Technical note on estimates of infrastructure investment needs

Background note to the report *Investing in Climate, Investing in Growth*

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This note describes the methodology and data sources used for the estimate of infrastructure investment needs in the OECD report *Investing in Climate, Investing in Growth* (OECD, 2017). It provides a comparison with other existing estimates of infrastructure investment needs, and highlights related uncertainties and potential areas for further work.

OECD estimate of infrastructure investment needs

OECD (2017) estimates global infrastructure investment needs of USD 6.3 trillion per year over the period 2016-30 to support growth and development, without considering further climate action (relative to mid-2016).

This estimate builds on a compilation of different sources available for each sector and as such carries a lot of uncertainties (see last section of this note). This estimate includes infrastructure investments in power and electricity transmission and distribution (T&D), the primary energy supply chain, transport (road, rail, airports and ports), water and sanitation, and telecommunications, as well as investments in energy efficiency in buildings, transport and industries (see Table 1).

Estimates for the energy sector - including power and electricity T&D, primary energy supply chain and energy demand – are derived from the Current Policy Scenario (CPS) in the IEA report *Perspectives for the Energy Transition: Investment Needs for a Low-Carbon Energy System* (IEA, 2017). This is a scenario that assumes no changes in policies from mid-2016. **Power generation, and T&D** includes investments in fossil-fuel power plants (coal, oil and gas), nuclear energy and renewable power generation, including bioenergy, hydro, wind, geothermal, solar (photovoltaic and concentrating solar plants), and marine energy. It also includes investment in the transmission and distribution of electricity. **Primary energy supply chain** includes investments in oil upstream, refining and downstream infrastructure, gas upstream and downstream infrastructure, and coal mining and related infrastructure.[1]

Energy demand includes both investments in: i) more efficient technologies that reduce energy and material use in end-use sectors; and ii) technologies that reduce direct energy-related emissions in the end-use sectors. In the transport sector, this includes the additional capital spent on electric or natural gas vehicles and trucks, used instead of conventional vehicles featured in the reference scenario (excluding the infrastructure investment needs related to electrification). In the industry and buildings sectors, this category includes investment for the use of renewable sources that can generate heat for direct use (e.g. solar thermal, geothermal and biomass), as well as expenditure to install Carbon Capture and Storage (CCS) in energy-intensive industries (IEA, 2017).

Transport infrastructure estimates are based on the IEA *Energy Technology Perspectives 2016* (IEA, 2016a) "six degrees" scenario (6DS) for road and rail infrastructure - a scenario that assumes no changes in policies from mid-2016 on -

and on *Strategic Transport Infrastructure Needs to 2030* (OECD, 2012) for airports and ports. Investments in road include the costs of new infrastructure and reconstruction. Rail includes new infrastructure and reconstruction costs for intercity rail, metro, light- and high-speed rail infrastructure. Infrastructure requirements for airports and ports include capital costs for new infrastructure (OECD, 2006; OECD, 2012).

Table 1. OECD estimate of global infrastructure investment needs: coverage and data sources (2015 USD trillion in the period 2016-30)

Sector		Definition	Annual average	Cumu-lative	Source
Power and electricity T&D		Generation of electricity and heat, transmission and distribution (T&D) and storage. This includes grid extension for the electrification of end-use sectors (e.g. transport).	0.7	11.2	IEA, 2017
Primary energy supply chain		Oil (upstream, refining and downstream), gas (upstream and downstream), and coal supply (mining and infrastructure).	1.0	14.3	IEA, 2017
Energy demand/efficiency		Investment in more efficient technologies that reduce energy and material use, and in technologies that reduce direct energy-related emissions in the end-use sectors: i) in the transport sector, this includes the additional capital spent on electric or natural gas vehicles and trucks that displace the use of conventional vehicles (excluding the infrastructure investment needs related to electrification); ii) in the industry and buildings sectors, this includes investment for the use of renewable sources that can generate heat for direct use (e.g. solar thermal, geothermal and biomass), as well as expenditure to install CCS in energy-intensive industries.	0.4	6.6	IEA, 2017
Transport	**Road**	Infrastructure and reconstruction costs for roads	2.1	31.9	IEA, 2016a
	Rail	Infrastructure and reconstruction costs for intercity rail, metro, light-rail and high-speed rail infrastructure.	0.4	6.4	IEA, 2016a
	Airports and ports	Infrastructure capital expenditure for airports and ports.	0.2	2.7	OECD, 2012
Water and sanitation		Water supply and wastewater management infrastructure primarily for urban areas in OECD (2006), water and sanitation and related equipment (not including for irrigation) in McKinsey (Woetzel et al., 2016), water in Booz Allen Hamilton (2007).	0.9	13.6	Average from: Booz Allen Hamilton, 2007; Woetzel, J. et al., 2016; OECD, 2006
Telecoms		Mobile, fixed-line, and broadband infrastructure.	0.6	8.3	Woetzel, J. et al., 2016; based on OECD, 2006
TOTAL			**6.3**	**95**	

The **water and sanitation** estimate is an average of the latest estimates available, namely: Booz Allen Hamilton (2007), McKinsey (Woetzel, J. et al., 2016), and OECD (2006). These include: water supply and wastewater management infrastructure primarily for urban areas in OECD (2006),[2] water and sanitation and related equipment (not including for irrigation) in McKinsey (Woetzel et al., 2016), water in Booz Allen Hamilton (2007).

The estimate for **telecoms** include mobile, fixed-line, and broadband infrastructure and are taken from McKinsey (Woetzel, J. et al., 2016). McKinsey converted OECD (2006) [3] estimates to a percentage of GDP and applied them on a global basis.

Infrastructure investment needs in a low-carbon future

The OECD estimates that for infrastructure to be consistent with a 2°C 66% scenario, investment needs amount to USD 6.9 trillion per year in the next 15 years, an increase of about 10% in total infrastructure investment from the reference estimate of USD 6.3 trillion. This includes additional capital costs of 29% in the energy sector, related to the decarbonisation of the power sector and to the grid extension for the electrification of end-use sectors (e.g. transport); and investment in energy efficiency in the transport, industry and buildings sectors (see Table 2).

Table 2. OECD estimate of infrastructure investment needs: reference case vs. low-carbon future scenario (2015 USD trillion)

Sectors		Reference case	Low-carbon (IEA 66% 2°C)
Energy supply	Power and T&D	0.7	1.0
	Fossil fuel supply chain	1.0	0.6
Energy demand		0.4	1.1
Transport infrastructure	Road	2.1	2.1
	Rail	0.4	0.4
	Airports and ports	0.2	0.2
Water and sanitation		0.9	0.9
Telecoms		0.6	0.6
TOTAL		**6.3**	**6.9**

Source: OECD, 2017

The estimates for water and sanitation and telecoms are kept constant across scenarios due to a lack of available information. More work is needed on i) assessing the impact of climate change kept to well-below two degrees on water infrastructure needs[4], and ii) on the impact of digitalisation of the energy system on telecom infrastructure needs.

The estimate for transport infrastructure is also kept constant across the two scenarios. Transport infrastructure estimates are based on the 2DS scenario in IEA

(2016a), which assumes a 50% chance of staying below 2°C (while energy estimates from IEA, 2017 are built on a 66% chance of staying below 2°C). In addition to this, the low-carbon estimate (2DS) for transport infrastructure in IEA (2016a) includes modal shifts - e.g. behavioural shifts from road to rail for passenger transport - while the model used to produce the IEA 66% 2°C scenario does not.

Comparison of existing estimates of infrastructure investment needs (reference case)

There have been several attempts to provide estimates of global infrastructure investment needs (Kennedy and Corfee-Morlot, 2012; WEF, 2013; NCE, 2014a; Bhattacharya et al., 2016; Woetzel et al., 2016; OECD, 2017). This section describes the estimates of infrastructure investment needs in Bhattacharya et al, 2016; NCE, 2014a; Woetzel et al., 2016 (Mckinsey); and OECD, 2017.[5] Other estimates such as NCE, 2016; WEF, 2013; Dobbs R. et al., 2013 (McKinsey) are not included in this comparison as they have either been updated, or are based on the same data sources as the estimates described below.

Table 3 presents the annual estimates in a reference scenario[6] for each publication (see Box 1 for a comparison of estimates in a low-carbon future scenario). The reference scenario assumes no further action by governments to mitigate climate change. All estimates are global, cover the period 2015/6-30, and build on secondary data sources.

At a first glance, infrastructure investment needs estimates vary widely - from USD 3.3 to USD 6.9 trillion per year – but this reflects important differences in terms of scope, data sources and methodologies.

Table 3. Infrastructure investment needs in selected publications
Annual average in the period 2016-30, reference scenario (2015 USD trillions)

	Annual infrastructure investment needs
OECD	**6.3**
Bhattacharya	**7.9**
McKinsey	**3.3**
NCE	**6.4**
Range	**3.3 to 7.9**

Source: OECD, 2017; Bhattacharya et al., 2016; Woetzel et al., 2016 (McKinsey); NCE, 2014a.

Box 1 – Estimates of infrastructure investment needs in a low-carbon future

Bhattacharya, NCE and OECD provide estimates for a low-carbon future scenario. Table A presents the OECD and NCE estimates per sector in a low-carbon scenario. Bhattacharya’s low-carbon estimate is not presented in this table due to lack of information at the sectorial level.

The estimates differ mainly on the data sources chosen and the ambition of the scenarios analysed. The NCE estimates for a low-carbon future scenario are based on the IEA Energy Technology Perspectives 2012 (IEA, 2012a) "two degrees" scenario (2DS). The 2DS refers to an energy transition and an emissions trajectory consistent with a 50% chance of limiting the average global temperature increase to 2°C by the end of the century. The OECD (2017) estimate is based on the IEA (2017) 66% 2° C scenario, i.e. an energy transition and emissions trajectory consistent with a 66% chance of keeping the temperature rise below 2°C.

Table A. OECD and NCE estimates in a low-carbon future scenario (2015 USD trillions)

		OECD (66% 2°C)	NCE (2DS)
Energy supply	Power and T&D	1.0	0.9
	Fossil fuel supply chain	0.6	0.6
Energy demand		1.1	2.4*
Transport infrastructure	Road	2.1	0.4
	Rail	0.4	0.3
	Airports and ports	0.2	0.2
Water and sanitation		0.9	1.5
Telecoms		0.6	0.5
TOTAL		**6.9**	**7.0**

* Includes the full cost of planes, ships and rail.

Source: OECD, 2017; NCE, 2014b.

Table 4 disaggregates the estimates per sector. The sectorial analysis shows that McKinsey's estimate – the lower-bound in the range presented in Table 3 – has a narrower coverage than the estimates in Bhattacharya, NCE and OECD. McKinsey measures "core" infrastructure, which includes power and electricity T&D, transport (roads, rail, airports and ports), water and sanitation, and telecommunications infrastructure; and excludes investments in primary energy supply chain infrastructure (coal, oil and gas) and energy demand.

Table 4. Infrastructure investment needs per sector
Annual average in the period 2016-30, reference scenario (2015 USD trillions)

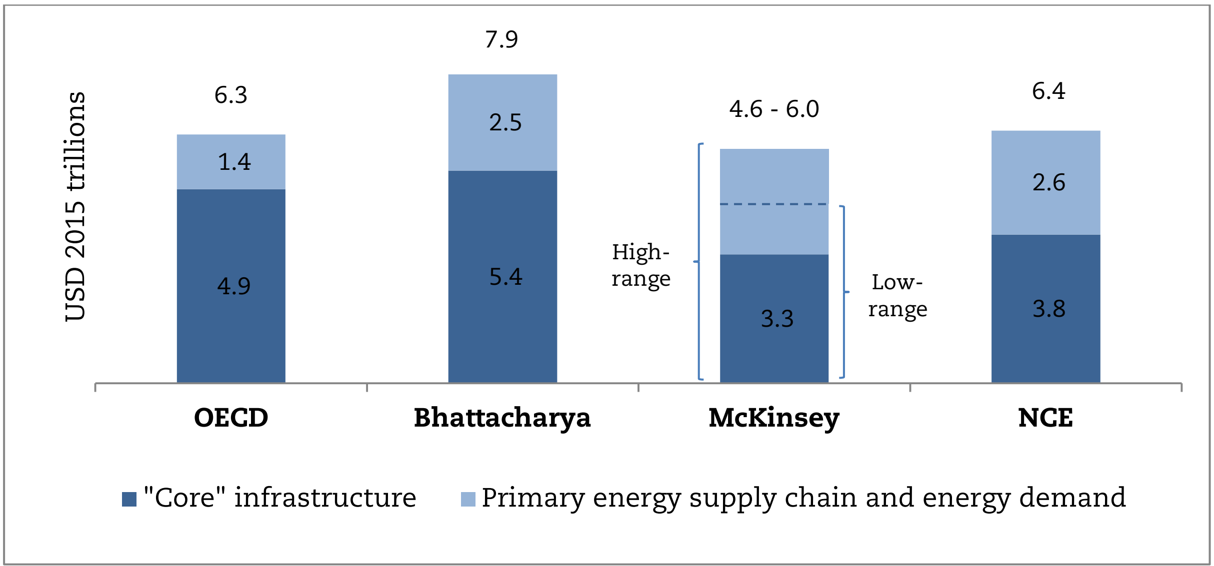
	Energy supply		Energy demand	Trans-port	Water and sanitation	Tele-coms
	Power and T&D	Primary energy use supply chain				
OECD	0.7	1.0	0.4	2.7	0.9	0.6
Bhattacharya	1.5	0.8	1.6	2.0	0.9	1.0
McKinsey	1.0	not included	not included	1.2	0.5	0.6
NCE	0.7	0.9	1.7*	1.0	1.5	0.5
Range	0.7 – 1.5	0.8 – 1.0	0.4 – 1.7*	1.0 – 2.7	0.5 – 1.5	0.5 -1.0

* Includes the full cost of planes, ships and rail.

Source: OECD, 2017; Bhattacharya et al., 2016; Woetzel et al., 2016 (McKinsey); NCE, 2014a.

Adding primary energy supply and energy demand (from Bhattacharya, NCE or OECD) to Mckinsey's "core" infrastructure estimate results in an estimate ranging from USD 4.6 to USD 6.0 trillion per year, closer to the estimates from the other publications. Figure 1 shows the range in comparable estimates (with harmonised coverage): between USD 4.6 to 7.9 trillion per year for the next 15 years.

Figure 1 - Infrastructure investment needs with harmonised coverage
Annual average in the period 2016-30, reference scenario (2015 USD trillions)



Note: "core" infrastructure includes power and electricity T&D, transport (roads, rail, airports and ports), water and sanitation, and telecommunications infrastructure. The low- and high-ranges for McKinsey refer to the lowest and highest estimates of primary energy supply and energy demand from the sources in Table 4.

Source: OECD, 2017; Bhattacharya et al., 2016; Woetzel et al., 2016 (McKinsey); NCE, 2014a.

An analysis of data sources and underlying definitions (Table 5) helps to understand the elements included in each sector and the differences in the final results. For example, the estimate of investments labelled as energy demand in NCE includes the full vehicle costs of planes, ships and rail,[7] which accounts for over 25% of the NCE estimate of this item.

Energy supply: power generation and electricity T&D

Estimates for power generation and electricity T&D range from USD 0.7 to USD 1.5 trillion per year.

McKinsey and OECD estimates for power generation and electricity T&D are based on the IEA *World Energy Model* (WEM) Current Policy Scenario. McKinsey uses IEA (2012b) data, while the OECD uses IEA (2017)'s. The USD 0.3 trillion difference between McKinsey and OECD is the result of updates in the WEM between 2012 to 2017.[8]

The NCE estimate for power generation and electricity T&D is taken from the *IEA Energy Technology Perspectives* 2012 (IEA, 2012a), and is close to WEM estimates.

Table 5 – Secondary data sources used for the infrastructure investment needs estimates.

	OECD	McKinsey	NCE
Power and electricity T&D	IEA, 2017	IEA WEO 2012	IEA ETP 2012
Primary energy use supply chain	IEA, 2017	Not included in estimate	Climate Policy Initiative (CPI) modelling, based on IEA, 2013
Energy demand	IEA, 2017	Not included in estimate	IEA, 2012b
Transport	IEA, 2016a	Own calculations based on OECD 2006 and OECD 2012	OECD 2006 for road, OECD 2012 for rail, airports and ports
Water and sanitation	Average from: Booz Allen Hamilton, 2007; McKinsey (Woetzel, J. et al., 2016); OECD, 2006.	Global Water Intelligence Database (GWI)	OECD, 2006
Telecoms	McKinsey (Woetzel et al., 2016)	Own calculations based on OECD, 2006	OECD, 2006

Note : Bhattacharya's estimate is not presented in this table or the sub-sections below due to lack of information on the sources used at the sectorial level.

Source: OECD, 2017; Woetzel et al., 2016 (McKinsey); NCE, 2014a.

Energy supply: primary energy supply chain (oil, coal, gas)

Estimates for primary energy supply chain are close to USD 1 trillion in the reviewed publications.

As for power generation and electricity T&D, the OECD estimates for the primary energy supply chain are based on IEA (2017).

The NCE uses the results of the Climate Policy Initiative (CPI) modelling exercise, which is in turn based on the IEA (2013).[9]

The McKinsey estimate does not include primary energy supply chain investments.

Energy demand

Estimates for energy demand vary widely, from USD 0.4 to USD 1.7 trillion.

The OECD estimate – USD 0.4 trillion – is based on IEA (2017).

The NCE estimate of energy demand – USD 1.7 trillion per year – is based on the "six degrees" scenario (6DS) from the *IEA Energy Technology Perspectives* 2012 (IEA, 2012a).

The NCE estimate includes: i) power trains for fossil-fuel light-duty vehicles, low-carbon light-duty vehicles, as well as full vehicle costs of planes, ships and rail; ii) investments related to energy use in buildings, e.g. ventilation and air-conditioning (HVAC) systems; and iii) investments related to energy use in the top five most energy-intensive sectors: chemicals and petrochemicals, iron and steel, pulp and paper, cement, and aluminium (NCE; 2014b).

Main differences between the NCE and OECD estimates for energy demand include the inclusion in NCE of full vehicle costs for planes, ships and rail; and higher estimates in NCE for buildings and industry.

McKinsey does not include energy demand investments in their estimate.

Transport

The differences in the estimates for transport infrastructure are significant, ranging from USD 1.0 to USD 2.7 trillion per year.

The OECD uses the *IEA Energy Technology Perspectives 2016* (IEA, 2016a) 6DS estimates for road and rail, and OECD (2012) for airports and ports.

The NCE transport estimates are based on OECD (2006) for road and on OECD (2012) for rail, airports and ports. Road infrastructure investment needs are estimated at USD 0.4 trillion per year (or 0.3% of GDP), rail infrastructure at USD 0.3 trillion per year, and airports and ports infrastructure at USD 0.2 trillion per year (OECD, 2006; OECD, 2012).[10]

The OECD (2017) estimate for road - USD 2.1 trillion per year, based on IEA (2016a) - is significantly higher than the OECD (2006) estimate of USD 0.4 trillion per year. Part of the difference between the estimates from IEA (2016a) and OECD (2006) can be explained by the methodologies used, and by differences in the: i) base year; ii) GDP projections; and ii) the approach to forecast vehicle ownership and vehicle-kilometers.

The OECD (2006) estimate for road infrastructure does not capture recent trends in transport infrastructure needs: while the estimate allocates 0.3% of the global GDP to transport, current transport investments account for 0.8% of GDP approximately (ITF, n.d.). Furthermore, a comparison of the IEA (2016a), and the International Transport Forum (ITF) estimates for urban transport infrastructure investment needs shows that IEA (2016a) and ITF estimates are of the same order of magnitude, suggesting that the OECD (2006) under-estimates investment needs in the road sector through 2030.

As for IEA (2016a), road estimates in IEA (2012a) – of approximately USD 1.6 trillion per year - are significantly higher than in OECD (2006). If the NCE had used IEA (2012a) as a source for transport infrastructure investment needs - rather than OECD (2006) - the overall annual estimate of infrastructure investment needs would have increased by USD 1 trillion, to USD 7.4 trillion per year. See Box 2 for a description of the methodological changes between IEA (2012a) and IEA (2016a).

McKinsey's estimate for road infrastructure assumes that future needs will follow historical spending as a percentage of GDP - estimated at 1% of GDP – and apply this percentage to GDP projections to 2030. McKinsey assesses that the OECD (2006) estimate is only 40 percent of what countries have historically spent on road infrastructure, and that it is unlikely for countries to reduce road investments by 60% through 2030 (Woetzel et al., 2016).

For rail, ports and airports, McKinsey builds on OECD (2012). For rail, they use the current stock of rail infrastructure, GDP growth, and information on recent and expected policy changes. For ports, they use the OECD (2012) estimate for China, India and the United States, and in order to get a global level estimate, they apply the United States estimate to advanced economies, and China and India's estimate to developing countries. For airports, estimates are based on OECD (2012).

Box 2 – Methodological changes in the IEA Energy Technology Perspectives

The cost assumptions and calculations were altered in IEA (2016a). Such changes explain part of the differences in the transport infrastructure costs between IEA (2016a) and earlier publications. The methodological changes include:

- *a road infrastructure assumption that developing countries' congestion levels converge to levels observed in OECD economies*. Developing countries are then expected to "catch-up" with OECD economies in terms of transport infrastructure stock; which would imply a massive increase in investment, as current levels of transport infrastructure stock in developing countries is significantly lower than in OECD countries.
- *passenger rail infrastructure cost estimates disaggregated per infrastructure type (e.g. rail, metro)*. Instead of using a single unitary cost estimate for different types of rail infrastructure, IEA (2016a) differentiates the costs by type of infrastructure, applying for example a higher unitary cost to a km of metro line, compared to a traditional railway. This results in more realistic, but higher estimates for rail infrastructure.

Source: IEA (2016a)

Water and sanitation

There is no broad consensus as regards the definition of water infrastructure, and estimates vary from USD 0.9 to USD 1.4 trillion annually.[11] Publications providing estimates of water infrastructure needs provide limited information about the scope and methodology used for the estimations, and it is thus challenging to fully explain why they conclude on such divergent figures.

The OECD estimate for water is an average of the latest estimates from Booz Allen Hamilton, 2007; McKinsey (Woetzel, J. et al., 2016); and OECD, 2006.

NCE builds on OECD (2006). The Mckinsey estimate is based on the Global Water Intelligence (GWI) database. The GWI database projects needs for water and sanitation and related equipment (excluding irrigation) through 2016, based on historical spending. McKinsey extended these projections through 2030 (Woetzel et al., 2016).

Telecoms

The OECD estimate builds on the McKinsey estimate. McKinsey converted OECD (2006) estimates to a percentage of GDP and applied them on a global basis. OECD (2006) estimate includes mobile, fixed-line, and broadband infrastructure in OECD countries, Brazil, China and India. The NCE builds on OECD (2006).

Caveats rergarding estimates of infrastructure investment needs

As highlighted above, there have been several attempts to provide estimates on global infrastructure investment needs.[12] But each projection is highly uncertain as it combines several distinct sources, each with different underlying assumptions. This section attempts to shed light on some of the major sources of uncertainties in current infrastructure needs estimates.

- **Lack of data on past and current infrastructure investments**. Projections attempt to take as a starting point existing infrastructure investment, but there is a lack of comprehensive and comparable country-level data on investments, including for G20 countries (AsDB, 2017, Bhattacharya et al., 2016). There is a need for national governments in collaboration with international organisations and development banks to gather more comprehensive, better quality data on infrastructure investment.

- **Caveats in the methodology**. Most infrastructure needs assessments are based on current infrastructure spending (which are insufficient to deliver the infrastructure needed for growth and well-being[13]) and on projected GDP growth and country-level elasticity of infrastructure spending to growth (Woetzel et al., 2016; NCE, 2016). This results in estimates that are highly dependent on the current level of infrastructure spending, and GDP assumptions. Few studies are based on achieving minimum quantitative benchmarks for infrastructure stocks and services (such as those used by Pardee Center, 2014), which would be more relevant in particular for low-income countries and in the context of the Sustainable Development Goals.

- **Country context matters**. Most infrastructure assessments are based on global models, but infrastructure needs and priorities depend on countries' specific circumstances – such as access to energy, quality of current infrastructure, growth rate and inequalities – and should be informed by country-specific long-term development strategies. Encouraging more efficient transport modes from the outset in developing and emerging economies where infrastructure continues to be built could generate significant savings, reducing the need for road and parking spaces, which in many non-OECD countries are more costly than the investments required in public transport infrastructure (IEA, 2016a). In addition, many assessments do not account for how infrastructure is managed and implemented at the country level. Some analysts suggest that better management of infrastructure could lower infrastructure investment needs (Woetzel et al., 2016).

- **Research gaps on the impact of a low-carbon future on infrastructure demand.** Further research is required to understand the impact of the digitalisation of energy on telecommunication infrastructure, for example. Deployment of bio-energy with carbon capture and storage (BECCS) may generate significant investments in CO_2 pipelines. Disruptive technologies or business models may significantly change demand for specific types of infrastructure (e.g. car ownership vs. car sharing, which would in turn reduce the needs for parking spaces). For example, the OECD (2012) estimate for airports and ports – used in most of the reviewed publications - projected doubling in air passenger traffic, a tripling of air freight and a quadrupling of port handling of maritime containers worldwide by 2030. However, in the long term, a world less reliant on fossil fuels is likely to require lower port capacities, fewer coal, oil and gas tankers, and hinterland railways to transport coal (Kennedy and Corfee-Morlot, 2012).[14]

End notes

[1] Oil upstream includes conventional and unconventional oil. Oil refining includes investments in capacity (greenfield, upgrades) and maintenance. Oil downstream includes oil, natural gas liquids, products and shipping transport. Gas upstream includes conventional and unconventional gas. Gas downstream includes transmission and distribution, and liquefaction and regasification. Coal supply includes mining and port and transport infrastructure (IEA, 2017).

[2] Comprising four major systems: i) Water abstracted for agricultural use – for rural communities and small urban areas. Most of this is groundwater; ii) Water resources – abstraction (and possibly storage) for human needs. The source can be upland rivers, lakes, lowland surface water, groundwater, sea or brackish sources or from evaporation systems; iii) Water supply network, including inputs from abstraction, treatment, storage and distribution, and outputs, including management of residual sludge; and iv) Wastewater system, including stormwater and sanitary drainage, treatment, effluent disposal and management of residual sludge. Of these, in urban areas in the developed countries, the networks in iii) and iv) are generally the most valuable assets, comprising some 60-80% of the total value of all urban water and wastewater systems (extract from OECD 2006).

[3] The OECD (2006) covers OECD countries, Brazil, China and India.

[4] A World Bank (2010) report estimates the costs related to water supply and riverine flood protection in a scenario without climate change, and in two scenarios with climate change: the IPCCs General Circulation Models (GMCs) NCAR_CCSM3 and CSIRO_MK3, carried out for the Fourth Assessment Report (AR4). The study concludes that the adaptation costs for water supply and riverine flood protection in a scenario with climate change range between USD 27 and USD 34 billion per year in the period 2010-50.

[5] Bhattacharya, NCE, McKinsey and OECD respectively here after.

[6] The reference case refers to the IEA Current Policy Scenario in Woetzel et al., 2016 (Mckinsey) and OECD, 2017; and to the IEA six-degrees scenario in NCE, 2014a. Bhattacharya et al, 2016 use investment spending as a baseline, and project investment requirements on assumptions of growth and investment rates.

[7] In addition to investments into more efficient technologies that reduce energy and material use in end-use sectors; and technologies that help to reduce direct energy-related emissions in the end-use sectors.

[8] For more information see http://www.worldenergyoutlook.org/weomodel/

[9] See NCE, 2014b, for more details on the CPI modelling.

[10] OECD 2006 and OECD 2012 apply the elasticity of capital stock (e..g paved-road) with respect to GDP growth, differentiated by GDP per capital level. Road investment are based on the estimate of future levels of paved-road capital stock. The following relationships are exploited in the estimation: i) levels of paved-road capital stock increase as the GDP grows;

ii) the quality of paved-road capital stock increases as GDP grows; and iii) the ration of paved-road capital stock to GDP converge in the long-term.

[11] Bhattacharya, 2016; Hutton and Varghese, 2016; Woetzel, J. et al., 2016; World Water Council and OECD, 2015; Pardee Center, 2014; Dobbs, R. et al., 2013; David Lloyd Owen, 2011; David Lloyd Owen, 2010; World Bank, 2010; and Booz Allen Hamilton, 2007.

[12] Kennedy and Corfee-Morlot, 2012; WEF, 2013; NCE, 2014a; Bhattacharya et al., 2016; Woetzel et al., 2016; OECD, 2017

[13] Current infrastructure spending is estimated at around USD 3.4 to USD 4.4 trillion (IEA, 2017; IEA, 2016b; Woetzel et al., 2016; Bhattacharya et al., 2016b).

[14] Fossil fuels accounted for an average of 42% of total maritime traded volumes between 2011 and 2015 (UNCTAD, 2016).

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