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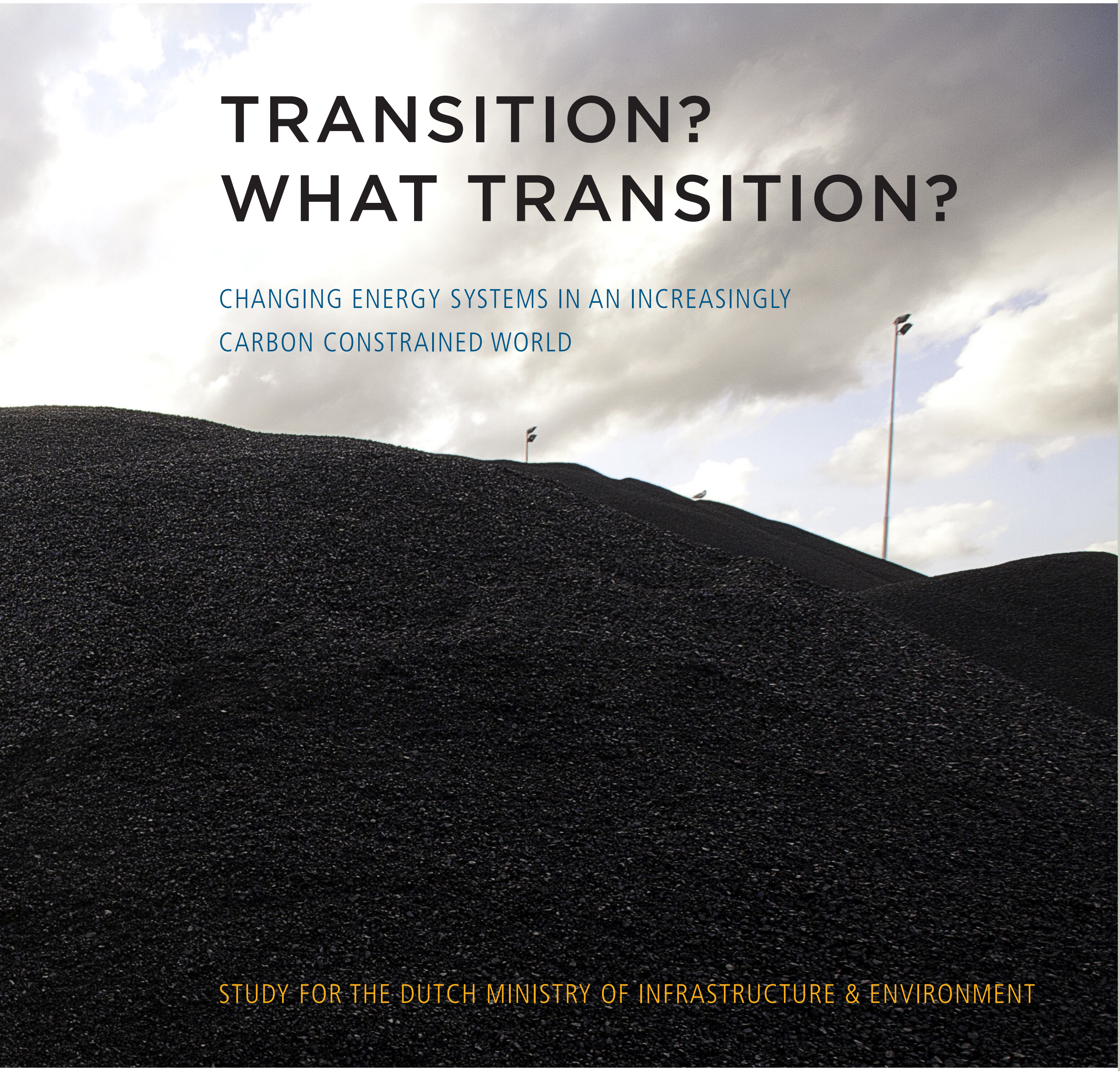

TRANSITION? WHAT TRANSITION?

CHANGING ENERGY SYSTEMS IN AN INCREASINGLY CARBON CONSTRAINED WORLD

STUDY FOR THE DUTCH MINISTRY OF INFRASTRUCTURE & ENVIRONMENT

CIEP PAPER 2014 | 05

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TITLE
Transition? What Transition?

SUBTITLE
Changing Energy Systems in an Increasingly Carbon Constrained World

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NUMBER
2014 | 05

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PUBLISHED BY
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THIS PAPER IS A COLLABORATIVE EFFORT OF RESEARCHERS FROM CIEP, TILBURG UNIVERSITY, EDHEC BUSINESS SCOOL AND DUISENBERG SCHOOL OF FINANCE.

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EXECUTIVE SUMMARY

Energy transitions have been taking place continuously since the Industrial Revolution. These transitions primarily involve energy mixes. Changes from the traditional energy mix dominated by coal or oil to one more diverse, including natural gas, nuclear and renewables, can be rapid at a national and regional level, while at a more global level they tend to be slow to materialize. In general, countries keep moving up the energy ladder, meaning that they integrate larger and larger proportions of specialized fuels into their energy mixes for dedicated types of energy demand (heat, cooling, electricity, mobility). These fuels often emit less carbon per unit of energy consumed and, due to technological developments, create more economic efficiency and convenience for consumers. The availability of domestic sources plays an important role in the composition of a national energy mix, and the ability to transport and trade energy is crucial in matching demand and supply.

Energy resources are only 'resources' when they are needed and there is a market demand. They can also become ex-resources. Proven reserves and resources have the potential to reach the market at some point in time, but economics, politics, government regulations and backstop technologies could change these resources back into 'neutral stuff'. The implication is that resources and their production and consumption are part of the wider social and cultural complex. The claim that all potential energy sources will be developed and used is deceptive.

Governments 'own' most of the world's proven energy reserves. Proven fossil fuel reserves are still growing in size. About three-quarters of proven conventional oil and gas reserves are exploited by state companies; only about a quarter are produced by publicly listed companies. Moreover, some oil and gas developments are exploited by a joint venture of state and publicly listed companies. Coal is mostly consumed within domestic economies; only a relatively small share is traded.

This report shows some of the history of how the nature of these transitions has changed over time. Earlier energy transitions were largely the result of innovations in the market or industry, and governments merely facilitated or enabled the further development of new energy value chains and their related industries or industrial complexes. The introduction of electricity, the adoption of gasoline as a transportation fuel, and more recently LNG (Liquefied Natural Gas) are good examples. Lamp oil was replaced by electricity for lighting, and in some countries natural gas, for instance, replaced coal heating in the residential sector. In the past few decades, natural gas has also become important in the generation of electricity in the US and the EU, and the development of combined cycle technologies has furthered this development. Innovative technologies and economically-driven transitions tend to diffuse to new applications and new geographies, creating a long expansion phase with accompanying applications. In the expansion phase it is difficult for other fuels and/or energy applications to enter the market. New fuels and applications usually arise during a (temporarily) mature phase of traditional fuels, when it is easier to develop niche markets. Throughout all these developments, the position of coal in the power mix has been fairly steady.

In the past 50 years the role of government in instigating energy transitions has risen noticeably, particularly when markets have not (or not sufficiently) served the three priorities of energy policy: affordability, security of supply and environmental protection. The introduction of nuclear energy in France, Sweden, Germany and Japan are good examples of government-enforced changes of the fuel mix in the power sector. These changes were stimulated by the two oil price increases of the 1970s and reduced the role of oil in the power sectors of these countries. Brazil introduced biofuels to its transportation fuel mix during that same period. In the case of Brazil, the recent introduction of the flex-fuel vehicle truly created more market maturity for biofuels, after several decades of difficulty keeping them in the transportation mix, allowing them to now compete head on with oil products. Throughout the world, the combination of a greater focus on environmental policies and on technological-economic developments in natural gas has been a catalyst that has given natural gas a greater role in the power mix, which in some countries has been enabled by governments. The lengthy transition time is particularly important in explaining the mixed success of government-enforced transitions. These often require long periods of support to keep the new fuel or fuels afloat in the energy mix. Government-induced transitions are always tough and are especially difficult when the shift to a new energy technology competes with another (traded) fuel that is still in the midst of its expansion phase.

The emphasis on transitions lays out a different way of thinking about the approaches to the phenomenon known as the ‘carbon bubble’ or the potential of future stranded assets and value loss in the fossil energy industries as a result of climate change policies.. The use of coal without CCS is by far the biggest contributor of CO_2 per kWh. With China’s consumption of coal being a little over 50% of the world’s total, most efforts should be focused there. Nevertheless, even though a substantial switch in China's power sector fuel mix from coal without CCS to natural gas would be a major shift in China's energy system, its impact on the global CO_2 emissions reduction would be more modest. In reality, replacing coal in the Chinese economy with natural gas or introducing a significant rate of CCS is unlikely. The implication is a continued contribution of coal to CO_2 emissions. This potentially reduces the carbon space (the amount of remaining carbon emissions in a 2°C in 2050 scenario) of other fossil fuels that have a much higher rate of energy per unit of carbon emitted.

In any case, if the world were able to come to an unprecedented level of cooperation with regard to climate change policies, fossil fuels would nevertheless continue to play an important role in the global energy mix (see for instance the 450 scenario of the IEA).[1] A core message is that the role of coal without CCS, as the largest source of future CO_2 emissions, would need to be addressed first. Such a policy focus would allow space for fuels with a higher energy output per unit of carbon emission to stay in the mix for a longer period of time. A global agreement to reduce the role of coal without CCS or another abatement technology would also help to keep important oil- and gas-producing countries interested in addressing climate change before 2050.

It seems, however, unlikely that the world will agree any time soon to push for a quick and definitive transition to a joint low-carbon economy, particularly in the current unstable geopolitical and economic situation. In this environment, national interests are most likely to prevail, in which the short-term costs of transition are easier to quantify than the long-term costs of climate change and therefore weigh more heavily. Germany is a closely watched example of government-enforced transition in which the short term costs are deemed high and the outcome with regard to carbon emissions remains unclear, despite the major strides the country has made in introducing renewables. Nonetheless, it is worth emphasizing that progress at the national level may result in a gradual development towards a low carbon economy. Moreover, given the experience in earlier national transitions and the current awareness of companies and investors of carbon abatement policies, a quicker transition, which may be possible, is also taken into account.

This report presents the position that the value of energy firms is complex and does not only depend on the carbon dioxide-bearing proven reserves of coal, oil and gas, as has often been assumed in prior literature. Technology, along with the ability to

1 A scenario presented in the *World Energy Outlook* that sets out an energy pathway consistent with the goal of limiting the global increase in temperature to 2°C by limiting concentration of greenhouse gases in the atmosphere to around 450 parts per million of CO_2" - http://www.iea.org/publications/scenariosandprojections/

manage technically and organizationally complex projects, is also part of the value that these companies create. Also, the logic of an earlier transition to move to higher quality fuels, which produce more useful energy per carbon emitted, underpins the value of oil and gas companies. It is therefore understandable why investors treat coal companies with more caution with regard to their future value than they do oil and gas companies. The 'harvest' of carbon emissions reduction will be the greatest with a change in the use of coal (at least in its use without CCS or when not combined with biomass), and thus investors may be right in expecting coal to be the first to be exposed to emissions reduction policies.

This report concludes that oil and gas companies should not expect, as a result of carbon abatement policies, to have materially different roles within the next 20 years. The market dynamics may change, since oil and gas firms will have to increasingly compete with renewable fuels for their market share. It also concludes that the coal sector, on the other hand, will likely undergo material changes to the business due to external shocks such as changes in climate change policy and local air pollution regulation.

1 TRANSITION

INTRODUCTION

The energy and climate change discussion has recently focused on the potential of future stranded assets and value loss in the fossil fuel energy industries as a result of climate change policies. This discussion is taking place under the name 'Carbon Bubble', where publicly listed companies and investors are scrutinized regarding their role and contribution to climate change.[2] The assumption is that if the world wants to stay within the limits of a 2°C temperature rise, atmospheric concentration of carbon dioxide (CO_2) should not exceed 450 ppm. Since the largest share of CO_2 emissions can be attributed to energy,[3] and since emissions compound, a 'carbon budget' emerges for the world.

NO CLEAR PATHWAY FOR TRANSITION

Given a growing world population and continuous economic development, the current energy system will soon push emissions over the upper limit of the 2°C policy goal. Limiting CO_2 emissions in order to avoid this scenario will require dramatic changes in the global energy system in the coming decades, ranging from energy efficiency improvements to CO_2 capture and storage (CCS) to substituting fossil fuels with renewable energy sources. These changes are often referred to as a 'transition to a low-carbon economy'.

Differences exist between countries' capabilities and capacities, as well as their ideas of the best path to follow. This creates diplomatic discourse on the time frame of the transition and the type of solutions that are available. Uncertainty about future technologies, business models and government policies make the transition path unclear. Both government policies and economic opportunities could invoke more technology push and pull, creating new avenues for transition. These avenues may not be known today: past experience suggests that surprising developments are more the rule than incidental.

Transitions in the energy system are not new; they have been ongoing since the Industrial Revolution. 'Transition' is in many ways a container word for many types of change to the global energy system, ranging from the introduction of completely new

2 Carbon Tracker, http://www.carbontracker.org

3 IEA, CO_2 Emissions from Fuel Combustion, Highlights 2013.

energy sources and energy system operations to a more gradual process with modest changes over a long period of time. Countries have evolved from energy economies based on firewood and direct wind and water use, to coal-based economies and thereafter to economies with a much more diverse energy mix, including oil, natural gas, hydro, nuclear, and recently also renewables such as wind and solar power. There is large variation in timing and in the evolving patterns. A country's energy mix is a result of its available energy resources, its economic development and its ability to adopt new energy technologies and consume new energy services. Last but not least, government policies also determine the energy mix.

MARKET– AND GOVERNMENT-DRIVEN TRANSITIONS

In the past such transitions resulted primarily from market developments in which the role of government was merely that of a facilitator. Often these transitions involved changes in which either demand for heat, power, cooling and transportation could be serviced more effectively by another fuel, or they involved the development of new applications, shifting fuels to serve a higher value of demand.

The immediacy of climate change requires that governments now drive the transition. This is not an easy task; the scale of the current energy system is vast and involves multi-trillions of businesses. The money flows in investment, trade and government incomes are enormous, and the fossil fuel value chains represent vested interests of both commercial enterprises and governments. The notion of a carbon budget for the world is pressurizing the incumbent energy industry to compete for limited emission space.[4] While transitions in the past consisted of sharing the growth of energy demand, the current government-led transition often involves policies that constrain demand and set aside a growing share of demand for low-carbon renewable technologies. Given the vastness of the current global energy system, in order to successfully arrive at a low-carbon global economy governments will have to take care to set the pace in a manner that avoids marginalizing the incumbent energy industries, considering the expected high costs and time sensitivity involved. To deliver on the low-carbon future, governments should contemplate constructive policies that include both fossil fuel and renewable energy industries and their stakeholders.

The global energy mix, relevant in the discussion about climate change, is not the level at which actual transitions take place. These have a much more local or regional dynamic. Nevertheless, new energy technologies and their benefits tend to diffuse over time to other economies, particularly when energy applications are offered in global markets. Despite the fact that coal, oil and natural gas industries are global

4 David Hobbs, *Energy Transitions – Cornering a Tiger?*, KAPSARC, 2014.

industries, responsible for substantial energy flows between countries, regions and continents, the energy mix of a country is largely determined at a national or supra-national (EU) level. The global reduction of carbon emissions is thus the sum total of national efforts to adapt the energy systems around the world to achieve a modern (low-carbon) energy economy with secure and affordable energy at its core.

At a global level transition appears to develop slowly, taking many decades, while at the national level transitions can be quite rapid. In a world with widely differing levels of economic development and government intervention, agreeing on a system to reduce carbon emissions has proven politically very difficult, in part because carbon emissions compound, implying that both past and future emissions must be accounted for.[5] The up-front abatement cost, intended to avoid the predicted long-term costs of climate change, increases the short-term cost of energy, while the distribution of costs and benefits may differ over time and per country. The expected costs of abatement in relation to adaptation differentiate preferences further. In some countries first mover opportunities in renewable technologies are weighed against cost efficiencies in later adoption. Moreover, many countries have other more urgent policy issues (poverty, health, education and domestic and/or regional conflicts) than committing to energy policies which would increase the cost of energy when externalities are priced in. In international relations the world is grappling with a diversity of interests and abilities to adopt new energy technologies and energy services with a lower carbon footprint. This brings the transition back to the levels where it has taken place in the past: the national or regional level and the sector or company level.

The desired transition also has implications for the asset base of energy-producing or -processing companies in various parts of the energy value chain, which will have to change from a resource base representing a certain carbon content to an asset base with either a lower carbon content or technologies to reduce and/or capture and store CO_2 emissions. These latter technologies could also be part of the asset base of energy-consuming companies and of companies producing goods that consume energy. Although these are not part of the energy industry, they could offer more cost-efficient applications and/or centralized points for CO_2 capture.

5 In the UNFCC, countries have discussed carbon abatement policies for two decades in their Conference of the Parties (COP). Some progress was recorded, but an over-arching agreement is missing. Instead, countries emphasize their national efforts. The G-8 confirmed in 2009 in L'Aquilla, Italy, that temperature should not rise above 2ºC of pre-industrial levels, agreeing that emissions should decline 50% by 2050, and implying an 80% decline for industrialized countries. http://www.g8italia2009.it/static/G8_Allegato/Chair_Summary%2c1.pdf

In this paper we look at the roles of technology, economics and governments in driving past energy transitions and juxtapose them against issues at play in the current transition. It will become apparent that there is no framework or model available for the current transition; each earlier transition had its own set of drivers and occurred in different situations and times. Earlier transitions were often driven by technology and economics, with government merely playing a facilitating role. The current transition, however, will rely largely on government policies, while the economy and technology must follow. This will impact the market and business models of companies involved in the energy sector. This paper will also analyse the impact of the market valuation of companies with carbon-holding reserves. This task will nevertheless suffer from the same incompleteness as other studies in bringing together the economic, technological, sociological and political aspects of transition. We refer to the wide body of literature on the various perspectives of transition and in particular to the various contributions in the journal *Energy Policy* (for instance nos. 38 (2010) and 50 (2012). But in the words of Roger Fouquet (*Energy Policy* 38 (2010)): "No matter how many studies are completed, future transitions will remain uncertain. Yet there is room to reduce our uncertainty. Economic analyses of historical transitions have tended not to disaggregate, to consider complex linkages and identify processes of change." The contribution we will make here is to identify the lessons for governments when implementing their transition policies.

In the next sections we will first look at the development of the energy mix and the way the carbon space is filled before looking at transitions that are based on technology and economics and where governments mostly play a facilitating role. We then turn to the role of companies and their valuation and conclude with a section of the different roles government can play in transitions.

2 EVOLUTION OF THE ENERGY MIX

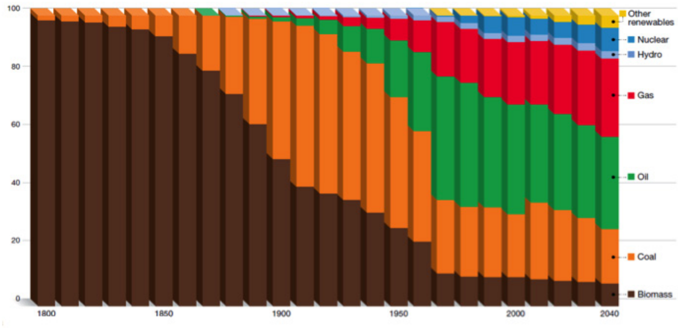
In the work of, for instance, the Carbon Tracker Initiative, publicly traded companies with proven fossil fuel reserves are investigated for their potential of having stranded assets if carbon emissions are reduced in accordance with the 'carbon budget', i.e., if their proven reserves become 'unburnable'. The calculation of the carbon budget is subject to some discussion, because certain greenhouse gases (GHG) are included in some studies but not in others (IFCC, IEA, IMF). The Carbon Tracker Initiative lists fossil fuel reserves according to energy resources and capital markets.[6] In the distribution of proven reserves over capital markets, only a small share of total proven fossil energy reserves are taken into account because, according to the World Energy Outlook (WEO) 2013 of the International Energy Agency (IEA), approximately three-quarters of oil and gas reserves belong to the asset base of state companies. Also, new proven reserves are still being added to the asset base of both publicly traded companies and non-traded companies (state companies).

The problem of the carbon bubble is mainly approached from the perspective of financial markets and the value of the potentially stranded assets of those companies.[7] In the valuation of companies, the short-term orientation may skew the proper pricing of the risk of stranded assets. Although the approach of the Carbon Tracker is interesting, the period of time in which value may or may not be realized is very long and is not in accordance with the way these assets are already valued by the companies. Moreover, the destruction of value, as referred to by the various studies, is not so unique as they make it appear. Plastics have replaced applications of wood and steel, while carbon fibres are replacing plastics.

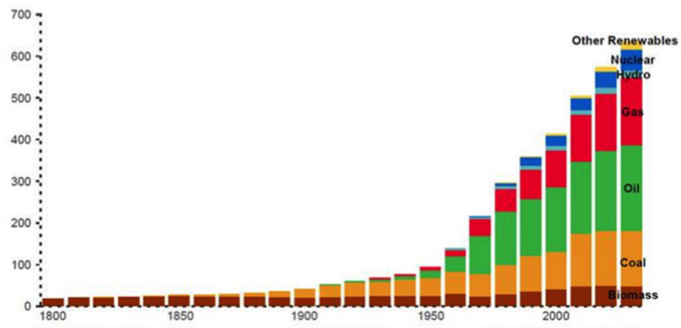
In the BP 2035 Outlook[8] the development of the global energy mix is described as follows: "(…) Taken together, fossil fuels lose share but they are still the dominant form of energy in 2035 with a share of 81%, compared to 86% in 2012." While the relative share of fossil fuels in the global energy mix has slowly increased, total energy demand and supply has also been growing consistently (see Figures 1 and 2).

6 Unburnable Carbon – Are the world's financial markets carrying a carbon bubble? http://www.carbontracker.org/carbonbubble#
7 Carbontracker.org
8 www.bp.com

GLOBAL FUEL MIX BY DECADE PERCENT



GLOBAL DEMAND BY FUEL QUADRILLION BTUs



FIGURES 1 AND 2. GLOBAL ENERGY MIX IN SHARES AND IN VOLUMES; EXXONMOBIL OUTLOOK 2040, 2012

At the same time, the carbon intensity of countries has declined as a result of a relative decline of coal (which has a relatively high carbon content) as compared to energy resources with lower carbon contents (such as oil and gas) (see Table 1).

TABLE 1. POUNDS OF CO_2 EMITTED PER MILLION BTU OF ENERGY FOR VARIOUS FUELS:

Coal (anthracite)	228.6
Coal (bituminous)	205.7
Coal (lignite)	215.4
Coal (sub-bituminous)	214.3
Diesel fuel & heating oil	161.3
Gasoline	157.2
Propane	139.0
Natural gas	117.0

SOURCE: EIA, HTTP://WWW.EIA.GOV/TOOLS/FAQS/FAQ.CFM?ID=73&T=11, JUNE 4, 2014

Depending on the type of consumption (heat, cooling, mobility, electricity) or conversion technology (electricity generation, internal combustion), differences in carbon emissions among the fuels are evident (see Figure 3). Apart from the fuel used, the efficiency of one technology over another offers further gains in abatement. For instance, when used for the generation of electricity, the differences in carbon emissions among the fuels become more obvious. Put differently, gas-fired power generation offers more energy within the same carbon budget. However, in the absence of more widespread pricing of carbon emissions, coal is often cheaper, explaining its high place in the merit order of many countries. In an increasingly carbon-constrained world, however, the trade-off between carbon dioxide emissions and energy production may change.

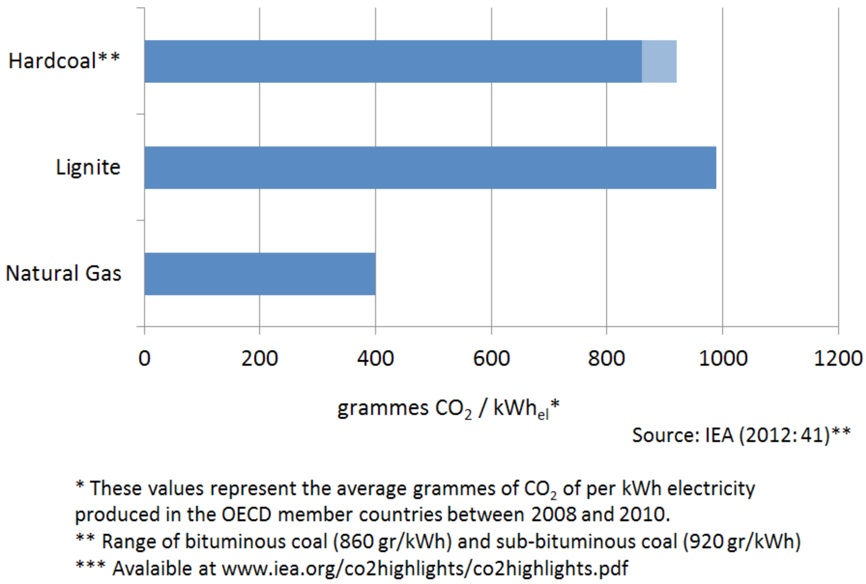


FIGURE 3. IMPLIED EMISSIONS FROM ELECTRICITY GENERATION*

The global energy mix has evolved with more or less equal shares of coal, oil and natural gas, and the share of fossil fuels is still substantial but declining. Energy efficiency and productivity play a role, too, in satisfying growing energy demand, as does the growing share of renewables.

Nevertheless, large international differences exist, often depending on the level of economic development. In some countries, coal is responsible for satisfying a large share of primary energy demand, such as in China, South Africa, Poland and Australia, while in others the share of coal is lower.[9] This also depends on the local availability of other energy resources and the ability to import or develop alternative technologies. Coal and gas reserves are much more distributed among countries than (conventional) oil. Shale resources, too, are more distributed than conventional resources.

INSTITUTIONAL EVOLUTION

The availability and exploitation of (certain) energy resources in a country also depends on the (political) ability to adopt new technologies and models of economic

9 In 2013 the share of coal in primary energy consumption was: US 20.1%, Brazil 4.8%, Czech Rep. 39.4%, Germany 25%, the Netherlands 9.6%, Poland 56.2%, UK 18.3%, Russia 13.4%, Turkey 26.9%, Ukraine 36.6%, Kazakhstan 58%, Israel 30.2%, South Africa 72.5%, Australia 38.8%, China 67.5%, India 54.5%, Indonesia 32.2%, Japan 27.1%, North America 17.5%, South America 4.3%, EU 17%, Asia Pacific 52.3%, Africa 23.4%, Middle East 1.1%, Former Soviet Union 17.4% and OECD 19.3%. BP.com/statistical review 2014.

organization. The creation of the new energy supply system during the Industrial Revolution was based on energy being produced in larger quantities and concentrated in fewer sites, along with the "mutually reinforcing interaction between coal, steam technology and iron and steel. (…) Great volumes of energy flowed along narrow, purpose-built channels. (…) Specialised bodies of workers were concentrated at the end-points and main junctions of these conduits (…) Their position and concentration gave them opportunities, at certain moments, to forge a new kind of political power."[10] As opposed to the previous period, in which energy production was more distributed and small-scale, the concentration of energy value chains and the industrial centres they supplied brought new ideas about political organization, which eventually developed into a new form of democracy. The diffusion of the Industrial Revolution was thus strongly related to societies' developing inclusive institutions which undermined the power of absolutist regimes and allowed a wider distribution of economic gains (higher wages) than before.[11] Although miners in other – non-European or American – countries also organized themselves and demanded economic benefits and political power, the lack of a connection to a large industrial production centre and thus the ability to control local energy systems did not result in the same type of institutional development.[12] Countries with absolutist regimes or and those that were colonized did not develop these inclusive institutions but rather developed extractive institutions, which hindered an economic development similar to that in Europe and the US.[13]

Some countries later managed to reverse this process and develop more inclusive institutions, adopting a more dynamic political and economic (and technologically more advanced) model of society. The adoption of the Industrial Revolution model created a wide diversity in wealth, and as a result also a wide disparity in the application of modern energy technologies. Economies with stronger inclusive institutions tend to adopt higher quality fuels sooner and more easily, because the gains and losses of these dynamic changes, also in the energy mix, are not tied to particular elites, nor to the political power in the country. Moreover, companies producing new fuels often manage to convince governments to create new markets for them, often as part of managing the various political interests.[14] Inherited wealth, such as energy resources and minerals, tends to collapse when the resources run out,

10 Timothy Mitchell, *Carbon Democracy, Political Power in the Age of Oil*, Verso, New York, 2013, p. 19.

11 Daron Acemoglu and James A. Robinson, *Why Nations Fail, The Origins of Power, Prosperity, and Poverty*, Crown Business, New York, 2012.

12 Timothy Mitchell, op.cit., p. 21.

13 Daron Acemoglu and James A. Robinson, *Why Nations Fail, The Origins of Power, Prosperity, and Poverty*, Crown Business, New York, 2012.

14 Timothy Mitchell, op.cit., p.59.

but as long it can be produced, it invokes competition among elites to capture the economic rents.[15] Created wealth and inclusive institutions help societies to renew and re-create, i.e., to benefit from technological improvements. Energy industries can be part of created wealth rather than inherited wealth sectors when they are driven by technology and entrepreneurship and when government facilitates the dynamics. The differences among institutional models and abilities to include technology in wealth creation continue to be important for the economic structure of countries and in part also influence their energy mix preferences.

PHASES OF DEVELOPMENT

It is clear that once countries have gone through the energy-intensive 'take off and expansion' phase of economic development and energy costs become a relatively smaller share of total factor costs in the production of goods (and services), their share of higher quality and less carbon-intensive fuels grows.[16] This is sometimes referred to as 'moving up the energy ladder'. It is usually related to the level of development of a country's economy and has often been facilitated by the decreasing cost of energy itself.[17] Emerging market economies (or newly industrializing countries, as they were called in the 1960s and 1970s) initially base their competitive position on relatively cheap factor costs, mainly labour and land. Their export sectors usually compete in price-competitive goods, such as textiles and other simple manufacturing, requiring relatively little know-how and capital. Once labour costs begin to increase and the knowledge level of the economy improves, they move into more quality-competitive (and more capital-intensive) sectors. The relative cost of energy declines in products with more added value, and cleaner, less carbon-intensive options become available without impeding the countries' competitive positions. When the new middle classes demand better quality of life, local issues of pollution control and security of food and energy supply gain importance, helping the energy industry to move up the energy ladder. For instance in China, demand growth for coal is tapering off. With the energy-intensive phase of economic development nearly over and economic growth in general slowing down, and with there being a switch to natural gas in urban areas along with increased investments in renewables and other measures to manage the (local) environment, coal demand could soon peak.[18] This could leave assets that have been developed to service the Chinese coal market stranded, unless other markets

15 Thane Gustafson, *Wheel of Fortune, The Battle for Oil and Power in Russia,* Belknap, Harvard University Press, Cambridge, MA, 2012.
16 BP Outlook 2035, 2014 slide pack.
17 Timothy Mitchell, *Carbon Democracy, Political Power in the Age of Oil,* Verso, London/New York, 2013.
18 Citi Research report, *The Unimaginable: Peak Coal in China*, 4 September 2013, https://ir.citi.com/z5yk080HEXZtoIax1EnHssv%2Bzm4Pc8GALpLbF2Ysb%2Fl21vGjprPCVQ%3D%3D

are found. Apart from economic considerations, security of supply constraints and domestic employment pressures could also prevent countries from rapidly switching away from coal, except where local pollution forces substitution with other fuels, initially in urban areas.

GOVERNMENT POLICIES

A reverse development became apparent in the late 1970s and early 1980s, underlining the additional importance of geopolitical factors in influencing the composition of the energy mix, when OECD countries diversified their power sectors away from oil. Some countries adopted nuclear power as the main base load in electricity generation (Japan, France, Germany, Sweden and, to a lesser extent, the US), while others adopted imported coal (Denmark) and domestic produced natural gas (the UK, the Netherlands).

Also in the EU-27 there is wide variation among national energy mixes, ranging from a large share of nuclear in France and Germany, to coal in Poland, Czech Republic and Germany, and oil and natural gas in the Netherlands, UK and Italy. Cyprus and Malta depend nearly completely on oil. Yet when presented for the EU-27 as a whole, the fuel mix looks much more balanced (see Figure 4). Also, the share of coal in the primary energy mix of the EU-27 is declining, while the share of natural gas increased

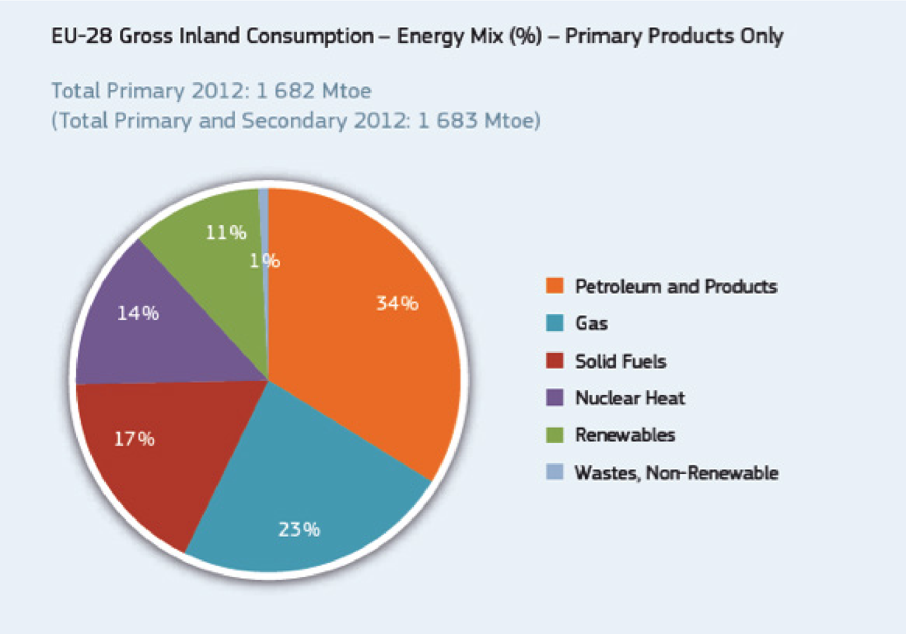


FIGURE 4. EU ENERGY IN FIGURES, POCKETBOOK 2014, HTTP://EC.EUROPA.EU/ENERGY/PUBLICATIONS/DOC/2014_POCKETBOOK.PDF

between 1990 and 2009. The diversity is based both on domestic availabilities (coal) and institutional differences. Eastern European countries, which had already been on a different development path since the Industrial Revolution and then became part of a different institution-building tradition in the Comecon, favoured the fuels dominant in the planned economy bloc.[19] This included nuclear, gas and, for some, domestic coal. As part of the EU entry conditions, Chernobyl-design nuclear facilities had to be closed and were mostly replaced by natural gas and coal.

The inclusion of Eastern European countries in the EU is still recent in terms of institution building, although some changes in the energy mix are becoming apparent. The vast energy resources of some Eastern and Central European countries (for instance Romania, Poland, Azerbaijan and Russia) were extensively exploited when the Comecon bloc was only marginally integrated in the world economy. Nevertheless, in the 1980s, rather than developing new coal fields, Russia decided to develop a natural gas value chain.[20] The development of both Russian gas fields and infrastructure (Unified Gas System) to bring it to consumers in both Western and Eastern Europe in addition to domestic consumers is still part of the legacy of its energy system today. It also proved that the centrally planned economies had developed sufficient technologies to be able to advance on the energy ladder, despite the fact that their political power structure would have suggested a more extractive development logic.[21]

The adoption of the EU 20-20-20 policy, urging EU member states to improve energy efficiency, reduce CO_2 emissions and include a 20% share of renewables in the overall energy mix, will pressure these new member states to continue to include higher quality fuels and renewables in their energy mixes. The 2030 framework will continue to push all member states in a certain direction. Despite geopolitical problems, along with a structural import dependency on gas imported from Russia, turning to coal should be made to be increasingly difficult within the framework of the EU climate and energy policy. Nevertheless, Germany is currently on exactly such a path (hopefully only temporarily) as a result of its *Energiewende*, combining large shares of solar and wind with coal in the power mix. Such a choice reflects the availability of domestic coal (lignite) and follows the country's decision to back out of nuclear and the particular internal market circumstances that pushed natural gas back out of the power mix.

19 Daron Acemoglu and James A. Robinson (2012); Gustafson (2012).

20 Thane Gustafson, Crisis Amid Plenty, *The Politics of Soviet Energy under Breznev and Gorbachov*, Princeton University Press, Princeton NJ, 1989.

21 Gustafson (2012).

The energy mix of the US has recently changed as a result of shale gas and tight oil developments. Although the American gas market circumstances played a major role in shale gas breaking through there, it took three decades of government support to develop the technology before commercial development was possible.[22] When shale gas entered the market, it had a profound impact on the energy mix. The low natural gas prices in the US market, partly due to the inability in the short term to export LNG, resulted in a switch from coal to natural gas in power generation.

At the same time substantial capacities of wind and solar are being built, resulting in increasing coal exports to world markets. Remarkably, much of this American coal finds its way to Europe, where, despite its climate and energy policy, space exists within the carbon trading system to absorb coal without a significant impact on CO_2 emission permit prices. The serious economic downturn impacted the demand for energy in Europe, while its carbon trading system was suitable for economic growth. The expansion of renewables in some member states further weakened CO_2 prices, creating a (temporary) oversupply of permits and helping coal to stay competitive compared to natural gas. With the European economy only now slowly recovering, natural gas power generation plants were mothballed or closed because they were not 'in the money'.[23] This counterintuitive development of the European energy mix can be addressed by the next round of carbon permit allocation, making sure that global and local economic developments do not thwart the policy to move away from carbon-intensive technologies or make carbon capture and storage impossible to adopt in internal market circumstances.

The composition of the primary energy mix thus depends on the availability of national resources, the type of institutions, import and export capacities, inter-fuel competition (comparative energy prices and energy subsidies and taxes), the industrial base, energy applications and government policy choices.

22 Michael Shellenberger, Ted Nordhaus, Alex Trembath, Jesse Jenkins, *Where the Shale Gas Revolution Came From, Government's Role in the Development of Hydraulic Fracturing in Shale,* Breakthrough Institute, May 2012.

23 Presentation Hans ten Berge, Secretary General Eurelectric, *The Electrcity Sector Stalled at the Crossroads?,* 4 September 2012, CIEP Gas Day (www.clingendaelenergy.com/events/2013 CIEP Gas Day).

3 FILLING THE CARBON SPACE

In the climate discussion the focus is mainly on managing CO_2 emissions in the energy sector. It is clear from Table 1 and Figure 3 that some energy sources and applications contribute more than others. At this point, the way in which the carbon budget and the ability of fossil fuels to fit into a low-carbon future are presented is important.

PROVEN RESERVES AND RESOURCES

Fossil fuel reserves are indeed large and are still growing. In terms of the number of years that production could theoretically continue at current levels, proven coal reserves are by far the largest, at 142 years (see Figure 5). With the development of shale technologies, the oil and gas resource base is expanding, although easy conventional resources are in decline due to a combination of geological and above-ground factors. Insinuations that carbon constraints on the economy were also necessary because of the near exhaustion of oil and gas resources have become less pertinent, but a distinction should be made between oil and gas reserves. Natural gas is a much younger industry. For a long time, energy companies searched actively only for oil rather than for natural gas. Yet as a result of improved LNG technologies, in the past two decades natural gas has been elevated from a national or regional resource largely dependent on pipeline infrastructure to a globalized sector. New developments in, for instance, East Africa, the East Mediterranean and the Yamal Peninsula show the potential for ongoing natural gas production.

Oil resources have been more intensely exploited, and the cost of replacing these reserves has been increasing.[24] Above-ground factors further limit the exploitation of conventional reserves, for instance in Iran and Iraq. Access to conventional oil resources is limited and often reserved for national oil companies. International oil companies have moved their efforts to technically difficult and more costly (marginal) resources in the deep offshore, tar sands and the Arctic. Tight oil production is still mainly limited to North America, but other regions show potential.

In terms of conventional sources, energy resources that have been in production for a long time, such as coal and oil, and in some countries also gas, are thus maturing. The new exploration techniques, such as a combination of horizontal drilling and

24 Apicorp, *Economic Commentary*, Volume 9, No. 7-8, July-August 2014.

fracking, have brought unconventional sources within a commercial range. However, the amount of energy and water needed to produce these new resources, climate change policies and public resistance to the technique in some countries pose constraints to the development of these resources.

Other above-ground problems could also hamper the development of resources. Nevertheless, the scarcity issue often referred to creates a false picture when discussing gas reserves, disregarding technology improvements and untapped potential around the world. In the case of oil there is more merit to this discussion, in part because oil has been politicized for much longer. Nevertheless, it is more accurate to refer to a scarcity of carbon emission space, because that also includes the coal reserves.

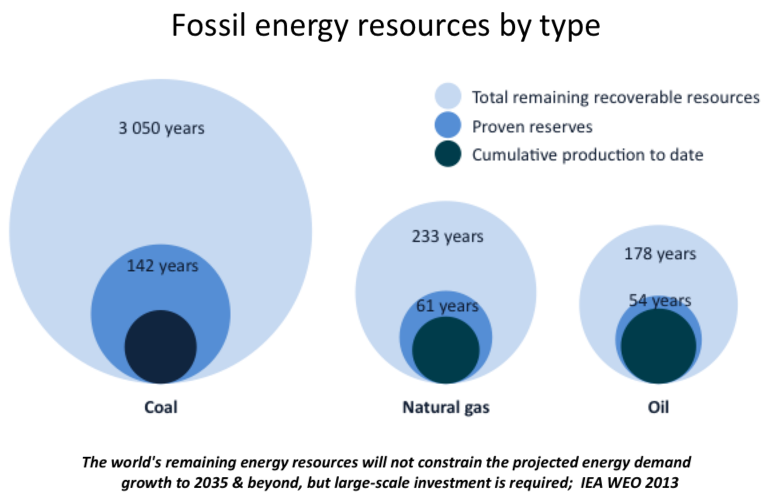


FIGURE 5. FOSSIL ENERGY RESERVES BY TYPE (IEA, WEO 2013)

FUNCTIONAL THEORY

With regard to understanding resources, and in light of claims of imminent scarcity being a reason to move away from fossil fuels, a connection to the insights of Zimmermann and his Functional Theory of Resources (1933, 1952) should be made: "Resources are not, they become; they are not static but expand and contract in response to human wants and human actions".[25] The assumed fixed nature of resources (and of their exhaustibility) creates a false impression. According to Zimmermann, resources are living phenomena which expand and contract in response to human effort and behaviour and which are, to a large extent, a human concept

25 Erich W. Zimmermann, *Introduction to World Resources (edited by Henry l. Hunker),* Harper Row, New York, 1964, p. 7.

based on knowledge and technology. Resources refer to a function which a thing or substance may perform or to an operation in which it takes part while satisfying a want. Resources can also become ex-resources when their use dissipates (and they stay in the ground). Based on Zimmermann's insights, the claim that all proven fossil fuel resources will be produced is thus deceptive. Apart from being a function of costs, proven reserves and resources show potential to reach the market at some point in time, but economics, governmental regulation and backstop technologies could change these resources back into 'neutral stuff'. The implication is that resources and their production and consumption are part of the wider social and cultural complex. Resources also embody resistances that must be overcome. Carbon could be one of these resistances. These are not only of a technological nature; air pollution and other local economic, institutional and political issues could be of influence, too.

All sort of reasons, among which short-term individual interests that ignore long-term group interests, have led to resource destruction according to Zimmermann: "As nations increase in size, as economies become more elaborate, and as global interdependence grows, the task of 'living together well', of good neighbourliness, of The Good Society, grows more difficult and the pitfalls become more numerous and deeper. Perhaps more resources are destroyed or left unborn by class struggle, internal strife, and, above all, by war, than by all other causes put together."[26] The oil and gas resources in Iraq immediately come to mind. Despite the efforts of the government to stimulate efficient production and consumption, natural gas is still flared on a large scale, while the civil problems, in addition to the (dis)organization of the sector, prevent the exploitation of its resources. The recent spill-over from the civil war in Syria is another danger to the production potential of Iraq. The rise in Iraqi oil production was cited in the WEO 2013 as a main contributor to world production growth, albeit in a less optimistic scenario than the Iraqi government would like to see.[27] With the persistent unrest in the Middle East it remains unclear how much potential will actually make it to the market and when. Civil war in South Sudan is also hindering local oil production. Afghanistan's resource potential remains untapped due to the long internal conflicts. Due to historical and socio-political problems in Bolivia, gas resources remain underdeveloped. In the US and Australia, rare earth materials returned to the category of 'neutral stuff' in the 1970s, when environmental legislation raised production costs and cheaper alternatives (without accounting for external costs) from China became available. When China recently reserved rare earth materials for domestic processing, the American and Australian mines were opened again, turning these ex-resources into resources again.

26 Zimmermann (1964), pp. 18, 19.
27 IEA, WEO 2013.

Also, in Europe, public acceptance of shale resources is so low that this potential might never be exploited. The existence of shale resources has been known for decades, but both the technology and the right economic environment were lacking to turn the 'neutral stuff' of shale into a resource. Other once-important resources have also become ex-resources. Peat, for example, was an important source of energy in the Dutch Golden Age but is now only used in winter gardens. It was replaced by human inventiveness to produce and consume coal, and in the Netherlands peat winning was quickly replaced to avert flooding of cities like Leiden and Haarlem.[28]

A modern version of the functional theory of natural resources could be the insight that the exploitation and consumption of certain resources have societal disadvantages. At the same time, Zimmermann's insights show that new solutions will be invented for the functions these resources fulfilled, for instance asbestos and coal. These solutions can have technical and institutional components, or both. In transportation, less carbon-intensive fuels are being introduced, while projected energy efficiency gains in oil-based and/or hybrid road vehicles are considerable.[29] With regard to coal, alternative technologies are in place, but the institutional framework to reduce the role of coal without CCS in the energy mix is incomplete and varies among countries.[30]

VISUALIZATION AND DEBATE

Based on these insights, the idea that *all* potential burnable energy resources are available for use is creating a wrong impression about carbon space, the valuation of carbon-emitting fuels and the companies that have fossil fuels in their books. Moreover, the carbon content of fossil fuels varies, and this difference in contribution to climate change should be taken seriously into account when weighing transition policies. In the studies of Carbon Tracker, the visualization of proven reserves in relation to the 2°C budget for this century (see Figure 6) suggests that hardly any space is available for fossil fuel consumption (at least not without CCS). The two red lines, which include the budget already used in the period 2000-2010 (small, dark green circle on the left) and the total budget of 886 $GtCO_2$ to stay within a 2°C limit in 2050 (both circles on the left), intersect the proven coal reserves nearly halfway, placing the proven oil and gas reserves definitely out of bounds. Moreover, the figure seems to assume that the production costs for coal, oil and gas will increase, thus shaping a particular supply curve. This, however, is not necessarily the case. Such a presentation makes it easier, however, to understand why all fossil fuels are approached in the same manner in the public debate.

28 Aad Correlje, column, *EnergieAktueel,* January 2014.

29 Olivier Appert, *Presentation: Lifestyles and Energy in the City,* Conseil de l'Energie, 5 June 2014.

30 Aad Correlje, column, *EnergieAktueel,* January 2014.

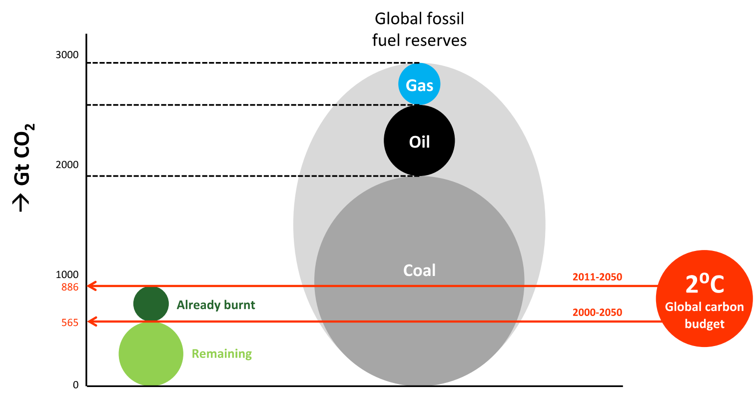


FIGURE 6. CARBON BUDGET AS PRESENTED BY CARBONTRACKER.ORG

Yet a simple redrawing of the image (see Figure 7), now with the proven oil and gas reserves at the bottom and the proven coal reserves on top, changes the impression completely; burning the current proven natural gas reserves is not necessarily in conflict with the climate change goal of 2˚C in 2050. Moreover, it includes some of the oil reserves.

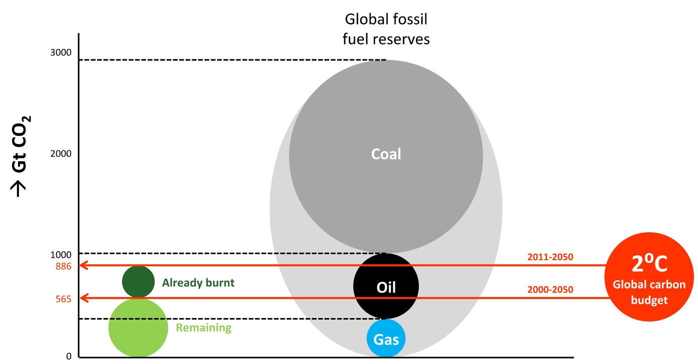


FIGURE 7. ALTERNATIVE PRESENTATION OF THE CARBON BUDGET

Although the alternative presentation clarifies the room in the global energy mix for fuels that deliver more energy per unit of carbon emitted, we have further simplified the figure, because only the height of the circles is relevant here, while the surface area of the circles is not representative for the potential $C0_2$ emissions involved. In Figure 8 we present the same concept in a bar diagram, with the presentation of Carbon Tracker on the left and an alternative presentation on the right. We have also removed the $C0_2$ emitted in the period 2000-2010 from the presentation and focus on the future (remaining budget) instead. To complete the alternative visualization, we have added Figure 9, separating the proven fossil fuel reserves to underline the individual role of fuels and potential efficient combinations that offer more energy per unit of carbon dioxide emitted.

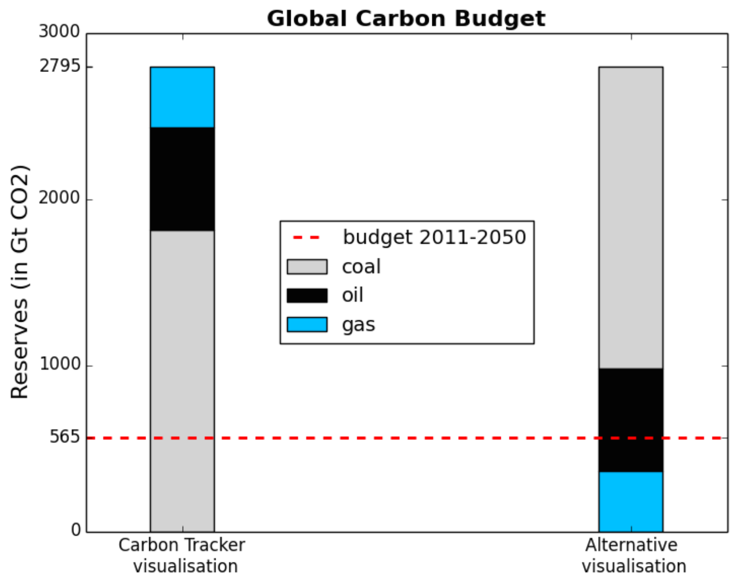


FIGURE 8. ALTERNATIVE PRESENTATION OF THE CARBON BUDGET

The ability to generate more energy per emitted unit of carbon while staying within the carbon budget depends on being able to significantly reduce the consumption of coal without CCS. It is clear from Figures 8 and 9 that the public debate about the carbon budget and its compatibility with proven gas, oil and coal reserves deserves more nuance; also because fossil fuels are needed to back up renewables in power generation as long as storage of electricity remains an issue. In heating and transportation, alternatives do present themselves, but they are only slowly gaining market share. New applications using new fuels is one thing, replacing the existing stock is another. From Figure 3 we can see that gas-fired power generation delivers more energy output per unit of $C0_2$ emitted. In a world where carbon space is constrained and energy demand is still increasing, such features should matter for policymakers driving transition.[31] Moreover, the composition of the energy mix and the choices governments make with regard to inter-fuel competition matter for transition and how the available budget is used over time.

31 "Agreements by governments on the concepts featuring in the climate change discussion, energy efficiency, energy intensity and energy productivity, would be helpful. The concept of efficiency is rather straightforward in the sense that increasing energy efficiency leads to lower emissions and less environmental impact, using the same amount of input (fossil or renewable fuels). One could argue that improving energy efficiency has no real disadvantages, since it just mitigates effects, and hence is the most effective tool for reducing global emissions. However, often governments and companies are not only concerned with impacts, but largely with economic consequences as well. Both of the other concepts mentioned do take this factor into account by measuring the amount of energy consumed per unit of economic output (energy intensity), or its reciprocal, the amount of economic output gained per unit of energy consumption (energy productivity)." Patrick Bean, Kapsarc, 2014.

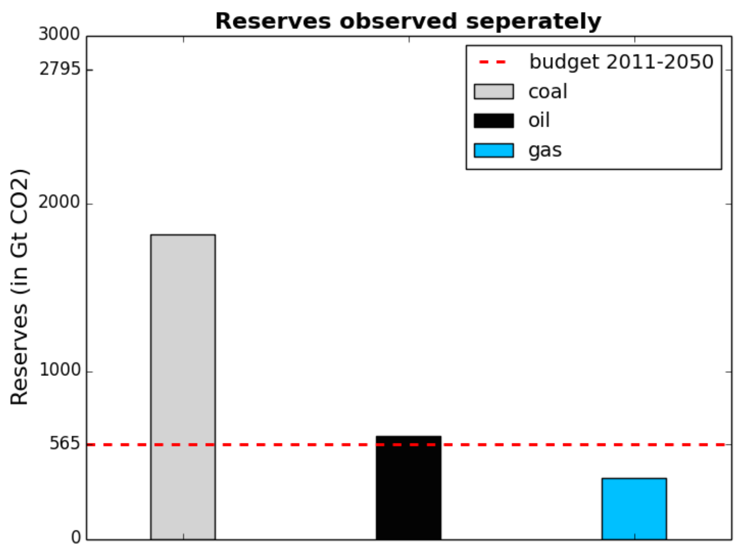


FIGURE 9. ALTERNATIVE PRESENTATION FOR SEPARATE PROVEN FOSSIL FUEL RESERVES AND THE CARBON BUDGET FOR 2°C

From Figures 6,7 and 8 we can derive some observations. The presentation in Figure 6 supports the impression that none of the fossil fuels can stay in the mix and that a radical move away from fossil fuels is the only transition path available. Figures 7 and 8 nuance this view. They clearly depict the inter-fuel competition for carbon space among fossil fuels (and their owners), showing that the continued consumption of coal without CCS or another abatement technology would be at the disadvantage of less carbon-intensive fuels in the coming decades. A global energy system aiming for the most energy output per unit of carbon dioxide emitted should develop a preference for natural gas, while a global energy system in which oil and particularly coal stay in the mix for reasons of security of supply (diversification) and energy cost (in lieu of a global system of carbon pricing) will hasten the need to employ CCS or other abatement technologies with these fuels or to replace them with carbon-poor alternatives. With regard to introducing renewables into the energy system, the impact of the necessary back-up capacities for intermittent energy sources should also be considered when determining the carbon emissions profile of a national or regional energy system.[32]

Policymakers should also be aware of the impact of installed capacities on future emissions. In Figure 10, representing a depiction from a panel of presentations on installed capacities and their expected contribution to CO_2 emissions, the global

32 Nora Meray, *Wind and Gas: Back-up or Back-out, That is the Question*, CIEP, December 2011.

installed power capacity per fuel is presented, showing a steep increase in coal capacity from 1970 onward.[33] The figure also shows that even though oil and gas power generating capacities have increased, their contribution to expected future emissions is much smaller than the contribution of coal without abatement technologies. The main future source of CO_2 emissions will be from coal-generated power stations. Some of this capacity may be retired and replaced by less carbon dioxide-intensive capacities in the course of the next decades when they reach the end of their economic or technical life.[34] Governments can shorten this lifetime when setting new efficiency and/or emission standards, and companies can do the same by deciding that the cost of investment to meet the new standards is too high compared to switching to a different fuel or energy technology. The recent measures to reduce emissions from existing plants in the US, is an example of policy measures that impact coal generation capacity.[35]

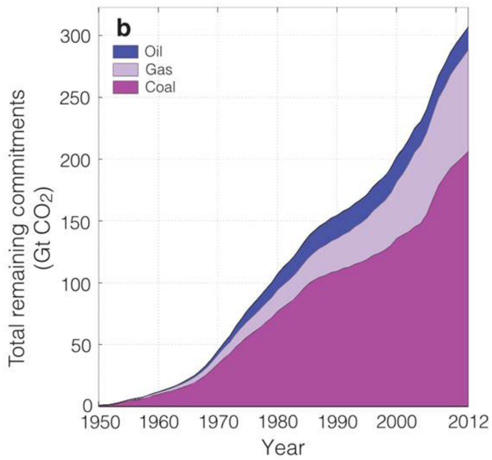


FIGURE 10. EXPECTED EMISSIONS FROM EXISTING POWER PLANTS, PART OF A PANEL OF FIGURES INVOLVING INSTALLED CAPACITY, HTTP://IOPSCIENCE.IOP.ORG/1748-9326/9/8/084018/PDF/1748-9326_9_8_084018.PDF

33 http://iopscience.iop.org/1748-9326/9/8/084018/pdf/1748-9326_9_8_084018.pdf. The depiction referred to is Figure 5b. Other figures in the Figure 5 panel of this study show that additions to capacity between 1970-1990 were mainly in the US and Europe, while most post-1990 additions to capacity were in China, consistent with government policy changes in the post-1973 period and the economic emergence of China.

34 Figure 4 of the study shows the emissions with different assumed lifetimes of the power generation plants. http://iopscience.iop.org/1748-9326/9/8/084018/pdf/1748-9326_9_8_084018.pdf

35 https://www.federalregister.gov/articles/2014/06/18/2014-13726/carbon-pollution-emission-guidelines-for-existing-stationary-sources-electric-utility-generating#h-8

The current political and economic reality is, however, that a switch in the global energy system to one that maximizes energy output per unit of emitted CO_2 is far away. The short-term inter-company and inter-government competition for economic rents from fossil fuels will override the competition for carbon space as long as carbon is not capped or priced in such a way that allows the world to stay within the 2°C limit. The inability among stakeholders to agree could influence the transition policy choices and trajectory in the future and will perhaps increase the likelihood of a sudden adaptation later on if short-term and long-terms costs of transition become more aligned. This would also explain the current faith of investors in fossil fuels assets delivering a return on capital.

GOVERNMENT AND MARKETS

The presentation of carbontracker.org is perhaps based on the geopolitical and geo-economic insight that coal without CCS, mostly consumed as a domestic produced fuel, is very difficult to ban from the energy mix without a coherent global climate change policy in place and in a world with growing security of supply concerns. Security of supply policies and employment issues in coal-producing regions can be strong incentives to keep coal in the mix, albeit at a smaller share, if, for example, China is to indeed experience a flattening coal demand as a result of slower electricity demand growth, the rise of non-coal generation capacity (renewable and natural gas) and energy demand efficiency gains.[36]

Apart from security of supply and employment reasons, the organization of the market and the impact of transition policies upon it also play a role in the development of energy mix choices and carbon emission profiles. The liberalization of the EU gas and electricity markets, for instance, has so far not delivered a merit order favouring gas in power generation, despite earlier expectations. Due to a combination of market circumstances and government policies, gas-fired power generation capacity has been retired or mothballed rather than developed into the natural companion of renewables. Germany has seen both renewables and coal-fired generation increase in market share and carbon emission go up, rather than down. Although some argue that this is temporary, in terms of the carbon budget this is a very unfortunate development.

The competition among energy resources for filling the constrained carbon space is also about competition among companies and governments to monetize subsurface and surface assets when alternative profits or sources of government income might otherwise be hard to find.

36 Citi Research/Commodities, *The Unimaginable: Peak Coal in China*, 4 September 2013.

4 INTER-FUEL COMPETITION AND OWNERSHIP

INTER-FUEL COMPETITION

There is a distinct conflict of interest among fuels. The owners of natural gas and oil reserves, as well as other market players that rely on these fuels elsewhere in the value chain, have a vested interest in making sure that coal without CCS does not usurp the carbon budget to their detriment. They prefer policies favouring gas and oil, such as carbon taxes and carbon emission schemes, in the hope that oil and gas will gain a more favourable position in the inter-fuel competition. In a carbon-constrained world, it is easy to understand that this relative advantage compared to coal without CCS can be easily acquired if carbon is priced accordingly. European governments have introduced the pricing of carbon emission permits, but these incentive fees have not been able to change the competitive position of coal without CCS or renewables in power generation. Efficiency requirements and air pollution regulations often have had a stronger impact on the merit order, while in the US abundant gas supplies and the accompanying relatively low natural gas prices did result in a switch away from coal.

In anticipation of the competition for carbon space, the coal industry promoted clean coal in the last decade, indicating that technologies to capture and store carbon would soon become part of new coal plant designs. But low carbon prices and resistance in certain countries to storing carbon output in the subsurface (for instance in onshore empty oil and gas fields in the Netherlands) have so far kept the coal industry from integrating the technology into their plants. Competition from government-backed renewable energy capacities, another emerging stakeholder in many countries, has created further uncertainty about the economic viability of CCS-equipped plants.

Coal trade has grown in recent decades because of Chinese demand, but the share of oil in the energy trade is still the most substantial. With China moving up the energy ladder, the growth of global coal demand depends on energy mix developments in other emerging markets, such as India. The recent change in coal demand in China could impact international coal prices in the short term, stimulating cost-sensitive economies to favour coal over less carbon-intensive resources. Geopolitical concerns and other security of supply issues with oil and gas have positioned coal as a 'safe fuel' in terms of geopolitical supply, although this disregards the potential geopolitical dimensions of climate change.

GOVERNMENT INCOME

Apart from companies competing for carbon space, government interests also play a role. Apart from in the US, the subsurface belongs to the state, and exploitation of the subsurface can generate substantial government income. State companies control about three-quarters of oil and gas reserves worldwide, while governments also accrue income from royalties and taxes from private company exploitation. In coal, employment issues in coal-producing regions and security of supply arguments could play a role in the reluctance of governments to steer the transition away from coal or enforce CCS technologies.

Discussions about moving the world towards a low-carbon energy mix have evoked trepidation among substantial resource-holding countries. Their dependence on economic structures dominated by producing energy resources, is expressed in the contribution of these resources to their GDPs, export revenues and government income. Income from energy exports in, for instance, OPEC countries, but also in Russia, depends largely on fossil fuel production and exports to international markets. Dependencies of 50% or more on export revenues are no exception. In particular, oil is an important contributor to government income because oil rents are higher than natural gas rents. In Russia, oil and oil products contribute close to 54% of export revenues from energy.[37] These dependencies of oil-producing and -exporting economies developed over the past decades, when global demand for energy continued to grow and net-importing countries had a vested interest in the timely expansion of production capacities in these countries. In a carbon-constrained world, structural adjustments along the value chain are likely to occur, but not every oil- or gas-producing country is able to restructure the sector and move up the value chain.

In OECD countries, levies and taxes on coal, oil and natural gas consumption are also import sources of government income. The ability to replace these income flows with other income sources can pose a problem for both fossil fuel-producing and -consuming countries. Apart from generating income, the energy sector is also subject to many different types of support schemes. Many developing countries subsidize the consumption of certain fossil fuel products,[38] sometimes to help their industry through an infant stage, other times to bring these energy products within purchasing reach of the poor. Yet in Germany, too, energy-intensive industries are exempted from paying the renewable energy surcharge in order to protect their competitive position in world markets. In other countries, renewables are backed by

37 EIA, Today in Energy, 23 July 2014.
38 IEA, WEO 2013.

government support schemes to meet policy objectives. This is the case in, among others, China, Brazil, the US and the EU. The main thrust of introducing renewables is in power generation, where several conventional fuels (coal, natural gas and nuclear) also compete for a place in the merit order.

GLOBAL AND LOCAL DIMENSIONS

The conflict of interest among fuels, companies, other stakeholders and governments also has another dimension. While conventional fuels compete on global markets, transition policies are a national affair, tailored to local political, social and economic circumstances and preferences. Often, aside from targeting climate change goals, government policies also have security of supply dimensions, while the cost of energy for end-users also plays a role. Governments are struggling with the global economic dimensions of their energy mixes and with their levels of commitment to the open markets, now being so 'globalized', in addition to their (geo)political positioning. They prefer diversified energy flows and domestic fuels. The support for renewables has caught some geopolitical tailwind as a result. The implication of this policy split – searching for low-carbon options but also wanting to keep up incomes from fossil fuels – is that it may compromise the energy mix in terms of being able to reduce carbon emissions. The push for a low-carbon economy has quickly become a source of conflicting government goals and policies, which are not all conducive to an efficient transition to a low-carbon economy.

5 ECONOMICS AND ENERGY TECHNOLOGY

The Oxford Dictionary defines *transition* as: "the process or a period of changing from one state or condition to another". Translated to the global energy system, transition constitutes a "switch from an economic system dependent on one or a series of energy sources and technologies to another".[39] Depending on how these energy sources and technologies are lumped or clustered together, many of these transitions, from traditional biomass to coal, to oil, to gas, to nuclear, to hydro, and recently also to solar and wind, have been going on since the Industrial Revolution. They have provided energy services like illumination, cooling, heat and mobility.

APPLICATIONS DRIVE TRANSITION

The development of the various energy value chains over time and the types of energy demand they serve is important in understanding past energy transitions. Coal is now mainly used in power generation, and no longer for space heating, while oil is mainly used in transportation and petrochemicals, and gas in power generation, industry (heat, cooling), residential (heat, cooking) and increasingly in transportation (CNG, GtL, LNG). The various energy resources all have gone through their own development logic, becoming dominant fuels and later more specialized fuels. Natural gas is the first of the conventional energy sources which has so far not become a fuel that services both stationary and non-stationary energy demand on a large scale.[40] Electricity, too, has followed a certain development path in terms of types of energy demand it has been able to satisfy. Electricity is now used for lighting, cooking, cooling, industry, in the service sector and increasingly also in transportation (trains, buses, cars). Electricity generation is the sector in which renewable energy sources (RES) have grown most substantially, making electricity a sector where various fuels compete for a place in the merit order.

Transitions occur because new applications discover 'new' energy sources. Most energy resources were known for a very long time before they were developed into modern commercial energy resources with the accompanying services. Oil was known for its medicinal qualities and was used for lamp oil before it became a main source

39 Editorial, *Energy Policy, no. 50 (2012)* 1-7.

40 Morris Adelman, *The Supply & Price of Natural Gas*, supplement to the Journal of Industrial Economics, Basil Blackwell, Oxford, 1962: "Hence, in 1959, natural gas was a more important form of stationary energy than was oil, and either of them was more important for this purpose than coal," p. 76.

of energy in power generation, industry and transportation. On the end-use side, inventions like the light bulb and the Diesel and Otto motor created a wide range of applications. Today, oil is no longer a dominant fuel in power generation or industry. Just like with coal before it, competing fuels and government policies have replaced the use of oil in certain market segments. Oil, coal, wind and solar power show up in historical accounts; along with many other technologies that have translated energy potential into, for instance, motion and heat, they were around long before claiming their share in the energy mix. Established energy technologies are continuously optimized, until not much gain can be achieved from further tinkering and a new approach (and fuel) is needed to provide a solution or satisfy a certain demand.

The mass adoption of new fuels (or new applications for existing fuels) rests on the establishment of value chains. The examples of electricity and gasoline show that value chains can be initiated by different players and at different levels. Once an application for energy emerges from demonstration, a value chain with accompanying processing and end-user sectors can be successfully developed.[41] A prime example is electricity and the development of electric lighting sparking the start of a range of products that rely on electricity to function. Sometimes new products have demanded a new energy service, setting into motion transitions of the energy system that have developed into economies of scale and scope. These value chains can develop internationally, particularly when the energy service provided is linked to certain end-user products that also trade globally. Other examples are the internal combustion engine in vehicles and the development of the oil industry. Both of these energy technologies relied on the successful creation of markets and/or business models in their start-up phase. The new markets or business models changed the energy economics of the day, and new energy value chains were built on the initial new market (e.g. petrochemicals, but also other oil products for electricity generation).

These examples illustrate how economics and/or technology help to create new markets both at home and abroad, even if these markets have different organizational styles. In the case of electricity, the technology diffused to other economies, where new value chains were developed based on the energy technology, often by local (government-owned) utilities. In the case of gasoline, the owners of the oil value chain, which was already internationally organized in oil companies, developed the markets. The fact that refining crude oil produces results in more end-user products than one stimulated the owners of oil production and refining facilities to develop multiple markets for their products, applying pricing policies that facilitated the development of new markets.[42]

41 Daniel Yergin, The Prize: The Epic Quest for Oil, Money, and Power, 1991.

42 Coby van der Linde, *Dynamic International Oil Markets,* Kluwer, Dordrecht/Boston, 1991.

The differences in business models, product cycles and markets among the various energy technologies are due to technical specificities and price gaps between fuels. Stationary energy sources require networks to transport the energy to end-users, while the (energy) cost of transporting energy may limit the geographic reach of energy transportation. An improvement in the efficiency of transporting energy and also new ways of transporting energy from the point of production to the point of consumption create new optionality in the market. The development of the LNG industry is an example in which a new technology brought gas overseas to economies that had no or insufficient access to this resource. Government policies played their roles in supporting – and in some cases driving – the transition to an energy mix that includes natural gas. More recently, some governments have driven their economies to become linked to the LNG market for reasons of security of supply.

DYNAMIC ENERGY MARKETS

Transitions are dynamic and can be described as chains of events. The emergence of new fuels (or applications) builds on pre-existing processes and institutions rather than taking place in isolation. During a transition, technologies, institutions and the industry evolve together in a relationship of mutual influence. The history of the oil product industry is a good example of such a dynamic development. Creating various market opportunities to develop energy services can launch a particular energy technology into a long development cycle, building one expansionary product cycle on the other and dispersing to other geographic markets. Various consecutive product markets drove the oil cycle (lamp oil, fuel oil, gasoline, diesel), each time creating a larger demand volume for crude oil.[43] In addition, the refineries producing these fuels became part of a petrochemical cluster, further integrating the oil-based technology deeper into the economy. The co-evolution of technologies, industries and institutions that enables energy technology to emerge from niche markets to dominance is important, while at the same time these clusters create lock-ins.[44] For instance, average growth of oil demand per year declined to low levels as the different oil product markets matured in terms of demand and geography, stagnated and declined in some sub-markets (when fuel oil was replaced in power generation by nuclear, coal and gas), and a new and expansionary oil product cycle failed to materialize.[45] Increasing mobility in China and India could perhaps be the last major volume push for oil-based transportation fuels, unless a new oil value chain can be developed based on an entirely new functionality. Energy efficiency and competition from new fuels (natural gas, electricity, hydrogen/fuel cells), but also lifestyles and

43 Coby van der Linde, 1991.

44 Past and Prospective Energy Transitions: Insights from history, Editorial, *Energy Policy 50 (2012),* p. 2.

45 Van der Linde (1991).

compact cities with public transportation systems, can present the oil industry as we know it with different growth perspectives than before. This does not necessarily imply the demise of oil as a resource but could imply its redefined role as an energy source to be used in applications and places where no alternatives are available.

CYCLES OF CHANGE

A successful transition of an (energy) industry is not by definition the same as a successful transition of the energy system, but firms introducing new energy technologies and services contribute to transitions of the energy system. The changes in markets result in new market circumstances, conditions and structures (De Jong, 1989), to which the firms must adjust in order to survive. These adjustments can entail the restructuring of large corporations or entire sectors of the economy. The experience of Standard Oil around 1900 powerfully shows what happens when a company does not adopt a new business model in time to capture new market opportunities.[46]

In many energy product cycles, we can observe a continuation of a cycle through the expansion in new product markets or geographies (see Figure 11. The mature market then moves into an expansion phase again, resulting in de-concentration (i.e., more suppliers). Consolidation and horizontal diversification can sometimes offer temporary remedies to the decline of a firm or sector by optimizing efficiencies and market share, but eventually firms and sectors must adjust their activities to the new market logic or disappear. In such situations companies are forced to radically restructure and buy into the new markets through mergers and acquisitions (M&A) to become part of the new expansionary cycle or see their markets disappear and lose value themselves as a firm. Not all companies are successful in entering these new markets and continue to decline along with the previous cycle logic. Many of the oil company household names of the 1970s no longer exist as separately listed companies. This was the result of the restructuring necessary after the nationalization of a large part of their proven oil reserves and production assets in OPEC countries. State oil companies and other newcomers have replaced them.

New technologies do not always play the same role in transitions; they sometimes dismantle old technologies and business models and sometimes perpetuate them. New technologies can thus extend a product cycle, either because of cost efficiencies, improved services or new applications. Yet they can expedite decline when they offer improved services or create new but competing demand. The emergence of a new (energy) product cycle does not always translate into a retooling of energy capacities

46 Daniel Yergin, The Prize, 1991; Coby van der Linde, *Dynamic International Oil Markets,* 1991.

and capabilities, but rather other core competencies are sometimes used to build a completely new company (for instance Nokia).

Markets are not static but are in constant transition. As a matter of fact, markets go through a number of phases, which can result either in the cessation of a certain production stream or in its 'reinvention'. Cost structures and the levels of competition and entry barriers are the most observable variables that change throughout these phases. When markets take off and expand, the technology diffuses and other companies begin to compete in the same markets. The expansion can usually continue until a substantial market share (20-30%) is achieved and the costs to expand further begin to increase. In the maturity phase, annual growth rates begin to decline, and efficiencies of scope and scale matter for the competitive position of firms. In this phase vertical and horizontal integration of firms increases in an attempt to manage costs and benefits efficiently.

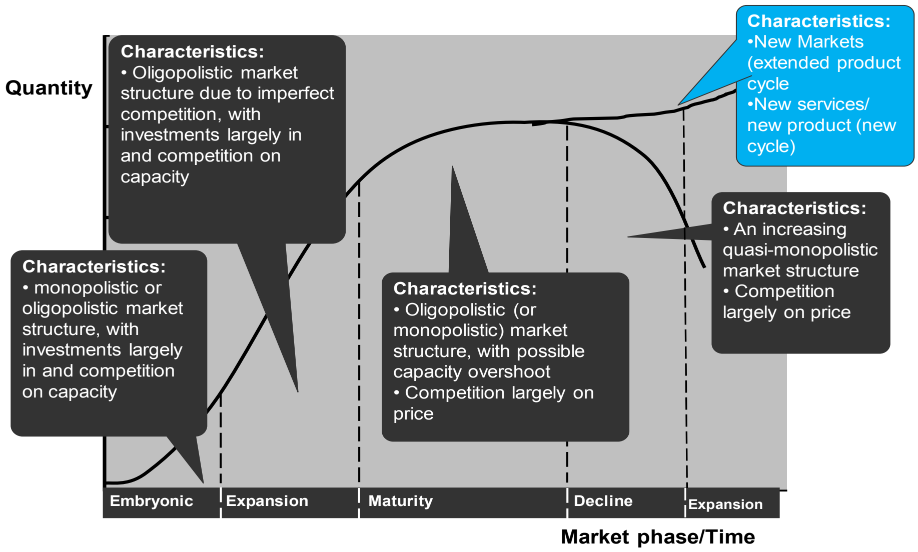


FIGURE 11. PRODUCT CYCLE

SOURCE: SMEEK, 2010, CIEP; BOON VON OCHSSEE, 2010, CIEP; BASED ON DE JONG, 1989

As entry barriers grow, a market becomes increasingly resistant to new technologies – which explains why known technologies sometimes remained unutilized for a long time.[47] This is particularly the case when the industry has substantial dedicated assets, such as processing facilities and infrastructure (for instance refineries, pipelines or ships) and applications that are dedicated to using a certain fuel. This might explain

47 Daniel Yergin, *The Quest*, 2012.

the plethora of technologies that are known for a long time but do not find a market (application) until a next round in the product cycle(s).[48] Shale gas, tar sands and tight oil were known for a long time, but the technology and economy did not allow an earlier introduction into the energy mix. Wind energy has been around for a long time, and cars have been running on natural gas (India) and biofuels (Brazil) for decades. When passenger vehicles can only consume a certain type of fuel, demand for mobility translates either into growth of that fuel demand or demand for other types of mobility. If passenger vehicles are able to use multiple fuels, as they do now in Brazil, a different market emerges. The integration of certain fuels into a technological or economic cluster, as often happens in the expansion phase when new applications become possible, secures the market for the firms. For a long time, in the absence of government policies facilitating these new markets, new entrants were unable to close the competitive gap as long as the competing fuels (coal, conventional oil and gas) could produce a similar energy service at much lower costs.

Before the maturity (or stagnation) phase is reached, new entrants must bring improved technology or cost structures to the market to successfully compete with the existing firms. Niche markets can help a new energy industry value chain to develop when such markets circumvent the 'economics' of the incumbent value chain. Another option for new energy sources or energy services is to piggyback on the established infrastructure, although here government regulation may be required to gain access. In mature markets, costs structures, reliability of service and regulation matter.

DYNAMIC COMPANIES

In the course of time, economic sectors merge or cluster, establishing new sectors, or they disappear. The continuity of sectors is large but not endless. Economic and technological developments regularly require substantial adaptations from the companies active in that sector and from governments regulating the sector. Companies are sometimes forced to make radical changes to solidify the future value of their firms. A good example is when IBM, a blue chip company with a lot of value invested in the electric typewriter, was challenged by competition from the personal computer. A radical change of the company's strategy moved its value creation away from the old business model into one that was new but still close to the company's old embedded knowledge base.

New technology can also be a driver for fuel switches and can impact the value of the asset bases of companies, when demand for the fuel is structurally changed. These changes can be positive or negative. New technologies can stimulate the

48 Ibid.

replacement of certain fossil fuels, for instance the switch from coal, oil or gas to biomass, wind and solar. Electrification of applications can help increase demand for (low-carbon) power. New technologies can also create new or renewed value for companies when new applications create new demand. In the case of low-carbon technologies, CCS can produce future value for the energy stored in fossil fuels, while technologies that improve energy efficiency and energy productivity can add value to existing reserves. These technologies help secure a larger share for fossil fuels in a low-carbon economy.

It is also possible that new technologies lead to the replacement of (certain) fossil fuels, and as such directly impact the value of companies with proven fossil fuel reserves. When power generation switches from coal to natural gas, the value of the asset base of the coal producer and the natural gas producer change because the ability to monetize the proven reserves in certain markets change. However, because energy markets are fairly integrated, a drop in demand in one market can often be compensated by an increase elsewhere. In the case of the recent switch from coal to natural gas in the US, the coal producers quickly adapted and, instead of delivering their coal on the domestic market, increased their supply to foreign markets. For proven coal reserves to be negatively impacted by low-carbon policies, such trade deflection would have to be stopped in order to harvest the improved CO_2 profile of US power generation.

In the valuation of companies in relation to a carbon budget, the type of fossil fuel and the carbon content of their reserves should be taken into account by markets. In Table 1, the difference in carbon content of various fossil fuels is listed. A distinction should be made between the impact of low-carbon policies on firms with proven reserves with high carbon content and those with lower carbon content. In an ideal transition to a global low-carbon economy, the highest carbon-containing fuels would be pushed out of the energy mix or forced to adopt carbon emission reducing strategies. Both oil and, particularly, natural gas are easier to accommodate in the transition to a low-carbon economy than coal. Of course, energy efficiencies and further technological developments to improve energy productivity are needed to secure their place in such an economy in the longer term. The current shift in the asset base of large international oil companies (IOCs) from oil to natural gas can be considered to be in agreement with the move towards a lower-carbon economy, even though access to reserves was one of the main drivers.

The value of an (energy) firm is not only a reflection of its proven reserve assets, although oil and gas production does contribute most to the economic rent extraction of these firms. Processing and distribution are often low(er) margin, but necessary, activities to monetize assets, in part due to market regulations. In the value of the firm, the technical ability and organizational capabilities are certainly also important value creating parts of these firms, while the reserves-to-production ratio of current reserves of IOCs say little about the long-term future value of the firms. The international oil companies, for instance, were confronted in the 1970s with the nationalization of a large part of their proven oil reserves and production capacity in OPEC countries. The discussion about their concessions and the distribution of income from oil production began in the mid-1950s and carried on throughout the first decade of OPEC's existence.[49] At that time, most of the processing facilities were located near production sites and oil products were exported to markets. From the late 1950s onward, in part to reduce the exposure to the risk of nationalization and in part due to changing economics in the oil value chain, processing facilities (refining and petrochemicals) were developed near oil *markets* rather than in producing countries. Investors also included the risk of nationalization of the reserves in their assessment of firms, and oil companies began to step up production to optimize their investment returns in the shorter term. In a more recent example, RD Shell was forced to sell part of its reserve assets to Gazprom in the Sachalin II project to accommodate the wish of the Russian government to have Russian participation in the project. This distinction between valuing reserves in environments that are stable and those that are unstable politically and/or regulatorily is common in the industry. Proven reserves are prone to a variety of political, economic, regulatory and environmental risks. These risks determine the likelihood that a particular firm can bring the resource successfully to the market. Portfolio risk management helps to spread these risks.

In a world keen to lower carbon emissions and manage local air quality, coal-producing companies must make more and earlier efforts to maintain the value of their reserves. Much depends on the demand for coal and the innovation of coal applications. CCS is the oft-mentioned technology that can help keep coal in a low-carbon energy mix. Unfortunately the cost of applying this technology rests with the power sector (the point of capturing). These companies will have to include the cost of CCS in their business models, while they also have other fuel options. For coal-producing companies the success of competitively internalizing the CO_2 externality is crucial if CO_2 abatement policies are to become widespread. Currently, the absence of coordinated climate change policies allows coal to flow from markets where it is competed or regulated out of the merit order toward markets where these obstacles do not exist. The carbon budget, however, spans the world. The importance of local

49 Christopher Tugendhat, *Oil, the Biggest Business,* Eyre & Spottiswoode, London, 1968.

employment, in addition to the cost of imported other fuels, feeds the reluctance of some governments to stimulate coal producers and the power sector to innovate the coal value chain. At the same time, the current relatively unhindered consumption of coal in power generation throughout the world reduces the emission space for less environmentally degrading fossil fuels in the future, such as oil and gas, and pushes other technologies to the fore (solar, wind, biomass) without taking the total impact on emissions into account.

CONCLUSION

Energy transition is of all times. The energy mix changed from being dominated by coal or oil to a more diverse energy mix that also includes natural gas, nuclear and renewables. Transitions are generally rapid at the national and regional levels and slow at a more global level. In general, countries keep moving up the energy ladder, implying their consumption of higher quality fuels for dedicated types of energy demand (heat, cooling, electricity, mobility). These higher quality fuels emit less carbon per unit of energy consumed.

The availability of domestic sources plays an important role in the composition of a national energy mix. A country's ability to transport and trade energy also affects its success in matching demand and supply.

Energy resources are only 'resources' when they are needed. They can also become ex-resources. Apart from being a function of costs and prices, proven reserves and resources show potential to reach the market at some point in time, but economics, politics, regulation and backstop technologies can change these resources back into 'neutral stuff'. The implication is that resources and their production and consumption are part of the wider social and cultural complex. The claim that all available resources will be produced is deceptive.

Addressing the role of coal without CCS or another abatement technology in the future energy mix is by far the most important in determining the attainability of the world's low-carbon goals. It also will decide the space or role for other fossil fuels, which produce more energy per unit of carbon dioxide emitted, in the mix.

Governments own most of the world's proven energy reserves. Proven fossil fuel reserves are still increasing. About three-quarters of proven conventional oil and gas reserves are controlled by state companies, and only about a quarter of the reserves are produced by publicly listed companies. Some oil and gas developments are exploited by a joint venture of state and publicly listed companies.

Most transitions are the result of innovations in the market or industry and are merely facilitated or enabled by government to further develop the new energy value chain and related industries or industrial complexes. With the introduction of new fuels, traditional fuels are replaced in certain market segments. Transitions driven by technology and/or economics tend to diffuse to new applications and new geographies, creating a long expansion phase with accompanying applications. In the expansion phase, it is difficult for other fuels or energy applications to enter the market. New fuels and applications usually arise in a phase of (temporary) maturity of the traditional fuels, when developing niche markets is easier. Transitions that spring from a period in which either a new fuel is introduced or the old fuel finds new expansion can expedite change.

Companies have been part of many transitions in the past. Business models have been adapted and new value chains developed in the course of time. However, not every company is successful in adopting these new business models. Lists of companies dominating the sector over the past five decades show the disappearance of some and the emergence of others, while some companies have proven their adaptability by featuring in the lists for many decades. Energy companies that were taken over by other companies or investors were reorganized to capture the stored value in the firm, leading to the termination of some activities. For investors to find their way in the current transition to a low-carbon economy, it is important that they understand the opportunities and risks involved. The next section focuses on these issues.

6 FINANCIAL MARKET RESPONSES TO THE CARBON BUBBLE

INSTITUTIONAL INVESTOR PERCEPTIONS ABOUT POTENTIAL CARBON EMISSION RISKS

We know from the previous chapter that the last two centuries were dominated by energy transitions that were based on the development of new energy value chains and a particular type of demand that they would serve. For the foreseeable future, fossil fuels are likely to remain the dominant source in the global energy mix. Yet new pressures from climate change and competition between different fuel sources will intensify over the next decade. As discussed above, a topic of much interest is the transition of the world's energy sector towards 2050. Identifying the alternative trajectories of the energy sector depends on drawing inferences about technology, trade, climate change politics and economic growth, and looking at how interactions between the different factors affect corporate investment and other activities. The literature on future energy developments and systems has shown how economic theory has been helpful in understanding the emergence of new energy systems.[50] This literature has demonstrated that due to many uncertainties about the key assumptions in these models, it is difficult to quantify the effects of the different scenarios of system development.

Recently, some analysts have predicted that the transition to a low-carbon economy – which could be triggered by a global political agreement to limit climate change or technology change – is likely to produce a carbon bubble. As such, this prediction is likely to raise a number of important questions about climate policies, as well as technology and economic growth. How will the shift to a low-carbon economy affect both investors and energy sector firms involved in the transition? What is the likely exposure to other sectors? In this part we study investor perceptions regarding key assumptions about a possible carbon bubble and the transition to a low-carbon economy. We do so by examining the perceptions of Dutch institutional investors regarding the transition in energy systems and their views on carbon and climate change risks. In the analysis here, we focus on whether any uncertainties surrounding a transition in the global energy system will likely influence investors away from making future investments in the fossil fuel sector.

50 OECD, *Energy: The Next Fifty Years,* Paris, OECD, 1999.

Our data comes from responses to a survey of Dutch institutional investors conducted in the third quarter of 2014. In our survey, we asked investors about the importance of the carbon risk and their potential exposure to losses due to high carbon holdings. We also needed to learn more about how they assess the carbon risk in their portfolios and implement carbon risk strategies. Next, we asked whether they would prefer measures for obtaining more financial information about the carbon risks of investments to be based on voluntary standards or regulatory requirements.

Our evidence suggests that while financial risks and social responsibility issues can influence investors' concerns about climate change and carbon risk, few appear to worry about their exposure to financial risks specific to carbon-intensive industries. At the same time, they are likely to have already invested in new tools to measure their carbon exposure and adopted strategies to invest more responsibly. Our findings suggest that most investors believe that current mandatory reporting requirements are not adequate for assessing carbon bubble risks. This may be consistent with hearsay that mandatory regulation is the preferred method for accessing additional information about carbon risk, since some measures are likely to strengthen institutional investors' abilities to interpret the CO_2 emissions as well as the production and exploration policies of fossil fuel firms. Finally, our study confirms that voluntary measures are still the preferred mechanism of allowing firms to disclose the sensitivity of their fossil reserves to possible price changes due to carbon risk. We find that an important driver for these disclosures is the communications that institutional investors have with management of the high fossil reserve corporations in their portfolios.

Methodology and Data

Previous studies have indicated that institutional investors are aware of potential risk associated to carbon emissions. However, few empirical studies have been conducted on the risk mitigation policies of these institutions. For example, information about whether institutional investors shift from high- to low-carbon-intensity firms to limit their exposure to potential carbon risk and about whether current accounting and reporting standards are adequate to assess carbon risk for their investments are generally not publicly available.

To analyse the perception of Dutch investors, we sent our survey to three large Dutch pension funds and an asset management firm. The asset holdings of these firms have a total aggregated value of 618bn Euros, showing that policies of these firms have a large impact on capital markets. To maximize the accuracy of the responses, we targeted sustainability experts within these firms. While we acknowledge the limitations in our sample size, the design of this survey allowed us to obtain more detailed responses.

The survey was anonymous, as we did not request that respondents reveal their identity. Interviews with these firms were later conducted to verify their responses and preferences. In the survey we used three different techniques in order to understand their perceptions of the carbon bubble and the importance of different regulatory responses. We asked respondents to provide 'yes' or 'no' answers to questions, numerical responses and to indicate the importance of different reasons why a carbon bubble risk might not exist in the financial market.

Perceptions About a Potential Carbon Bubble

Long-term institutional investors, such as pension funds, have raised concerns about the risks associated with a potential carbon bubble. There is, for example, evidence that in the presence of a carbon bubble that could burst and harm shareholder value, investors are likely to have a greater awareness of the corporate strategies and government policies in order to reduce the risks in their investment portfolios. As a result of such concerns, institutional investors are more likely to have lobbied lawmakers for improved disclosure standards for energy reserves and to agitate managers of corporations to disclose their environmental and social factors, climate risk and mitigation strategies for possible stranded assets. For example, ExxonMobil was one of the first publicly listed oil companies to publish a report on stranded assets that addressed the concerns of institutional investors.

The fact that long-term institutional investors are more likely to acknowledge the risks of a carbon bubble is due to their exposure to companies with the large carbon reserves. In principle, because clients of institutional investors, such as pension funds, may have long-term liabilities, these investors will respond differently to the information of un-priced carbon risks than short-term investors. To shed light on the pricing mechanism, we asked institutions to indicate whether a carbon bubble exists in terms of the overvaluation of carbon assets. In Figure 12 we show that the investors are fairly evenly split between those who find that there is a carbon bubble and others who are not sure. One of the explanations for their responses is the ambiguous definition of 'carbon bubble'. On the one hand, an argument exists that with the business-as-usual scenario, CO_2 emissions will exceed the carbon budget required to limit temperature to 2ºC, but that such a bubble would only burst if significant CO_2 prices were imposed globally in a very short time period. On the other hand, valuations of energy companies still reflect the most realistic increases in energy demand, and even if more stringent policies are adopted companies will be able to adjust their capital allocations if given sufficient time to do so. Given current energy demand, as projected for example by ExxonMobil,[51] carbon assets might not necessarily have to be overvalued.

51 ExxonMobil, 'Energy and Carbon – Managing the Risks,' dn.exxonmobil.com/~/media/Files/Other/2014/Report – Energy and Carbon – Managing the Risks.pdf

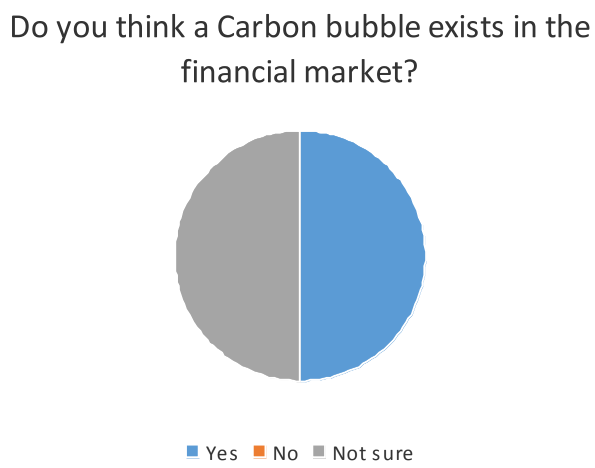


FIGURE 12. EXISTENCE OF CARBON BUBBLE

To further explore the perceptions of institutional investors, we asked respondents who were unsure or did not believe that there is a carbon bubble to indicate the most important reasons for not detecting carbon bubble risks on a scale of importance from 1 (not very important) to 5 (very important). In the Annex Table 1, we provide the ranked reasons for the uncertainty of a carbon bubble. We find that investors offer a number of reasons for not acknowledging the existence of a carbon bubble in the market. Among the reasons, investors are divided about whether technology advancements and the capacity of management to mitigate stranded assets are undervalued. Market expectations of the growth potential of firms with high fossil reserves may change over time, leading to a smaller impact should a carbon bubble materialize.

Risks associated with carbon emissions were mostly noticed by respondents in 2012-13. Even if this date is not in line with the academic publication of Meinshausen,[52] earlier research identified how investors had raised concern about the contribution of carbon emissions to financial performance. In 2002, for example, thirty-five institutional investors demanded relevant information concerning greenhouse gases from FT500 global index companies.[53] Similarly, in our sample, one institution acknowledged that a risk of a carbon bubble existed as early as 2008. Consistent with prior studies, institutional investors that have large passive stakes in firms with high

52 Malte Meinshausen, Nicolai Meinshausen, William Hare, Sarah C.B.Raper, Katja Frieler, Reto Knutti, D. Frame, M. Allen, 2009, Greenhouse-Gas Emission Targets for Limiting Global Warming to 2 Degrees C, *Nature* 458 (7242), 1158-1166.

53 Carbon Disclosure Project, Climate Change Report 2003 (https://www.cdp.net/en-US/Results/Pages/All-Investor-Reports.aspx).

carbon content on their balance sheets tend to have stronger incentives to detect earlier the risks of a greenhouse gas. Thus, early awareness of the risks related to carbon may lower the likelihood that a carbon bubble will materialize in the short term.

Reactions to a Possible Carbon Bubble Risk

Previous studies found that the institutional investors, with different types of assets and their respective costs and performance, are more likely to understand their exposure to diverse risks and produce appropriate internal policies. Accordingly, we expected that this class of institutional investors would have implemented a climate risk and carbon bubble policy.

Table 3 (Annex) shows the assessment of the different policy and governance mechanisms that institutional investors view as the most effective tools to identify the potential losses due to carbon bubble exposure. More specifically, respondents were asked to indicate which mechanisms were important in identifying the carbon risk for their fund. The results that follow are broadly in line with what prior research found about what institutional investors value in terms of identifying carbon risk exposure.

Recent empirical research showed that across 23 European pension funds, holdings of high-carbon companies varied from 0% to 19% of total equity investments. Consistent with this, the results reported in Table 4 (Annex) show that an estimated 12% of the current equity holdings of half the respondents are in high-carbon-intensity firms (mining, oil and gas, fossil electricity), while one respondent reported this figure at 16%. Half the respondents indicated that their largest portion of investment was in low-carbon holdings (ranging from 37% to 49%), with an estimated 11% to 39% in medium-carbon-intensity firms (industry). This large exposure to carbon assets will incentivize institutions to demand information about carbon risk mitigation strategies.

Previous studies have found that reducing exposure to high carbon assets to limit funds' potential losses due to climate change is not a popular option for fund managers. The idea behind the current debate on large risks posed by stranded assets is that, due to uncertainty about the move toward a low-carbon economy, fund managers find it challenging to assess the risks of a carbon-related shock on equities, bonds and commodities. If fund managers are certain about future developments, they will be able to assess the level of carbon-related risks for the financial system accurately and have incentives to decrease their fossil fuel firms in their equity portfolio. The results reported in Table 4 (Annex) are consistent with the uncertain transition scenario that it is unclear to investors how slowly or rapidly a transition to a low-carbon economy will take place. For example, one respondent indicated that mitigation strategies have not resulted in significant changes in sector allocation and that the transition from high-carbon assets will likely be a gradual process in reducing the carbon risk for their institution.

Regulatory Responses to Carbon-Related Risks

So far, we have looked at the perceptions of institutional investors about the risks associated with a carbon bubble in the financial markets and the their actions to mitigate losses on high-carbon assets, including developing responsible investment policies while decreasing exposure to high-carbon fossil fuel companies. To extend our analysis, we will also look at what accounting standards and investor protection measures might be relevant to institutions. To stimulate risk management regarding carbon policies, investors often demand from corporations that they provide quantitative and qualitative disclosures concerning their carbon risk. Such disclosures about strategic decisions will enable investors to improve their valuations of the firms.

Accounting and Reporting Standards

Recent research argues that current accounting regulation does not provide incentives for energy companies to disclose the possibility of having stranded assets on the balance sheet.[54] These studies assume that once the information becomes public, mandatory reporting on CO_2 emissions or climate change matters will help place investors in a better position to identify firms' levels of exposure to carbon risk. As noted, prior studies have only surveyed institutional investors about the assessment of ESG[55] ratings and the non-financial reporting of GHG emissions of equity portfolios, loan books and life insurance policies. Our survey provides an alternative way to shed light on institutional investor preferences relating to current accounting and reporting standards and their effectiveness for assessing CO_2 and climate change related risks.

We directly asked institutional investors whether they believe current standards are adequate to assess carbon risk for individual firms, based on their experience with current accounting and reporting standards. The responses (see Figure 13) show that 75% do not agree that the current mandatory reporting requirements are adequate for assessing carbon bubble risks. The other institutions report that they are not sure about the effectiveness of current standards. One the one hand, this might imply that mandatory regulation is preferred in accessing additional information about carbon reserves. Some regulatory measures may increase the carbon disclosure of firms, strengthening institutional investors' abilities to interpret CO_2 emissions as well as the

54 Greens/EFA Group-European Parliament, *'The Price of Doing Too Little Too Late, the impact of the carbon bubble on the EU Financial System'*, Green European Foundation, Brussels, February 2014.

55 Environmental Social and Governance ratings

production and exploration policies of fossil fuel firms. On the other hand, this could imply that the current standards are not coherent across markets or that current voluntary disclosures have not fully matured. For example, after the publication of the ExxonMobil report, other large oil corporations followed by releasing their carbon emission reports.[56] To further investigate the preferences of the institutions, we asked respondents to rank their preferred way of enhancing the carbon disclosure of firms.

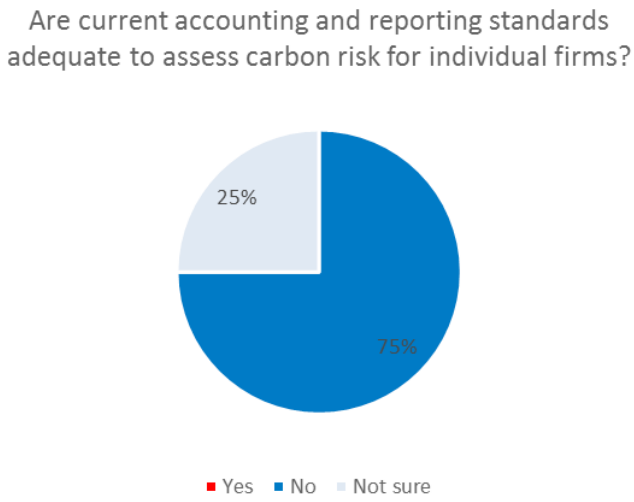


FIGURE 13. REPORT STANDARDS

Figure 14 indicates that 100% of the respondents find voluntary measures the preferable mechanism for allowing firms to disclose the sensitivity of their fossil fuel reserves to possible price changes due to carbon risk. This suggests that all the funds surveyed form their own views about the carbon risks and long-term strategies of the fossil fuel-based firms in which they invest. An equally important driver for these disclosures is that institutions themselves communicate extensively with corporations in their portfolio that have high fossil reserves. Such communication allows institutions to influence the carbon reporting of corporations and enhances the disclosure of these firms. When communication is less successful in fulfilling the demands for information, investors can attract attention with a proxy proposal. Figure 14 also shows that 75% of respondents indicated that shareholder engagement, through the use of proxy proposals, is the second most important way of promoting enhanced disclosure of firms' carbon-related risks. This confirms earlier studies which showed that the propensity of funds to use the proxy process contributes to their strategies to manage climate change risks.

56 ExxonMobil (2014).

This figure shows the number of firms that prefer certain regulatory measures.

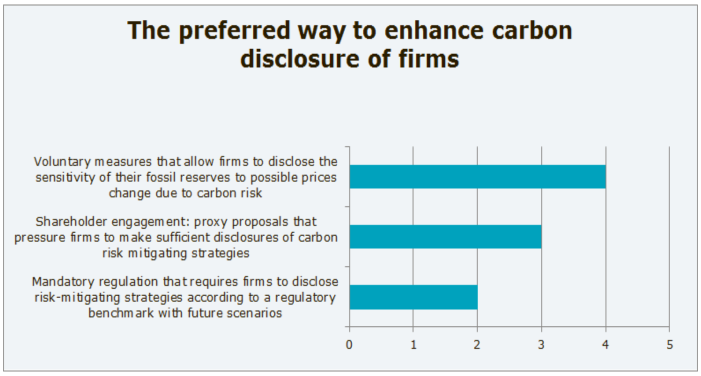


FIGURE 14. DISCLOSURE OF FIRMS

Respondents strongly agreed that hard regulation requiring firms to disclose risk-mitigating strategies according to a regulatory benchmark was the least positive way to enhance the carbon disclosure of firms. Soft law in the form of guidelines to harmonize reporting standards for corporations across markets received attention as well. These guidelines would allow for a better comparison of voluntarily disclosures of corporations.

Conclusion

This section investigated for the first time the regulatory measures that institutional investors in the Netherlands prefer in enhancing disclosure of the carbon and climate change-related risks of fossil fuel companies. We show that institutional investors are sensitive to the accounting, governance and disclosure mechanisms that make it possible to both assess the potential return on investments relative to other investments and to mitigate the risks related to the carbon bubble and climate change.

We analysed the potential risks of an undetected carbon bubble for institutional investors. Our findings confirm the view that Dutch institutional investors assume a slow transition to a low-carbon economy. We observe, however, a significant development of carbon risk tools and mitigation strategies at the fund level. We also find limited change in carbon holdings. Our findings conform to the view that Dutch institutional investors will not suffer a sudden carbon-based shock leading to significant losses on equities, bonds and commodities and may have the resources to effectively mitigate the losses on such investments.

We have also analysed investors' perceptions about the most effective regulatory response to the elevated risks posed by a carbon bubble. We evaluated the effectiveness of current accounting and disclosure requirements in verifying the carbon risk of individual firms. Considering the importance of uncovering the risk of stranded assets among pension funds, 75% of our respondents reported that current mandatory reporting requirements are not adequate for assessing carbon bubble risks. However, mandatory regulation is not the preferred mechanism to improve disclosure. These results provide direct support of empirical research on the impact of voluntary corporate disclosures, as documented for example in Peters and Romi.[57]

Finally, we consider the role of three distinct mechanisms to enhance the carbon disclosure of firms. Our results indicate that pension funds believe that shareholder engagement strategies, such as proxy proposals, are the most effective method for enhancing disclosure and contributing to the effective management of climate change risks. The findings have implications for policy, since the funds in our sample also believe that mandatory regulation requiring firms to disclose risk-mitigating strategies according to a regulatory benchmark is the least preferred mechanism for enhancing carbon disclosure of fossil fuel firms.

EVIDENCE FROM STOCK MARKET REACTIONS TO REPORTING AND GOVERNANCE INITIATIVES

The last section detailed Dutch investors' perceptions about the potential impact of a carbon bubble for the financial market and individual investors. In the previous section and in prior research, concerns are highlighted that question whether sufficient mechanisms or policies are in place to ensure that emissions are kept at a level sufficient to prevent a 2°C increase in average global surface temperature. We also note that there is uncertainty about how much of the coal, oil and gas reserves of publicly listed companies will be unburnable if emissions are kept at a level not to exceed global warming of 2°C.

When it comes to the carbon bubble, the starting point is the research of Meinshausen.[58] This paper shows that if policies are employed to limit the temperature increase with respect to the pre-industrial era to 2°C, a substantial amount of the energy reserves will not be able to be used for production. The conclusion drawn by Meinshausen

57 G.F. Peters and Andrea M. Romi, 'Does the Voluntary Adoption of Corporate Mechanisms Improve Environmental Risk Disclosures? Evidence from Green House Gas Emission Accounting', *Journal of Business Ethics*, (2013), 1-30.

58 Meinshausen et al. (2009)

et al.[59] is that the potential damages are likely to be great because the value of energy companies is linked to future earnings from selling fossil fuels that may be left unburned.

There are two opposing views on how to assess the valuation of these potentially stranded assets. According to the first view, most carbon-derived assets will become stranded assets and cause substantial revaluation of the energy market. This hypothesis forms the foundation for most of the studies done by Carbon Tracker[60] that focus on future scenarios in which stringent policies substantially reduce the emissions possibilities of these firms. In such scenarios, energy firms would not be able to liquefy a substantial part of their assets before 2050. In fact, it is estimated that the carbon bubble shock will imply a loss of as much as 85% of fossil fuel proven reserves.

Conversely, a second view held by publicly listed companies in the energy sector, such as Shell and ExxonMobil, estimates that the rising emissions will stabilize around 2030 in response to activist shareholders' questions regarding the uncertainty of future energy demand and supply. While the oil companies' analyses are silent about estimates of CO_2 and temperature in the future, they are confident that the effect of population growth in non-OECD countries and increasing demand for fossil fuels will offset potential restrictive carbon emission policies.[61]

The stock market incorporates the information of both views in its valuation of the energy sector. Finance theory asserts that markets will price the possible effects of the unburnable carbon of fossil fuel firms. While little empirical research has examined the market response to the potential risks of a carbon bubble, it is typically assumed that the predicted investor exposure to long-term investment risks of carbon-intensive holdings could cause large-scale problems in the future. While traditional perspectives on the ability of pension funds to measure their carbon risks may not examine market reactions to new information about carbon assets, the recent literature tends to develop a more germane view. In extending the finance literature on investor reaction to news and scientific articles, Dominguez-Faus et al.[62] find that the response of the stock market to the research reports of Meinshausen et al. is relatively limited.

59 Ibid.
60 www.carbontracker.org
61 ExxonMobil (2014).
62 R. Dominguez-Faus, P. Griffin, A. Myers Jaffe and D.H. Lott, 'Science and the Stock Market: Investors' recognition of unburnable carbon', Working paper, 2014; http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2362154

The results of the this event study suggest that if it is unclear that governments will adopt policies to trigger a transition to a low-carbon economy, investors will not reduce their exposure to carbon intensive equities in the energy sector.

Institutional Investor Reactions

Clearly, understanding the stock market response can help us specify how large the risks are of a carbon bubble shock. Recent studies have used this approach to examine the potential consequences of stranded carbon assets for investors. However, what this research does not fully explicate is why investors have little or no reaction to scientific or news stories on the carbon bubble. There is clearly room to consider other explanations for why investors ignore the potential losses that they would suffer due to a large shock to the value of carbon assets in their portfolios.

Theory suggests that looking at the investment horizon of investors can explain the limited stock market reaction to the scientific news stories. Prior studies emphasized that the investment horizon for investors is an important factor in determining asset allocation in a portfolio. In line with this research, long-term institutional investors respond differently to information on un-priced carbon risks than short-term investors. In recent years, long-term institutional investors, such as pension funds and hedge funds, have raised concerns about the risks associated with a potential carbon bubble and the portfolio of corporate strategies and government policies that could mitigate the impact on shareholder value.

Concerns about the fossil fuel assets owned by listed companies are particularly salient for institutional investor activism that has emphasized the need for the disclosure of energy reserves and carbon liabilities of large oil companies such as ExxonMobil and Royal Dutch Shell. More recent empirical research has confirmed the positive effect of activist engagements, between institutional investors and large energy companies, on the disclosure of risks of high-carbon producers.[63] Shareholder activism is likely to be amplified and could have a spill-over effect on other investors. Thus, the effect on other investors can lead to a greater awareness of the potential risks associated to carbon emissions. In Figure 15, we show evidence that financial markets can react strongly to this sort of investor activism.

63 Julie Cotter and Muftah Mohamed Najah, ‘Institutional Influence on Global Climate Change Disclosure Practices’, *Australian Journal of Management,* 57, 2 (2012).

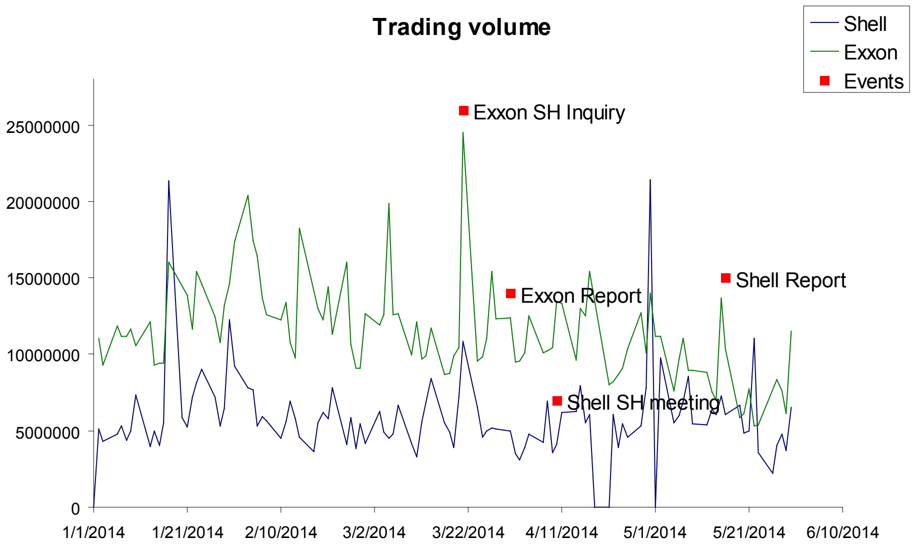


Figure 15. The trading volume of energy firms' stocks

Figure 15 presents the trading volumes of ExxonMobil and Shell from January 2014 to June 2014. The Exxon shareholder (SH) inquiry denotes the day of the filling of the carbon assets inquiry. In the Shell report, the company responded to a question at the shareholders' general meeting. The other events denote the day the company report was published by both firms.

With these concerns in mind, the evidence shows that the transaction volumes of both the ExxonMobil and Shell shares increased sharply on the day that the ExxonMobil inquiry about carbon assets was filed by the institutional investors. At the same time, the report of ExxonMobil was one of the first responses of the energy sector to future projections of energy demand and emission policies. Perhaps as a result, the energy market has internalized the notion of a carbon bubble through this filing. If that is the case, the report of ExxonMobil had substantially less effect on the financial market, suggesting that the report was roughly in line with investors' expectations. It is possible, however, that because Shell's 20-page report was issued at its annual shareholders' meeting in the Hague, it is difficult to disentangle other possible factors influencing the price movement from the carbon bubble inquiry. But even more importantly, the trading volume increased substantially for the ExxonMobil shares following the release of the Shell report. Moreover, Shell's announcement indicating a low probability that current reserves will become stranded assets had a strong market-wide affect. The evidence highlights exactly how (and where) the market incorporates the effects of a possible carbon bubble.

Underlying Factors

Building on research in finance, prior studies suggested that key factors other than shareholder activism could have effects on the prices of energy stocks held by institutional investors. The first factor underlying this concern is technology advancement. The energy sector initially responded by arguing that non-OECD countries will see an increase in their energy demand that cannot necessarily be offset by the increasing production of renewable energy. An important example of a rapidly changing case of energy production is Germany. As mentioned above, regulators have focused on substantially reducing the impact of fossil fuel energy, which will likely increase the uncertainty of the demand for this type of energy in the long term.

Another important factor that might contribute to the limited price effect could be the uncertainty of the effect of carbon emission on temperature change. In fact, while the literature on climate change has reduced the uncertainty about the impact of climate change, substantial uncertainty remains. Accordingly, Figure 16 represents the uncertainty of carbon emission for the three scenarios defined by the IEA.

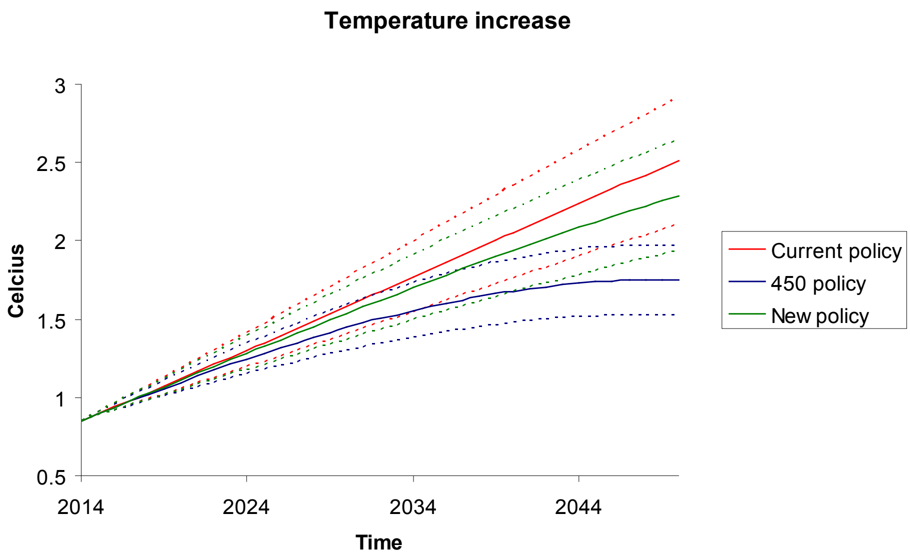


FIGURE 16. TEMPERATURE UNCERTAINTY FOR THE IEA SCENARIOS

This figure presents the temperature changes and the associated uncertainty using the confidence interval found by Tung, Zhao and Camp.[64] The current increase in temperature with respect to the pre-industrial era is estimated by the IPCC to be 0.85°C.

64 K.K. Tung, J. Zhou and C.D. Camp, 2008, 'Constraining Model Transient Climate Response Using Independent Observations of Solar Cycle Forcing and Response', *Geophys. Research Lett.*, 35, L17707.

The evidence suggests that if the temperature effect in 2050 is used as a steering mechanism for climate and environmental policies on carbon emissions, uncertainty about the future projections will be an important factor for market participants. Figure 15 presents a small likelihood that even current policies on carbon emissions may achieve the required temperature impact. Figure 15 does not, however, incorporate uncertainty about the current temperature rise with respect to the pre-industrial era. While the IPCC uses the primary estimate of 0.85^{o}C, according to its reports the associated confidence interval is 0.65^{o}C to 1.06^{o}C. Thus, if a lower temperature estimate is used, the likelihood of achieving the 2^{o}C will substantially increase. Given this uncertainty, short-term investors may be reluctant to incorporate the effect of carbon emissions into the valuation of energy firms. Of course, the uncertainty could increase market segmentation because short-term investors are not strongly affected by these policies.

The third factor that drives future uncertainty about carbon assets is carbon taxation. Various countries and districts, such as British Columbia and Ireland, have implemented a carbon tax, leading to additional costs for fossil fuels. Government policies such as this, aimed at altering CO_2 emissions, are slowly gaining ground. In fact, they may accelerate innovation for renewable energy technology and lower the demand for fossil fuel energy. Furthermore, since these policies are aimed lowering the cost differences between fossil fuels and renewable energy sources, the low cost of fossil fuel energy that drives current production may disappear with these taxations. As a result, the fossil fuel reserves will decrease in value on the balance sheet, so that long-term institutional investors may demand policies from the energy market. However, imposing a carbon tax is very unpopular (as evidenced by the jubilant response to the Australian Government's recent decision to abolish the tax as of July 1, 2014) due to concerns that it will have a negative impact on consumption and investment.

Empirical Analysis of Stock Market Reaction to Regulation and Governance Initiatives

Recall our discussion above, in which we pointed out how previous research has focused on the relation between share price reactions of publicly listed firms in the US and the appearance of scientific articles. In that analysis it was hypothesized that a significant number of firms holding fossil fuel assets will be subject to large losses if a carbon shock occurs. Yet Dominguez-Faus et al. show that even though news articles revealing a potential carbon bubble shock can lead to a 1.5% to 2% negative change in energy company stock prices, due to uncertainty about future developments investors will likely prefer to maintain their investments in fossil fuel firms, since they remain worthwhile.[65]

65 Dominguez-Faus et al. (2014).

Our study attempts to extend this line of empirical analysis by attempting to shed some light on whether announcements of various regulatory and tax policy responses to climate change, climate news and corporate disclosures about firms' carbon risk will positively or negatively influence the share prices of publicly listed energy firms. With little empirical research on these broader legal and governance factors, qualitative evidence predicts that the market is likely to respond positively to the announcement of new disclosure legislation. The qualitative evidence seems consistent with the idea that investors would benefit from obtaining better information about climate change risks. At the same time, in light of increased liability risk associated with carbon disclosures, investor response could be negative in the long run due to higher litigation costs associated with the enhanced disclosures.

The data sets used in this study are described in Table 5 (Annex). We began with the Oil and Gas Journal (OGJ) data set that comprises 139 oil and gas firms derived from the list of the largest publicly traded US energy companies as ranked by OGJ. Next we included a data set of the 23 firms listed by Petroleum Institute Weekly (PIW) as the largest oil and gas firms in Canada, the United States and Europe that are traded on the US stock market. We also employed the database of Dominguez-Faus et al.,[66] which consists of a selection of 63 US oil and gas firms listed in the Datastream Energy Index with CUSIP and CIK codes.

We collected announcements by the SEC, the Australian government, the United Nations and publicly listed companies and articles by scientific researchers. Table 6 (Annex) shows a list of regulations, climate news publications, corporate disclosures and sustainability reports. To calculate the daily returns we used daily closing prices from DataStream and the S&P Energy Index as the market factor instead of the S&P500 as market index.

Effect of Type of Regulation, Disclosure and Climate News

We proceed with our event study, which then measured the market's perceived effect of announcements of new disclosure regulation, company disclosures on carbon risk and new articles on unburnable carbon. Table 7 (Annex) reports the average stock price response to the announcement of new SEC regulations on the disclosure of energy company reserves and on carbon and climate risks. As expected, the announcement returns (CARs) were positive, given the monitoring benefits that one might expect from the implementation of new disclosure standards requiring all listed energy companies to distinguish between conventional and unconventional reserves. The implementation of this legislation represents a substantial shift in the

66 Ibid.

financial reporting standards for publicly listed US energy firms. Even though the abnormal returns and CARs, measuring from -1 to 1, were positive for both OGJ and PIW firms, the expected long-term market reaction is mixed and deviates from long-term expectations.

In contrast, we expected a negative stock price reaction to the announcement of the SEC's January 2010 ruling requiring US publicly traded companies to inform investors of the financial risks and rewards associated with climate change. These results are consistent with the hypothesis that the market responds negatively to stock companies that must disclose high-carbon risks. Interestingly, recent evidence shows that S&P500 climate disclosures are brief and do not quantify impacts or risks.[67]

The largest economic effects found were related to the Australian Government's announcement in 2011 of its decision to implement carbon tax legislation. The negative abnormal returns reflected the high cost of carbon emission and few benefits, as the tax had relatively little impact on reducing emissions. The results of the PIW abnormal returns -0.83%** and CAR (-1,1) indicate that the significantly negative CAR is consistent with our hypothesis. In addition, we observe the negative stock market reaction to the *Nature* publication, which is consistent with the results of Dominguez-Faus et al.[68] These findings may also be convincing evidence that could drum up support for the uncertain transition scenario.

The next set of results test the hypothesis that there is a negative relationship between observations over six years relating to events surrounding the UN Climate Change Conferences and market returns. The evidence in Table 8 (Annex) supports the hypothesis that the market may have responded weakly due to the Doha talks and other climate change proposals that were thought to negatively impact the economies of these countries.

In addition to the effect of announcements of various policy responses to climate change, we also explored the effects of the large oil company disclosures to shareholders. We reported on the responses of energy companies to questions posed directly by institutional investors to the management of carbon fossil companies. This set of results is consistent with the conjecture that proxy-induced company disclosures are likely to generate the relevant increases due to the associated benefits of the enhanced monitoring of management's carbon risk policies.

67 Ceres, *Cool Response: The SEC & Corporate Climate Change Reporting*, 2014 (ww.ceres.org/resources/reports/cool-response-the-sec-corporate-climate-change-reporting)

68 Ibid.

We also tested the effects of public policy responses, climate news and company disclosures in response to shareholder questions for agency and control variables. We used four agency proxies (cash holdings, capital expenditure, dividend payout ratio and leverage) and five variables that relate to control (return on assets, Tobin Q, financial slack, employment and R squared). Taken together, the results (see Tables 8 through 15, Annex) are certainly consistent with the propositions and results discussed in Table 7 (Annex).

Finally, we also looked at the impact of the EPA's recently announced Clean Power Plan Proposed Rule, which is intended to restrict emission of power plants. It is widely expected that the implementation of the propose rule will cause a shift in the coal demand as other fossil fuels, such as natural gas, contribute less to the emission profile of such plants. Confirming this view, our evidence shows that the EPA announcement had a negative impact on large US coal firms.[69] For longer periods, however, we do not find a significant downward adjustment of the valuation of coal firms, which may be driven by market segmentation of short term and long-term investors. This is another example, as we saw earlier with oil and gas, of investors not responding strongly to regulatory announcements designed to cut carbon emissions.

Summary

In light of prior studies that showed a limited stock market response to the scientific article of Meinshausen et al.[70] on stranded carbon assets, we used the carbon bubble to study how the stock market responds to different public policy on climate change, news stories and company disclosures that were triggered by shareholder questions regarding climate-related risk for their investments.

Our data was found in the Oil and Gas Journal (OGJ) dataset that comprises 139 oil and gas firms derived from the list of the largest publicly traded US energy companies as ranked by OGJ. We also used a dataset of the 23 firms listed by Petroleum Institute Weekly (PIW) as the largest oil and gas firms in Canada, the United States and Europe traded on the US stock market. We also employed the database of Dominguez-Faus et al. (2014), which consists of a selection of 63 US oil and gas firms listed in the Datastream Energy Index with CUSIP and CIK codes.

69 A similar event study methodology was used to detect significant abnormal returns of -1.5% and a CAR (-1,1) of -4.5% for the EPA announcement on 2 June 2014. For longer periods, however, we do not find a significant impact.

70 Meinshausen et al. (2009).

Our empirical analysis looked at the market reaction to announcements by the SEC, the Australian Government, the United Nations, publicly listed companies and articles by scientific researchers. We observed the stock price response to the announcement of new SEC regulations on the disclosure of energy company reserves and carbon and climate risks. For the new SEC standard on disclosure of reserves, we found that the abnormal returns and CARs measured from -1 to 1 are positive for both OGJ and PIW firms, but the expected long-term reaction of the market is mixed and deviates from long-term expectations.

Our empirical investigation also looked at the market reaction to the announcement of the SEC's January 2010 ruling requiring US publicly traded companies to inform investors of the financial risks and rewards associated with climate change. Our findings confirm the view that the market responds negatively to publicly listed companies that must disclose high-carbon risks. Interestingly, recent evidence shows that S&P500 climate disclosures are very brief and do not quantify impacts or risks.

Our findings of the negative abnormal returns for the enactment of Australia's carbon tax may reflect the high cost of carbon emissions and the relatively small impact of the measure on reducing emissions. In addition, we also observed a negative stock market reaction to the *Nature* publication, which is consistent with prior results. Finally, our study uncovers the positive effects of large oil company disclosures on climate risk to shareholders. We find that the ability of institutional investors to ask questions directly to the management teams of portfolio companies seems likely to generate the associated benefits of the enhanced monitoring of management's carbon risk policies.

Conclusion

This part has shown that the value of firms is complex and does not only depend on carbon-dioxide-bearing proven reserves, as sometimes is assumed. Technology and its ability to manage technically and organizationally complex projects is part of the value these companies create. Also, the logic of earlier transitions to higher quality fuels, which produce more energy per unit of carbon emitted, underpins the value of oil and gas companies. It is clear, however, that coal companies are treated with more caution by investors with regard to their future value than oil and gas companies. The potential 'harvest' of carbon emissions reduction is the greatest for coal (without CCS or not combined with biomass), and investors expect coal to be the first fuel affected by policies to reduce emissions.

Oil and gas companies should not expect to have materially different roles within the next 20 years as a result of carbon abatement policies, although they will have to increasingly compete with renewable fuels for their market share. The coal sector is correct to expect material changes to the business, for both climate change policy and local air pollution reasons.

In assessing the risk, investors look not only at the specific information about carbon assets but also at other company characteristics and how management proposes to handle the transition to a low-carbon economy. We found that investors consider shareholder engagement strategies to be the most effective method in enhancing the disclosure of carbon- and climate change-related risks. Investors view voluntary disclosure as likely to be a more effective method than mandatory regulation for enhancing carbon disclosure of fossil fuel firms. These results provide support for encouraging increased transparency and information about these issues and may actually help smaller investors with less sophisticated models to assess the limits of carbon bubble risks as well as help clarify the true extent of the carbon bubble.

7 GOVERNMENT

GOVERNMENT ROLES IN ENERGY

Governments have played important facilitating and/or shaping roles in earlier energy transitions. They have provided substantial and long-term support to new technologies and have created a framework for energy value chains to develop. This support has varied from granting licenses to explore, produce and process resources (for instance oil, natural gas and coal), to providing support for research & development (for instance in the US to improve hydraulic fracturing and other key natural gas recovery technologies), to securing markets for the new energy resource (for instance natural gas in the Netherlands[71]), to providing capital and/or abandonment cost protection (for instance in the nuclear industry in the UK and France), to offering tax incentives for new energy technologies. Government is thus not new to the energy sector.

Governments are also often owners of energy production and transportation facilities, depending on the country's political and institutional organizational structure.[72] The investment decisions of these companies, which inevitably favour certain fuels, influence the energy mix of countries, just like energy taxes and subsidies can change the inter-fuel competition and consequently the energy mix. Sometimes governments expect foreign companies to deliver beyond the energy policy sphere or assume that due to collaboration in energy projects at home or abroad special relations will develop with the company's home country, for instance that of an IOC.

71 In the Netherlands, a market for natural gas was created when, in addition to its industrial use, natural gas was developed for household cooking and heating in the 1960s. The change to natural gas-based heating and cooking was part of a national plan to roll out the energy resource in residential markets, while also stimulating industrial demand. In this plan, in addition to better energy services, incentives played an important role to convince consumers to participate in the city-by-city and street-by-street transition. Aad Correlje, Coby van der Linde and Theo Westerwoudt, *Natural Gas in the Netherlands, From Cooperation to Competition?*, ONG, 2003.

72 State companies often operate oil and gas assets, while these companies are also active further down the value chain (in refining, petrochemicals and distribution). In some cases state companies (NOCs) have developed into international companies, with assets at home and abroad, often in order to secure markets for their products (forward integration). NOCs from Kuwait, Saudi Arabia, Norway, Russia, Malaysia, China, Brazil, Thailand and India function like International oil companies (IOCs) and collaborate in international consortia as well as alone. In Russia, Brazil and China, but also elsewhere, the collaboration with IOCs involves complex offshore developments or shale developments, while conventional developments in their home markets are the prerogative of the state or home companies. The IOCs bring both technical qualities and capital to these projects in exchange for equity. Partnering with state companies can help expedite the licensing procedures and also prevent renegotiations on the contractual terms. The legal framework in many countries does not allow the operation of a production project without a local partner. In some countries the partner can be a local private company, but often it implies partnering with a state company. Government partnership protects investors from changing government policies, while governments demand delivery on their objectives by the consortium. Demands for local content and development of local energy industries are often part of the collaboration.

State companies are often the implementation tools of government policies and organize many of the energy services needed in a country.[73] In many countries, full or partial government ownership of power companies is common, while (minority) state participation in upstream developments is the rule rather than the exception. Local content is deemed important for the local labour market, and diffusion of technology is seen as valuable for developing local expertise. Government companies are often interested in taking their share 'in kind' in order to deliver energy to the local economy, often for less than world market prices.

Government ownership of energy assets can influence future energy policies because of dependence on income flows and/or vested interests in dedicated assets. Governments can behave as incumbent firms, riding the product cycle and maximizing the use of their asset bases. When governments need the income from energy and energy services to finance other government tasks, their capacity or willingness to innovate and improve is often hampered, to the detriment of investments new technologies and resource development.[74]

In addition to owning centralized or local energy ventures, governments also regulate their energy sectors, setting the market framework and often also stimulating one fuel over another. They do this to serve the main priorities of energy policy. These priorities are: affordability, security of supply and protecting the environment. Yet other fields of policy and vested interests in other sectors may also have implications for either energy production or consumption.

ENABLING OR ENFORCING TRANSITION

During transitions, governments, energy technology and economics all play their roles in creating or shrinking markets for certain energy sources. In the case of government, the focus is mostly national or supranational, while technology and economics can influence the mix beyond one country or region. Very often, though,

73 In many countries certain energy services (such as residential heating and cooking) are provided below cost to allow energy consumption by poorer groups in society. In other countries, for instance some oil producing countries, end-user prices of transportation fuels have historically been very low and are politically difficult to change. This is why the presentation of energy subsidies in the IEA WEO (2013) is dominated by fossil fuel subsidies in these countries. The cost of providing these services is absorbed by the state company and by government forfeiting potential returns as an owner. In other countries, fossil fuels are taxed, raising government income and thus its ability to spend on energy and other sectors of society. In some countries, the state company also represents the country's foreign energy policy, while it also has an important role in domestic industrialization policy implementation. Other governments favour ownership (sometimes minority ownership) to improve government information about the companies active in their countries and to optimize (tax) income from energy activities.

74 For instance, privatization of the power sector and the lifting of the obligation to burn coal paved the way for the switch in the UK from coal to gas in the power sector. This energy transition was preceded by a long struggle between the labour unions and the government.

all three influences take part in a more complex interplay between energy and capital markets, government regulations and the types of energy services demanded in society. Transition is often a national or regional affair, while the global transition is the sum total of the national changes in the energy mix. Currently the world combines traditional biomass in some developing countries with complex energy systems elsewhere. The stage of economic development, types of political organization and institutions all play a role in the way the world's energy systems are organized and how susceptible they are to change.

Environmental concerns increasingly influence government import interventions in the energy sector, in part because of public pressure. The American Clean Air Act in the early 1990s forced foreign refiners to adapt to stricter specifications on fuels in order to continue exporting to the US. The US has also developed a growing biofuel sector based on corn by setting a blending standard. Yet for economic reasons Brazilian biofuels, based on sugar cane, face restricted access to the US market and are not allowed to compete. This shows the complex interplay between energy and other policy priorities, in this latter case protecting the agricultural sector from competition and in the previous case protecting local refiners from foreign competition. In Europe, the pressure on governments to ban tar sand and/or shale gas and oil from European markets for environmental reasons under the new clean fuel directive (2014) was difficult to understand when coal imports, with a much more intense CO_2 profile, are increasing.

Geopolitical and geo-economic relations can also affect the energy mix, creating a preference for energy sources from certain countries or the exclusion of certain fuels or countries. The oil crises of 1973-74 and 1979-80 created support for a policy to move away from fuel oil in electricity generation. The European Community stimulated member states to switch their power mix from oil to either coal or nuclear to reduce the import dependency on OPEC countries, then seen as a strategic risk. Diversification of energy sources and geographic origins is a tested policy with which governments can influence the energy mixes of their countries. The nuclear sectors in Germany, France and Sweden derived their expansion from this policy re-orientation away from oil in the early 1980s, while Denmark switched largely to coal at the time. Local preferences for certain types of fuels and dislikes of others determine the transition path a government initiates.

Government involvement in the energy sector is wide-ranging and deep. Apart from their involvement in domestic energy matters and the composition of the energy mix, governments also intervene in relationships with foreign energy flows and companies.

In the past, domestic energy production was protected from competition of other producers or fuels by subsidies (for instance for coal in Germany), while trade tariffs shielded local processing industrial clusters from competition from third countries (for instance in petrochemicals in the EU). Export and import bans disturbed supply and demand in regional energy markets (for instance the Oil Import Quota in the late 1950s to protect domestic producers and the US crude oil export ban of the 1970s), and natural gas was disqualified from power generation (for instance in the EU in the 1980s, with the Netherlands in breach of this policy for its duration). China now also has a gas plan, earmarking gas for certain types of consumption and not others.[75]

Domestic resources, whether won through mining or recycling, are deemed important for the organization of new energy technology value chains. In countries where the new energy technologies are part of a strategic re-orienting of the national energy system, long-term security of supply of vital parts of the value chain in the new renewable energy technology is crucial for the transition to proceed. If these supplies are uncertain for technical, economic or political reasons, for instance with rare earth materials, the share of the new technology in the national energy mix will very likely remain much smaller, particularly on a global scale, unless these scarcities can be overcome by substitution or other solutions.

It is clear that transitions, and in particular the role of government in these transitions, differ. In some cases government is involved in enabling (transition) policies, where the market and/or technology makes the first step and government facilitates their expansion. Other times government enforces (transition) policies; in these situations government takes the lead and the economy and/or technology must follow. It is clear that enforced transitions are highly country specific, based on geological, technological and industrial factors and on the political and institutional landscape. As a result, not all low-carbon economy transitions focus on efficiently reducing CO_2 emissions. Rather, they involve a mixture of introducing new fuels – either those in which the country can expect to take the lead, or fuels that deliver more immediate local benefits, such as air quality – and serving various types of energy demand with other, more traditional fuels. Long-term policy goals can also have short-term effects that can derail a transition when short- and long-term costs remain out of sync or when another fuel supply expands rapidly and delivers more results on the three priorities of energy policy than the fuel initially chosen by the government.

Carbon emissions reduction policies fall under the enforcing category of transition policymaking and serve the environmental priority of energy policymaking. Examples

75 Yi Chen, *Development Strategies of the Chinese Natural Gas Market,* CIEP, September 2013.

of such policies are the German *Energiewende*, emissions policies for ships and the EU 20-20-20 energy policy. Another category of policy enforcement targets local pollution and includes the switch away from coal to natural gas in large Chinese cities, the efficiency targets for coal plants in the US and CNG vehicles in India. The already mentioned move away from oil in the 1980s (US, Europe and Japan) and the build-up of nuclear in France, Japan and elsewhere are examples of government-enforced transitions for security of supply reasons. The liberalization of energy markets in the US and later in the EU are examples of interventions to improve market efficiency.

THE EU AND TRANSITION

Governments derive their energy activities from the three main goals of energy policy: affordability, security of supply and environmental protection. In the OECD countries, affordability was based in past decades on stimulating global competition in energy supplies. For a long time the main agents that were able to deliver security of supply were the IOCs, which were mainly headquartered in the US and Europe. They supplied the OECD with cheap oil from the Middle East and North Africa, and after the nationalization of these resources they invested elsewhere.[76]

The policy comeback of coal in response to the oil crises of the 1970s in the EU was counter-intuitive to increasing demands for stronger climate change policies, showing that policymaking priorities do not always converge. Gas finds in the North Sea (UK, Norway and the Netherlands) and the gas supplies from the Soviet Union and Algeria helped to satisfy growing demand. In the 1990s these led to the liberalization of energy markets and a growing share of natural gas, also in power generation.[77]

In the utility sector government ownership was even more common, although the EU liberalization process and privatizations in the 1990s and 2000s changed that profile substantially. Nevertheless, because the EU member state governments continue to

76 International oil companies thus engaged in renewed backward integration after the nationalization in the late 1970s, opening up new producing areas in Alaska, the North Sea and offshore in the Gulf of Mexico. These investments also delivered on another policy goal of OECD governments: security of supply. Diversifying investments to include those in OECD countries, and subsequently the origin of oil, helped to keep OPEC market power in check. Not all oil companies survived the drastic restructuring of the international oil market in the 1980s and 1990s; many were taken over or merged, while new companies managed to enter the industry in the new producing areas. The EU depended on imports in coal, oil and natural gas. North Sea oil and gas production created a greater level of comfort with the net-importing status, but with declining production this level of comfort declined, too, in the early 2000s. In general, the nationalization of the oil assets in the Middle East had invigorated the regional investments in energy and the end of the Cold War brought Eastern energy riches within its scope.

77 Until the late 1990s, oil and gas companies in Italy, France and the Netherlands were also (partly) government owned. A liberalization and privatization drive reduced government ownership to either minority shares or transportation assets only (the Netherlands). Norway actually increased its government share in oil and gas operations, while the company also internationalized its operations.

lay their claim on being sovereign over their energy mixes (this being reaffirmed by the European Council in 2007), governments continue to tie their countries' energy companies (whether owned privately, by government or both) into national energy and industrial policy through an intricate system of subsidies and taxes.[78] Nevertheless, because state ownership has declined, governments in the EU are now predominantly regulators, setting the market framework and the competitive conditions in the market while regulating tariffs on networks. However, they do still remain owners of energy businesses.

20-20-20 Policy

When governments in the EU adopted the 20-20-20 policies for 2020 (20% reduction of carbon emissions through EU-ETS; 20% share of renewable energy sources in energy production and 20% energy efficiency gains), they mixed various transition trajectories in one policy framework to try to achieve a low-carbon economy. The underlying assumption was that the same economic activities should be able to be performed while consuming less energy and emitting less carbon. However, in a dynamic international economic environment, other factors (e.g. cost of labour and capital) determine what and where products are produced. The EU carbon emission reductions in the last two decades were largely the result of de-industrialization and the switch to natural gas in electricity generation in various countries.[79] Despite the professed reduction in carbon production in industrialized countries, carbon consumption increased through carbon embedded in trade (for instance with China), showing that transition to a low-carbon economy is not just about energy production but also about consumption.

The 20-20-20 EU policy also re-emphasized the drive for national energy and climate policy-making. The attempt of the EU 2050 roadmap exercise to show that 'various energy transition roads all lead to Rome' failed to obscure the fact that the playing field has become increasingly more uneven among fuels, companies and sectors. Germany, with its *Energiewende*, is currently not delivering affordability to the German '*Mittelstand*'[80] and residential consumers, who have to pay the renewable surcharge, while large energy-intensive industries are exempted.[81] Moreover, some of

78 In Eastern Europe, smaller utilities were taken over by larger Western European ones, although some state ownership persists. Local authorities also have a substantial stake in the power sector, either through ownership of the transmission and distribution networks and/or production companies (Germany, the Netherlands, UK). The nuclear sector in the EU is largely government-owned or -backed (France, UK).

79 Dieter Helm, *Carbon Crunch, How We're Getting Climate Change Wrong- and How to Fix it,* Yale University Press, New Haven and London, 2012, p. 68-72.

80 Small and medium size companies in German speaking countries

81 *The Wall Street Journal,* "Germany's expensive Energy Bet", August 28, 2014.

these energy-intensive industries also do not have to pay for electricity transportation, shifting the cost of connecting supply and demand onto other parts of society. With renewables mostly producing in the north of the country and industrial consumers mostly located in the south, these government policy choices are telling. The switch in Germany from supporting energy-intensive heavy industries in the past to lighter, more technology-intensive industries has facilitated the change in energy policy, but also the change in the relationship with the large utilities in the country.

Liberalization has not broken the connection between energy and industrial policy. Instead of in the state company boardroom, these decisions are now simply taken by fiscal and industrial policy leaders. The problem is that fiscal instruments have uncertain outcomes, particularly in a framework where electricity and natural gas markets are competitive; i.e., the composition of the energy mix and affordability, security of supply and climate reflect the complex interaction between markets and interventions. The unique combination of severe economic problems (financial and fiscal crisis), the shale revolution in the US freeing up coal for exports, and the climate and energy policies of the EU have challenged the position of natural gas in the EU power generation merit order rather than coal (without CCS).[82] Although governments could not have foreseen the unique combination of circumstances, they also did little to reduce the impact of this 'perfect storm' for conventional power generators. With a pending imbalance in the two parts of the system, more interventions are being lobbied for, which in practice are further reducing the market space and increasing the government space. Increasing the capacity of renewable sources, apart from the costs per Kwh, also challenges security of supply policies when back-up capacity is not rewarded sufficiently in markets and, as a result, conventional capacities are being mothballed or closed. Energy system costs have not been taken into account but instead have been left for the network and incumbent companies to absorb. The ability to carry such system costs appears to be less than governments had anticipated, as is the share of renewables being introduced in the system. At the same time, each addition to renewable capacity has a downward impact on wholesale market prices. The decline in price is steeper than the decline in cost, preventing these renewables from 'standing on their own feet' any time soon.[83]

In the short- to medium term, reconciliation of government energy policy priorities is impossible, while meeting the priorities of energy policy is also becoming harder

82 Pier Stapersma, *Sunset or Sunrise? Electricity Business in Northwest Europe, CIEP* April 2014; and Security of Supply in the run up to the post-2020 period, CIEP, May 2014.

83 Pieter Boot, Jacques de Jong en Nico Hoogervorst, *Reflections on Coordination Mechanisms for Accommodating Increasing Amounts of Wind and Solar in the Power Market*, a CIEP/PBL Study, forthcoming September 2014.

for individual companies. This initial stage of the transition process has delivered less affordable (more expensive), less secure (more intermittent) and less clean energy (CO_2 from coal). The attempt of the European Commission to focus its policy priority on CO_2 emission reductions for 2030 in their proposal is running into political problems. Proponents of renewable energy are lobbying hard for obligatory shares for renewables, while energy and other industries are lobbying for a revitalized emissions trading scheme (EU-ETS). Here, the competing energy and industrial policy interests of the various member states come to the fore.

LESSONS FOR GOVERNMENT

The effectiveness of policies enforcing transition is not always clear; they sometimes need a longer time to prove their value to society. For instance, the introduction of biofuels in Brazil was a response to the oil crises of the 1970s and was intended to reduce oil import dependency. After a long period of struggling to stay in the market, all the while losing market share to oil products because of low prices in the 1990s, biofuels became important again when oil prices increased and environmental policies elsewhere promoted blending biofuels in with transportation fuels. Although the US market did not open completely for Brazilian biofuels because of its own programme, the EU became an important destination for Brazilian biofuels. In the Brazilian market, biofuels in transportation came of age when a flex-fuel vehicle was introduced, replacing the dedicated biofuel vehicles that were produced for the Brazilian car market and opening real competition between gasoline and biofuels.[84]

It is clear that the time factor is also relevant to take into account. In the example of the creation of Brazil's biofuels market, it took nearly 25 years for the market to finally work when a new technology, the flex-fuel vehicle, was introduced to the market. The cost of creating the biofuel market was high and competition from cheaper oil products fierce, until consumers were equipped with a vehicle that could arbitrate between the fuels. In most other economies, biofuels are blended into oil products until they hit a limit due to the fact that current vehicles are not designed to run on a flexible composition of fuel.

The time factor time also plays a role in the *Energiewende*. In an attempt to create investor certainty, long periods of price guarantees were awarded (20 years), while the amount of money or capacity constructed under the scheme was initially not restricted. The resultant dash for wind and solar is increasing the cost for consumers, while the capital destruction in the conventional power sector is vast. Despite the

84 http://www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/2013_events/GBEP_Bioenergy_Week_Brasilia_18-23_March_2013/4.5_JOSEPH.pdf

guarantees, the investor uncertainty has not been remedied. Investors in renewables increasingly suspect that the schemes might not run as long as they were promised because of the costs involved, while they are also increasingly uncertain about whether they can keep pace with price declines in wholesale markets. At the same time, investor uncertainty in the conventional sector has nosedived. The lack of balance is a very costly result of government policy attempting to introduce new fuels and energy sources to the energy mix in a market environment that has difficulty adjusting to the new market circumstances. The fact that conventional generation was confronted with a decline of economic activity and a loss of market share to renewables further unhinged the balanced transition that was foreseen. Mixing policy instruments was less benign than anticipated and created expectations among various interest groups with regard to the priorities of a follow-up policy. The fact that the EU Commission's proposals for the period 2020-2030 have been widely criticized for their attempt to focus more on CO_2 pricing than on renewable shares is a case in point.

The conclusion with regard to EU energy and climate policymaking is that mixing too many instruments can undermine the effectiveness of all instruments. Also, more thought should be given to how government can enforce transition in an internal market framework when governments rather than markets or companies choose energy technologies and business models.

CONCLUSION

Government drives some transitions, for instance when markets are not (or not sufficiently) serving the three priorities of energy policy: affordability, security of supply and environmental protection. The success of government-enforced transitions is mixed in terms of time considerations. They often have very long lead times, requiring long periods of support to keep the new fuels in the energy mix, particularly when the introduction of a new energy technology competes with another (traded) fuel still in the midst of its expansion phase.

Coal without CCS or another abatement technology is by far the biggest contributor of CO_2 per kWh. Currently, China is responsible for a little over 50% of world coal consumption, and the rate at which China can reduce the role of coal without CCS in its economy might not be fast enough for an efficient global transition before 2050. The implication is a continued contribution of coal to global CO_2 emissions. This potentially reduces the carbon space for other fossil fuels with a much higher rate of energy per carbon emitted.

If the world is able to come to an unprecedented level of cooperation with regard to climate change policies, fossil fuels will and can play an important role in the energy mix. It is clear that as the largest source of future CO_2 emissions, the role of coal without CCS or another emissions reduction technology needs to be addressed first, to allow space for fuels with a higher energy per unit of carbon emission to stay in the mix longer. Such an agreement would also help to keep important oil- and gas-producing countries interested in addressing climate change before 2050.

It is, however, unlikely that the world will agree any time soon on a collaborative climate change strategy; instead countries will continue to approach their transitions in their own particular way. Achievement of a joint low-carbon economy is unlikely in the current unstable geopolitical and economic situation. It is more likely that national interests will prevail, also because the short-term cost of transition and the long-term cost of climate change is unclear for individual countries.

ANNEX

TABLE 1: RANKED REASONS FOR FAILURE OF A CARBON BUBBLE TO BURST

This table ranks the reasons for failure of a carbon bubble to burst:

Government policies regarding carbon emissions will not affect the liquefying of fossil reserves
Technology advancements to reduce Greenhouse gasses are undervalued
Management of high carbon emission firms have the capacity to mitigate stranded assets
Market expectations of firms with high fossil reserves will change
Scientific evidence of the relation between emissions and temperature is overvalued

TABLE 2: TIMELINE OF DETECTION OF CARBON RISK

This table presents the timeline for which institutions identified carbon risk.

Year	Firms
2007	0
2008	1
2009	0
2010	0
2011	0
2012	2
2013	1

TABLE 3: POLICY AND GOVERNANCE MECHANISMS

This table shows the number of firms that employ a carbon risk mitigation strategy.

Policy	No. of firms
The identification of carbon risk was done by sector reports	4
Recent carbon emission disclosures were analyzed	4
Our firm sent inquiries to firm to assess carbon emissions	3
Our firm has not yet identified carbon risk for our portfolio	1
Direct interaction with firms on carbon policies	4

TABLE 4: PORTFOLIO HOLDINGS

This table shows the average portfolio weights of the institutions' investments characterized by carbon intensity.

Carbon factor	Portfolio weight
High carbon intensity firms (Mining, Oil and Gas markets, fossil electricity firms)	16%
Middle carbon intensity firms (Industry)	28%
Low carbon (Service industry)	53%

TABLE 5: SAMPLE CHARACTERISTICS

This table presents the sample characteristics of the used datasets. The OGJ dataset is derived from the list of largest publicly traded US oil and gas firms ranked by OGJ 2014. The PIW datasets compromises of the largest international oil and gas firm listed by PIW 2014 that have the majority of their shares traded on the financial markets. The Dominguez-Faus dataset is taken from Dominguez-Faus et al. (2014) and consists of a selection of U.S. firms in the Datastream Energy Index with CUSIP and CIK codes.

Dataset OGJ	
Total number of firms	139
Large size firms (larger than $50B marketcap)	6
Middle size firms (less than $50B marketcap larger than $9.5B)	20
Small firms (smaller than $9.5B marketcap)	113
Dataset PIW	
Total number of firms	23
US and Canadian firms	11
European firms	7
Other	5
Dataset Dominguez-Faus	
Total number of firms	63
Large size firms (larger than $50B marketcap)	6
Middle size firms (less than $50B marketcap larger than $9.5B)	16
Small firms (smaller than $9.5B marketcap)	41
Total number of firms in OGJ dataset	50

TABLE 6: EVENTS

This table presents the events of our study. For each event the number of included firms is noted. The OGJ refers to the OGJ list of 139 US oil and gas firms, the PIW to the PIW list of 21 international firms and the DOM to the dataset used by Dominquez-Faus et al. (2014).

Events	Date
Regulation	
Concept Release	
Concept release of the modernization of oil and gas reporting by SEC	12/12/2007
Proposing Release	
Proposing release seeking public comment on proposed amendments	6/26/2008
Law implementation	
Law enforced modernization of oil and gas reporting	1/01/2010
Carbon Tax	
Australia announced carbon taxation	4/11/2011
Climate Change disclosure	
The SEC issues Interpretive guidance on disclosure related to business or legal developments regarding climate change	1/27/2010
Climate News	
Publication	
Publications of Meinshausen et al. (2009)	4/30/2009
Conferences	
All the UN Climate change conferences from 2007 to 2013 and the 2009 World climate conference.	
Disclosure	
Carbon Initiative	
Exxon mobile receives carbon questions from shareholder	3/21/2014
Carbon Reports	
Exxon mobile and Shell presents their carbon report.	3/31/2014 5/16/2014
Sustainability report	
A collection of all sustainability proxy meetings outside the annual shareholders meeting between 2005 and 2012.	

TABLE 7: ABNORMAL RETURNS AND CARS

This table presents the abnormal and cumulative absolute returns calculated from the day before and after the event. For all datasets, we use the S&P500 Energy index as market factor instead of the S&P500. We report for all the firms in the sample. Superscripts ***,**, and * indicate a statistical significance at the 1%, 5% and 10% (two-tails) tests levels, respectively. This notation applies to the tables 7-15 in this Annex.

	OGJ				PIW			
Events	Ab return	CAR (-1,1)	CAR (-5,5)	CAR (-10,10)	Ab return	CAR (-1,1)	CAR (-5,5)	CAR (-10,10)
Regulation								
Concept Release	0.92%	1.62%	1.33%	1.08%	1.63% ***	2.02% ***	3.09% ***	-2.81% **
Proposing Release	0.93% **	0.00%	-5.90% ***	-3.08%	1.33% ***	1.43% **	-2.42% **	-5.64% ***
Law implementation	-0.01%	1.48%	3.28% **	3.76%	-0.09%	1.48% **	1.36%	0.65%
Carbon Tax	-2.50% ***	-3.39% ***	-3.76% **	-3.26%	-0.83% **	-1.74% ***	-2.49% **	-2.58%
Climate Change disclosure	-1.08% **	-0.73%	1.23%	0.23%	-1.10% **	-1.11%	-3.15% **	-6.42% ***
Climate news								
Nature publication	-1.77% ***	0.67%	5.47% ***	9.25% ***	-0.61%	2.44% **	5.60% **	4.41%
Conferences	-0.03%	-0.97% ***	-1.07%	-2.01%	0.01% **	-0.50%	-1.11%	-0.92%
Disclose								
Carbon Initiative	0.65%	-0.91%	1.45%	2.13%	0.02%	0.01%	3.54% ***	4.10% ***
Carbon Reports	0.45%	-0.48%	0.46%	1.67%	-0.34%	-0.30%	2.36% ***	3.62% ***
Sustainability report	0.06%	-0.12%	2.24%	1.08%				

TABLE 8: REGRESSION ON EVENT FOR CONCEPT RELEASE OF RESERVE REGULATION

	Abnormal	CAR (-1,1)	CAR (-5,5)	CAR (-10,10)
Cons	-0.017 **	0.015	-0.011	-0.016
Agency				
Cash holding	0.050 **	-0.112 *	0.085	0.067
Capital expenditure	0.074 ***	0.095 *	0.004	0.076
Dividend pay-out ratio	0.001	-0.011	-0.016	-0.014
Leverage	0.001	-0.007	-0.011 *	-0.016
Control				
ROA	0.071 ***	0.024	0.118 **	0.277 ***
Tobin Q	0.000	0.003	0.011 ***	0.003
Financial Slack	0.037 **	-0.038	0.120 **	0.158 *
Ln(employ)	0.004 ***	0.006	0.015 ***	0.019 **
R squared	0.347	0.143	0.291	0.289

TABLE 9: REGRESSION ON EVENT FOR PROPOSAL RELEASE OF RESERVE REGULATION

	Abnormal	CAR (-1,1)	CAR (-5,5)	CAR (-10,10)
Cons	0.015	-0.001	0.025	0.019
Agency				
Cash holding	0.047	0.097	-0.039	-0.026
Capital expenditure	-0.053	-0.038	-0.031	-0.145
Dividend pay-out ratio	0.007	-0.024	-0.040	0.002
Leverage	-0.005 *	-0.010 **	0.000	-0.015 *
Control				
ROA	-0.028	-0.043	-0.201 **	-0.154
Tobin Q	0.001	0.005	-0.006	0.003
Financial Slack	0.070	0.084	-0.105	0.038
Ln(employ)	0.003	0.009 *	0.012	0.005
R squared	0.075	0.108	0.103	0.080

TABLE10: REGRESSION ON EVENT FOR IMPLEMENTATION OF RESERVE REGULATION

	Abnormal	CAR (-1,1)	CAR (-5,5)	CAR (-10,10)
Cons	-0.001	0.036 **	0.072 ***	0.083 ***
Agency				
Cash holding	0.006 ***	-0.118 *	-0.141 *	-0.037
Capital expenditure	-0.003	0.082	-0.160 **	-0.185
Dividend pay-out ratio	0.000	0.000	-0.002	-0.010
Leverage	0.000	0.000	0.001	0.002
Control				
ROA	0.001	-0.044 *	-0.032	-0.140 ***
Tobin Q	0.000	0.000	-0.002	-0.004
Financial Slack	0.003 ***	-0.108 ***	-0.108 ***	-0.164 ***
Ln(employ)	0.000 *	-0.001	-0.014 ***	-0.013 **
R squared	0.136	0.147	0.277	0.251

TABLE 12: REGRESSION ON EVENT FOR CARBON TAX

	Abnormal	CAR (-1,1)	CAR (-5,5)	CAR (-10,10)
Cons	-0.039 **	-0.026 ***	-0.032 *	-0.043 *
Agency				
Cash holding	0.095 *	0.012	-0.001	0.022
Capital expenditure	0.033	-0.092 ***	-0.051	0.004
Dividend pay-out ratio	0.001	0.000	-0.004	-0.004
Leverage	0.000	-0.001	-0.002	-0.001
Control				
ROA	0.006	-0.022	-0.022	-0.040
Tobin Q	0.001	0.002	0.002	0.000
Financial Slack	0.019	-0.002	-0.015	0.011
Ln(employ)	0.008 **	0.003 *	0.005	0.005
R squared	0.075	0.127	0.048	0.029

TABLE 13: REGRESSION ON EVENT FOR NATURE PUBLICATION

	Abnormal	CAR (-1,1)	CAR (-5,5)	CAR (-10,10)
Cons	-0.046 ***	-0.009	0.126 ***	0.155 ***
Agency				
Cash holding	0.124 *	0.125	-0.187	-0.285
Capital expenditure	0.101 **	0.234 ***	-0.117	-0.138
Dividend pay-out ratio	-0.015	-0.027	-0.030	-0.020
Leverage	-0.003 *	-0.003	0.003	0.000
Control				
ROA	0.029	0.070	-0.030	-0.250 ***
Tobin Q	0.001	0.001	-0.002	-0.003
Financial Slack	0.002	-0.141 **	-0.112	-0.154
Ln(employ)	0.004	0.011 **	-0.018 **	-0.028 ***
R squared	0.118	0.196	0.087	0.166

TABLE 14: REGRESSION ON EVENT FOR CARBON SHAREHOLDER INITIATIVE

	Abnormal	CAR (-1,1)	CAR (-5,5)	CAR (-10,10)
Cons	-0.019 **	-0.001	0.035 *	0.031
Agency				
Cash holding	0.065	-0.017	-0.087	-0.123
Capital expenditure	0.031	0.085 ***	0.254 ***	0.276 **
Dividend pay-out ratio	0.000	0.000	0.000	0.000
Leverage	0.000	0.003 *	0.009 **	0.010
Control				
ROA	0.049 ***	-0.014	-0.125 ***	-0.125 **
Tobin Q	0.001	-0.001	-0.007 ***	-0.007 *
Financial Slack	0.066 ***	-0.037 ***	-0.157 ***	-0.132 **
Ln(employ)	0.005 **	0.000	-0.001	0.003
R squared	0.251	0.155	0.310	0.167

TABLE 15: REGRESSION ON EVENT FOR CARBON REPORTS

	Abnormal	CAR (-1,1)	CAR (-5,5)	CAR (-10,10)
Cons	-0.019 ***	-0.008	0.006	0.020
Agency				
Cash holding	-0.007	-0.037	-0.056	-0.103
Capital expenditure	0.005	0.093 ***	-0.046	0.001
Dividend pay-out ratio	0.000	-0.001	-0.002	-0.003
Leverage	0.000	0.001	0.001	0.012 ***
Control				
ROA	0.027 *	-0.041 ***	0.049 **	-0.063 *
Tobin Q	0.001	0.000	0.000	-0.005 **
Financial Slack	0.042 ***	-0.045 ***	0.028	-0.001
Ln(employ)	0.001	0.001	-0.002	-0.004
R squared	0.150	0.196	0.081	0.171

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