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Current Opinion in Environmental Sustainability

Investing for rapid decarbonization in cities

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Cities offer some of the best opportunities for decarbonization. And a few sectors such as buildings, transport, water, and waste have the greatest potential for high impact decarbonization investments. Creating an enabling environment for cities to invest heavily to achieve systemic transformations in these sectors is essential for meeting the less than 2 °C target of the Paris Agreement in view of an urban population growing by approximately 1.4 million weekly. Unfortunately, significant barriers exist for these investments to grow at the required pace. The good news is that there are many initiatives such as the alliance of cities that have committed to achieving 80 percent reductions of GHG emissions by 2050, networks such as the C 40 network of city mayors from around the world that connect leaders and undertake research and programs to help cities implement low carbon and climate resilience strategies, and those of major private and institutional investors committed to ramp up their low carbon investments. Furthermore some 110 Paris Agreement country commitments include actions in cities with a focus exactly on those sectors with the greatest potential for decarbonization.

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Current Opinion in Environmental Sustainability 2018, **30**:42–51

This review comes from a themed issue on **Environmental change assessment**

Edited by **Karen Seto** and **Diana Ürge-Vorsatz**

Received: 14 June 2017; Accepted: 15 February 2018

https://doi.org/10.1016/j.cosust.2018.02.010

Introduction

The global temperature targets of the Paris Agreement cannot be reached without massive new investments for energy systems transformation in cities. Currently responsible for more than 70 percent of carbon dioxide emissions and with a projected growth of some additional 2.5 billion urban residents by 2050 [1], cities offer the best chance but also the greatest challenge for decarbonization. In developing countries, where there are major needs for large new investments in infrastructure to attend to the most basic needs of the current and growing urban population, the chance to decarbonize lies in making sure that the low carbon transition goals are incorporated into the development agenda [2]. With an estimated 90 percent of the urban growth increase to 2050 taking place mostly in Africa and Asia [3], the opportunities for creating major impact through low carbon development strategies and low carbon investments in these regions are immense but so are the challenges. And for existing building stock and infrastructure worldwide, from where a large portion of the current carbon dioxide emissions originate, large investments for transformation through retrofitting would need to be a central part of that low carbon strategy [4••,5].

Except for South Africa which has one of the highest green-house gas emissions intensities in the world due to its coal endowment, the African continent has one of the lowest GHG emissions per capita and accounts for less than 2.4 percent of the world's emissions. But this is mostly due to its poverty and a long period of economic stagnation rather than to a low carbon development. Now the continent is growing and rapidly urbanizing with a few of its cities being among the fastest growing. Consequently, emissions will rise considerably along with this growth and urbanization trends unless comprehensive strategies and policies are introduced to keep this emissions growth to a minimum. Ethiopia is among the very few countries in the continent that is doing exactly that. But this is an exception. Its Climate Resilient Green Economy (CRGE) Vision Strategy adopted in 2011 is designed to introduce a low carbon strategy. And the Growth and Transformation Plans (GTP) I and II of 2016, the main government policy instruments, aim for high growth levels but with climate neutral investments and policies. Many of them are directed to infrastructure in cities [6,7]. In its Nationally Determined Contribution commitment to the UNFCCC, Ethiopia makes extremely ambitious commitments to curb its GHG emission by 64 percent by 2030 focusing on a few sectors such as energy, buildings, water, agriculture, forestry, and transport and programs to strengthen governance. The type of comprehensive and low carbon strategy of Ethiopia is an example of that which is needed across the continent as GHG emissions begins to rise (Box 1). The combination of immense needs for new urban infrastructure, coupled with rich endowments suitable for renewable energy, is an excellent opportunity for Africa to embark on a low carbon development path. But this potential will be hampered severely, at least in the

short-term, by the lack of comprehensive strategies, lack of capital, lack of skills needed to develop and deploy the right technologies, and a weak local governance system throughout the continent [8].

As for Asia, it is a continent where 40 percent of global GHG emissions are currently emitted (rising from some 25 percent in the 1990s), and due to rise to some 50 percent by 2030 if the right policies are not put in place to prevent it. It is the region of the world where the urban population grew the fastest and where the rapid and carbon intensive economic growth has been driven by cities [9]. It is estimated that by 2050, 67 percent of the Asian population will be urban. Massive investments in infrastructure for energy, buildings, transport, and water provision will be needed to provide services to this additional population. Currently, it is estimated that over 650 million people lack electricity in Asia, many of them living in cities. According to the Asian Development Bank, the incremental cost of a low carbon development compatible with the Paris Agreement temperature targets would be in the order of US $ 300 billion per year through 2050 [10]. Countries in the region are facing these daunting challenges in different ways. India, which appears in the top ten global GHG emitters has some 25 percent of its growing energy supply covered by renewables and under the new government has launched one of the world's largest renewable energy expansion programs. Much of this will be directed to cities and its 'smart city' program. China, the largest carbon dioxide emitter in the world has announced a goal of 20 percent of its primary energy in renewable sources [11]. For the Paris Agreement, most Asian countries have submitted their Nationally Determined Contributions (DNCs), but according to estimates, these commitments are not nearly enough for the Paris Agreement. Under the current NDCs, the reduction of GHG emission would be halved whereas they would need to be in the order of three quarters according to estimates. The most promising means to achieve these reductions are through low carbon energy generation for the millions that still need access, and through end use energy efficiency in a few selected sectors, mostly in cities [10].

It should be said from the outset that there is no universally agreed definition of 'cities' or of what is 'urban' [12]. To illustrate the complexity, the UN Demographic Yearbook of 2005 presents a list of more than 100 countries from around the world and their diverse definitions of what they consider 'urban' [13]. The IPCC AR5 [14], refers to the existence of a vast literature on the efforts to come up with definitions of urban based on delineation of physical boundaries. It goes on to summarize the three most common types of boundaries as: administrative, territorial or political boundaries [15], functional boundaries dictated by interactions [16–18], and morphological boundaries based on built environment and land use [19,20]. In a more recent publication [21], the United Nations goes on to list three types of definitions or urban concepts that are based on those listed by the IPCC. The first type of definition refers to the administrative boundaries of cities and which includes even very small localities and settlements. The second type of definition uses the concept of 'urban agglomeration' and which refers to contiguous urban or built-up areas. And a third concept refers to the 'metropolitan area', whose boundaries are dictated by the economic and social interactions not only of the city itself but also neighboring areas in an open system. For the purposes of this review, the latter two categories would be most relevant for this review and for the subject of decarbonization and investments in urban infrastructure in cities.

The term 'infrastructure' also has broad definitions ranging from the physical, to the technological and institutional. For the purposes of this review, the narrower definition, that is, the capital-intensive and long-lasting physical assets such as buildings, transport, and energy and water infrastructure in cities are the ones that are most relevant. It is here where the investment decisions will have long lasting impacts and potential for decarbonization, or lock-in with severely negative consequences given the long life of many of these assets. Consequently,

Box 1 Decarbonizing the development strategy in Ethiopia.

Ethiopia was one of the first countries to formally merge the development and climate policy agendas by combining its climate resilience and the green economy strategies at a national planning level by adopting a Climate Resilient Green Economy (CRGE) Vision and Strategy in 2011. The strategy is based on four pillars: Improving agricultural practices while reducing emissions, building and regenerating forests with a focus to improve ecosystems services and carbon stock, increasing the share of renewable energy in final energy use, and introducing new technologies in transport, industry and building for better energy efficiency. The expected investment in infrastructure in the next five years alone is in the order of some $ 50 billion. The strategy promotes an economic development that pursues a low emissions path while building resilience to adapt to climate change. The Growth and Transformation Plans (GTP) I and II, the main government policy instruments on the economic and social development of the country, set out high growth levels for the country while striving for a growth that is climate-neutral or at least not harmful to the environment.

Ethiopia was the first Less Developed Country (LDC) to submit its INDC to the UNFCCC. In it, Ethiopia makes some very ambitious commitments to curb its greenhouse gas emissions between now and 2030. It commits to a 64% reduction of emissions by 2030 from the BAU scenario and targets key sectors such as forestry, agriculture, energy, buildings, water, and transport, and others. Most of these sectors, with the exception of forestry and agriculture, will have a big impact on the urban investment strategies in years to come. The strategy also contains an ambitious program on adaptation and capacity building that includes institution building and strengthening of governance. The immense donor support and national commitment make it an excellent example, particularly at this stage when the country gears up to deliver on such an ambitious commitment to climate change and a robust SDG implementation plan.

examining investment decisions to determine the long-term emissions through a forward-looking life-cycle assessment is essential [14].

Challenges and barriers to low carbon investment

The ambitions for a more sustainable and low carbon development in cities around the world in recent years has surged [22]. Other recent trends are equally encouraging. There is news regarding advances in technology and the economics of these technologies that have made them cheaper and more competitive [6]. In many parts of the world, there have been important system transformations that have moved away from carbon intensive energy sources [23]. There are also recent shifts in investment behavior with large private and institutional investors incorporating climate and low carbon within their objectives and goals [24]. There are global movements which have been effective in forcing considerable divestments in fossil fuel related portfolios of financial institutions [25]. But despite these positive signs, there are still many barriers that create obstacles for low carbon investments in cities to grow at a much larger pace. Some of these barriers are specific to low carbon investments nested to infrastructure investment in general [26••]. One of the biggest constraints is money and how to unlock the necessary financial resources for the less than 2-degree global temperature target. Financial constraints will need to be addressed by policies and regulatory frameworks as well as by efforts to incentivize innovative financial mechanisms and to de-risk low carbon investments which are often considered more risky particularly in developing countries [27]. More information needs to be disseminated to show the economic case for low carbon investments in cities and the multiple benefits that come with them [28••]. More information and research is needed to show the economic case for early action and the economic benefits of such strategy [29]. And more research is needed to understand the behavior of capital markets in energy systems transitions [30]. Clearer definitions and rules as to what constitutes climate finance is essential. Currently, these definitions and reporting are not well established [31,32]. Clearer definitions would help not only to mobilize climate finance in support of low carbon investments in cities and their low carbon strategies, but also to tackle some of the barriers that are specific to climate mitigation finance such as covering the incremental costs of low-carbon options [26••].

The magnitude of physical infrastructure required by cities in the next few decades is in the trillions of US dollars. What type of infrastructure is built over the next decade and beyond will determine whether the Paris Agreement targets will be reached and the degree of resilience of cities. This provides an opportunity for making sure that these investments are in low-carbon infrastructure specifically designed to use significantly reduced amounts of energy and that emits either Zero or close to zero GHG emissions. It is also an opportunity to ensure that these infrastructure choices consider the climate risks and the measures that are needed to reduce societal vulnerabilities and risks to investments. According to the United Nations [21], 56 percent of cities with more than 300 000 inhabitants are considered at high risk of at least one type of natural disaster. This translates into some 1.4 billion people in 2014 who were at risk. Thus, the urgency of having a better picture and understanding of the risks and of the most common barriers to low-carbon and resilient infrastructure investments. During the past few years, there have many efforts to understand and classify these barriers to give policy makers elements for tackling them. Below is a summary of the most common.

As already mentioned, many of the barriers to low carbon investments in cities are nested within those that are common to all infrastructure investment [26••]. These fall into several categories ranging from the political-economy related such as the frequent failure of local authorities to appropriate sufficient resources for needed investments and to allocate spending to those activities that maximize benefits; to the multilevel-governance related constraints that come with local decision makers having to depend on higher political levels or other actors of society [33–36]; and to the diffused nature of public spending benefits which often makes them difficult to translate into a price, thus making it less attractive to private investment. One recent study on the political economy of infrastructure in the UK [37] concludes that many of the problems in the decision making process around investments in infrastructure in cities are due to the lack of strong institutions where interest groups, experts, politicians, and representatives of local communities can have well organized and well informed discussions about policy options for infrastructure investment. Developing country cities furthermore face several other barriers such as lack of expertise, weak governance and regulatory frameworks, inadequate revenue base, poor credit and political, macroeconomic and currency risks [14]. As for barriers more specific to low-carbon infrastructure, the most common categories include the following: the lack of 'level-playing field' [38,26••,39] in investments where the costs of creating low-carbon investments are often more costly, are high capital intensive, often have high transaction costs, and need to compete with investments that benefit from fossil fuel subsidies or with the lack of accounting for 'negative externalities' of competing investments or appropriate carbon price; low carbon policy risks, those related to the predictability, longevity and reliability of policy and regulatory frameworks on which private investors specially base their decisions [14]; specific technology and operational risks related to performance and learning curves [14]; the existence of environmentally damaging infrastructure that creates a 'lock-in' which makes

replacements or retrofit costly or even impossible before the end of the life cycle of the current facilities [26••]; other more subtle barriers include the 'soft lock-in' created by path dependencies caused by existing institutions, lack of information, vested interests, cultural values, and political interests that need to be factored in [40,34].

New and innovative financial mechanisms to address some of these barriers have grown exponentially in recent years. These mechanisms and capital market instruments include the use of green bonds, guarantees, results based financing, revolving funds particularly for financing energy efficiency in buildings, microfinance and micro-leasing, carbon markets, hybrid instruments that bring together debt and equity, blended finance that use grants and non-grant financing from private and public sources, instruments that offer more risk mitigation and guarantees rather the traditional public finance instrument [41,42], and other innovative financial mechanisms and special measures needed to attract those institutions that manage trillions of US dollars [43••]. Business models in general need to be reviewed and reformed so that they can be more receptive to new low carbon technologies, energy service companies (ESCOs) need to be used more actively to help reduce risks and costs of investments, and leasing, with or without securitization, needs to increase when relevant and appropriate. And proper provisions or planning needs to be implemented to reduce the cost of stranded assets. But none of these would be successful without the right policy frameworks that provide confidence and security to the investors and in some cases funding for the early stages of project development and innovation [44] as well as the removal of both market and non-market barriers [45]. All the signals point to the fact that energy systems are indeed changing. But there is also evidence that integrated and systems approaches, which is what is needed particularly in cities, is lacking. Because technologies interact, integrated approaches will lead not only to optimal solutions but also to more efficient and cost effective solutions [46••]. This in turn has implications on governance and institutions of cities. Investing on building their capacities and their ability to operate in a systems world is a priority.

Addressing urban decarbonization through sustainable infrastructure investment

According to recent estimates, there will be more infrastructure built throughout the world in the period between 2015 and 2030 than the value of the infrastructure existing at the start of that period [47••]. According to estimates, this will generate a need for some $ 90 trillion (in constant 2010 US dollars) in new investments when the value of the current infrastructure is estimated at some $ 50 trillion [48]. This translates into some US $ 6 trillion a year in new investments [26••]. It is estimated that over 70 percent of this additional needed investments fall in the category of urban infrastructure investments or investments to serve urban population needs. The current annual level of investments is estimated to be around US $ 2.5 to US $ 3 trillion compared to the estimated $ 4.1 to $ 4.3 trillion that is needed [49]. Recent studies have tried to estimate the incremental cost of switching to or ensuring a low-emissions scenarios for these investments [49] and the additional costs of ensuring that urban infrastructure adapts to new conditions and risks of climate change [50,51]. According to research conducted by the World Bank, the additional annual costs required for adaptation infrastructure are between US $ 21 to US $ 37 billion and of these, some US $ 11 to US $ 20 billion is for urban infrastructure [51]. This infrastructure comprises the physical networks that provide, among others, energy, transport, building, water, and waste management services. Industry, particularly in Latin America and Asia, is also an important sector to target for decarbonization through greater efficiency and a switch to renewable energy [4••]. And more recently, district heating and cooling has come into focus by many major cities around the world [52] A large portion of this infrastructure will be built to satisfy the needs of the growing urban population mostly in developing countries where some two thirds of the new investments will need to take place and some one third in developed countries needed to replace aging infrastructure [53].

As mentioned above, given the long life of much of the infrastructure in cities, some 50–100 years, the types of investments made and in which technologies, will influence the carbon footprint of those cities for decades to come. It will also have a major influence on the urban form or physical structure of many cities, particularly with the type of investments made in buildings, transportation and mobility in general [54,13]. Will these investments lead to higher density and consequently to lower energy use and GHG emissions or to a continued urban sprawl [55]? The importance of the need to examine the impact of investments on the urban form is that they have a lasting influence of decades on the patterns of energy use of cities [56]. Systemic characteristic of urban energy use are important factors to take into consideration in the drive toward low carbon cities and in investment decisions of cities. For example, a shift to more compacts forms of urban development that allow for easier access and carpooling and that reduce congestion of vehicles results in lower energy use and improved air quality [49]; and investments that promote infrastructure and facilities for high density energy efficient buildings and non-motorized mobility would have a major positive impact in GHG emissions [57••]. Because of path dependencies, breaking carbon lock-in, particularly in the transportation sector is often difficult for policy makers trying to introduce aggressive low carbon goals. Often, these are challenged by interest groups that consider it a priority to provide automotive mobility for political goals and economic growth and development [58].

Governance, particularly governance with devolution at the subnational level, able to identify and formulate policy frameworks, identify and formulate projects, and then have budgetary control to fund and implement them, is central to the decarbonization efforts [48,59]. Unfortunately however, many cities around the developing world lack the political authority, and the budgetary, financial, technical, and institutional capacity to identify the best low carbon options and opportunities and orchestrate a switch to a low carbon development and low carbon investments [14,60,59]. Therefore, and as mentioned above when referring to the political economy of infrastructure investments, institutions and capacities need to be strengthened to empower cities to carry out consultations with stakeholders across sectors and interest groups and identify the best investment options [36]. The policies and measures of governments, at the national as well as the subnational levels will influence investment behavior and will either make it more difficult or eliminate barriers to unlock the needed financial resources [61]. These policies and measures will also have some influence on the behavior of people which in turn has a big influence on end-use energy and on the types and intensity of energy use [62]. The scientific understanding for assessing policy interventions and behavior is also still somewhat limited [63]. Behavior is particularly relevant to the end-use energy and the carbon emissions efforts in this regard. Carbon emissions are usually tackled in two areas of the economy. At the front-end, this refers to power generation and at the end-use it refers to the carbon generated from energy use in buildings, transport, water, waste management and other services [64].

In search of criteria for less than 2 °C investments

Given the magnitude and the impact of infrastructure investment in years and decades to come, criteria that would direct these investments to low carbon infrastructure is necessary and urgent. As shown above, the scale of the investments required points to a great opportunity to lower the footprint and avoid costly lock-in. And the potential for financial markets to mobilize the necessary finance is actually there given the right policy frameworks and incentives [65]. But currently, investment flows are not nearly aligned with the up to 2 °C target of the Paris Agreement [66]. Consequently, there are many of ongoing efforts to come up with criteria, principles, metrics, and indicators that could help direct financial resources to the massive investment needs and low carbon ambition of the Paris Agreement. There are also many voluntary actions by major investors. A combination of these, coupled with clear policies and measures, with active participation of public and private sector is what is required. Neither sector can do it alone. The role of the private sector is central. It is from the private sector that a large portion of the financial resources will need to come [67]. The public sector, however, needs to play an active role by putting in place the proper incentives and adequate policy and regulatory frameworks to attract private investment and by also investing, particularly in those social infrastructure areas where it is difficult to attract private investment.

Some of the most interesting and promising on-going research efforts are aiming at coming up with a 2 °C investment criteria [68•] or the use sectoral and cross-sectoral emissions intensity thresholds to show consistency of investment decisions with climate targets [66]. In the former, the approach is to group together technologies and investments that are 2 °C compatible based on underlying assumptions of available models. There are still many challenges to the application of such criteria including complexity, tradeoffs, and regional and local differences [68•]. Another stream of efforts includes those undertaken by Development Finance Institutions during the last decade. The objective of these institutions, which include both multilateral and development banks, has been to integrate climate related goals into their project analyses and policies of the institutions. Introduced long before the Paris Agreement, these efforts do not of course aim for the 2 °C target but rather for overall climate goals [69]. However, the methodologies, screening criteria, guidelines, metrics and tools used for tracking progress provide a good basis on which to ramp up the low carbon ambition of their portfolios and their programs in support of Nationally Determined Contributions. Since 2009, the Clean Technology Fund managed by the World Bank has been applying GHG emissions reduction potential in their project analysis and applying this for screening its portfolio [70]. In July 2013, the European Investment Bank introduced criteria for their fossil fuel generation projects [71]. In December 2013, EBRD includes in its energy sector strategy the promotion of energy system transformation to low carbon [26••]. Most bilateral agencies have been incorporating climate related goals into their policies and portfolios. In 2010, the Agence Francaise de Developpement introduced a directive that gives preferential treatment to projects that promote low carbon and began screening their projects according to their climate impact [72]. These are examples of on-going efforts to align project portfolios with low carbon goals by institutions with great global impact, influence and visibility. Some multilateral development banks are slowly shifting their priorities and evolving toward more support for low carbon portfolios [73].

Changes in investment behavior

Given the magnitude of the infrastructure investments needed in cities, it is impossible to succeed without increased involvement and investment by the private sector [47••]. And the private sector is responding [24]. However, this will not happen at the pace needed without the active engagement of the public sector which will need to provide not only some of the investments but also

the proper policies and regulatory frameworks to make these investments secure and attractive. In some areas such as renewable energy, availability of financial resources does not seem to be the main obstacle if the right policy frameworks are in place. In fact, the desire of investors to finance what they consider mature technologies helped drive the major acquisition in history in the clean power sector [74]. In the last few years, financial institutions have begun introducing measures to align their portfolios to low carbon and carbon related goals. Literature and research related to the need to transform business models so that they can account not only for economic but also for social and environmental considerations has also begun to appear [75]. Initiatives such as those of the Portfolio Decarbonization Coalition (PDC), co-founded by UNEP in 2014, and with some 25 signatories of major asset managers holding some $ 3 trillion USD in assets is just one of several examples of major shifts in investor behavior. The list includes some major private investors committed to decarbonize their investment portfolios to be aligned to a low carbon economy. The list of signatories included major investors such as ABP of Netherlands, Allianz of Germany, BNP Paribas Investment Partners of France, and Storebrand of Norway, to name just a few [76]. The next big drive needs to come from institutional investors such as pension funds which manage assets of some US $ 100 trillion, the banking system which manages funds in the order of some US $ 140 trillion, capital markets managing bonds and equities and which manage funds in the order of some US $ 173 trillion [77], and sovereign wealth funds which are even larger. Finding ways to shift these funds to low carbon activities through credible international and national policies and frameworks, innovative financial mechanisms, and perhaps, according to some, the introduction of carbon prices, would need to be a priority.

The Climate Summit of the UN Secretary General of 2014 triggered a series of commitments by many important coalitions of institutional investors and financial institutions toward a low carbon transition. These commitments need to be sustained and monitored over time as they have the potential of making a big contribution to the necessary shift in investment behavior. The commitments included those of the Portfolio Decarbonization Coalition mentioned above plus important coalitions and investors such as Bank of America Merrill Lynch which announced a Catalytic Finance Initiative designed to stimulate investments in low carbon projects around the world by 2022; Swiss Re which committed to providing advice to sovereigns and subsovereigns on resilience to climate risk and offering some US $ 10 billion for protection against this risk by 2020; the International Cooperative and Mutual Insurance Federation (ICMIF)/International Insurance Industry which committed to increasing significantly 'climate smart' investment with targets of more than US $ 100 billion which they have now surpassed [24]. Others in this coalition, such as Russell Investments, undertake and share their research on decarbonization strategies [78].

The 21st Conference of the Parties (COP) of the UNFCCC in 2015 marked an important event in the history of city commitments to renewable energy targets. On December 7, some 700 city leaders and mayors came together to commit to 100 percent renewable energy by 2050 and since then, a few more have been added to the list [79]. Several networks, such as ICLEI's (International Council for Local Environment Initiatives) 100% Renewable Energy Cities and Regions Networks supports cities and regions in their transition to 100 percent renewable by peer-to-peer learning and sharing of experiences. In 2014, the UN launched a Compact of Mayors to support local leaders in the fight against climate change. And on June 22 of 2016, this initiative merged with the already existing Covenant of Mayors of the European Union to form the Global Covenant of Mayors which then became the largest network of Mayors from around the world committed to sustainable development. NAZCA, the GHG emissions reduction commitments tracking mechanism established by the UNFCCC, keeps an open register for transparency. And it tracks commitments not only of cities, but also regions, businesses, and civil society organizations.

Investment trends are good but not yet good enough

In its most recent global energy investment report [80], the International Energy Agency reminds the reader that 'globally, energy investment is not yet consistent with the transition to a low carbon energy system envisaged in the Paris Agreement reached at the end of 2015'. While the trends in solar PV, electric vehicles and wind are on a promising trajectory, investments in other technologies have not been as robust as for example in Carbon Capture and Storage (CCS). Seventy percent of the investments in power generation in 2015 went to renewable energy. This figure decreased somewhat in 2016 mostly due to cost reductions and decreases in investments in Japan, China and some other emerging economies [81]. And 12 percent of the global energy investments of $ 1.8 trillion USD went to energy efficiency, with a large amount of this amount going to improve the efficiency of the envelope of buildings in cities (heating and cooling and half of this going to retrofits) where energy demand is being impacted by regulatory standards [82••]. Sales of electric vehicles around the world increased by 70 percent in 2016 to an estimated total investment of $ 4 billion USD and over one half a million cars [80]. These last two trends are mostly relevant to cities where these investments are mostly made. Some 19.3 percent of the global final energy use was provided by renewable energy in 2015 and the growth trend continued in 2016. Most renewable energy investments in new power sector generating capacity

have been in developing countries, mostly in China, but spreading to other parts of the developing world [81]. But are these new investments enough for helping us reach the Paris Agreement?

In its latest projections based on its main scenario (to 2040), IEA projects a need of some $ 44 trillion USD in investments in energy supply, of which some 20 percent will go to renewable and some 60 percent for oil, gas and coal, 10 percent less than in the period 2000–2015. This represents a major shift in reallocation of capital and investments in the energy sector. Some $ 23 trillion are estimated to be needed for energy efficiency [83••]. But this is not nearly enough for the less than 2 °C target of the Paris Agreement. In its more stringent scenario that would get us closer to this target, the IEA projections are for an additional investment in renewable energy to further decarbonize the energy supply. And added investments in energy efficiency of some extra $ 12 trillion USD compared to the main scenario. In its recent report, the IEA also points to another rising trend. That is the nexus between energy and water, mostly relevant to, but not totally exclusive to cities. The projections are that increase in water demand by a rising growing urban population will give rise to an increased demand in energy. Concurrently, the water needs of the energy sector will also increase [83••]. In its latest report, the International Renewable Energy Agency (IRENA) projects that in order to double the renewable energy mix, and thus contributing to a closer chance of arriving at the Paris Agreement global temperature targets, renewable energy share in the final energy mix would need to double by 2030. And this would mean an annual investment of some $ 770 billion USD between now and 2030 [44]. Much of this potential is in cities throughout the world and particularly in cities in emerging economies where some 70 percent of the energy use growth will take place [4••].

Conclusion: an optimistic landscape for the future

The magnitude and urgency of the investment challenge should not be underestimated. The Paris Agreement global temperature targets of less than 2 °C and up to 1.5 will not be easy to achieve. According to a recent study [84], to stay on track for reaching 1.5 degrees, GHG emissions would need to peak soon and then begin to decline very rapidly in the second half of the century and eventually becoming net-zero with actions that would include removals. The magnitude, speed and cost of the required energy transformation that this requires is immense but feasible, the study says, with the technology available. The level of ambition however requires a determined level of joint action and collaboration working at all levels of the economy and society. The good news is that there are many signs for optimism as illustrated in the examples below:

- A good international treaty is in place: the Paris Agreement [85] which has just been reached is the most universal commitment to date of the UNFCCC and the most inclusive in terms of almost universal engagement by nations and a diverse set of stakeholders.
- A landmark agreement by the international community on target-based action for development to 2030 by all nations: more and more, there is evidence that climate and development actions need to be interlinked, thus, the global endorsement of the Sustainable Development Goals (SDGs) [86] is a major boost to the climate effort and vice versa.
- An evolving climate finance regime [87] composed of public, international, bilateral, international institutions, private sector, and other multiple actors is becoming more mature, better funded, understood and well organized. The establishment of the Green Climate Fund, the on-going support to the Global Environment Facility and other funding mechanisms is a positive trend.
- Clean energy technologies are becoming more available, affordable and competitive.
- Over 100 NDCs commit to action in cities and in key sectors for decarbonization [1].
- Major city initiatives are gaining strength: a good example of this is the Carbon Neutral Cities Alliance with cities committing to 80 percent reduction of GHG emissions by mid-century [88].
- Better information is helping to mobilize funding and support for major infrastructure projects and investments.
- Better knowledge of co-benefits across areas including economic opportunities, health, business, and quality of life are now more known to the public.
- Smart city initiatives in different parts of the world (e.g. India and China) are becoming more commonplace.
- Development strategies in many countries are being linked to decarbonization: a good example of this is Ethiopia which was one of the first countries to link climate and development agendas formally and committing to stringent carbon reductions in its NDC [89,6,7,90].
- Low carbon and zero emissions urban mega projects are slowly increasing: the city of Masdar and several being establishes in China are good examples of cities in search of zero emission solutions.

Conflict of interest

The author declares that there is no conflict of interest.

Annex glossary

Carbon footprint: The amount of GHG emissions produced to support human activities, either directly or indirectly.

Climate finance: There is no agreement on a definition of climate finance. For its analysis, the IPCC AR5 defines it

as financial flows that are expected to reduce GHG emissions or to promote resilience.

ESCO: Energy Service Companies are companies that develop, design, build and implement projects designed for energy savings and their compensation is directly derived from the energy savings costs achieved.

Low carbon urban infrastructure: Infrastructure that is specifically designed to use significantly reduced amounts of energy and that emits either zero or close to zero GHG emissions.

Nationally determined contributions (NDCs): Prior to 2009, only industrialized countries had specific objectives to reduce Green House Gas (GHG) emissions. After 2009, a few developing countries made commitments. The significance of the COP 21 Paris agreement is that this commitment is now universal through the NDCs. As of December 26, 2017, 165 countries have submitted their NDCs (http://www4.unfccc.int/submissions/indc/ downloaded 26 December, 2017).

Paris Agreement: The Paris Agreement entered into force on 4 November 2016. For the first time, and building on the UN Framework Convention on Climate Change, the agreement brings almost all the countries of the world to combat climate change. The hope is that all nations will join without exception.

Portfolio decarbonization: This refers to action by investors to align their investment portfolio with the goals of a low carbon economy.

Smart city: There is no agreed definition of what a 'smart city' is but generally it refers to cities that connect the physical infrastructure, its people, and information and other high technology to optimize their use of resources.

Sustainable development goals (SDGs): Also known as the 2030 development agenda, the SDGs were globally endorsed in 2015 and are composed of 17 broad development goals and 169 targets to be achieved by 2030.

Stranded assets: This is a term in finance that refers to some assets that becomes obsolete well ahead of its projected useful life. When this happens, these assets need to be recorded as a loss or profit to the investor.

Sustainable infrastructure investment: Infrastructure that is socially sustainable because it addresses the needs of all and particularly the poor, economically sustainable because of its positive and lasting impact on the economy, and environmentally sustainable because it contributes to the transition to a low carbon economy.

Urban form: It refers to the shape, size, density and configuration of built up areas and transportation networks in a city.

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