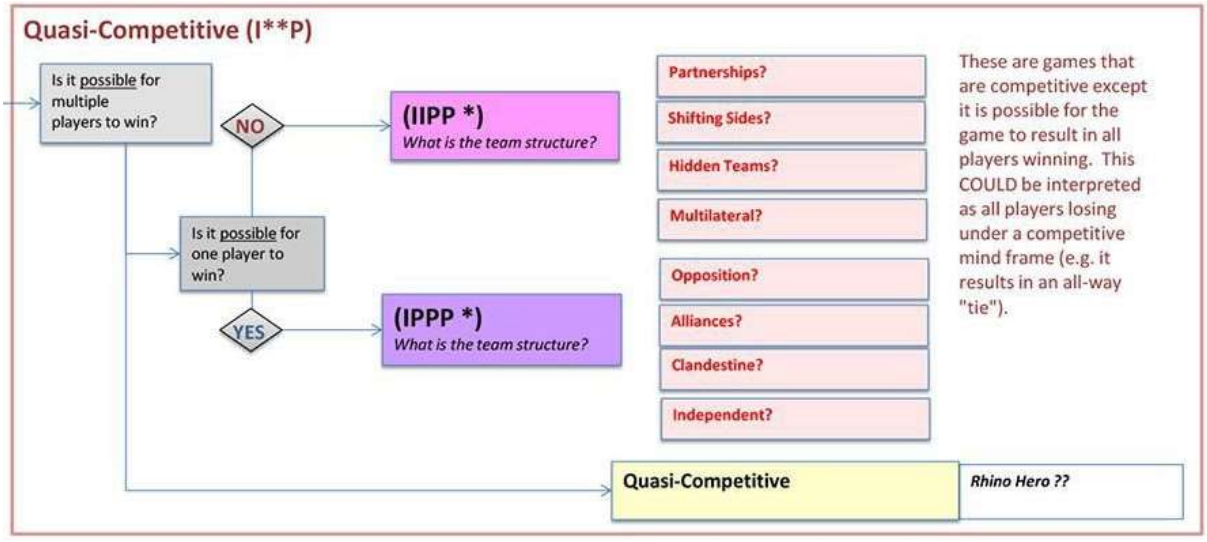

Figure 97: Quasi-competitive games
Source: Boardgame geek

When defining what type of game sustainable development is in the sense of the above typology, it is important to distinguish between ever-lasting rules such as natural laws, and man-made rules. During the sustainability process, the first ones are fix, whereas the second ones may change. Sustainable development is a special game with a set of fix rules (natural laws) and a set of adaptive rules (man-made) that are part of the strategies of players.

The fix rules of a “Sustainable Development Game” do not exclude that nobody wins, nor that one player wins, nor that several players win, nor that all players win. For this reason, the fix rules are a cooperative game in the sense of this typology.

The framework of the true cooperative game (prisoners’ dilemma) is, however, too narrow to describe the fix rules of sustainable development at global scale. In global sustainable development, the fix rules do not have as consequence that if only one player fails to cooperate, the outcome will be the worst case for all the players. Usually, some players can still cooperate among themselves in view of improving their outcome, independently of the action of other non-cooperative players. Possibly cooperation among players may even improve the outcomes of non-cooperating players as a spill-over effect, or the action of non-cooperating players may deteriorate the outcome of cooperating players.

In order to avoid spill-over effects, the adaptive or man-made rules of the “Sustainable Development Game” could provide for ways how cooperating players interact with non-cooperating players. While it is certainly desirable that man-made rules provide for inclusion of cooperating players, these rules may be less inclusive for players that do not show enough willingness to cooperate.

These questions are examined by using two real-life examples below. These examples are usually described in literature in terms the narrow frame of non-cooperative games or prisoners’ dilemma situations. For reasons of simplicity, they will be considered hereafter in these terms, even if the reality would require using the broader framework of cooperative games in the sense of the above typology.

(2) Economy also contributes to the analysis of sustainable development by defining internalization of externalities as key principle for making markets more efficient. Hereafter, the meaning of internalization of externalities will be shown on two real-life examples: The Tragedy of the Commons, and the Braess’ Paradox.

The Tragedy of the Commons[163] is an important real-life example of a non-cooperative game. This designates the different forms of (mis)management of so-called common pool resources (CPR) which are publicly owned (in contrast to privately owned) natural resources. Such resources can be found in the lithosphere, the hydrosphere, the atmosphere and the biosphere. Overuse designates either a too high volume of resource use, or a too high volume of waste disposal in such a resource. Basically, the following mechanism creates a situation of overuse along the following principles:

Every producer knows that if there is overuse of the common resource, it will run out. Conversely, if all the producers could agree (i.e. cooperate) to use it at a sustainable level, it would last forever. If one producer starts to overuse the resource, he might think that it does not make any difference as he is the only one. As he earns money based on a common

resource, it becomes logical that all the other producers should do the same thing, allowing them, too, to earn as much as possible before the resource runs out.

Examples of overuse of common pool resources that are:

- The gold rush (overuse of the lithosphere),
- pollution of rivers, lakes, groundwater aquifers and oceans (overuse of the hydrosphere),
- atmospheric pollution (smog, acid rain, ozone depletion and greenhouse gas effect, overuse of the atmosphere)
- all forms of overfishing, overhunting, uncontrolled logging or deforestation (overuse of the biosphere)
- congestions identified as overuse of a road network (overuse of public infrastructure).

All the five spheres (lithosphere, hydrosphere, atmosphere, biosphere, infrastructure) are affected by overuse. All these examples have in common to be based on externalities.

In economic theory, an externality (or external effect or spill-over effect) is any effect caused by a third party that impacts a market participant (producer or consumer) other than through prices. Externalities are a type of market failure that cause inefficient allocation of resources and should be internalized. Internalizing external effects means creating a way to reflect an external effect in prices. Externalities can be positive (external benefits, external economies or beneficial externalities) or negative (external costs, external diseconomies). An ideal way of internalizing negative externalities is shown by restaurants: The clients not only pay for food, but also for dishwashing which is included in the dish price. One can say that the clients who demand food as well as clean dishes, cooperate in some manner through the owner of the restaurant with the clients following them who otherwise would not have clean dishes. The result of cooperation is a payment included in the dish price. This is the simplest example to have in mind when internalizing negative externalities.

Box 7: Externalities

Any measure that successfully addresses the tragedy of the commons will bring users to cooperate in view of internalizing negative external effects caused by overuse of the resource. Where cooperation does not yield enough good results, the externality can be declared a public issue. Its internalization can then be done by the authorities by creating a cooperative or public body specially for this purpose. This body can be financed by an incentive (or Pigou) tax[164]. The level of incentive taxes depends on the behaviour to be changed, i.e. the quantity of excessive demand. The tax proceeds are either used to eliminate the harmful effects of the externality (e.g. for pollution), or, if there is no other harmful effect, they are neutrally redistributed to everyone, meaning that everybody should get back the same amount. The following explanations will help the reader to better understand what externality and internalization means.

Positive externalities:

- The typical phenomenon of positive externality is the free rider. The use of urban transport without paying for it cause the provider of urban transports to lack resources for providing adequate supply of services. Internalization means making the free rider cooperate and change behaviour or, if that fails, pay for transport and, possibly, pay a fine as contribution to cover the cost of ticket controlling.

- Other examples of positive externalities are public goods. Public goods are characterized by so-called non-rivalry (consumption by one consumer will not diminish consumption by another consumer) and by non-excludability (no consumer can be excluded from consuming it, even if he does not want it). Urban street lighting satisfies both criteria: If one pedestrian benefits from urban street lighting, this will not exclude any other pedestrian to equally benefit. Furthermore, a pedestrian will benefit from urban street lighting even if he does not want it (e.g. a gangster who in this case is free rider against his will). The main rationale for urban street lighting is to increase security at night. Public goods have no market. Internalizing public goods means that suppliers of public goods seek cooperation from demanders of such goods in form of voluntary funding. If that is not enough to allow sufficient supply, supply can be declared as public issue. Authorities can then levy a tax which all urban residents will have to pay.

No externalities:

- Natural phenomena such as sunshine are not externalities as they are not caused by third parties. This is true for any similar, mostly beneficial natural phenomena such as wind, rainfall, the flow of water in rivers, natural regeneration of wild fauna or flora, the natural decomposition and regeneration of waste. It is also true for harmful natural phenomena, such as earth quakes, weather storms and flooding, to the extent that these phenomena are not caused by third parties. Beneficial natural phenomena can be used on a commercial basis for increasing social welfare by concentrating their effect and making it useful for sale (e.g. wind turbines, solar panels, hydropower, irrigation systems, farms). Negative natural phenomena require producers and consumers to shield themselves from impact of these phenomena (e.g. earth quakes, weather storms, flooding) which should partly be done in the latter's own responsibility to the extent that these phenomena are not caused by third parties.

Negative externalities:

- Due to our lifestyle, the most important negative externality relates to pollution of commons (especially air and water). CO_2 emissions causing climate change, as well as other emissions into the atmosphere or hydrosphere impacting health or causing other damages are negative externalities as they have anthropogenic origin. The Stern Review on the Economics of Climate Change[165] concluded that climate change was the greatest market failure ever. Internalization of pollution externalities require cooperation between polluters and pollution victims. If that is not enough to allow eliminating harmful effects, a specific pollution can be made a public issue. Authorities can then then create a financially autonomous cooperative or public body tasked to clean up the pollution. It may levy an incentive (or Pigou) tax[166] from the polluters to eliminate harmful effects the pollution ("polluter pays" principle). Alternatively, it can compensate the pollution victims for the cost they incur to eliminate the pollution. For negative externalities such as smog, payment should include the part of health cost related to smog. For externalities such as pollution of freshwater or oceans, the polluters should pay for the additional cost of wastewater treatment and the additional cost of removing or neutralizing pollution and regenerating biosphere. For negative externalities such as climate change, payment should cover at least those adaptation measures shielding producers and consumers against more extreme or more frequent climate events ("mitigation pays adaptation").

- The overuse of biological resources through hunting, fishing and logging is a negative externality to the extent that the harvest of such a resource is larger than its natural regeneration. Internalizing these externalities requires producers to cooperate in view of restraining use of the limited resource by means of quotas, thereby creating homeostatic regulation (see above). If this cooperation is not enough, the overuse of the resource can be made a public issue. Authorities can then create a financially autonomous cooperative or public body for managing it. This body can sell harvesting permits (hunting, fishing or logging permits) whose price per unit harvested should depend on the amount of excessive demand. The sale of such permits is equivalent to levying an incentive tax. The tax should incentivize farming of such resources where it is technically feasible; farming would of course be exempt from the incentive tax. Surplus of proceeds from such incentive tax should be neutrally redistributed to the economy (producers and consumers) by reduction of tax burden.

- The (over)use of fossil resources (oil, gas, coal), as well as of any other minerals, metals (such as uranium) and stones is a negative externality as these resources regenerate much slower than their depletion, if at all. Internalization can only be partial. Producers are not expected to be able to cooperate sufficiently in view of restraining extraction to a sufficiently low level as almost any level is excessive. Authorities should declare this a public issue. They should oblige producers to pay for extraction permits whose price per extracted unit should depend on total demand. The sale of these permits is equivalent to levying an incentive tax. Producers should be incentivized to use renewable energy resources which are exempt from the tax. The payment of this tax ("oil rent, royalty") should go to a financially autonomous public body created specially to control extraction. As internalization is only partial, this body should be tasked to feed a financial asset compensating for the depleted geological asset satisfying at least weak sustainability as defined by Solow[167] (see further down). Proceeds of the sale of extraction permits should go to a resource fund for future generations, like a Sovereign Wealth Fund[168]; which should invest all its funds and only harvest interests or dividends. Interests or dividends should be neutrally redistributed to the economy (producers and consumers) by reduction of tax burden, after deduction of its own administrative cost. The transformation efficiency of oil funds depends on the oil price and has been estimated to be around 11%[169] (see further down).

- The use of geothermal energy is a negative externality to the extent that the amount of harvested energy exceeds the natural regeneration capacity of the soil which in global average amounts to only 0.087W/m^2 and is, therefore, very limited[170]. It may be much higher in volcanic areas. Users of high-temperature geological energy for electricity production should be made to cooperate in view of limiting resource use to the local regeneration rate. Where they use geothermal energy at a higher rate, they should pay a part of their receipts to a resource fund for future generations of the type described for fossil energies. Users of one-way geological low temperature heat pumps for space heating and warm water should pay a local incentive tax, incentivizing them to use reversible heat pumps (storing heat in summer and taking it in winter, which would be exempt of this tax) to avoid local exhaustion of the resource, as otherwise they deprive newly entering neighbours of this resource. The proceeds of this tax should be neutrally distributed by means of reduction of local tax.

- Where glaciers melt more rapidly under the effect of climate change, this is a negative externality as a freshwater storage is being depleted more rapidly than normal, creating the treat of potential future water shortage. Communities that are affected by these changes are victims of climate change and should be compensated from the public body tasked to eliminate the harmful effects of climate change as described above. They should use any compensation funds to develop technologies protecting glaciers. As long as these technologies do not show satisfactory effects, distributers of the associated supplementary water should be made to cooperate. The supplementary proceeds of using the associated water should be fed into a resource fund for future generations like the one described for fossil energies.

- Finally, the production of solid waste is a negative externality. Producers of solid waste should be incentivized to cooperate in order to produce less waste, or else pay a local incentive tax. The proceeds of an incentive tax should cover the cost of waste treatment. If waste treatment produces useful by-products such as heat or electricity, the incentive tax should be correspondingly lowered.

Sustainable Development Goals (SDG) as well as the Paris Climate agreement (see Chapter 3) can be considered as cooperative agreements concluded in response to various types of externalities or other market failures, even though they may still fall short of completely internalizing externalities. The process of specifically internalizing environmental externalities will eventually lead towards so-called environmental-economic efficiency.

Another important real-life example of a non-cooperative game is the overuse of road infrastructures and the forming of road congestions of the type that is explained by the Braess (or Braess's) paradox[171]. The Braess paradox states that adding a road to an existing road network can increase overall congestions. The Braess paradox was first described for a situation where a shortcut that was added to a route network, resulted in an increase (instead of a decrease) of traffic time for every user. In the pattern in the figure below, the addition of the short-cut (WE) causes longer journey times for everyone, which is paradox as a street has been added. The paradox has also been observed in the reverse situations when a road was closed, and this did not create any congestion.

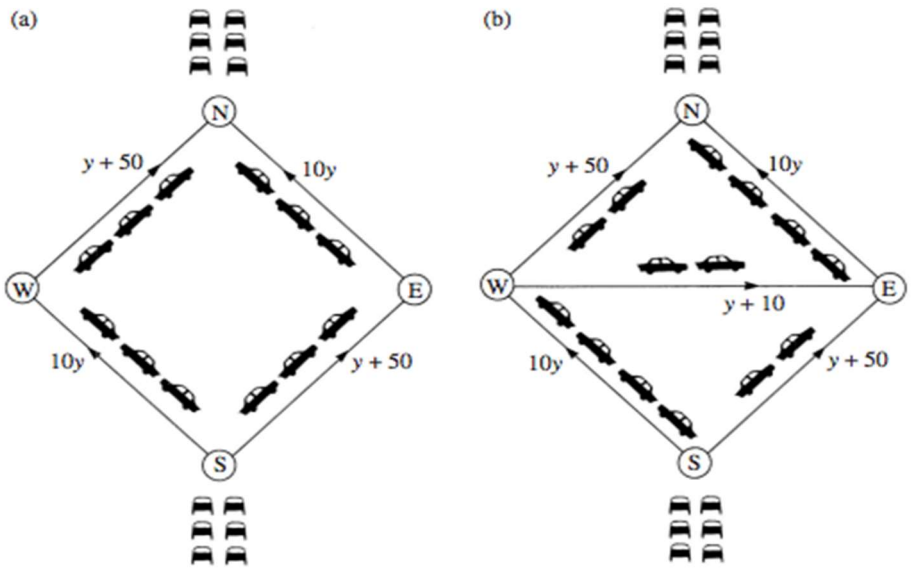

Figure 3 Braess's paradox. The addition of a link causes everyone's journey time to lengthen.

Figure 98: Design pattern that creates Braess' paradox
Source: *The Mathematics of Traffic in Networks*[172]

This paradox is the result of selfish behaviour in a non-cooperative game setting. To illustrate this paradox independent of road configuration in the more general setting of a non-cooperative game, take e.g. a two-lane highway narrowing down at a certain point to a one-lane highway. If drivers act in selfish behaviour according to the game-theoretical predictions, they will occupy the closing lane until the point where it merges with the other lane. This will cause a congestion at the bottleneck point. If, however, drivers act in cooperative manner and agree to quit the closing lane as early as possible, this congestion will not appear as the merger of the two lanes can spread over a long distance, thereby avoiding congestion at the bottleneck point and keeping the traffic fluid.

Braess' paradox has been empirically observed in several cities where roads were closed, but traffic did not become congested thereafter. The city of Seoul has closed the 16 lane Cheonggyecheon avenue and recreated the river as it existed earlier[173]. On each side of the river it has left a two-lane street. Simultaneously, public transport hubs have been increased, taking vehicles off the road. As a result, traffic became fluid again. Similar examples have been described for Rouen, France, where a bridge burned by accident, or Warsaw, Poland, where a bridge has been closed for repair. In both cases, no congestion appeared, hinting to the interpretation that the closed road section was superfluous. Some authors referred to the phenomenon of missing congestion as "evaporation" of traffic[174].

It has been shown that Braess' paradox is not only valid in human traffic, but in networks in general[175]. Electricity networks behave according to this paradox, as electrons have no cooperative behaviour. Therefore, the behaviour described in this paradox represents a general behaviour of complex flow networks in certain specific system design patterns.

Braess paradox is a challenge for city planners as it shows that adding more lanes and broaden transit avenues does not automatically improve congestion, measured in mean time to reach a given destination from a given starting point.

As Braess' paradox is the result of drivers' behaviour, it can be overcome by a change of behaviour. Congestions are created by selfish (or user-optimizing) behaviour in which travellers individually select their optimal travel routes. On the other hand, they are being avoided by cooperative (or system-optimizing) behaviour in which a central controller directs traffic[176]. One of the possible instruments of traffic control is an economic instrument, namely a peak load priced congestion toll which varies as a function of traffic density. If well-designed, such a toll would transform the drivers' selfish behaviour to cooperative behaviour. Other instruments such as mere "wisdom of crowd" have been suggested to address traffic congestions, but they would rarely suffice for these situations as car drivers are closed in iron cages that give them little possibilities to cooperate. Besides the economic instrument, there is a technological instrument consisting in the introduction of fully automated and connected self-driving vehicles. If such vehicles are connected by the Internet of Vehicles (IoV), they can be programmed to cooperative behaviour and offer great advantages in terms of decongestion of cities and avoiding Braess' paradox.

Braess' paradox could also be lessened by improving road infrastructure with the help of simulation tools. These could analyse and simulate the causes of congestions in view of eliminating them. Congestions are not simple aggregations of vehicles, but dynamic systems that have their own life. They can be stationary, i.e. remain at the same place, or they can move along a road with speed that is different from the mean speed of vehicles[177]. Congestions may form from specific obstacles on the road. Such obstacles can, however, be so small that congestions are almost self-organizing. They usually build up very rapidly, caused by very small and insignificant events, and decompose much slower. For this reason, these congestions increase the potential for road accidents.

4.2. Measurement Systems Supporting Sustainability

4.2.1. UN Integrated Environment-Economic Accounting

Economic analysis contributes to sustainable development by enlarging the UN System of National Accounts to the System of Environmental-Economic Accounts. The UN System of National Accounts SNA 2008 is the cornerstone for harmonized national economic accounting. While it had been developed for the economic sphere already since the second part of the 20th century, the corresponding accounting systems for the social and environmental spheres have been started considerably later. The absence of integrated accounting, including especially the environment, became evident during the Rio Earth Summit in 1992. Much of the substance that was being discussed in Rio was not yet measurable or, if it was so, then the measurements were only partial.

The most commonly used aggregate measure for economic activity and well-being is called the Gross Domestic Product (GDP) and derives from the System of National Accounts. Its most recent version dates from 2008 (SNA 2008) and was developed by the statistical division of the UN in cooperation with other intergovernmental organizations[178]. GDP is a frequently misunderstood concept, not because it is badly defined, but because the economy is a complex input-output system in which the cost of the ones is the revenue of the others. If that was the full description of the economy, would the economy therefore be a zero-sum game where the sum of all losses is equal to the sum of all gains? If yes, how can there be growth? And if there

is growth, how can the difference between non-sustainable and sustainable growth be measured?

The table below shows a highly simplified economy that is just enough complex to allow visualizing two of the tree definitions of GDP (expenditure and income approach). In this simplified table, the third definition of GDP (value added approach) coincides with the income approach. The table is a square table (same number of lines and columns) whose line totals are exactly equal to the corresponding column totals. The names of branches or aggregate agents are given in the first line or column in bold and underlined. Wherever the name of a column is different from the name of the corresponding line, it is because the table reflects conventional notation used in economics as this is close to everyday terminology. Receipts of branches are in columns, expenses in lines.

The most important column and line is the last one (**I** and **S**). This is not an aggregate agent but an accumulation account. The term **I** stands for investments and represents creation of fix capital and the increase of stocks, the term **S** stands for savings or profits and is the balance which is calculated as result of all the other terms, given that the line sum is always equal to the corresponding column sum. The table is expressed in terms of money flows. The sales of branch **A** to branch **B** (noted AB) is the product of the physical flow times the unit price of the good or service delivered.

The last column **I** accounts for net increase of stocks evaluated by physical counting as difference between closing stocks at the end of the year and opening stocks at the beginning of the year. The last line **S** notes the balance of all other terms for each agent, making that each agent's line total always equals his column total. The term SI is zero by definition.

Due to line **I** and column **S**, the economy is not a zero-sum game, but a non-zero-sum game that allows for growth. The simplest type of growth is the one originating from increased sales of products produced by intermediary branches **A**, **B** and **R** to the final sectors **G**, **C** or **X**. Thus, an increase of, e.g., energy sales AG, AC or AX increases G, C or X, respectively, and hence the GDP.

The internalization of negative externalities, as shown further above, does not alter the definition of GDP, as all the public or cooperative bodies in charge of internalizing externalities can be accounted for under line **T** and column **G**. Internalization is, however, likely to change the size of GDP as it changes some of its components. Internalization makes markets more efficient by increasing the well-being of some economic agents more than it decreases the well-being of other economic agents. In a first step, internalization is a transfer payment that impacts the surplus (S) of payers and of the receiving cooperative or public body, but not the total S. In a second step, the receiving cooperative or public body creates jobs ("the dishwasher") or transfers money to the impacted persons who will spend it on eliminating the negative effects. In a third step, behaviour (e.g. polluters behaviour) changes. As total economic losses of negative externalities outweigh their total economic benefits, eliminating negative externalities due to behaviour change results in net increase of welfare.

Take a simplified economy consisting of an aggregate branch **A** (e.g. energy and food producers), a branch **B** (all other industry except financial industry), **R** (financial industry), Government (all levels of government, being also the owner of natural resources, column **G** stands for government spending and row **T** for taxes), households (the labour-supplying branch, column **C** is household consumption and line **W** are wages), the rest of the world (column **X** for exports and line **Z** for imports) and an accumulation account (column **I** for investments and line **S** for savings and profits). Line **S** is also the balancing line making that all line-sums always equal the column-sums. AB shows supply from branch A to branch B, while the payment goes in reverse direction, etc. AV is the intermediary total of AA+AB+AR and gives the intermediary production of **A**. The Leontief matrix of intermediary production is the light grey matrix. AU is the intermediary total of AG and AC. Total output of branch **A** is A in column **SUM**. Likewise, for the vertical sums: AG+BG+RG=G, TG+WG=UG, etc.

	A	**B**	**R**	**V**	**G**	**C**	**U**	**X**	**I**	**SUM**
A	AA	AB	AR	AV	AG	AC	AU	AX	AI	A
B	BA	BB	BR	BV	BG	BC	BU	BX	BI	B
R	RA	RB	RR	RV	RG	RC	RU	RX	RI	R
V	VA	VB	VR	VV	G	C	VU	X	I	V
T	TA	TB	TR	T	TG	TC	TU	TX	TI	T
W	WA	WB	WR	W	WG	WC	WU	WX	WI	W
U	UA	UB	UR	UV	UG	UC	UU	UX	UI	U
Z	ZA	ZB	ZR	Z	UG	ZC	ZU	ZX	ZI	Z
S	SA	SB	SR	S	SG	SC	SU	SX	0	S = I
SUM	A	B	R	V	T	W	U	Z	I = S	TOT

Matrix representation of the economy
Source: own work

The GDP, noted Y, is defined in three ways; in this simplified table, only two definitions can be represented as distinct definitions:

Expenditure approach: $Y = G + C + X - Z + I$

Income and Value-Added approaches: $Y = T + W + S$

The equality of both is easily seen by considering

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

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

All these aggregates are flows, expressed in monetary units, measured on annual basis. The different types of capital stocks are only captured in their annual increase as written in column I (investments).

Box 8: GDP made easy

The GDP is an appropriate measure for evaluating value-added of an aggregate production-consumption system. The example of energy sales just above witnesses that it does, e.g., not distinguish between renewable and non-renewable energy. This distinction should not be made by a change of definition of GDP, but (1) by internalizing externalities, see above, and (2) by widening the SNA to the more complex System of Environmental and Economic Accounting SEEA allowing to measure the aggregate closing stocks (see hereafter).

Agenda 21, proclaimed in Rio in 1992, called for the development of an internationally standardized approach to integrated economic and environmental accounting. Early works were the 1993 Handbook of National Accounting: Integrated environmental and economic accounting (SEEA 1993) and its successor that followed ten years later (SEEA 2003). It has taken almost ten more years for the six leading statistical organizations of the world (UN; European Commission, FAO, OECD, IMF and World Bank) to publish the first international statistical standard for environmental-economic accounting (SEEA 2012). As a matter of fact, it is notably coherent with the System of National Accounts SNA (2008), the International Standard Industrial Classification of all Economic Activities (ISIC) and the Central Product Classification (CPC).

The SEEA Central Framework is based on standardized concepts, definitions, classifications and accounting rules. As an accounting system, it enables the organization of information into tables and accounts in an integrated and conceptually coherent manner. This information can be used to create coherent indicators to be used to inform decision-making and to generate accounts and aggregates for a wide range of purposes.

And yet, the SEEA 2012 is not yet a finished product. Its annex 2 contains areas for further research. One of the still important critical areas is the full valuation of assets and flows related to natural resources and land beyond the valuation included in the SNA. Furthermore, while the SEEA 2003 included marine ecosystems and atmospheric systems within its assets, the SEEA 2012 does not include oceans and the atmosphere, except in specific assets (e.g. fish stocks attributable to economies based on international agreements on access rights). The overall scope of the asset boundary of SEEA 2012 is narrower than in SEEA 2003.

SEEA 2012 requires depletion of non-renewable resources to be recorded as a deduction from income in the production accounts, generation of income accounts, allocation of primary income accounts and distribution of income accounts, in a manner like that in which the deduction for consumption of fixed capital is made in the SNA. SEEA 2012 abolishes the earlier distinction between proven resources, probable resources and possible resources and uses instead the UN Framework Classification for Fossil Energy and Mineral Reserves and Resources (UNFC-2009).

United Nations Committee of Experts on Environmental-Economic Accounting will further develop the system in the years to come. As research is still in progress, the future editions of the SEEA might require a profound reshuffling of basic concepts to be in line with new research.

An example, relevant for urbanization, is given below in the land cover change matrix. All the entries are measured in ha. The urban land is the line and column called « artificial surfaces ». In this example, the newly urbanized land is registered in the second last column (183 ha), adding to the opening stocks (12'292.3 ha) at the beginning of the period to give the total of 12'475.3 ha at the end of the period. The table shows what other land stocks have decreased in this example (crops, grassland, mangroves). The classification system for land

cover (lines and columns of the table) is based upon the Land Cover Classification System, version 3 (LCCS 3) of the FAO (FAO, 2009).

Land cover	Opening area	Increases (positive numbers) and decreases (negative numbers) from other land covers											Net change (increase –decrease)	Closing area
		Artificial surfaces	Crops	Grass land	Tree-covered area	Mangroves	Shrub-covered area	Regularly flooded areas	Sparse natural areas	Terrestrial barren land	Permanent snow, glaciers and inland water bodies	Costal water and intertidal areas		
• Artificial surfaces	12 292.5		147.0	27.0		9.0							183.0	12 475.5
• Crops	445 431.0	-147.0		4 677.0	3 118.5		1 560.0	1.5					9 210.0	454 641.0
• Grassland	106 180.5	-27.0	-4 677.0			9.0	69.0						-4 635.0	101 545.5
• Tree-covered area	338 514.0		-3 118.5										-3 118.5	335 395.5
• Mangroves	214.5	-9.0										-1.5	-10.5	204.0
• Shrub-covered area	66 475.5		-1 560.0	-69.0									-1 629.0	64 846.5
• Regularly flooded areas	73.5		-1.5										73.5	72
• Sparse natural areas	1 966.5													1 966.5
• Terrestrial barren land														
• Permanent snow, glaciers and inland water bodies	12 494.5													12 949.5
• Costal water and intertidal areas	19 351.5												1.5	1.5

Table 10: Example of land cover change matrix in the SEEA 2012
Source: SEEA 2012

The SEEA allows calculating some important concepts that have been outlined in the preceding sections, such as estimating the resource rent, which is the operating surplus from harvesting natural resources. For natural resources such a forests or fishery, it allows estimating the asset life. If a renewable resource is to be preserved in perpetuity, the harvest should not exceed the renewal rate of a stable resource, i.e. sustainable yield. If the density of e.g. a fish resource decreases, the catch per unit effort (CPUE) also decreases. This can be traced back in the SEEA 2012 in the specific account. For finite natural resources, their net present value (NPV) can be calculated in analogous manner as it is being done for industrial investment projects or in the System of National Accounts SNA.

It can now be shown how the SEEA 2012 is an extension of the SNA. A very simplified SNA had been presented further above. That table showed the columns corresponding to industry (V), households (C), government (G), rest of the world (X) as well as produced assets (I). That table corresponds to the second line of the integrated account measured in monetary terms (table below): Intermediate consumption V, household final consumption expenditure C, Government consumption expenditure G, Exports X, Gross Capital I. The SEEA adds a supplementary first column (Product-supply) and a supplementary last column (Environmental assets). Furthermore, it adds first supplementary lines (Opening stock) and the third and following supplementary lines (Physical supply and use table). The dark grey fields are zero by definition. At the bottom right, the closing stocks appear.

Two APEC cities have adopted the SEEA: Yokosuka in Japan and Melbourne in Australia[179].

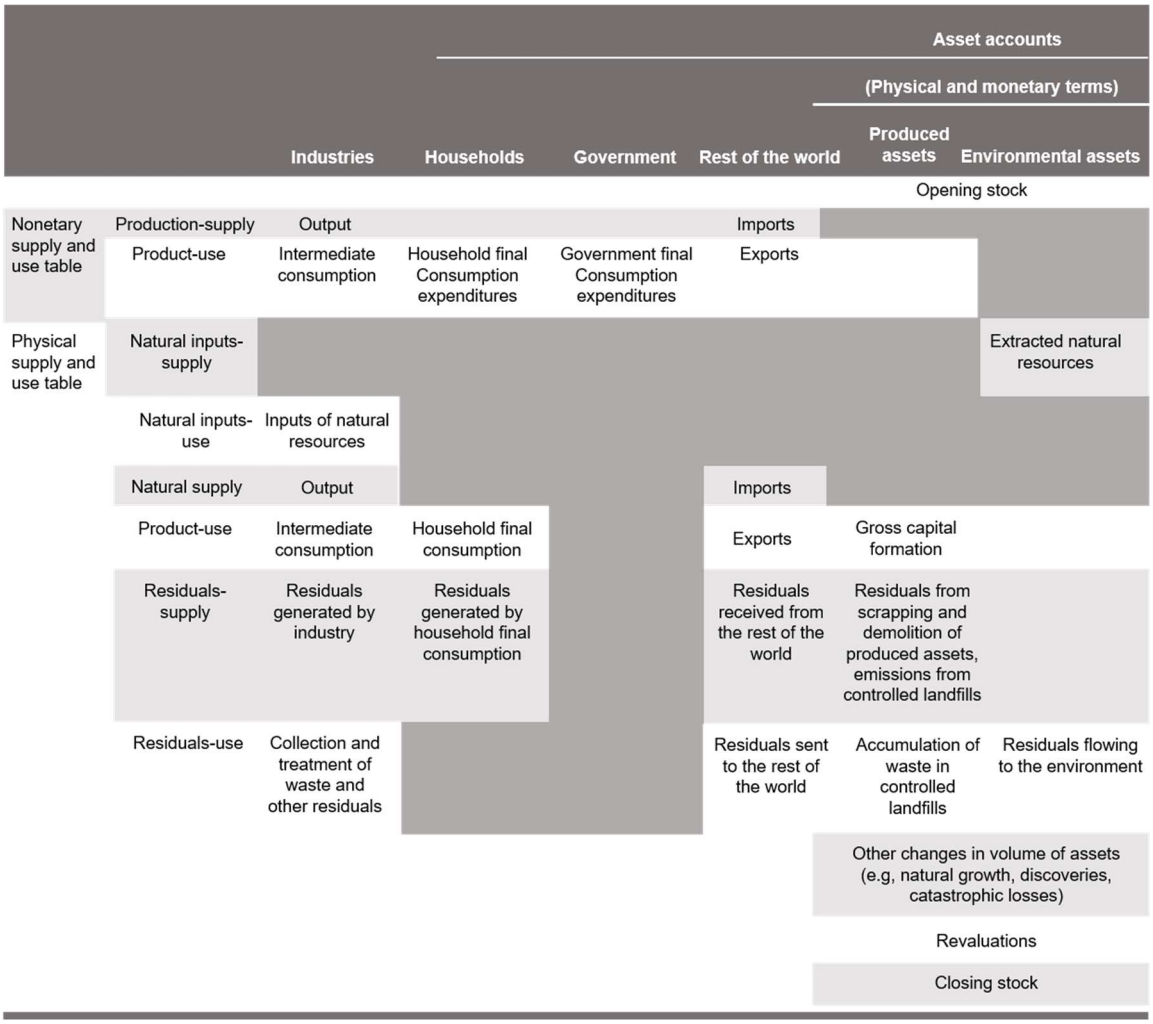

Table 11: Connection between the accounts
Source: SEEA (2012)

The SEEA 2012 incorporates the capital approach to Sustainable Development, as far as this approach gives feasible measurement results. Once the SEEA will be fully developed, it will totally integrate that approach. Scholars[180],[181] distinguish between the following different forms of capital.

Manufactured capital is the total of produced fix assets and infrastructures used by private or public enterprises in any way in the production process. For manufactured capital, the general principle of evaluating stocks is to use their production cost as starting point (initial price) and use the projected life span as end point, allowing to determine the annual amount of depreciation.

Human capital is the totality of human skills, but also the human health condition. Not to be underestimated is the motivation factor which also enters human capital and can alter it decisively. Human capital can also be evaluated using the production cost, which can be calculated from the cost of formal education, and a projected life span until the end of professional activity that can be used to calculate an annual write-off. Alternatively, human capital can be estimated using the value approach: if a given education offers a known specific incremental wage on the market, this increment can be used to calculate the value of such education. The annual increment can be considered as annual depreciation, so that the original

value of the human capital would be the sum of all annual depreciation amounts during professional activity.

The natural capital (lithosphere, hydrosphere, atmosphere, biosphere) contains all the "commons" that provide natural resources. The value of natural commons can, strictly speaking, only be measured once externalities of all these overused natural commons have been internalized one by one and each of the overused stocks has received a scarcity price. Before such internalization, an artificial price must be calculated, considering the natural regeneration speed and the demand of the resource. Living stocks should ideally be measured in vintages, i.e. annual generations, each of which is depreciated over the projected life span.

Social capital is the sum of social institutions such as families, communities, business enterprises, NGOs, public organizations such as municipalities, states, international organizations. If this can be measured at all and considered as stocks, it should follow a similar approach as for measuring the capital of enterprises. Families may own real estate or movable family property that can be considered as capital. Civil organizations may raise membership fees, part of which is not spent during the year and goes into capital-like reserves. Cities, communities and states are the sum of their constituents and, furthermore, may have their own infrastructures, natural resources, human and financial capital that are all evaluated as described.

Financial capital is the tradable form of all other forms of capital. It often bears a face value (e.g. of stocks, bonds, currencies, etc.), yet it has no value by itself, and its market value depends for more than other types of capital on "how the market" evaluates it and is, therefore, volatile. Given the tendency of markets to be gregarious, a sudden loss of confidence of opinion leaders towards a given category of financial capital can entail a panic movement and a "black Friday" event which will destroy trillions of dollars of assets within a few days. Market evaluation of stocks is not a zero-sum game. As all currencies are also financial assets when they are being traded on foreign exchange markets, they may be subject to the same gregarious behaviour.

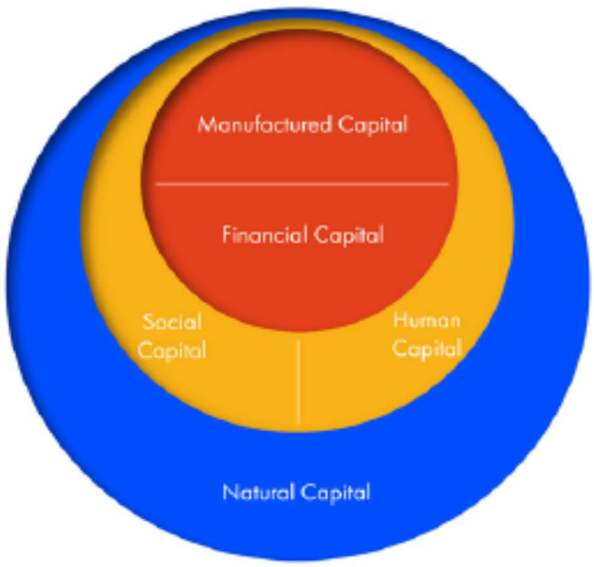

Figure 99: Five forms of capital
Source: Forum for the Future[182]

This section concludes by elaborating the distinction between “strong” and “weak” sustainability. Proponents of “strong” sustainability claim that each form of capital described above must be maintained without possibility of substitution among the various forms of capital. This is the rigorous form of sustainability. It allows for very little flexibility.

On the contrary, the proponents of “weak” sustainability express all forms of capital in money and, consequently, allow to freely substitute between the different forms of capital described above, if their (monetary) sum remains constant. Nobel Laureate Robert Solow[183],[184] has been one of the proponents of weak sustainability. Weak sustainability allows consuming natural resources to set up infrastructures, human capital or financial capital.

While weak sustainability allows for flexibility, it may be questioned how sustainable weak sustainability really is. If, e.g., natural resource assets are being transformed to infrastructures or human capital, these latter have depreciation rates having as effect that the infrastructure or the human capital disappears after some decades while the natural resource would have survived much longer. It has, therefore, been suggested to transform natural assets to financial assets which, in theory, could survive very long time. Examples of such assets are the funds for future generations that have been mentioned earlier.

The question is what proportion of the natural asset can really be transferred to a financial asset. As a matter of fact, only the resource rent can be stored in a fund, i.e. the surplus after deduction of production cost of a natural resource. If production cost is high or the market price of the raw material is low, only a fraction of the value of the natural resource can go into the financial asset. Hence, if the financial asset is used to buy back the resource, it will usually only be able to buy back a fraction of the original amount. The back-transformation from financial asset to natural resource will depend on the market price of the resource. In a pilot estimation[185] it has been shown that this transformation efficiency could be as low as 11%, meaning that 89% of the original value could be lost and that a fund for future generations could contain as little as 11% of the value of the original geological asset.

This transformation efficiency of 11% can be interpreted to show that the weak sustainability, while offering flexibility, is of lower quality than the strong sustainability which would maintain stocks of natural resources at the same level. More generally, this reflects the principle that for physical reasons, it cannot be possible to transform energy to money and back to energy without a kind of cost that is like an energy transforming efficiency and can never be 100%.

This transformation efficiency can also be used to make the relationship between the H indicator presented above (see section on physical and biological concepts supporting sustainability), and a similar indicator that can be derived from the SEEA.

The SEEA has an account called closing stocks, evaluated at the end of each year. This contains the total of all the stocks (economy and environment) at the time of closing. An indicator like the H indicator can now be constructed when the closing stocks of each year is multiplied by the corresponding year, and the sum of all these measures is taken for the whole life cycle of the system. This indicator should be named H’ as it is expressed in the unit [money x time]. This indicator is the weak sustainability indicator which corresponds to strong H indicator. The above transformation efficiency (11%), calculated for each year during the life cycle of the system, can be used to convert the indicator H’ to the indicator H, and hence to express H’ in terms of H.

4.2.2. The Evaluation System of the GCoM

The Global Covenant of Mayors for Climate and Energy Reporting Guidelines[186] are based upon the *Global Protocol for Community-Scale Greenhouse Gases Emission Inventories* (GPC)[187] elaborated by the World Resources Institute, the C40 and ICLEI. An executive summary is available online[188].

Strictly speaking, the GPC only applies to reporting the mitigation aspect. Reporting the adaptation aspect (Sendai Framework) follows different rules.

Pursuant to the GPC, cities measure and disclose a comprehensive inventory of GHG emissions and total these emissions using two distinct but complementary approaches. One captures emissions from both production and consumption activities taking place within the city boundary, including some emissions released outside the city boundary. The other categorizes all emissions into "scopes," depending on where they physically occur.

To use the GPC, cities first define an inventory boundary. This identifies the geographic area, time span, gases, and emission sources, covered by a GHG inventory. Any geographic boundary may be used for the GHG inventory. Depending on the purpose of the inventory, the boundary can align with the administrative boundary of a local government, a ward or borough within a city, a combination of administrative divisions, a metropolitan area, or another geographically identifiable entity. The GPC is designed to account for GHG emissions in a single reporting year and covers the seven gases covered by the Kyoto Protocol. The GPC divides emissions into six sectors, of which the following sub-sectors are distinguished:

Figure 100: Sectors and Sub-Sectors of CO2-emissions in the GPC
Source: World Resources Institute

A very important further distinction is made by attributing all the emissions to one of three scopes, defining where they occur:

- Scope 1: GHG emissions from within the city boundary
- Scope 2: GHG emissions occurring as a consequence of the use of grid-supplied electricity, heat, steam and/or cooling within the city boundary
- Scope 3: All other GHG emissions that occur outside the city boundary as a result of activities taking places within the city boundary

The distinction of scopes captures the fact that cities emit greenhouse gases not only within their geographic boundaries, but also outside, and it furthermore establishes the distinction between grid-bound transfer of the attributable emissions and other type of transfer of such emissions. The careful distinction between scopes avoids double-counting or omission of counting in case of economy-wide implementation of this scheme for all communities. The GPC has been specially created for allowing aggregation of local GHG emission inventories at all higher levels.

For most emission sources, cities estimate GHG emissions by multiplying activity data by an emission factor associated with the activity being measured. Activity data is a quantitative measure of a level of activity that results in GHG emissions taking place during a given period (e.g., volume of gas used, kilometres driven, tonnes of waste sent to landfill, etc.).

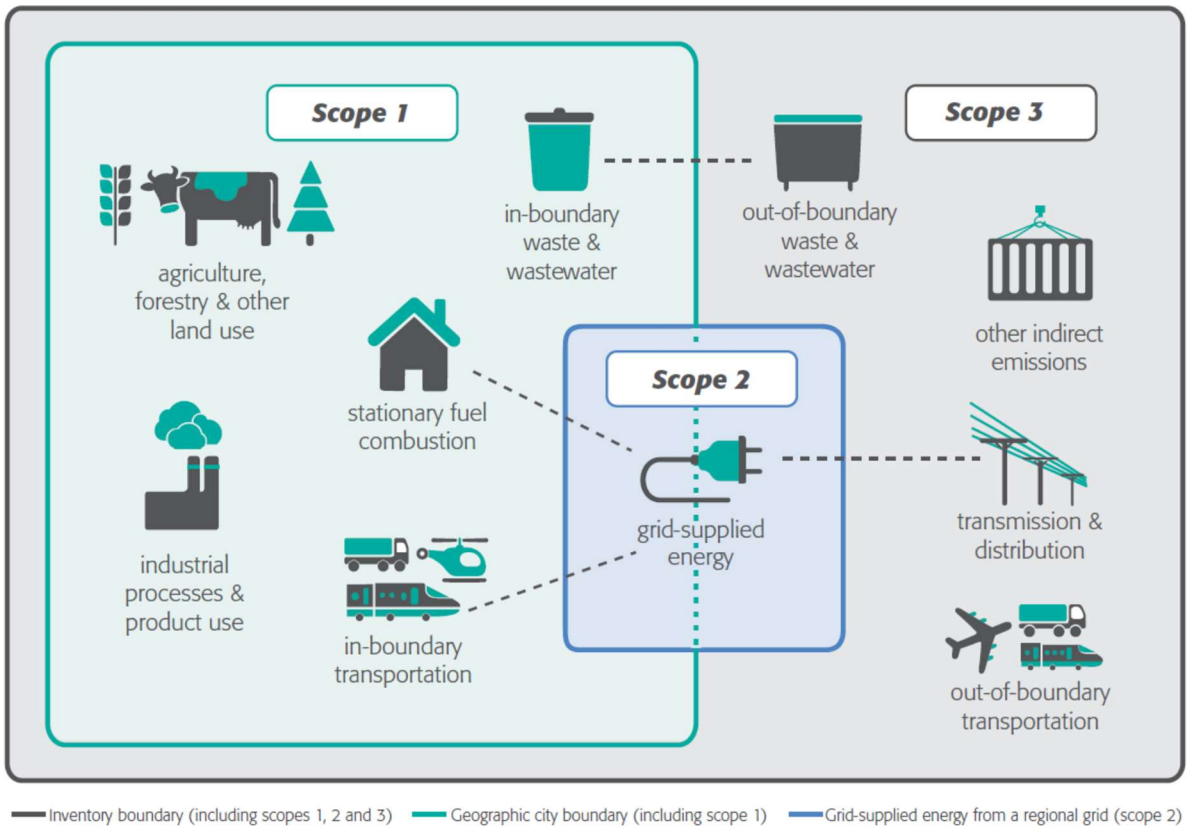

Figure 101: Distinction of CO2 emissions by scope
Source: World Resources Institute

The Global Covenant of Mayors for Climate and Energy (GCoM) goes beyond the GPC in the sense that it requires the adhering cities not only to fill in the baseline emissions inventory (BEI) corresponding to emissions of the base year, but also to make a Climate Risk and Vulnerability Assessment (RVA). As the aim is to improve the sustainability of cities for both these dimensions, the cities adhering to the GCoM take the engagement to formulate a Sustainable Energy and Climate Action Plan (SECAP) allowing them to fix reduction targets, formulate strategies of how to attain them and to monitor progress. All this can be done by filling in excel tables. As a rule, the cities' reduction targets and action plans for mitigation / low emission development should be quantified so that they can be made consistent with, or exceed, relevant commitments defined through the relevant UNFCCC Intended Nationally Determined Contribution (INDC).

For making the Climate Risks and Vulnerabilities Assessment (RVA), the city will make reference to any extreme weather event in the past that is attributable to climate change. It will specify the arrangements in place for risk management, post-disaster recovery and reconstruction and describe how it captures lessons learned after an extreme weather event has taken place, or whether there is a process of embedding lessons learned into planning or longer-term adaptation strategy in order to reduce the impacts of such extreme weather-related damages in the future. Cities also indicate investments made for mitigating the risks after extreme climate events.

Some examples of indicators include of Climate Risk and Vulnerability are:

- Vulnerability-related indicators
  - Number of days/nights with extreme temperature
  - Frequency of heat/cold waves
  - Number of day/nights with extreme precipitation
  - Number of consecutive days/nights without rainfall
- Impact-related indicators
  - Number or percentage of (public / residential / tertiary) buildings and other (transport / energy / water / ICT) infrastructures damaged by extreme weather conditions/events
  - percentage of grey/blue/green areas affected by extreme weather conditions/events
  - Number of days with public service interruptions

As extreme climate events are each very different in their type and in their impacts upon built or natural environments, it is not possible to use standardization for these events as it can be done for CO2 emissions.

4.2.3. The Index System of APEC Low Carbon Town LCT-I

For the development of the Low-carbon town concept, APEC has elaborated a specific index system LCT-I[189]. The concept is designed to be as simple and as user-friendly as possible for practitioners in order to allow as many as possible Low-Carbon towns to emerge in the APEC region. The indicators should also reflect the specific circumstances of each APEC economy as well as the characteristics of each project.

The LCT-I reflects international best practices such as those developed by the International Standardization Organization ISO in Technical Committee 268 and the OECD and uses existing indicators such as CASBEE as reference.

The LCT-I system is a self-assessment tool that can be used in each department involved in a Low Carbon Town project, and at each development phase (conceptualisation, planning, implementation, maintenance and management) of the project.

It is hoped that the LCT-I system will help lower the project risks, improve the rating by financial agencies and thereby help to attract investors.

Four types of communities can be assessed: Central Business Districts (CBD), commercially oriented towns, residentially oriented town, and rural area or islands.

The system comprises three tiers, divided into two groups: directly related to energy usage (first three indicators of tier 1) and indirectly related to energy usage (the fourth and fifth indicators of tier 1). The LCT-I system contains a total of 14 tier-2 indicators and 23 tier-3 indicators, see figure below.

Depending on the assessment area, the levels are assessed using either a five-level or a three-level score. Where uncertainty is too large, no score is given.

The LCT-I also contains a detailed methodology for the calculation of the CO2-emissions which is based upon the IPCC guideline:

(http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html) and the ISO 14064 standard about the estimate, the report and the verification of GHG emissions and reductions: (http://www.iso.org/iso/catalogue_detail?csnumber=38381).

This system is divided in three parts: Industry, transport and absorption.

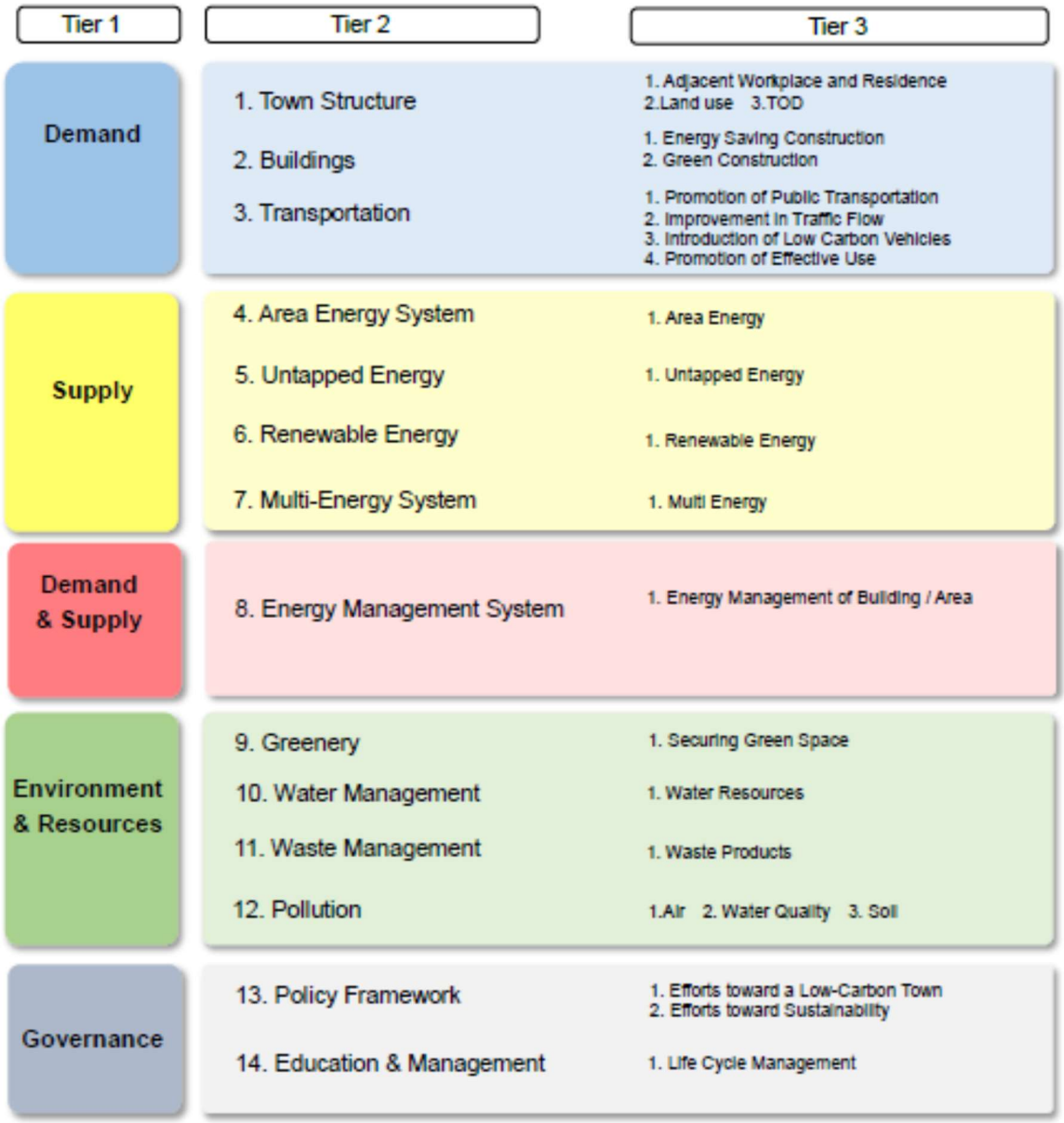

Figure 102: Three tiers of the LCT-I assessment tool
Source: APEC Energy Research Centre APERC

Without going into detail, the basic idea of the tier-3 indicators is given in the table below:

3-tier indicator	**Is highest if:**
Adjacent workplace and residence	A CBD-building has at least 30% residential floor area
Efficient land use	Floor area ratio exceeds the standard floor area ratio
Transit Oriented Development (TOD)	Upper-level plans exist to concentrate residential and non-residential districts within 750 to 1000 meters from public transit hubs

Energy saving construction	Systems, standards or regulations and incentives are in place to evaluate and implement energy-efficient buildings or their equipment or use of passive energy
Green construction	Guidelines have been implemented and incentives exist
Promotion of public transportation	90% or more of the target area is in walking distance from public transport and if 5 or more measures for public transport are in place
Improvement in traffic flow	Five or more transportation demand management (TDM) are in place and plans for road improvement have mostly been implemented
Introduction of low-carbon vehicles	Subsidy schemes are in place for low-carbon vehicles
Promotion of effective use	Eco-driving plans and incentive schemes are in place
Area energy	70% or more of the annual air-conditioning costs are covered by area energy (district cooling)
Untapped energy	More than 5% of annual electricity or thermal energy costs are covered by untapped (recycled) energy
Renewable energy	15% of annual electricity/thermal energy are covered by renewable energy
Multi-energy	CHP (combined heat and power) introduction plans have been implemented and incentives for extension exist
Energy management systems (EMS) in buildings and areas	EMS or Area-EMS and smart micro-grids have been implemented and incentives exist
Securing green space	60% or more of the target area has green shade from trees, and ratio of greenery + water surface to total constructed surface is 40% or higher and efforts exist to go higher
Water resources	Efforts are being made and reduction goals and fiscal measures to implement water consumption in buildings are in place, and rainwater is being used, and recycled wastewater is being used in over half the facilities and incentives are in place
Waste products	Waste reduction goals have been established and measures enacted, and separation is performed and efforts to improve exist
Air	Exhaust gases from facilities and vehicles are regularly checked, and goals for further improvement have been established
Water	Regular checks of facilities where pollution is expected, and goals to prevent pollution have been established
Soil	Regular checks of facilities where pollution is expected, and goals to prevent pollution have been established
Efforts towards low-carbon town	Policies, plans, goals and efforts are in place, and budgets have been secured and efforts (e.g. newsletters) have been performed
Efforts towards sustainability	Business Continuity Plan/Life Continuity Plan/disaster prevention and response plans have been established in more than half the area, and

	regulations for Less Impact on Natural Environment exist and development under such regulations has been completed
Life Cycle Management	Efforts in enlightenment and education for energy savings and low-carbon town are being made and budgets for continuous management have been established, and community associations or area management organisations are established or planned

Table 12: The LCT-I Indicators

Based on the scores of the 3-tier indicators, the five 2-tier indicators are calculated and mapped in a radar chart. The methodology allows calculating a total number of points for the community.

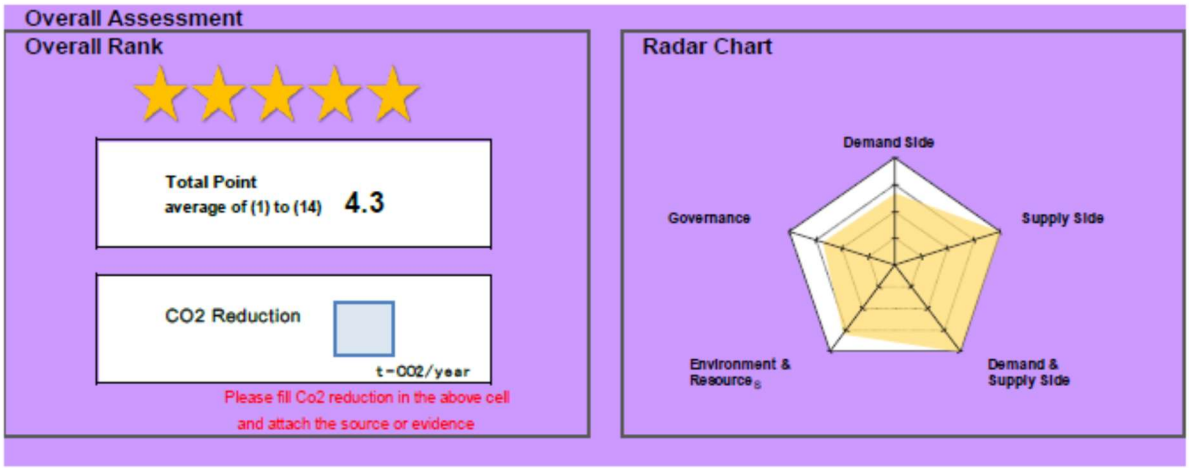

Figure 103: Radar chart and overall assessment of the LCT-I
Source: APEC Energy Research Centre APERC

The 3-tier indicators are primarily applicable to a district or a group of houses. They may not really be applied to entire cities.

4.2.4. Other Index Methods for Measuring Sustainability

Besides cardinal measures of sustainability like those introduced in the previous section, and the LCT-I index, a great number of indices have been proposed to measure sustainability of cities. The Achilles heel of indices is that they require assigning arbitral weights to the different components that are integrated into these indices. Indices are very sensitive to the choice of weights of their components. Nonetheless, indices can be helpful in assessing the multi-dimensional aspect of sustainable development and measure some form of “strong” sustainability, provided that not only the totals of indices are used, but also their components are considered and mapped into graphics.

The City Development Index is one of the global urban indicators often used in the framework of UN Habitat[190]. Its formula is given below. Remark that this index does not include the economic dimension and can, therefore, hardly be qualified as a sustainability index.

Index	*Formula*
Infrastructure	*25 x Water connections + 25 x Sewerage + 25 x Electricity + 25 x Telephone*
Waste	*Wastewater treated x 50 + Formal solid waste disposal x 50*
Health	*(Life expectancy - 25) x 50/60 +(32 - Child mortality) x 50/31.92*
Education	*Literacy x 25 + Combined enrolment x 25*
Product	*(log City Product - 4.61) x 100/5.99*
City Development	***(Infrastructure index + Waste index + Education index + Health index + City Product index) / 5***

Figure 104: Components of the City Development index
Source: UN Habitat

Another index, the City Prosperity Index, has been proposed in 2012 by the City Prosperity Initiative and is described in the SDG 11 Global Synthesis Report 2017 Tracking Progress towards Inclusive, Safe, Resilient and Sustainable Cities and Human Settlements, compiled by UN[191].

Figure 105: Linkages between the SDG11 and the City Prosperity Index CPI
Source: SDG11 Synthesis Report, UN Habitat, 2017[192]

City Prosperity Index is a composite index based on six dimensions (infrastructure development, productivity, quality of life, equity and social inclusion, environmental sustainability, governance and legislation) and 15 sub-dimensions. A link to other SDGs can be made and is shown in the same figure. The particularity of the CPI index is to integrate all ten goals of SDG 11. For that reason, and also because the six CPI dimensions include more than the three dimensions of sustainability (see e.g. the sixth dimension), the CPI has the potential to be a global monitoring platform for SDG 11.

A Sustainable Cities Index has been proposed since 2015 by the Dutch design, engineering and management company Arcadis (see Sustainable Cities Index – putting people at heart of city sustainability)[193]. This index follows the idea of the people – planet – profits strategy, putting people first. The survey is annual and has been extended to 100 cities worldwide since 2016.

The Sustainable Cities Index is constructed by a three-stage averaging process. Some of the indicators are composites. These take the simple average of their component sub-indicators. The three sub-indices are calculated by taking simple averages of their component indicators. In turn, the overall score is calculated by taking the simple average of the three sub-indices.

The averaging process demands that the scores be converted into common units, for which percentages are used. Each one is scaled such that the worst-performing city receives 0% and the best performer receives 100%. Since the sub-indices and the overall Index are simply averages of the indicators, they are also measured in percentage terms.

The Sustainable Cities Index includes information from all three sustainability dimensions. For the mathematics of its construction it is not relevant which of the dimensions comes first. A matter of concern for the index construction is, however, the fact that the index apparently aligns variables with positive meaning (e.g. literacy rate, tertiary education) side by side with variables that have negative meaning (e.g. obesity rate, Gini coefficient, homicide rate, congestion). It is not clear from the explanations whether these indices enter with negative sign or not. Equally unclear is how variables with ambivalent meaning (e.g. energy use, energy intensity, dependency ratio) enter this index which should unambiguously show positive contributions of each indicator.

INDICATOR NAME	INDICATOR DESCRIPTION	MAIN SOURCE	SUB-INDEX
Education	Literacy rate	World Bank	People
	University rankings	QS	
	Share of population with tertiary education	Barro & Lee, various national sources	
Health	Life expectancy	World Bank	People
	Obesity rate	World Health Organization	
Demographics	Dependency ratio	World Bank	People
Income Inequality	Gini coefficient	World Bank	People
Affordability	Consumer price index	UBS Prices and Earnings	People
	Property prices	UBS Prices and Earnings	
Work-life balance	Average annual hours worked	OECD, UBS Prices and Earnings	People
Crime	Homicide rate	UN Office on Drugs and Crime	People
Environmental risks	Natural catastrophe exposure	The International Disaster Database	Planet
Green spaces	Green space as % of city area	Siemens Green City Index	Planet
Energy	Energy use	Energy Information Administration (EIA)	Planet
	Renewables share	Energy Information Administration (EIA)	
	Energy consumption per $ GDP	Energy Information Administration (EIA)	
Air pollution	Mean level of pollutants	World Health Organization	Planet
Greenhouse gas emissions	Emissions in metric tonnes (per capita)	CDP Cities open data	Planet
Waste management	Solid waste management (landfill vs recycling)	World Bank	Planet
	Share of wastewater treated	OECD & FAO Aquastat	
Drinking water and sanitation	Access to drinking water (% of households)	World Health Organization	Planet
	Access to improved sanitation (% of households)	World Health Organization	
Transport infrastructure	Congestion	TomTom Traffic Index	Profit
	Rail infrastructure	Metrobits World	
	Airport satisfaction	Skytrax World Airport Awards 2015	
Economic development	GDP per capita	Brookings Global Monitor	Profit
Ease of doing business	Ease of Doing Business Index	World Bank	Profit
Tourism	International visitors per year, absolute & per capita	Euromonitor International	Profit
Connectivity	Mobile connectivity	United Nations Statistics Division	Profit
	Broadband connectivity	United Nations Statistics Division	
	Importance in global networks	Geography Department, Loughborough University	
Employment	Number of people employed, % of city population	Brookings Global Monitor	Profit

Figure 106: Components of the Sustainable Cities Index
Source: Arcadis

The Asian Green City Index has been elaborated by the Economist Intelligence Unit EIU, sponsored by Siemens, in 2011 (see EIU: Asian Green City Index: Assessing the Environmental Performance of Asia's Major Cities)[194].

In order to assess the environmental performance of 22 major Asian Cities, the EIU used an index method comprising the 29 following indicators grouped in 8 categories:

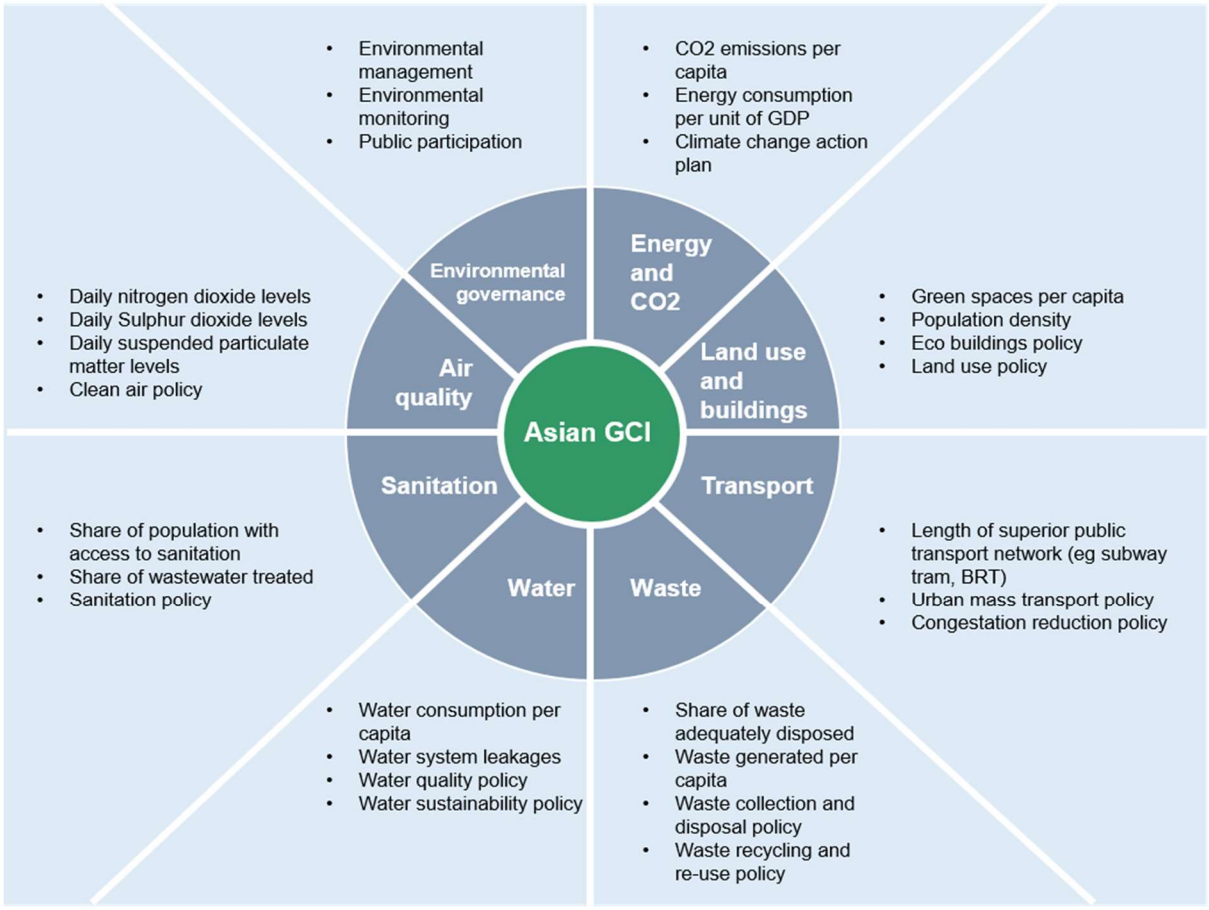

Figure 107:Asian Green City Index: List of categories and indicators
Source: EIU: Asian Green City Index

Each of these 29 indicators is being normalized on a scale from 0 to 10, so that it can be used in a composite index formula. All the indices of one category enter the sub-index of that category with equal weights. All the eight categories enter the global index with equal weight.

Cities use varying definitions for certain indicators, notably definitions of green spaces, municipal waste generated, length of superior transport networks, and administrative areas. In such cases, the EIU has sought to standardise the definition. However, some differences still exist, and where significant, they are identified in footnotes (see source). The indices are first aggregated within each category, and all categories are then aggregated with equal weight to a composite index and rescaled from 0 to 100.

The overall ranking of the 22 Asian cities is given hereafter.

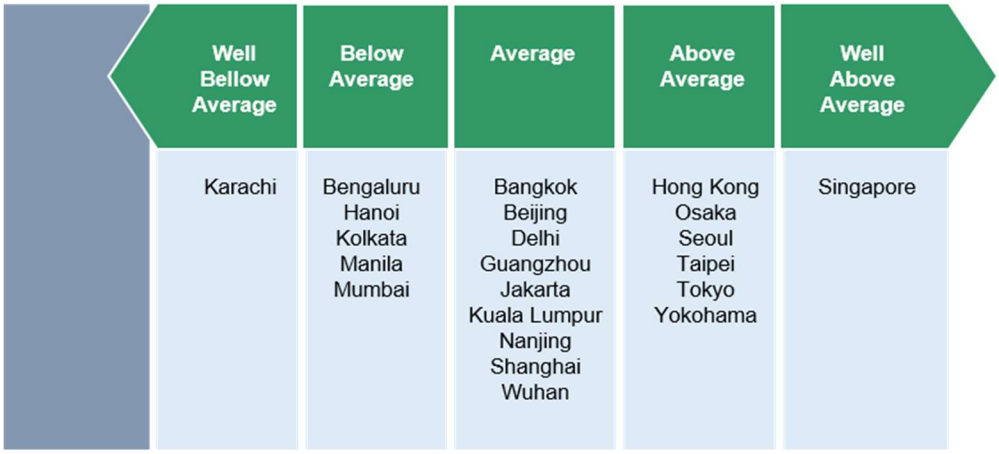

Figure 108: Overall score of the 22 cities analysed in the Asian Green City Index
Source: EIU: Asian Green City Index

Judging from its content which focuses strongly on the environmental pillar, the Asian Green City Index does not contain sufficient information on the two other pillars of sustainable development to qualify as a sustainable development index.

An Urban Competitiveness Index has been proposed by the University of Canberra[195]. It is designed to provide Australian urban leaders and citizens with evidence-based understanding of the competitive strengths and weaknesses of 18 Australian cities having more than 100'000 inhabitants.

The urban competitiveness index is a composite index based on the weighting on the cities' progress in population growth, employment growth and proportional high-income bracket growth. As its name states, these components are exclusively destined to measure competitiveness, predominantly in the economic domain.

Besides that, the system of indices also includes 20 other indices in the three dimensions productivity, sustainability, liveability. The collection of these indices gives a good picture of sustainability of the 18 most important Australian cities.

The collection of indices is not designed to determine an overall "winner" or "most sustainable city" of Australia, but rather to give the ranking of the 18 cities as measured in each of the 20 indicators separately. This is done in a perspective of giving the decision-makers the information to identify scope for improvement.

This multi-dimensional approach considers that it is impossible to measure sustainability as a single index, reduced to a single number.

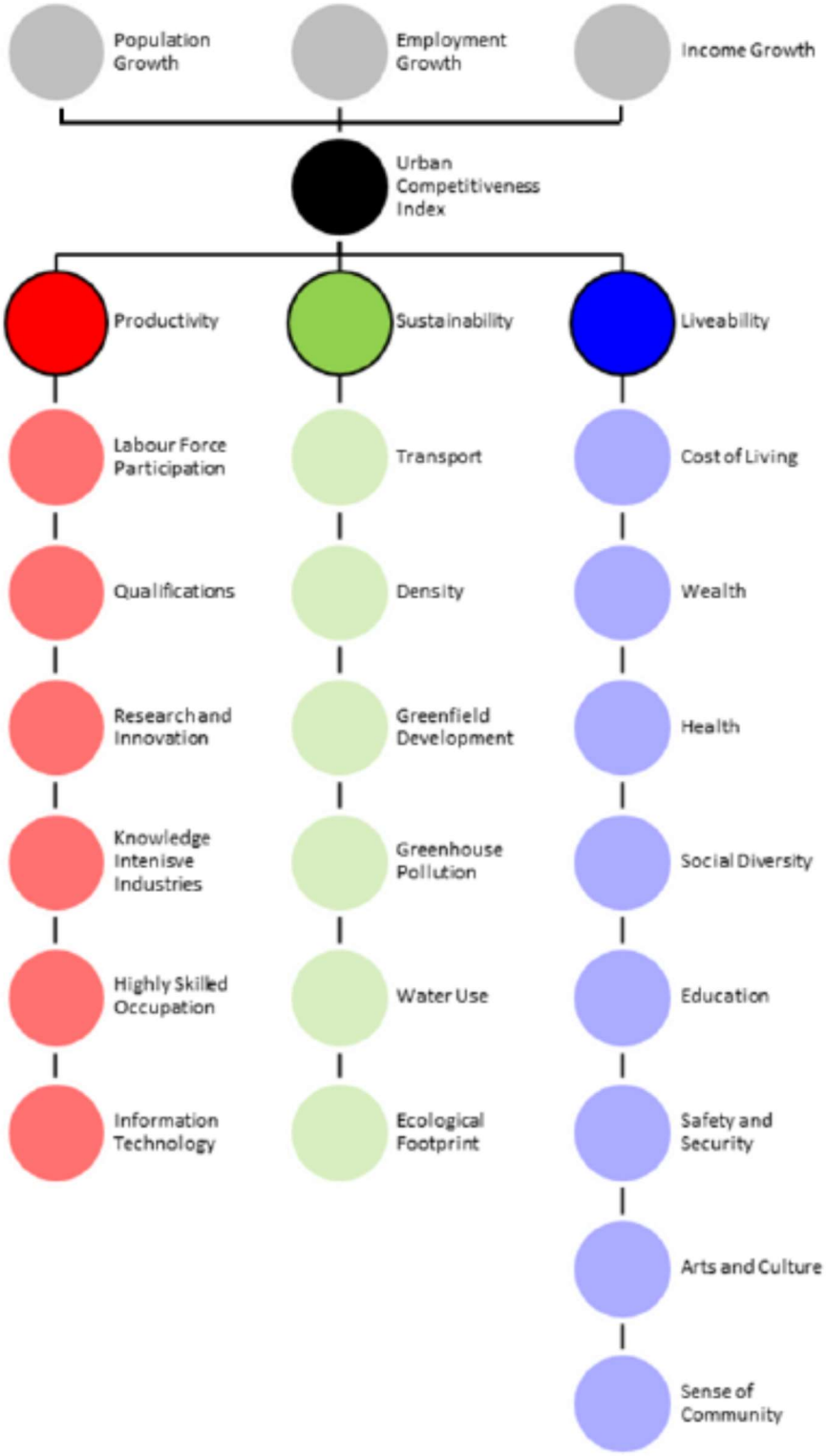

Figure 109: Urban Competitiveness Index
Source: University of Canberra

An Economic Competitiveness Index and a Sustainable Competitiveness Index have also been elaborated by UN Habitat in cooperation with the Chinese Academy of Social Sciences[196]. This research is based on principles of the New Urban Agenda (NUA) adopted at Habitat III in Quito in 2016. Both these competitiveness indices worldwide are calculated for 1038 cities with population over half a million. By focusing on real estate prices, the report touches on a key factor influencing urban competitiveness. Unfortunately, this voluminous report does not give enough information about the ingredients of the two indices and the aggregation method used for constructing them that would allow interpreting the results. Neither does it propose an analysis of the cities in two-dimensional space, Economic Competitiveness vs Sustainable Competitiveness, which would allow drawing some general conclusions about their relationship.

To conclude this section, it should be mentioned that a Global Municipal Database (GMD) was launched by UN Habitat in September 2018[197] as a means to address the problem of worldwide scarcity of urban data.

4.3.5. The D-P-S-I-R framework

The Driver-Pressure-State-Impact-Response (or DPSIR) framework is a genuinely multi-dimensional sustainability indicator system measuring sustainability without attempting to sum up the result in an overall single "note". Multi-dimensional sustainability indicators use the score-board approach to show sustainability.

The "DPSIR framework" was jointly developed by the OECD and the EU[198]. The different letters stand for:

D: Driving forces: these are the economic or social drivers such as those behind the GDP growth.

P: Pressures: these are the negative effects of the driving forces onto the environment

S: State: these measure the state of the environment

I: Impacts: these measure the negative effects of environmental degradation on human health and the economic losses due to environmental disasters

R: Responses: these measure the policy responses that can take place on any of the four other categories of variables.

The advantage of this framework is to show on the one hand the cycle between drivers, pressures, the resulting state of the environment and the backlashing impact on human activity, and on the other side the response of the governing system on all these variables.

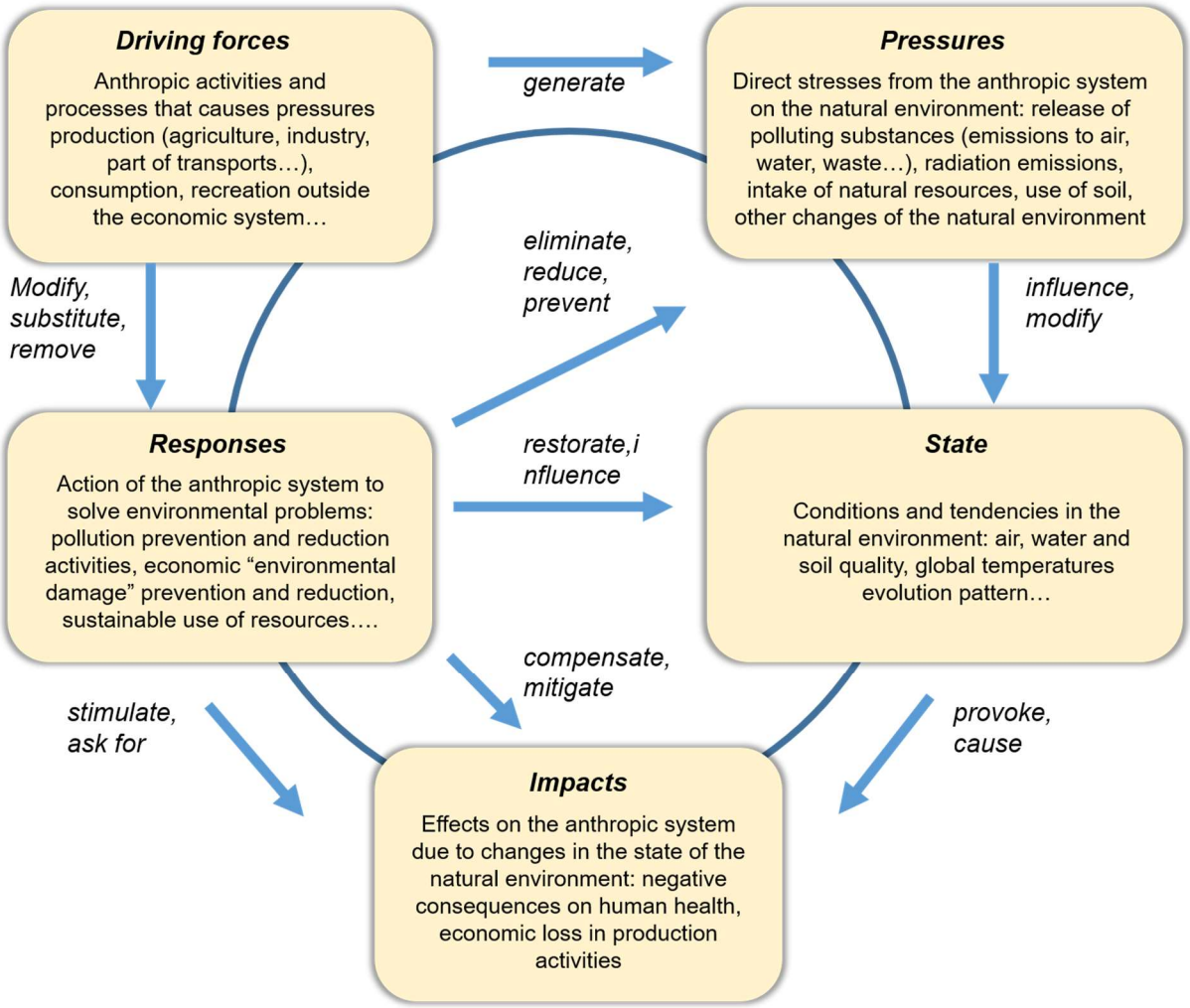

Figure 110: DPSIR framework
Source: University of Kiel, Germany[199]

4.3. Planning Tools and ICT in Support of Sustainability

4.3.1. Planning Tools in Support of Sustainability

Sustainable Development Goals (SDG) consist of a set of goals and targets set by the UN to be attained by 2030. As sustainability is not a spontaneous process, it is important that public authorities dispose of the required planning tools. Sustainability planning is not without posing challenges to planners. Planning must simultaneously allow fulfilling more than one goal, which may cause conflicts among goals (trade-offs). Methods need to be made available for addressing this kind of planning challenge in an Integrated Systems Approach (ISA).

The Multiple Criteria Decision Making (MCDM) is known for jointly maximizing a set of conflicting objectives as may be the case in sustainable development. Stanley Zionts has popularized it for a non-initiated public[200]. In the context of sustainability analysis, it has been applied for assessing integrated water-energy system transformation pathways in a water-stressed country such as Saudi Arabia having the triple objective of satisfying aspirations concerning total cost, water sustainability and electricity sector CO_2 emissions[201]. Contrary to

linear programming methods that perform either cost minimization or utility maximization, the necessity in addressing sustainability objectives is to balance the objectives of economic, energy and water sustainability against each other. Saudi Arabia needs on the one hand to move away from using non-renewable groundwater among others by increasing desalination and the associated water transport from the coast to consumption centres. On the other hand, Saudi Arabia needs to move away from fossil energies, and thirdly, it needs to consider long term cost of these choices in terms of setting up the electricity and water infrastructure.

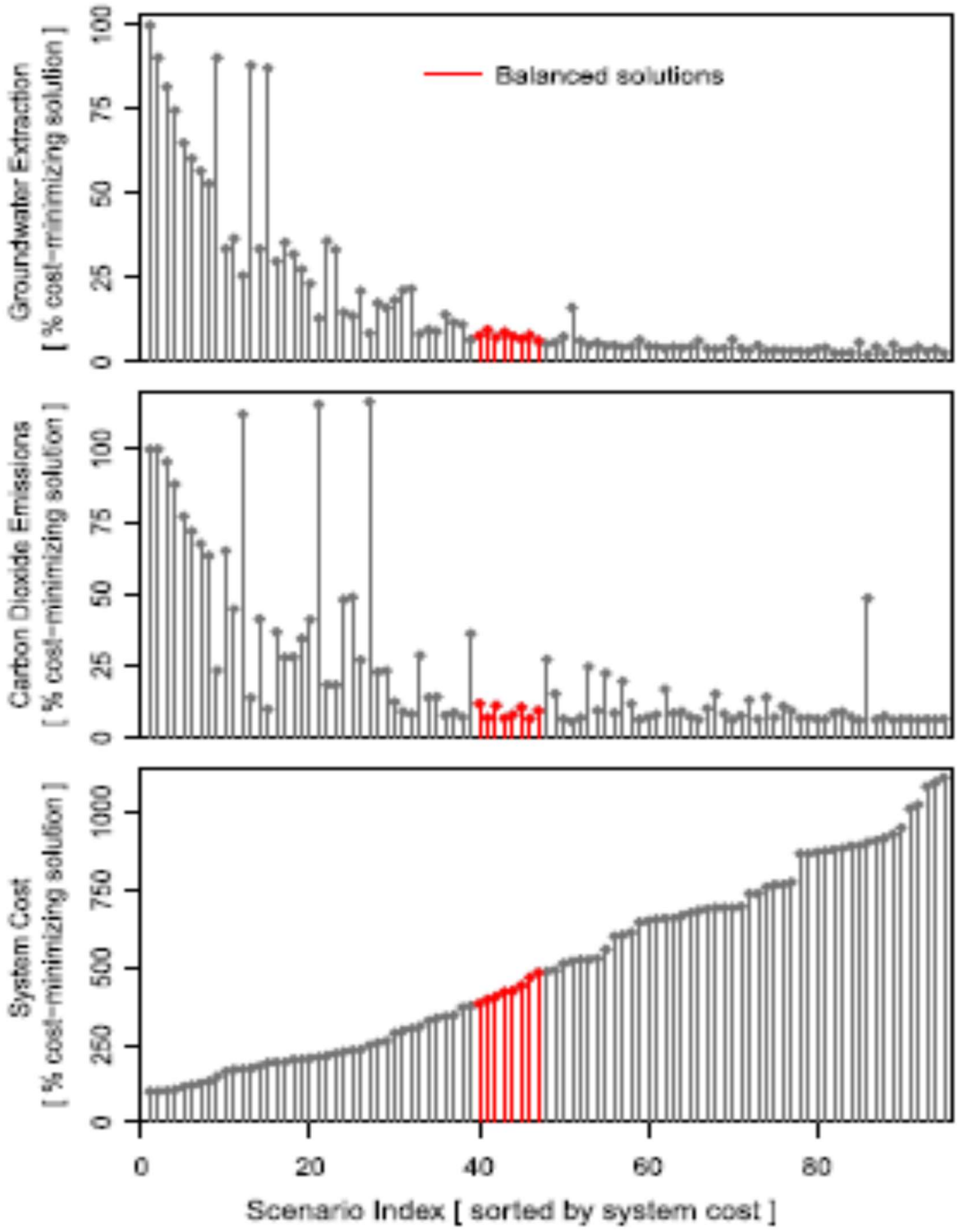

Figure 111: Solutions of the MCDM study, sorted by increasing cost
Source: *A multi-criteria model analysis framework for assessing integrated water-energy system transformation pathways*

The results show, as expected, that all three objectives cannot be satisfied simultaneously. The least cost option produces the highest emissions and very high groundwater extraction. Similarly, the lowest groundwater extraction and the lowest emissions imply the highest costs. The tool identifies a whole series of balanced solutions which show near-to-minimal emissions and groundwater extraction at moderate cost.

Other planning tools have been listed by the UN during a conference on sustainable development planning[202]:

- The Sustainability Grid, a MS Excel based tool that is used to conceive, plan and report on sustainable development goals. Its systems-based approach helps users see the inter-linkages among goals, and thereby see the co-benefits of development policies and objectives;

- Economy-wide Modelling Tools are useful in simulating macro-scale socio-economic issues and can provide short and informative policy notes for decision-makers. Data availability has improved over time along with statistical capacities, and today environment modelling capabilities are being incorporated to more fully capture the multi-dimensionality of sustainable development;

- Integrated assessment models were also described, including the CLEW model for Climate, Land, Energy and Water simulations, the Threshold 21 (T21) model and its companion model iSDG, which simulates fundamental trends in SDGs through the year 2030, and the Multi-hazard Risk Assessment model that explores approaches for critical infrastructure failure prevention to better understand investment priorities for reducing risk;

- Bayesian Networks are a powerful tool for modelling systems that are not well understood and for which there is a lack of data to support assessment. Internet search engines are an example of Bayesian models, which use past experience as a means to provide results to new problems. Such systems models are good at providing support for adaptive management and adaptive decision-making; and

- VISIS, Vision-Indicators-Systems-Innovation-Strategy, is an open-source methodology for inter-disciplinary collaboration in the context of sustainable development, and has been used by governments, NGOs, development agencies, and corporations around the world.

Large-scale Computable General Equilibrium (CGE) models of the economy are available. The widespread use of the GAMS (General Algebraic Modelling System)[203] has lowered cost of production of large-scale CGEs and made them more transparent.

Another tool, the Spatial Microsimulation Urban Metabolism (SMUM)[204], has been developed by UN Environment acting as secretariat of the Global Initiative for Resource Efficient Cities (GI-REC). Its aim is to operationalize urban metabolism at the city level. Two approaches are possible, either top-down (urban metabolism) or bottom-up (spatial microsimulation).

A City Performance Tool (CyPT)[205] has been elaborated in 2014 by Siemens, allowing to compare and simulate more than 70 transport, building and energy technologies.

As the human systems become dominant within the Earth system, eminent scientists call for integrated systems approaches to sustainability by considering specially population, inequality, consumption and the mutual effects of both, the human and the Earth system upon each other[206]. Above all, a global Earth-Human interactive model should have the capability to be coupled to corresponding regional and local models that can show the five key policy areas (climate, energy, water, urban planning and family/health policies).

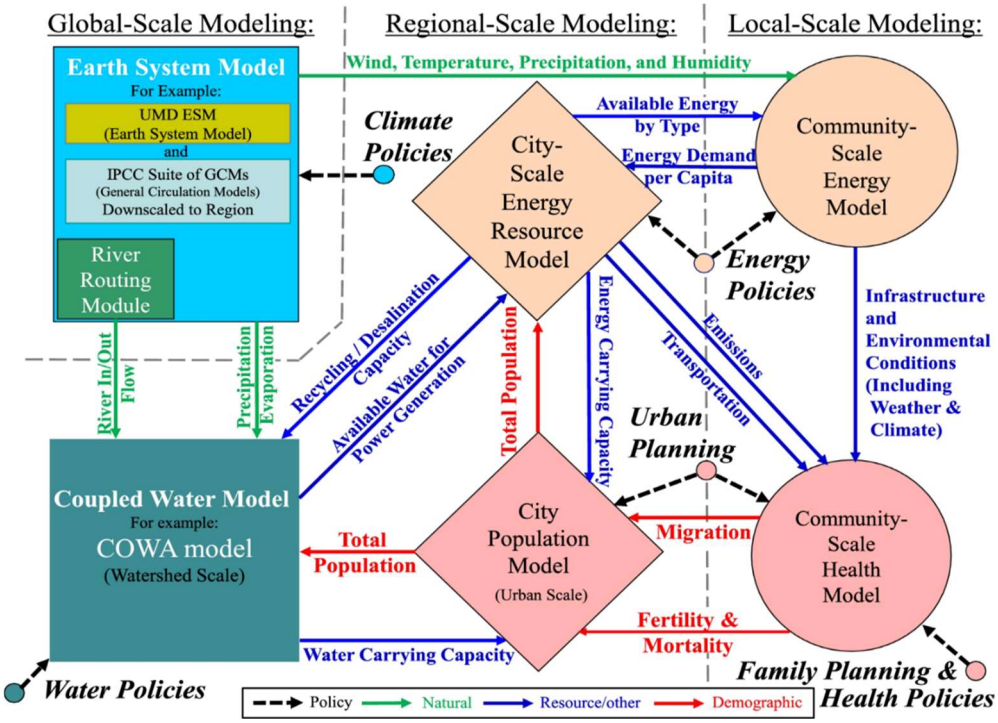

Figure 112: Coupling global, regional and local modelling
Source: *Modelling sustainability: population, inequality, consumption and bidirectional coupling of the Earth and Human Systems*[207]

The modelling approach shown above does not, however, include any economic variable and may, therefore, fails to represent an adequate integrated systems approach for sustainable development.

4.3.2. E-Government in Support of Sustainable Urbanization

Every two years, the UN releases an e-government survey to monitor the development of information technology among the UN member states. The 2016 survey bears the title *E-Government in Support of Sustainable Development*[208], and the 2018 survey has the title *Gearing e-Government to support Transformation towards Sustainable and Resilient Cities*[209].

E-government is of course of high importance to smart cities. Smart cities in general can be defined as management of urban environments using information and communication technology (ICT). If a smart city includes the whole chain of gathering, storing, transforming, and disseminating information, then it can contribute in various ways to make cities more sustainable and inclusive while at the same time saving the cities' resources.

The UN survey contains country scores of the E-Government Development Index (EGDI). The EDGI is a weighted average of normalized scores on the three most important dimensions of e-government: the scope and quality of online services as indicated by the Online Service Index (OSI), the status of the development of telecommunication infrastructure rated through the Telecommunication Infrastructure Index (TII) and the inherent human capital scored through the Human Capital Index (HCI). Each of these indices is by itself a composite measure that can be extracted and analysed independently. The composite value of each component index is then normalized to fall between the range of 0 to 1 and the overall EGDI is derived by taking the arithmetic average of the three component indices.

There is a persistent positive global trend towards higher levels of e-government development. 40 countries scored EGDI values in the range of 0.75 to 1.00, as compared to 29 countries in 2016 and 10 countries in 2003. The average world EGDI has been increasing from 0.47 in 2014 to 0.55 in 2018 due to the continuous improvement of its subcomponent indices. APEC economies score all above 0.5, except Papua New Guinea which scores in the group between 0.25 and 0.5. There is a relationship between the income level of an economy and its EGDI.

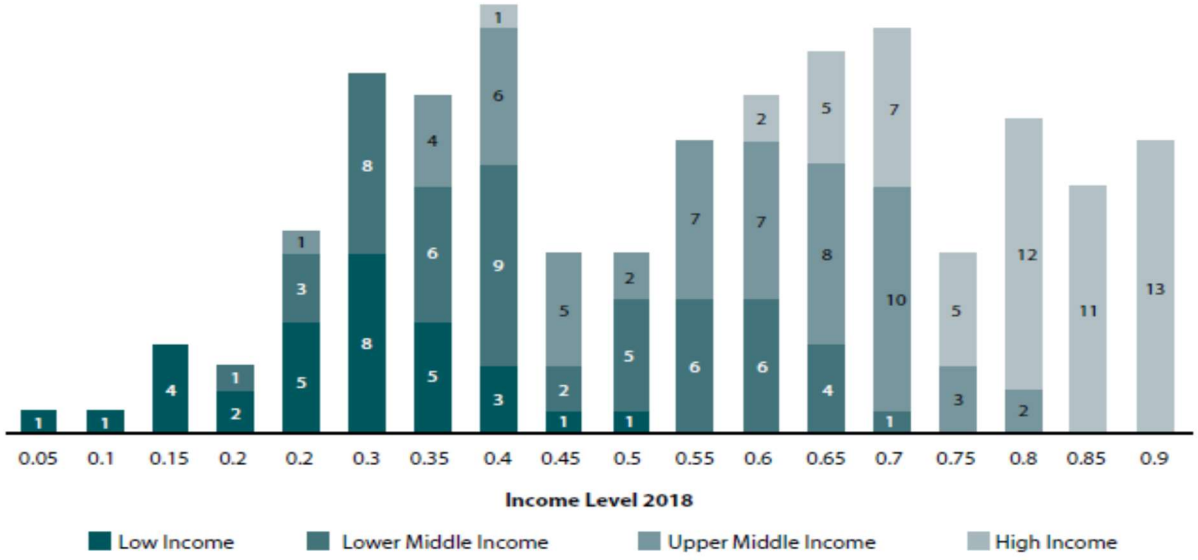

Figure 113: Relationship between income level and EGDI
Source: UN 2018 e-Government Survey

It should, nevertheless, not be forgotten that most of the world's population remains offline, which increases the risk that vulnerable groups without Internet access will fall further behind in the rapidly progressing digital society. Thus, technology can both aid and impede the overarching goal of leaving no one behind.

Cities are best placed to bind the SDGs with local communities. Municipalities, aligning with Sustainable Development Goals, act on policies related to eradicating poverty; providing equal opportunities for all, including vulnerable groups; land development and land-use planning; economic development; smart growth; transport optimisation including in connection with inner-city public transit; pollution prevention, energy, water and resource conservation; eco-projects and alternative energy development policies. This underlines the need for web-based local government systems to enhance access to services and prompt greater engagement among constituents.

Technology (12)	**Content Provision (26)**
Browser compatibility	Contact details
Ease of portal finding	Organization structure
Portal loading speed	Names and contacts about heads of departments
Mobile device accessibility	Municipality information
Navigability	Budget related information
Internal search mechanism	Information about procurement announcements
Internal advanced search mechanism	Information about procurement results
Alignment with markup validation standards	Information about provided services
Alignment with display standards	Information about municipality partnership with third parties
Alignment with accessibility standards	Facilitation of free internet access
Customization of display features	Health information
Foreign language support	Environmental information
	Education information
	Social welfare information
	Sport and culture information
	Privacy policy
	Open data policy
	Open data provision
	OGD metadata
	Smart cities initiatives
	Use of emergent technologies
	Online user support
	Guiding information on online services use
	Links for government agencies
	Statistical data and studies provision
	Evidence of portal content update
Service Provision (18)	**Participation and engagement (13)**
Portal authentication	Real time communication
Personal data accessibility	Feedback/complaint submission
Personal data updating	Online deliberation processes
Municipality responsiveness t emails	Social networking features
Delay of email response	Reporting of occurrences in public spaces
Quality of email response	Participatory budgeting
e-Procurement service	Participatory land use plan
Police online declaration	Announcement of upcoming e-participation activities
Address change notification	Feedback about consultation processes
Service Provision	Participation and engagement
Portal authentication	Real time communication
Personal data accessibility	Feedback/complaint submission
Personal data updating	Online deliberation processes
Online residentship	
Online building permit	
Online vacancies	
e-Payment	

Table 13: Criteria of best practice urban websites
Source: UN 2018 e-Government Survey

A sample of 40 large cities was evaluated according to an index containing criteria in the table above and compared with a comparable index of their respective economies. The result (see figure below) shows that some cities score as good as their economy (Moscow, New York City, Seoul, Shanghai, Port Moresby), some score worse than their economy (Kuala Lumpur, Tokyo, Bangkok). In some cases (Mexico City), cities score even considerably worse than their economy. Only one city (Abidjan) scores better than its country. In other words, the ICT gap is larger for cities than for countries. With all the responsibilities cities have in fulfilling the SDGs, the ICT gap at local level may become a key issue. Improving the local level of e-government is inseparable from attaining SDGs.

City/Municipality classification in the LOSI 2018

Country classification in UN OSI ranking 2018	Low	Medium	High	Very high
		5%	25%	37.5%
Very high		Bogotá Mexico City	Almaty Athens Berlin Buenos Aires Dubai Kuala Lumpur Mumbai Riyadh Tokyo Toronto	Amsterdam Cape Town Helsinki Istanbul London Madrid Moscow New York City Paris Rome Seoul Shanghai Sidney Tallinn Warsaw
		12.5%	12.5%	
High		Accra Bangkok Colombo (commercial) Karachi Santo Domingo	Addis Ababa Cairo Jakarta Nairobi Prague	
		5%		
Medium		Luanda Port Moresby		
		2.5%		
Low		Abidjan		

Figure 114: Cities versus their countries Online Service Index classification
Source: UN 2018 e-Government Survey

E-government in smart cities incorporates three approaches: Whole-of-Government (WoG), Open Government Data (OGD), and e-participation.

Whole-of-Government aims at integrating policies of different domains in order to achieve best possible coordination. This approach takes account of the numerous interrelations between all the SDGs and targets among each other. The WoG includes online one-stop-shops for services but goes in fact much further than that. It can, e.g., consist of a computerised environmental assessment tool called the Environmental Load Profile (ELP) to assess the environmental load from a whole city district. ELP is based on environmental systems analysis (ESA) and life cycle assessment (LCA). The purpose of the LCA is to evaluate the total environmental impact of the whole life-cycle of a product, process or activity.

Open Government Data (OGD) is a second approach of smart cities, allowing easy dissemination of timely data to the public. Eight principles of OGD have been defined in 2007[210] and are now generally accepted.

1. Complete: all public data is complete;
2. Primary: data is collected at the source, that is to say it has a high level of granularity[38] and is not in bulk;
3. Timely: it is released as soon as possible to ensure that it is readily usable;
4. Accessible: it is available on the Internet and in a form that allows it to be reused;
5. Machine readable: it is in a format that is readable by a machine for it to be reused;
6. Non-discriminatory: anyone can access the data without having to register online;
7. Non-proprietary: no entity has exclusive control over the data nor determines how it will be used; and
8. License-free: it is not subject to property rights, trademarks, patents, etc.

Box 9: Eight Principles of Open Government Data
Source: UN E-Government Survey 2016

The comparison between 2016 and 2018 shows remarkable progress of OGD during these two years, even though the machine-readable data are still lagging behind data dissemination on pdf files.

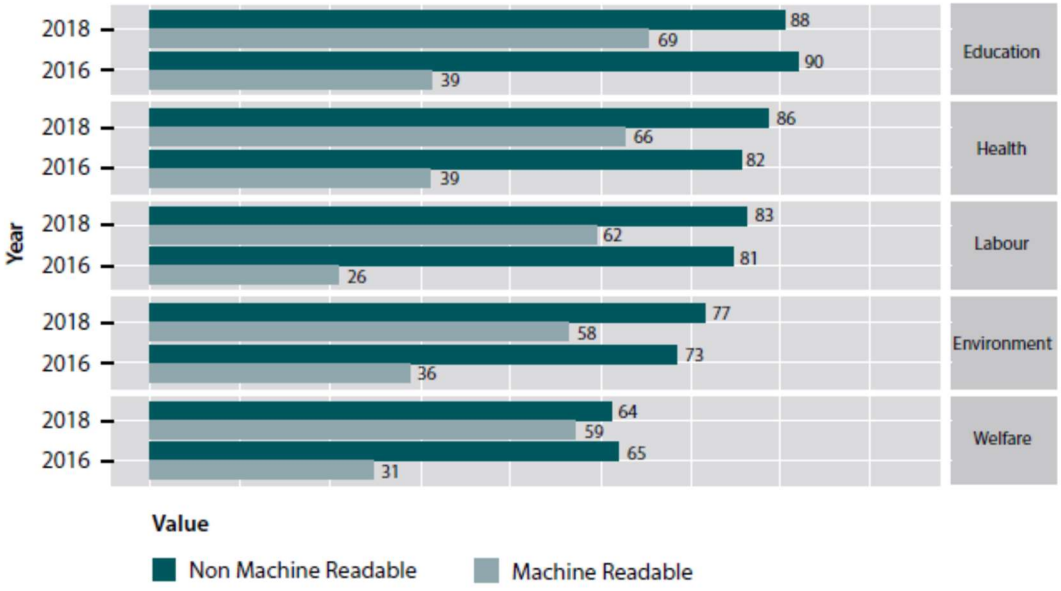

Figure 115: Trends in Open Government Data 2016 to 2018
Source: UN E-Government Survey 2018

A third approach to e-government in smart cities is to enhance public participation. This so-called e-participation has many different features and many different forms. Three conditions are essential for the involvement of public participation:

- (i) explicit focus on official policies, decisions and governance practices to ensure that they respond to people's needs;

- (ii) explicit focus on the means of interaction – people should be connected to communication channels in order to express themselves and communicate both among themselves as equal peers and with public authorities as equal partners; and
- (iii) explicit focus on the content of the interaction process between citizens and government to ensure the quality and legitimacy of e-participation outcomes.

4.3.3. New ICT in Support of Sustainable Urbanization

Data is being currently referred to as the new oil, the new raw material driving innovation and growth in both the private and public sectors. Indeed, data use will grow exponentially in the next decade and will offer the ability to systematically analyse and act in real time in solving more complex business problems, creating more competitive advantage and making better informed decisions in a tightly connected world. Yet, integrated approaches to achieving synergies and minimizing trade-offs may remain relatively untapped in many economies.

ICTs play an important role in ensuring that disaster response and recovery, as provided for in the Sendai Framework for Disaster Risk Reduction 2015-2030, are fast and efficient. Indeed, ICTs are recognized as an enabler in supporting all phases of disaster risk management from prevention, reduction, and preparedness to respond and recover, and the Survey emphasizes the need to protect critical ICT infrastructure from disaster impacts. Indispensable tools for disaster risk reduction are mobile technology, the Internet, Web 2.0 tools like social media, Geographic Information Systems (GIS), remote sensing and satellite communications, as well as different types of radio communication including amateur and satellite radio.

An interesting case example involving renewable energy and ICT in remote areas has been reported in early 2018[211], when a Danish ICT company, in collaboration with the Ministry of Communications in Ghana, launched an affordable and sustainable “connecting the unconnected project” in four rural communities in western Ghana, prior to it being rolled out across the country. A base station 100 per cent solar energy powered establishes a Wifi hotspot with a range of up to one kilometre in diameter. The hotspot is connected to the Internet by existing infrastructure such as microwave link and fibre, satellite, balloons or drones, bringing connectivity to even the most remote areas of the world.

Box 10: Case example of renewable energy and ICT
Source: UN E-Government Survey 2018

The following ICTs are thought useful for improving sustainability[212]:

- Data, intelligent apps and analytics: Public communities are at the source of large amount of data, which they can make available through automated capabilities, also called dark analytics. Algorithms can reveal trends, population movements, user preferences, demographics, transportation data, etc.

- Artificial Intelligence and Robotic Process Automation is the process when machines are starting to learn, or to make calculated decisions like what previously only human beings have been able to do. Artificially intelligent systems can soon catch up with creativity, ingenuity and experience of human beings

- Intelligent “things”, cyber-physical integration and edge computing: The internet of things evolves to intelligent things that use locally gathered information, process it locally (edge computing) and decide on what action to take.

- Virtual and augmented reality can enable users to be immersed in a virtual reality which can be mixed with real data. The spectrum of possibilities opened by this technology is almost without limits.

- High Performance- and Quantum Computing serves to execute the increasing computing needs of some 20 billion or more connected devices worldwide. Quantum computing can leverage the power of computers exponentially.

- Blockchain and Distributed Ledger Technologies allow to increase trust and protect stored information from being falsified. This is an advantage for some categories of official documents such as identity proofs, land registries, but also smart contracts, and money transactions, all of which can now be detached from their conventional paper form.

Research papers on blockchains are booming with more than half a million publications in the last two years. The World Economic Forum has suggested that by 2027, 10% of the world’s GDP might be stored on blockchain. In March 2018, the UNDP published an introductory manual on blockchains[213].

Despite this boom, it is certainly important to state that blockchains are still an immature technology[214]. Blockchains are three to five years away from commercial large-scale application. One of the reasons is the impossibility to decide general standards. For the moment, each blockchain is still a separate Universe, and is, therefore, a source of fragmentation rather than integration.

Furthermore, the most notorious blockchain, the Bitcoin, is an extremely bad example of energy inefficiency, as it uses the method of deep mining as proof of work. Energy consumption of the Bitcoin increases with the market price of Bitcoins and with the number of participants and doubles every six months. By end 2018 the consumption of the entire Bitcoin blockchain could reach 67TWh annually or 0.3% of world energy consumption, which is of the same order of magnitude as the standby consumption of electronic devices in the US[215]. As energy regulators have in the past regulated standby consumption of electronic devices, they might one day also regulate blockchain consumption.

A case example of an application of blockchain to sustainable development can be seen by the Australian firm Power Ledger of Perth, which in August 2018 announced a partnership with Thai renewable energy business BCPG to launch the world-first peer-to-peer (P2P) renewable energy trading trial at the T77 urban precinct in Bangkok[216].

Another example of blockchain application is the Australian start up Okra[217], providing decentralized electricity to rural areas in Asia. This firm installs plug & play solar powered microgrids, supported with crypto wallets for secure payment, distant meter reading, and guaranteed high quality service.

Box 11: Examples of blockchain use in sustainable development

The common characteristics of blockchains is that they are stored on a great number of computers and that therefore there is no centrally administered database. Given these characteristics, three sectors have been named where blockchain could make a difference in the sense that blockchains will not only have high impact but also high feasibility:

- Public sector, especially in smart cities
- Financial sector
- Technology, media and telecom

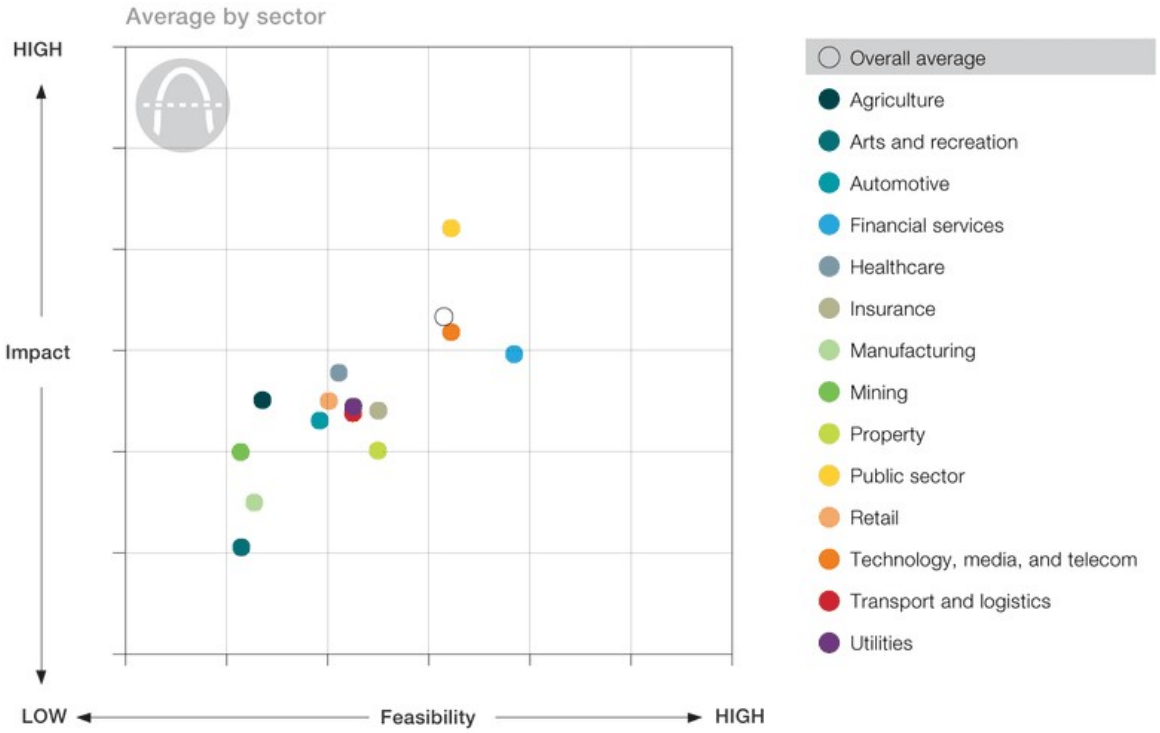

Figure 116: Potential opportunities of blockchains by sector
Source: Mc Kinsey (2018)

Not all blockchains are of the same type. Four types of blockchains exist, depending on ownership of data and infrastructure or on permissions to read, write or commit:

Governments, either at local or economy-wide level, could play a major role in accelerating the process of blockchains for improving and becoming operational. They could commission services to be provided by blockchain and fix, e.g., the maximum allowable energy consumption of the chain. Such involvement of government in land registry or personal identity would accelerate the emergence of a common standard with corresponding applications.

In 2017, Standard Australia took a leading role in developing a common terminology within the ISO framework[218]

The immediate benefits of blockchains to local governments would be to lower costs and increase speed for providing services.

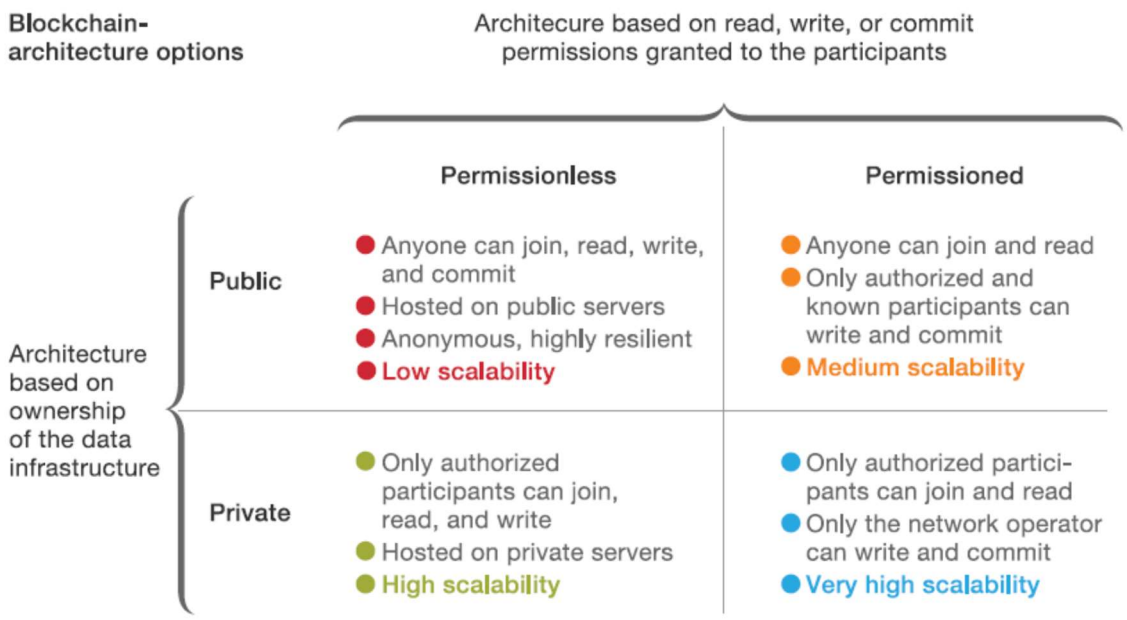

Figure 117: Four types of blockchains
Source: Mc Kinsey (2018)

4.4. International Technical Standards Supporting SDGs

4.4.1. ISO Standards for SDGs

The International Standardization Organization ISO in Geneva has been working for some time on sustainability standards. Standards and certifications are voluntary, usually third party-assessed, norms and standards relating to environmental, social, ethical and food safety issues, adopted by companies to demonstrate the performance of their organizations or products in specific areas. Standards are documents that can be bought from the ISO website[219]. There are perhaps up to 500 such standards and the pace of introduction has increased in the last decade.

The trend started in the late 1980s and 90s with the introduction of Ecolabels and standards for Organic food and other products. In recent years, numerous standards have been established and adopted in the food industry in particular. Most of them refer to the triple bottom line of environmental quality, social equity, and economic prosperity. A standard is normally developed by a broad range of stakeholders and experts in a particular sector and includes a set of practices or criteria for how a crop should be sustainable grown or a resource should be ethically harvested. This might cover, for instance, responsible fishing practices that don't endanger marine biodiversity, or respect for human rights and the payment of fair wages on a coffee or tea plantation. Normally sustainability standards are accompanied by a verification process - often referred to as "certification" - to evaluate that an enterprise complies with a standard, as well as a traceability process for certified products to be sold along the supply chain, often resulting in a consumer-facing label. Certification programs also focus on capacity building and working with partners and other organizations to support smallholders or

disadvantaged producers to make the social and environmental improvements needed to meet the standard.

The different components of sustainability, namely the economic, social and environmental components, have each been the object of a series of standards that were developed prior to knitting them together to sustainability standards.

In the economic area, the ISO 9000 series on quality management, in the environmental area the ISO 14000 series on environmental management, in the social area the ISO 26000 series on corporate social responsibility could be named for each of the three components.

The relevance of ISO standards for SDGs has been reviewed in the publication "ISO and SDGs"[220] which summarizes the role of these standards in SDG implementation. This is reproduced in the following table.

SDG	**Examples of relevant ISO Standards**
1 No poverty	ISO 20400, Sustainable procurement – Guidance
	ISO 37001, Anti-bribery management systems
2 Zero hunger	ISO has over 1 600 standards for the food production sector
	ISO 22000 series on food safety
	ISO 26000 on social responsibility
	ISO 20400 on sustainable procurement
3 Health, well-being	ISO has over 1 300 standards supporting safe, quality medical practices and equipment
4 Quality education	ISO 21001, Educational organizations – Management systems for educational organizations – Requirements with guidance for use (under development)
	ISO 29993, which covers all types of lifelong learning including vocational education and in-company training (under development)
5 Gender equality	ISO 26000, Guidance on social responsibility
6 Clean water	ISO 24518 to help communities manage their drinking water and wastewater services in the event of a crisis of water utilities (under development)
	ISO 24521 gives practical guidance on the management and maintenance of basic on-site domestic wastewater services
	ISO 30500, Non-sewered sanitation systems – Prefabricated integration treatment units (in development)
7 Clean energy	Over 200 standards related to energy efficiency and renewables, further ones are developed
	ISO 50001, Energy management systems – Requirements with guidance for use
	ISO 52000 series of standards for the energy performance of buildings
	ISO 9806, specifies test methods for assessing the durability, reliability, safety and thermal performance of fluid-heating solar collectors
	ISO 17225 series determines the specifications and fuel quality classes of solid biofuels.

8 Decent work, economic growth	ISO 45001, Occupational health and safety management systems – Requirements with guidance for use
	ISO 37001 on anti-bribery management systems
9 Industry, Innovation, Infrastructure	ISO 44001, Collaborative business relationship management systems – Requirements and framework
	ISO has over 1 000 standards for the construction industry
	ISO technical specification 37151 (performance metrics) defines 14 categories of basic community needs (energy, water, transportation, etc.) by which to measure the performance of smart community infrastructures
	ISO technical regulation 37152 (common framework for development and operation) describes the planning, development, operation and maintenance methodology that ensures the interactions between multiple infrastructures are well orchestrated
	ISO 50501 on innovation management systems (forthcoming)
	ISO 50503 on tools and methods for collaborative innovation partnerships
10 Reduced inequalities	ISO 26000, Guidance on social responsibility
11 Sustainable cities	ISO 37101 helps communities define their sustainable development objectives and implement strategies to achieve them
	ISO 37120 on indicators for city services and quality of life
	ISO 37122 indicators for smart cities (upcoming)
	ISO 37123 (indicators for resilient cities)
	ISO has hundreds of standards on intelligent transport systems, water management, business continuity and community resilience
	ISO 22313 on business continuity management systems
	ISO 22326 emergency management (in development)
	ISO 22395 guidelines for supporting vulnerable people in emergency situations (in development)
	ISO 24526 water efficiency management systems (in development)
12 Responsible consumption and production	ISO 20400, Sustainable procurement – Guidance
	ISO 14020 series contains standards on environmental labelling
	ISO 15392, Sustainability in building construction – General principles
	ISO 20245, Cross-border trade of second-hand goods
13 Climate action	ISO 14000 family of standards for environmental management systems
	ISO 14001, Environmental management systems – Requirements with guidance for use
	ISO 14064 series gives specifications for the quantification, monitoring and validation/verification of greenhouse gas emissions

	ISO technical specification 14067 specifies the principles, requirements and guidelines for measuring and quantifying the carbon footprint of products (currently under revision)
	ISO 14080, framework to develop consistent, comparable and improved methodologies in the fight against climate change (under development)
	ISO Guide 84, Guidelines for addressing climate change in standards
14 Life below water	ISO has over 250 sustainability-related standards for the design, construction, equipment, technology and marine environmental matters related to shipbuilding
15 Life on land	ISO 14055, Environmental management – Guidelines for establishing good practices for combatting land degradation and desertification
	ISO 38200 Chain of custody of wood and wood-based products
16 Peace and justice	ISO 37001 anti-bribery management systems
	ISO 19600, Compliance management systems – Guidelines
	ISO 37000 Guidance for the governance of organizations (under development)
17 Partnerships	ISO Standards are developed with the collaboration and consensus of a wide range of stakeholders from all corners of the Earth, including representatives from government, industry and standardization bodies

Table 14: List of ISO Standards relevant to each SDG
Source: ISO and SDGs, ISO

For sustainable cities, ISO 37101 is the first international standard on sustainable development in communities and cities. This international standard has been developed to help city leaders create a vision for the future of their cities, implementing steps to achieve sustainable development goals. It is intended to help communities become more resilient, smart and sustainable, through the implementation of strategies, programmes, projects, plans and services, and demonstrate and communicate their achievements. It is applicable to communities of all sizes, structures and types, in developed or developing economies, at local or higher levels, and in defined urban or rural areas, at their respective level of responsibility. It has been developed to help city leaders set and achieve their city's sustainable development agenda. It sets out requirements and guidance to help create a sustainable future for communities with the support of methods and tools including smartness and resilience. It can help communities improve in a number of areas such as:

- Developing holistic and integrated approaches instead of working in silos (which can hinder sustainability)
- Fostering social and environmental changes
- Improving health and wellbeing
- Enabling engagement by the community with external organizations to drive positive change
- Encouraging responsible resource use

- Achieving better governance

The Chinese city of Hangzhou has introduced ISO 37101 in a testing perspective[221].

The technical committee ISO/TC 268 in charge of elaborating these standards plan to complete several more standards in the area of SDG 11.

The draft standard ISO 37102 standardizes vocabulary used to describe sustainable development and resilience of communities. ISO 37106 gives guidance for leaders in smart cities and communities (from the public, private and voluntary sectors) on how to develop an open, collaborative, citizen-centric and digitally-enabled operating model for their city that puts its vision for a sustainable future into operation.

ISO 37120 is a standard on indicators for sustainable cities. It allows any city to measure its sustainability performance in a standardized manner in many different areas, including economy, education, energy, environment, recreation, safety, shelter, solid waste, telecommunications and innovation, finance, fire and emergency response, governance, health, transportation, urban planning, wastewater, and water and sanitation.

ISO 37121 provides an inventory of existing guidelines and approaches on sustainable development and resilience in cities.

ISO 37122 will provide indicators for smart cities.

ISO 37151 is designed to support city and community managers in planning and measuring performance. In doing so, they will help compare and select procurement proposals for products and services geared at improving community infrastructures.

This report particularly suggests referring to ISO standard 37151 for smart cities, and to the ISO standards on energy efficiency in buildings (ISO 52000 series).

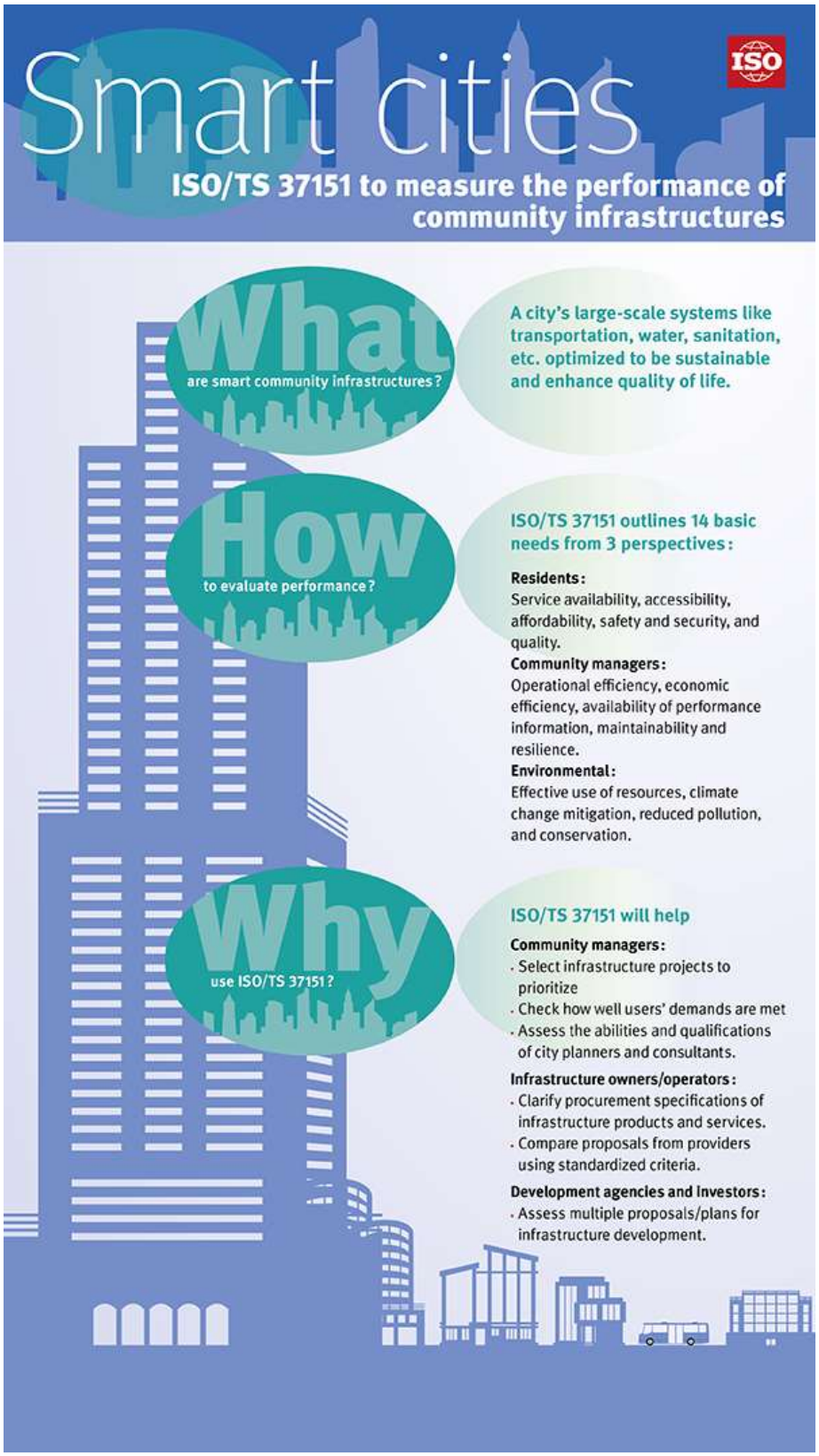

Figure 118: ISO 37151 at a glance
Source: ISO[222]

4.4.2. IEC Standards for SDGs

The International Electrotechnical Commission IEC is the sister organization of the ISO. It produces all electrotechnical and IT standards and plays therefore a crucial role in implementing progress in these domains. In their publication, the IEC and the Sustainable Development Goals[223], the IEC points out that energy and especially electricity is the golden thread that impacts most of the 17 SDGs. IEC work directly impacts 12 of the 17 SDGs.

Because IEC International Standards are highly technical, there are literally hundreds of Standards that apply to different technologies that impact the SDGs and nearly all the time they are used by experts in those fields. It is therefore difficult to give a detailed listing of Standards that apply to SDGs[224]. IEC work facilitates reaching the following SDGs:

SDG 7, cleaner energy: The IEC provides more than 300 International Standards that directly impact energy efficiency outcomes in the generation, distribution and use of electricity by billions of devices. Hereafter a list of some of the IEC TC/SCs who develop publications that are relevant to SDG7:

- TC 4 - Hydroelectric power generation (dams, river, pico, micro, estuary, etc.)
- SC 8A - Grid integration of renewable energy
- SC 8B - Off-grid electricity generation
- TC 82 - Solar PV
- TC 88 - Wind energy generation
- TC 114 - Marine energy
- TC 117 - Solar thermal
- SyC LVDC - Off-grid energy access
- Several other TCs provide supporting Standards including for built-in energy efficiency
- IEC/TS 62257 – 18 publications related to rural electrification

SDG 1 (ending poverty) and SDG 2 (ending hunger): Today more than 1/3 of food produced is never eaten. Food waste is the third largest greenhouse gas emitter. By strengthening the cold chain after slaughter or harvest, food waste and emissions could be halved. IEC work provides the foundation for domestic and industrial cooling systems. Irrigation technologies and electric pumps help improve agricultural efficiency, allowing farmers to increase productivity. As an example:

- SC 59M develops the efficiency Standards for refrigeration.
- SC 61C is in charge of the safety of refrigerating appliances.
- TC 2 develops the Standards for the electric motors that drive pumps.

SDG 3 (better health): The cooling and proper conservation of medicines and vaccines is the first step towards better health. And IEC International Medical Device Standards apply to most essential devices that are used in medical diagnosis and treatment.

- TC 62 develops the large majority of IEC Standards that apply to medical equipment for diagnosis and treatment

Figure 119: Solar powered camel clinic: cooled medicine – Kenya/Ethiopia – inhabitat.com
Source: IEC and Sustainable Development Goals (online ppt).

SDG 4 (education and learning): Education and learning uses electrical and electronic hardware that is often built to IEC International Standards. IEC work in this area is done under three committees:

- TC 100 covers computing equipment, terminals, chargers and power transfer, cables, protocols, energy efficiency, e-books, wearables, etc.
- TC 103 covers equipment for radio communication.
- TC 110 is in charge of electronic display devices.

SDG 6 (water and sanitation): Clean water extraction and waste water treatment require pumps, filtration and desalination systems. Increasingly sensors control the length of flow for example on faucets, toilets or in irrigation systems. The IEC has published over 90 Standards that apply to water management.

SDG 8 (decent work) and SDG 9 (industrialization): The technical information included in IEC International Standards allows economies to more easily upgrade their manufacturing and energy infrastructure and improve their production efficiency. IEC International Standards encourage technology transfer and provide a reliable basis for innovation. Several IEC TCs address safety considerations of workers and equipment used in manufacturing.

SDG 11 (sustainable cities): IEC work directly impacts all aspects of cities both in developing and developed economies. IEC International Standards cover all the hardware and systems, displays and sensors that help make cities smarter. Think trains or subways and their supporting infrastructure, electric vehicles and charging stations, lighting, hospitals, ATM machines, waste and water management, cooling and ventilation, and so much more.

The IEC also publishes the majority of technical Smart Grid Standards. Electric grids play a key role in shaping a city's liveability and sustainability. To increase their performance and efficiency, the many elements of these critical city systems need to be integrated.

Over 1800 Standards for energy generation, intelligent mobility, health care, financial and administrative services, security and alarm systems, access control, smart buildings, etc.

- TC 47 - Sensors
- SyC AAL - Active assisted living
- SyC - Smart city
- SyC - Smart energy

Graphically the IEC standards applicable to sustainable cities are represented in fig. 89.

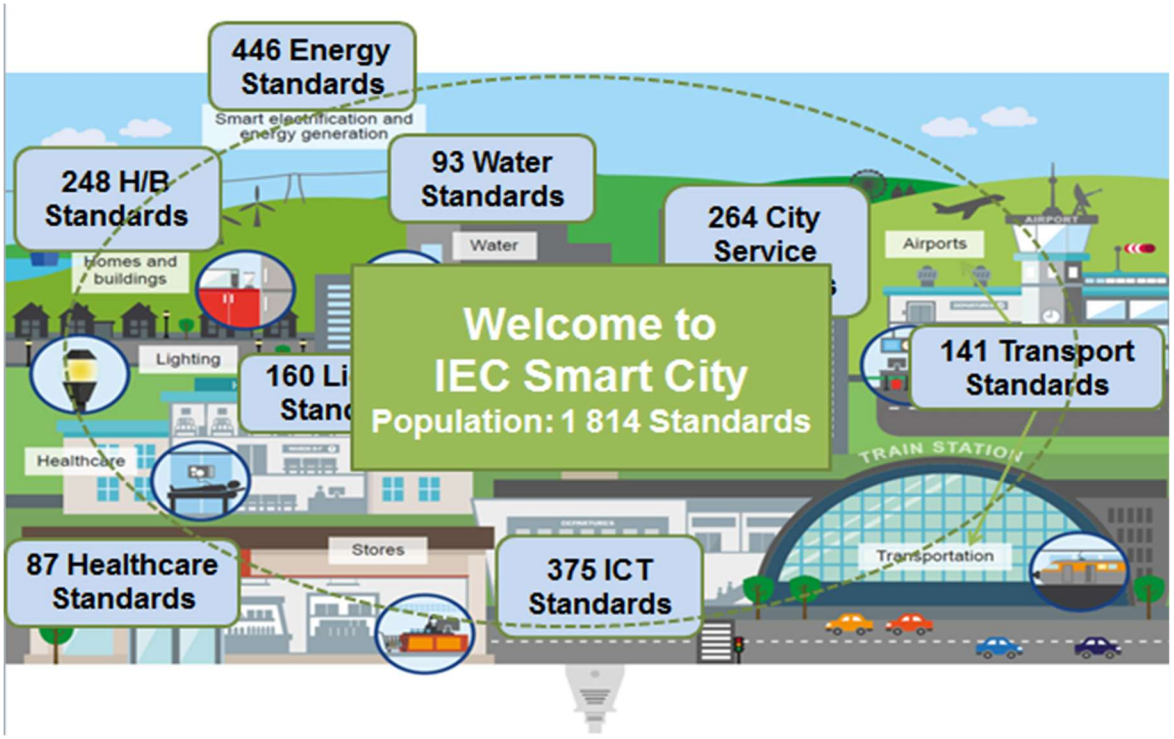

Figure 120: IEC Standards applicable to sustainable cities
Source: IEC and Sustainable Development Goals (online ppt).

SDG 12 (sustainable consumption and production): IEC work provides the technical foundation for many types of harvesting, storage, production and cooling technologies. IEC International Standards together with the IEC Conformity Assessment Systems can help control the use of hazardous substances in the manufacturing of electrical and electronic devices. In particular, IEC TC 111 addresses environmental standardization for electrical and electronic products and systems. IECEE and IECQ, two of the four IEC Conformity Assessment Systems, also help ensure the safety and sound management of hazardous substances in the manufacturing and disposal processes of electrical and electronic devices.

SDG 13 (climate change action): In addition to facilitating energy efficiency measures that reduce greenhouse gas emissions, IEC International Standards, together with testing and verification, help strengthen the disaster resilience of cities and infrastructure through built-in safety mechanisms. They help mitigate disaster risks and accelerate disaster recovery, reducing overall disaster impact. All IEC Standards include industry-wide best practice, and many are important for power generation and microgrids.

A myriad of IEC Standards are used in the building of infrastructure, including for example in power generation or water management. Several TCs develop the Standards that ensure that alarm systems are able to operate under extreme conditions, still others ensure the safety of workers during repair operations, for example live working on downed power lines or the installation of electricity generators.

- TC 56 and TC 57 Dependability and resilience of systems
- TC 78 Disaster recovery (live-working)

The work of many different IEC technical committees directly impacts disaster preparedness and improves the resilience of electrical and electronic infrastructure in the face of natural and man-made disasters. An important fact: close to 60 IEC Standards are foundational and fully integrated in the ISO 31000 risk management Standard.

SDG 17 (global partnerships for sustainable development): IEC International Standards contain a vast amount of technical know-how and expertise that provides developing economies with the means to build better products that can also be exported. Standardized markets offer more fertile ground for new business opportunities. IEC International Standards support the development and dissemination of environmentally sound technologies.

In sum, both, IEC and ISO standards are important, even indispensable technical frameworks that can help attaining SDGs. While the ISO standards have some degree of relevance to almost all the SDGs, the IEC standards have a high relevance to all those SDGs where electricity and IT play a key role.

4.5. Cutting-Edge Technologies Supporting Sustainability

As mentioned earlier, APEC has a database with projects that use new technologies in projects (http://esci-ksp.org/). The collection below is intended to show cutting-edge technologies that are only just emerging.

4.5.1. Plus-Energy Districts

In the housing sector, the paradigm of energy transition consists of setting up so-called plus-energy districts. Sometimes it they are also called Energy-Positive Neighbourhoods (EPN)[225]. As experience shows, the pure function of residential living can be conceived as plus-energy districts. If, however, due to the secondary objective of minimizing transportation, such districts also contain a certain percentage of commercial activity or the necessity to charge electric vehicles of their inhabitants or workers, the plus-energy characteristic will usually be lost, even with present best available technology. Among the rare commercial activities that allow developing towards becoming energy-positive (besides commercial energy

producers) are hotels. Some rare examples of plus-energy hotels exist, such as one set up in the Swiss Alps near St. Moritz[226].

Plus-energy districts are certainly positive from the energetic and environmental point of view. They can also become positive from the economic point of view if applied as newly built settlements in rapidly growing cities. As shown above, the Global Covenant of Mayors for Climate and Energy is one of the main institutional vehicles driving this type of change, as it numbers already more than 9000 cities and is especially useful for small and medium-size cities. Even though the diminution of CO_2 emissions is put at the forefront, this strategy goes hand in hand with the strategy of producing and regenerating more CO_2-free energy locally. This "second leg" is the economic driver and the synergy with the growth strategy and can help medium-sized and fast-growing cities to leap-frog.

The question as to which technology is the right one to achieve plus-energy districts is of course extremely difficult to answer, especially as technologies progress so rapidly, that a new technology can suddenly emerge which will render former technologies obsolete.

Some general tendencies, which characterize the buildings in a smart energy town can nonetheless be outlined. They combine the knowledge of the three disciplines architecture, civil engineering and ICT. The ten points below may describe the essence of such districts:

1) Plus-energy districts should be designed and modelled by computer simulation prior to realization to eliminate possible flaws. It is also advised that ex-post evaluation takes place.

2) Plus-energy districts are completely integrated districts using local energy sources management, with the ability to sell energy (electricity and capacity) to the overlaid grid if there is excess or, conversely, to buy energy if there is not enough generation at the local level.

3) Plus-energy districts should be mixed residential and commercial complexes to minimize urban transport needs. These districts should be able to generate commercial value-added and host about the same amount of well-paid jobs as there are working-age people who live in these districts. Note that if such a district comprises charging of electric vehicles or use of commercially needed energy equipment, it might lose its ability of positive energy and become net buyer.

4) Electricity will be the dominant energy source, collected in PV or binary PV-heat collectors fixed on the building. District heating or district cooling can play a role, depending on the circumstances.

5) Heat and cold will be delivered by bidirectional heat-pumps coupled to geological heat storage. In cold climates, heat will be stored during summer in the ground for use in winter. In warm climates cold comes from a cold aquifer. If it must be further cooled by heat pump, the surplus heat generated will be used as sanitary warm water.

6) These districts will have devices to visualize and track energy consumption for consumers and local district-managers.

7) These districts will use up-to-date cloud ICT and Internet of things (IoT) structures or, once operational, blockchain-based platforms, for communication and efficient data exchange. The organizational structures will be optimized to eliminate organizational failures (lack of power of energy manager, setting up organizational culture emphasizing energy and environmental issues).

8) These districts will have schemes to incentivize the consumer to « play the game » and eliminate behavioural failures (inability to process information, lack of trust, inertia, rebound effect). Responsible consumer behaviour is an essential element as technology alone will not be able to deliver the expected results.

9) Plus-energy districts may need a specific regulatory environment eliminating market failures (eliminate asymmetric or imperfect information, imperfect competition, minimum size to enter the market, hidden costs; put through of market price volatility to final consumers, possibility to hedge risks). District dwellers should be able to task Energy Service Companies with the energy management of their district.

10) These districts should be resilient against extreme climate events by local water- and windproof electricity and water storage capacity for a duration to be defined (e.g. one or two days of average consumption).

Some first pilot projects of plus-energy districts have been set up and are already operational. In Germany, the Ludmilla residential estate in Landshut has been completed with the cooperation of the Technical University in Dresden and the Munich High School for Applied Sciences.

The complex covers 7,300 square meters, consisting of five single-family homes, two semi-detached houses, six terraced houses and eight apartment buildings with 55 apartments.

All building components have a value well below the minimum values required by the German Energy Saving Ordinance EnEV 2009, as well as the specifications outlined in EnEV 2014. All apartments on the housing estate fulfil at least the standard of a KfW 55 Efficiency Building according to EnEV 2009.

The use of innovative building technology is an important aspect of these energy-positive housing estates, with the most important energy suppliers including the photovoltaic (PV) systems on the roofs of the estate, a combined heat and power plant (CHP) and a condensing boiler as a peak load boiler; a 10,000-litre buffer storage tank is also available.

Scientists measured energy flows, using sensors. Questions were asked to the residents about energy saving and their personal behaviour and usage as well the extent of comfort in their energy-optimised buildings. During the project, it emerged that energy consumption could also be further minimised through optimisation of operations.

Figure 121: Plus-energy district Ludmilla Wohnpark in Landshut, Germany
Source: *Energy-Plus Concept tested on Housing Estate*[227]

4.5.2. Next Generation Photovoltaic Cells

More than 90% of all installed photovoltaic cells are today still of first or second generation. The first generation[228] (1G) was composed of thick, mainly Si, crystalline films characterized by high efficiency and high cost. The theoretical maximum efficiency of a single p-n-junction PV cell under typical unconcentrated sunlight conditions is given by the Shockley-Queisser (SQ) limit, which is at 33.7% for the maximum semiconductor band gap of 1.34 eV[229]. This theoretical maximum limit can increase for tandem solar cells with multiple layers. Tandem solar cells with infinite number of layers could theoretically have a maximum efficiency of 86.8%, using concentrated sunlight[230]. Such high-efficiency PV cells are very expensive. Reacting to the high cost of 1G PV devices, the second generation (2G) PV devices was characterized by low cost and low efficiency devices; it was composed of thin films, including amorphous or polycrystalline Si, CIGS, or CdTe films. The third generation (3G) PV cells attempted to keep costs low while increasing efficiency. 3G devices include, among others, organic PV cells and dye-sensitized solar cells (DSSC or Graetzel cells[231]). Contrary to 1G and 2G devices which were available only as PV panels, 3G cells are available in a great variety of forms and can be framed into building walls, window glass, roof tiles, or, as they are flexible, they can be sewed into handbags, backpacks or clothing. DSSC cells have evolved to become perovskite cells, which have increased efficiency beyond 20%, with a theoretical maximum predicted to be at 34%. They can easily be used indoors at low light intensity. Fourth generation (4G) PV devices or “inorganics-in-organics” 4G polymer solar cells are currently under development and include a great variety of nanomaterials and nanotechnologies.

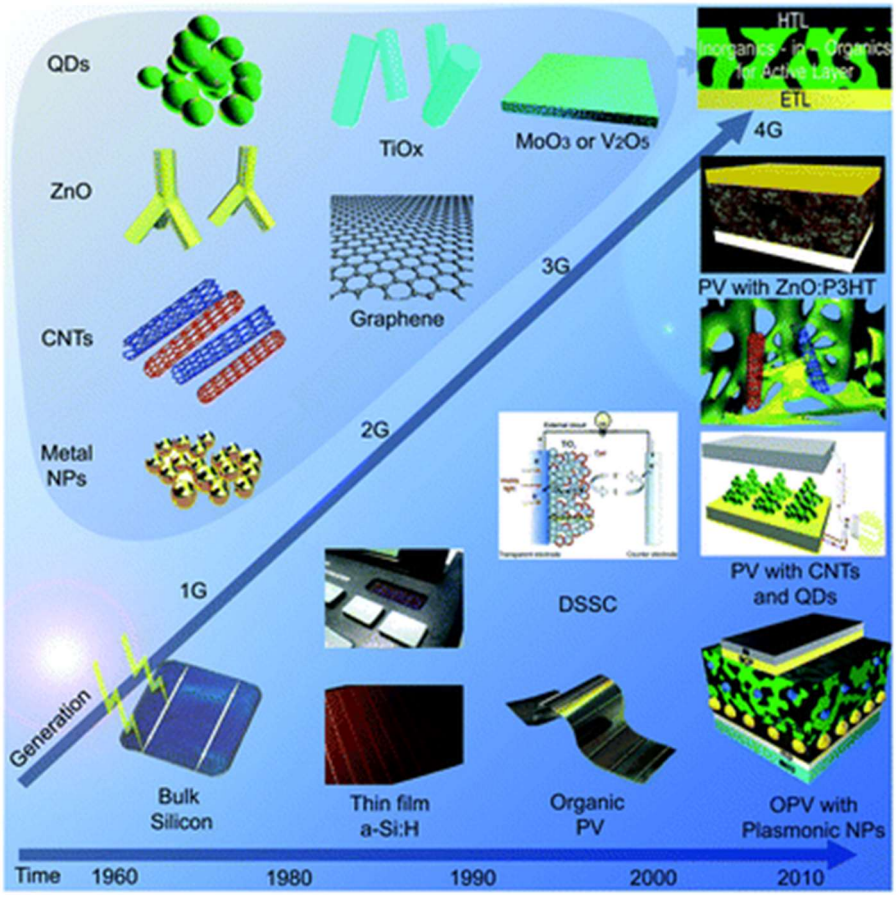

Figure 122: Timeline of four generations of PV devices
Source: Nanoscale, 2013, 5, 8411

3G and 4G devices are expected to drive not only the plus-energy districts described further above, but also the integration of solar energy into a wide variety of other activities requiring decentralized, cheap and clean energy, contributing thereby to increased energy security and greater user comfort.

4.5.3. Wastewater-to-electricity

Besides plus-energy districts and next generation PV, the generation of electricity from wastewater ought to receive higher attention in APEC economies. It is a win-win solution especially in dry and urbanized areas where both, electricity and clean water are rare.

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 $10^7 J/m^3$ of wastewater, i.e. around five times the energy consumed to treat the wastewater[232]. 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. In the US the daily amount of

wastewater produced is around $1.26x10^8m^3$ representing the potential of 13GW or the equivalent of 13 large nuclear power stations. City planners should not leave this source untapped.

The simplest technology to tap this energy is anaerobic microbial treatment yielding methane. With this technology, 80% of the energy contained in the original wastewater can be transformed to methane. The use of methane fuel cells allows harvesting around 60% of this energy in form of electricity. In its simplest form the process is not yet supplying net energy. In many European Member states, however, the point of break-even has been reached, above which wastewater can start becoming net electricity producer.

The technology is adapted to emerging APEC economies as the example of Thailand shows.

Figure 123: Wastewater to electricity in Thailand
Source: MyClimate[233]

4.5.4. From Electric Vehicles to Fuel-Cell Vehicles

A crucial point for the sustainability of transport systems is of course the evolution of the energy type such systems use. The 20th century has been marked as the century of fuel cars. In the early 1970s oil had become so important that it became a factor in geopolitics.

The 21st century will not simply extend this paradigm. Electrification of vehicles has started and is now under deployment. For cities, the gains can be manifold and show themselves in terms of diminished air pollution, diminished noise, higher fuel efficiency. The driving force behind electric vehicles is however greater sense of comfort. This comes along with integrated computer systems and the internet of things that offer semi-automatic and fully automatic driving.

Electric vehicles are only the beginning of the evolution. The central element is the change of the engine from a fuel engine to an electric engine. However, a next step of evolution is planned to happen in the sense that methods have to be found to extend the range and the capacity of electric vehicles. The development leads towards hybrid and fuel-cell vehicles powered by hydrogen.

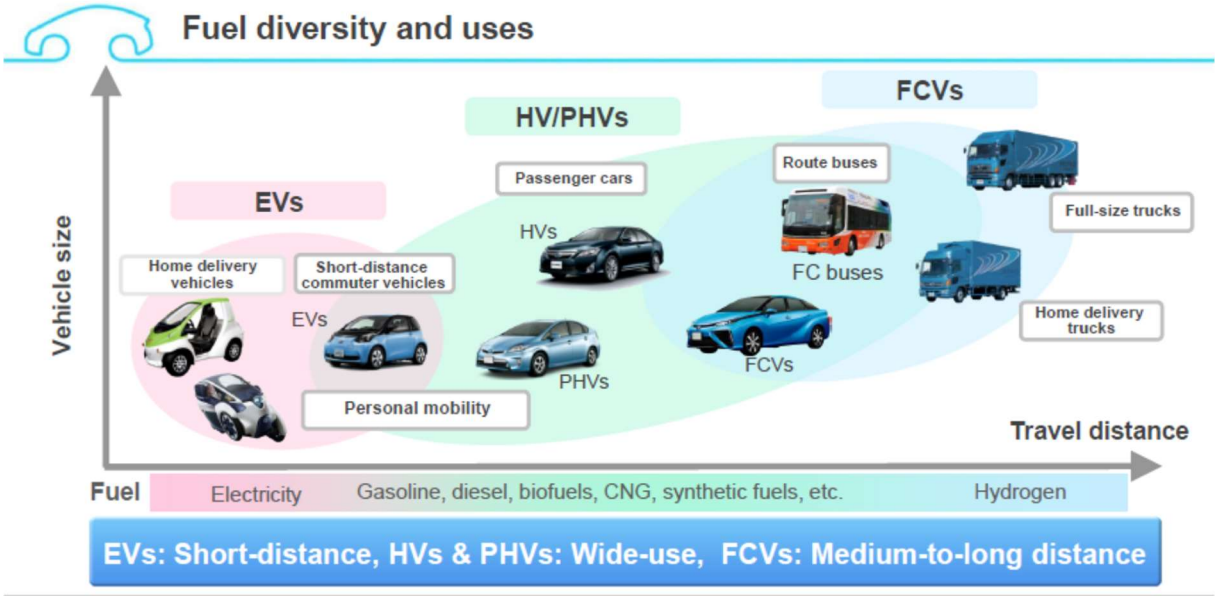

Figure 124: Development from electric vehicles to fuel cell vehicles
Source: Toyota[234]

The likely breakthrough of fuel cell vehicles might come from the heavy transport vehicles as they have the greatest need for extending power and range. Already in 2016 plans were announced in the US to produce hydrogen fuel cell trucks to start operation in 2020[235]. The question of availability of hydrogen fuelling stations is to be addressed in cooperation with local and regional planning authorities. Currently all hydrogen fuelling stations worldwide can be seen on the website http://h2stations.eu/. The site also allows for user-feedback so that all information should normally be up to date.

Within the “Made in China 2025 Strategy”, China has developed an “Energy Saving and New Energy Vehicle Technology Roadmap”, which contains the Hydrogen Fuel Cell Vehicle Roadmap[236].

4.5.5. Self-Driving Cars

If there is any technological development that has astonished almost everybody for its speed and the many surprises it brought, it is the development of self-driving cars[237]. The moment may have arrived soon when the self-driving cars will receive a better name. Just as the “horseless carriages” became simply “cars”, the self-driving cars will receive a simpler name.

The change from cars to self-driving cars is of the same magnitude as the one from horse-driven carriages to cars. The physical and legal infrastructure as well as the business models need to be radically adapted. Self-driving cars are likely to be rolled out as part of the sharing economy. And they are mostly electrically driven.

It is very likely that self-driving cars will be part of sustainable urbanization just as the smoking chimney and the conveyor belt was part of the industrial revolution. City planning should start early to accommodate for the specific infrastructure needs of this evolution.

With the high speed of this progress, it is foreseeable that the challenges of safety will be rapidly resolved. In a few decades, the robot driver will possibly not only overtake the human driver in accuracy but might in the end also become the human's driving instructor.

Self-driving cars can be a chance for congested cities, as self-driving cars could be programmed to overcome selfish driving patterns and hence avoid the Braess' Paradox described earlier. In that situation, everybody could win.

4.5.6. Photovoltaic Roads and Mobile Wireless Electric Vehicles Charging

The idea to use roads and highways to produce electricity might date back as far as 2010[238]. At that time, it was concluded that the cost was still prohibitive compared to normal road pavement.

Since then, significant technological progress has been made, not only for the photovoltaic road pavement, but also for the wireless charging notches of electric vehicles driving over it.

In December 2017, China has inaugurated a first experimental section of a photovoltaic highway in Jinan, capital of East China's Shandong Province[239]. While for the moment the road will mainly be used to test electricity production and to defreeze itself from ice, future use may include testing mobile wireless charging of electric vehicles, internet of vehicles and dynamic road signalling.

Figure 125: Inauguration of the photovoltaic highway in Jinan, China, December 2017
Source: Xinhuanet[240]

Given the enormous drive of China to build new infrastructures, this type of infrastructure could make progress. If this happens, it is likely to be in urban areas where the demand for the multiple services provided by this kind of infrastructure, such as charging electric vehicles, de-freezing and road signalling, is far greater and could justify the high investment cost of these roads.

One of the problems to be solved for solar roads is the sensitivity of crystalline silicon solar panels to shading of any kind, especially due to nearby objects, but also due to dust or other objects blocking sunshine and creating serious damage due to the hot spot effect. This can be overcome by using thin film solar cells. The problem of thin film solar cells is, however, that they can up to now only withstand the weight of cars, but not the weight of lorries.

4.5.7. Automatized Underground Freight Transport

It can be observed that cites develop fast once a subway system is in place. Underground transport plays, therefore, a leading role in city expansion. It has been suggested to apply the paradigm of underground transport also to freight. Given the ever-increasing amounts of freight transport, there could be a further leap-frog towards growth of cities. The transition towards sustainable energy should then be part of such leap frog.

As early as 2004, a study prepared for the New York State Energy Research and Development Authority[241] made a detailed assessment of the technology development of pneumatic capsule pipeline (PCP). It was found that twin lines of PCPs of various sizes and of both round and rectangular cross-sections can be used in New York City for a number of applications including but not limited to:

(1) underground tunnel construction,

(2) transportation of municipal solid wastes from transfer stations to a common out-of-state landfill/processing-recycling centre,

(3) transportation of mail and parcels from (to) the five boroughs of the City to (from) Washington D.C. and other cities along the route,

(4) transporting pallet goods via a network of tunnels under New York City,

(5) dispatching standard containers from (to) the container ports in New York City to (from) an inland station in rural area for inspection and intermodal transport, and

(6) ferrying trucks across the Hunts Point peninsula to reduce traffic jam and air pollution caused by trucks serving the largest food processing centre.

It was found that all the aforementioned six potential applications are technically feasible by using well-proven technologies such as PCP, blowers, linear induction motors, tunnel boring machines, micro-tunnelling, horizontal directional drilling, barcodes, and radio-frequency identification (RFID), etc. The cost of each application has also been assessed and compared with the current cost of using trucks for the same purpose. It was found that the first five of the six potential applications are more cost-effective than using trucks. In all these five cases, great savings can be accomplished by using PCP instead of trucks. The sixth potential application

(i.e., the Hunts Point project) is the only one found to be uneconomical. Even so, the project can still be justified for its social and environmental benefits to the residents of Hunts Point and Bronx.

Due to lack of investor interest this project has not been realized despite its cost advantages. The United States, an economy whose infrastructure scores a D+ according the American Society of Civil Engineers[242], may simply not be the right place to produce new infrastructures.

Considering the evolution of the number of total public transport journeys between 2000 and 2014 (see figure below), this singles out China as economy with biggest increase, whereas Eurasia (Russia and Ukraine) and Eastern Europe show decreasing total number of public transport journeys. China has much stronger drive to set up large transport infrastructures than many other economies.

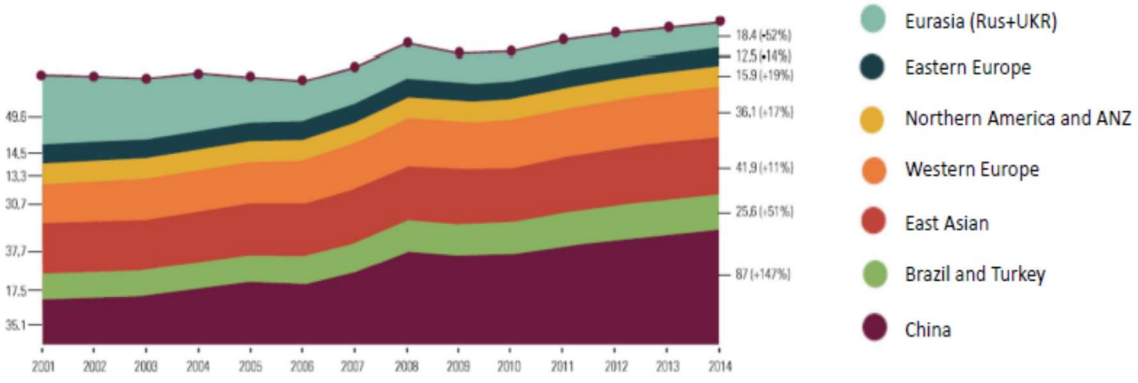

Figure 126: Total public transport journeys 2000 – 2014
Source: SDG11 Global Synthesis Report, UN Habitat

An overview of underground freight transport has been published in 2018 by Johan G.S.N. Visser[243].

The International Society for Underground Freight Transportation (ISUFT) has held its 8th international symposium In China in November 2018[244].

Six underground logistic system (ULS) projects in China were mentioned during this symposium[245], three in the Beijing region and three in other parts of China:

- ULS of Tongzhou Sub Center
- ULS in pipeline at the Beijing New Airport
- ULS in a New District
- "Waigaoqiao Port -Jiading" underground container logistics system in Shanghai
- Underground container rapid transit system in Shenzhen West Port
- Underground container rapid transit system in Tianjin Port

Recently (2018) Switzerland has decided to embark on shifting freight transportation into underground tunnels using electrically powered automated self-driven vehicles that can be linked to convoys[246]. This project is called Cargo Sous Terrain and will be totally powered from renewable energy sources. It is designed to remove as much as possible cargo freight from the streets. A first module of this system is planned to start operation in 2030. When completed,

the planned network will be about 500km long and cross the country in East-West direction from Geneva to St. Gallen with a branch to Basel.

The important factor to note is that the region where this project is planned to be realized is not a big city, but a cluster of medium-sized cities with population between 100'000 and 400'000 persons. With this project, this cluster of cities will grow together even faster than would be possible by the existing surface transport railway system. One of the driving factors for the realization of Cargo Sous Terrain is that enough investor interest has been found that allowed creating an industrial consortium.

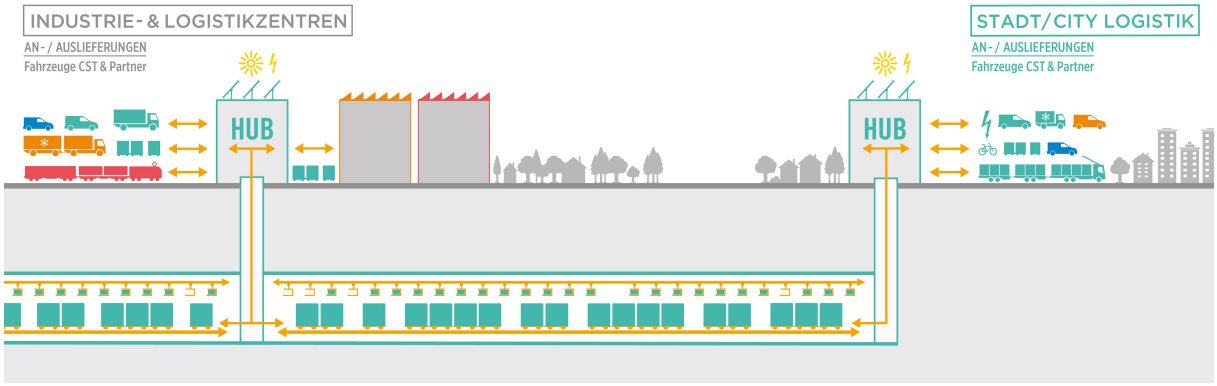

Figure 127: The Swiss Cargo Sous Terrain project
Source: Cargo Sous-Terrain[247]

The Cargo Sous Terrain planned as a two-layer transport system. In an upper hanging layer, the average speed will be higher than in the lower rolling layer. The fully automated process management should allow to charge and discharge the lower layer while it is in movement.

Cargo Sous Terrain is not a railway tunnel. It is complementary to the North-South railway infrastructure which includes the longest railway tunnel of the world that was opened in 2016. This railway tunnel serves to transport lorries from Germany to Italy with minimal environmental impact in Switzerland.

4.5.8. Plastic to Oil

To conclude the display of cutting-edge technologies, it is appropriate to briefly mention a technology that is resolving the problem of plastic waste. On 20 September 2018, the Austrian firm oil producer OMV opened the ReOil plastic recycling plant at the Schwechat Refinery near Vienna. This pilot project allows to transform 100kg of plastic to 100 litres of synthetic crude oil per hour[248].

The energy that can be used in this manner is neither renewable nor CO_2-free. Yet it helps closing a cycle of plastic waste that, otherwise, is difficult to close, unless by waste incineration.

Conclusion – Elements of a Cooperative Strategy

This Conclusion assembles the elements of a results-oriented cooperative strategy for scaling up APEC sustainable urbanization by targeted focus on energy technologies that synergize resilience with better economic performance, social inclusiveness and less environmental impact. The term 'results' includes: impact (overall objective), outcomes (specific objectives) and outputs.

This strategy is based on the elements exposed in the preceding Chapters. First, on the fact that strong urbanization pressure exists in emerging APEC economies and on the fact that cities contribute as growth engines to the well-being of their economies. Second, on the finding that sustainability deficits exist in APEC cities across the board, of which the lack of circularity, the lack of disaster resilience, the insufficient decoupling of growth from emissions, and the danger of slum formation have been specially earmarked. It bases itself also on findings that a major sustainability deficit is the lack of urban data. Third, the strategy bases upon the wide array of policy measures that have been adopted by the UN (SDGs), by APEC Leaders, especially the APEC Disaster Risk Reduction framework and the five energy-related APEC goals. It uses the best practice of selected APEC economies and cities, as well as of the European Union that has been pioneering sustainability during the past. Fourth, it draws upon five categories of instruments that support sustainability policies: physical and biological sustainability concepts as well as economic sustainability concepts, measurement methods (environmental-economic accounting, index methods), planning tools and ICT (multicriteria decision making, e-government, ICT), technical standards (ISO and IEC), and cutting-edge technologies (plus-energy districts, wastewater-to-energy, fuel cell vehicles and self-driving cars).

This concluding Chapter spells out the elements of the strategy by identifying cooperation partners, core values, the time frame, activities, targets and events of the strategy. In substance, the strategy proposes to scale up sustainable urbanization by complementing existing activities with a results-oriented monitoring approach of entire APEC cities acting as volunteers. The strategy focuses on the most urgent areas identified by APEC leaders either within APEC (energy goals), or within the Sendai DRR Framework as implemented by the APEC DRR Framework, or within the Paris Climate Agreement. The strategy uses the single most effective tool, namely integrated urban policies and planning, to achieve sustainability improvement. In response to the scarcity of urban data, the strategy proposes to collect relevant statistics at city level needed to monitor the mentioned APEC goals. It proposes to make these statistics available on the website of a city network, following the standards of Open Government Data (OGD) described in chapter 4. The strategy calls for the adopting authority (i.e. EWG) to fix targets in form of numbers of cities to be monitored by the implementing agency. Subsidiarily, the supervising authority (NEA) could fix targets of Chinese cities. These targets should be incremental so that they can be phased into the existing planning.

The strategy has an exploratory activity, namely the implementation of the system of environment-economic accounting (SEEA) at the local level, for which no APEC group could be found to adequately lead this activity.

Cooperation Partners

A cooperative strategy identifies cooperation partners that cooperate in order to attain the set goals. When referring to a cooperative strategy for sustainable urbanization, this necessarily implies cities or municipal authorities as **key cooperation partners**, acting primarily on voluntary basis.

Within cities, municipal authorities cooperate with other stakeholders such as interest groups or the civil society. The **most interested stakeholders** are the city service providers who build and maintain infrastructures or essential services. APSEC has a network of city service providers, as has been described in Chapter 3.

Cities reap benefits from cooperation with other cities, mainly for information and experience sharing. This cooperation gives rise to a city network with a corresponding **platform**.

Cities are usually part of a greater entity such as a state which is the **overarching rule setter**. Depending on the circumstances, member economy governments must be added as cooperation partners in this role. APEC has two city-economies, namely Singapore and Hong Kong, China. In the meaning of this strategy, “cities” should be understood to mean APEC cities, and governments to mean leading authorities of APEC economies.

Within APEC, this report is being prepared by China, an APEC Member economy, cooperating actively in the APEC Energy Working Group EWG. The Chinese National Energy Administration NEA coordinates Chinese policies in the EWG. The NEA is therefore the **primary addressee** of this strategy, the first governmental body to take note and, possibly, to decide on the follow-up. Procedurally speaking, the present report is the background report on the strategy, stating the elements of the strategy insofar as this task is in the competence of the concept author. If NEA decides to follow up, the present report may act as background report to the internal NEA procedure.

This report is a contribution elaborated under the umbrella of the Energy Working Group (EWG). Therefore, the EWG is the **secondary addressee** of this strategy.

A strategy must have an **adopting authority**. An adopting authority is an existing body which has the necessary legal competence and authority to adopt the strategy and either execute it itself, or task other bodies to execute the strategy and to report back. The Energy Working Group (EWG) is the secondary addressee of this strategy and its adopting authority. The EWG acts in consensus of the 21 APEC member economies, and within the framework adopted by APEC leaders and APEC Ministerial Meetings. Within APEC, this strategy does not require approval by a higher body than EWG. EWG has not approved this strategy yet. If EWG decides to adopt the strategy, the proposed specific measures, their cost, timing, executing authority, etc, will be written into a specific decision paper submitted to EWG and adopted by EWG pursuing the existing decision-making rules. The present report can then act as background report to this procedure.

If the strategy is adopted by EWG, it can thereafter be submitted to high-level APEC bodies for information. These bodies are **informed authorities**.

A strategy can only work if it has an executing agency. One possibility is that the adopting authority of the strategy is at the same time the executing agency of the strategy. This requires

the adopting authority to have the corresponding organizational and other resources. The Energy Working Group channels contributions from its members, especially APEC member economies, but does not have its own executive body. In APEC, the execution of projects is made by APEC member economies who may task special institutions with execution. The present report containing this strategy has been submitted by China to the EWG. The National Energy Administration (NEA) of China is the **supervising agency**.

The NEA normally tasks the institution representing it in the Energy Working Group, namely the APEC Sustainable Energy Center APSEC, with the task of carrying out executive work. In this logic, APSEC is the **executing agency**.

APSEC vision, missions and aims as noted in Chapter 3 include not only the role of being executing agency of this strategy, but also the role of **concept author** conceiving and adapting the strategy.

As urbanization is a cross-cutting issue, other APEC Working Groups are involved in this topic. These are considered as interested APEC cooperation partners. The following APEC bodies are **interested APEC cooperation partners:**

- Working Groups under the SOM Steering Committee on ECOTECH: Transport Working Group TWG, Emergency Preparedness, Science Technology and Innovation
- Friends of the Chair (FotC) on Urbanization
- ABAC Sustainable Development Working Group
- APEC Policy Support Unit PSU
- Under EWG: APEC Energy Research Centre APERC and LCMT-TF

It is not entirely sufficient for this strategy to only consider partners within APEC. Several non-governmental organizations from outside APEC (Global Covenant of Mayors GCoM, ICLEI, C40, Cities' Alliance – Cities without slums) are already partners of APEC cities with whom they cooperate, but outside APEC structures. These organizations are called **external cooperation partners**. APEC has special rules for cooperation with external bodies.

APEC cities that are members of one of these external cooperation partners, especially GCoM and C40, can play the role of **advisory cities** or **knowledge partners** in this strategy, but they are normally not the primary target focus of this strategy.

The strategy may also be relevant to other bodies beyond APEC. These may include various intergovernmental organizations (UN-ESCAP, UNDP, UNIDO, UNEP, UN-Habitat) as well as any other stakeholder external to APEC. This group of partners can be called **like-minded external observers**. APEC special rules for cooperation with external bodies also apply to external observers. The table below summarizes the different roles of this strategy and the partners identified in each role.

Role	Partners identified for the role
Key cooperation partners	APEC Cities acting on voluntary basis
Most interested stakeholders	Service providers of APEC
Platform	Network of APEC cities
Overarching rule setters	Leadership of each APEC economy
Primary addressee	National Energy Administration NEA of China
Secondary addressee	APEC Energy Working Group EWG
Adopting authority	APEC Energy Working Group EWG
Informed authorities	High level APEC bodies
Supervising agency	National Energy Administration NEA of China
Executing agency	APEC Sustainable Energy Center APSEC
Concept author	APEC Sustainable Energy Center APSEC
Interested APEC cooperation partners	Other APEC Working Groups under the ECOTECH: TWG, Emergency Preparedness Working Group EPWG, Science Technology and Innovation; FotC Urbanization; ABAC Sustainable Development Working Group; APEC PSU; APEC Secretariat; under EWG: APERC and LCMT-TF
External cooperation partners	GCoM, C40, ICLEI, Cities Alliance – Cities without slums, Economist Intelligence Unit EIU
Advisory cities, knowledge partners	APEC City members of External cooperation partners
Like-minded external observers	UN-ESCAP, UNDP, UNIDO, UNEP, UN-Habitat

Table 15: Roles and identified partners of the strategy

Core Values

A strategy requires defining the core values and main commitments of its partners. The most obvious core values to be chosen for this strategy are core values taken from among the Sustainable Development Goals. These goals are the common value of all the partners involved in this strategy. Within the scope of sustainable urbanization, it is possible to choose one particular goal such as SDG 11 on sustainable cities, or even one particular target, such as target 11.b as core value.

Target SDG 11.b states:

"**By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans** towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015-2030, holistic disaster risk management at all levels". Note that the SDGs state 2020 as deadline for this target, as it is more urgent than other targets.

Target 11.b explicitly includes integrated urban policies and planning in order to attain several objectives, namely resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and a holistic disaster risk management.

In other words, this target, if properly implemented, includes a certain number of other SDG targets, in particular:

Target 1.5. stating: “By 2030, build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate related extreme events and other economic, social and environmental shocks and disasters”. Integrated urban policies and planning takes care, or at least facilitates, building of resilience.

Target 3.9. stating: “By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination”. Integrated planning determines sites for disposal of dangerous waste.

Four targets of goal 6 (water), namely:

Target 6.1: “By 2030, achieve universal and equitable access to safe and affordable drinking water for all”.

Target 6.2: “By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations”.

Target 6.3: “By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally”.

Target 6.b: “Support and strengthen the participation of local communities in improving water and sanitation management”. The proper handling of freshwater and wastewater is one of the most important tasks of integrated policies and planning. Participation of the local community will make this planning inclusive.

Target 7.b: “By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all …”. Integrated urban policies and planning includes expanding infrastructure.

Target 9.1: “Develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all”. This target includes all types of infrastructure, also urban infrastructure.

At least two targets of SDG 11 on cities:

Target 11.2: “By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons”.

Target 11.3: “By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries”. The provision of these two targets is included, or at least facilitated, by integrated urban policies and planning.

Target 13.2. stating: “Integrate climate change measures into national policies, strategies and planning”. Properly implemented integrated urban policies and planning includes measures allowing the city to assume its share of the intended nationally determined contribution (INDC). For the INDCs of APEC economies see Chapter 3.

Figure 128: SDGs directly affected by integrated urban policies and planning

In sum, the core value of **commitment to integrated urban policies and planning**, as mentioned above, fulfils the aim of the strategy that synergizes resilience with better economic performance, social inclusiveness and less environmental impact.

In case a city wishes to broaden the results-oriented monitoring beyond the targets outlined above and monitor its sustainability at large, it is recommendable that the city considers introducing the System of Environmental-Economic Accounting (SEEA), see Chapter 4. Two APEC cities have done so (Yokosuka in Japan and Melbourne in Australia).

Time Frame

Timing is determined between two opposing forces, on one side the degree of emergency to achieve a goal, and on the other side the available resources.

Objectively, there is some degree of emergency to implement this strategy. Judging from the most recent IPCC report published in autumn 2018 (see Chapter 2), climate change is accelerating, and its harmful effects are increasing. Also, disaster reduction in SDG target 11.2. is an urgent matter. The UN has timed first steps (“substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans”) to be completed by 2020.

The timing set by overarching frameworks for starting the process is as soon as possible. The time horizon for reaching objectives is 2030. This strategy proposes to use the same time frame for the results-oriented monitoring.

Activities

This strategy proposes to scale up APEC sustainable urbanization. Scaling up means making something greater in size, amount or production, than it used to be. This is used when production is being scaled up from prototypes to serial production, implying also that production becomes more efficient.

The following activities can be derived from the above core values for each cooperation partner:

APEC cities' activities are to implement integrated urban policies and planning as set out in the Core Values above. APEC cities would be acting on a voluntary basis (unless their member economy authorities provide otherwise).

The **service providers' activities** are, within each or these APEC cites, to participate in the planning and/or implementation process to the extent the municipal authority will require them to do so. The service providers having capability to perform tasks of integrated urban planning can be called upon by the city to perform specific tasks related to integrated urban planning.

The **Network of APEC cities' activities** consist of making available to the public the integrated urban policies and planning of each participating city, including urban plans and policies on disaster risk reduction (DRR), on climate resilience and mitigation, and on fulfilling the APEC Leaders' energy goals. This should be done following the eight principles of Open Government Data (OGD) policy described in Chapter 4, providing in particular that published data should machine readable and made available free of charge. Data should be time series that can show progress in time. A network will either be created, or an existing network be adapted to this task.

Energy Working Group (EWG) activities consist in closing the policy cycle and doing efficient monitoring by sharing results (output monitoring), rather than reporting about efforts made (input monitoring) to attain the results. This paradigm shift towards results-oriented output monitoring requires relevant statistics. These are probably available, but not systematically collected and published.

A **first activity** of EWG to implement this strategy is results-oriented monitoring of implementation of the Sendai Framework at city level, which is done as part of integrated urban policies and planning. For APEC, the basis is the APEC Disaster Risk Reduction DRR framework which implements the UN Sendai Framework at APEC level. As the Sendai framework has five quantitative targets, the APEC DRR has not added any further quantitative targets. Results-oriented monitoring of both frameworks (APEC and Sendai) require collecting and sharing quantitative information by each volunteering city on casualties or losses for each disaster so that a record can be held over the years. The APEC Disaster Reduction Action Plan 2016, which is applicable at the level of member economies, proposes, among others, open sharing data platforms, however without indicating their content. As EWG is not directly in charge of the DRR framework, this activity is to be done as cross-sectoral activity implying EWG and EPWG and keeping informed the FotC Urbanization and PSU. The table below states the requirement of statistics for the first activity of this strategy.

Disaster (date and type), e.g.	**Mortality**	**People affected**	**Economic loss**	**Damage to critical infrastructures**	**Risk reduction strategy (date)**
Hydrometeorological Disasters, e.g.:					
Storm					
Flood					
Landslide					
Heat wave/drought					
Forest fire					
Hail					
Avalanche					
Subsidence					
Salt water intrusion					
Geological disasters, e.g.:					
Earthquake					
Volcano					
Diseases, e.g.:					
Epidemic					
Air pollution disease					
Water pollution disease					
Insect infestation					
Total					

Table 16: Results-oriented disaster monitoring at city level

The **second activity** of EWG to implement this strategy relates to monitoring emissions at city level, whereby cities assume their respective share of the economy's INDCs detailed in Chapter 3. Results-oriented monitoring requires establishing a baseline emission inventory in the base year and, possibly, a BAU scenario or the scenario of another instrumental variable (e.g. GDP) for the time frame of the strategy (2030). All the variables will then be updated for subsequent years so that the progress can be evaluated. The Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) offers the best basis for building community-level statistics in view of results-oriented monitoring of emissions at city level. The table below states the requirements of statistics for this case.

Monitored goal	Statistics required	Remarks
INDC share at city level	Series of annual GHG emissions; member economy BAU emissions projection until the target year; size of city relative to economy (percentage); series of annual GDP of city at constant prices	Depending on the specification of each INDC (e.g. absolute reduction with respect to base year, reduction with respect to BAU, or intensity reduction)

Table 17: Results-oriented emissions monitoring at city level

A **third activity** of EWG to implement this strategy relates to results-oriented monitoring of the two aspirational APEC goals as well as of the three other EWG goals at city level. The two aspirational goals require EWG to collect relevant statistics from volunteering cities on final energy consumption, primary energy supplied to the city, and city-level GDP (value-added) at constant prices (deflated).

Monitoring the city's contribution to the APEC low carbon development goal would normally be implemented by way of using the APEC Low Carbon Town Index LCT-I. However, the LCT-I is not really applicable to entire cities, and it may be burdensome for the city to calculate all the tier-3 indicators. This strategy proposes to use two proxies instead. The most useful proxy is to collect the percentage, with respect to final consumption, of low carbon energy produced within the boundaries of the city, including solar energy, geothermal energy, biomass, waste-to-energy and wastewater-to-energy, as well as the total related installed production capacity.

Monitoring the city's contribution to the APEC goal of enhancing energy security could be done in many ways. EWG provides for a vast array of measures, which might, however, be too burdensome for the city to evaluate. The present strategy proposes to use proxies. The chosen proxies are the energy storage within the city, including fossil stocks, biomass (incl. harvestable forests, if applicable), thermal and battery stocks, as well as the installed storage capacity.

Monitoring the city's contribution to rationalizing and phasing out fossil fuel subsidies is not directly possible as such subsidies are usually not in the hand of cities, but anchored in overarching legislative frameworks. There are only two areas where cities could possibly be involved in any subsidizing, namely wastewater treatment and solid waste treatment. These do not, however, consist of subsidizing energy, but of subsidizing waste treatment, whereby the sale of the energy produced is diminishing the subsidy. In other words, monitoring this type of subsidy is only indirectly covered by the APEC goal on rationalizing and phasing out inefficient fossil subsidies. Such subsidy is nonetheless an externality in the sense of Chapter 4 of this report and is harmful for market efficiency and should be rationalized and phased out. Monitoring would offer an occasion to discuss strategies for phasing out. Monitoring such subsidy is of interest to both, sustainable energy and sustainable urbanization. EWG could do it in cooperation with the FotC Urbanization who published the APEC Guidebook "Development of Sustainable Cities focusing on Resource Circulation and Waste Treatment" described in Chapter 3. This monitoring allows also monitoring implementation of the recommendations of this Guidebook by cities. The requirement of consists of gathering some statistics about the percentage of total cost of waste treatment that is covered by the sale of energy produced from these two forms of waste. The gathering of this type of statistics from cities would not be too difficult, but cities would profit from having knowledge about it.

The table below resumes the requirement of statistics for the third activity.

Monitored APEC goal	Statistics required	Remarks
Reducing city-level energy intensity on 2005 basis	Series of annual energy supply (or final consumption) and annual GDP of city at constant prices since 2005	
Doubling renewable energy share in city's energy mix, on 2010 basis	Series of annual final consumption (or energy supply) and renewables consumption of city since 2010	
Low carbon development goal	Series of annual low carbon energy production within the city, including solar and geothermal energy, biomass, waste incineration, wastewater-to-energy, and the installed production capacity	proxies
Enhancing energy security	Series of annual energy storage within the city, including fossil stocks, biomass, thermal and battery stocks, and the installed storage capacity.	proxies
Indirectly: Rationalizing and phasing out inefficient fossil fuel subsidies	Series of annual percentages of total cost of treatment of municipal waste and wastewater, respectively, that is covered by sale of energy	In cooperation with FotC Urbanization

Table 18: Results-oriented monitoring of EWG goals at city level

An **exploratory activity** for EWG can be the implementation of the system of environmental-economic accounting (SEEA) at city level. Two examples of cities having implemented SEEA exist within APEC have been mentioned: Melbourne (Australia) and Yokosuka (Japan). However, this activity can only be exploratory for EWG, as EWG could certainly contribute to this activity, but it could not take the leading role. A leading role for any activity is essential to guarantee results. EWG can convey the message to the APEC PSU and the FotC Urbanization, that if any one of them wants to take the lead, EWG could follow.

The **National Energy Administration (NEA)** of China receives an important activity in this strategy. China is taking very seriously the effort to implement the SDGs domestically. It is likely that the above information at city-level is available in China, either at the NEA, or at the NDRC or MHURD. The NEA could launch the idea among other Ministries, that China could reap international goodwill in communicating openly the detailed progress of some of its cities towards fulfilling the SDGs by using the above-mentioned results-oriented method.

The **APEC Sustainable Energy Center** APSEC as concept author of this strategy has the key activity to be its focal point and driver, determining the speed at which it will be implemented. APSEC is interacting with the other partners. These interactions are listed below.

The interaction with the (actual and future) **city members** of the network is done with the objective to maintain the platform for the relevant city statistics mentioned above under EWG

activities 1 to 3. Strictly speaking, the platform is only a means to attain the overarching objective, namely, to be able to show results achieved by the cities. For this, APSEC can analyse these results and compare them with the targets that have been set in the three applicable frameworks, namely the Sendai Framework, the INDCs and the APEC energy goals. APSEC might help improving the smartness of city infrastructures by proposing cities to refer to the ISO 37151 standard (see Chapter 4) on smart community infrastructures, containing, among others, recommendations for analysis of interoperability, synergy and resilience of energy, water, transportation, waste and ICT infrastructures. APSEC might discuss with cities the application of the ISO 52000 standards on energy efficiency in buildings, revised in 2017.

The interaction between APSEC and the **city service providers** will be done to facilitate the cities to reach or to exceed the set goals, as the case may be. City service providers have technologies as one of their main assets. APSEC might consider choosing city service providers as a function of the technologies they have. Some cutting-edge technologies have been described in Chapter 4. The mix of technologies available in the city services network should include buildings, transportation, water, waste and ICT.

The **network of APEC cities** is run by APSEC. To the extent warranted, APSEC will care for the seamless integration of its urban statistics platform with existing or new APEC platforms, above all with the urban data repository suggested to be created by the APEC Policy Support Unit PSU. With the exception of city GDP, the data repository proposed by the PSU will most likely not contain the kind of statistics proposed in this strategy. Neither is APERC likely to collect energy statistics at city level. Outside APEC structures, APSEC might at some stage be searching for linkage with existing providers of urban statistics, especially the Global Covenant of Mayors, C40, the Economist Intelligence Unit EIU, and UN Habitat, who all collect at least one data set included in this strategy for selected APEC cities.

Interaction of APSEC with the **APEC Energy Working Group EWG** is institutional. Incremental interaction relates to preparing the discussion and adoption of the strategy in EWG. APSEC might assist EWG when EWG is contacting the Energy Preparedness Working Group EPWG for implementing its first activity (implementing the Sendai Framework), and the FotC Urbanization for implementing a part of its third activity (subsidies in waste treatment).

Interaction of APSEC with the **National Energy Administration NEA of China** is equally institutional. Incremental interaction relates to preparing the position of China in the EWG as well as the supervising the implementation by the implementing agency (APSEC). APSEC might assist the NEA when the NEA is contacting other Chinese Ministries such as the NDRC and MHURD.

The interaction of APSEC with **APEC city members of External cooperation partners** acting as advisory cities or knowledge partners will facilitate the process. Chapter 3 has described Hong Kong, China as a city-economy having a well-developed system of integrated urban policies and planning.

APSEC will use opportunities to inform other **Interested APEC cooperation partners** as well as **Like-minded external observers** about this strategy.

Targets

The only targets to be discussed in this strategy are the **number of cities** to be monitored by the implementing agency. The targets for cities have all been set by overarching political frameworks, i.e. outside this strategy.

The important activity is to accomplish results-oriented output monitoring in a certain number of APEC cities by 2030. The target sets the number of APEC cities to be monitored. The monitoring agency is the APEC Sustainable Energy Center APSEC, i.e. the executing agency.

The total number of APEC volunteering cities to be monitored can be determined by the Energy Working Group as adopting authority. If solely the Energy Working Group determines the whole number of APEC volunteering cities, there is only one target to be set. Subsidiarily, the Chinese National Energy Administration could wish to determine the number of Chinese volunteering cities. In that case, there are two groups of volunteering cities, one of Chinese and one of other APEC cities.

The number of volunteering cities to be monitored must be phased into the current Five-Year Work Plan 2017 – 2021 of APSEC. Currently the Plan provides for policy exchange, information sharing, capacity building, collaborative research and technology cooperation. Results-oriented monitoring is one type of information sharing and can in principle be built into the current Plan.

For fitting into the Plan, the number of cities included into the monitoring scheme in each group could be increased every two years until the desired target number of cities is attained in each group.

This strategy does not need to go further in setting these targets. Setting the targets concerning these two groups is in the competence of the adopting authority, i.e. the Energy Working Group. The monitoring of these targets by these two bodies can easily fit into the existing institutional reporting.

Events

The strategy can be executed within the flagship events that are either organized by APSEC or in which APSEC participates.

- Annual anniversary forum held at APSEC
- Half-yearly meetings of the Energy Working Group
- Workshops
- Expert lectures
- Training activities
- Technical tours

The precise implementation by means of identification of single actions is part of the concretization of this strategy. It can be done after the adoption of this strategy for the first two-year period, and in form of rolling planning for subsequent periods.

Annex 1: APEC Leaders' Guidelines since 2014

Year	Event	Main content of the document
2014	22nd APEC Economic Leaders Meeting	The meeting approved the "APEC Cooperation Initiative for jointly establishing an Asia-Pacific Urbanization Partnership", involving a commitment to jointly promote cooperation projects, in-depth discussion of building green, efficient energy, low-carbon, people-oriented new urbanization and sustainable urban development path.
2014	26th APEC Ministerial Meeting Beijing	The meeting recommended the implementation of the APEC Low-Carbon Model Town (LCMT) and related promotion activities and the Energy Smart Communities Initiative (ESCI) under the EWG. The meeting welcomed the establishment of the APEC Sustainable Energy Center (APSEC). The meeting reiterated the aspirational goal of reducing APEC's aggregate energy intensity by 45 percent from 2005 levels by 2035 and to rationalize and phase out inefficient fossil fuel subsidies that encourage wasteful consumption while still providing essential energy services to those in need. The meeting agreed to trade in ICT products by converging energy efficiency regulations and enhance public-private dialogue through the ICT product Energy Efficiency Convergence Forum. The meeting endorsed the "APEC Cooperation Initiative for jointly establishing an Asia-Pacific Urbanization Partnership" and encouraged more support for urbanization cooperation activities. The meeting encouraged relevant APEC fora to incorporate urbanization-related topics to their work programs. It agreed to set up a Senior Officials Meeting (SOM) Friends of the Chair on Urbanization to guide future work in this field. It commended efforts made in the implementation of APEC Low Carbon Model Towns (LCMT) and Energy Smart Communities Initiative (ESCI) under the Energy Working Group and instructed officials to explore pathways to sustainable city development and to a new type of urbanization that is green, circular, low-carbon and people-oriented, thus striking a balance between economic growth, inclusive social development and sustainable use of the environment and the resources. The meeting also agreed to establish a cooperative network of sustainable cities in APEC economies. http://mddb.apec.org/Documents/2014/MM/AMM/14_amm_jms.pdf
2014	11th APEC Energy Ministerial Meeting Beijing	The meeting affirmed the work of the expert groups and the Task forces; expressed satisfaction with the positive progress made by APEC Low-Carbon Demonstration Towns (LCMT) Project and Low-carbon town promotion activities. It encouraged member economies to exchange ideas, technology, development and construction experiences of Low-carbon cities and towns and continue to strengthen practical cooperation in low-carbon towns. The meeting

		agreed to continue to implement the Energy Intelligence Community Initiative (ESCI) and build the ESCI knowledge platform to, share best practices and strengthen capacity-building. The meeting also endorsed the creation of the APEC Sustainable Energy Center (APSEC) to promote advanced ideas and models of sustainable energy development across the APEC region and facilitate cooperation among member economies in information exchange, policy dialogue, technology R&D, demonstration and dissemination and capacity building in the field of sustainable energy. http://mddb.apec.org/Documents/2014/MM/EMM/14_emm11_jms.pdf

Year	Event	Main content of the document
2015	23rd APEC Economic Leaders Meeting	The Leaders' Declaration reaffirmed the aspirational goals to reduce aggregate energy intensity by 45% by 2035 and double renewable energy in the energy mix in the regional energy mix by 2030 to achieve sustainable and resilient energy development within Asia-Pacific. The Declaration commends the initiative of creating a Task Force on Energy Resiliency, the initiative for enhancing the quality of electric power infrastructure in the Asia-Pacific region, and the establishment of the APEC Sustainable Energy Center. The Declaration commends the efforts of member economies in implementing the APEC Cooperation Initiative for Jointly Establishing an Asia-Pacific Urbanization Partnership and welcomed China's initiative to host an APEC high-level forum on urbanization in 2016.
2015	27th APEC Ministerial Meeting	The Ministers welcomed efforts in implementing the APEC Cooperation Initiative for Jointly Establishing an Asia-Pacific Urbanization Partnership. They encouraged relevant fora and sub-fora, including platforms like the Asia-Pacific Sustainable Energy Center (APSEC), to make contribution to the implementation process. They welcomed the outcomes of the first SOM Friends of the Chair on Urbanization, the 2015 APEC City Mayor's Forum: Building Better Cities, and China's initiative to host a high-level forum on urbanization in 2016. They welcomed projects to assess and demonstrate technology deployment for urban waste management that also include the recovery of economic worth from solid waste. http://mddb.apec.org/Documents/2015/MM/AMM/15_amm_jms.pdf
2015	2015 APEC Energy Ministerial Meeting	The meeting affirmed the establishment of the Low-carbon Town concept and index in the APEC Low-carbon Demonstration Town Project and encourages and supports the newly established APSEC work in sustainable cities and clean energy fields. http://mddb.apec.org/Documents/2015/MM/EMM/15_emm12_jms.pdf

Year	Event	Main content of the document
2016	28th APEC Ministerial Meeting	On energy, the joint statement reaffirms the commitment towards Leaders' aspirational goals to reduce aggregate energy intensity by 45 percent by 2035, to double the share of renewable energy in the APEC energy mix by 2030, and to achieve sustainable and resilient energy development within the Asia-Pacific. The declaration commits to rationalizing and phasing out inefficient fossil fuel subsidies which encourage wasteful consumption, while still providing essential energy services. The Ministers express appreciation to the economies that have volunteered to undergo a voluntary inefficient fossil fuel subsidy peer review in APEC and the G20 and encourage more economies to participate in peer review. On urbanization, the declaration acknowledges the need to implement sound, sustainable and people-oriented urbanization processes in order to create new opportunities and to invigorate innovative development. It noted with appreciation the APEC High-Level Urbanization Forum held in Ningbo, China, and the Ningbo Initiative. It encouraged APEC economies to further and deepen urbanization cooperation and enhance APEC economies' urbanization quality. It takes note of the project on Developing the Methodology for Measuring and Realizing the Sustainability of Cities in the APEC region. http://mddb.apec.org/Documents/2016/MM/AMM/16_amm_jms.pdf
2016	APEC High-level Urbanization Forum 2016	Key deliverable of the APEC High-Level Urbanization Forum 2016 Ningbo Initiative: Progress towards jointly establishing an Asia-Pacific Urbanization Partnership and resolve issues in eight key areas: 1) promote inclusiveness and dynamic growth of cities, 2) improve urban infrastructure, 3) build smart cities, 4) develop green cities, 5) encourage urban regeneration and retrofit, 6) drive innovative urban development, 7) advocate good urban governance, and 8) boost APEC cooperation on sustainable urban development. http://mddb.apec.org/Documents/2016/SOM/SOM3/16_som3_005.pdf http://mddb.apec.org/Documents/2016/SOM/SOM3/16_som3_006.pdf

Year	Event	Main content of the document
2017	29th APEC Ministerial Meeting	The Joint Ministerial Statement welcomed the implementation of the APEC Cooperation Initiative for jointly establishing an Asia-Pacific Urbanization Partnership, including the PSU's study on Partnerships for Sustainable Development of Cities. It recognized the APEC 2017 Dialogue on Sustainable Urbanization and noted the Guidebook for Development of Sustainable Cities. http://mddb.apec.org/Documents/2017/MM/AMM/17_amm_jms.pdf

Annex 2: Cross-cutting activities of APEC EWG (2017)

Cross-cutting activity	Work areas by which Energy Working Group contributes
Quality Growth	Energy Database and Analysis
	Low Carbon Model Towns
	Energy Security Initiative
Services	Energy Smart Communities Knowledge Sharing Platform
	Projects on sustainable urbanization; Energy Efficiency; Renewable Energy
Urbanization	Low Carbon Towns
	Energy Smart Communities
	Sustainable Cities
	Smart Power
	Low Emissions
	Zero Energy Building
	Lighting Design
	Design Sustainability
	Global Lighting Challenge
	Green Financing Mechanisms
	Innovative Solar, Green Buildings
Environmental Sustainability and Climate Change	Doubling Renewables Goal
	Energy Efficiency Goal
	Low-Carbon Model Towns
	Energy Smart Communities Initiative
	Energy Resiliency Task Force
	Global Lighting Challenge Partnership
	Green Energy Financing
	Fossil Fuel Subsidy Reform
	Clean Coal Technology
	Cooperative Network of Sustainable Cities
	Electric Power Infrastructure
	Net-Zero Emissions Buildings
	Water-Energy Nexus
	Fuel-Cell Batteries
	Solar PV and Wind Energy
	Green Energy Farms
	Biomass/Biogas Capture
	Electric Vehicle and Hydrogen Technology
Connectivity	Nearly (Net) Zero Energy Building
	Maximizing Energy Efficiencies of Supply Chain Connectivity by Improving Rail-Waterway Intermodal Transport Project
Environmental Goods and Services	Public-Private Dialogue on Promoting Trade and Investment in Renewable and Clean Energy

Food Security	Energy Security Initiative
	Green Energy Smart Farm
Finance	Green Finance
	Climate Finance
Security	Oil and Gas Security Initiative
	Energy Resiliency Task Force

Annex 3: List of APEC Sustainable Urbanization Projects

Projects are divided into two Parts:

- Part A: Low Carbon Model Town LCMT Projects, currently comprising the first seven phases
- Part B: Other projects of relevance to sustainable urbanization

Source: APEC Projects Database[249]

Project name	Part A: APEC Low-Carbon Model Town Projects	Total Project Value USD	Duration
APEC Low-Carbon Model Town (LCMT) Project, Phase 7	The APEC Low-Carbon Model Town (LCMT) Project Phase 7 selected Krasnoyarsk, Russia, for the case study. Phase 7 seeks to promote low-carbon town development to manage rapidly growing energy consumption especially in residential or industrial areas in the APEC region. The key activities are; 1) to **assess** both technical and policy aspects of real low-carbon town development projects; 2) to **disseminate** low-carbon towns in the APEC region through utilising the Concept of Low-Carbon Town and APEC Low-Carbon Town Indicator (LCT-I) System. **Feasibility Study** will be conducted by qualified urban design consultants. **Policy Review** of a selected low-carbon development project will be conducted by experts from interested member economies and relevant Expert Groups under the APEC Energy Working Group (EWG). The nomination of low-carbon town development project is on a voluntary basis. A low-carbon town development project for the Feasibility Study and the Policy Review will be selected through the EWG[250].	717,454	Aug 2016 to Jan 2019
APEC Low-Carbon Model Town (LCMT) Project - Phase 6	LCMT Project phase 6 selected Mandaue City, the Philippines, for the case study. Description as for phase 7, with the following change: The key activities are; to **refine** the "Concept of the Low-Carbon Town in the APEC Region". The refinement of the "Concept" and policy review of selected low-carbon development projects will be conducted by experts from interested member economies and relevant Expert	715,514	Aug 2015 to Dec 2016

	Groups under the APEC Energy Working Group (EWG)[251].		
APEC Low Carbon Model Town (LCMT) Project, Phase 5	LCMT Project Phase 5 selected Bitung City of Indonesia for the case study. Description as for phase 6[252].	829,989	Jan 2015 to Dec 2015
APEC Low Carbon Model Town (LCMT) Project, Phase 4	Under the LCMT Phase 4, San Borja, Lima, Peru was selected for the case study. Description like LCMT phase 5[253].	844,804	Jan 2014 to Dec 2014
APEC Low Carbon Model Town (LCMT) Project Phase 3	The LCMT Project Phase 3 selected Da Nang (Viet Nam) for the case study. Phase 3 seeks to promote low carbon town developments in order to manage rapidly growing energy consumption in the APEC region. The key activities are: 1) to **develop** "the Concept of the Low Carbon Town in the APEC region"; and 2) to **assess** the Da Nang (Viet Nam) low carbon town development project as a model on both technical aspects through Feasibility Study and policy aspects through policy review.	764,202	Jan 2013 to Dec 2013
APEC Low Carbon Model Town (LCMT), Phase 2	The LCMT Project Phase 2 selected Samui Island (Thailand) for the LCMT case study. Project description like in Phase 3.	799,340	Dec 2011 to Dec 2012
APEC Low-Carbon Model Town (LCMT) Project, Phase 1	The first phase of the LCMT Project, covered by this proposal, developed an initial version of the "Concept of the Low Carbon Town" and provided a feasibility study and policy review of a planned low-carbon urban development in Tianjin, China. The LCMT project consists of two activities, namely, i) **development** of the "Concept of the Low-Carbon Town" and ii) **feasibility studies** and **policy reviews** of planned urban development projects ('Low Carbon Model Towns') as examples of real-life applications of the concept. The key objectives of the project are; 1) To develop the "Concept of the Low-Carbon Town", which is intended to be a	811,000	Dec 2010 to Dec 2011

	guidebook to the principles and implementation of low-carbon urban design; 2) To assist in the implementation of the concepts in selected Low Carbon Model Towns by providing feasibility studies and policy reviews of these planned urban development projects; 3) To share best practices and real-world experiences with low-carbon urban design with planners and policymakers throughout the APEC region. The case study was made for the Central Business Districts (CBD), The Yujiapu Central Business District Development Project in Tianjin, China, prioritizing green field development.		

	Part B: Other Projects related to Sustainable Urbanization		
Promoting Innovative Green Financing Mechanisms for Sustainable Urbanization and Quality Infrastructure Development in APEC Region	The project aims to promote innovative green financing mechanisms for sustainable urbanization and quality infrastructure development in APEC economies. It will research the existing but less known financing mechanisms and integrate them with PPP and other mechanisms, encourage communications through different parties, identify the successful experience that are effective and applicable to more than one economy, provide a platform for experience sharing and lessons learning, and building capacity for APEC economies to utilize effective financing mechanism to support quality infrastructure development and sustainable urbanization.	176,473	Aug 2016 to Jan 2018
APEC Nearly (Net) Zero Energy Building Roadmap Study Responding to COP21	According to UNFCCC 2015, carbon emissions during building life cycle analysis account for 30% of global carbon emissions and this proportion will be up to 50% if the building energy consumption continues at current speed. This also increases risks and vulnerability of economies, regions and local communities to climate change impact. Rapid	191,926	Nov 2016 to Jan 2018

	urbanization, especially in emerging economies is only going to accelerate this impact. The promotion of Nearly (Net) Zero Energy Building (NZEB) has been proven to be the most effective measure of reducing energy consumption in building sector. The studies and experiences that have been shared during the previous projects received enthusiastic responses amongst APEC economies: NZEB policy, definition, R&D programs in "EWG-03-2013A" and best practices in "EWG-02-2015A". More than 300 participants from 17 APEC economies attended the 4 workshops from 2013 to 2016 on this topic. The objective of this program is to strengthen the energy reduction goals between UN and APEC 2035 energy intensity target for the building sector, harmonize the Nearly/Net Zero Energy Roadmap within the APEC region, find a flexible, approach to reducing building energy consumption through readily accessible methods to achieve NZEB in all climatic zones, prioritize a list of policy and technology recommendations for APEC economies to promote NZEB in the future. As an important supplement to trading regimes, this project will contribute to enhanced economic cooperation on building materials and building energy systems, equipment and appliances, thus promoting regional economic integration, leading to the fourth statement on Peru's Priorities. Within the program, APEC NZEB roadmap workshops is planned to be held in Hawaii, 2017[254].		
Workshop on the Establishment of a Cooperative Network of	The Asia-Pacific is currently experiencing booming urbanization. Sustainable development of urbanization is conducive to promoting sustainable development of APEC. To respond to Beijing Leaders' Declaration,	Self-funded, 0	Jan 2015 to Dec 2015

Sustainable Cities (CNSC) in APEC Economies	APSEC is willing to undertake the task of establishing a Cooperative Network of Sustainable Cities (CNSC) in APEC economies. The CNSC is intended to promote urbanization cooperation in the Asia-Pacific region, and to contribute to the Asia-Pacific Urbanization Partnership. The establishment of CNSC is based on the progress made in the APEC LCMT Project and the promotion activities as well as in the ESCI Program. A 2 days' workshop will be held in October 2015. Related stakeholders will join and discuss the feasibility and practical plan. The establishment of Sustainable Cities Mayors Alliance will be discussed, and the Initiative for Sustainable Urbanization might be released out as the achievement. The CNSC will benefit all member economies to recognize the challenges and opportunities in urbanization and provide opportunities for practical cooperation projects on sustainable cities featuring green, energy efficient, low-carbon and people-orientation[255].		
Capacity Building on Strategies and Implementation of Low-Carbon Town in APEC Economies	The project belongs to the field of energy and urbanization. Presently, APEC economies are experiencing rapid urbanization, facing significant environmental and energy stress. In order to enhance the capability to realize substantial sustainable development, low-carbon town model should be implemented and promoted widely (2014 APEC ministerial meeting, 8 Nov 2014). Thus, strategies and measures to implement low-carbon towns are in great need. The project aims to train professionals in APEC economies to build capacities of sustainable developing strategies, implementation measures and promote the current low-carbon town models.	244,425	August 2015 to Dec 2016

	This project is in consistency with the 2014 APEC leaders' declaration and the ministerial statement in Beijing, China. Projects proposed activities include: 1) Technical training; 2) Policy training; 3) Expert interaction; and 4) Low-carbon town review. Objectives of this project are: 1) The project is to build capacity of low-carbon town strategies, implementation measures and practices of the participants. Participants from various economies will have the opportunity to reach the most up-to-date strategies from administrators, technologies from experts, and experiences from practitioners. 2) The project is to form a communication mechanism of low-carbon town strategies and practices periodically. Workshop on the issues of low-carbon town study will be formed after this event, based on which a bi-annual workshop will continue to exchange information in this field. 3) The project is to develop recommendations to better promote low-carbon model towns. Voices from all participants will be heard and discussed, based on which, recommendations of how to better promote low-carbon model town will be formed. These objectives have been attained. A workshop has been organized on 19 – 20 October 2015 in Haikou, China. Details can be seen in the Completion Report[256].		

Clean and Efficient Use of Energy and Water Resources - Initiating an APEC Road Map and Best Practices for the Energy-Water Nexus	Reliable, affordable energy and abundant clean water are inextricably linked. The energy-water nexus is challenged by population growth, economic development and climate change. Understanding the implications of energy demand for water production; and energy system vulnerabilities from water dependency is critical to clean and efficient use of both resources. This study will identify energy-water nexus issues in the region, develop a baseline understanding of these challenges and identify ways to improve water and energy efficiencies. The United States, China and Australia, under APEC's Energy Smart Communities' Initiative (ESCI), will develop modelling capabilities to examine water use in energy production and energy use in water production, and identify potential vulnerabilities--particularly in urban areas. The project will 1) develop standardized definitions and data collection strategies, 2) gather relevant data from APEC economies, 3) determine data gaps, and 4) identify potential vulnerabilities and adaptive strategies to help mitigate energy-water nexus impacts and promote more efficient and sustainable use of energy and water resources[257].	75,000, self-funded	Aug 2014 to Dec 2015

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Sustainable Urban Development Report
From Models to Results

Asia-Pacific Economic Cooperation

APEC Sustainable Energy Center

APEC leaders repeatedly recognized the decisive role of sustainable energy in making cities and human settlements inclusive, safe, resilient and sustainable. APEC developed initiatives demonstrating the feasibility of Energy Smart Communities, Low Carbon Towns and a Cooperative Network of Sustainable Cities.

This report outlines elements of a results-oriented cooperative strategy for scaling up APEC sustainable urbanization by targeted focus on energy technologies that synergize resilience with better economic performance, social inclusiveness and less environmental impact.

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