

Carbon regulation and infrastructure: risk or opportunity?

Infrastructure research paper



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Executive summary

- Climate change is an important theme for investors, with infrastructure assets at the forefront of society's transformation to a low-carbon economy.
- This report seeks to explore, on a sector-by-sector basis, the key issues affecting infrastructure assets under global carbon regulation, noting that significant uncertainty still remains.
- Investors need to be aware that in most instances, the underlying demand for infrastructure services is expected to remain robust. What will change is the technological or modal mix through which the services are delivered.
- Energy infrastructure – in particular, generation – is likely to be most impacted, with a wide range of outcomes possible across the sector.
- Water utilities are also highly exposed due to the interdependence between energy and water.
- Transportation infrastructure will be affected indirectly, via the impact of carbon regulation on demand for various forms of transportation.
- Given the diverse range of regulatory, political, technological and environmental impacts possible, an active portfolio and asset management approach is crucial.

Climate change looms as arguably the single biggest issue affecting the planet. It encompasses direct impacts, such as changes in average temperatures and greater variability in weather patterns; as well as indirect impacts, which include the response of households, industries and governments to what has been described by Nicholas Stern as ‘the greatest market and widest ranging failure the world has seen.’¹

The purpose of this report is to provide an overview of the key risks and opportunities that global carbon regulation may create for infrastructure investors.

An assessment of the direct impacts of climate change is beyond the scope of this paper, as is a detailed analysis of the mechanics of carbon regulation (such as comparing emissions trading schemes to carbon taxes or modelling different carbon prices). Indeed, carbon regulation is still very much in flux around the world.

Instead, the report focuses – at a high-level and qualitatively – on the issues that affect ‘core’

infrastructure assets on a sector-by-sector basis.² What are the likely demand trends under carbon regulation? What technological or operational changes will be needed? Is the sector positioned to benefit from these changes? What, if any, risks are there to this outcome?

An understanding of these issues is an important first step in allowing investors to navigate the infrastructure landscape under carbon regulation, and ultimately make better investment and allocation decisions.

Box 1: Carbon emissions regulation worldwide

A global regulatory scheme for what is essentially a global issue is desirable, as it reduces the overall cost of emissions abatement and prevents ‘leakages’ via relocating emissions-intensive activities to other jurisdictions. Yet the difficulties of reaching ‘top-down’ multilateral agreement have been evident since the adoption of the United Nations Framework Convention on Climate Change (UNFCCC) in 1992.

Nevertheless, it is easy to overlook the considerable ‘bottom-up’ unilateral progress worldwide in introducing carbon regulation schemes – including sub-national schemes in heavy polluters such as the United States (US) and China.

Country/region	Carbon emissions regulation
European Union (EU27+3 countries)	EU Emissions Trading Scheme (ETS) since 2005, covering approximately half of Europe’s CO ₂ emissions. Trial phase from 2005 to 2007, with current phase running to 2012. Aviation and shipping to be added in Phase III.
United States	10 Northeastern states currently participating in the Regional Greenhouse Gas Initiative (RGGI), regulating power plant emissions; California to introduce ETS from January 2012.
Japan	Planned ETS delayed in late 2010.
Australia	NSW ETS in place in 2003; national ETS with fixed-price phase planned from July 2012.
China	Emissions-intensity of GDP reduction program piloted in eight cities and five provinces from August 2010.
India	Targeting 20-25% reduction in emissions intensity of GDP by 2020 relative to 2005 level.
New Zealand	ETS for forestry introduced in 2008, with transport, energy and industry added in July 2010. Transitional fixed-price phase in place between July 2010 and December 2012.
South Korea	ETS introduction planned from January 2013 although this may be delayed to 2015.

Sources: Garnaut Update Paper 2: Progress towards effective global action on climate change (2011), Reuters and CFSGAM research.

Notes:

1. The Stern Review on the Economics of Climate Change (2006).

2. Consistent with the focus on ‘core’ investments, the report largely considers the impacts on brownfield assets in developed markets, such as those within the OECD.

Climate change and carbon regulation

Climate change will have profound and far-reaching implications for society as it requires a fundamental reorientation of the dominant model of economic growth and development in advanced economies, which has existed since the industrial revolution over 200 years ago.

Governments around the world are responding by trying to break the link between greenhouse gas emissions and economic growth, with regulation of carbon dioxide emissions (the major source of anthropogenic or man-made emissions) the focus of these efforts.³ This process of 'decarbonisation' can take the form of direct regulation (such as carbon dioxide (CO₂) reduction targets or emissions trading schemes, with key examples shown in Box 1), or indirect regulation (such as subsidies and other stimulus to encourage greener forms of activity).

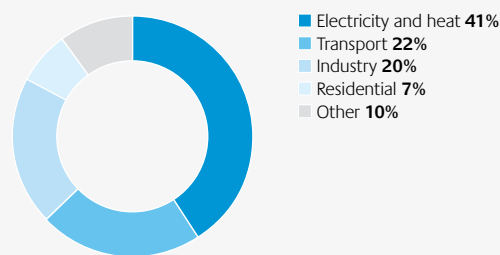
What does it mean for infrastructure?

Infrastructure, even at its most basic, underpins the functioning of modern society. Access to clean drinking water, sanitation and waste, the supply of electricity and heat, the ability to commute to and from work, leisure travel, the transportation of goods and the facilitation of trade flows with the broader global economy are all dependent on the availability of infrastructure assets.

It is little surprise, then, that infrastructure assets are very much at the vanguard of society's efforts to deal with climate change. While this report does not focus on the direct impacts of climate change (as these tend to be quite asset-specific), it is worth highlighting that these are material for infrastructure assets, which are tangible and have long lives. For instance, ports are susceptible to rising sea levels, the efficiency of high-voltage transmission infrastructure will be affected by ambient temperatures, and the output of solar and wind installations will also be governed by climatic conditions.

Turning to the indirect impacts of climate change – specifically the impact of carbon regulation – it is evident that infrastructure assets are again highly exposed. Figure 1 reveals that the electricity and heat sector is the main source of carbon emissions, underscoring the point that while energy costs often form a moderate part of the cost base for a typical service or manufacturing-oriented business, they represent the core business for generation, transmission and distribution assets.

Figure 1: Global CO₂ emissions by sector, 2008



Source: IEA and CFSGAM Research.

The second largest source of carbon emissions – transportation – indirectly affect assets such as toll roads, airports, ports and railroads, via the impact on vehicles, airlines, ships and trains. Even water utilities – which are among the largest industrial users of energy – will not only be affected by, but also influence decarbonisation efforts across the economy via the use of water in thermal electricity generation.

The critical point for infrastructure investors, however, is that the underlying demand for infrastructure services is expected to remain robust – provided the industry itself is defined broadly enough. Theodore Levitt, in his 1975 paper 'Marketing Myopia,' illustrates how companies that defined their markets too narrowly risk missing out on significant growth opportunities – or worse still, becoming obsolete. Referring to the decline of US railroads, he wrote:

'The railroads did not stop growing because the need for passenger and freight transportation declined. That grew. The railroads are in trouble today not because the need was filled by others (cars, trucks, airplanes, even telephones) but because it was not filled by the railroads themselves. They let others take customers away from them because they assumed themselves to be in the railroad business rather than in the transportation business.'

These themes resonate clearly for infrastructure asset owners faced with carbon regulation. According to the International Energy Agency (IEA), projected global demand for electricity is set to rise between 64% and 96%, depending on future policy outcomes. The IMF predicts that demand for transport is set to increase by 45% by 2030. What will change, however, are the *forms* of electricity generation or the *modes* of transportation.

Note:

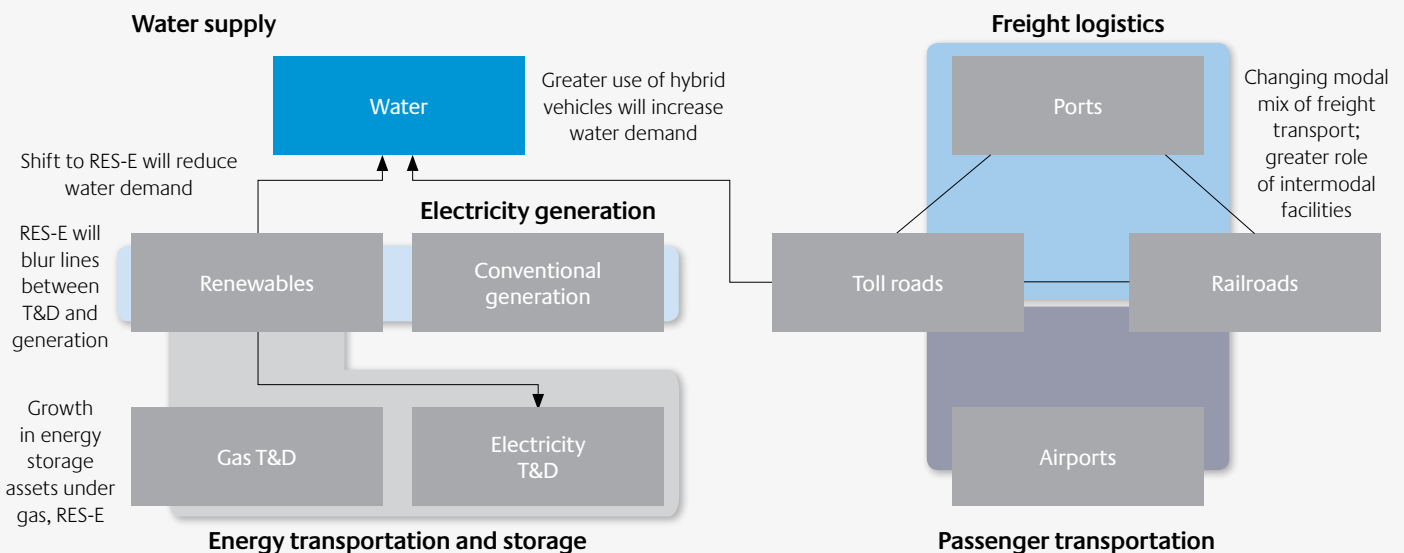
3. The six Greenhouse Gases are Carbon Dioxide, Methane, Nitrous Oxide, Hydrofluorocarbons, Perfluorocarbons and Sulfur Hexafluoride. These gases differ in their potential impact on global warming, and are often measured in tonnes of carbon dioxide equivalent (CO₂-e). Regulation may target either CO₂ or CO₂-e; therefore the discussion in this report treats these interchangeably and refers to both as simply 'carbon'.

Owners of fossil-fuel based power plants, therefore, should seek to focus on electricity generation more broadly, with the shift to renewable energy source electricity (RES-E) technologies more than offsetting the decline in conventional generation. Likewise, investors with exposure to different forms of transportation will be less susceptible to modal shift under carbon pricing, and better able to capture the overall growth in transportation demand.

This view of the infrastructure universe – as less of a collection of discrete subsectors, and more of a portfolio of alternate technologies/modes of delivering underlying services – is depicted in Figure 2.

With this perspective, it becomes clear that infrastructure is as much part of the solution to dealing with climate change as it is part of the problem, providing opportunities for investors as well as posing risks. The remainder of the paper is devoted to providing, at a high level, a sense of the opportunities and risks present for each of the traditional infrastructure asset sectors.

Figure 2: Infrastructure assets and underlying services



Source: CFSGAM.

Box 2: Infrastructure investment vehicles and climate change

Investment in infrastructure assets can be made via listed and/or unlisted vehicles. With regard to carbon regulation, each form of investment carries different risks and benefits for investors.

Listed investments carry less asset-specific risk due to the higher degree of diversification achievable. In addition, the ability to exit from assets is much higher with listed investments.

Unlisted infrastructure funds, by contrast, typically have a higher level of concentration risk and lower liquidity. This enforces a long-term investment horizon in decision making, bringing issues such as carbon regulation to the fore. So how do unlisted investors mitigate these risks?

CFSGAM's own infrastructure investment strategy is to typically manage a large enough interest in each individual business to enable CFSGAM Infrastructure to add value through board and board committee representation. Through such representation, CFSGAM is able to provide strategic input on environmental, social and governance (ESG) issues along with other key drivers of value such as business strategy, capital expenditure, structure, etc.⁴

This report complements the macro-level discussion with asset-level examples of carbon emissions reduction initiatives for infrastructure assets which are actively managed by CFSGAM. Our case studies include Anglian Water Group and Brisbane Airport Corporation.

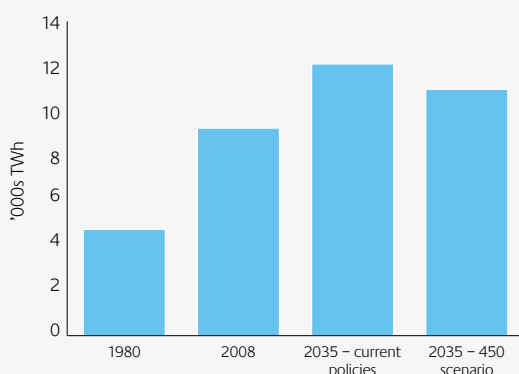
Note:
4. Colonial First State Global Asset Management: Guidelines for corporate engagement on the implementation of the United Nations Principles for Responsible Investment – Environment, Social and Governance issues. (Feb 2010)

Electricity generation

Electricity generation is highly affected by carbon regulation. While the share of fossil fuel-based generation is set to decline, the opportunity for new, RES-E generation is immense.

According to the IEA, overall OECD electricity demand is expected to grow at a CAGR of 1.0% to 2035 if carbon regulation policies that have been formally adopted by mid-2010 are taken into account. If, however, national pledges to reduce carbon emissions are kept and complementary policies are implemented (the IEA's '450' scenario), then OECD demand growth would soften to a CAGR of 0.6% over the same period.⁵

Figure 3: OECD electricity consumption projections

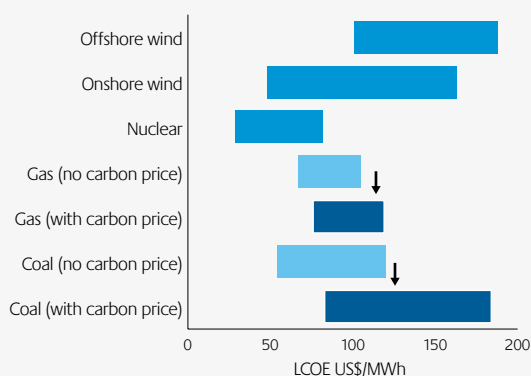


Source: IEA and CFSGAM Research.

Carbon pricing will reset the generation goalposts

Carbon regulation is set to increase whole-of-life generation costs of fossil-fuel based technologies, bringing these more in line with nuclear and RES-E as Figure 4 highlights.

Figure 4: Projected costs of electricity generation in 2015*

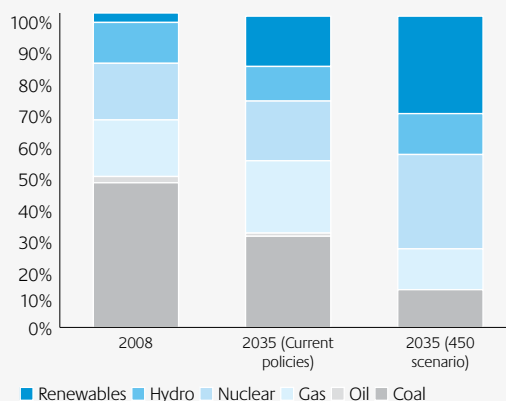


* Levelised costs, assumes 5% discount rate and carbon price of US\$30/t in 2015.

Source: OECD and CFSGAM Research.

Just under half of the electricity generated in the OECD currently comes from coal and oil, as Figure 5 highlights. Yet according to the IEA's 450 scenario, approximately 87% of all electricity will be generated from 'clean' energy sources (including gas) by 2035.⁶

Figure 5: Projected change in OECD electricity generation mix



Source: IEA and CFSGAM Research.

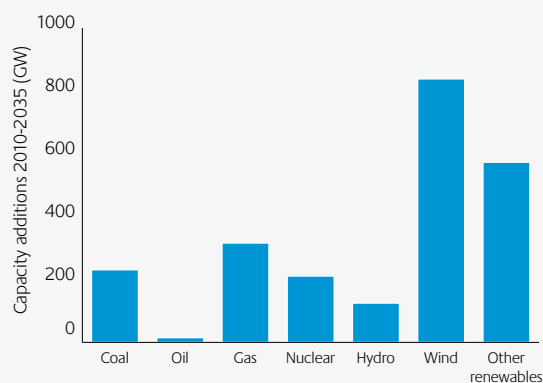
Notes:

5. The IEA's '450 scenario' assumes the near-universal removal of fossil-fuel consumption subsidies (such as subsidised petrol in developing countries) and stronger carbon reduction policies beyond 2020 to achieve the objective of limiting the concentration of greenhouse gases in the atmosphere to 450 ppm of CO₂-equivalent and global temperature increase to 2°C.

6. The recent accident at Japan's Fukushima power plant and associated resurfacing of safety concerns has the potential to significantly impact the role nuclear generation will play in the medium term. At the time of writing, it is still too early to predict whether the impact will be transient or more lasting, but we point out that it is likely to vary across countries, and is likely to provide a boost to gas and RES-E in particular.

In total, 6400 GW of additional electricity capacity is required from 2010- 2035. As Figure 6 reveals, approximately 61% of this is in RES-E (including hydro); which corresponds to approximately US\$7.9 trillion in investment opportunity, according to IEA estimates.⁷ Only 10% of new capacity is expected to be coal-fired in the OECD, roughly half the level forecast in non-OECD countries.

Figure 6: OECD capacity additions by fuel (450 scenario)



Source: IEA and CFSGAM Research.

Emissions-intensive generation: high regulatory uncertainty

Ultimately, the net impact of carbon pricing on the value of existing generation assets will depend on the level of cost pass-through achieved. This, in turn, depends on:

- The degree of **liberalisation** in a given market (eg whether changes in wholesale prices are allowed to flow through to retail prices, or whether regulation impedes this adjustment process).
- Carbon regulation specifics, such as the level of **compensation** granted under an emissions trading scheme, method of allocating permits (eg whether they are allocated for free or are auctioned), or whether a particular market's emissions cap is binding or not.
- The **emissions-intensity** of a particular generation asset relative to other generation assets in a given market. Typically, if permits are auctioned in an imperfectly competitive market, the most carbon-intensive (while profitable) generator will become the price setter, benefitting cleaner plants to varying extents depending on their relative emissions-intensity.

Box 3: Electricity Generators and the EU's ETS

Phase I of the EU's ETS ran from 2005-2007, covering large-scale electricity generation assets (over 20MW). The phase was criticised for allowing existing generators to reap 'windfall' profits (an estimated £800m annually in the UK alone)⁸, as the vast majority of emissions permits were allocated at zero cost, while wholesale power prices rose significantly. There are, however, a number of factors to consider:

Firstly, much of this price increase was due to rising fuel costs (such as coal and natural gas) during the same period.

Secondly, the uneven level of market liberalisation across European countries led to different outcomes. In liberalised markets such as the UK, the Netherlands and Nordic economies, retail prices were able to rapidly adjust to the change in wholesale market price. Thus, generators were able to effectively pass through the market value of their freely-obtained emissions permits.⁹

Thirdly, the initial over-allocation of free emissions allowances created a non-binding EU-wide cap. This occurred by design in Phase I, which was intended to be a learning phase rather than achieve any meaningful emissions reductions. In Phase II, however, weaker economic activity (2008-2012) may also have created a non-binding situation as demand contracted to levels below those envisaged at the time the policy was set.

Phase III is expected to be more effective on these fronts, as the vast majority of generation permits will be auctioned, which will reduce the level of windfall profits achieved.

The complex interactions between market structure and regulation create a high level of regulatory uncertainty, which makes quantifying the impact of carbon pricing on generation assets singularly difficult.

To illustrate, the 2008 White Paper on Australia's then-proposed CPRS contained estimates of the total change in asset value of Australian's coal-fired plants ranging from -A\$147 million to -A\$9.2 billion.¹⁰ Significantly, the estimated change in value for black coal plants ranged from a net positive impact of A\$2.2 billion to -A\$5.3 billion, highlighting that carbon regulation could well prove to be a positive for certain fossil fuel generators (as has been the case in Europe).

Notes:

7. Note, this is based on the IEA's 'new policies' scenario, which is based on different assumptions to the '450 scenario.' Comparable figures for the 450 scenario were not published.

8. IGCC & Monash University: Potential Earnings Impacts from Climate Change – Energy Infrastructure. (Nov 2007)

9. Note that the market value of emissions permits would equal the opportunity cost of using the permit (the resale value), and not the accounting value (zero).

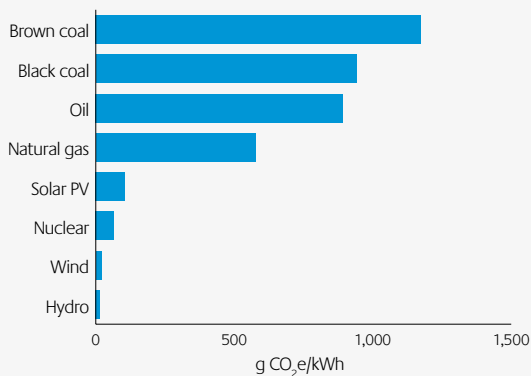
10. Australian Government, Carbon Pollution Reduction Scheme: Australia's Low Pollution Future, White Paper, Volume 2. (Dec 2008)

Carbon Capture and Storage (CCS) technology has the potential to reduce emissions from fossil-fuel generation assets, however the technology is still nascent and entails high costs.

Gas-fired generation: vital 'bridging' role

Gas-fired electricity generation has almost half the CO₂ emissions of conventional brown coal power generation, as Figure 7 highlights, and is therefore considered a relatively 'clean' fuel.

Figure 7: Lifecycle CO₂ emissions intensity for electricity generation sources



Source: Sydney University and CFSGAM Research.

Gas-fired power stations are generally used to supplement baseload power during peak demand periods, with new combined cycle gas generators able to be used for longer periods efficiently. The established technology and suitability for baseload generation are two important advantages gas has over renewables, many of which are intermittent and/or still emerging technologically.

As such, natural gas is set to occupy a strategically vital 'bridging' role in electricity generation in many countries under carbon pricing. This is particularly the case for countries that have avoided or limited the use of nuclear energy, which is even less emissions-intensive than gas, and is also a viable baseload generation option. With regard to the emergence of unconventional sources of gas (such as shale gas) in recent years, it must be noted that these extraction processes carry a higher emissions-intensity than conventionally sourced gas, reducing their green credentials somewhat.

RES-E generation: subsidies, not carbon pricing the main driver

Despite technological improvements resulting in cost reductions over the past few decades, RES-E generation remains almost entirely dependent on various forms of

policy support to be financially viable. These mechanisms have included tax credits, RES-E quotas, feed-in tariffs (FITs) and tendering schemes.

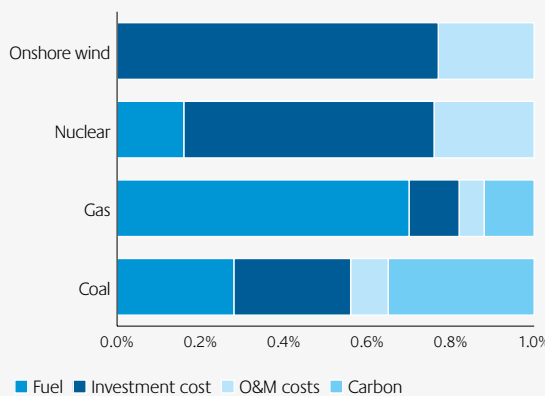
Given the 2001 Renewables Directive (which aims for an overall target of 20% RES-E by 2020) was already in place, the introduction of the EU's ETS in 2005 has had a relatively limited incremental impact. However, it is anticipated that Phase III will result in a higher emission permit price and therefore provide a more significant boost to RES-E generation.

The key risk for investors in RES-E, therefore, is adverse changes to regulatory arrangements, which may include:

- Changes to planning/development laws
- Reductions in tariff levels for new installations, retrospective reductions or both. (This is relatively rare, but a recent notable example was the reduction in Spanish solar tariffs)
- Changes in the relative support levels offered to different technologies. This occurred in the UK with 'technology banding' and the regulators decision to support some technologies more than others
- The risk that an existing support scheme becomes superseded by a new scheme altogether (for example, the current US state-based regimes being replaced by a national scheme in the future).

Because RES-E installations have negligible fuel costs and are not affected by carbon pricing, investors in brownfield assets are faced only with initial investment costs as well as ongoing operations and maintenance capex requirements, as Figure 8 highlights. This offers a different risk exposure to conventional generation assets.

Figure 8: Generation cost breakdown for selected technologies



Source: IEA and CFSGAM Research.

Carbon regulation will increase complexity of what was once a relatively simple industry. New-build opportunities abound for network operators, but stability of economic regulation will be crucial.

Across the OECD, approximately US\$2.5 trillion of investment in electricity transmission and distribution (T&D) assets is required between 2010 and 2035.¹¹

Much of this investment opportunity is a direct result of decarbonisation in the electricity generation sector, which will profoundly change the nature of T&D networks as Table 1 summarises. For example, RES-E generation sources such as wind and solar tend to be dispersed in nature, requiring additional grid connections to be built. However, the small-scale nature of these installations means that it is often uneconomical to connect these to the grid.

At worst, inadequate transmission infrastructure has the potential to undermine national RES-E targets and overall carbon reduction efforts. As an example, China has the largest installed capacity of wind energy in the world. Yet more than half of the output from Chinese wind farms goes unused due to inadequate transmission infrastructure.¹² Elsewhere, California and the UK have both sought to prioritise network additions for RES-E.

Transmission system operators (TSOs) and distribution network operators (DNOs) typically earn a regulated rate of return on invested capital meaning they face relatively little demand risk. As such, they rank among the most attractive infrastructure assets for investors. The additional network infrastructure requirements for RES-E installations are potentially a positive for TSOs and DNOs as they are able to earn revenues off a larger asset base. It must be noted, however, that higher electricity prices are likely in this case, which may face obstacles in some countries.

Although higher electricity prices expected from the expansion of RES-E are not likely to impact TSOs and

DNOs directly, they may indirectly impact operators to the extent that they precipitate (or contribute to) a change in regulatory arrangements governing network infrastructure. In the UK, one of the factors driving the introduction of the RIIO model of regulation is climate change, as the UK electricity and gas regulator OFGEM notes.¹³

*'Companies will need to experiment with network design, operation and pricing, in order to connect significant volumes of emerging and untested low- and zero-carbon technologies over relatively short timescales. To drive these changes to the way networks operate, the way we regulate needs to change.'*¹⁴

The growth in distributed generation may actually reduce the level of throughput for a given transmission network, depending on where RES-E installations are located. If they are situated closer to end-users, they may reduce transmission losses, which typically total around 6-7% across modern transmission and distribution networks combined.¹⁵

On the other hand, the more complex flows of electricity imply a greater coordination role and opportunity for investment in assets such as interconnectors. For example, the widespread use of wind power for electricity generation in Denmark has necessitated the construction of interconnectors with Norway and Sweden to supplement supply when wind resources are low. Other investment opportunities include infrastructure associated with 'smart grid' technology and storage facilities.

The net impact of carbon regulation on TSOs and DNOs will depend on the extent to which they are able to enjoy continued regulatory support while taking advantage of new growth opportunities.

Notes:

11. IEA (2010) op. cit.

12. Source: China Daily: Grid Shortcomings Taking Wind Out of Energy Plan's Sails (Feb 2011).

13. RIIO stands for Revenue = Incentives + Innovation + Outputs. OFGEM stands for Office of Gas and Electricity Markets.

14. Nixon, H. Its Name is RIIO: A New Model for Regulating Britain's Energy Networks (Nov 2011).

15. World Business Council for Sustainable Development: Transmission and Distribution Issue Brief (Oct 2006).

Table 1: Traditional versus distributed networks

Traditional	Distributed
Centralised, large-scale generation sources	Dispersed, smaller-scale generation
Consistent, reliable supply, suited to baseload needs	RES-E such as wind, solar intermittent in nature
Distant sources, users result in transmission losses	Sources closer to users may reduce transmission losses
'Passive', with mostly unidirectional electricity flows	'Active' networks with greater coordination, balancing required
Minimal transmission infrastructure needed given centralised model	Need for additional links to backup generation sites, energy storage facilities

Box 4: Smart grids

The IEA defines a smart grid as ‘an electricity network that uses digital technology to monitor and manage the generation and transport of electricity from all sources in order to meet the varying electricity demands of end users as efficiently as possible.’

The advantages of a smart grid include the potential to minimise costs and carbon emissions, as well as maintaining stability of transmission and distribution networks by reducing peak demand.

According to a McKinsey study,¹⁶ successful deployment of smart grid technologies could yield savings of \$130 billion annually in the US alone over the next decade.

However, there are significant costs associated with introducing smart grid technology with this level of capability. Consequently, most smart grid schemes currently proposed are not ‘fully-fledged’ versions.

Indeed, US regulators have questioned whether the massive investment needed delivers value for money. Likewise, in the EU there have been only tentative moves in some member states to promote smart metering rollout.

Note:
16. McKinsey & Company:
McKinsey on Smart Grid
(Number 1, Summer 2010).



Gas transmission and distribution stands to benefit enormously from the bridging role of gas-fired electricity generation under carbon regulation. Additional investment opportunities will arise from the increased globalisation of the sector.

Currently, two-thirds of natural gas in the OECD is used directly for applications such as heating, cooking and transport fuels. The remaining third is used indirectly, via gas-fired electricity generation (discussed in the electricity generation section of this report). The latter segment is expected to benefit most from carbon regulation and drive overall demand growth.

This growth will also be accompanied by the need for greater investment in gas transmission and distribution. According to the IEA, as much as US\$862 billion is needed 2010 to 2035 across the OECD.¹⁷

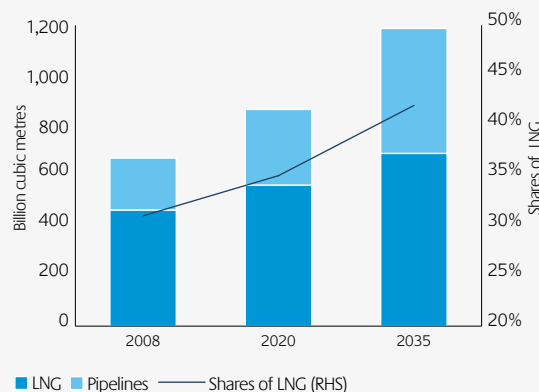
As indigenous gas production is forecast to decline in many countries, gas will also become an increasingly globalised energy source. Indeed, international trade in natural gas is forecast to expand by almost 80% from 2008 to 2035, as Figure 9 depicts. With a higher proportion of gas expected to be transported in the form of liquefied natural gas (LNG), assets such as LNG storage, liquefaction and regasification facilities will become more widespread, creating additional investment opportunities. The IEA's estimate of the global LNG infrastructure investment requirement from 2010 to 2035 is US\$622 billion.

LNG-sourced gas is more emissions-intensive than domestically or locally-sourced natural gas due to the additional transportation required, but is nevertheless generally less emissions-intensive than coal or oil-fired generation.

With the share of world gas production from non-OECD countries rising from 29% in 1973 to a projected 74% by 2035, developed economies heavily reliant on supply from potentially unstable regions such as the Middle East and former Soviet Union countries will increasingly seek to diversify import sources. Investors will need to be cognisant of these geopolitical factors, as they have the potential, in some cases, to outweigh or subvert purely carbon regulation-driven changes in LNG demand patterns.

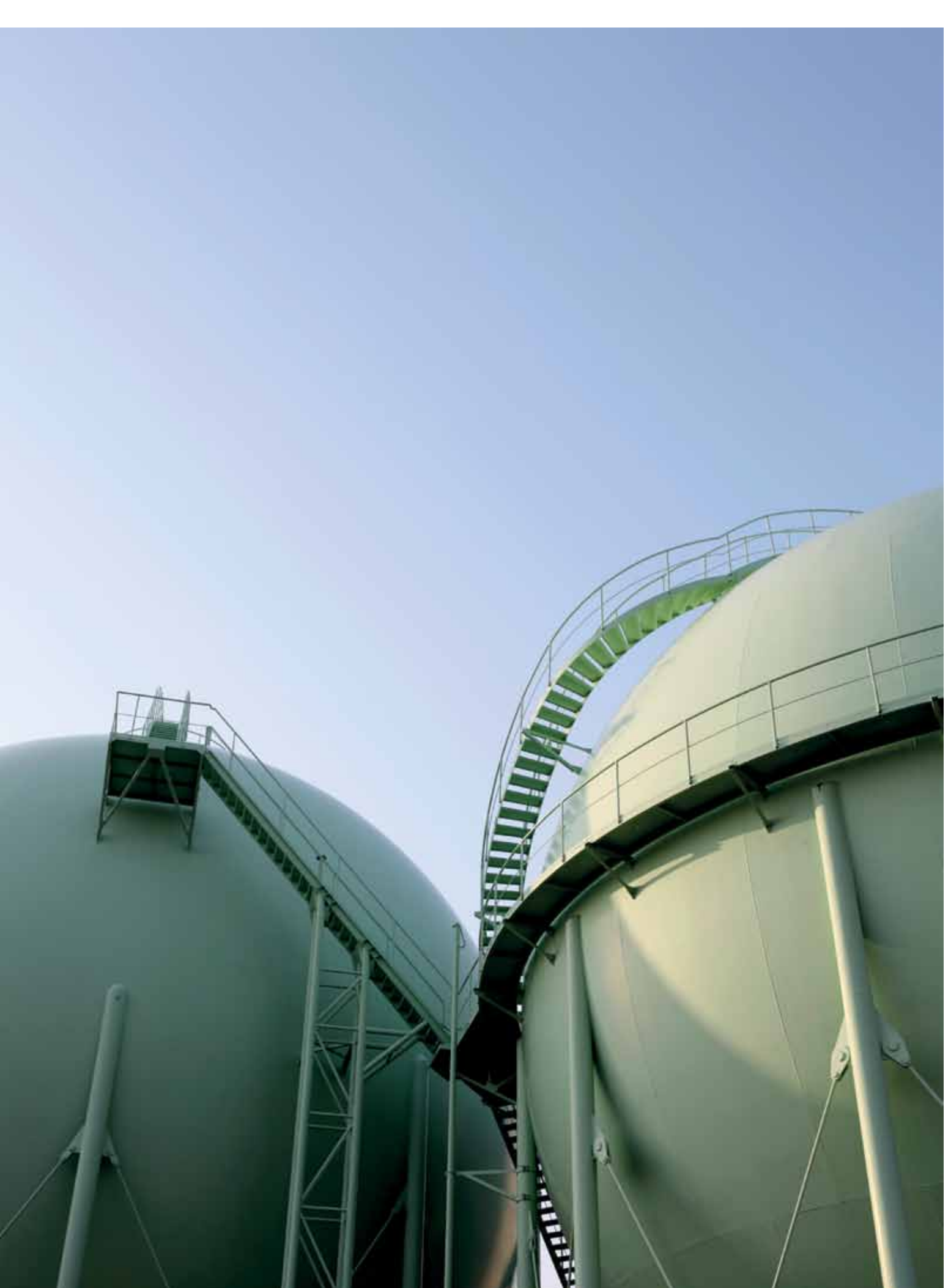
Consequently, LNG export infrastructure in politically stable countries such as Australia will be highly sought after by investors.

Figure 9: Global inter-regional gas trade projections



Source: IEA and CFSGAM Research.

Note:
17. International Energy Agency: World Energy Outlook 2010.



The impact of carbon regulation on ports is likely to be minor and indirect. The focus on reducing emissions across the wider supply chain is likely to create ancillary investment opportunities for investors.

Ports exist as one link in a wider supply chain, and when evaluating the impact of carbon pricing on ports, it is necessary to consider both the indirect impacts on the shipping and logistics markets, as well as the direct impacts on ports themselves. In both cases, the impacts are expected to be marginal in nature.

Shipping industry: largely staying on course

International shipping is not currently covered by the Kyoto Protocol framework, although the EU is considering including shipping in its ETS scheme from 2013. According to UNCTAD, if no action is taken, emissions from ships may triple or even quadruple by 2050. Regardless of the form and timing of any carbon regulation, however, the impact is likely to be relatively minor, for the following reasons:

- The imposition of a carbon price will qualitatively be similar to an increase in fuel costs. To a large extent, the resulting emphasis on improving fuel efficiency already exists among cargo shippers.
- Shipping is one of the least emissions-intensive forms of freight transportation, particularly over long distances. Around 90% of current world trade is seaborne, with this proportion only likely to increase once carbon regulation is applied to all transport modes.
- Related to the above point, demand for shipping is relatively price inelastic. A technical report prepared for the European Commission estimated the price elasticity of demand for shipping to be in the range of 0.2 to 0.3 (although this varies slightly across different segments of shipping).

An International Maritime Organisation (IMO) study estimated that carbon emissions could be reduced by 15-20% between 2007 and 2020 through technological and operational improvements to ships.¹⁸ These include hull, engine and propeller design modifications to improve fuel economy, the use of larger ships, and the optimisation of ship voyages (eg reducing average speeds to improve fuel efficiency). Again, most of these trends have already been evident across the sector against a backdrop of rising and volatile fuel prices, and so do not represent a radical departure from the status quo.

Port operations: coordination and support role

Ports themselves are not major carbon emitters, but have the potential to influence emissions levels and patterns at other stages in the broader supply chain.

For example:

- Ports may introduce **pricing schemes** to incentivise lower carbon emissions among ships. Already, a number of ports in North America and Europe are doing so by linking port dues to emissions levels. This pricing strategy is likely to gain wider acceptance under carbon regulation.
- Ports can provide **infrastructure** to help reduce shipping emissions. For example, a growing trend at ports is the provision of shoreside power, which allows berthed ships to plug into an onshore electrical power source instead of powering lighting, refrigeration, etc. via comparatively emissions-intensive diesel engines. A 2005 report found that carbon emissions could be halved via the use of shoreside power based on EU electricity costs.¹⁹
- Through improved coordination of operations, ports can minimise **waiting times** for ships at port, again reducing overall emissions.
- Terminal **operating concessions** and agreements may include **modal shift** criteria imposed by the port authority in order to meet emissions reduction targets.

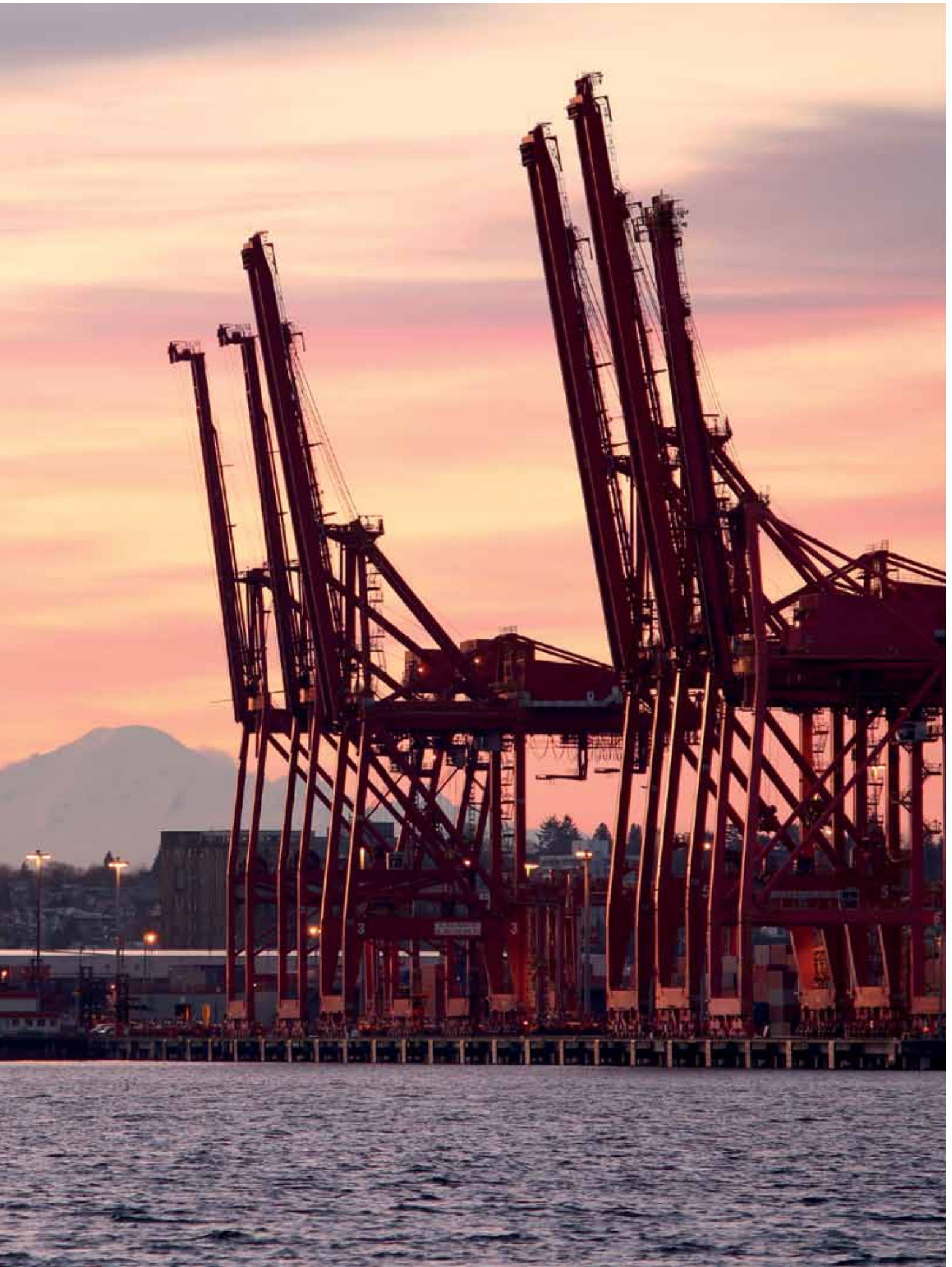
Other risks and opportunities from carbon pricing include:

- The costs of activities such as harbour or channel deepening (needed to accommodate larger ships in shallow ports) are likely to increase with carbon pricing. This increases the relative attractiveness of ports which have natural deepwater berths, which potentially avoids the risk of significant capital expenditure requirements for shallow ports.
- As the relative costs of different transport modes change, logistics chains are likely to be reconfigured to minimise end-to-end carbon emissions. Port owners may seek to invest in complementary assets along the supply chain such as intermodal and storage facilities to take advantage of this.
- Demand for bulk traffic is generally less elastic than general containerised cargo. However, investors will need to factor in the impact of carbon pricing on the demand for particular commodities (for example, LNG-oriented ports may offer superior growth to brown coal-oriented ports).

Notes:

18. IMO. Second IMO GHG Study 2009 – Prevention of Air Pollution from ships (Apr 2009)

19. Entec UK – Service Contract on Ship Emissions: Assignment, Abatement, and Market-based Mechanisms. (Aug 2005).

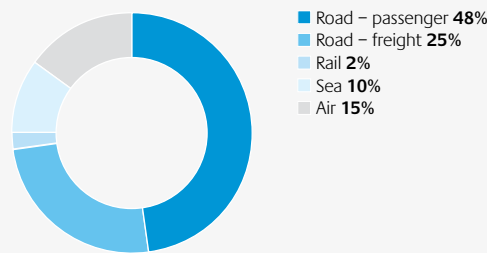


Toll roads face little direct impact from carbon regulation. Range of transport emissions reduction policies possible for transport, with differing impacts on toll road assets.

Toll roads are carbon-intensive during the construction phase, but operational emissions are relatively low. For brownfield investors, therefore, the key impact of carbon regulation on the value of toll roads will be the indirect effects of carbon regulation on the road transport sector.

Despite accounting for the vast majority (72%, as highlighted in Figure 10)²⁰ of carbon emissions in the transport sector, carbon regulation of road transport lags behind other modes such as aviation and shipping. For instance, while the latter two sectors are set to be included in the EU's ETS from 2013, there are no immediate plans to do the same for road transport.

Figure 10: Global transport CO₂ emissions by mode, 2008



Source: IEA and CFSGAM Research.

Road transport emissions: non-price regulation likely

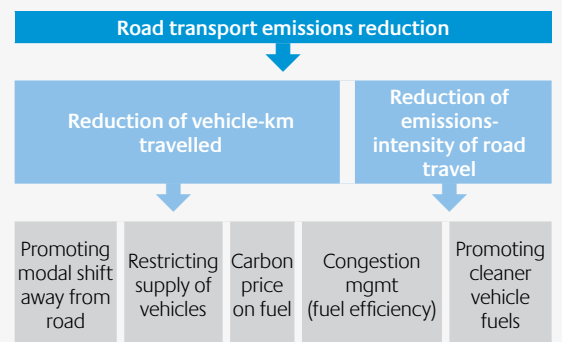
Road travel demand is relatively price inelastic, at between 0.1 to 0.25 in the short-term and, 0.3 to 0.6 in the long-term. This suggests that a carbon price on fuel alone is unlikely to induce mass changes to transport patterns, particularly compared to the more material increases in general fuel prices over the past few years.

Instead, any significant reduction in carbon emissions from the road transportation sector is likely to be achieved through a combination of the policy options shown in Figure 11. Clearly, the choice of carbon regulation policies may have a positive, neutral or negative effect on toll road patronage.

For instance, a widespread shift to cleaner fuels (such as biofuels or hydrogen) could reduce overall road transport emissions without affecting toll road patronage, depending on the relative cost of fuel sources. On the other hand, the implementation of policies to restrict supply, such as the Singaporean government's scheme of car-ownership rationing, reduce vehicle usage and artificially cap patronage levels.

Another potential threat to toll road patronage is a modal shift away from road, which will depend on regulatory developments in other transportation markets as well as the provision of adequate infrastructure. These factors are likely to differ across and even within countries.

Figure 11: Road emissions reduction policy options



Note:
20. The rounding error (72% v 73%) account for the difference as per the chart in Figure 10.

Individual toll road characteristics will differ

At the asset level, the impact of carbon regulation on the value of toll roads will depend on the interaction of several factors. For example:

- Toll roads with a high ratio of freight to passenger traffic may be relatively insulated against fuel price increases given that transport costs form a relatively small portion of the overall costs of final goods, and that other considerations such as flexibility and speed tend to compete with price concerns.²¹
 - The potential for modal shift of freight from road to rail is generally greater for long-haul movements than it is for short-haul movements, a factor which should favour urban toll roads.
 - The risk of modal shift is higher in high-density areas such as Japan and parts of Europe than in less dense areas, such as Australia and Canada.
- Patronage levels may be more vulnerable in markets such as the US, where fuel is currently taxed lightly relative to markets such as Europe (meaning the imposition of a carbon cost would represent a proportionally higher additional cost).
 - Traffic congestion not only reduces the relative attractiveness of toll-road journeys but also increases the emissions-intensity of vehicles. In this context, congestion reduction measures such as dynamic tolling or high-occupancy toll (HOT) lanes represent a key opportunity for toll road operators to influence traffic flows and volumes, while at the same time reducing the emissions-intensity of road travel on their toll roads.

Note:
21. IEA – Transport, Energy and CO₂ – moving toward sustainability (Oct 2009).



Significant opportunity for a ‘rail renaissance’ in a carbon-constrained world, but policy support and infrastructure are required.

For the rail sector, which has lost modal share to road and air transport over recent decades, carbon regulation is a welcome development. In terms of emissions-intensity, rail is one of the least intensive forms of transport, as Table 2 highlights. According to the Association of American Railroads (AAR), rail is up to three times more fuel efficient than road transport on a tonne per mile basis. In addition, the electrification of rail has the potential to further reduce the carbon emissions-intensity of rail travel.

Table 2: Emissions intensity of freight transport modes

Transport mode	gCO ₂ equivalent per tonne/km
Air	1422
Road transport	
Light commercial vehicles	1294
Rigid Trucks	183
Articulated Trucks	60
Rail	
Government	20
Private	5.4
Coastal Shipping	13

Source: Australian Greenhouse Office, 2007.

However, while the opportunity for both freight and passenger rail is immense, it is important to recognise that the introduction of a carbon price alone may not necessarily induce a significant modal shift to rail without policy support. Other prerequisites include having a regulatory/tax environment that is broadly competitively neutral²², sufficient market liberalisation as well as adequate infrastructure.

These and other factors are discussed with regard to each of the key rail segments below:

- **Passenger rail:** high-speed rail (HSR) looms as the major area of development for passenger rail services. However, the penetration of HSR is dependent on market characteristics. For example Europe’s relatively high population density and level of economic development has supported a current HSR network of 10,000 km, which is expected to double over the next decade.

A 2009 Report by the UK’s Committee on Climate Change found that high-speed rail (HSR) dominates journeys below 400 km, is uncompetitive with air travel for journeys over 800 km, and has the ‘potential to enable significant modal shift’ for distances between 400 and 800 km.

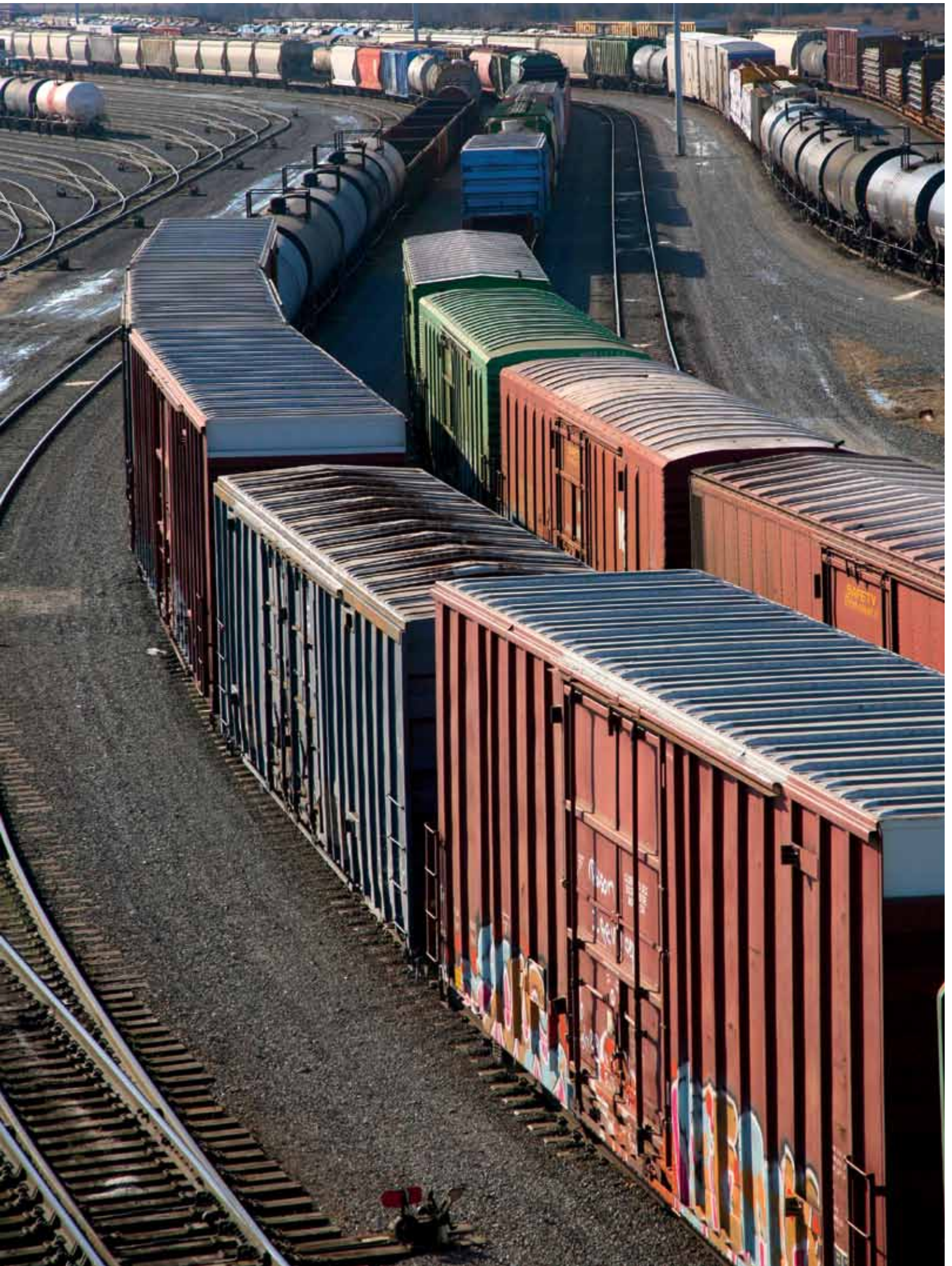
In developed countries such as Australia, Canada, and parts of the US, high-speed rail is less viable due to the relatively low population density and significant distances between cities.

- **Freight rail:** Inadequate infrastructure and regulation are the key constraints. As an example, freight rail services in many developed countries share rail infrastructure with higher-priority passenger rail services, creating unnecessary delays and limiting the industry’s potential growth.

The potential for modal shift to freight rail is limited for short haul journeys, where road transport is preferred due to the added flexibility it provides. For long haul movements, however, the introduction of a carbon price would imply a clear advantage for rail. (In this sense the dynamics of freight rail are the opposite to that of passenger rail, where longer distances diminish rail’s advantage.)

- **Intermodal facilities:** The substitution from road to freight rail, and the need for goods to be efficiently transported between trucks and trains will require increasing intermodal terminals. These represent a key opportunity for infrastructure investors.

Note:
22. Competitive neutrality is a situation where a given mode of transport is not advantaged over another via more favourable taxation, regulation or lower effective access charges for users.



Airports have limited direct exposure to carbon regulation, but are tied to the fortunes of the airline industry, where regulation is still nascent.

Like other forms of transportation infrastructure, airports themselves are not significant carbon emitters, with direct emissions reduction efforts targeted at reducing the energy-intensity (as Box 5 indicates). Additionally, airports – in conjunction with air traffic authorities – may play a coordination role in optimising aircraft movements during take-off, landing and taxiing. This is estimated to improve fuel efficiency (and hence carbon emissions) by 6 to 12%.²³

Box 5: Brisbane Airport Corporation (BAC)

BAC is Australia's third largest airport, handling approximately 20 million passengers per annum. The airport occupies 2,700 hectares, making it Australia's largest capital city airport by land area. Of this, 285 hectares is reserved as a biodiversity zone, representing the largest conservation zone within an Australian capital city.

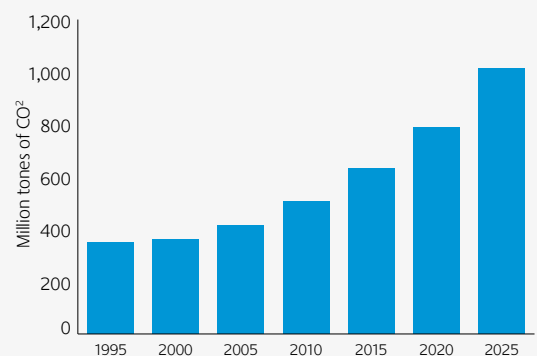
With up to 80% of BAC's carbon emissions coming from energy consumption, BAC's environmental strategy has been to improve energy efficiency and then substitute with alternate energy supplies where appropriate.

Recent energy efficiency initiatives include:

- Reducing existing base energy demand and including standard efficiency requirements for new developments.
- Installing smart metering, thus enabling tenants to access their own consumption data to improve their own energy savings processes.
- Retrofitting electrical fittings and improving lighting and ventilation controls (which have reduced energy consumption in selected buildings by 15% to 20%).
- Energy efficient design, for example in the recently expanded International Terminal Building, with the new design increasing energy efficiency through the inclusion of a centralised energy plant, use of natural lighting, and efficient lighting fixtures.

The main impact, however, of carbon regulation on airport valuations will be indirect, via the impact on the airline industry.

Figure 12: Projected CO₂ emissions from global aviation sector



Source: Australian National University and CFSGAM Research.

Regulating aviation emissions has proved to be challenging, with progress from the International Civil Aviation Organisation (ICAO) body being disappointing to date. As a result, the EU has decided to go ahead and include aviation in its ETS from 2013 (Refer to Box 6).

Aviation accounts for a relatively small proportion (1.6% in 2008) of global carbon emissions. However, the sector attracts attention due to the rapid historical and projected growth in emissions. Indeed, aviation was the fastest growing sector (in terms of emissions) between 1990 and 2006, with emissions increasing by 98%. Furthermore, ICAO predicts that aviation emissions will increase 88% by 2020 and 667% by 2050 compared with 2006 levels,²⁴ with rapid growth expected to overwhelm reductions in carbon emissions through measures such as improved fuel efficiency.

Qualitatively, the inclusion of carbon pricing will have the same impact on airfares as an increase in fuel prices, which form as much as 40% of airlines' cost base. According to one study, the nominal additional carbon cost in the European context was estimated to be equivalent to only a 7% increase in the price of fuel.²⁵

Notes:

23. IGCC – Climate Change & Airport Infrastructure. (Nov 2007)

24. International Civil Aviation Organisation (ICAO) & Group on International Aviation and Climate Change (GIACC), Report 4, IP-1: Global Aviation CO₂ Emissions Projections to 2050. (Apr 2009)

25. Standard & Poor's: Airline Carbon Costs Take off as EU Emissions Regulations Reach for the Skies. (Feb 2011)

The net impact of carbon pricing on airlines will depend on the level of regulatory compensation received by carriers (for example, the proportion of allowances granted for free under an ETS), as well as the degree of cost pass-through that individual carriers are able to achieve. This, in turn, will depend on a range of geographical, regulatory and modal competition factors.

Box 6: Aviation's inclusion in the EU ETS

The upcoming inclusion of aviation in Phase III (which runs from 2013 to 2020) of the EU's ETS represents the first time that transportation will be included in a formal carbon regulation regime. In the case of aviation, the decision has highlighted some of the conceptual and practical challenges in pioneering regional regulation of what is essentially a global industry.

Initially, 82% of the permits – which are based on historical emissions levels – will be allocated free of charge, which will reduce the impact on airline profitability in the early years of the scheme.

The scheme is intended to apply to all flights arriving and departing from EU airports, including those from non-EU based carriers. This prompted a legal challenge from several US carriers, which, at the time of writing, is with the European Court of Justice.

Another concern for the European Commission is the potential for 'carbon leakage'. For example, under the envisaged operation of the ETS, multi-stop flights that enter the EU from afar will only have the final stage of their journey subject to emissions regulation. Consequently, airlines may have an incentive to restructure some of their routes so that their penultimate stop lies just outside the EU.

Finally, the historical benchmarking of airline emissions allowances could result in some counterintuitive, albeit transient, outcomes. For example, an airline that had not yet implemented significant fuel efficiency initiatives would find it easier to reduce its emissions below the allowable limit than an airline that had already implemented efficiency measures and was therefore benchmarked against a tougher standard.

These issues are expected to persist until such time as other regional schemes are introduced, or a global carbon emissions framework is brokered.

Higher airfares will inevitably result in some softening of overall demand growth relative to a no carbon-regulation scenario. Beyond this, however, the impact on airports will depend largely on the following factors:

- Airports with a greater orientation to the **low-cost carrier** (LCC) market than full-service carriers are likely to be adversely affected, as the LCC passenger segment is generally more price-sensitive. This is closely tied to the proportion of leisure versus business travellers.
- Airports in regions with **lower population density** may be relatively insulated from carbon pricing, as modal alternatives such as high-speed rail are less likely to be viable.
- Airports which have exposure to **less fuel-efficient** airlines may be advantaged or disadvantaged, depending on the source of inefficiency. For example, airlines that have not yet adopted fuel-efficiency initiatives (eg switching to biofuels) may be somewhat advantaged (see Box 6). On the other hand, airlines whose fuel inefficiency stems from other factors (such as operating a relatively **old fleet**), may not enjoy the same 'low hanging fruit' mitigation options.
- Airports exposed to regional carriers may be more at risk than those with exposure to **global carriers**, which have greater flexibility around route optimisation, etc
- Airports located in certain **regions**, such as the Middle East or other hubs outside the EU are likely to benefit from the rerouting that will take place to minimise airlines' carbon liabilities.

Climate change induced resource constraints and energy intensity of water production the key issues for water utilities under carbon regulation.

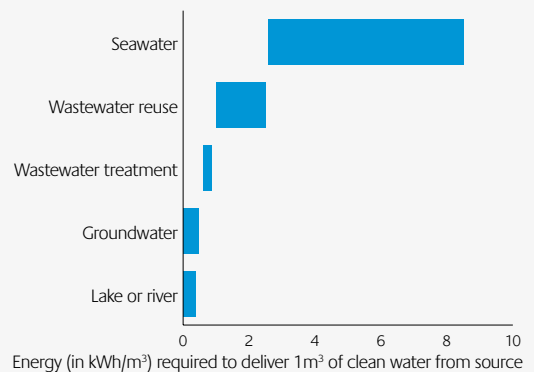
The demand outlook for water is highly uncertain. The transition to lower carbon-intensity in the broader economy will have flow-on effects on water consumption levels, often in unexpected ways. For example, if hybrid or all-electric vehicles replace conventional petroleum fuel-based vehicles, water consumption is likely to increase if the majority of electricity generation is still thermal or nuclear.²⁶

The key to mitigating such counterproductive outcomes lies in changing the electricity generation mix and breaking the current link between water and energy, which is highlighted in Box 7. As Table 4 outlines, renewable energy sources such as wind and solar are much less water-intensive than conventional thermal electricity generation sources such as coal and nuclear. As the proportion of RES-E rises in the future, this will reduce water demand from the sector – without necessarily incurring a carbon penalty.

Climate change induced water shortages will increase the role of non-traditional sources of water, such as recycled water and desalination. The market for the latter is expected to grow by over 20% annually to 2015 in Australia and the US, with the total investment requirement in new plants estimated at US\$56bn.²⁷ These trends will have two main impacts on the water sector.

Firstly, alternative water sources are more energy-intensive than surface water abstraction, as Figure 13 demonstrates. Furthermore, the need to pump water from distant sources will significantly increase energy requirements. As an example, the water pumped through nearly 600km of pipes to Kalgoorlie, in Western Australia costs about 10 times more than locally supplied water in Australian capital cities.²⁸ An increase in the energy intensity of the water sector will increase its exposure to the introduction of a carbon price, although a high degree of pass-through is likely.

Figure 13: Energy intensity of supply from water sources



Source: WBCSD and CFSGAM Research.

Notes:

26. Source: King, C.W. & Webber, M. E. Plugged-In Automotive Economy in Environmental Science and Technology, Vol. 42, No. 12, 2008.

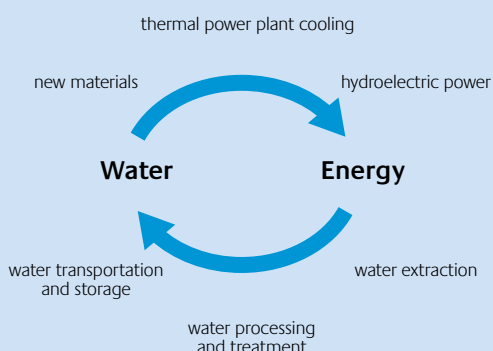
27. World Economic Forum: The Bubble is Close to Bursting (Jan 2009).

28. PMSEIC: Challenges at Energy-Water-Carbon Intersections (Oct 2010).

Box 7: The water-energy nexus

Water abstraction, pumping, treatment, desalination and distribution all require significant amounts of energy. Likewise, one of the biggest uses of water by industry is for cooling in thermal power generation.²⁹ Energy production currently accounts for about 39% of all water withdrawals in the US and 31% in the EU.³⁰

Figure 14: The Water-Energy nexus



Source: CFSGAM Research.

In this context, water and energy consumption can almost be seen as a trade-off, noting that this is based on a predominantly conventional power generation mix. Going forward, the challenge for policymakers and society more broadly will be to balance the often-competing goals of energy and water efficiency.

Secondly, there will be significant additional capital expenditure requirements for water utilities in order to build and maintain and improve water infrastructure. One example is reducing leakage rates, which vary from around 4% to 30% in the developed world. In total, an estimated US\$ 200 billion is needed annually in the OECD alone to replace ageing water infrastructure to guarantee supply, reduce leakage rates and protect water quality.³¹

Table 4: Water Intensity of Alternative Generation Sources

Water consumed to produce 1 MWh of electricity (in m ³)	
Wind	0.0001
Solar	0.0001
Natural Gas	0.2 – 1.0
Coal	0.7 – 3
Nuclear	0.9 – 3.3
Oil/petroleum	0.1 – 6.5
Hydropower (evaporation losses)	17
Biofuels (first-generation)	32.6 – 360

Source: WE Forum.

Regulatory risk is relatively low for the water sector. As an example, most European water utilities operate under an incentive-based regulatory regime. This means they will theoretically be able to completely pass-through higher carbon costs as these form the basis of the regulator's determination of allowable revenues (and hence water prices).

However, there may be some regulatory risk to the extent that competing goals exist for the regulator. For instance, improving water quality and capital expenditure to minimise leakages may both run counter to the goals of minimising electricity consumption and carbon footprint for a water utility.

Box 8: Anglian Water Group (AWG)

AWG is the largest water company by area in the UK, serving around six million customers. AWG is also one of the largest users of electricity in the east of England, due to the power required to treat water and pump it around such a geographically flat region.

In order to minimise energy usage, AWG has implemented a number of energy efficiency measures such as:

- Real-time Pressure Control which maintains minimum pressure levels to reduce leakage and consumption.
- Impeller (rotor) replacement inside existing pumps to return pumps to design efficiency.
- Replacing air valves at the diffused aeration plant to minimise volume of air flow required for aeration.

In addition to the abovementioned measures, CO₂ footprint analysis is now embedded into AWG's standard cost-benefit analysis across the business.

Note:

29. Includes coal, oil, gas, and nuclear.

30. European Environment Agency; C40 Cities, Climate Leadership Group.

31. World Business Council For Sustainable Development: Water Facts and Trends (Version 2), (Aug 2009).

What this paper demonstrates is that although much uncertainty remains over the future evolution of the carbon regulation landscape, it is nonetheless clear that both opportunities and risks exist for infrastructure investors. The essential nature of infrastructure services ensures that demand for infrastructure assets will remain robust under carbon regulation.

However, investors need to be aware of the likely reconfiguration that will take place in areas such as electricity generation technologies and transportation modes once carbon pricing is factored into the calculus of economic activity. This will better enable them to seize investment opportunities and avoid potential risks across the infrastructure spectrum.

Table 5 outlines some of the key opportunities and risks identified in the report. They include a mix of regulatory, political, technological and environmental factors. While not a comprehensive checklist by any means, the diverse impacts do suggest that active portfolio and asset management have a crucial role in delivering the best risk-return outcomes for infrastructure investors.

Table 5:

Sector	Key opportunities	Key risks
Electricity generation – conventional	<ul style="list-style-type: none"> – Generous transitional arrangements under carbon regulation – Increased interest in for cleaner forms of conventional generation (eg cleaner coal, plants with abatement technologies such as CCS) 	<ul style="list-style-type: none"> – Inadequate compensation under carbon regulation schemes impairing asset values for some generators (dependent on market liberalisation, etc) – Lower growth trajectory for electricity demand under carbon regulation
Electricity generation – gas	<ul style="list-style-type: none"> – Most likely technology/fuel to displace more emissions-intensive forms of baseload generation such as coal 	<ul style="list-style-type: none"> – Geopolitical factors may subvert purely carbon regulation-driven outcomes – Embedded carbon costs for unconventional sources may increase gas prices
Electricity generation – renewables	<ul style="list-style-type: none"> – Large installed capacity requirements driven by high-level political/regulatory targets 	<p>Adverse changes to RES-E regulation:</p> <ul style="list-style-type: none"> – particular forms of RES-E generation being support at expense of others – tariff reductions – replacement of one green scheme with another – inadequate transmission infrastructure or removal of priority access to grid for RES-E
Electricity T&D	<ul style="list-style-type: none"> – New transmission links needed to connect new RES-E capacity – Energy storage facilities, smart grids – Potentially lower network transmission losses 	<ul style="list-style-type: none"> – Greater complexity in transmission function with RES-E in contrast to simple centralised model (eg grid stability issues) – Potential changes in regulatory arrangements impairing ability to pass-through costs – High fixed costs

Sector	Key opportunities	Key risks
Natural Gas (T&D + storage)	<ul style="list-style-type: none"> – Significant growth in T&D will accompany expansion in gas-fired generation – Growth in LNG market will create opportunities in storage, transportation facilities 	<ul style="list-style-type: none"> – Geopolitical factors may subvert purely carbon regulation-driven outcomes – Increased cost of gas due to higher transportation costs may offset green credentials of gas
Ports	<ul style="list-style-type: none"> – Potential revenue sources include facilities to minimise emissions in wider supply chain (eg shoreside power, intermodal terminals) – Modal share of sea freight could potentially increase for some markets/routes 	<ul style="list-style-type: none"> – International nature of sector may cause teething problems with carbon regulation (similar to aviation) – Ports without natural deepwater berths may be disadvantaged if carbon regulation accelerates trend to larger ships – Some ports may be exposed to commodity risk
Toll Roads	<ul style="list-style-type: none"> – Focus on fuel/carbon efficiency policies, rather than policies aiming for overall reduction in travel could potentially be positive for patronage levels – More widespread use of congestion reduction features such as HOT lanes and other pricing schemes could be positive for revenue levels 	<ul style="list-style-type: none"> – Adverse policy developments (eg high-level support for alternative forms of transport such as rail) could negatively affect some toll roads – Individual toll roads with high exposure to long-haul traffic and price-sensitive traffic segments may be more at risk than others
Railroads	<ul style="list-style-type: none"> – Potential to capture market share from other modes of transport, particularly in market for: <ul style="list-style-type: none"> – long-haul freight movements – short-haul passenger movements – Investment opportunity in HSR, electrification of lines and intermodal facilities 	<ul style="list-style-type: none"> – Need for high-level policy support, viability of new infrastructure to ensure modal shift – Potential commodity risk for some bulk cargo railroads
Airports	<ul style="list-style-type: none"> – Rerouting by airlines to take advantage of uneven global regulation landscape could benefit some airports – Airlines taking advantage of generous compensation/transition arrangements into carbon regulation may also benefit some airports 	<ul style="list-style-type: none"> – Softening in demand growth due to additional carbon cost – Airports with exposure to price-sensitive segments of market (eg LCC leisure travellers), or those competing directly with HSR may see dampening of demand – Uneven pace of regulation globally may disadvantage some hub airports over others
Water	<ul style="list-style-type: none"> – Additional capex requirements to build and maintain and improve water infrastructure – Increased proportion of RES-E likely to reduce the water requirement from generation sector 	<ul style="list-style-type: none"> – Non-traditional sources of water likely to increase energy intensity of water utilities – Some regulatory risk due to competing objectives under carbon regulation (eg maintaining water quality standards versus minimising carbon footprint)

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