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Peter B. Meyer, Reimund Schwarze

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Financing Climate-Resilient Infrastructure: A Political-Economy Framework[*)]

Peter B. Meyer, Reimund Schwarze

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Abstract: Urban infrastructure investment is needed for both, mitigation of climate risks and improved urban resiliency. Financing them requires the translation of those benefits into measurable returns on investment in the context of emerging risks that capital markets can understand and appreciate. This paper develops a generic framework to identify what are the necessary and sufficient factors to economically favor climate-change resilient infrastructure in private investment decisions. We specifically demonstrate that carbon pricing alone will not generate the needed will, because market prices at present systematically fail to account for climate change risks such as the costs of stranded assets and the national and local co-benefits of investments in climate resiliency. Carbon pricing is necessary, but not sufficient for an enhanced private financing of climate-resilient infrastructure. The Paris Agreement and other supra-local policies and actors including city networks can concretely help to generate the sufficient social and political will for investments into climate change mitigation and resiliency at the city level.

Keywords: infrastructure, urban finance, resilience, low carbon economy, city networks, Paris agreement, carbon pricing

Zusammenfassung: Der Klimawandel und eine verbesserte Resilienz erfordern weltweit erhebliche Investitionen in die städtische Infrastruktur, die nur mit Hilfe privater Kapitalbeteiligungen aufgebracht werden können. Deren Finanzierung erfordert die Übersetzung von Klimarisiken und der Nutzen von Resilienz in messbare Kapitalerträge und finanzmarktmäßige Risikobewertungen vor dem Hintergrund klimapolitischer Willenserklärungen. Dieses Papier entwickelt einen Theorierahmen zur Bestimmung notwendiger und hinreichender Faktoren zur Förderung klimaresilienter Infrastrukturen in privaten Investitionsentscheidungen. Insbesondere zeigen wir, dass eine CO2-Bepreisung allein nicht hinreichend wäre, die nötigen Investitionsentscheidungen anzustoßen, weil sie als Marktsignal nicht sämtliche ökonomischen Vorteile einer verbesserten Resilienz abbildet. Beispiele sind plötzliche, unerwartete Kapitalentwertungen oder nationale und lokale Zusatznutzen von Klimaschutz und Klimaanpassung. Eine marktmäßige CO2-Bepreisung ist notwendig, aber nicht hinreichend für eine Steigerung der privaten Investitionen in klimaresiliente Infrastruktur. Das Übereinkommen von Paris und die globalen Akteursnetzwerke von Städten tragen dazu bei, den hinreichenden sozialen und politischen Druck für die Mobilisierung privater Investitionen im Klimaschutz und zur Stärkung der Resilienz in den Städten zu erzeugen.

Schlagworte: Infrastruktur, Finanzierung, Resilienz, Klimaneutralität, Städte, Akteursnetzwerke, Parisabkommen, CO2-Bepreisung

1 Introduction

Infrastructure financing is a perennial problem: the public sector tends to focus on immediate needs and raising funds for current expenditures rather than longer-term investment. At the municipal or local authority level, many countries limit or ban independent debt financing by cities. In those countries in which such borrowing is permissible, there is a resistance to debt financing infrastructure investments associated with concerns over creditworthiness. There is thus an ‘anti-infrastructure bias’ (Ingram and Flint, 2011) built into the budgeting process that becomes even more acute when it comes to the incremental costs associated with climate-resilient infrastructure.

Such investments, however, can both mitigate climate risks and improve urban resilience and adaptive capacity. Financing them requires the translation of those benefits into measurable returns on investment in the context of emerging risks that capital markets can understand and appreciate. This need is recognized by many international institutions and efforts are underway to encourage capital markets to invest more in climate-resilient infrastructure (e.g.: UNISDR, 2015; CIEL, 2016; WBG, 2017).

Much of the literature on the actual experience of urban infrastructure finance is presentation of case studies of cities and their successes (or failures) in raising funds (e.g.: Young, 2011; Bulkeley et al., 2013; O'Brien and Pike, 2015; EEA,2017). There has been only limited effort committed to generalize from those experiences, and where such analysis has been conducted, it is generally deriving lessons for investors, not the cities (CIEL, 2016). This paper, by contrast, raises the question of how climate change may affect the private investment decision processes of such investors as insurers and pension funds and their potential interest in cities’ efforts to develop climate-change resilient infrastructure.

It is essential to focus on such private decision processes since most of the capital needed to finance climate change impact adaptation will have to come from the private sector (CCFLA 2015). To some degree, this capital is already beginning to flow as builders and building owners take actions to protect their investments. When it comes to climate change mitigation, that is taking actions to reduce the extent of climate change and the risks it poses, the private sector is doubly important: it not only is an important source of capital but also a powerful political actor, and mitigation requires both political will and financial capacity.

We first provide some key definitions, since “infrastructure” is not always consistently defined, and then examine the infrastructure finance problem, the special issues pursuit of resilience raises, and the major tools for raising funds. Next, we turn to the severity of the need to respond to climate change with new public investments to both mitigate and adapt to the emerging threats. We then examine the urban action opportunities that the logic and process of the Paris Agreement provides, regardless of national commitment. The importance of carbon pricing for providing a basis for climate (and carbon) risk disclosure is considered next, since it provides information needed to evaluate risk-adjusted return on investment in resilient infrastructure. We review the need to complement any such monetization with some elaboration of the diverse immediate co-benefits that may be experienced at the local level as the result of new investments in climate-resilient infrastructure before concluding by returning to the need to assure a local willingness to act, a necessity as fundamental as access to investment capital.

2 What is climate-resilient infrastructure?

The term "infrastructure" when used in casual conversation tends to be perceived as hard–physical systems – and public – as in roads, bridges, schools, public offices. But this is a very narrow definition of what needs to be considered in the context of generating more resilient systems in cities. Infrastructure really consists of two elements:

- HARD MEASURES for resilient systems in cities are physical interventions, such as the retrofitting of critical and defensive infrastructure, adapting buildings and urban spaces, managing the physical settlement relocation from at-risk areas, and adapting accounting for and promoting eco-systems services to a changing climate.
- SOFT MEASURES to enhance cities' resilience encompass land use and urban planning, community awareness and preparedness, monitoring of hazards and risks, early warning systems, emergency and evacuation plans, and the political will to pursue hard and soft measures.

In the modern age of information technology (IT), infrastructure is inherently a mix of hardware and software. That includes the programming, not merely the wiring, so to speak. In traditional transportation systems planning, the emphasis on the built roads, rails and related hardware remains dominant. When people talk about "smart" transportation, however, the softer elements – programming of lighting, coordinating of schedules, on-demand systems – enter the redefinition. All these additions are, arguably, from the world of IT. The soft elements of the 'smart city' and hard components of 'urban resilient infrastructure' seem to be defined by different metrics, but the true climate resilient city must combine both elements: "Resilience describes the ability of a system to withstand or accommodate stresses and shocks such as climate impacts, while still maintaining its function. […] The resilience of a city depends on both the fragility of the urban system and the capacity of social agents to anticipate and to take action in order to adjust to changes and stresses." (World Bank, 2011)

Recognizing this reality, we thus cannot limit resilience "infrastructure" to physical components, and we need to include the social, cultural and legal systems that link those hard elements to each other. Thus, our broader conception includes not merely roads, utilities, buildings and transportation or communication networks, but also health care, education, emergency and support networks, the so-called "safety net", and other welfare programs, not to mention the legal structures of markets for employment and exchange of goods and services. Neither element, it should be noted, is exclusively public or private; both types of ownership may – and, in most cases, do – coexist and coordinate.

For purposes of describing how climate-resilience may be ascribed to some infrastructure elements but not others, we might accept the broadest definition available on the web, that from Wikipedia:

Infrastructure refers to the fundamental facilities and systems serving a country, city, or other area, including the services and facilities necessary for its economy to function.

With this broad definition, we can move on to ask what changes in those facilities and systems are needed to promote the resilience that we argue is needed.

Climate-resilient infrastructure differs from traditional infrastructure in that it is less affected by the different impacts that may be associated with climate change. On the one hand, it must be more capable of recovery from climate-related physical impacts associated with extreme weather and/or rising sea levels. In this context, it must be capable of recovery from unexpected short-term shocks, but also able to respond and adapt to longer-term trends, including major changes in precipitation and temperature patterns. Beyond this capacity for climate adaptation, however, it must also be resilient to both local and supra-local regulatory and other measures addressed to mitigating future climate change since such efforts may affect residents' quality of life, local business continuity and regional economic and social growth potential.

Mitigation-responsive infrastructure decisions involve those over the technological and sectoral bases on which a local economy should depend (obviously arguing against public efforts to support local reliance on fossil fuel extraction, processing or use). But they also include both the choices of technologies used in infrastructure investments and those over regulatory practices and rules including building codes and land use controls. Climate mitigative infrastructure might also include what are often labeled as "nature-based solutions" for urban climatic challenges, e.g. urban forests, constructed wetlands, environmental education.

3 The economic and the political issues of climate infrastructure finance

Across the globe, the need for urban physical infrastructure investment vastly exceeds the funds readily available to cities. Estimates of annual infrastructure investment needs have ranged from some US$ 3.7 (WEF 2015) to US$ 6.5 (CCFLA 2015) trillion. A more recent (2018) United Nations finding is that "An estimated $5-7 trillion a year are needed to realize the 2030 Agenda for sustainable development worldwide." (UN Alliance for SDG Finance). It appears that the failure to make sufficient investments now or near term is driving up the cost of those investments over time as the extent of needed adaptive infrastructure investment climbs due to climate change and the prospect of more severe changes in the future rises. Those annual investment figures, while high, fail to take into account the possibly higher costs associated with assuring climate resilience.

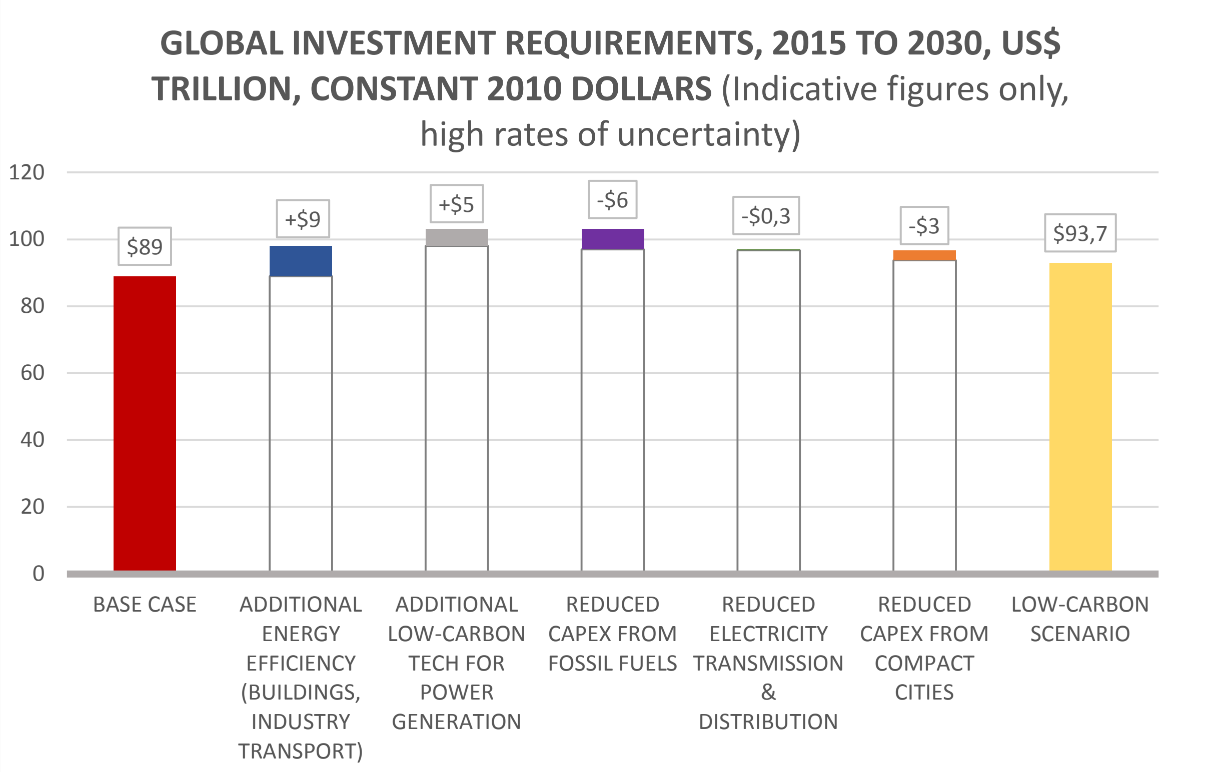
Available funds, however, are three orders of magnitude smaller: global climate finance climbed up to a record $437 billion in 2015, driven by private investment in renewables, then dropped to only $383 billion in 2016 (CPI, 2017). Since the need appears to grow with each passing year, the investment gap does so as well. This failure for fund or invest is generally ascribed to the fact that cities do not meet the standards of the private investment community that controls the vast majority of the capital available. The World Bank observed that only 4% of the 500 largest cities in developing countries were creditworthy in international financial markets and 20% are creditworthy in local markets (World Bank Group, 2013). Perhaps even more significant, as of 2013, only about 25% of the entire world's largest cities have the minimum analytical capacity to plan for a lower carbon future, such as a greenhouse gas inventory (Ibid).

Obviously, inadequate current soft infrastructure investment is not merely a third world problem. Examination of the legacy urban rail systems in Europe and North America shows rising problems due to inadequate maintenance and renewal of systems, so hard infrastructure investment is also inadequate. The real problem may be that infrastructure financing may be available but perceived by decisionmakers to be too expensive. In some cases the needs are so extreme that the cost of fully financing them through bond issuance may exceed even creditworthy cities' capacity to service the debt. Until such time as physical infrastructure systems regularly fail on a daily basis, repair and maintenance investments may well appear to be less immediate needs to local decisionmakers than other current expenditures. The more urban public systems are funded through local taxation and fees, the greater the local pressure to limit the imposition of infrastructure costs on the current population.

The basic problem is that the costs of *not* investing in infrastructure are not communicated to or recognized by the political constituents of the urban and supra-local decisionmakers. Similarly, the immediate, not merely longer term, benefits of making infrastructure more climate-resilient tends to be overlooked. There is no evidence to suggest that such infrastructure could not compete on current cost grounds *if* carbon risks and lifetime returns on investment are considered *and if* the political will is there to act locally on climate change. Data on almost 1000 office properties in the US over the 1999-2008 period showed that “Responsible Property Investment” (RPI) properties – those buildings with better mass transit access, greater energy efficiency or similar “sustainable” features – generally had higher net operating incomes and market values per square foot than those without such features and none were less profitable than the non-RPI buildings (Pivo and Fisher, 2010). More recent evidence from commercial real estate markets in the US suggests that such measures as increased energy efficiency in buildings can drive rents higher by as much as 14% while also generating higher occupancy rates (IMT, 2016). Similarly, an analysis of European property markets found that, “Energy Efficiency has a relevant and measurable impact on the value of assets and it should be considered in the valuation process” (Capelli, 2017).

It is also important not to overstate the incremental costs associated with climate resilient infrastructure. Fig. 1 below offers indicative figures that illustrate the cost savings associated with higher expenditures on assuring greater energy efficiency and less polluting power generation. Reduced capacity needed for expansion of fuel exploration and for power transmission permitted by decentralized generation and reliance on renewables comprises two types of savings. But reduced costs associated with the need to assure a more compact, denser, but still livable, city are generated as well.

Historically, households with the capacity to choose have shown a preference for lower residential density given the disamenities of urban living (noise and pollution associated with manufacturing activities, poor and underfunded schools). That preference pattern appears to have shifted to some degree in recent decades as the cultural and recreational amenities of urban living have attracted both younger people and ‘empty nesters,’ older households with no school-age children and the cost-savings associated with denser locations have become more important to many households (Myers and Gearin, 2001; Schwanen and Mokhtarian, 2004; Senior et al., 2004; Karsten, 2007; Buys and Miller, 2012; Liao, 2014). Awareness of climate change and experience with disamenities of low density living may also play a role (Talen, 2001). As a result, public investment in more climate-resilient, denser infrastructure may not just pay off on financial grounds but also in citizens’ quality of life which may be more important to local officials seeking reelection than the financial rewards according to our shared new institutional economic understanding of local governance.



- Including operating expenditures would make a low-carbon transition even more favorable leading to a further reduction of US$5 trillion

Fig. 1 Global investment requirements 2015-2030, US$ trillion, constant 2010 dollars

Source: Better Growth, Better Climate (Adaptation of an original work by The Global Commission on the Economy and Climate (2014). Views and opinions expressed are the sole responsibility of the authors of the adaptation and are not endorsed by The Global Commission on the Economy and Climate).

The Global Commission on the Economy and Climate (2014) assessed the net additional cost for low carbon investment required to meet the Paris Agreement goals to stay below 2° Celsius average global warming (projecting a 66% probability of success). Fig. 1 demonstrates that those incremental costs are required chiefly to make city buildings, industry and transport more energy efficient ($9 Trillion, or an increment of +10 per cent in cost). Additional spending is needed for a major energy transition in the power sector (a $5 T cost increment). But this cost increase of roughly 15% is balanced by some important cost savings. By far the largest cost savings ($6 T) accrue in reduced investments needed into fossil fuel-based capacity. Almost one third of those savings (-$ 1.8 T) result from avoiding the expected increases in the cost of financing fossil fuel-based investment. In other words, increasing carbon risks, including the risk of a city finding itself with “stranded assets,” comprise a significant offset to the costs of more climate-resilient infrastructure investments.

The term ”stranded asset” refers to the fact that changes in technology, markets or regulation may render economic assets worthless, eliminating their economic value and leaving those holding them “stranded” with no recourse. While often perceived as an irrelevant one-time effect (loss of sunk costs) for the economy as a whole, a sudden loss in the value of the assets it holds can severely impact any single economic actor’s ability to finance in capital markets. Cities are single actors in this sense and, thus, put their future creditworthiness at risk when holding on – or investing further – in business-as-usual fossil fuel-based infrastructure investment. Carbon risk accounting, if it were to become a systematic element of investment planning in cities, could address the stranded asset risks and turn them into actual cost savings associated with loss reduction that may be generated by city investments in low carbon and climate-resilient infrastructure.

Additional cost is saved through opportunities of smart transmissions and distribution of power in more compact and better connected, IT driven city systems (-$3.3 T). The net incremental cost for a low carbon transition of cities' infrastructure will settle at an investment of around $ 4.7 T and, thus, only about 5 per cent more than would be required under 'business as usual' (the base case).

But this minimal increase in actual investment needed for low carbon and thus more resilient infrastructure is only half the issue that needs to be addressed. However small the additional expenditure required, there remain significant barriers to making the actual investment.

Even if the economic and financial barriers to accessing capital fall to better long-term accounting, the political and social barriers remain. These include an excessive reliance on public funding and resistance to incurring new debt as well as to raising taxes. Overall, however, local concerns for current year budgets and short time horizons may be the greatest barriers to climate infrastructure finance (CIF) of cities.

The local political will to look beyond the immediate budget year is not an unmovable obstacle. It is, perhaps, ironic, that the short term perspective is most readily upset by the experience of climate related shocks. Disasters are events that communities do not want to experience again, so pressures to change in order to avoid feared future events can overcome the traditional focus on the most immediate impacts.

Supra-local policies and actors including city networks (e.g.: C40 Cities Climate Leadership Group, Carbon Neutral Cities Alliance, ICLEI, and Global Compact of Mayors) can also affect local political will (Gordon and Johnson, 2018). Conditions placed on the availability of funds from supra-local sources and/or peer-learning from other localities' experiences can overcome local ideological resistance to courses of action deemed appropriate by the national state. Overall, however, discernible local benefits of resiliency and low carbon development are necessary ingredients for generating the local political commitment required for the full range of sustainable infrastructure investment options to get thoroughly examined.

3 Opportunities and barriers of bottom-up climate financing under the Paris Agreement

Under the United Nations Framework Convention on Climate Change, the Paris Agreement went into effect in late 2016 after ratification by over 85% of the countries originally signing the pact. Under the leadership of President Trump, the United States federal government has since declared its intention to withdraw. States and local governments as well as companies headquartered or operating in the US have committed to pursuing the goals of the pact and other countries across the globe continue to abide by the agreement. (The continuing US commitment was made physically evident at the COP 23 meetings in Bonn in November, 2017, as an "unoffical" US Pavillion was opened by a coalition of those sub-state actors.)

The Agreement places heavy emphasis on what is referred to as Non-state Actor Zone Climate Action (NAZCA; http://climateaction.unfccc.int/). Cities are the primary actors in NAZCA, along with regions, states (where they exist in federal systems), companies, individual investment houses (including banks, insurers, and pension or superannuation funds), and community service organizations with significant (sometimes multinational) reach.

Cities thus are central to the aspirational goal of the Agreement to stay significantly below 2°C global temperature change, and strive for 1.5°C. (In a global 2017 survey of experienced climate change experts, 73% ranked them as important contributors to climate change progress, while national governments were ranked at 81% (Globescan-Sustainability, 2017)). The current Nationally Determined Contributions (NDCs) under the agreement are inadequate since the proposed actions are likely to lead to a warming of at least 3°C (UN Environment, 2017; Tobin et al., 2018). The need for a more stringent approach that involves 'ratcheting' the NDCs upward can only be met through the recognition on the part of city planners, businesses and financial markets of the mitigation efforts needed at all levels of society and government.

To the extent that the Agreement serves to guide and promote collaborative global action, it can help address the issue of the availability of needed social and political commitments at the city level:

- Ideology may have blocked commitment of available funds to sustainable or climate-resilient infrastructure in the past – but the national commitments on GHG and climate risk reduction may change ideologies even if the national states do not demand specific actions by cities
- Without prior political commitment, available sustainable infrastructure investment options may not have been examined, but with heightened incentives to find to act on reducing emissions, new options will be welcomed
- The previously limited local commitment was not fixed and could be altered by the actions and programs of supra-local political and social entities, and the Paris Agreement has already made a difference! (Arguably more so in the United States than elsewhere after the Federal commitment was visibly weakened by the Trump Administration.)

But having the will – and the legal and even financial means – does not assure that efficient and cost-effective investments will be undertaken. If actions do not meet expectations, they may be discontinued even when the need for some effort is recognized.

Cities with limited analysis staffs and capabilities may not be able to identify the cost-effective climate resilient infrastructure investments available to them. Perhaps even more problematically, limited staff capacities may make it difficult for some cities to set appropriate expectations or even to recognize the gains they have made and to maintain commitments to a course of action.

That limited analytical capacity is shared by urban areas across the globe. In the more advanced and industrialized countries, smaller cities may not have the staff needed to utilize available data for planning and evaluating climate-resilient infrastructure investment options. In the global south the issue may be the unavailability of the data themselves, even for (or perhaps especially for) mega-cities. There is thus a need for a simpler basis for accounting for impacts of different approaches to infrastructure. One such accounting tool of great potential value is a price on the cost of carbon.

4 On the role of effective carbon pricing and the need of social cost accounting

The availability of climate infrastructure finance (CIF) will always be related to investors being able to determine the returns on their investments. Thus, CIF depends on the reliability of predictions of the risks of higher future costs of releasing carbon or the returns on reducing emissions, that is Carbon

Risk Disclosure (CRD). Carbon Pricing (CP) offers a means for such disclosure since it provides a metric for assessing climate-related risks and opportunities in private financial terms, so CP is arguably essential to CIF availability.

But CP is an incomplete measure. The price that carbon emitters may be willing to pay for the right to add to the volume of greenhouse gases in the atmosphere is unlikely to reflect the full Social Costs of Carbon (SCC). Carbon risk arguably includes the risk of increasing prices in the future (either for the carbon source itself or for the right to emit it), the risk of stranded assets (of acquiring or holding carbon sources that become unusable), and the carbon effect mitigation costs that may be imposed by future regulatory policies.

Those are all costs incurred by the carbon producer or user. However, the damage done by the use of the carbon source and its emissions may be experienced by third parties at no cost to the producer or user. In economists' terms, reliance on carbon generates an array of negative externalities. These include immediate costs partly to be borne at the local level such as respiratory problems and soot or smoke cleanup costs generated by emissions, possible ground water and other contamination costs associated with spent fuel residues, and the reputational costs to local economies associated with carbon emitting activities. But the social costs also include the accentuation of local vulnerabilities to climate change and rising seas, some of which may be only minimally evident today but could become acute at some unknown future date. A prime example of such social cost, above and beyond the many negative externalities, is the construction of municipal infrastructure that is vulnerable to rising sea levels: those assets may become stranded – by being under water or flooded regularly.

The availability of CIF would be far greater if the SCC, rather than a simple CP, were used for CRD. This is because the many co-benefits associated with the SCC will tend to give it a value that exceeds CP. Thus the returns on cost avoidance – thus the returns on investment – will be higher. The SCC involves a complex weighting and measuring problem, fraught with its own uncertainties, but the CP can be easily determined through one of a number of pricing schemes, most notably emissions trading.

Proceeding with a reliance on CP involves pursuing a smaller total CIF objective than the SCC could theoretically make available. However, if this CIF is adequate to permit a move towards climate-resilient infrastructure, it may suffice in the shorter term. Therefore, we should examine what has been happening with respect to CP efforts around the globe. Fig. 2 illustrates the recent acceleration in adoption of trading mechanisms intended to generate carbon prices that ideally should influence investment decisions.

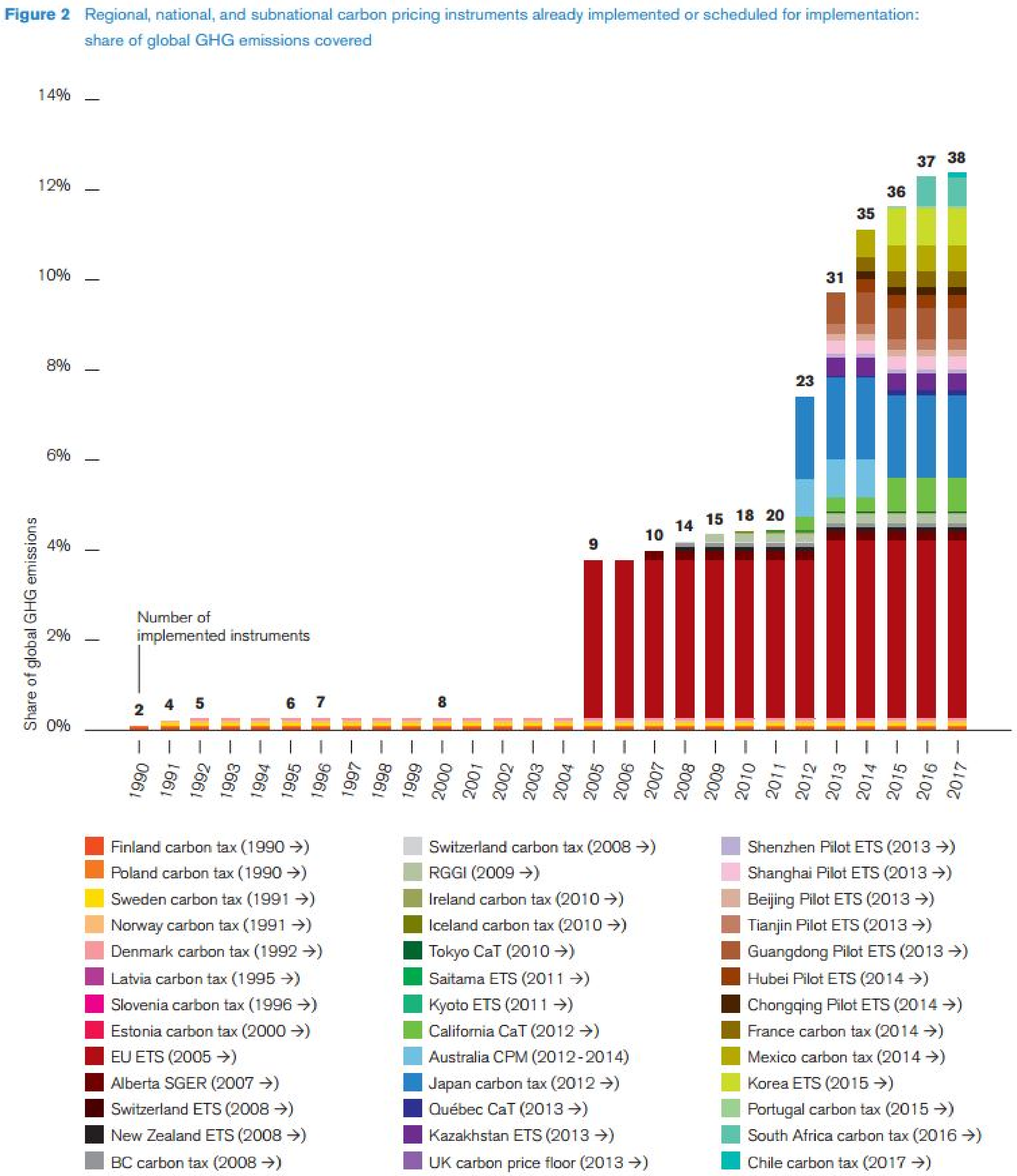


Fig.2 Regional, national, and subnational carbon pricing instruments already implemented or scheduled for implementation: share of global GHG emissions covered

Source: World Bank and Ecofys (2018). Creative Commons Attribution CC BY 3.0 IGO

The far right-hand column, year 2017 reflects China's declared intent to decrease its carbon intensity by 40–45% (in 2020_{2005}) and raised ambition to -60-65% (in 2030_{2005}). To achieve this target, China adopted numerous programs, including an ETS pilot. During 2014–2016, China's pilot ETS, included two provinces and five municipalities (that between them accounted for about 25% China's GHG). That pilot was expected to lead to a national ETS (delayed to 2018). The local emissions caps are decided on a bottom-up basis by provinces and municipalities based on historical emissions (‘grandfathering’) with some benchmarking (cp. Zhang et al., 2018). The progression to a national trading scheme has been delayed and China’s ETS efforts at the local level have intensified. National level is delayed and in fact, other than centralized China’s ETS becomes more decentralized. Shenyang (capital of the Liaoning province) launched its own City-Level Carbon Market in 2017. The city of Tianjin held its first Fixed Price Carbon Auction on November 3, 2017, offering 12,944 allowances. The first 1,000 allowances went for a set price of 15 RMB ($2.19) each, while the remaining allowances will be made available for a set price of 12.5 RMB ($1.82). These low offering prices demonstrate that there is a long way to go before significant effects are likely to be seen, beyond learning, from the world wide largest new ETS: Clearing prices nationwide are currently reported at only 1–8 USD/tCO_2 (Tang, 2017).

By contrast to the Chinese efforts, we can consider the Regional Greenhouse Gas Initiative (RGGI), the first emissions trading scheme in the US and see that it has had significant impacts in its ten years’ existence, mainly because allowances are competitively auctioned. Quarterly auction prices have varied substantially but most recently hit $4.50/ton. In the year 2015 alone, the program resulted in energy-related investments that would generate:

- $2.3 billion in lifetime energy bill savings;
- 9 million MWh of electricity use avoided;
- 28 million MMBtu of fossil fuel use avoided; and,
- 5.3 million short tons of CO_2 emissions avoided (RGGI, 2017).

The European Unions’ European Trading Scheme (ETS) has moved even further, with their carbon price rocketing up from €4.38 ($5.08) per ton in a year to €18.28 ($21.83) in August 2018 (16.8.). Not only does that price induce much more voluntary emissions-reducing investment by carbon users, but it constitutes a substantial pool of revenues for investment in other climate-resilient infrastructure.

These national and regional public-sector led efforts are complemented by a growing body of voluntary efforts at measuring carbon footprints (and their associated costs), as evidenced by some recent data from the Carbon Disclosure Project (CDP) on the number of subnational entities attempting to measure and thus address their carbon emissions:

Table 1: Voluntary self-generated reports of cities and regions

	2013	**2017**
Companies	4500	5600
Cities	200	533
States and Regions	72	72

Source: CDP cities and regions data [https://data.cdp.net/]. Own compilation.

This increased measurement effort really reflects a significant rise in the urban action being pursued in support of the Bonn-Fiji Commitment. The European Covenant of Mayors and the more global Compact of Mayors have joined forces to create the Global Covenant of Mayors for Climate & Energy, a massive global coalition of over 9000 cities from six continents and 121 countries, representing over 780 million people, which exceeds 10 percent of the total global population. The Covenant (GCOM) is intended to promote the implementation of the Paris Agreement in the jurisdictions of its member cities. Building new data collection and analysis capabilities, the Covenant is aiming to build high-level political commitment to sustainable urban development in rapidly urbanizing countries as well as those already heavily urbanized. As of September, 2018,

"… the potential of the 9,149 commitments made by Global Covenant of Mayors cities is equivalent to reducing nearly 1.4 billion tons of CO_2 emissions per year by 2030 – equal to the emissions of taking all cars off the road in the United States in 2030."

The Covenant has announced that it will have a new global framework for reporting city-level greenhouse gas emissions inventories ready by January, 2019 in order to support its members in meeting their commitments (GCOM, 2018).

These municipal and other efforts are admirable on political grounds, but they may, in themselves, constitute a barrier to systematic national, let alone global, action to stimulate investment in climate-resilient infrastructure. The carbon emissions benchmarking and announced actions to reduced GHG creation are not consistent and, to date, have failed to adhere to any globally accepted standard, which is what is required to create the information set needed to allow a new class of investment instruments or opportunities to evolve.

Current costs and immediate effects are more readily known than benefits and future impacts, so the tendency toward underinvestment in any infrastructure will not be overcome. Formalized measures such as those about to be launched by GCOM may or may not be modified even as new data on the costs of inaction or vulnerability of infrastructure emerge from the experience of natural disasters linked to climate change (such as recent hurricanes, fires and floods in the US, fires and coral bleaching in Australia, and both flooding and drought conditions in Europe.

City-wide aggregate measures are also not useful for guiding investment towards the prospects offering the greatest returns, whether measured in monetary, emissions reduction, or improved resilience terms. It is obvious that accounting for carbon prices and risks at the sectoral level would help decision-making by firms and industries. Simultaneously, reliable but disaggregated sectoral and city data on future carbon cost scenarios are needed to shift the decision processes in favor of more sustainable urban infrastructure.

In order for climate-resilient infrastructure investment projects to be *bankable*, however, there is a need is for standardized tools that can identify the cash flow generated by a GHG emissions-reducing investment. While prices exist, they are not standardized. As a result, investors cannot tell if they reflect the social cost of carbon (shadow prices), technology or enterprise-specific internal charges (fees and implicit prices) or some amalgam of the two. A market-based carbon pricing process may provide an appropriate initial basis for a more global standard but none is yet available for wide-spread use (that is, one that is applicable in widely different economies).

Such an initial basis could be utilized to promote the flow of capital to all efforts to reduce GHG emissions. However, a price alone is not likely to be sufficient to assure a sufficient level of investment, since the International Energy Agency (IEA) estimates total investment in GHG reduction needs to be $2.3 Trillion a year to limit warming to 2° C. (Reicher et al., 2017). Investment risk would also need to be addressed to attract the needed capital. A price alone – or even an increased level of investment – will not assure that enough of those funds would flow to climate-resilient infrastructure rather than energy efficiencies for individual firms that might contribute more to profits than GHG reductions. Finally, even if the funds were available for infrastructure, knowledge of price and risk are not sufficient to assure that the investments funded made will best serve to both efficiently reduce emissions and to preserve or promote human well-being in the face of major technological change.

What is really needed to assure maximum political as well as financial support for climate-resilient investment and for appropriate targeting in project selection is, s we noted above, a measure that goes beyond a market price to a social accounting. That is, what is required is a means of consistently measuring the social cost of carbon (SCC), both globally and within the individual political jurisdictions that will guide infrastructure investment decisions. The SCC measure, unlike the market price, would incorporate the costs of health damage risks associated with extracting, transporting, refining and burning carbon-based fuels, the potential political conflicts over access to those natural resources, and the societal costs imposed by the need to distribute centrally-generated electricity (that is, potentially avoidable infrastructure costs) in addition to the very obvious risks and costs associated with climate change itself.

5 The need for local co-benefits frameworks

We have noted the importance of measuring and reporting co-benefits, , that is the stream of readily identifiable and accepted outcomes of climate action that make positive contributions to human well-being beyond limiting climate change, in terms of their potential contribution to the stream of monetizable returns need to attract private investment. SCC will always tend to exceed CP, and thus the more project planners can demonstrate those social costs and benefits, the more readily they can make an economic case for investment in climate-resilient infrastructure.

Arguably, however, identifying such impacts of public efforts to develop climate-resilient infrastructure is even more important for local decision-making and the will to act. All local officials seeking reelection must seek to demonstrate that they are responding to the immediate, not just future, needs of their constituencies. They thus must be able to demonstrate local, not regional or national benefits and co-benefits. Since those constituencies are not homogeneous and have different needs, elected officials must be able to describe those beneficial outcomes disaggregated terms, not monetizing them all or otherwise offering a blended calculation if they are to generate local political will for any project.

Co-benefits (and costs) thus need to be identified and measured in more detail than monetary or budgetary costs and savings: each one must be measurable individually and the series of discrete benefits must then be subject to some forms of aggregation. While there are many dimensions of co-benefits and many different possible investments in climate-resilient infrastructure, the example of investment in energy efficiency and renewable energy (EERE) offers a useful example of an array of co-benefits that can be measured individually as well as in aggregate.

Public or private investors pursue EERE opportunities because they can see that they will lower their energy costs over a time frame that provides the returns per year that they require. Those investments, however, have external effects that the investors may not value but that provide real returns to their communities:

- **Job Creation** – by virtue of the new investment in construction that provides income to other businesses and thus wages and salaries to their employees.
- **Energy Cost Savings** – which accrue to other power users in a locality if the energy provider does not need to build new generating capacity which always has initial unit costs that exceed those of existing generators.

- **Higher Energy Cost and Electrical Supply Certainty** – which accrues primarily to those getting the EERE direct benefits, but also accrues to other electricity consumers since demand for fossil fuel power is reduced and thus cost increases may be avoided.
- **Improved Local Business Competitiveness** – which benefits workers and nonbusiness taxpayers to the extent that resulting business expansions generate new jobs and tax revenues.
- **Aesthetic gains and enhanced quality of life** – which may be associated with less major new construction for power generation and distribution facilities, cleaner air quality form reduced burning of fossil fuels, and the like.
- **Enhanced City Image and Reputation** – which is associated with the evidence of EERE investment and which can benefit the community as whole with new business, population and willingness to invest in the local economy rising as a result.

Given this array of impacts, local elected officials with the capacity to recognize them will be able to point to different co-benefits associated with efforts to promote EERE investments depending on the specific constituencies they address. They also can combine the co-benefits to enhance their city's external image and improve its marketing to compete for business and attract labor. As they demonstrate benefits from climate-resiliency promotion to both local constituents and prospective inward investors, those officials will increase their population's – and they own – willingness to promote climate-resiliency.

6 Conclusion

In conclusion, we need to stress that an excessive focus on how to attract capital to climate-resilient infrastructure investments is inappropriate and may be detrimental to the pursuit of resilience and the fight to restrain climate change. Access to capital is necessary, but clearly not sufficient.

Capital availability may be facilitated by carbon pricing, so the efforts to better account for and value the right to emit carbon are valuable. However, CP alone will not generate the needed political will, in large part because current market prices at present fail to account for climate change risks such as the costs of stranded assets falling in value to zero as well as the local, national and global co-benefits of investments in climate resilience. Carbon prices may be necessary, but even they are not, in themselves, sufficient.

The political will needed to utilize the capital available for investment in truly carbon-resilient infrastructure depends not on the CP, but on the SCC. Constituents need to become aware of and place value on the co-benefits associated with such investments for sustained action to be undertaken. Only with recognition of the co-benefits that carbon pricing and emissions trading schemes make possible will cities overcome their myopic focus on minimizing the short-term cost (and maximizing the short-term ROI) on their infrastructure investments. The prospect of improved air quality, reduced health problems and the prospect of great population longevity may not be measurable in detail. Success in attracting new businesses, the experience of rising wages for existing employees or in-migration of a higher skilled labor force may not be attributable exactly to any one source, but they are all politically accepted co-benefits of climate action, identifiable and measurable in their contributions to the quality of life of local citizens and the electorate, and may thus serve to catalyze action that would not take place if those impacts were overlooked.

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