Energy Policy 59 (2013) 773–783

Contents lists available at SciVerse ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Past performance and future needs for low carbon climate resilient infrastructure– An investment perspective☆

Christopher Kennedy[a,*], Jan Corfee-Morlot[b]

[a] Department of Civil Engineering, University of Toronto, 35 St. George Street, Toronto, Canada M5S 1A4
[b] OECD, Development Co-operation Directorate, Paris, France

HIGHLIGHTS

- Conceptualisation of interactions between low carbon and climate resilient infrastructure (Fig. 1).
- New performance measures of national GHG emissions vs. capital formation (Section 2).
- Comparion of global infrastructure costs under low and high carbon scenarios (Table 1).
- Understanding of infrastructures that support virtuous cycles of low carbon growth (Fig. 8).

ARTICLE INFO

Article history:
Received 20 January 2013
Accepted 13 April 2013
Available online 15 May 2013

Keywords:
Infrastructure
Climate change
Gross fixed capital formation

ABSTRACT

This article explores the investment implications of moving to low-carbon, climate-resilient infrastructure. It begins with analysis of gross fixed capital formation and decarbonisation trends to examine past performance of OECD countries in reducing GHG emissions from 1997 to 2007. Many OECD countries made progress in decoupling GHG emissions from infrastructure investment in residential buildings, and to a lesser extent from power and industry, but increased efforts are required, especially in the transportation sector. The analysis highlights the need to accelerate the pace and scale of change to reverse GHG emission trends to bring into reach ambitious climate policy goals. It then assesses future global infrastructure needs under low-carbon and business-as-usual (BAU) global warming scenarios, and the incremental costs of going "low-carbon" are estimated to be small relative to the magnitude of the BAU infrastructure investment needs. Global infrastructure needs for 2015–2020, including buildings and transportation vehicles, are approximately 6.7 trillion USD/year under BAU. Incremental costs of low-carbon infrastructure are of the order −70 to +450 billion USD/year. Achieving climate resilient infrastructure may add costs, but there is potentially synergistic overlap with low-carbon attributes. Although estimates are incomplete, the technical and financial inter-dependency between infrastructure systems suggests the potential to generate infrastructure investment to support a "virtuous cycle" of low-carbon growth.

1. Introduction

Infrastructure lies at the heart of economies. Buildings, water and waste systems provide the basic services that households and businesses require, while transportation and communications infrastructure link consumers to producers to suppliers, enabling markets to function. Clean, efficient, well-maintained infrastructure supports a high quality of life in developed countries; and provision of such infrastructure in developing countries is critical to raising living standards in the context of future development.

Achieving a low carbon, climate resilient (LCR) economy also revolves around how infrastructure develops. It necessarily entails constructing, or renovating, infrastructure systems (power, road, rail, water, buildings, etc.) to substantially reduce global greenhouse gas (GHG) emissions, while simultaneously making these systems, and the societies they serve, more adaptable to extreme weather conditions and rising sea levels. Global emissions of GHGs are to a large extent dependent on the choice and design of infrastructure systems. In 2009, power generation, building energy use, transportation systems and waste management infrastructure accounted for 74% of net GHG emissions for developed countries, i.e., those referred to in Annex I of the UN Framework Convention on Climate Change.[1]

☆ This article highlights the results of work commissioned by the OECD. However the views presented in this paper are those of the authors; they are not intended to represent views endorsed by the OECD nor by its member countries.

* Corresponding author. Tel.: +416 978 5978.
E-mail addresses: christopher.kennedy@utoronto.ca (C. Kennedy), Jan.CORFEE-MORLOT@oecd.org (J. Corfee-Morlot).

[1] Author's analysis using the UNFCCC database. Net GHG emissions from public electricity and heat production, transport, commercial/institutional, residential and waste are 73.9% of total net emissions, including LULUCF/LUCF.

0301-4215/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.enpol.2013.04.031

Decisions on infrastructure investment are also critical for adapting to the continuing changes in climate (Helio International, 2009; Eichhorst 2009; WHO, World Health Organization, 2009). New infrastructure built in the coming decades will have to be designed for changes in mean climate conditions (e.g., temperature and precipitation) and to withstand more extreme weather conditions. Some existing infrastructure may have to be adapted, and other infrastructure may be purpose built to protect from flooding of rivers or coastal areas. Infrastructure needs for adaptation to climate change will be particularly high in developing countries where lack of basic infrastructure is a challenge to resilient development.

The need to invest in infrastructure that is both low-carbon and climate-resilient comes at a time when government budgets, the traditional sources of infrastructure funding, are under significant pressure, yet infrastructure investment is important for stimulating economies and growth. Governments face the challenge of enacting policies and leveraging public spending to both: (i) attract private capital to invest in infrastructure; and (ii) ensure that the infrastructure is consistent with a green and climate-resilient economy. To enable investment in LCR infrastructure and green growth, governments can develop comprehensive strategic infrastructure plans, strongly coupled with national climate change goals (Corfee-Morlot et al., 2012; Hall et al., 2012).

As a result of the long lifetimes of physical infrastructure, choices made today about types of and features of new infrastructure provision or renovation of existing systems, will lock-in emission “commitments” as well as vulnerability or resilience to climate change in a given location for decades to come. Infrastructure decisions are of course not irreversible, however infrastructure investment typically has high capital expenditure requirements. It may be a cost-effective decision not to “over-invest” to boost resilience in an infrastructure system today, given the uncertainty of certain climatic conditions in the future (e.g., to withstand heavy precipitation events or windstorms). That decision, however, is better taken on the basis of sound information than due to ignorance about predicted climate change for a given location (Hallegatte et al., 2010). Recent studies also point to the “self-interest” of the private sector to invest in adaptation (Agrawala et al., 2011; IFC 2010a,b). However, this assumes that private actors have sufficient information to make the right decisions and this may not be the case. Moreover, some adaptation measures, such as disaster warning systems and evacuation planning, are public goods and warrant public action. Altering infrastructure post-construction can also be difficult and more costly than if it were designed to integrate climate change from the start. Further, on-going renovation and upgrades of infrastructure systems provide the opportunity to build in adaptation performance features which add resilience to climate change in an incremental and cost-effective way.

The interdependency between infrastructure systems should be recognised in assessing the GHG impact of infrastructure or its resilience to climate-induced or other shocks. Such interdependencies are typically bi-directional. Electricity supply, for example, is clearly a necessary input for telecommunications equipment, for electric trains, and to operate water and wastewater systems, but there are also converse relationships. Telecommunications can be used to establish more efficient electricity infrastructure; railways are used to transport fuels (coal) for electricity generation; and water is also used for cooling in thermal and nuclear power plants. No one infrastructure system is more fundamental than any of the others.

With respect to resilience and disaster risk management, land transport can be used in emergencies to carry drinking water to disaster-affected locations, but poor water infrastructure, such as drainage systems, also pose risks to road and rail infrastructure when flooding occurs. Thus, the resilience of infrastructure to climate change is typically dependent on the overall combination of infrastructure systems and their interconnections (Hallegatte et al., 2008; Kirshen et al., 2008; Nelson et al., 2007).

Interdependency between infrastructure systems is also important when designing strategies for reducing GHG emissions. Greening of electricity supply, for example, is a useful strategy because it lowers the carbon footprints of buildings, especially when combined with demand side management, and potentially may help to establish electric vehicles or electric rail systems, for example, as a low carbon form of transportation in dense urban areas. The interdependency of systems also has a bearing on the potential for public sector spending to leverage private sector investment on low carbon infrastructure. For example, electrically powered public transit systems are typically low carbon, but often require substantial public subsidies both for initial investment and on-going operation, thus making them less financially attractive than higher emission alternatives. Transit infrastructure, however, will typically spur private sector land-development, which governments can influence through greening of building codes, while collecting revenues through land-value capture (Merk et al., 2012). An integrated approach in designing infrastructure systems helps enable low-carbon development (Engel Yan et al., 2005).

Potentially greater economic efficiency can be achieved by designing infrastructure that is simultaneously low carbon and climate resilient, but sometimes there may be tradeoffs (Klein et al., 2007; Moser, 2012; Sugar et al., 2013). Some infrastructure strategies for mitigating GHG emissions will also help in adapting to climate change (Fig. 1). For example, at the building scale, increased insulation and use of white (or, to a lesser extent, green) roofs may both save energy and make buildings more resilient to extreme temperatures during heat waves, or temporary losses of energy supply. Similar synergies may occur for water efficiency measures, water storage, distributed renewable energy supply and multi-modal transportation systems, but with details highly dependent on context. Nonetheless, some adaptation strategies may be undesirable for mitigation, e.g., conventional air conditioning makes buildings liveable in extreme heat, but often with increased emissions. Desalination can be an important source of supply in water scarce regions, increasing their adaptive capacity, but requiring substantial energy consumption. An opposite case is very high urban density, which supports the financial viability of sustainable modes of public transportation, lowering GHG emissions, but generally involves prevalence of impermeable surfaces, greater heat island effects (Stewart, 2011) and increased climate change risks through higher concentrations of people in urban areas. This may increase exposure of urban populations to climate change driven shifts in extreme events, such as flooding and heat waves, while also complicating disaster management and evacuation processes in the case of such events. Similarly, water supplies may be affected by climate change to become scarcer, and in this case hydro power can be a positive mitigation measure but unhelpful towards adaptation.

Although such trade-offs between mitigation and adaptation may be apparent for individual policies, sometimes policies can be combined to achieve win-win strategies. Viguié and Hallegatte (2012) demonstrate, for example, how greenbelt policies, flood zoning and transportation policies can be combined synergistically through careful assessment and planning, even though individually each policy involves trade-offs between adaptation and mitigation.

To assist formulation of policy for developing LCR infrastructure, the objectives of this paper are twofold:

1. To assess the past contributions of infrastructure investment towards low carbon growth for OECD countries.
2. To broadly assess the future global needs for LCR infrastructure, including their interdependencies.