

CLIMATE
POLICY
INITIATIVE

Moving to a Low-Carbon Economy: The Financial Impact of the Low- Carbon Transition

Climate Policy Initiative

David Nelson
Morgan Hervé-Mignucci
Andrew Goggins
Sarah Jo Szambelan
Julia Zuckerman

October 2014

CPI Energy
Transition Series

Descriptors

Sector	Renewable Energy Finance
Region	Global, United States, European Union, China, India
Keywords	Stranded assets, low-carbon, finance, renewable energy
Contact	David Nelson, david.nelson@climatepolicyinitiative.org

Acknowledgements

The authors gratefully acknowledge input from expert reviewers, including Billy Pizer of Duke University, Karthik Ganesan of CEEW, Michael Schneider of Deutsche Bank, Nick Robins of UNEP, and Vikram Widge of the World Bank. The perspectives expressed in this paper are CPI's own.

We also thank our colleagues who provided analytical contributions, internal review, and publication support, including Ruby Barcklay, Jeff Deason, Amira Hankin, Federico Mazza, Elysha Rom-Povolo, Dan Storey, and Tim Varga.

About CPI

Climate Policy Initiative (CPI) works to improve the most important energy and land use policies around the world, with a particular focus on finance. We support decision makers through in-depth analysis on what works and what does not. CPI works in places that provide the most potential for policy impact including Brazil, China, Europe, India, Indonesia, and the United States.

Our work helps nations grow while addressing increasingly scarce resources and climate risk. This is a complex challenge in which policy plays a crucial role.

About this project

The reports were commissioned by the New Climate Economy project as part of the research conducted for the Global Commission on the Economy and Climate.

Copyright © 2014 Climate Policy Initiative www.climatepolicyinitiative.org

All rights reserved. CPI welcomes the use of its material for noncommercial purposes, such as policy discussions or educational activities, under a [Creative Commons Attribution-NonCommercial-ShareAlike 3.0 Unported License](http://creativecommons.org/licenses/by-nc-sa/3.0/). For commercial use, please contact admin@cpisf.org.



Executive Summary

A major concern regarding a transition to a low-carbon economy is the impact that it could have on the global financial system. Would the scale of investment required consume financial resources and crowd out investments elsewhere in the economy? Would the impact that the transition would have on the value of existing investments — that is, the assets it would strand — reduce the capacity of investors and governments to invest?

This paper assesses the impact of a potential transition, looking not just at the investment required and the impact of a transition on the value of existing assets, but also looking more broadly at other factors that could affect the financial capacity of the global financial system, including operating expenses, risk, and the lifespan of investments. A savings in operating costs, for instance, could provide investors additional cash that could then be invested back into the economy. Lower risk frees up reserves and enables investment in further growth. And longer asset life means that investments need not be replaced as often, freeing cash for investment that would otherwise be needed for asset replacement.

When all of these factors are taken together, we find that transitioning to a low-carbon electricity system could actually increase the capacity of the global financial system by as much as \$1.8 trillion between 2015 and 2035.

Transitioning from oil to low-carbon transport could also result in a positive impact on the financial system over the same period, with an estimated impact ranging from a negative impact of \$2.5 trillion to a net benefit of \$3.5 trillion, depending on policy choices. Increasing the capacity of the system to invest creates opportunities for growth and lower costs that could reverberate across the economy.

These overall benefit estimates capture the following dynamics in a move from business-as-usual to a 2-degree pathway:¹

Electricity (Figure 1)

- Low-carbon energy infrastructure is less expensive to operate, primarily because of avoided operating costs associated with extracting and transporting coal and gas. We estimate that operating savings would be significant, totaling \$4.6 trillion.
- The global electricity industry (including fuel extraction, generation, and transmission and distribution) would see more capital investment under a low-carbon pathway, because low-carbon energy tends to be more capital-intensive than fossil fuel energy. Low-carbon investments tend to have slightly longer lives, somewhat offsetting the higher investment levels. Taken together we estimate that total depreciation and amortization (D&A) (the amount of the investment capital actually used up over a given time frame) would increase by \$1.1 trillion between 2015 and 2035 — the net impact of a \$2.8 trillion increase in low-carbon capital (D&A) and a \$1.7 trillion decrease in fossil fuel D&A.
- Financing costs, which reflect both the level of investment and the riskiness of those investments, would increase by \$0.6 trillion. Many low-carbon electricity investments carry lower inherent risk than some of the fossil fuel investments they replace and would particularly see lower costs of capital if the institutional and financial systems are fine-tuned to low-carbon investments rather than fossil fuel investments. However, total financing costs would still increase because of the larger quantity of capital investment under the 2-degree pathway. Globally, existing fossil fuel assets that would otherwise be employed in electricity generation (including coal, oil, gas and power plants) would lose an estimated \$1.1 trillion in value during the low-carbon transition.
- The net impact of transition is an increase in available investment capacity of \$1.8 trillion.

¹ Our modeling is based on scenarios defined in the International Energy Agency's Energy Technology Perspectives 2012. We define the "low-carbon transition" as the difference between the 6-degree (business as usual) scenario and the 2-degree, or 450 ppm, scenario. Scenarios and methodology are discussed further in Section 2.

Transport (Figure 2)

- Operating expenses would decrease by \$2.8 trillion.
- Total depreciation and amortization of capital would increase by \$3 trillion between 2015 and 2035 — the net impact of a \$6 trillion increase in investment in low-carbon vehicles and mass transit and a \$3 trillion decrease in investment in fossil fuel transport (including the extraction, refining, and movement of oil for transport, as well as investment in fossil fuel powertrain vehicles).
- Financing costs would increase by \$0.5 trillion. The impact of the low-carbon transition on the value of existing assets would depend on the policy pathways chosen. We estimate that the impact could range from a \$1.8 trillion net loss in asset value to a \$4.2 trillion net benefit.
- The net impact of the transition ranges from a \$2.5 trillion reduction to a \$3.5 trillion increase in capacity, depending on policy impact on asset values.

Decisions by policymakers, regulators, and institutional and other investors have a major influence on the financial impact of the low-carbon transition. Our analysis suggests the following priorities to maximize the financial benefit of the low-carbon transition:

Power

- In developed countries, create and expand financing vehicles that can efficiently channel low-cost institutional investment into low-carbon energy infrastructure.
- In both developed and developing countries, consider restructuring the electricity industry, market design, and regulation to clarify the infrastructure characteristics of the low-carbon assets and appropriately allocate risks between investors, consumers and governments.
- More broadly, policy measures such as pricing carbon, eliminating fossil fuel subsidies, and supporting the development of new low-carbon technologies also change the risk/reward equation in a positive direction for low-carbon infrastructure.

Transport

- To reduce the use of oil in transport, focus on policies that reduce demand for oil, rather than policies that restrict supply. A combination of taxes and innovation appears to be the most promising policy approach.

Figure 1: In the electricity transition, increased investment in low-carbon technology is offset by avoided operating costs

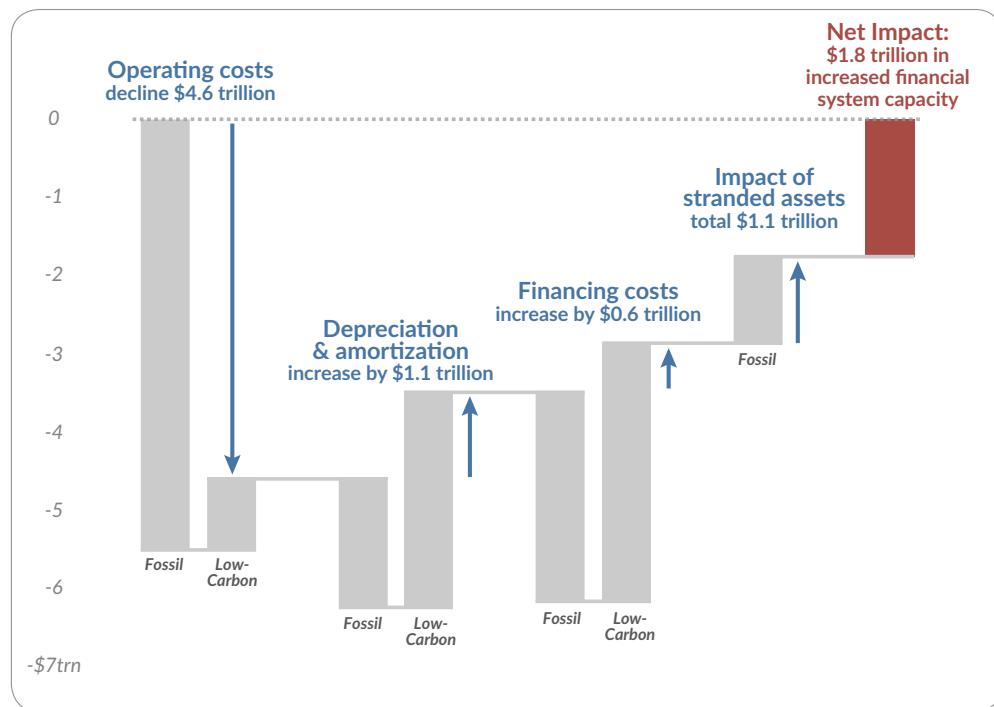
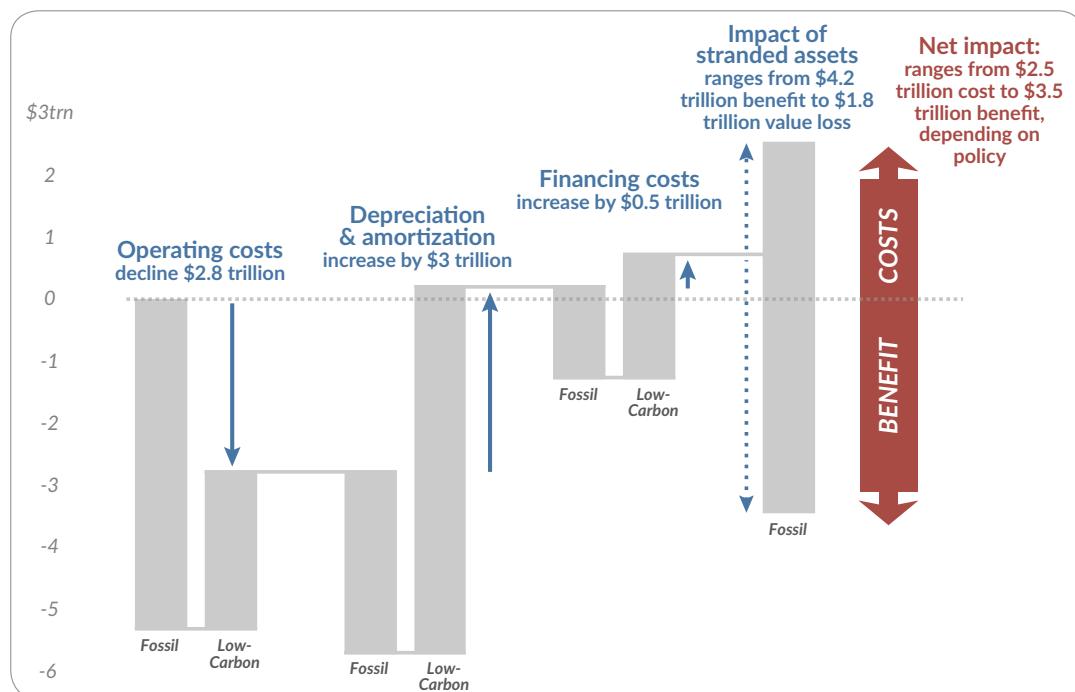


Figure 2: Financial impact of reducing oil in transport depends on policy decisions that affect asset values



Note: These figures are based on CPI Stranded Assets models (for oil, gas, and coal) and CPI analysis based on data from IEA WEIO 2014, IEA ETP 2012 (2DS scenario), Rystad and Platts. Depreciation and amortization, financing costs, and operating costs are undiscounted, accumulated expenses over the period from 2015-2035. Stranded assets represent a one-time reduction in asset value.

TABLE OF CONTENTS

1. INTRODUCTION	1
1.1 Looking beyond upfront investment	1
1.2 The components of the low-carbon transition	2
2. CALCULATING THE IMPACT OF THE LOW-CARBON TRANSITION	4
2.1 Investment needs	4
2.2 Operating expenses	5
2.3 Use of capital stock: Depreciation and Amortization	5
2.4 Financing costs	6
2.5 The impact of stranded assets	8
3. THE FINANCIAL IMPACT OF THE POWER SECTOR TRANSITION AWAY FROM COAL	11
3.1 Operating expenses	11
3.2 Depreciation and Amortization	11
3.3 Financing costs	12
3.4 Stranded assets	12
3.5 Net impact	13
4. THE FINANCIAL IMPACT OF THE TRANSPORT SECTOR TRANSITION AWAY FROM OIL	14
4.1 Operating Expenses	14
4.2 Depreciation and Amortization	14
4.3 Financing Costs	14
4.4 Stranded Assets	15
4.5 Net Impact	15
5. CONCLUSIONS AND POLICY IMPLICATIONS	16

1. Introduction

1.1 Looking beyond upfront investment

Estimates of the financial impact of a low-carbon transition often focus on the incremental, upfront investment required. Incremental investment is important because it can describe how much of the available global investment capital would need to be shifted to the low-carbon energy investments. If for example a doubling of investment into the power sector were required (relative to a “business as usual” scenario), it would be challenging to grow global energy supplies in an affordable way. But incremental investment tells only a part of the story.

First of all, the mix of assets will change beyond just incremental investment, since there would be a reduction of investment in fossil fuel assets like coal mines, oil production facilities and coal fired power stations. Furthermore, incremental investment does not adequately capture the effect that this shift in investment will have on other costs that then feed back into financial markets, for investment in an energy transition can create or destroy value in a number of ways, in so doing freeing up (or consuming) additional cash to the economy that could then be recycled into other investments in the future. In particular, we highlight four adjustments to incremental capital investments that we must make to understand the true impact of financing needs on the economy and financial markets:

- **Operating Expenses.** Capital investment will replace some operating expenses, freeing up cash for further investment. For example, wind turbine investment reduces the need to mine coal and transport it to power stations, as well as the power plants’ other operating costs. The money saved would then be available for investment elsewhere in the economy.
- **Asset Life.** Investment assets vary in lifetime: Some assets can last 20 years or more, while others may last only five. Both a high-carbon and low-carbon energy system have mixes of long and short term assets, but in general, the average life of the assets of a low carbon system is slightly longer, particularly when considering the short useful lifetimes of some upstream fossil fuel assets (for example, 10-15 years for upstream coal and gas investment, compared to 20 years for renewable energy projects). Thus, long life low carbon infrastructure may require more initial investment, but the longer life will delay future investment to replace capacity. During the transition more initial investment

may be required, but many low-carbon assets have long lives and will continue producing energy into the future. For example, an investment made in 2025 with a 20-year life will still have half of its production remaining in 2035; in our analysis we therefore amortize the investment over the life of the asset.

- **Risk and Required Return.** Lower risk assets with appropriate regulatory regimes reduce the incentives that are required to meet investor needs. Investors in a project can require double or more the investment return to invest in a riskier project. Reducing risks in the energy portfolio could free risk capital to invest in risky, value producing ventures elsewhere in the economy.
- **Stranded Assets.** On the other side, a transition can create “stranded assets” where assets lose value when they are no longer needed after a transition. Stranded assets have an impact on the economy at large because valuable assets can be used as security for future investments, so losing asset value can take value directly out of the potential investment pool.

We will begin with incremental investment requirements and then evaluate the impact of the adjustments that need to be made, before returning to stranded assets and the implications that potential asset stranding might have for policy choice.

Our analysis of the low-carbon transition takes as a starting point two scenarios defined by the International Energy Agency’s *Energy Technology Perspectives 2012*: the “6-degree scenario,” representing business as usual, and the “2-degree scenario,” representing a low-carbon pathway. We then undertake more specific analysis of capital investments, operating costs, financing costs, and stranded assets based on additional data. Of course, the data presented here are only estimates, since there are many possible scenarios for a low-carbon transition with very different investment implications. Nonetheless, the IEA investment figures provide a credible starting point from which to evaluate the impact of a transition on financing and financial markets, and ultimately, on the cost of transition. We also note that most of these estimates make no specific assumptions as to the policy pathways used to achieve the low-carbon transition;² they do not include direct

2 The Energy Technology Perspectives publication includes several scenarios

costs of policy implementation, such as program administration or research funding. An exception is our analysis of asset stranding in the oil sector, which includes an assessment of the impact of alternate policy pathways (see section 4).

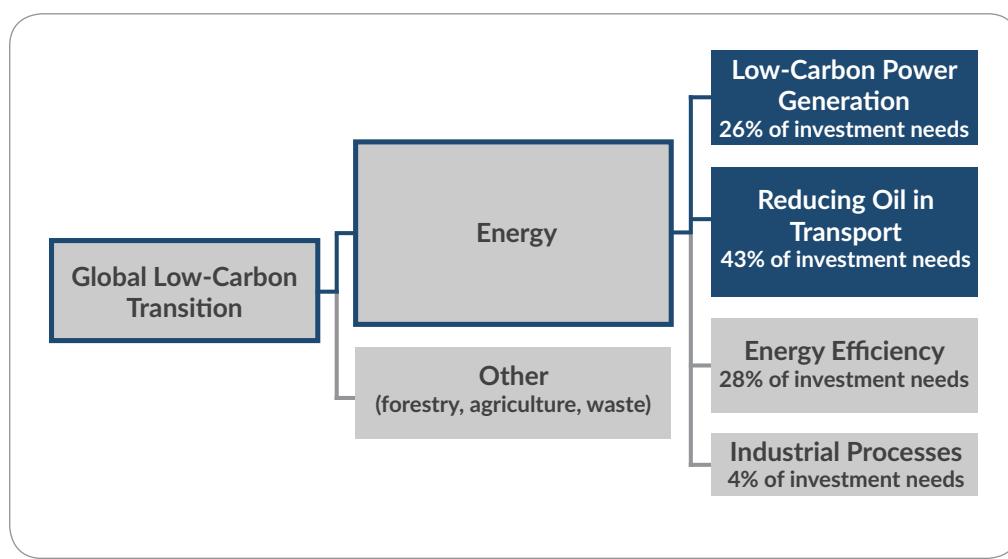
1.2 The components of the low-carbon transition

This paper focuses on two transitions — from fossil fuel to low-carbon power, and from oil to low-carbon transport — to represent the broader picture of financing the global low-carbon transition. Figure 3 illustrates the elements of the low-carbon transition, highlighting the

two areas of focus for this paper. These two transitions are a significant part of the overall picture, from the perspective of both emissions and investment. Energy (including power, transport, and industry) accounts for the majority of global emissions. It is also more capital-intensive than land use and other sectors, which means that financing options and financing costs play a larger role.

Within the energy sector, there are four main elements to the low-carbon transition: low-carbon power generation, reducing oil in transport, improving energy efficiency, and reducing emissions from industrial processes.

Figure 3: Components of the global low-carbon transition



Of the four energy transitions, power and transport — the focus of the analysis in this paper — account for approximately two-thirds of investment needs.³ Energy efficiency in buildings and industry is also expected to see large-scale investment as part of the low-carbon transition, but this investment is largely self-financed through existing channels (see Box 1).

including the 6DS scenario meant to portray investment need if zero climate action is taken, and the 2DS scenario to portray investments estimated to be need to limit global temperature rises to two degrees. Analyses that specify alternative climate goals (e.g. 500, 550 PPM) and pathways to these goals could change substantially the estimates of incremental costs incurred by low carbon systems and associated value stranding. However, the consequent analysis of what such transitions mean for the average cost of capital, how these costs are distributed, and what political reactions might be expected would be logically similar.

³ CPI modeling based on IEA ETP 2012 and Rystad data, covering the period 2015-2035.

Box 1: Financing Energy Efficiency Investments

Increasing energy efficiency is a key part of developing better energy systems. Energy efficiency also poses specific financing challenges. Achieving investment at the scale needed (an incremental investment of \$7 trillion in energy efficiency for buildings and industry between 2015 and 2035^a) will require new policy and financing vehicles. While many energy efficiency investments generate substantial savings relative to the initial investment, few projects are large enough to attract the attention of financiers. Energy efficiency projects generally offer poor collateral. Credit risk is the principal driver of financing costs for most energy efficiency projects, and that risk — being uncollateralized — is substantial enough that interest rates for small commercial and residential consumers are relatively high. In developing countries, where credit-based lending is rare, energy efficiency financing is often not available for small-scale borrowers. Even lending to large industrial actors with collateral is restricted to five years or less and may depend on targeted lines of credit financed by international institutions.

Despite these difficulties, private sector interest in energy efficiency financing is growing, with new business models emerging that shift risks in helpful ways. Public programs that add security to investments by tying them to utility bills, mortgages, or property tax assessments may lower rates from financiers. Sales of securities backed by energy efficiency loans have begun to emerge, potentially making energy efficiency lending more liquid and attracting cheaper capital. Energy performance contracting also serves as a tool to attract private financing; in these arrangements, an energy services company guarantees the energy savings associated with a project and often helps secure private financing in the form of a loan or lease-purchase agreement. More recently, some insurance companies have begun offering energy savings insurance and warranties, in order to help build investor confidence and attract low-cost private financing to energy efficiency projects.

Most financial programs, even those that offer substantial concessions, have struggled to motivate customers. The extent to which improved financing drives project uptake has not been well studied, and may vary substantially in different markets. That said, improvements in financing clearly offer potential.

a Calculations based on scenarios in IEA ETP 2012, including energy efficiency in buildings and in energy-intensive industries.

2. Calculating the impact of the low-carbon transition

2.1 Investment needs

The International Energy Agency (IEA) uses a number of models and analyses to estimate future energy investment needs. Included in these estimates are scenarios that reflect current perspectives on “business-as-usual case” investment needs and scenarios with substantial carbon abatement, including the “two degrees scenario,” or “2DS.” Both scenarios define the investment requirements for: power generation (fossil fuel and low-carbon power generation, plus transmission and distribution), building energy efficiency, industry (energy efficiency and other measures), and transport (i.e. vehicles and mass transportation). They exclude the upstream energy investment requirements in oil, gas, and coal and non-energy infrastructure investments (roads, railways, bridges, agriculture, etc.). The difference between these two scenarios is an estimate of the **incremental** investment required to achieve substantial carbon abatement.

Incremental investment needs will be approximately \$11 trillion over the next 15 years — a relatively modest share of total capital formation

Based on IEA projections, we estimate that approximately \$34 trillion of investment in energy infrastructure will be required from 2015 through 2030 regardless of climate goals. We estimate that the 2DS scenario requires approximately \$11 trillion of **additional** investment over the same time period.⁴

We examine this figure in context: Using data from the OECD and the World Bank, we estimate that approximately \$400 trillion of new investments into fixed capital (that is, total global investment in the economy) will be made over the same time period.⁵ Of this \$400

Table 1: Investment requirements under a business-as-usual scenario and a 450/2DS scenario over 2015-2035 (in USD trillion)

	BAU OVER 2015-2035	2DS OVER 2015-2035	DIFFERENCE
Oil	7.1	4.8	-2.3
Gas	4.4	3.7	-0.7
Coal	1.0	0.3	-0.7
Power - fossil fuel	3.0	1.0	-2.0
Fossil light-duty vehicles	7.0	6.6	-0.4
SUBTOTAL — FOSSIL	22.5	16.4	-6.1
Power - low carbon	2.8	7.5	4.7
Low-carbon transport	7.1	10.9	3.9
SUBTOTAL — LOW CARBON	9.9	18.5	8.6
Transmission & distribution	4.3	4.0	-0.3
TOTAL	36.7	38.8	2.1

Note: This is based on CPI Stranded Assets models (for oil, gas, and coal), and CPI analysis based on IEA WEIO 2014 and IEA ETP 2012.

trillion, the above IEA estimates suggest that the total investment needs for energy are 9% of fixed capital formation without taking any climate action, and 12% including the extra costs of low-carbon investments. While these are significant additional capital requirements, our assessment is that a 3% additional investment is modest relative to the overall scale of capital formation likely to occur over the next 15 years.

The bigger challenge will be to generate the required quantity of attractive investments, through technology improvements and supporting policy, and to ensure that financial vehicles are able to properly intermediate between the sources of financing and such investments.

In Table 1, we highlight investment requirement for the power and transport sectors based on a more detailed dataset. The numbers here are different from the IEA-derived numbers mentioned above as these more detailed numbers (1) exclude buildings and industry investment and (2) covers the 2015-2035 time horizon (instead of 2015-2030). The underlying changes in capital expenditures are the following:

- Instead of USD 23 trillion needed in fossil fuel investment (extraction, transformation, transformation, power generation and fossil light-duty vehicles), only USD 16 trillion is needed under the 450/2DS scenario.

⁴ Based on projections in IEA’s Energy Technology Perspectives 2012. It is important to note that in comparing the 6DS and the 2DS, the 2DS does not simply include the investments made in the 6DS with additional investment; certain types of investments are reduced and certain types are increased. It’s a change of mix as well as scale.

⁵ Based on World Bank data on the historical ratio of Fixed Capital Formation to GDP and OECD projections of GDP growth.

- Low carbon investment (power generation and transport) increases from USD 10 trillion to USD 18 trillion under the 450/2DS scenario.
- Investment in transmission and distribution is similar under the two scenarios (USD 4 trillion).

The additional investment for power and transport sectors (i.e. excluding building and industry sectors) is \$2.1 trillion.

2.2 Operating expenses

Lower operating expenses — primarily from avoiding operating expenses in the extraction, refining and transport of fuel — are the major driver of savings in the low-carbon transition, across both power and transport. The savings from lower operating expenses create value throughout the economy, since the saved cash can be put toward more productive investments. Table 2 lists the change in operating expenses we estimate for each type of asset; Figures 4 and 5 illustrate the changes in operating expenses over time. Note that the transition to a 450 ppm/2DS scenario results in a net reduction in operating costs for both power and transport.

Box 2 explains why this calculation is based on operating costs rather than prices for fossil fuels.

2.3 Use of capital stock: Depreciation and Amortization

Our analysis above shows that around \$39 trillion of additional capital will need to be invested in a 450 ppm/2DS scenario between 2015 and 2035. Although that much capital will need to be invested over the period, only a portion of this capital will be actually used

Figure 4: Impact of the low-carbon transition on operating expenses in power (\$billion)

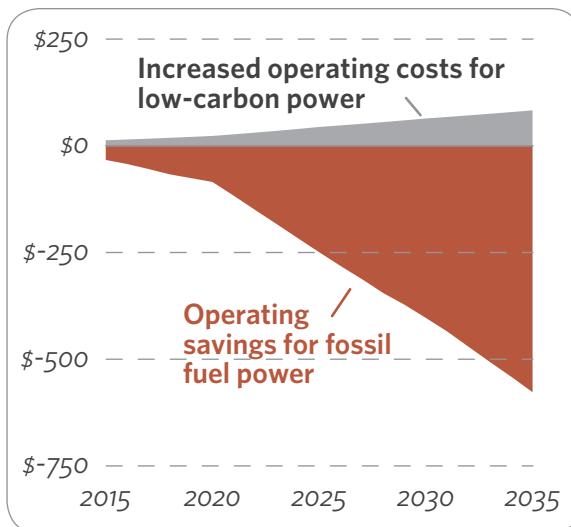


Table 2: Change in operating expenses for the major types of assets in the two transitions (BAU to 450/2DS)

TYPE OF ASSET	CHANGE IN OPERATING EXPENSES (IN USD TRILLION OVER 2015-2035)
Coal Mining and Domestic Transport	-3.3
Coal International Transport	-0.5
Gas Production and Transport	-0.3
Fossil Fuel Generation	-1.5
Nuclear Power Generation	+0.4
Renewable Energy Power Generation	+0.6
SUBTOTAL — POWER	-4.6
Oil Production, Refining, Transport	-3.9
Fossil Light Duty Vehicles	-1.4
Low Carbon Light Duty Vehicles and Mass Transit (Plane, Ship and Rail)	+2.6
SUBTOTAL — TRANSPORT	-2.8

Note: This is based on typical O&M costs for the different types of assets and this is derived from pure players' annual reports and IEA OECD NEA Projected Costs of Generating Electricity (2010). Please note that this operating expenses numbers in this table cannot be directly related to the capital expenditures numbers in Table 1 as not all the investment requirements end up playing a role in the power sector and transport transitions (fossil fuel to chemicals or industry for instance).

over this period; that is, an investment made in 2015 with a 40-year expected life would only be half used during these 20 years. Accountants and financiers use the concept of depreciation and amortization to account for the cost of assets with different lifespans.

Figure 6 illustrates this relationship between upfront capital expenditures, depreciation and amortization

Figure 5: Impact of the low-carbon transition on operating expenses in transport (\$billion)

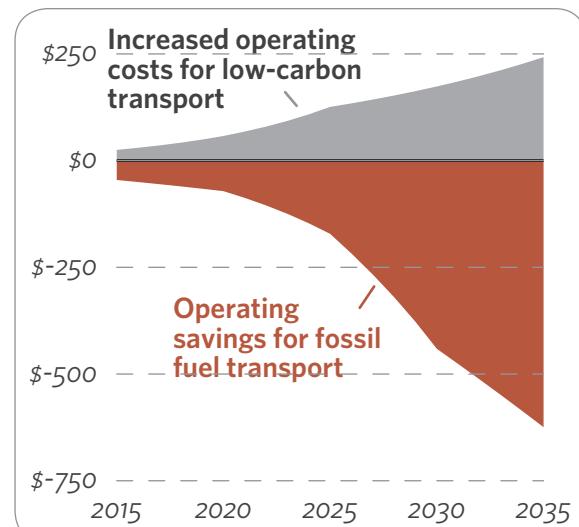
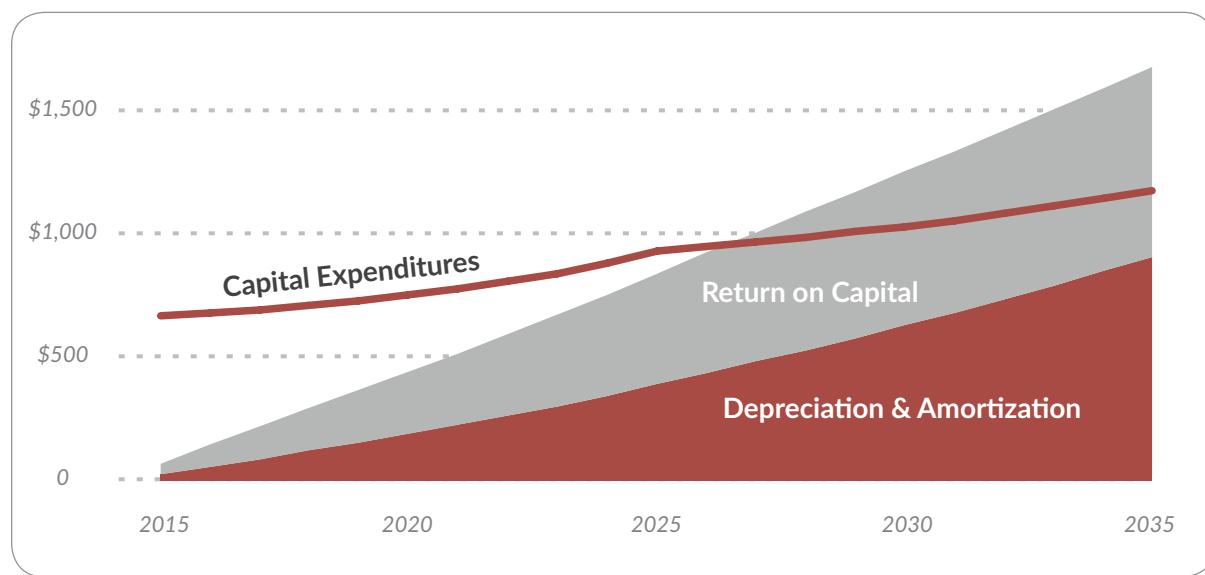


Figure 6: Relationship between incremental capital expenditures, depreciation and amortization, and return on capital for the power generation transition (USD bn., 450/2DS scenario)



Note: This is based on CPI Stranded Assets models (for oil, gas, and coal), and CPI analysis based on IEA WEIO 2014 and IEA ETP 2012.

(D&A) of capital expenditures, and corresponding return on capital for the case of the power sector transition only. Our analysis looks at capital investment in two parts: D&A and return on capital (the financing costs associated with the capital investment). As shown in Figure 6, D&A is much lower than upfront capital expenditures on a year-by-year basis during the period shown, because it is spread out over the full lifetime of the investment.

Different types of energy assets have different useful lifetimes, and therefore different D&A rates. In the power sector, power plants tend to have long lifetimes, but coal and gas extraction infrastructure is relatively short-lived. This means that assets associated with low-carbon electricity are longer-lived on the whole than fossil fuel assets, because low-carbon electricity does not require upstream extraction equipment. In transport, the useful lives of fossil fuel and low-carbon passenger vehicles are similar, but rail and mass transit have much longer lifetimes.

Table 3 summarizes the D&A assumptions applied to different types of investment in our analysis, based on industry and company analysis.

2.4 Financing costs

Assets require investment returns on the entire value of the investment, not just on the portion used (amortized) during a given period. Here the total investment pot will be much larger for the low-carbon asset group, meaning that financing costs will grow as well. However,

Table 3: Useful lifetimes for low-carbon assets involved in the energy transition are generally longer than for high-carbon assets

TYPE OF ASSET	AVERAGE INVESTMENT LIFE IN YEARS (DEPRECIATION AND AMORTIZATION)
POWER – FOSSIL FUELS	
Coal Mining	15
Gas Upstream Investment	10
Gas Transport Investment – Global Markets	25
Fossil Fuel Generation Investment	25
POWER – LOW CARBON	
Nuclear Generation Investment	30
Carbon Capture and Sequestration Investment	20
Renewable Energy Investment	20
Power – Other	
Transmission Investment	25
TRANSPORT	
Oil Upstream Investment	10
Oil Transport Investment	25
Oil Refining Investment	20
Light Duty Vehicles Investment (gasoline engines, diesel engines, LPG/CNG, hybrid, plug-in and EV, and fuel-cell vehicles)	5
Plane, Ship and Rail Investment	20

Note: This is based on typical investment lifetimes and pure players accounting assumptions for investment depreciation.

Box 2: Financial impact depends on costs, not prices

In estimating the financial impact of the low-carbon transition, this paper takes the perspective of the global economy as a whole. This means that costs, rather than market prices, are central to the calculation of financial impact.

For example, the price a consumer pays for a barrel of oil can be broken down into two components: the actual cost of extracting and delivering the oil, and the profit earned by the producer. From the perspective of the economy as a whole, only the producer's cost counts as an expense; the profit is simply a transfer of wealth from consumers to producers. A transfer between entities in the economy (producers, consumers, or governments) does not register as a loss or gain unless it has an additional impact in the global economy. In the case of profits, that additional impact comes in the form of stranded assets, discussed in section 2.5. An ongoing decline in profits lowers the value of the underlying asset, which means that there is less money available to invest throughout the economy. As we will see in the next section, loss of value in a low-carbon energy transition is limited, or can be minimized, with the right policies.

the difference in financing costs depends on the cost of capital as well as the total pool of investment.

High capital costs for infrastructure investments impose costs on the economy beyond the individual projects or borrowers. In general, the cost of capital reflects the perceived riskiness of an investment. Investors have a limited appetite for risk, so there is a limited supply of capital available to higher-risk investments: growth in investment in one high-cost sector will make it more difficult for other high-cost sectors to find investors.

Much low-carbon energy infrastructure — in particular, renewable energy — currently faces higher capital costs than are justified by its risk profile. The result is not only that the resulting cost of energy is higher than it could be, but also that low-carbon infrastructure is drawing capital away from other higher-risk, higher-reward investment opportunities. Beyond what this means for investors, this has an impact on the economy as a whole.

The cost of capital for low-carbon assets is lower

Not meeting the required investment return means that investors will misallocate their capital by diverting it to alternative uses, including possibly less productive uses like money markets or futures trading. This can also create bankruptcies, which end up being costly to

societies and have detrimental secondary effects on the global economy.

New investment models are emerging that can lower the cost of capital for renewable energy projects, in combination with market and regulatory reforms — these solutions are discussed further in Box 3. Our modeling assumes that some of these reforms take effect, lowering the cost of capital for renewable energy from current levels.

Table 4 lists the required return on investment (cost of capital) for the technologies involved in the two transitions discussed in this paper. Overall, the required return on investment is lower for low-carbon assets because they are generally lower risk than the high carbon assets they replace.

Why is low-carbon energy lower risk than fossil fuel energy? Although fossil fuel generation technologies are well established, fossil fuel investment must still manage substantial risks across the supply chain, including exploration and transportation of the fuel. The riskiness of fossil fuels can be observed in their historically volatile prices. Fossil-fuel power generating assets are exposed to this risk as fossil fuels have to be purchased as inputs. This is particularly true when the fossil fuel generator is participating in a competitive electricity market and is not guaranteed a fixed return for the power it sells.

Renewable energy investments, by contrast, are not exposed to volatile inputs, and deliver electricity over the life of the investment at low operating costs (up to 90% of the total cost of a wind or solar plant is in the

Table 4: Cost of capital for low-carbon assets involved in the energy transition is generally lower than for high-carbon assets

TYPE OF ASSET	RETURN ON INVESTMENT (WEIGHTED AVERAGE COST OF CAPITAL)
POWER – FOSSIL FUELS	
Coal Mining Investment - Internationally traded coal, or domestic markets in countries with lower financing costs	9%
Coal Mining Investment - Domestic markets in countries with high financing costs	12%
Gas Upstream Investment	12%
Gas Transport Investment - Global Markets	6%
Fossil Fuel Generation Investment	10%
POWER – LOW CARBON	
Nuclear Generation Investment	6%
Carbon Capture and Sequestration Investment	10%
Renewable Energy Investment - Low Interest Countries	6%
Renewable Energy Investment - High Interest Countries	10%
POWER – OTHER	
Transmission Investment	6%
TRANSPORT	
Oil Upstream Investment	12%
Oil Transport Investment	6%
Oil Refining Investment	6%
Light Duty Vehicles Investment (gasoline engines, diesel engines, LPG/CNG, hybrid, plug-in and EV, and fuel-cell vehicles)	6%
Plane, Ship and Rail Investment	9%

Note: This is based on typical investment lifetimes and pure players disclosed weighted average costs of capital. This analysis presents a scenario where costs of capital for renewable energy decline from current levels due to the implementation of policy and financial reforms. Interest rates are separated out for renewable energy because of the significant difference in capital costs across countries; there is less variation in fossil fuel capital costs.

initial investment) and with a high degree of predictability. Thus, renewable energy sources can supply electricity at lower risk, if not at lower cost, than fossil fuel generators.

Whether the inherent low risk of renewable energy translates to a low cost of capital depends on the policy and market structures in place. If renewable energy

generators can sign long-term contracts to provide power to a credible off-taker, they are not exposed to fuel price risks. But if renewable energy generators participate alongside fossil fuel generators in a competitive market, they will receive a market price based on fossil fuel costs — and will still be exposed to fossil fuel price risk. In many countries, low-carbon energy also faces risks associated with policy uncertainty, the credit-worthiness of off-takers, and currency risk; addressing these factors would lower the cost of renewable energy considerably. Box 3 discusses policy and financing solutions that could help renewable energy projects access low-cost financing.

The same argument holds true for some investments in the transportation sector. Investment in oil extraction is risky, and accordingly, its capital costs are high. For passenger vehicles, investment risks are more related to the consumer than the vehicle itself, so the cost of capital would likely not change much in the transition to low-carbon vehicles.

Lowering the cost of capital for low-carbon energy infrastructure would yield broader benefits to the global economy. The lower risk of renewable energy sources could lead to lower overall financing costs: equity investors would require a lower rate of return, and more of the total investment could be financed through debt. The lower financing costs would not only reduce energy prices but would also free up capital for savings and investment. From the investor side, relatively risk tolerant capital is then freed to invest in new businesses elsewhere in the economy.

2.5 The impact of stranded assets

Stranded assets are the final piece in our analysis of the financial impact of the transition to a low-carbon energy system. Owners of existing fossil fuel assets may find that the value of their assets could fall in a transition. Valuable assets and the cash flows that they generate are used to underpin future investments. Reducing the value of these assets removes investment potential from the economy. Unlike capital and operating expenses, declining asset value does not represent a cost, but a one-time hit to the financial system. Therefore, we have discounted this investment loss to 2015 to reflect the impact on the system.⁶

⁶ Stranded asset values are discounted at an 8% return, reflecting typical average capital costs for fossil fuel companies invested in moderate to low risk assets. This represents the return in the general market that the re-invested revenues from these assets could support were they not to be stranded. Higher or lower discount rates affect the headline number, but do not materially alter the relative impact and insight that this analysis brings.

Asset stranding could limit the ability of the financial system to finance new investments. When the value of an existing asset falls, there is no obvious immediate cash impact on the economy. After all, the physical asset is still an asset that could be used in the same way as before, only the price has changed. However, there is an important impact on the ability of an economy to finance its growth and investment needs. Take the example of a homeowner whose house value falls 50%. After the price drop, the owner may no longer be able to borrow against the house to finance home improvements or buy additional properties, and, in the worst case, may no longer be able to pay off the debt. For the energy industries, stranded assets related to the transition could be particularly important if the very companies we expect to finance the transition, like electric utilities, are the ones who no longer have the financial firepower to make new investments. For the economy as a whole, a large enough quantity of stranded assets could cause systemic risk that could have an impact throughout the global economy.

The numbers we use for estimating stranded assets value for the two transitions in the next sections are from CPI's report for the Commission, "Moving to a Low Carbon Economy: The Impact of Policy Pathways on Fossil Fuel Values." The report details who is at risk, the role policy can play in the value and allocation of stranding, the market structures of different fossil fuel markets and linkages between them, and the perspective and risk for the different types of investors.⁷

Note that the calculations in this paper represent only a portion of potential stranded assets — the portion of coal in power and the portion of oil in transportation, but not other coal or oil end uses (chemicals, etc.).

⁷ Climate Policy Initiative, 2014. "Moving to a Low Carbon Economy: The Impact of Policy Pathways on Fossil Fuel Asset Values." <http://climatepolicyinitiative.org/publication/moving-to-a-low-carbon-economy/>

Box 3: Ways to improve the risk/reward equation under a new climate economy

Several innovations are underway in business models, policy, and finance that can help match low-carbon energy infrastructure with investors better suited for their low-risk, low-return profile. In particular, new financing arrangements, industry structures and market designs that better reflect the infrastructure characteristics of many of the assets underpinning the low-carbon transition (particularly renewable energy assets) could help improve the risk/reward equation. Some promising options include:

- Develop commercial investment vehicles that provide investors direct access to low-carbon infrastructure including renewable energy. These alternative investment vehicles, including YieldCos, municipal finance, and crowd funding, may reduce the annual investment return requirement by 1-2% and in so doing reduce the cost of renewable energy by up to 20%.^a
- Explore expanding direct financing of low-carbon infrastructure by regional, municipal and national governments to reduce capital costs — potentially using national infrastructure banks, infrastructure bonds, or green bonds as instruments. Such direct infrastructure finance also reduces costs by as much as 20%.^b
- Apply other financing instruments that can reduce risk and help attract low-cost private financing — for example, offering risk guarantees, or taking on a share of risk associated with a pool of low-carbon infrastructure investments.^c
- In middle-income countries facing high interest rate environments, replace all or a portion of support for low-carbon infrastructure, such as feed-in tariffs, with low cost debt. This would reduce the total subsidy (including debt concession) by as much as 30% or more; reduce the cost of energy; and harness other benefits from renewable energy such as reducing foreign currency needs to buy imported fossil fuel. For countries where currency exchange risk contributes significantly to the cost of debt, indexing a portion of renewable energy tariffs to foreign currency can also help, by

allowing the government to assume some of the cost of currency hedging that would otherwise add significantly to the cost of the project.^d

- Develop or strengthen the capabilities of national development banks to perform this new role of providing low-cost debt to low-carbon infrastructure projects, while enhancing systems to ensure the efficiency of project selection and development. These banks may be an appropriate conduit for international financial flows into the industry.^e
- For low income countries, continue multilateral and bilateral development bank assistance as a major source of investment and aid for energy system and infrastructure development. Where needed, development finance institutions should be strengthened or created to support low-carbon financing.^f
- In both developed and developing countries, consider restructuring the electricity industry, market design, and regulation to take advantage of the infrastructure characteristics of the low-carbon assets and appropriately allocate risks between investors, consumers and governments. The nature of this restructuring would depend on the market, but potential measures might include lowering barriers to entry in the electricity generation market or creating separate markets for flexible generation.^g
- More broadly, policy measures such as pricing carbon, eliminating fossil fuel subsidies, and supporting the development of new low-carbon technologies also change the risk/reward equation in a positive direction for low-carbon infrastructure. In particular, providing predictable long-term revenue support can bring down the cost of financing for a renewable energy project.^h

a Climate Policy Initiative, 2014. Roadmap to a Low Carbon Electricity System in the U.S. and Europe. Available from: <http://climatepolicyinitiative.org/publication/roadmap-to-a-low-carbon-electricity-system-in-the-u-s-and-europe/>

b Ibid.

c Examples include: The World Bank, n.d. Climate finance options: IFC partial credit guarantees. Washington, DC. Available at: <http://www.climatefinanceoptions.org/cfo/node/152>. Global Climate Partnership Fund, n.d. Shareholder Structure. Available at: <http://gcpf.lu/shareholder-structure.html>.

d Climate Policy Initiative, 2014. Finance Mechanisms for Lowering the Cost of Renewable Energy in Rapidly Developing Countries. Available from: <http://climatepolicyinitiative.org/publication/finance-mechanisms-for-lowering-the-cost-of-renewable-energy-in-rapidly-developing-countries/>

e Bloomberg New Energy Finance (BNEF), 2013. Development Banks: Breaking the US\$100 billion a year barrier. New York. Available at: <http://about.bnef.com/white-papers/development-banks-breaking-the-100bn-a-year-barrier/>.

f Organisation for Economic Cooperation and Development (OECD), 2013. Putting Green Growth at the Heart of Development. OECD Publishing: Paris. Available at: <http://www.oecd.org/dac/environment-development/putting-green-growth-at-the-heart-of-development.htm>.

g Climate Policy Initiative, 2014. Roadmap to a Low Carbon Electricity System in the U.S. and Europe.

h Climate Policy Initiative. 2011. The Impacts of Policy on the Financing of Renewable Projects: A Case Study Analysis. Available from: <http://climatepolicyinitiative.org/publication/the-impacts-of-policy-on-the-financing-of-renewable-projects-a-case-study-analysis/>

3. The financial impact of the power sector transition away from coal

The preceding section outlines how incremental investment needs to be adjusted to account for asset life, operating expenses, risk and return, and stranded assets to assess the full financial impact of an energy transition. Figure 7 and Table 5 summarize these adjustments for one of the key components of the transition: moving to low-carbon energy to replace fossil fuel fired generation (primarily coal).

3.1 Operating expenses

While the transition to low-carbon electricity requires more capital investment than business-as-usual, this increase is more than offset by significant savings in operating expenses. For example, coal mining is less investment intensive than low-carbon energy, but coal mining requires substantial operating costs to mine the coal and transport it to the power station where it will be used. If that coal is replaced by wind energy, the reduction in mining, transportation, and other operating costs more than offsets the additional investment in wind. Coal fired power stations themselves have higher

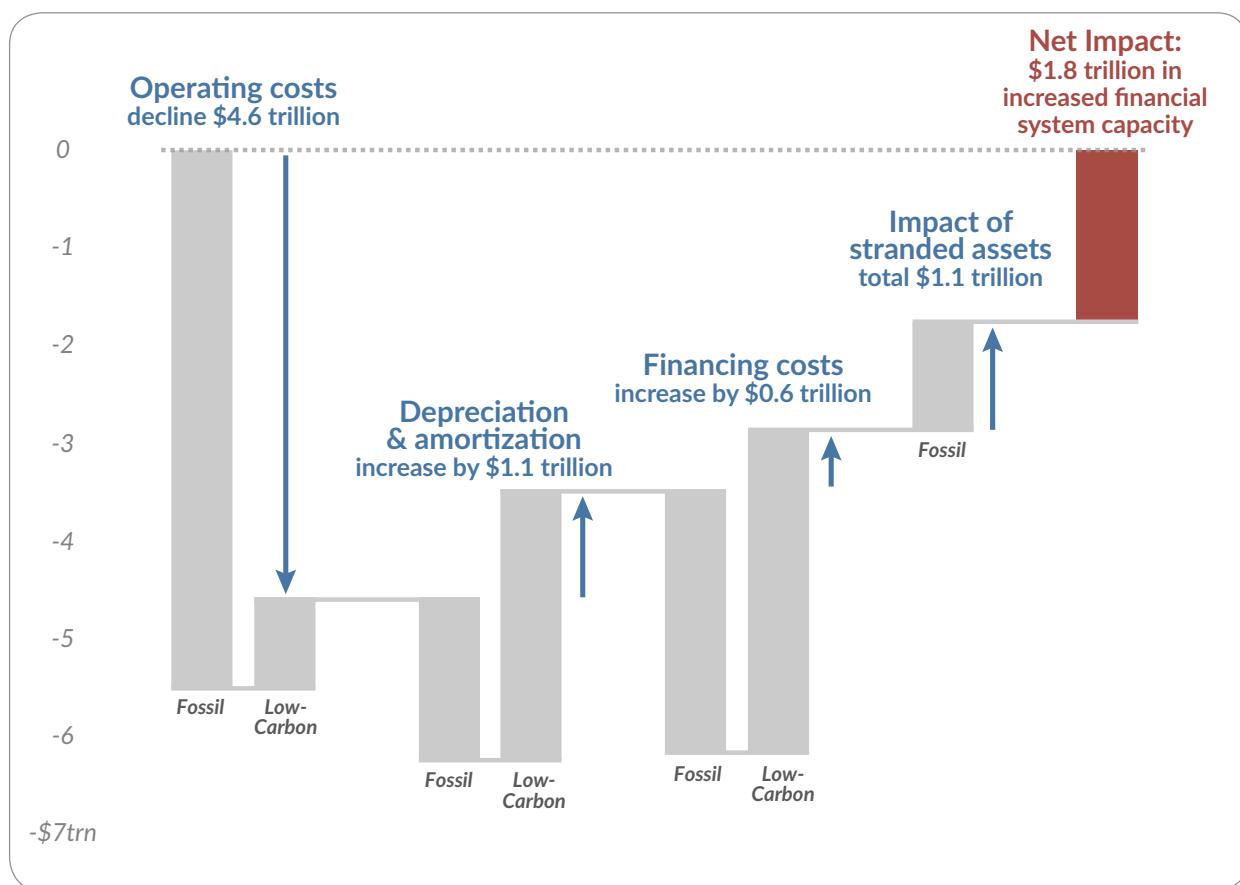
operating expenses than comparable renewable energy generators, even when the costs of purchasing fuel are excluded.

We find that operating expenses associated with fossil fuel power — excluding fuel use in power plants which is already accounted for in the fuel production expenses — will fall by \$5.5 trillion. The incremental costs of generating more low-carbon electricity, including nuclear fuel, will consume \$900 million between 2015 and 2035. These estimates are based on the IEA investment paths and our modelling for upstream gas, oil and coal (these analyses are based on commercial databases, including the Rystad oil and gas production economics database and a variety of industry and government data sources). Total operating costs, including both fossil fuel and renewable energy, will fall by \$4.6 trillion.

3.2 Depreciation and Amortization

Our analysis shows that \$2.8 trillion of additional capital will be used, or amortized, between 2015 and 2035 for

Figure 7: In the electricity transition, increased investment in low-carbon technology is offset by avoided operating costs



Note: These figures are based on CPI Stranded Assets models (for oil, gas, and coal) and CPI analysis based on data from IEA WEIO 2014, IEA ETP 2012 (2DS scenario), Rystad and Platts. Depreciation and amortization, financing costs, and operating costs are undiscounted, accumulated expenses over the period from 2015-2035. Stranded assets represent a one-time reduction in asset value.

renewable energy, nuclear energy, carbon capture and sequestration and transmission under the IEA's 2DS scenario compared to business as usual. Table 6 details the different trajectories for investment under the business-as-usual and low-carbon pathways. The total amount of additional capital invested in these low-carbon activities is \$6.8 trillion, but our analysis indicates that by the end of 2035, \$4 trillion of this additional would be available for continued production after 2035. Thus, although \$6.8 trillion of additional capital would be invested under the low-carbon scenario, only \$2.8 trillion of this capital would be amortized for the 2015 to 2035 period.

Our analysis shows that reducing coal and gas consumption in power plants would avoid about \$1.7 trillion of fossil fuel D&A (and avoid a further \$2.8 trillion that would not be fully amortized and would still be on the books as of 2035).

3.3 Financing costs

For the electricity transition, total financing costs are higher under the low-carbon system because the volume of investment is greater. However, the difference in financing costs is not as large as the difference in total investment, because the cost of capital is lower for low-carbon assets.

In our modeling, we assume that low-carbon energy infrastructure will be financed with lower-cost capital than fossil fuel infrastructure, because of its lower risk. Once the incremental cost and relative risk of investments is considered, our modelling suggests that the transition will require \$600 billion of additional investment return to investors (i.e., financing costs) over the twenty year period.

In total, while the transition will consume \$1.1 trillion more capital during the period and incur an additional \$600 billion in financing costs, total capital and operating expenses actually fall by \$2.9 trillion over the 20-year period.

3.4 Stranded assets

For the power transition we estimate asset stranding — or the decline in asset value due to reduced prices for ongoing production as well as delayed or curtailed production resulting from the transition — to reach approximately \$1.1 trillion. Coal mining investments comprise the majority of lost value, with gas production assets also feeling the impact. The impact on power plants is relatively small, as there are policies easily available to manage coal plant stranding risk. We believe that this \$1.1 trillion is likely to significantly overstate the impact on financial markets as valuations currently seem

Table 5: Financial impact of the power sector transition

TECHNOLOGY	CHANGE FROM BUSINESS-AS-USUAL TO 2DS PATHWAY, 2015-2035 (\$TRILLION)				
	OPERATING EXPENSES	DEPRECIATION AND AMORTIZATION	FINANCING COSTS	STRANDED ASSETS	TOTAL
Coal	-3.7	-0.4	-0.4	0.6	
Gas	-0.3	-0.2	-0.1	0.4	
Fossil fuel power plants	-1.5	-1.1	-2.2	0.05	
SUBTOTAL - FOSSIL	-5.5	-1.7	-2.7	1.1	-8.8
Nuclear	0.4	0.3	0.5		
Renewables	0.6	2.1	2.2		
CCS		0.5	0.8		
Transmission and distribution		-0.2	-0.2		
SUBTOTAL - LOW CARBON	0.9	2.8	3.3	N/A	7.0
Total	-4.6	1.1	0.6	1.1	-1.8

Notes: See Section 2 for discussion of methodology and data sources. Transmission and distribution is included in the low-carbon category because IEA's 2DS scenario includes energy efficiency savings that reduce the need for new transmission and distribution build. The savings due to energy efficiency offset the additional investment in transmission and distribution infrastructure needed to integrate intermittent renewable energy sources.

likely to reflect some action towards reduced fossil fuel use.

3.5 Net impact

When the cost of finance and the one-time cost of asset stranding are taken into account, we estimate that the transition would have a net financial benefit of up to \$1.8 trillion in the case where demand and fuel mix reaches

the IEA's 450 ppm scenario. However we should note that this is based on just one scenario. We should also note that the IEA scenarios assume a significant increase in energy efficiency in the 2DS scenario. We have not attempted to value either the investment or operating costs of energy efficiency, except to note that much energy efficiency, if it can be achieved, has a net financial benefit, some, but not all, of which is reflected in the \$1.8 trillion figure.

Table 6: Capital expenditures, depreciation and amortization, and remaining value of fossil fuel and low-carbon technologies in the business-as-usual and 2-degree pathways (\$trillion)

	TOTAL CAPITAL EXPENDITURES, 2015-2035	DEPRECIATION AND AMORTIZATION, 2015-2035	VALUE REMAINING IN 2035
Fossil Fuel, 2DS	2.7	1.5	1.2
Fossil Fuel, BAU	7.2	3.2	4.0
CHANGE, BAU TO 2DS	-4.5	-1.7	-2.8
Low-Carbon, 2DS	16.3	7.1	9.2
Low-Carbon, BAU	9.6	4.4	5.2
CHANGE, BAU TO 2DS	6.8	2.8	4.0V

4. The financial impact of the transport sector transition away from oil

The electricity transition is not the only one that is characterized by higher capital expense, lower risk and lower operating costs. The same story plays out in an oil transition to higher electric vehicle penetration, fuel substitution, more mass transit and higher efficiency. In this case, we again used a combination of the IEA 2DS and business as usual scenarios with our modeling.

Figure 8 and Table 7 summarize the financial impact of the transition from oil to low-carbon transport.

4.1 Operating Expenses

We find that the increased use of invested capital with lower operating costs for the IEA's 2DS case is nearly entirely offset by the reduced cost of oil production, refining, transport and fossil fuel powertrains in the business-as-usual scenario. Low-carbon technologies in transportation, while capital intensive upfront, have significantly lower associated operating costs relative to fossil fuel technologies. For example, hybrid and plug-in electric vehicles are more expensive than gasoline

or diesel powered light-duty vehicles, due largely to increased production costs associated with batteries, but they reduce the need for upstream operating costs associated with exploration and transportation of oil.

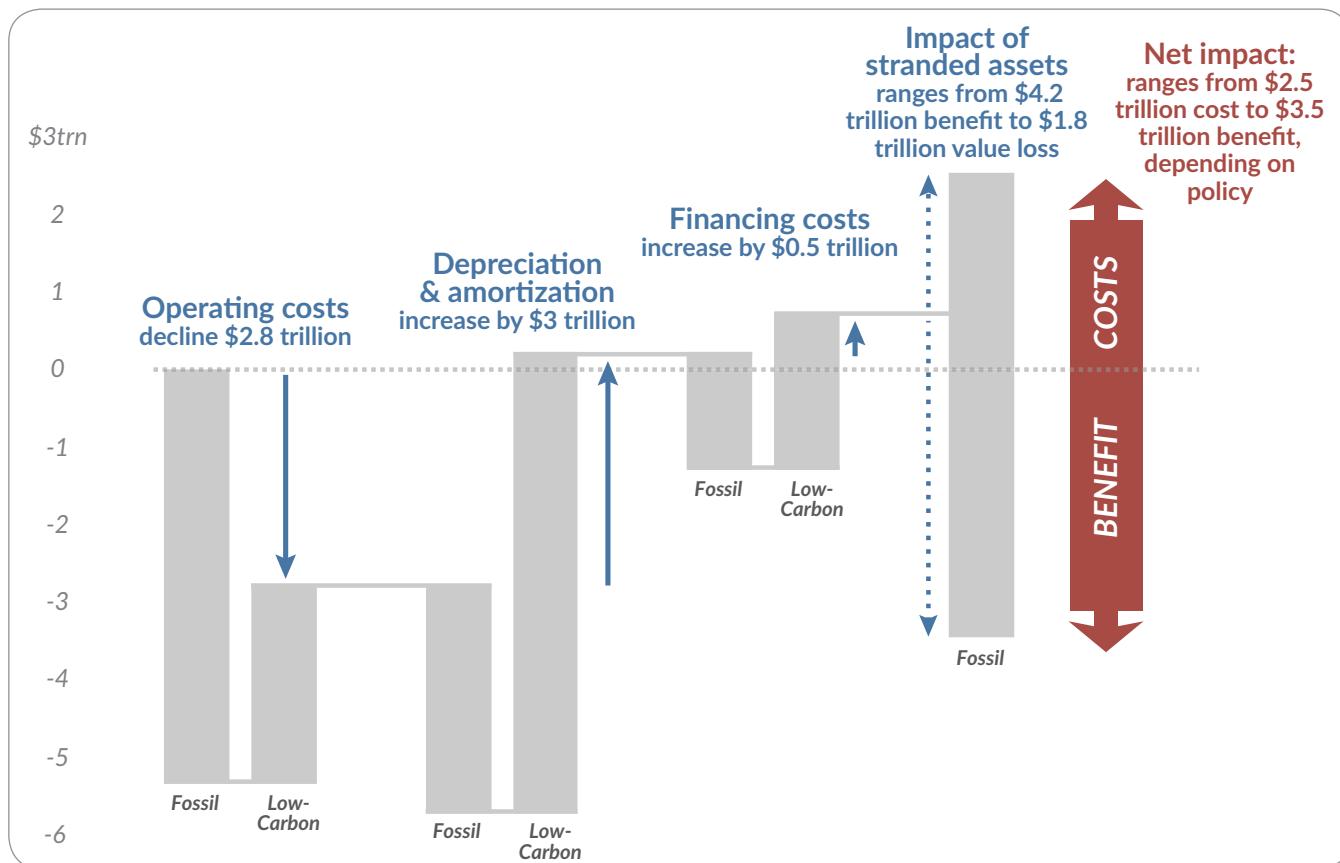
4.2 Depreciation and Amortization

In the transport sector transition we find that a further \$6 trillion of capital will be amortized for low carbon technologies between 2015 and 2035 under the IEA's 2DS scenario relative to business as usual. For fossil fuels nearly \$3 trillion of additional capital use is avoided as low carbon technologies are more widely adopted in the 2DS scenario. Taken together, we estimate that just over \$3 trillion in capital will be needed to transition from the business-as-usual scenario to the 2DS.

4.3 Financing Costs

As was the case in the power sector transition, lower risk and higher capital investment lead to slightly higher financing costs: Financing costs grow by \$500 billion

Figure 8: Financial impact of reducing oil in transport depends on policy decisions that affect asset values



Note: These figures are based on CPI Stranded Assets models (for oil, gas, and coal) and CPI analysis based on data from IEA WEO 2014, IEA ETP 2012 (2DS scenario), Rystad and Platts. Depreciation and amortization, financing costs, and operating costs are undiscounted, accumulated expenses over the period from 2015-2035. Stranded assets represent a one-time reduction in asset value.

Table 7: Details of the transport sector transition

TECHNOLOGY	CHANGE FROM BUSINESS-AS-USUAL TO 2DS PPM PATHWAY, 2015-2035 (\$TRILLION)				
	OPERATING EXPENSES	DEPRECIATION AND AMORTIZATION	FINANCING COSTS	STRANDED ASSETS	TOTAL
Oil	-3.9	-1.5	-1.2	-4.2 – 1.8, depending on policy choices	
Fossil fuel light-duty vehicles	-1.4	-1.5	-0.3		
SUBTOTAL - FOSSIL	-5.4	-3.0	-1.5		RANGE: -8.1 TO -14.1
Hybrid, plug-in, and electric light-duty vehicles (includes electricity cost)	1.8	4.5	0.8		
LPG, CNG, and fuel cell light-duty vehicles	0.3	0.6	0.1		
Plane, ship, and rail	0.4	0.9	1.1		
SUBTOTAL - LOW CARBON	2.6	6.0	2.0	N/A	10.6
Total	-2.8	3.0	0.5	Range: 1.8 to -4.2	Range: 2.5 to -3.5

in the 2DS scenario compared with business as usual. Reductions in capital investments for fossil fuels that lower financing costs by \$1.5 trillion are offset by an even greater capital investment in low carbon transport that increase financing costs by roughly \$2 trillion – despite low carbon technologies having slightly lower return on investment requirements from investors.

In total, before considering stranded assets, the global transition would decrease global financial capacity by around \$750 billion cumulatively for the 20 years from 2015 to 2035.⁸

4.4 Stranded Assets

Our oil supply and demand curve modelling and analysis demonstrates the impact of policy on asset stranding. Here we looked at the impact of the transition on consumers as well as producers and the government. The impact that lower demand would have on benchmark, wholesale oil prices is far more important to producers as a group than lost production, though both will have a negative impact on producers. But when prices fall, consumers benefit.

Policies that reduce consumption or force consumers to switch transport due to costs – for instance through higher consumption taxes – result in a net loss for the

economy due to consumers' loss of value. However, if new and lower-cost transport options — perhaps developed through innovation policy — attract consumers away from oil-based transport, the economy wins. Our modeling of the implications of these two different policy approaches informs the range for oil asset stranding in Table 7 and is presented in greater detail in CPI's publication "Moving to a Low Carbon Economy: The Impact of Policy Pathways on Fossil Fuel Asset Values." In that paper, we calculate that the net impact of the low-carbon transition would range from \$3 trillion in net cost under a pure price-based policy pathway to \$7 trillion in net gain under a purely innovation-driven transition. Transport accounts for approximately 60% of the world's oil use,⁹ so we apply 60% of the oil stranding figures here.

4.5 Net Impact

Including all of the cost elements, a purely tax or cost based policy would decrease global financial capacity by \$2.5 trillion over 20 years while pure innovation would increase financial capacity by \$3.5 trillion. In practical terms, a mix of policies will be needed as higher prices are a major spur to innovation and tax receipts can be used to invest in innovation. Meanwhile, the more successful innovation is, the lower taxes will be needed to reach a low-carbon trajectory.

⁸ Calculated as the total cost of depreciation and amortization, financing costs, and operating expenses for the period 2015 to 2035: (all in billions) \$3,012 + \$507 - \$2,777 = \$742 billion

⁹ International Energy Agency, 2013. Key World Energy Statistics. Available at: <http://www.iea.org/publications/freepublications/publication/KeyWorld2013.pdf>.

5. Conclusions and policy implications

Policymakers at all levels should consider the full financial picture when evaluating the potential gains or losses from transitioning to a low-carbon system. We find that in the transition from fossil fuels to renewable electricity, the savings from avoided fossil fuel investment and operating costs would more than offset the increased capital investment and stranded assets, leading to a net financial benefit of up to \$1.8 trillion from 2015-2035. For the transition from oil to low-carbon transport, the net impact will depend on policy choices that affect asset stranding. Policy choices that reduce demand for oil

with a combination of taxes and innovation could lead to a financial benefit of over \$3 trillion for the low-carbon transition in transport. Both of these figures would grow significantly if health and environmental benefits of reducing emissions were taken into account.

Decisions by policymakers, regulators, and institutional and other investors (discussed in Box 3) have a major influence on the financial impact of the low-carbon transition. In both cases, given the scale of investment needed, reducing the cost of capital is critical.