DNA Economics

Carbon lock-in: Infrastructure Investment Research Piece

NPC low carbon economy work programme

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EXECUTIVE SUMMARY

A failure to consider future climate change policies when investing in infrastructure may lead to suboptimal long-term investment outcomes. Infrastructure investments have very long useful lives, and investments made today are likely to continue providing services for decades to come. Even infrastructure that is in place for relatively short periods of time can still have long-term systemic impacts. The design life-span of road infrastructure in South Africa, for instance, is relatively short in infrastructure terms at 20 years (the design lifespan for a new coal-fired power station, in contrast, is around 50 years). But the positioning of new roads has longer-term impacts through their influence on spatial development patterns. Moreover, the expected useful life of infrastructure is not always fixed, and the actual operational lives of assets can be longer than anticipated. Locomotives, for example, have an average life span of 16 years and wagons 20-25 years internationally. Transnet's locomotives are on average 30 years old and its wagons 35 years. Capital is also typically bulky and supplied in large discrete components. Just before investments are undertaken, demand typically exceeds capacity, and thus necessitates the additional investment, while in the period directly after an infrastructure investment supply typically exceeds demand.

The longevity and bulky nature of infrastructure investments mean that expectations of future demand for infrastructure is a more important determinant of infrastructure investments than current demand of infrastructure. If the future demand for a type of infrastructure is overestimated, the value provided by investments will be reduced and the capital invested could have been deployed more efficiently elsewhere in the economy. This outcome is referred to as carbon lock-in.

Carbon lock-in can occur in three ways. **Emissions lock-in** refers to the emissions implications of current and planned investments being largely irreversible for significant periods of time under normal circumstances. While opportunities for retrofitting do exist in some instances, the large technological and operational changes needed to significantly reduce greenhouse gas (GHG) emissions from infrastructure are usually only possible when capital stock is installed or replaced. Should conditions require it, however, the future emissions from current infrastructure can be avoided – but only at a high cost. Tough policy interventions are required to force infrastructure to be retired before the end of its useful life or to be only partially utilised. Infrastructure investments that do not consider the possibility of such future policy interventions run the risk of significantly reduced returns. The useful life of assets may turn out to be much shorter than envisaged due to regulatory fiat, or the assets may simply become uneconomical due to the implications of policy (i.e. the financial cost of having to pay for the right to emit GHGs). An investor or public agency may thus end up locked into owning an asset (or worse, a portfolio of assets) that is worth considerably less in the future than was expected. This constitutes **asset lock-in**, and assets of which the financial value has been significantly reduced as a result of unforeseen policy, regulatory or legislative changes are referred to as stranded assets.[1] Addressing the risk of asset lock-in thus effectively removes the need to focus on emissions lock-in.

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[1] For public infrastructure, the financial value of the asset can be seen as the cost of alternative infrastructure avoided. The financial value of road, for instance, can be measured as the value of an alternative road or railway line that does not need to be built.

A combination of economies of scale achieved in current infrastructure, and vested interests by stakeholders in developing, operating, financing and supplying the infrastructure, create strong incentives for maintaining the status quo. Users of existing infrastructure also often locate and organise themselves based on expectations that the current configuration will continue indefinitely. Additional forces that create inertia range from technical standards to the greater availability of financing for proven technologies, and even the existence of networks of private associations and educational institutions geared towards advancing existing technologies. When this combination of incentives and expectations becomes so entrenched that it delays the adoption of more efficient technologies, it is termed **institutional lock-in**. Institutional lock-in in the context of climate change thus doesn't refer to the impact of individual investments, but rather to an outcome where past investment decisions make it difficult to direct new investment into areas or technologies that would increase overall economic efficiency.

From an individual investor perspective, the main concern when considering carbon lock-in is avoiding asset lock-in and stranded assets. This risk of stranded assets increases as the useful lives of assets, payback periods and lead times of projects increase, the higher up the cost curve the technology employed sits, the more fluid the policy environment is, and the larger the GHG emissions associated with the project are. The factors that influence vulnerability to asset lock-in are highly project-specific and consequently generalisations are problematic. In order to reduce the risk of asset lock-in, it is critical that the issue is explicitly included in project assessments. Assessment frameworks should take a long-term perspective and consider the risk that climate change policies may render an investment stranded. Ideally a number of different climate change policy scenarios should be evaluated. A necessary (but not sufficient) component of such assessments is understanding the GHG emissions associated with the use of infrastructure over its lifetime. When investment decisions are made, the extent of exposure of the project to the cost of future policy decisions is not the only area of concern. The general cost-effectiveness of the technology employed is also important as the more efficient the technology is compared to its competitors (i.e. the further down the cost curve it is), the better able a project will be to cope with the shock of unanticipated policy-induced costs. Being more efficient than competitors also reduces the probability of infrastructure becoming stranded as a result of more direct regulatory interventions, like production or efficiency standards. On the policy front, a fluid climate change policy framework increases the possibility that carbon costs may affect project viability sooner and/or more severely than anticipated. To reduce the risk of policy uncertainty and stranded assets, it is paramount that infrastructure be developed in a way that is compatible with current climate change policies and strategies.

Unlike investors, policymakers are primarily concerned with the wider systematic impacts of institutional lock-in. Transport infrastructure investments that do not consider the impact on the wider transport network, for instance, can easily lock in high emissions transport systems which are resistant to change. Focussing on individual infrastructure investments (even when they are lowest-cost and efficiency enhancing) can mean that sight is lost of the overarching emissions reduction path of an economy. A focus on marginal efficiency improvements may mean that more significant trigger points to switch to new technologies or processes are missed. It is thus important to focus on the impact of investment decisions over an entire transition period. Absent this long-term perspective, the risk increases that infrastructure plans may not be consistent with the long-term mitigation objectives of an economy – potentially leading to stranded assets and/or missed mitigation targets. The compatibility of infrastructure investments with the economy's overall emissions reduction trajectory (not just in terms of emissions outcomes, but also whether certain types of investments will be possible in future, given current technology choices) is thus the factor that determines whether investments avoid institutional lock-in. The difference between the useful life and the payback period of infrastructure is also an important consideration in avoiding institutional lock-in. Once the initial capital investment has been recouped, only the operating/maintenance cost of the infrastructure is considered when new investment decisions are made. New infrastructure or technology, albeit more competitive on a levelised cost basis, may thus be uncompetitive against current infrastructure since the combined capital *and* operating costs of a new system need to be lower than the incumbent's operating cost only before a switch will occur. Given the need for coordination and adherence to existing planning frameworks to reduce institutional lock-in, it is worrying that local public corporations largely invest based on internal imperatives, rather than a broader set of strategic, integrated infrastructure development goals. Even with greater coordination, it is questionable whether the Peak, Plateau and Decline (PPD) trajectory currently provides sufficient detail to guide infrastructure investments that avoid institutional lock-in.[2]

Key to answering the question of whether infrastructure investments are locking in a high emissions path is good quality data sources on actual infrastructure spend. However, current sources of infrastructure investment data are not ideal for investigating the impact of infrastructure investment on GHG emissions patterns. They are too aggregated, and more granularity in the reporting of infrastructure spending (ideally splitting out individual technologies or sub-sectors) is required. Furthermore, the carbon intensity of infrastructure investments, used on its own, is a highly imperfect indicator of the risk of carbon lock-in. More important is understanding how individual infrastructure investments impact on the future efficiency of South Africa's total infrastructure network under different climate change policy scenarios, and how these different policy scenarios affect the relative competitiveness of different technologies and investment opportunities over time. It is thus difficult to assess carbon lock-in risks without a review of the individual project assessment criteria used to determine the attractiveness of projects, and a detailed comparison of current and planned infrastructure projects with the PPD trajectory assumptions.

Given the complexities of determining whether or not infrastructure investments are vulnerable to lock-in effects and the lack of detailed data on investment in South Africa, it is not possible to provide a definitive conclusion on the current risk to South Africa's infrastructure portfolio. That said, it would appear that most current major infrastructure projects come with relatively high GHG emissions, while for planned projects, the there is a sharp shift towards relatively low carbon projects.

Despite these improvements, the relatively short-term focus used to evaluate infrastructure projects (by placing undue emphasis on capital costs at the expense of other life cycle costs), and the lack of attention paid to the possibility of lock-in in project assessments (although it is about to start, the DBSA

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[2] The National Climate Change Response White Paper released in 2011 used the PPD trajectory as the basis of a National GHG Emissions Trajectory Range defined to 2050 to serve as a benchmark against which the efficacy of mitigation action will be measured.

does not yet evaluate GHG emissions as part of its standard project assessments – and neither does the Department of Public Works), raises the possibility that some infrastructure asset lock-in will occur. Similarly, the lack of coordination with respect to public infrastructure investment, and the lack of a sufficiently detailed local emissions trajectory to guide infrastructure spending, seems to indicate that institutional lock-in should be a serious concern.

In order to form a better understanding of the risk of carbon lock-in associated with current South African infrastructure spending patterns, detailed investigations of the project assessment processes and a comparison of current and planned infrastructure investments against the assumptions of the current National GHG Emissions Trajectory Range (currently presented as the PPD trajectory) for specific types of infrastructure, are recommended. Rather than viewing the National GHG Emissions Trajectory Range as an absolute cap on infrastructure emissions (since it is subject to change), however, it should be seen as signalling the expected future extent of climate change policy interventions.

1 INTRODUCTION

The link between infrastructure and growth is widely acknowledged. It is also commonly acknowledged that inadequate investment in infrastructure has led to a significant infrastructure backlog in South Africa. The South African government has shown that it is serious about addressing this backlog, with both the National Planning Commission (NPC) and the Presidential Infrastructure Coordinating Commission playing an active role in facilitating infrastructure delivery. A substantial expansion in infrastructure investment was also presented as one of the central themes of the 2012 Budget. In addition to increasing the amount of funds allocated towards infrastructure investment, there is a strong emphasis on increasing the quality of infrastructure investments. Taking these factors into account, Minister Gordhan has declared that "[n]o good project will be short of funding" (Gordhan, 2012:11).

One of the many factors that influences whether or not an infrastructure project can be considered 'good', is its impact on the carbon intensity of the economy.[3] This report aims to provide a high level answer to the question of whether South Africa's current infrastructure spending pattern is likely to lock the economy in to a high carbon development path. This would be inconsistent with the NPC's vision of a "competitive, resource-efficient and inclusive future", which in turn entails a significantly reduced dependency on carbon, natural resources and energy, increased levels of employment and reduced inequality (NPC, 2011:179).

This research is part of an ongoing programme run by Sustainable Energy Africa to assist the NPC in interrogating issues that may influence the development of a national development plan. The research programme aims to stimulate wider South African discourse around these issues in order to inform the country's transition to a low-carbon economy in general, and the NPC's long term plan in particular.

The report commences by defining what is meant by infrastructure, and then considers some of the main trends in infrastructure investment in South Africa. It then proceeds to explain the concept of carbon lock-in before assessing the risk of carbon lock-in in South Africa. A short conclusion follows.

2 DEFINING INFRASTRUCTURE

There are two general approaches to defining infrastructure, neither of which is entirely unambiguous. The first approach involves merely listing those economic units that fall under the definition used in a specific study, or for a specific purpose. For instance, in the South African Reserve Bank Quarterly Bulletin, economic infrastructure is defined as: "Roads, bridges, dams, electricity and water supply, etc." and social infrastructure as: "Schools, hospitals etc. and administrative services". This approach is relatively open-ended, as there is no clear indication of what is included and what is excluded from the "etc".

[3] The transition to a low carbon economy is only one of many government policy objectives. Then assessing the attractiveness of publicly funded infrastructure projects, the likely impact on other policy objectives like employment creation, reducing inequality etc would obviously also need to be considered.

In another example, the NPC (2011b:21), defines “a nation’s infrastructure” as:

> *“...a network of roads, rail, ports, information and communication technology (ICT) channels, energy, water and basic service systems – overlaid with social infrastructure assets such as schools, hospitals, and prisons...”*

The second approach to defining infrastructure, as used in Fourie (2006), begins by defining a set of characteristics commonly accepted as referring to infrastructure. Fourie (2006) favours characteristics provided in Hirschman (1958), where infrastructure is described as “capital that provides public service”. Infrastructure thus has two defining characteristics: it has a ‘capital’ element and a ‘public’ element (Fourie, 2006). The capital element indicates that infrastructure is a stock variable that provides services over a long time frame. Infrastructure investments typically have high initial fixed costs and also incur maintenance, replacement or upgrading costs over time. Capital is also typically bulky and supplied in large discrete components, making short term demand-supply mismatches common. Just before investments are undertaken, demand typically exceeds capacity, and thus necessitates the additional investment, while in the period directly after an infrastructure investment supply typically exceeds demand.

The public element of this definition is important in that it implies that infrastructure exhibits at least one of the characteristics associated with public goods, i.e. it is non-rival and/or non-excludable in consumption.[4] Infrastructure thus benefits the broad public rather than individual users. Transfers from the fiscus to Eskom and municipalities to fund solar geysers and energy efficiency lighting and technologies for individual households, would not be counted as infrastructure in terms of this definition. From a practical and policy perspective, this exclusion is clearly debatable.[5]

Irrespective of the approach used to define infrastructure, a distinction is usually made between economic and social infrastructure. Economic infrastructure “promotes economic activity” by providing access to inputs, logistical services, and access to technology (Fourie, 2006: 532; National Treasury, 2012),[6] whereas social infrastructure “improves the health, education and mobility” of people (National Treasury, 2012:6).

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[4] Non-excludability indicates that a consumer cannot be excluded from using a good in the absence of payment, while non-rivalry indicates that a good can be used by additional users without reducing the benefit received by the original users. For example, a public lighthouse displays both characteristics – a very large number of people can use it simultaneously without affecting the quality of each other’s benefits, and the lighthouse must be visible to the public to function – so no one can be excluded from seeing/using it.

[5] Since the eventual ‘private’ investments impact on the demand for ‘public’ infrastructure (solar geysers and energy efficiency investments, for instance, reduce the amount of electricity that needs to be delivered by the ‘public’ electricity grid) there may be a case for arguing for a broader definition of infrastructure based on a specific context. Using a broader definition in general, however, is a challenge because defining exactly where ‘private’ investment stops and ‘public’ infrastructure begins is problematic.

[6] Using the ‘list’ definition, economic infrastructure includes categories like railroads, airports, sea ports, roads, highways, electricity, telecommunications, water supply and sanitation (Fourie, 2006).

An important characteristic of infrastructure, as already mentioned, is its longevity. While infrastructure investments have benefits in the short term (i.e. stimulating economic activity and employment during the construction phase), the National Treasury (2012:101) notes that

> *"the real value of [infrastructure] projects ... is in the economic and social development they enable over the long term – including lower business costs, improved access to markets and increased productivity".*

Projects therefore need to be carefully assessed and designed to ensure that they deliver "lasting value for the country". Put slightly differently, the challenge when investing in infrastructure is to choose "the most cost-effective projects that provide optimal long-term benefits" (National Treasury, 2012:91).

3 INFRASTRUCTURE IN SOUTH AFRICA

This section provides an overview of the infrastructure data sources available locally, and then proceeds to describe infrastructure investment trends in South Africa. A more detailed account of the information available from the different data sources is provided in Appendix 1.

3.1 Data sources

Surprisingly, given the current emphasis placed on infrastructure as a driver of growth, disaggregated data on infrastructure investment is relatively scarce. The South African Reserve Bank (SARB) has the most complete data on overall investment trends, but the high level of aggregation used complicates analysis. Statistics South Africa (Stats SA) used to provide detailed infrastructure data, but Perkins (2012) mentions that many of the main infrastructure data series were discontinued in the 1980s. Stats SA does still publish some useful information on capital expenditure in the public sector, but once again, aggregation is a problem. There are additional private sector data sources on investment and infrastructure (like Quantec and Industry Insight), but because this data is proprietary, it was not included in the analysis that follows. The data available from Industry Insight is described in more detail in the data appendix. For the purpose of this paper, the most useful data on current and future infrastructure investment was obtained from the 2012 Budget Review.

3.1.1 South African Reserve Bank

The SARB Gross Fixed Capital Formation (GFCF)[7] time-series classifies investment according to economic activity, such as "transport, storage and communication", "electricity, gas and water", etc. The SARB also divides gross fixed capital expenditure according to the type of organisation that is spending the money, namely general government, public corporations or private sector business. It is then further divided into economic infrastructure, social infrastructure and economic services. At this high level of aggregation, this data cannot be used to provide meaningful insights into the carbon profile of South Africa's investment spend.

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[7] GFCF is defined as "acquisition less disposals of produced fixed assets, i.e. assets intended for use in the production of other goods and services for a period of more than a year" (OECD, 2010:1) .See Appendix 1 for a more detailed definition.

3.1.2 Statistics South Africa

Statistics South Africa produces a wide range of data publications that are released either quarterly or annually that are applicable to this study. Most relevant are the *Capital Expenditure by the public sector* and *Annual Financial Statistics* publications. Again, however, the high level of aggregation of data is a challenge. Conversely, some large sample surveys conducted by StatsSA for individual sectors do contain useful disaggregated information on investment, but in these cases, it is not possible to split out infrastructure from general investment. Moreover, these large sample surveys are compiled infrequently, only providing a snapshot of each industry.

3.1.3 National Treasury

The South African National Treasury supplies detailed information on public expenditure in the Budget Review and other more detailed documents that accompany the budget speech every year. Splitting out specific types of infrastructure investment from the budgets of departments and agencies is however challenging (see Appendix 1). The Budget Review 2012 (National Treasury, 2012) does provide a list of the most significant infrastructure projects that are being undertaken and planned. This information is very useful from a carbon lock-in perspective.

3.1.4 SAFCEC, Industry Insight and the Construction Industry Development Board

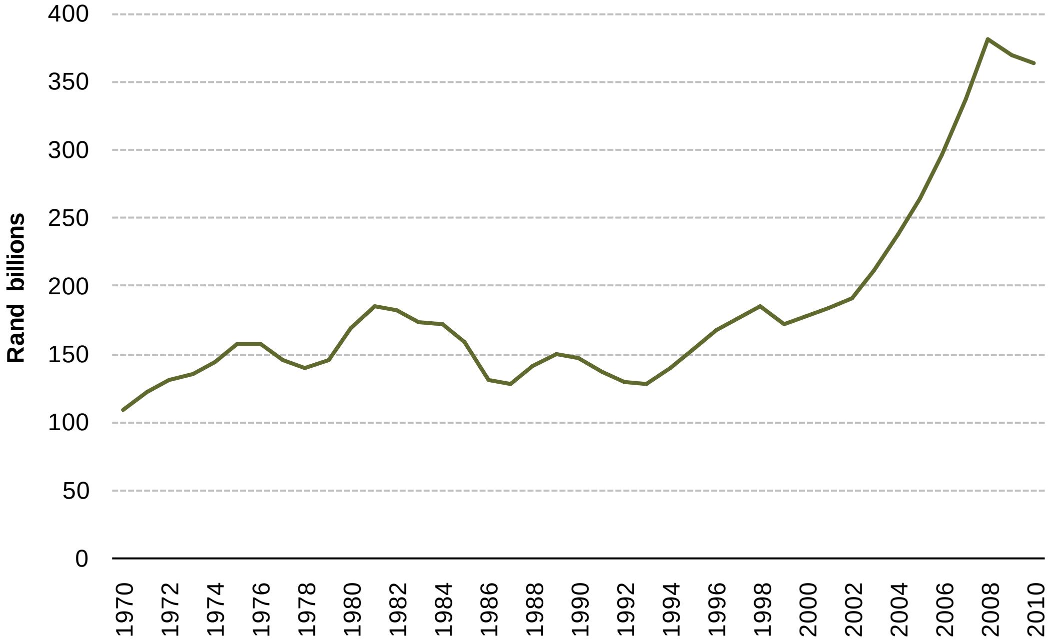
The South African Federation of Civil Engineering Contractors (SAFCEC) represents the private civil engineering contractors in South Africa. SAFCEC gathers information on behalf of the industry and publishes a status of the industry report to support decision-making. In addition to general macroeconomic indicators obtained from official sources, SAFCEC also has a database of projects that are out to tender or contracted. Since 2011, however, it seems that many of SAFCEC's data functions have been outsourced to a private industry data provider, Industry Insight. Industry Insight is now the custodian of the project database and this data is not available to the general public and this study.

The Construction Industry Development Board or CIDB was founded in 2000 to support sustainable construction development and growth. It maintains a register of contractors and a register of projects. According to an industry expert, however, the register of projects is still in the development phase and is relatively incomplete.

3.2 Trends

Investment in infrastructure in South Africa peaked in 1981, and then languished for two decades. Only in 2002 did the country manage to surpass the real level of annual investment experienced in 1981. This pattern of investment indicates that South Africa "effectively missed a generation of infrastructure modernisation" (NPC 2011a:16). Even after a decade of accelerating infrastructure investment, South Africa still faces an infrastructure backlog that is now acting as a major constraint on economic growth (DBSA, 2011; NPC, 2011a).

Figure 1 Gross fixed capital formation (constant 2005 prices)

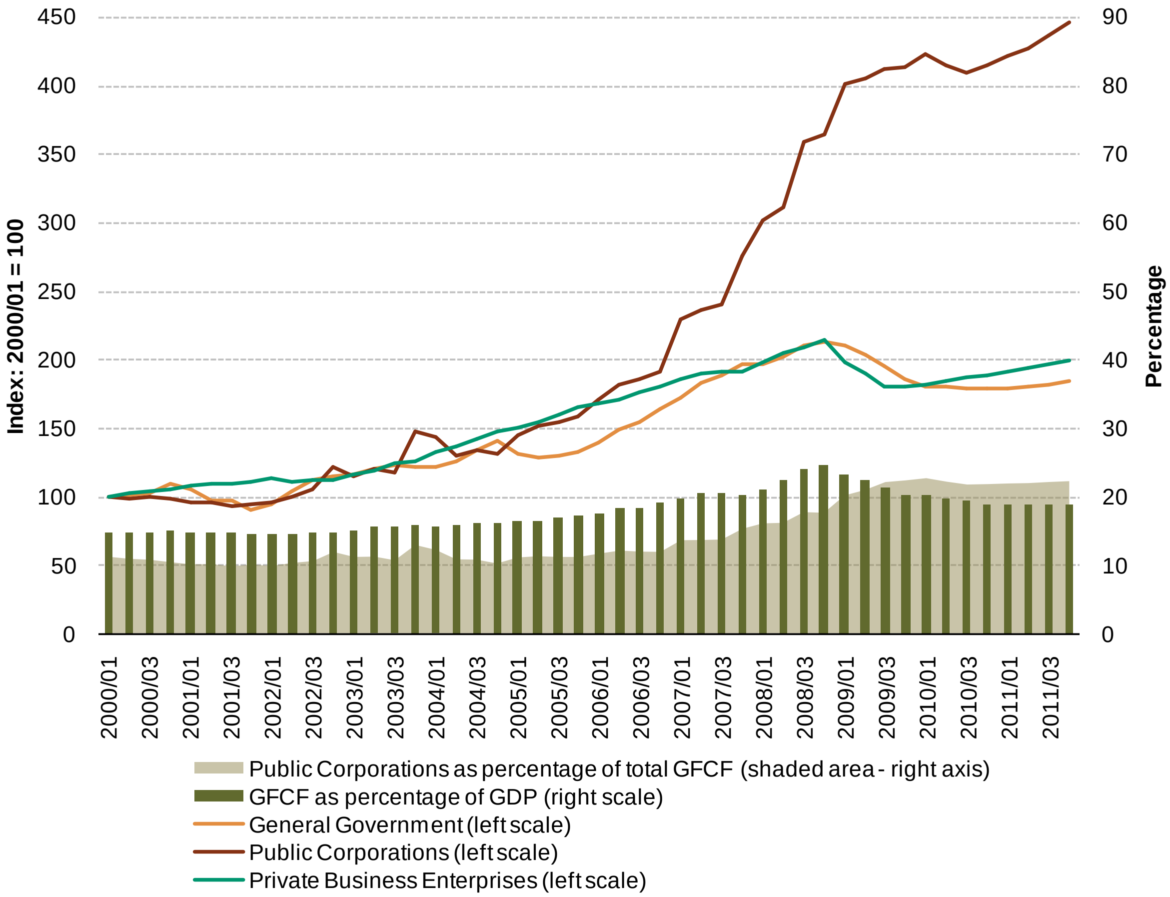


Source: SARB (2012)

From 2000 onwards, gross fixed capital formation increased dramatically, doubling in a period of 8 years. In the wake of the global financial crisis of 2008 investment levels dropped somewhat, but as a result of the FIFA 2010 World Cup and the related infrastructure projects, remained at a high level.

The figure below shows gross fixed capital formation by the main participants in the economy, and shows that South Africa's infrastructure investment drive has been spearheaded by the public sector, and public corporations in particular. Whereas the spending patterns of general government and private business have remained relatively stable since 2000, investment by public corporations has risen sharply, and this largely explains the recent rise in overall capital formation. Over the period 2000-2011 the percentage of total investment in the South African economy originating from public corporations increased from 11.2% to 22.3%, whereas the contribution of the private sector declined from 71.9% to 63.9%.

Figure 2 Trends in gross fixed capital formation, 2000-2011 (seasonally adjusted 2005 prices)



Source: DNA Economics based on SARB (2012)

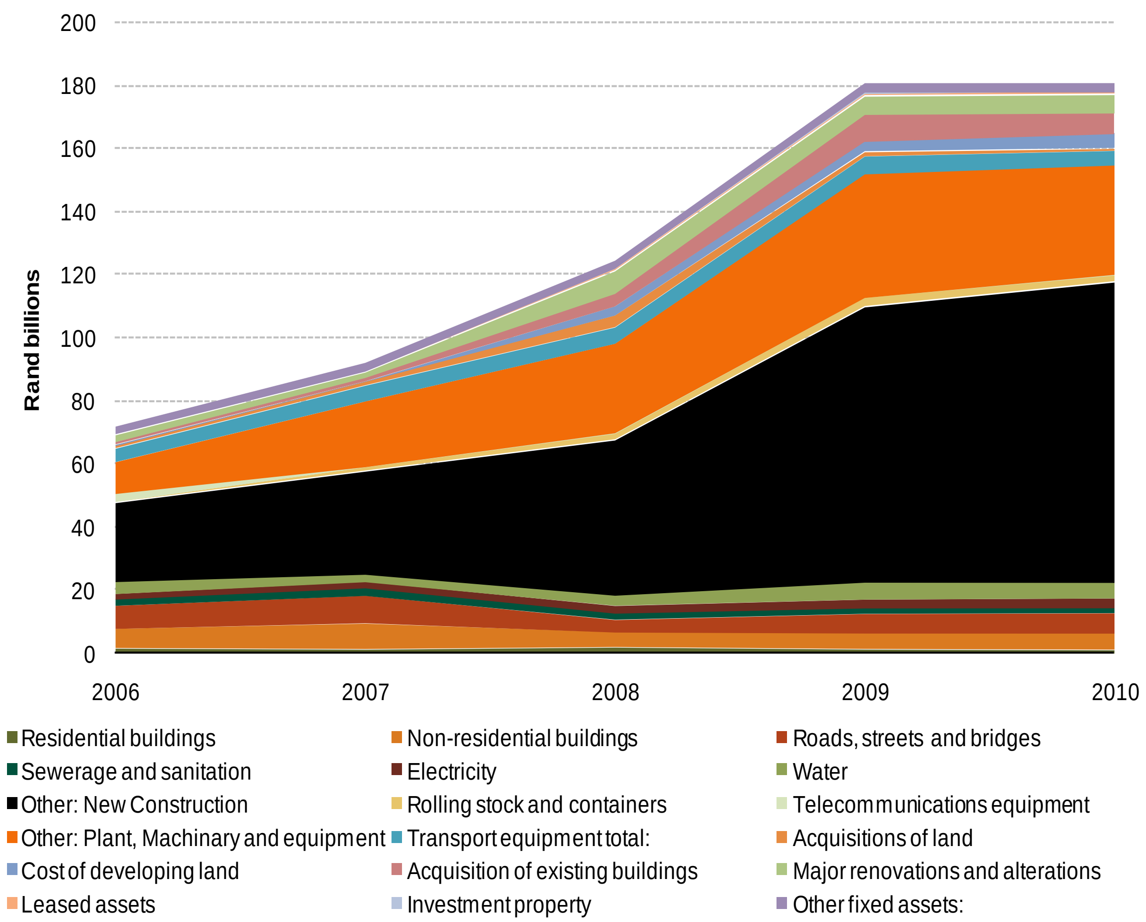
Given the critical role played by public corporations in facilitating investment in the South African economy, it is important to critique the efficiency of these organisations. In recent times, many of South Africa's state-owned enterprises have undergone messy leadership transitions, and their investment strategies have largely been driven by internal imperatives rather than a broader set of strategic, integrated infrastructure development goals (DBSA Development report, 2011). Price escalations and delays in the construction of Medupi and Kusile, for instance, have raised questions as to whether Eskom is able to implement new build projects at least cost.

Figure 3 shows capital expenditure by the public sector, as per Stats SA, for the period 2006 to 2010.[8] Unfortunately, however, the largest shares of the graph constitute investment in "other" sub-sections (the bright orange and black areas). The classification of this data is thus not ideal for analysis of the

[8] Public sector is defined as: Higher Education Intuitions, Municipalities, National Government, Provincial Government and Public Corporations.

potential carbon lock-in of infrastructure investments. This graph does however confirm the dramatic increase in public expenditure from 2006 to 2009.

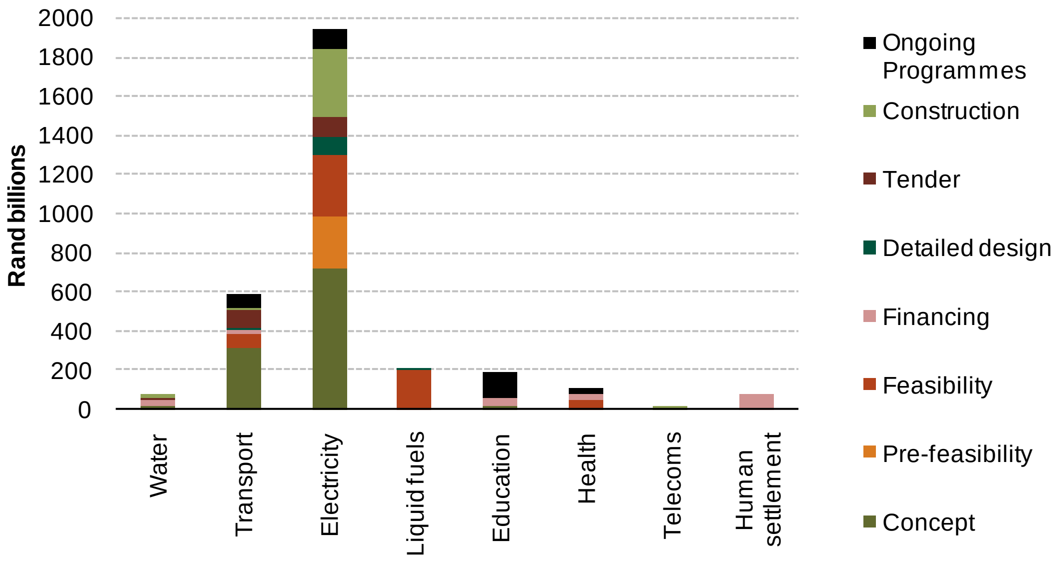
Figure 3 Public sector capital expenditure 2006-2010 (Nominal Values)



Source: Stats SA (2012)

The distribution of ‘mega’ projects by sector and according to their stage of development, as reported in the 2012 Budget Review, is provided below. The bulk of these mega projects will take place in the electricity sector. How this links (or not) to the idea of carbon lock-in will be addressed later in the document.

Figure 4 Mega-projects under consideration, 2012 – 2020



Source: National Treasury (2012)

4 DEFINING CARBON LOCK-IN

The concept of carbon lock-in refers to the possibility that if climate change considerations are not considered when making long-term infrastructure investment decisions, the decisions may lead to suboptimal investment outcomes.[9] There are three ways to conceptualise carbon lock-in: institutional lock-in, emissions lock-in and asset lock-in. As will become clear below, the second definition is really a subset of the third. As such only institutional and asset lock-in will be considered in the remainder of the document.

4.1 Institutional lock-in

Unruh (2000; 2002) explains how systemic forces could sustain a reliance on fossil fuel-based infrastructure even after the emergence of more environmentally friendly and cost-effective alternatives. A combination of economies of scale achieved in current infrastructure, and vested interests by stakeholders in developing, operating, financing and supplying the infrastructure, create strong incentives for maintaining the status quo. What's more, the users of the infrastructure often also organise themselves to derive the maximum benefit from existing infrastructure, based on expectations that the current infrastructure configuration will continue into the future. This combination of wide-spread incentives and expectations, which reinforces the status quo, can be termed

[9] Suboptimal outcomes in this context refer to the possibility that after the fact it may become clear that capital could have been more efficiently deployed elsewhere in the economy for the reasons elaborated on in the remainder of this section. There are a number reasons why investments may turn out to have been suboptimal in hindsight, but the focus in this report is on a failure to adequately considering the need to reduce GHG emissions to avoid the effects of anthropogenic climate change (and the policies employed to reduce emissions) potentially being the main factor for projects that lead to significant GHG emissions.

technology lock-in (Markusson and Haszeldine, 2010). Examples of factors that contribute to technology lock-in range from technical standards to the greater availability of financing for proven technologies and even networks of private associations and educational institutions (Unruh, 2000).

Technology lock-in in itself is not a problem, and is often an important step in the adoption of new and useful technologies (Markusson and Haszeldine, 2010; Unruh, 2000, 2002). When technology lock-in becomes so entrenched that it delays the adoption of more efficient technologies throughout society, it is termed **institutional lock-in** (Markusson and Haszeldine, 2010; Unruh, 2000, 2002). In the context of climate change policy, institutional lock-in does not refer to the impact of individual investments, but rather to a state where path-dependence makes it difficult to direct investment to new, more carbon-efficient classes of infrastructure that would increase the overall efficiency of the economy.

The NPC (2011) National Development Plan refers to the risk that current investments may lock South Africa into a development pathway that reduces its flexibility and competiveness in adapting to a carbon-constrained world. The NPC (2011) highlights the fact that institutional lock-in will not necessarily emerge if vested interests block investment into more carbon-efficient technologies. The new technologies also need to be more efficient overall, given a certain state of the world[10], before institutional lock-in can be said to occur.

4.2 Emissions lock-in

A second way of looking at carbon lock-in is to define it in terms of the future GHG emissions that will be emitted as a result of infrastructure that is already in place (or being put in place). This is the approach followed in the *World Energy Outlook 2011.* It points out that emissions from infrastructure that is currently in place or under construction already accounts for 80% of the energy-related emissions that will lead average global temperatures to increase by two degrees Celsius by 2035 (IEA, 2011). The reason that **emissions lock-in** occurs is that while opportunities for retrofitting may exist in some instances, large changes in technology that will lead to significant reductions in emissions are usually only possible when capital stock is installed or replaced (Barker et al, 2007). Emissions lock-in therefore focuses only on the emissions implications of current and planned investments, given currently available information, and takes these emissions as given (i.e. locked in).

4.3 Asset lock-in

Whereas the environmental risks associated with emissions lock-in might be significant, they do not provide a complete picture of the risks associated with infrastructure investment. Future emissions from current infrastructure can be avoided, but only at a very high cost (IEA, 2011). Tough policy interventions can force infrastructure to be retired before the end of its useful life, to only utilise a proportion of its total capacity, or to undergo costly refurbishments and retrofits (although, as mentioned above, there is usually a limit to what can be achieved through refurbishments and retrofits). Infrastructure investments that do not take into consideration the possible impact of future

[10] In this case a world where carbon space is a scarce and therefore costly resource.

policy interventions thus run the risk of reducing the actual useful life of an asset (and thus its expected return over its life) to well below that which was expected when the investment decision was made.

The shortened life of the asset could be due to regulatory fiat or the asset simply becoming uneconomical due to carbon pricing.[11] An investor, public agency etc may thus end up being locked into owning an asset (or worse, a portfolio of assets) that is worth considerably less in the future than was expected when the investment decision was made. This can be referred to as **asset lock-in**. Assets of which the financial value has been significantly reduced as a result of unforeseen policy, regulatory or legislative changes are referred to as stranded assets (Crew and Kleindorfer, 1999).[12] The risk of stranded assets as a result of investments made without sufficient foresight is acknowledged in the NPC (2011:185) development plan, which states that "[m]oney invested in the current economic structure runs the risk of being a sunken cost *if spending is not aligned with the country's future goals* [emphasis added]".[13]

Asset lock-in is usually interpreted from the perspective of the individual investor trying to avoid investing in assets which will eventually become stranded (Markusson and Haszeldine, 2010). Apart from leading to a misallocation of capital, which affects overall economic efficiency (and is of particular concern in South Africa, which is not only savings-constrained but is also embarking on an accelerated infrastructure investment drive while faced with a number of competing immediate spending priorities), asset lock-in can have more direct economy-wide impacts. For example, while investments in coal-fired power plants in South Africa may be the most cost effective strategy in the short-term, Bazilian et al (2011) assert that the possible cost of stranded assets in the energy sector economy[14] may be eclipsed by the cost of stranded assets within the rest of the economy. The potential magnitude of this cost has become clearer since local electricity prices have risen sharply in the wake of the 2007-2008 electricity supply crisis. The viability of a number of local industries (like the aluminium industry, for instance) has been questioned when faced with permanently higher electricity prices. The longer energy prices remain below their expected total future average real costs (including the impact of policy measures to mitigate climate change), the higher the risk that new investments may be made that will become stranded.

Financial assets (like contracts or shares) can also become stranded (Crew and Kleindorfer, 1999).This creates another channel whereby stranded assets in one industry could affect the rest of

[11] This may be due to, for instance, the cost of operating the infrastructure exceeding revenues or benefits generated, or demand falling below sustainable levels as consumer preferences switch to assets delivering services at a lower total cost.

[12] For public infrastructure, the financial value of the asset can be seen as the cost of alternative infrastructure avoided. The financial value of road, for instance, can be measured as the value of an alternative road or railway line that does not need to be built.

[13] While more commonly associated with more stringent mitigation policies, asset lock-in can also occur when mitigation policies are reversed or become less beneficial to certain types of investment. If unforeseen, a reduction in subsidies for renewable energy like those recently experienced in Germany, for instance, could lead to investments in renewable energy manufacturing capacity or firms becoming stranded (Nielsen, 2012).

[14] Energy-intensive industries that invest in additional capacity on the basis of electricity prices expectations that turn out to be lower than actual future electricity prices (possibly as a result of climate change policies are) are vulnerable to ending up with stranded assets.

the economy. This issue was highlighted by an open letter sent to the Governor of the Bank of England recently, highlighting the possibility that systemic risk may result from the large exposure of investors to sectors that are disproportionately vulnerable to asset-lock in should the world transition to a low carbon economy.[15]

5 ASSESSING CARBON LOCK-IN RISK

5.1 Theoretical considerations

When assessing the risk of carbon lock-in in infrastructure investment, the emphasis should be on public investment in infrastructure. This is true both from a theoretical and practical perspective. The 'public' element of the definition of infrastructure provided in Section 2 means that the majority of private investment in what is commonly referred to as infrastructure, irrespective of its other characteristics, should not be viewed as 'infrastructure'.[16] Furthermore, as shown in Section 3.2, public corporations are playing an increasingly important role in driving investment in South Africa, and the bulk of 'public' infrastructure is likely to be created by public corporations.

The risk of carbon lock-in derives from the bulky and long-lived nature of infrastructure. The table below, taken from the Fourth Assessment Report from the Intergovernmental Panel on Climate Change (IPCC), highlights the longevity of capital stock associated with selected GHG-emitting activities.

Table 1 Estimated lifetimes of major GHG-related capital stock

Typical lifetime of capital stock			Structures with influence > 100 years
Less than 30 years	30-60 years	60-100 years	
Domestic appliances	Agriculture	Glass manufacturing	Roads
Water heating and HVAC systems	Mining	Cement manufacturing	Urban infrastructure
Lighting	Construction	Steel manufacturing	Some buildings
Vehicles	Food	Metals-based durables	
	Paper		
	Bulk chemicals		
	Primary aluminium		
	Other manufacturing		

Source: Barker et al (2007a)

[15] The letter is available at: http://www.climatechangecapital.com/media/256968/letter%20to%20bank%20of%20england%20financial%20policy%20committee%20-%2019th%20january%202012%20-%20final.pdf and the Bank of England's response, which outlines the conditions that would need to be in place for there to potentially be a threat to financial stability, at: http://www.climatechangecapital.com/media/257552/fpc%20bank%20of%20england%20response.pdf. It should be noted, however, that at present the Bank of England is not convinced that these conditions are met.

[16] See Footnote 5.

Some infrastructure, which might not itself be in place for long, can still have very long term systemic impacts. For example, the design life-span of road infrastructure in South Africa is 20 years (SAICE, 2011). But the positioning of new roads can have longer-term impacts through their influence on spatial development patterns (see Section 5.3). Moreover, the expected useful life of infrastructure is not always fixed. Locomotives, for example, have an average life span of 16 years and wagons 20-25 years internationally (SAICE, 2011). But the actual operational lives of these assets can be even longer. Transnet's locomotives are on average 30 years old and its wagons 35 years (SAICE, 2011).

Because of the long-lived nature of infrastructure, expectations of the future demand for and value of infrastructure are therefore more important determinants of infrastructure investment than the current demand for (or usefulness of) infrastructure. If these expectations turn out to be wrong, the ongoing feasibility of such projects might be jeopardised. Eskom, for example, is working on a design lifespan of 50 years for its Medupi power-station (Eskom, 2011). Bazilian et al (2011) point out that if the initial investment in Medupi has to be recouped in 10 years rather than 20 years, the annual benefits derived from it would have to be almost four times larger to justify the investment.

If the operational life of an asset is reduced to the point where the net present value falls below a set cut-off level (calculated when the investment decision was made), or the asset is retired before the end of its payback period[17], the investment would be deemed to have been suboptimal and the capital invested could have been deployed more efficiently elsewhere in the economy.[18] However, because of the discounting of the revenue or benefits generated by an asset, the impact of shortening the useful life of an asset becomes less critical the further out in the future it happens. Depending on the discount rate used, there is thus a point in time beyond which future revenues or benefits have a negligible impact on the net present value of an asset[19] – and thus do not significantly impact the investment decision.[20]

Long lead times also increase the risk of assets being stranded. A coal-fired power station typically takes eight years to build (Eskom, 2011), which means that construction needs to start long before the power station is actually needed. There is a risk that policy or consumer preferences may change even before the power station is operational. For example, consumer boycotts, public protests or litigation may affect the viability of projects even if they have been shown to be optimal by a least-cost resource planning process (Bazilian et al, 2011).

Furthermore, the inherent uncertainty that comes with long investment horizons can be exacerbated by project- and context-specific factors. When investment decisions are made, the extent of exposure of the project to the cost of future policy decisions (i.e. around GHG emissions) is not the only area of

[17] Factors like the opportunity cost of capital and risk considerations often result in the payback period for investments being expected to be significantly shorter than the useful life of assets.
[18] In the case of energy investments, for instance, the more efficient use of the capital may have been an investment in a more carbon-efficient technology.
[19] While there are other metrics that can be used to evaluate the attractiveness of investments (like the internal rate of return, for instance) they are not addressed in the interest of brevity.
[20] The location of this point is influenced by the discount rate used. The higher the discount rate, the earlier this point will be reached.

concern. The general cost-effectiveness of the technology to be employed is also important, as the more efficient the technology is compared to its competitors (i.e. the further down the cost curve it is), the better able a project will be to cope with the shock of unanticipated carbon costs.[21] This is because the success of a project will continue to depend on its overall cost effectiveness, and not just its carbon efficiency (although that obviously will play an increasingly important role as carbon costs increase). Being more efficient than competitors also reduces the chance that infrastructure could become stranded as a result of more direct regulatory interventions, like the imposition of production or efficiency standards.[22]

On the policy front, a fluid climate change policy framework increases the possibility that carbon costs may affect project viability sooner and/or more severely than has been anticipated.[23] In order to reduce the risk of policy uncertainty and stranded assets, it is paramount that infrastructure be developed in a way that is compatible with current climate change policies and strategies. This should provide additional protection against direct regulatory interventions.

5.2 Avoiding Asset Lock-in

From an individual investor's perspective, the main risk arising from carbon lock-in is the prospect of being left with stranded assets. This risk increases as the useful lives of assets, payback periods and lead times of projects increase; the higher up the cost curve the technology employed sits; the more fluid the policy environment is; and the larger the GHG emissions associated with the project are.[24] Because the factors that influence the vulnerability of individual projects to asset lock-in are highly project-specific, it is difficult to provide general guidance.

This can be illustrated by looking at the examples of Medupi and Kusile. Medupi is closer to completion, so in theory there should be less risk of it becoming a stranded asset in the face of tighter

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[21] There is always an option value to waiting for better information and more efficient technologies before investing. But there is a limit to how long investment decisions can be delayed given the demand for the services provided by infrastructure. A choice thus needs to be made based on the best current available information when investments become necessary.

[22] In China, for instance, regulatory measures were recently deployed to close down more than 2000 outdated and energy intensive factories in 18 sectors (Global Times, 2010). While this may seem extreme, it cannot be discounted even in a democratic country like South Africa.

[23] The National Climate Change Response White Paper (DEA, 2011) sets ambitious time lines for the implementation of policies like carbon budgeting. It is, however, a high-level policy document and uncertainty still exists around the implementation of climate change policies (i.e. design, severity and timing of policies). A carbon tax is also now on the cards for the 2013/2014 budget year, but the design and level still needs to be finalised (National Treasury, 2012). Local policies will also be influenced by the negotiations under the United Nations Framework Convention on Climate Change (UNFCCC). Under the Durban Platform a legally binding international agreement in climate change is to be agreed by 2015 and put in place by 2020 (UNFCCC, 2011).

[24] GHG emissions need not be directly caused by the infrastructure to lead to stranded assets. Policies aimed at reducing transport emissions may discourage the use of a toll road, thereby affecting traffic flows and revenues. Infrastructure also doesn't have to generate revenue to be vulnerable to becoming a stranded asset. A national road that is not utilised to its full potential can be viewed a stranded asset. The present value of the future benefits (rather than the future revenue streams in the case of the toll road example) could thus be reduced by policy interventions. There is after all an opportunity cost to having capital tied up in an underperforming asset, never mind the criteria that is used to measure performance.

climate change policies. Kusile, however, is carbon capture and storage-ready (and can thus potentially utilise carbon capture and storage technology in future), whereas Medupi is not (Eskom, 2011; National Treasury, 2010).[25] Both of them are more efficient than existing coal-fired power plants in South Africa. So if policy does reduce the attractiveness of coal-fired electricity generation in South Africa (as by all current indications it will), existing and less efficient coal-fired power plants will be decommissioned before Medupi and Kusile (Eberhard quoted in Terblanche, 2011).[26] Medupi is likely to be decommissioned before Kusile, but Kusile faces a longer lead time before it is operational, which increases the risk that it may never be completed. Both plants are seemingly included in the Department of Environmental Affairs' updated Peak, Plateau and Decline (PPD) trajectory (DEA, 2011a), and are thus consistent with current official mitigation plans.[27] In theory, they should therefore have some protection from direct regulatory action for an extended period of time. While both are coal-fired power stations, it is clear that the likelihood of either one of these stations becoming a stranded asset differs and depends on the policy context as well as the timing and technology of their individual build programmes.

To reduce the risk of asset lock-in, it is therefore critical to ensure that the issues mentioned above are thoroughly dealt with during the project assessment phase. The assessment framework should take a long-term perspective and explicitly address the risk that climate change policies may render an investment stranded. Ideally, a number of different climate change policy scenarios should be evaluated. To do so, it is clearly necessary (but not sufficient) to obtain a clear understanding of the GHG emissions associated with the use of this infrastructure over its life time.

In South Africa, there is little evidence that Government considers the risks of carbon lock-in, or broader sustainability issues, when making infrastructure investment decisions. The IRC (2010:10) argues that infrastructure provision in South Africa is often provided on a "flawed basis," and may not be geared towards providing sustainable infrastructure. The overall life-cycle cost of providing infrastructure is generally neglected.[28] In support of this view, DPW (2012) notes that a focus on capital costs only by client departments and agencies means that the Department of Public Works is often not able to include the optimal level of energy efficiency in the design of new construction projects. It is therefore not surprise that the Department of Public Works, while trying to incentivise energy efficiency, does not currently calculate the lifecycle GHG emissions profile of new buildings

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[25] How useful this will be in reducing the risk of Kusile becoming a stranded asset depends on the effective commercialisation of carbon capture and storage technology – by no means a certainty (Bazilian et al, 2011).

[26] While Medupi and Kusile are expected to be the last coal-fired power plants operating (of the current stock), it is not clear how the efficiency of recommissioned plants like Camden, Grootvlei and Kommati compares to the rest of the fleet. Given the smaller investment in recommissioning plants, however, the projects are expected to have much shorter payback periods than new-build projects.

[27] The National Climate Change Response White Paper released in 2011 used the PPD trajectory as the basis of a "National GHG Emissions Trajectory Range" defined to 2050, to serve as a "benchmark against which the efficacy of mitigation action will be measured" (DEA, 2011a:27).

[28] Life-cycle costs include not only capital, but also operating and maintenance expenditure requirements over the useful life of projects (IRC, 2011). Climate change policy can affect the life-cycle cost of a project by adding (or increasing beyond expectation) the cost of GHG emissions. Since capital expenditures are usually fully depreciated long before the end of the useful life of a project, the other life-cycle cost components typically determine at what stage infrastructure is retired or replaced.

(DPW, 2012). Similarly, the Development Bank of Southern Africa, which is at the forefront of South Africa's infrastructure investment drive, does not assess the GHG emissions impact (or the possibility of carbon lock-in) as part of its standard project assessment process (see Box 1). This casts doubt about the effectiveness of public sector project assessment processes in determining the vulnerability of infrastructure projects to asset lock-in.[29]

Box 1: Carbon lock-in and the DBSA[30]

The Development Bank of Southern Africa (DBSA) is trying to balance its traditional long-term infrastructure programmes that may be subject to carbon lock-in (such as a R15 billion credit line to Eskom) with a new approach to greener infrastructure. Key initiatives include advisory and policy work on the Renewable IPP Programme, the roll-out of Solar Water Heaters and the issue of Green Infrastructure, co-hosting a Knowledge Week with DEA on Green Infrastructure and co-authoring two initiatives on Green Programmes and Green Jobs.

DBSA's environmental assessment now requires the assessment of the impact of carbon emissions and the institution has recently improved its monitoring and evaluation function to consider the emission potential of projects. Moreover, as part of its triple-bottom-line reporting requirements, the DBSA has set in motion a process to collect relevant data on sustainability for publication with its annual reports.

The DBSA intends greening its project portfolio. Current environmental appraisal procedures (EAP) geared towards compliance with environmental legislation have been recently reviewed (DBSA, 2011c) to include:

- climate resilience/assessment of vulnerability to physical impacts of climate change
- desktop greenhouse gas (GHG) categorisation of projects, and carbon footprint assessments

The carbon footprint assessments will initially be applied to selected projects on a pilot basis. If successful, they will be rolled out across all projects. In the long term it is hoped that the EAP will include a full sustainable development analysis (including ecological and water foot printing) which could be used to grade projects and offer more environmentally sustainable projects preferential lending terms. The DBSA is currently working with the CSIR to try and develop a methodology for assessing whether a project utilises best-practice technology.

In terms of investments, earlier investments in wind (Darling Wind Farm) and hydro energy (Bethlehem Hydro) are soon to be joined by substantial investments in renewable energy as part of the Renewable Energy IPP Procurement Programme. In addition DBSA is assisting the Department of Environmental Affairs to identify a number of programmes to support South Africa's transition to a green economy, including the hosting of a Green Fund that will support initiatives that promote the transition to a green economy, and may play an important role in

Box continues on next page...

[29] Expanding standard sensitivity analysis processes to include the effect of a range of carbon price levels over the useful life of an investment both directly and indirectly (through the impact on demand for services provided by infrastructure) on the economic feasibility of projects should, at least initially, provide a good indication of the level of carbon lock-in risk. In order to implement this methodology, however, a clear understanding of the emissions impact of prospective projects is required.

[30] In addition to cited references, this section also draws on DBSA (2012) and comments provided by DBSA representatives at an NPC workshop dealing with carbon lock-in. The views represented in this section are solely that of the project team.

Box 1 continued...

facilitating the 43 major infrastructure projects listed in the 2012 Budget Review (together constituting an investment of R3.2 trillion) by raising finance (DBSA, 2011a; Gordhan, 2012).[31]

In 2010 it established an Environmental Finance Unit within its Investment Banking Division (DBSA, 2011b). One of the functions of the Unit is to "further 'carbon proof'" the DBSA's infrastructure projects (DBSA, 2011b:49).

Given this background, and the issues raised in this report, one would expect the DBSA to be far ahead of other financial institutions in assessing the risk of carbon lock-in. However, at present a broad assessment of the carbon lock-in risk to which the DBSA is exposed, based on the categories of projects it invests in, is not feasible.

DBSA's accounting and management systems only include aggregated project category markers, and since it often provides debt funding to other entities (such as municipalities), it does not have full control and information related to the projects in which these entities invest. While it may be possible to see how much the DBSA has invested in local government (and often in broad areas like energy or transport for instance), it is not possible to get a breakdown of the specific types of projects included in these portfolios. As a result, the DBSA is not able to provide a reliable estimate of the overall GHG emissions footprint of its investment portfolio and a methodology for assessing the potential impact of carbon lock-in on project is not yet in place.

5.3 Avoiding institutional lock-in[32]

Institutional lock-in has a wider systemic impact than asset lock-in (although asset lock-in can also have systemic impacts, as mentioned earlier). Anas and Timilsa (2009), for instance, show that investment in transport infrastructure on the periphery of cities leads to patterns of land use and location choices that make it difficult to create public transport systems that connect the city centre to surrounding areas.

Decisions on specific transport infrastructure investments that do not incorporate an assessment of the impact of this investment on the wider transport network can easily lock a city or region in to a high emissions transport systems which is resistant to change. Neuhoff et al (2009) highlight the fact that focussing on individual infrastructure investments (even when they are lowest-cost and efficiency enhancing) can distract from the overarching emissions reduction path of an economy. Similarly, a focus on marginal efficiency improvements, (i.e. increasing the efficiency of coal-fired power stations in small increments), may mean that more significant trigger points to switch to new technologies or processes are missed (Neuhoff et al, 2009). It is therefore important essential that Government adopts a broad perspective to infrastructure planning and considers the long-term impact of its investment decisions. Attention should be given to ensuring that new infrastructure is consistent with the long-term mitigation objectives of the economy – thereby reducing the risks associated with stranded assets and/or missed mitigation targets.

[31] A green economy was broadly defined in terms of programmes that link environmental imperatives with economic growth (DBSA, 2011a).

[32] The focus is on avoiding physical investments that strengthen institutional lock-in, rather than on the behavioural and other remedies that are necessary to overcome institutional lock-in.

The compatibility of infrastructure investments with the economy's overall emissions reduction trajectory (not just in terms of emissions outcomes, but also whether certain types of investments will remain feasible or conducive to other investments in future)[33] is thus the most critical factor in determining whether investments avoid or strengthen institutional lock-in. This idea is supported by NPC (2011). It envisages that by 2015, sufficiently detailed carbon budgets will be in place in South Africa to guide infrastructure spending and avoid lock-in effects. Infrastructure investments that are in line with these overarching planning frameworks, like the PPD trajectory in South Africa (and the carbon budgets expected to flow from it), will then serve to protect the country from institutional lock in.[34]

The useful life (or rather the difference between the useful life and the payback period) of infrastructure is also important to consider in avoiding institutional lock-in. Once the initial capital investment has been recouped, only the operating/maintenance cost of the infrastructure is important when evaluating whether or not to make new investments. New infrastructure or technology that is more competitive on a levelised cost basis may thus be uncompetitive against the current infrastructure, since its combined capital and operational costs must be lower than the incumbent's operational cost alone before a switch is likely to occur (Bazilian et al, 2011). The scale of these sunk costs could therefore be a powerful force for institutional lock-in, and do need to be fully considered during the policy and decision-making process.

Given the need for coordination and adherence to existing planning frameworks to reduce the risk of institutional lock-in, it is worrying that the investment decisions of local SOEs (who are currently driving infrastructure spending in South Africa) are based largely on internal imperatives rather than on a broader set of strategic, integrated infrastructure development goals (DBSA, 2011). Even if greater coordination can be achieved, it is questionable whether the PPD trajectory currently provides sufficient detail to guide infrastructure investments and to avoid institutional lock-in.[35] Hopefully, this issue will be addressed once detailed sector-level carbon budgets are put in place.

5.4 Current infrastructure investment plans

The preceding sections indicate that it is difficult at present to determine whether South Africa's current infrastructure plans run the risk of leading to either asset or institutional lock-in. A review of the project assessment criteria used to evaluate the attractiveness of individual projects will provide the best indication of whether asset lock-in is a serious concern, whereas a detailed comparison of current infrastructure projects with those included in the PPD trajectory is required to assess the risk of institutional lock-in. Both these exercises are beyond the scope of the current report, but it is possible

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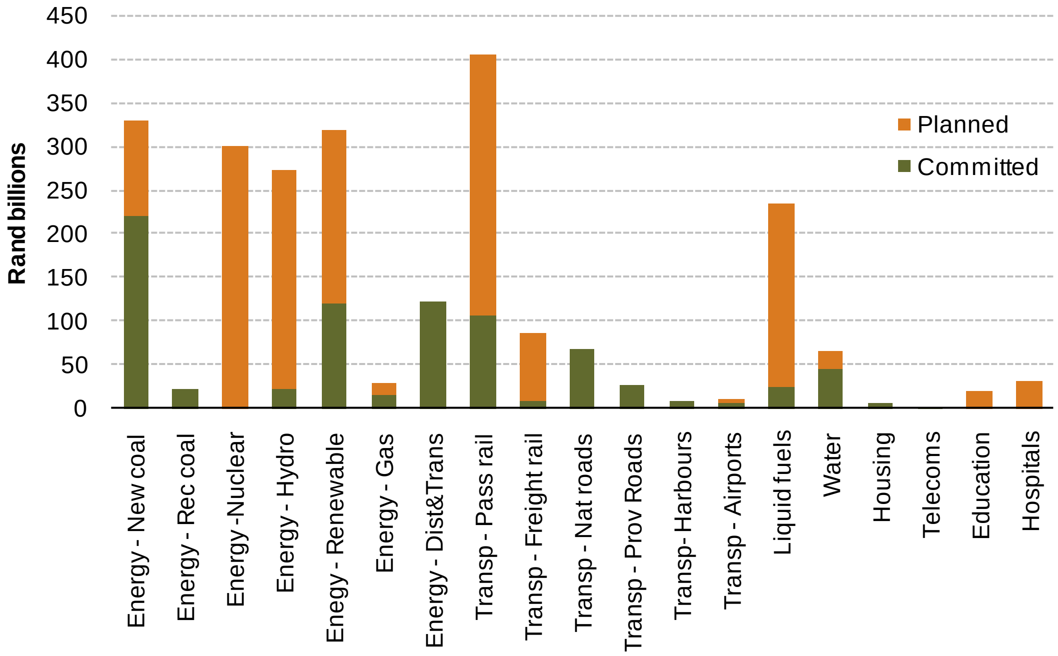
[33] Certain investments can block off future investments choices through timing, scale or the use of incompatible technologies.

[34] Since by their inclusion in the emissions reduction trajectory, the explicit assumption is made that the investments made and actions taken after the investments to stay in the trajectory is physically possible. And if the trajectory meets policymakers stated emissions reductions over time, the investments can be viewed as consistent with climate change policy even if they are very emissions intensive.

[35] See footnote 27.

and insightful to look briefly at the distribution of South Africa's planned and committed major infrastructure projects, between activities generally viewed as relatively high or low carbon.

Figure 5 Current committed and planned major infrastructure projects



Source: DNA Economics based on National Treasury (2012)[36]

With respect to current infrastructure investments, the balance seems to be skewed towards relatively high carbon investments (although not by as a large margin as is commonly believed). Investments in new and recommissioned coal-fired power stations, national and provincial roads and liquid fuels as a whole outweigh investment in hydroelectricity, renewables, gas electricity generation and rail infrastructure. In terms of planned projects, however, low carbon infrastructure investments predominate. Investments in hydro and nuclear energy, renewables, gas electricity generation and rail capacity outweigh those in new coal-fired power generation and liquid fuels.

[36] Additional information for projects recently completed and mentioned in National Treasury (2012) was obtained from the 2010 Budget Review and Naidoo (2011). Additional projects added to those provided in National Treasury (2012) are: Gautrain, Gauteng Freeway Investment Project (Phase 1), King Shaka Airport, Transnet's multiproduct pipeline and an estimate for airport upgrades (mentioned in National Treasury (2012) but not included in list of major infrastructure projects).

6 CONCLUSION

When considering the question of whether South Africa's current infrastructure investment is likely to lock the country in to a high carbon development path, both the definition of infrastructure put forward and current investment patterns indicate that the emphasis should be on public infrastructure expenditure in general, and SOE investment in particular. Current sources of infrastructure investment data are unfortunately not ideal for answering this question, due to data being reported in a relatively aggregated form. More granularity in the reporting of infrastructure spending (ideally splitting out individual technologies or sub-sectors) would allow for a more detailed analysis of high versus low carbon infrastructure investments.

With respect to carbon lock-in, two dimensions are of particular interest, namely the vulnerability of investments to ending up as stranded assets; and the risk that infrastructure investment patterns may complicate the task of staying on a predetermined GHG mitigation trajectory. With regards to avoiding stranded assets, the best indication of vulnerability is the quality of project assessment procedures followed to decide whether or not to invest in infrastructure projects. These assessments need to take into account all life-cycle costs, technology choices, lead times, the policy environment and plans, and very importantly, payback periods and the useful life of assets. In terms of avoiding institutional lock-in, a systemic view of the emissions resulting from infrastructure investment and adherence to stated official emissions trajectories are paramount, as is cognisance of the impact of the difference between the useful life of assets and their payback periods.

Given the complexities of determining whether or not infrastructure investments are vulnerable to lock-in effects and the lack of detailed data on investment in South Africa, it is not possible to provide a definitive conclusion on the current risk to South Africa's infrastructure portfolio. That said, it would appear that most current major infrastructure projects come with relatively high GHG emissions, while for planned projects, the there is a sharp shift towards relatively low carbon projects.

Despite these improvements, the relatively short-term focus used to evaluate infrastructure projects (by placing undue emphasis on capital costs at the expense of other life cycle costs), and the lack of attention paid to the possibility of lock-in in project assessments (although it is about to start, the DBSA does not yet evaluate GHG emissions as part of its standard process assessment processes – and neither does the Department of Public Works), raises the possibility that some infrastructure asset lock-in will occur. Similarly, the lack of coordination with respect to public infrastructure investment, and the lack of a sufficiently detailed local emissions trajectory to guide infrastructure spending, seems to indicate that institutional lock-in should be a serious concern.

In order to form a better understanding of the risk of carbon lock-in associated with current South African infrastructure spending patterns, detailed investigations of the project assessment processes and a comparison of current and planned infrastructure investments against the assumptions of the current National GHG Emissions Trajectory Range (currently presented as the PPD trajectory) (DEA, 2011) for specific types of infrastructure, are recommended. Rather than viewing the National GHG Emissions Trajectory Range as an absolute cap on infrastructure emissions (since it is subject to change), it should be seen as a measure of the strength of future climate change policy interventions, and as such it also provides a good indicator of the potential risk of carbon lock-in.

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APPENDIX 1 DATA AVAILABILITY

South African Reserve Bank

- **Economic infrastructure**: Roads, bridges, dams, electricity and water supply, etc.
- **Social Infrastructure**: Schools, hospitals, etc. and administrative services.
- **Gross fixed capital formation (GFCF) (OECD, 2010)**: Defined in the national accounts as acquisition less disposals of produced fixed assets, i.e. assets intended for use in the production of other goods and services for a period of more than a year. Acquisition includes both purchases of assets (new or second-hand) and the construction of assets by producers for their own use. The term produced assets signifies that only those assets produced as a result of a production process recognised in the national accounts are included. The national accounts also record transactions in non-produced assets such as land, oil and mineral reserves for example; which are recorded as non-produced assets in the balance sheet accounts and not as GFCF. Acquisition prices of capital goods include transport and installation charges, as well as all specific taxes associated with purchase.
    - Investment is reported in two ways:
        - Gross Fixed Capital Formation
            - Agriculture, forestry and fishing
            - Mining and quarrying
            - Manufacturing
            - Electricity, gas and water
            - Construction
            - Wholesale and retail trade, catering and accommodation
            - Transport, storage and communication
            - Financial intermediation, insurance, real-estate and business services
            - Community, social and personal services
        - By type of organisation
            - General Government
                - Economic Infrastructure
                - Social infrastructure
                - Economic services
            - Public corporations
                - Economic infrastructure
                - Economic services
            - Private business enterprises

Statistics South Africa

- **Capital expenditure:** Capital expenditure refers to any expenditure incurred in or incidental to the acquisition or improvement of land, buildings, engineering structures and machinery and equipment. The expenditure normally confers a lasting benefit and results in the acquisition of, or extends the life period of, a fixed asset. Capital expenditure includes spending on vehicles, office furniture and equipment, but excludes minor items that are generally regarded as being expendable even though in some instances their useful lives may extend beyond one year. Military expenditure (e.g. ships and aircraft) are now treated as fixed assets consistent with the UN System of National Accounts 2008 and the 2001 IMF's Government Financial Statistics. Previously, these weapons were treated as current assets.[37]

- **Capital expenditure on new construction works:** Capital expenditure that is contractually and/or physically not connected to the existing assets and infrastructure. Capital expenditure on new construction works consist of the following:
    - expenditure on fees payable to architects, engineers and other
    - professional firms;
    - renovations of existing constructions;
    - expenditure on works under construction; and
    - Expenditure on improvements.

- **Other construction includes**:
    - airports;
    - civil engineering works;
    - development of plantations;
    - electricity projects;
    - forestation;
    - mining development;
    - oil exploration;
    - railways and harbours; and
    - the development of land.

- **Capital Expenditure on new assets (Large Sample Surveys):**
    - the erection of new buildings and works, additions to and alterations
    - of existing buildings and works;
    - work in progress capitalised;
    - new plant, machinery, equipment and vehicles;
    - new computers, network equipment and other information technology equipment;
    - intangible assets;
    - used plant and machinery, which was imported by or on behalf of the

[37] United Nations. 1993. System of National Accounts 1993. Available from: http://unstats.un.org/unsd/nationalaccount/sna1993.asp

- enterprise whether paid to outside contractors/concerns, or which was
- done by the enterprise itself; and
- other new assets not specified

National Treasury

- **Payments of capital assets**: Payments made by a department for an asset that can be used for more than one year and from which future economic benefits or service potential are expected to flow. Payment for capital assets is disaggregated by government department. Payment for capital assets by the Department of Transport, for instance, is broken down as follows:
    - Rail Transport
    - Road Transport
    - Civil Transport
    - Maritime Transport
    - Public Transport
- Payment for capital assets only refers to spending by the line department only. Also, capital assets in this case likely to only capture a small subset of infrastructure investment, with the bulk of infrastructure cost being spit over other cost items like contractors, planning etc. A similar difficulty is present when trying to tease out infrastructure spending from the expenditure of agencies funded by the Department of Transport agencies shown in the detailed expenditure estimates by vote.

Industry Insight

Industry Insight has a breakdown of spending on different project types within different provinces:[38]

- Air
- Bridges
- Building - Other
- Civil - Other
- Commercial
- Education
- Entertainment
- Health
- Hotels
- Housing
- Industrial
- Low-income
- housing
- Power
- Protective

[38] It is unclear to what extent this data can be disaggregated.

- Rail
- Retail
- Road
- Water
- Health