Leaving room for 'green growth': identifying near-term actions to avoid long-term carbon lock-in

Background

Policy-makers increasingly aspire to a low-carbon future, with a "green economy" fuelled by renewable energy sources, not fossil fuels; highly efficient technologies; an end to congested roads and smog, and a safe climate. Yet many past development choices hinder a low-carbon transition. In just the past decade, we have invested trillions of dollars in coal-fired power plants, oil and gas supply infrastructure, extensive road networks and car-dependent travel, and inefficient buildings that are costly to retrofit.

That is the essence of carbon lock-in: once certain investments are made, institutions are created, and development pathways are chosen, the behaviours – and carbon emissions – associated with them are more or less "locked in", and shifting to a new pathway becomes ever more difficult and expensive.

The lock-in of carbon-intensive technologies, institutions and economic interests poses a formidable barrier to achieving climate protection goals. Yet carbon lock-in continues, with billions of tonnes of future carbon dioxide emissions "committed" by investments in high-carbon infrastructure each year. To ensure that a low-carbon future is possible, it is crucial to identify and avoid the greatest lock-in risks.

This policy brief presents an innovative process to analyse the lock-in risk associated with new infrastructure investments, drawing on recent SEI research. It then applies the approach to fossil fuel infrastructure at the global scale, suggesting the project types of greatest lock-in concern. Finally, it explains how policy-makers and analysts might apply a similar approach at the national and regional scales.

Assessing carbon lock-in

Limiting carbon lock-in can bring many benefits. Most notably, policy-makers can limit the costs and challenges of achieving ambitious emission reductions targets. Limiting lock-in can also help leave more room open for green growth, where opportunities to fully embrace a low-carbon, sustainable development path may not be possible in the near term.

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Dave Johnson coal power plant in central Wyoming

Key findings

- Assessing carbon lock-in can lead to important insights and potential new policy directions for achieving climate protection objectives. This policy brief outlines an approach that can be applied at national and regional scales to help ensure that near-term investments do not compromise the ability to reach green growth and low-emissions development goals.
- From a global perspective, investments in new coal-fired power plants appear to pose the greatest risks of carbon lock-in over the next 15 years. While this finding may come as little surprise to many, the assessment approach, applied here at the global scale, also points to significant lock-in risks from the expansion of gas power and private vehicle travel.
- Carbon lock-in can occur due to investments in fossil fuel supply infrastructure as well. This assessment points to capital-intensive oil resource extraction, such as yet-to-be-developed offshore oil platforms, as one of the greater carbon lock-in challenges related to fossil fuel supply.

Through policies to slow the expansion of carbon-intensive infrastructure, policy-makers can minimize lock-in in the short term and create the space to develop and implement more effective policy approaches.

Policy-makers and analysts can use the following four steps to help identify investments that create the greatest carbon lock-in risk:

1. Define the context for considering carbon lock-in. The first step is to identify key decisions that will influence infrastructure investments for consuming or producing energy; the sectors that are most relevant (e.g. power, transportation, buildings), the investment time-frame of interest (e.g. 10–15 years), and whether fossil fuel *supply* investments should be considered. The context of the analysis must also be defined: the climate protection objective(s) of interest (e.g. ensuring that warming does not exceed 2°C); the relevant reference or business-as-usual (BAU) scenario(s) and their underlying assumptions; and policies under consideration (e.g. carbon pricing or emissions performance standards).

2. Identify infrastructure and technology investments that may be inconsistent with climate protection objectives. The goal of this second step is to shed light on investments that are inconsistent with climate protection objectives but are likely to proceed under a business as usual (BAU) scenario. This step requires having access to the results of analyses that model both BAU and low-carbon pathways. Numerous institutions already undertake such analyses for low-emissions development or "green growth" planning at the national level. At a global level, models and study results are generally available from research and intergovernmental institutions such as the International Energy Agency (IEA) and the Intergovernmental

Panel on Climate Change (IPCC). These results can be used to estimate **over-committed emissions**, as an indicator of lock-in risk for specific categories of technologies that consume fossil fuels. Over-committed emissions are the "extra" carbon emissions resulting from the lifetime operation of technologies or infrastructure that that are put into operation in a BAU scenario but not in a low-carbon scenario. This metric represents a variation on the recent innovation of commitment-based CO_2 accounting. For investments in fossil fuel supply, a similar indicator, **over-production** of fossil fuels, can be used, and also denominated in CO_2. It represents the "extra" fuels produced in a BAU scenario that would not be produced in a low-carbon scenario.

3. Assess the strength of lock-in and resistance to unlocking of these investments. For the infrastructure and technology investments associated with over-committed emissions and over-produced fuels (step 2), analysts can then examine the strength of the lock-in effect – i.e. the likelihood that, once the investment is made, it will continue to emit (or supply) fossil fuel carbon. For fossil fuel demand technologies, expected **equipment lifetime** (in years) offers one measure of the strength of carbon lock-in. Because opportunities to invest in lower-carbon technologies arise less often for long-lived technologies such as power plants or transport systems than they do for short-lived equipment such as lighting or many appliances, the former have greater potential for lock-in. For fossil fuel supply resources, **capital intensity** (USD per tonne of CO_2) can reflect the relative likelihood that production will continue, so as to repay creditors. For both demand and supply investments, the carbon price needed to stop using or retire a carbon-intensive investment (in favour of a less carbon-intensive alternative) can reflect the **financial barrier to "unlocking"**, and server as another indicator of the strength of lock-in. (For investments in fossil fuel supply, it might be calculated as the economic rent intensity, also in USD per tonne of CO_2.)

4. Consider lost opportunities and techno-institutional effects. Carbon lock-in also "locks out" low-carbon technologies, by strengthening the social, technical, and political institutions of competing high-carbon technologies, such as extensive networks of skilled labour, relatively easy access to finance, and political strength. Further investment in incumbent technologies misses the opportunity to strengthen similar institutions for low-carbon technologies, or to benefit from the resulting cost reductions (e.g. for electric vehicles, solar photovoltaics, electric heat pumps). While there is no single, simple metric that reflects these effects, analysts can use, as we do here, a simple measure of technology-specific market share as a proxy for the overall strength of these "**techno-institutional effects"** along a high-carbon vs. low-carbon path. For the demand side, we use a ratio of the proportional market share gained by the low-carbon technology in moving from a BAU to low-carbon pathway to the proportional market share lost by the high-carbon technology. For the supply side, we use the sum of **capital** and **rent intensity,** i.e. the economic surplus per unit carbon generated by oil, coal, or gas extraction, as a proxy for techno-institutional effects.

The specific tools and methods used to conduct this four-step assessment can be flexible, and draw from many models and scenarios already used to support low-emissions development or national energy planning, where analysts' use of long-term scenario planning approaches can take these lock-in risks into account, even implicitly, within commonly used modelling frameworks.

Applying the approach globally

As a demonstration of this approach, we apply it to assess carbon lock-in at the global level, from both the demand- and supply-side perspectives. For the first step, we define the context for considering lock-in investments as those that might occur in a "conventional wisdom" BAU but not under a climate protection objective of no more than 2°C warming.

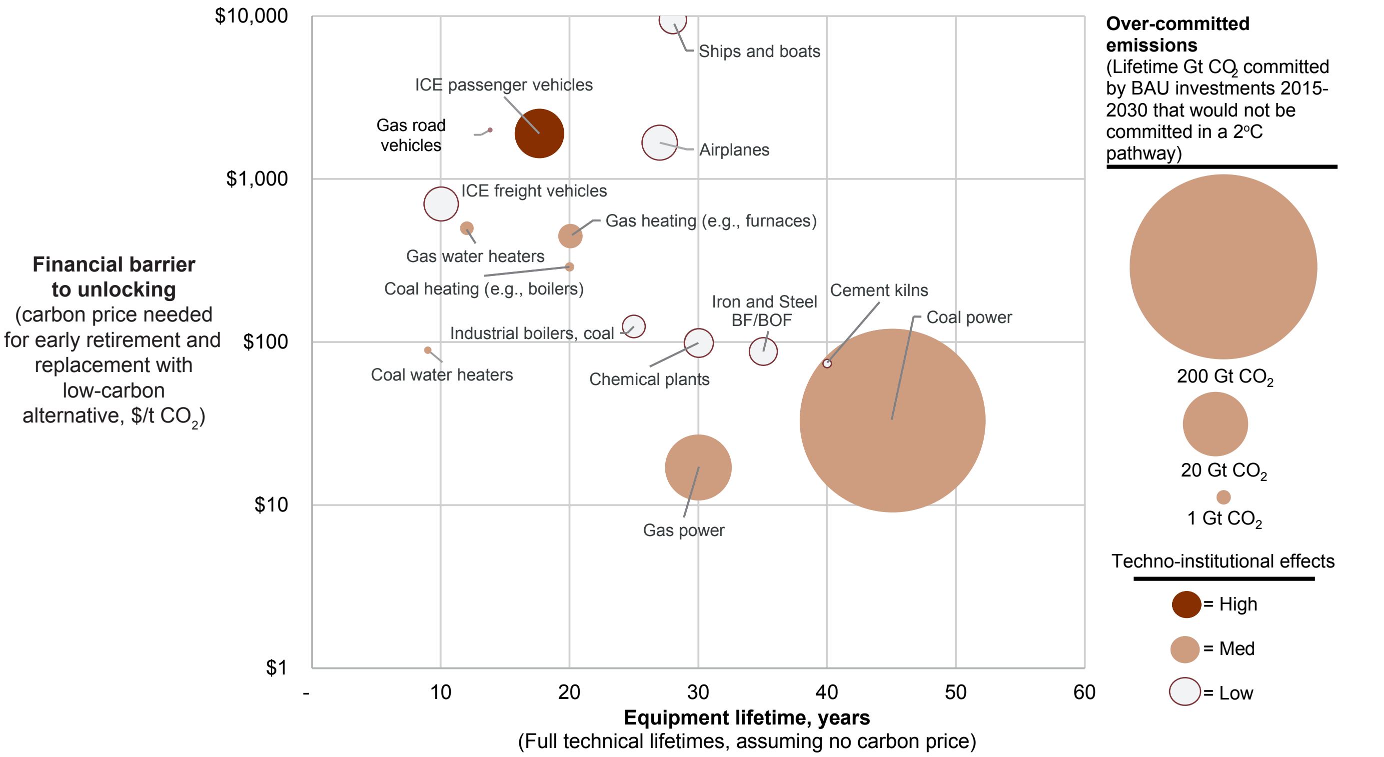

Figure 1: Global carbon lock-in analysis, demand side. Technologies are placed on the chart based on their technical lifetimes (x-axis) and financial barrier to unlocking (y-axis). The size of each bubble is proportional to the over-committed CO_2 emissions due to business-as-usual investments in 2015–2030. The bubble's colour reflects the degree of the techno-institutional lock-in, from low (light brown) to high (darker brown).

Table 1: Global carbon lock-in analysis, supply side.

Fossil fuel over-production is the quantity of fossil fuels produced in 2030 under BAU that would not be produced under a 2°C scenario, in billion tonnes CO_2. Average capital intensity is the amortized capital cost required to extract each unit of fossil resource, in USD per tonne CO_2 content. **Average rent intensity** is the average economic rent yielded per unit of fossil resource over-produced, in USD per tonne CO_2 content.

Resource group	Indicators		
	Fossil fuel over-production, 2030 (Gt CO_2 annually)	Average capital intensity (USD/tCO_2 over-produced)	Average rent intensity (USD/tCO_2 over-produced)
Coal	5 Gt CO_2	3	[a]
Of which, seaborne	1 Gt CO_2	5	3
Oil	2 Gt CO_2	97	5
Of which, offshore	1 Gt CO_2	100	4
Gas	1 Gt CO_2	108	[a]
Of which, offshore	0.6 Gt CO_2	137	[a]
Total	7 Gt CO_2 [b]		

[a] We do not report average rent intensities for natural gas or for domestic coal, since unlike for oil and seaborne coal, there are very wide variations in prices by region.
[b] Over-production numbers do not add up perfectly to 7 Gt due to rounding.

We consider those investments undertaken and completed (put into operation) over the next 15 years, through 2030 – the time frame of focus in the negotiations leading up to the UN Climate Change Conference in Paris this December.

For the second step, we turn to the IEA's widely cited scenarios (*Energy Technology Perspectives* 6DS and 2DS scenarios) to identify the difference in investments under BAU (with little new policy implementation) and under a cost-efficient 2°C degree trajectory. As the third and fourth steps, we use data and assumptions from the IEA and other industry sources to characterize the strength (lifetime and resistance to unlocking) and techno-institutional lock-ins.

Figure 1 presents our findings for the demand side. It suggests that for several reasons, investments in coal-fired power plants pose the most substantial lock-in risk: they are long-lived (x-axis) and over-commit by far the greatest quantity of CO_2, 180 Gt CO_2. That amount would represent a significant addition above the remaining 2°C carbon budget of about 1,000 Gt CO_2. Unlocking coal plants would, on average, require a carbon price of about 50 USD per tonne, lower than for any other technology except gas plants, but still higher than current carbon prices in most countries. This relatively high cost is driven primarily by the fact that coal power has relatively low running costs, and thus an existing plant presents stiff competition to any newly built alternative.

At the same time, two other technologies also over-commit significant quantities of CO_2: natural gas power plants, which are also being over-built relative to a 2°C objective, and internal combustion engine passenger vehicles, which, in addition to being relatively costly to replace with low-carbon alternatives, risk further entrenching these technologies and their fuelling networks at the expense of needed development in low-carbon fuels and transport.

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Heavy traffic on a highway in Beijing

For fossil fuel supply, analysis by the IEA has suggested that investment in fossil fuel infrastructure is proceeding at levels considerably above what would be cost-effective in the IEA's 2°C scenario. Combining that analysis with more detailed assessments by industry consultants, we find a range of levels of over-production, and associated capital and rent intensities of over-produced deposits, by major fuel type under a BAU scenario.[1] As shown in the table above, and not surprisingly, over-investment in coal supply leads to the greatest amount of over-production (5 of 7 Gt CO_2). However, coal mining is not particularly capital-intensive, nor does it yield high economic rents (not calculated but typically less than 3 USD/tCO_2), suggesting that, on average, coal mining investments may be far less locked-in than coal power plants.

In contrast, offshore oil and (to a lesser extent) gas investments also must be scaled back (on the order of 1 Gt CO_2 each in 2030) to meet a 2°C constraint, but are far more capital-intensive (>50 USD/tCO_2) and can generate higher economic rents (up to USD 100/tCO_2), especially once the capital has been invested. Because they are capital-intensive and costly to develop, these resources would not be developed in a cost-effective, low-carbon scenario (e.g. with a carbon price). Once they are in place, however, extraction is likely to continue, as the marginal cost of production is only the operating cost, which, even for offshore oil and gas, is much lower than expected fuel prices (20 USD/bbl vs. 87 USD/bbl oil price in 2030 in our analysis).

Applying the approach at the regional or national scale

Policy-makers and analysts can apply this step-wise approach to assess carbon lock-in at national or regional scales. For each of the four steps outlined above, national-scale analyses may need to be adjusted as follows:

1 See forthcoming SEI papers for more details. For this analysis, due to limitations in fossil fuel industry data, we use a lower emission BAU (the New Policies Scenario from the IEA's *World Energy Outlook 2014*, more consistent with a 4°C temperature rise) than the BAU used for the demand-side assessment.

Policy recommendations

- Policy-makers should consider assessing which technologies and infrastructure pose special risks of carbon lock-in, and leave room for green growth by developing new policies focused on restricting new investments in these technologies. To do so, they can apply the four-step approach discussed here at the national and sub-national levels.
- Though regional results may vary, global analysis suggests that policy-makers should give special attention to the carbon lock-in risks posed by coal power plants, gas power plants, private vehicle infrastructure, and capital-intensive oil and gas supply infrastructure.
- Greater attention should be devoted to policies that can limit carbon lock-in, such as strict emissions performance standards for carbon-intensive technologies, or the use of steep carbon prices in the evaluation of new investments.

1. The decision context for lock-in will clearly depend on national circumstances, but may be integrated, as in our analysis here, with internationally agreed goals and timelines.
2. The scale of infrastructure and technology investments inconsistent with a low-carbon objective, e.g. as assessed using the concept over-committed emissions, will vary by country based on the business-as-usual investment trends as well as low-carbon technologies and resources available. Analysts can rely on their own modelling assessments or, if and where such assessments are lacking, they can build on aggregated data and scenarios results assembled for global analyses, such as those used above.
3. The strength of lock-in and resistance to unlocking may, likewise, vary by jurisdiction, to the extent that there are variations in technology and fuel costs and in the cost of producing fossil fuels.
4. The unique nature of lost opportunities and techno-institutional effects may require metrics and qualitative analysis particular to local circumstances, such as market share of different technologies.

Developing policies to minimize carbon lock-in.

In principle, an adequately high and rising global carbon price can limit carbon lock-in to levels consistent with climate protection objectives, while at the same time stimulating the rapid development and implementation of low-carbon technologies. However, given the present-day challenge of adopting such a widespread and ambitious policy, many policy-makers have instead opted for portfolios of multiple strategies that, in aggregate, tend to focus more heavily on promoting low-carbon technologies (e.g. renewable energy requirements or incentives) than on limiting carbon lock-in.

Therefore, to the extent that minimizing lock-in becomes an objective, policy analysis and development may need to be strengthened in a number of ways:

- Greater emphasis on codes and standards that are set stringent enough to avoid the lock-in of inefficient infrastructure and technology, including building envelopes and heating systems, vehicles, and industrial facilities.
- Wider consideration of moratoria or curtailment of specific investment types, where the risk of over-committing emissions is particularly high, such as for new coal power plants and capital-intensive oil and gas supplies.
- Use of high proxy or shadow carbon prices for decision-making by governments and the private sector on large investments (e.g. power plants, refineries, pipelines), to test the compatibility of the investments with stringent climate goals.

Such measures could help limit carbon lock-in and, in so doing, help reduce the cost, and increase the likelihood, of achieving ambitious climate objectives. However, on their own, these types of measures are insufficient to encourage adequate development of low-carbon technologies, and would do little to encourage low-carbon transitions in already-existing infrastructure, which is especially important for industrialized countries. Accordingly, they are just one piece of a comprehensive and effective approach to climate change mitigation, and to leaving room for green growth.

Furthermore, carbon lock-in assessments do not necessarily indicate who should be responsible for avoiding these emissions. Indeed, much of this pending new investment is likely to occur in the developing world; coal-fired power in Asia is the largest source of projected over-committed emissions. Global efforts to reduce carbon lock-in thus need to take equity into account, distinguishing between the location of mitigation potential and responsibility for providing the technical and financial resources to realize it.

This policy brief is based on SEI research funded by GIZ, described in detail in two forthcoming papers: "Assessing carbon lock-in", and "Carbon lock-in from fossil fuel supply infrastructure". The research was conducted by Peter Erickson, Sivan Kartha, Michael Lazarus, and Kevin Tempest.

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