2

The Potential Role of Gas in Decarbonizing Europe: A Quantitative Assessment

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2.1 Introduction

The dynamics of energy markets in Europe are currently experiencing a paradoxical transition. On the one hand, a revival of coal imports and a reduction of gas consumption, with an associated negative impact upon greenhouse gas (GHG) emissions in some major European economies, have been observed in recent years. On the other hand, the European Commission and all EU countries, by committing to

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the INDC submitted at Paris COP 21, have adopted ambitious GHG emissions targets.

The European Commission itself has acknowledged the increased use of coal as a key issue for Europe, with increased CO_2 emissions being an important concern. The European Commission's contribution to the European Council of 22 May 2013 titled "Energy challenges and policy" notes that "EU consumption and imports of coal (hard coal and lignite) have increased by, respectively, 2% and almost 9% over the first 11 months of 2012, relative to the same period in 2011" (European Commission 2013).

Policies to promote the transition towards a sustainable energy system—which are likely to favour natural gas, at least in the short and medium term—have not materialized to the extent expected only a few years ago. Nevertheless, the role of natural gas as a transitional fuel within the joint climate and energy framework is an important component of the EU strategy. This was highlighted within the EU Energy Roadmap 2050, which noted that the scenarios utilized within the Roadmap "are rather conservative with respect to the role of gas … economic advantages of gas today provide reasonable certainty of returns to investors, as well as low risks and therefore incentives to invest in gas-fired power stations" (European Commission 2011).

Hence, there is a need to conduct additional analysis on the role of natural gas within the EU policy framework to address climate change. The European Union is unlikely to achieve its ambitious climate targets without relying heavily on gas rather than coal as a primary energy source. Therefore, appropriate measures need to be implemented to move energy markets in Europe closer to the optimal energy mix (where optimality obviously includes the internalization of the climate externality). Gas is likely to play a relevant role in the optimal energy mix for at least four decades (as shown within the analysis below).

To address these issues, this chapter focuses on three climate-related policy scenarios with two additional policy assumptions (two possible policy variations). In doing so, it reviews the role of natural gas within climate efforts which include the post-Copenhagen Pledges and the EU Roadmap.

It should be noted that a range of studies have focused on the impact of climate targets upon Europe, e.g. refer to Böhringer et al. (2009), Blesi et al. (2010), Capros et al. (2012a) and Bosello et al. (2013).

However, this is the first study to specifically focus on the role of natural gas across different EU climate policy scenarios. Our focus on natural gas is due to the above statement within the Energy Roadmap 2050, the current debate concerning the additional sources of gas, and the potential role of gas as a transitional fuel within the shift towards a low-carbon energy future as it provides a flexible power source which can counter the intermittency of renewables. While gas has been acknowledged to remain in the European primary energy mix within the long term (Knopf et al. 2013), the extent to which natural gas plays a role has not been given sufficient attention.

The analysis has been conducted using the World Induced Technical Change Hybrid (WITCH) model, an integrated assessment and a widely used model in the global assessment of climate and energy policies. Within the model, the main macroeconomic variables are represented through a top-down intertemporal optimal growth economic framework. This is combined with a bottom-up compact modelling of the energy sector, which details energy production and provides the energy input for the economic module and the resulting emission input for the climate module. Further information about the model is available at the website www.witchmodel.org or can be sourced from Bosetti et al. (2007), as well as in Bosetti et al. (2006, 2009).

The chapter is compiled of four sections. An introduction appears before this point, while three sections follow. Section 2.2 outlines the scenarios utilized within the analysis. Section 2.3 focuses on the main results of the analysis, with a focus on the future of natural gas within Europe. Section 2.4 concludes with a discussion of the key findings of our analysis.

As a prelude to the results of the chapter, the conclusions have been separated into three key points. The first is the importance of setting a suitable carbon price which ensures that the right incentives are given to energy markets, so that a consistent energy mix can be achieved, thus reducing the policy costs of all climate policy targets reviewed within the analysis. The second point is that natural gas is indeed a key transitional fuel for a range of climate policy targets, and therefore, policy should be very careful in designing the right incentives to sustain gas consumption, at least until intermittency remains a problem for renewables' expansion. And lastly, the importance of avoiding distortive policy instruments, e.g. subsidies, is highlighted. For example, in the near term (2020), the renewable target and related subsidies to renewables have been found to reduce carbon prices by about 10 $/t$CO_2$, with clear negative impacts on incentives to adopt more energy-efficient business strategies and to invest in climate-friendly technologies and production processes. What this study shows is that a correct carbon pricing can sustain gas consumption at while transitioning coal out of the power generation mix without damaging the development of renewables, even with lower or zero subsidies.

2.2 Scenario Description

With a focus on the importance of climate policy for natural gas in Europe, we have developed a range of scenarios which capture a realistic representation of the current conditions under which policy-makers are operating. As part of this, we have implemented the scenarios presented below with underlying assumptions regarding economic growth and the expansion of nuclear power. For example, stagnant economic growth in Europe until 2020 is implemented by lowering labour productivity, and within the baseline, this results in a growth rate of approximately 0.4% per year for Europe between 2010 and 2020, increasing to approximately 1.5% per year after 2020. Table 2.1 presents the population and GDP assumptions that are implemented within the baseline scenario.

Table 2.1 Baseline demographic and economic estimations

	2010	2015	2020	2025	2030	2035	2040	2045	2050
Population (Billions)	0.513	0.520	0.525	0.528	0.530	0.530	0.530	0.528	0.526
GDP (Trillion 2005 USD MER)	15.17	15.67	16.15	17.39	18.86	20.33	21.96	23.67	25.52
GDP per Capita (2005 USD per person)	29.54	30.14	30.77	32.92	35.57	38.31	41.44	44.79	48.50

A gradual reduction of nuclear power in western Europe is also implemented across all scenarios to reflect the post-Fukushima apprehension towards the technology. Within the baseline, this results in an 8% reduction in nuclear power generation in comparison with 2010 levels at the European level for 2020, increasing to a 14% reduction in 2030.

Climate policy stringency is implemented across four different scenarios. The No Policy (No Pol) scenario is a comparative counterfactual state of the world in which no climate policy is implemented (not even in 2020) in any country in the world. As our focus is on Europe, the counterfactual nature of this scenario is clear as it does not include any of the existing policies which have already been implemented (such as the 2020 renewable and emissions target) and the main use of this scenario will be in providing a benchmark for the calculation of policy costs, including the costs of the 2020 renewable target.

The Moderate Policy (Pledge) scenario is a case where there is fragmented moderate action on climate and includes region-specific policy objectives based on the post-Copenhagen Pledges. These region-specific policy objectives include the following: (1) 2020 emission reduction targets, (2) technology-specific policies (e.g. expansion of renewable and/or nuclear) and (3) post-2020 carbon intensity targets. Within the Moderate Policy scenario, regions can trade carbon offsets internationally (for example, through a clean development mechanism type of project or via a linkage of the ETS to other regions). However, this is limited to be equivalent to 20% of abatement as at least 80% of emission reductions have to be conducted domestically. For Europe, this scenario includes the legislated 2020 targets (specifically emissions, renewables and energy efficiency) and a post-2020 extrapolation of climate policies, with a 2030 and 2050 target of 25 and 45% emissions reductions with respect to 2005.

The Stepped up Policy (Pledge+) scenario replicates much of the settings of the Moderate Policy scenario, except that the level of ambition is stepped up in 2020 and beyond within all regions. This scenario mimics the implications of the Paris agreement for the EU. This results in a tightening of the supply of emission carbon offsets up to and including 2020 (or equivalently, this can be interpreted as having raised the ambition of emissions reductions in 2020 to 30% wrt to 1990). For 2030 and 2050, emission reductions would be 40 and 60% wrt 2005, respectively.

The 2 °C Policy (2°) scenario moves away from the fragmented representation of climate policy and captures a situation where the Durban

Action Platform delivers a binding international climate treaty entering into force in 2025 with the aim of maintaining global temperature increase below 2 °C with sufficiently high probability. It is important to remark that since the model has a global scope, each policy scenario has a detailed formulation for all the regions of the model (13 regions), and not just for Europe.

Two additional policy assumptions are then imposed on top of the implementation of the level of climate policy stringency with the Base case, being the standard representation of the policy. Note that for Europe, this means that the Base case includes the legislated 2020 targets (specifically emissions, renewables and energy efficiency) in all scenarios, except for NoPol. The first additional policy assumption that is implemented is the no renewable target (No RET), where the 20% renewable target (as a share of final energy) in Europe for the year 2020 and beyond is not activated. This allows disentangling the impact of the renewable target upon Europe—its cost for the EU in particular—in comparison with the alternative cases.

The second additional policy assumption is a case where Europe pursues energy efficiency policies in 2020 and beyond. This, in turn, stimulates high energy efficiency (HEE) where demand stays relatively flat between 2010 and 2050. The implementation of the HEE scenario has been separated into two potential options for policy design and implementation. The first of which is an energy intensity (HEE_I)-based policy where technical change improves energy efficiency. The second is where the policy is imposed as a target on energy demand (HEE_D) and can be achieved by reducing energy demand, rather than through energy intensity. As will be discussed in Sect. 3.1, the distinction is important with respect to policy design and policy costs but is irrelevant with respect to the energy mix. Thus, the distinction will be retained only when presenting carbon prices and policy costs.

2.3 Main Results

Before focusing upon Europe, it is important to briefly review the overall climate policy framework that is being implemented in all world regions as part of the same scenarios. Figure 3.1 reviews the impact of the climate policy stringency scenarios upon global greenhouse gas emissions between 2010 and 2050. The Pledge and Pledge+ policies lead to a peak of global emissions by 2050 and 2040, respectively (and decline thereafter), whereas the 2Deg policy moves this peak back to 2020. The graph highlights the growing global gap in emissions between the case in which no action on climate is undertaken (NoPol) and the different climate policy scenarios. If emissions continued to grow unabated, in line with historical trends, the effects of climate change would be potentially significant, with a global increase in temperature by the end of the century estimated around a mean of 4 °C. On the other hand, the three policies analysed in this chapter have the potential to reduce the temperature increase, depending on the stringency of emission reductions.

Greenhouse gas emissions of selected major regions for the Pledge and Pledge+ policies, reflecting the commitments made within the Copenhagen Pledges, are shown in Fig. 2.1.

In these fragmented policy scenarios, OECD countries would reduce emissions, while emissions in China and India increase before 2030. In the case of China, emissions level off in 2030 and decrease thereafter, as decided at Paris COP 21, thus reflecting a firm commitment towards climate and air pollution reduction objectives, while emissions in India continue to increase up until 2050, given the different stages of

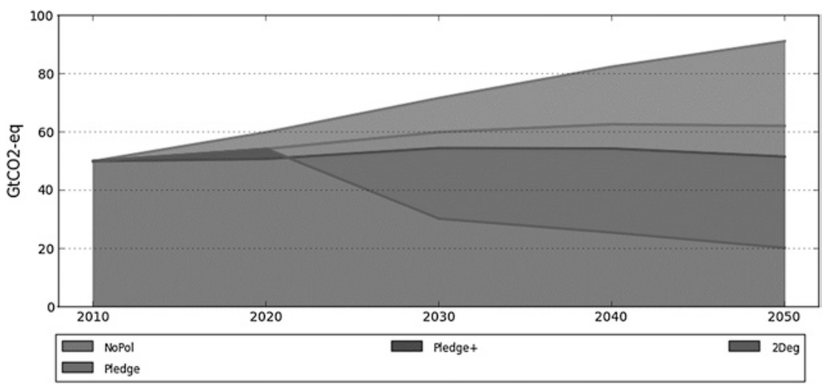

Fig. 2.1 Global greenhouse gases by scenario

economic development. In the case of China, CO_2 emissions in 2010 are 22.7% of the global total and peak at 30.1% in the pledge case in 2030, decreasing to 26.7% in 2050. This is in comparison with 31.5% of global emissions in 2030 and 30.8% in 2050 within the no policy scenario.

Let us now pay attention to the level of action by Europe across the scenarios presented in Fig. 2.2. CO_2 emissions associated with Europe were 12.1% of the global total in 2010, and under the Pledge scenario, this would decrease to 6.6% in 2050 (in comparison with 8.7% in the no policy baseline). In terms of abatement, in 2050 Europe would be responsible for 13.6% of global emission reductions in the Pledge scenario, which decreases to 11.6% in Pledge+ and 8.4% with a unilateral focus on achieving 2Deg. Note that the percentage of emissions/abatement differs based on the level of commitment by regions outside Europe and the overall worldwide emissions in total.

Before reviewing the role of natural gas, it is important to evaluate the climate policy stringency targets for Europe. Figure 2.3 shows the European greenhouse gas targets for the Pledge and Pledge+ scenarios with a comparison between emissions with respect to the NoPol case. Note that Fig. 3.3 makes a distinction between the allowance allocation of emissions and the total amount of emissions that occur within Europe, once international carbon offsets have been accounted for. As

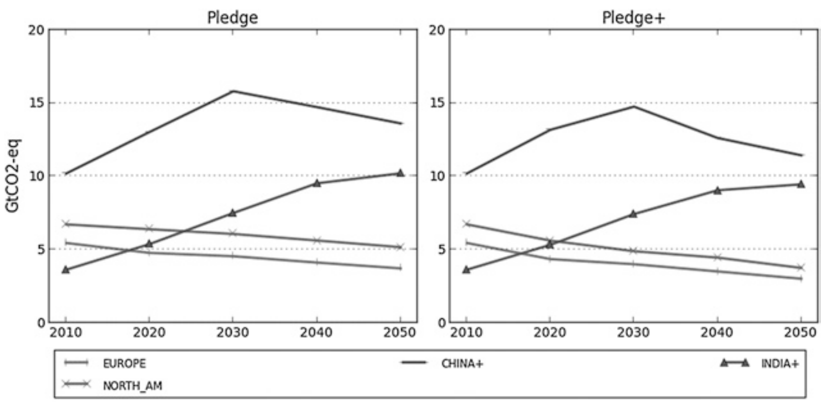

Fig. 2.2 Greenhouse gases by selected major region—Pledge and Pledge+

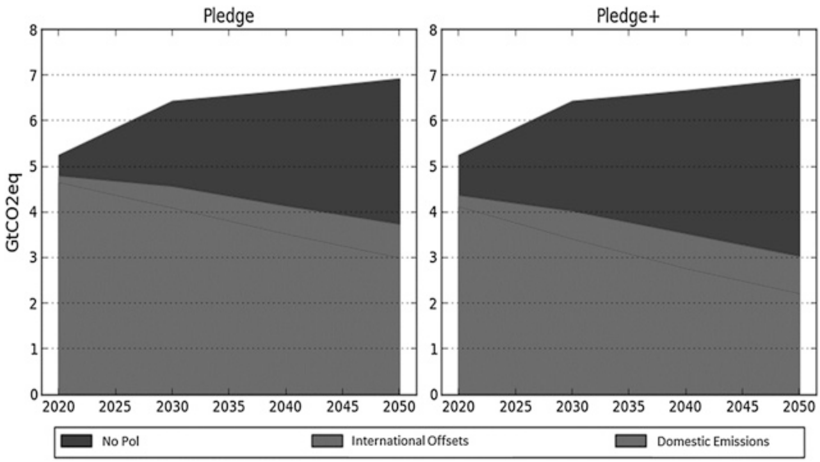

Fig. 2.3 European greenhouse gas targets—Pledge and Pledge+

already implemented today, Europe is allowed to fulfil a fraction of its domestic emissions reductions targets by buying a certain amount of emission permits outside the region, most notably in the developing countries where abatement opportunities are cheaper.

As previously noted, the two policies considered foreseeing a gradual reduction in emissions in Europe, with emission reduction targets in 2030 of 25 and 45% (with respect to 2010) for the Pledge and Pledge+ policy scenarios, respectively. These targets would increase to 45 and 60% by 2050, with a rather linear schedule.

2.3.1 Power Generation Within Europe

We start by providing an overview of the welfare-maximizing power generation mix for coal, gas, nuclear and non-biomass renewables across the Pledge and Pledge+ scenarios and the additional policy assumptions. These are shown in Figs. 2.4 and 2.5. The general trend in power generation for the Pledge and Pledge+ policy scenarios is a reduction in coal and an increase in gas and renewables, as well as a decreasing role for nuclear due to the inclusion of the potential impact of post-Fukushima apprehension within western Europe. These trends are robust across the different policies.

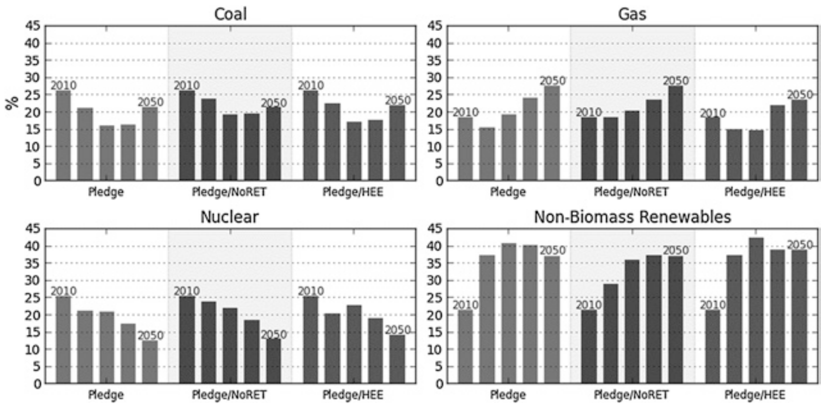

Fig. 2.4 Power generation shares by fuel—full range of Pledge scenarios, from 2010 to 2050

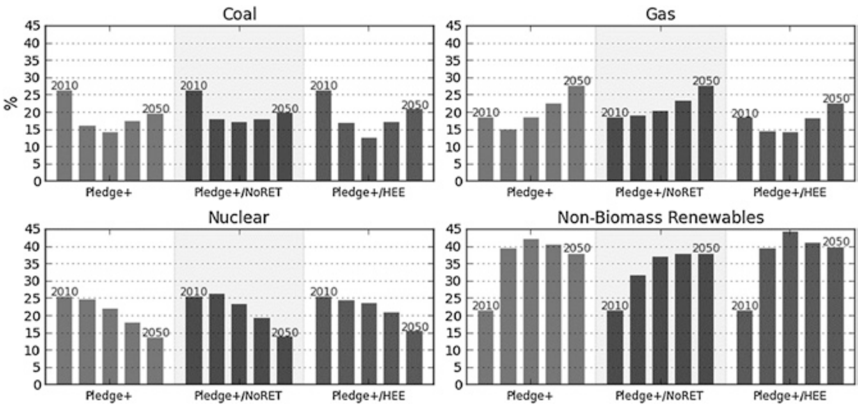

Fig. 2.5 Power generation shares by fuel—full range of Pledge+ scenarios, from 2010 to 2050

In all scenarios, coals lose 10% of market share by 2030, recuperating slightly thereafter due to the deployment of CCS technology. Gas gains 10–15% points, after an initial reduction in 2020 over 2010 due to the economic recession. Renewables show a fast growing pattern in the short term, spurred to a large extent by existing incentives, but also a long-term saturation, due to increase in system integration costs.

Specifically, the power generation shares for Europe within Pledge in 2020 are 21% for coal, 16% for natural gas, 37% for non-biomass renewable and 21% for nuclear, in comparison with shares of 25, 17, 27 and 25% in 2015. The removal of the renewable target for 2020 results in power generation shares for Europe within Pledge/NoRET in 2020 of 24% for coal, 18% for natural gas, 29% for non-biomass renewable and 24% for nuclear, with an additional 5% decrease in total electricity demand.

In the case of Pledge+, the power generation shares for Europe in 2020 are 16% for coal, 15% for natural gas, 39% for non-biomass renewable and 23% for nuclear, in comparison with shares of 25, 17, 27 and 25% in 2015. The removal of the renewable target for 2020 results in power generation shares for Europe within Pledge+/NoRET in 2020 of 18% for coal, 19% for natural gas, 32% for non-biomass renewable and 26% for nuclear, as well as a 6% decrease in total electricity demand.

Underlying a review of Europe which focuses on 2020, as done above, are the issues of low economic growth and the impact of the renewable target. Figures 3.4 and 3.5 show indeed that natural gas within Pledge and Pledge+ is expected to slightly decline in 2020 wrt 2010 and this is related to the slow demand growth in total electricity. However, the impact of the renewable target is notable with no contraction in the share of natural gas occurring within the NoRET cases.

Irrespective of the impact of the renewable target, after 2020 both the Pledge and Pledge+ climate policies induce gas to increase significantly and coal to continue decreasing (until it is somewhat revived when coupled to CCS by mid-century). Figure 2.6 provides the changes in natural gas from electricity in terms of the level of production. The chart indicates that natural gas would eventually increase its contribution to the power mix in a significant way, with an expected generation by mid-century of 1000–1200 TWH, which roughly corresponds to a doubling from today's levels.

The exact timing of the increase in the use of gas depends on assumptions about the economic recovery and the set of policies in place after 2020. As evidenced from Fig. 2.6, the impact of the renewable

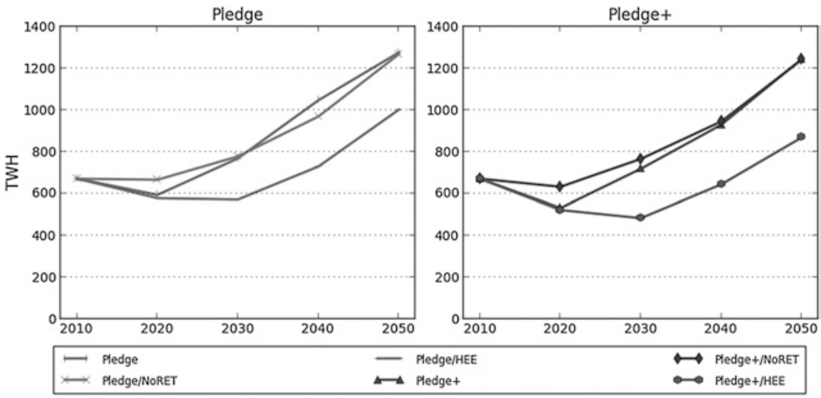

Fig. 2.6 Natural gas electricity—level of power generation

target upon the amount of gas within power generation is visible only in 2020. The impact of the renewable target in 2020 vanishes after that due to an increased role played by renewable energy sources in the long term across all of the additional policy assumptions due to the level of carbon prices in the market. On the other hand, strong post-2020 legislation on energy efficiency is shown to have a sizeable impact on the prospects of natural gas, as a result of lower electricity demand due to increased savings.

Underlying results that have been shown in this section are changes in the investments related to providing the capacity for the power generation options reviewed. Focusing on the Pledge and Pledge/NoRET scenarios, Fig. 2.7 focuses on the impact of the renewable target on investments across coal, natural gas and modern renewables.

The chart shows two contrasting trends for coal and gas on one side, and renewables on the other. Investments in both coal and gas are expected to grow over time, in the range of 100–300 USD billions per decade, but only after the post-2020 economic recovery. Despite its decreasing role in the power mix, investments in coal remain substantial, due to the higher overnight capital costs of coal power, and the fact that after 2030 the majority of coal is equipped with carbon capture and storage (CCS) technology. Indeed, for coal

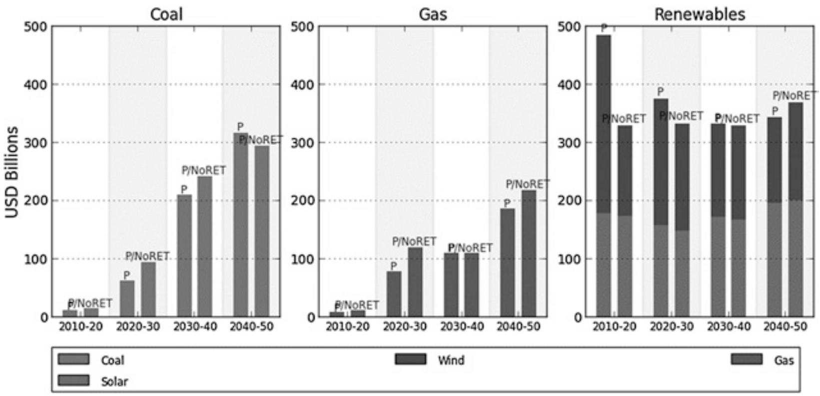

Fig. 2.7 Decadal investments across key power generators

to remain in the optimal energy mix, and still enable the achievement of emissions consistent with Copenhagen Pledges, coal needs to be equipped with CCS after 2030. As a comparison, natural gas is also coupled with CCS; however, this occurs after 2040 within the Pledge scenario. Despite providing a much larger electricity share, investments in gas are smaller, due to the low overnight capital costs assumed for CCGT technologies.

For renewables, investments on the other hand slightly decrease after 2020, due to the improved economics of renewables, as well as a saturation of their contribution due to the already highlighted system integration constraints. In 2020, policies supporting renewables increase investments by about 50%. Between 2010 and 2030, the Pledge scenario corresponds with investments in modern renewables, being 55% of total investments related to the supply of electricity. In terms of capacity, this equates to 65% of new power capacity between 2015 and 2030. Note that projections completed by Bloomberg New Energy Finance forecast that renewables will account for between 69 and 74% of new power capacity added between 2012 and 2030 at the global level.

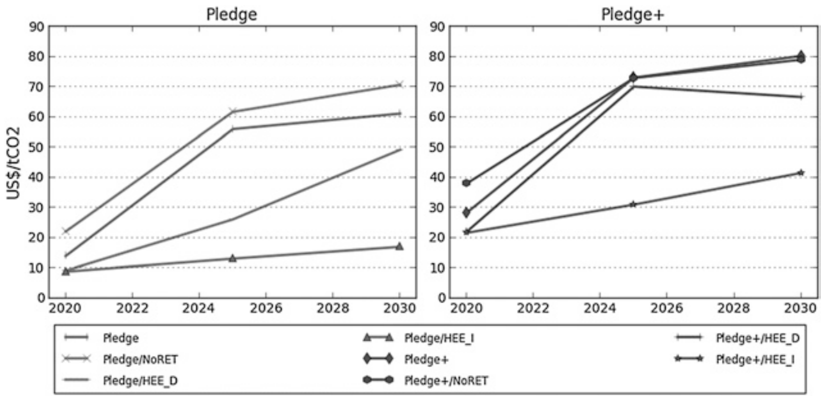

Fig. 2.8 Carbon prices—full range of Pledge and Pledge+ scenarios

2.3.2 Carbon Market and Policy Costs

We now turn to the economic implications of the economic, energy and climate scenarios analysed within this chapter. We begin by looking at an important indicator, namely the carbon prices which emerge from the EU carbon market, see Fig. 2.8. The chart highlights the expected fact that carbon prices grow in the stringency of the emissions reduction target, both over time (by about 5 $/t$CO_2$ each year) and across the policies (with Pledge+ adding 10–15 $/t$CO_2$ to the Pledge case).

Carbon prices in 2020 for the cases where the renewable target is implemented are 9–14 $/t$CO_2$ in the Pledge policy and 22–28 $/t$CO_2$ in the Pledge+ policy scenario, depending on the impact of high energy efficiency. However, the carbon price without the renewable target imposed would be 22 $/t$CO_2$ in Pledge/NoRET and 38 $/t$CO_2$ in the Pledge+/NoRET. This indicates that the renewable target suppresses carbon prices in 2020 by approximately 10 $/t$CO_2$. The importance of the differences in carbon prices lies in the need to provide clear incentives to energy markets—indeed, a stable and long-term signal which increases over time would prevent the recent expansion of coal within Europe which was noted within the introduction.

In addition, if full auctioned, the sales of permits have the potential to generate significant fiscal revenues, which are important at times of

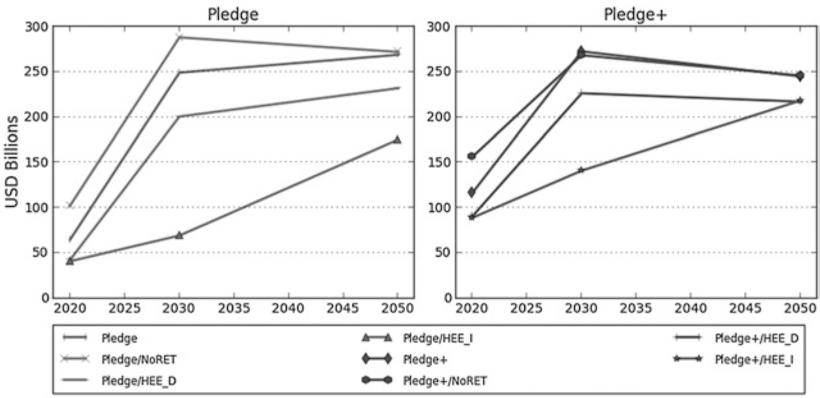

Fig. 2.9 Fiscal revenues from the carbon market

consolidation of public debt. We estimate that public revenues with Pledge and Pledge+ are associated with potential revenues of 65–166 billion USD and exceed 200 billion USD after 2030 (refer to Fig. 2.9). In 2020, the renewable target would reduce revenues by almost 40 billion USD irrespective of whether Pledge or Pledge+ is followed. This highlights that subsidies and/or incentives for modern renewables, in addition to being costly, also reduce the revenues from issuing emission permits.

Figures 2.8 and 2.9 also show the carbon prices and permit revenue associated with two different approaches to implement the same energy efficiency improvements—that being either through energy intensity improvements with technical change (HEE_I) or through energy demand reductions (HEE_D). Between these two scenarios, the differing impact of the imposition of the energy efficiency improvements is highlighted with energy intensity improvements through technical change reducing the burden of emission reductions which occur within the economy and hence have a downward impact upon the amount of carbon offsets which are sourced by Europe from abroad.

Carbon prices are imperfect indicators of macroeconomic costs. Hence, we assess these costs—as measured by GDP losses—separately in Figs. 2.10 and 2.11. Policy costs in the Pledge scenario are found to be in the order of 0.5% GDP loss in 2020, growing to 1.5% by

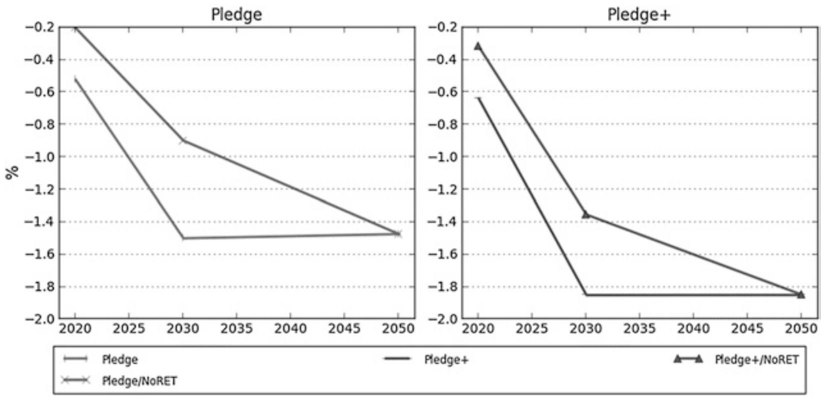

Fig. 2.10 Policy costs in comparison with the no policy scenario—selection of Pledge and Pledge+ scenarios

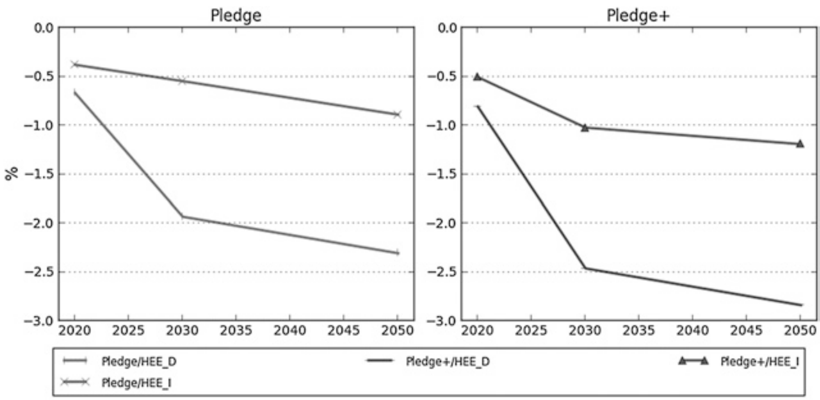

Fig. 2.11 Policy costs in comparison with the no policy scenario—focus on high energy efficiency (HEE) Pledge and Pledge+ scenarios

the mid-century. The renewable target is responsible for a considerable fraction of short-term costs, more than doubling 2020 policy costs; however, these converge over time once the impact of the 2020 renewable target disappears. The Pledge+ policy induces moderately higher costs—0.6 and 0.3% for the Base case and NoRET, respectively. Note that upon adjusting their analysis for an economic recession, Bosello et al. (2013) find a similar level of policy costs for a scenario similar to Pledge using the ICES model (another integrated assessment model developed and used at FEEM), with a policy cost of 0.5% for the EU when implementing its energy and climate policy unilaterally.

Figure 2.11 also shows policy costs associated with the two different approaches to implement the same energy efficiency improvements—that being either through energy intensity improvements (HEE_I) or through energy demand reductions (HEE_D). In 2020, the difference in policy cost is limited as the difference in energy demand with respect to the baseline is small due to the assumption of suppressed economic growth. However, over time the level of electricity demand within both of these scenarios is notable (20% lower in 2050) with policy costs between HEE_I and HEE_D differing by approximately 1.5% of GDP. Indeed, the changes over time show that the costs of the HEE scenarios crucially depend on policy design and implementation. If the energy efficiency target is designed as energy intensity improvements and implemented as increased technological change, then costs are lower than in the other scenarios.

However, if the energy efficiency target is designed as a target on energy demand reduction (as done in the EU Energy Efficiency Directive), then costs and the demand for offsets are notably higher. In reality, the response to a target would likely be made up of a mixture of energy efficiency improvements and reduced energy demand. However, the policy costs shown within Fig. 2.11 highlight the importance of providing an incentive for a mixed response to a given target. Whether the current European target within the Energy Directive is based on energy demand is suitable will be contingent on the response of industry and consumers, rather than being driven by policy design.

2.3.3 2 °C Durban Action Policy

Let us now turn to how these scenarios differ to a situation where the Durban Action Platform delivers a binding international climate treaty entering into force in 2025 with the aim of ensuring that the

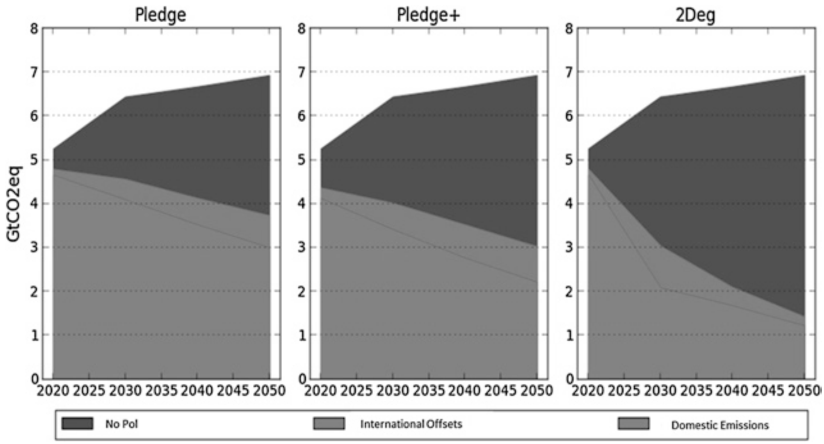

Fig. 2.12 European greenhouse gas targets—Pledge, Pledge+ and 2Deg scenarios

2100 global temperature increase is below 2 °C with sufficiently high probability.

Figure 2.12 updates the European greenhouse gas targets for the Pledge, Pledge+ scenarios, including also the case of 2Deg. Under the 2Deg policy, emissions in Europe would need to be cut significantly more than in the Pledge and Pledge+ policies, by 60% in 2030 and 80% in 2050. This result is consistent with the emission reductions specified within the EU 2050 Roadmap.

The power generation shares for Europe in the 2Deg policy scenario are shown in Fig. 2.13. In 2030, the power generation shares are 11% for coal, 19% for natural gas, 38% for non-biomass renewable and 26% for nuclear, in comparison with Pledge shares of 16, 19, 41 and 21%, respectively. Natural gas maintains a similar (albeit slightly lower) share in the power mix than in the moderate and stepped up policies (i.e. Pledge and Pledge+). Underlying these numbers are strong energy efficiency improvements with 2Deg in 2030, having a 10% reduction of total electricity demand in comparison with the Pledge case which is almost equivalent to the high energy efficiency scenarios reviewed within the fragmented policies. The strength of the reduction in energy demand results in the spike for nuclear within Fig. 2.13 in 2030 as the

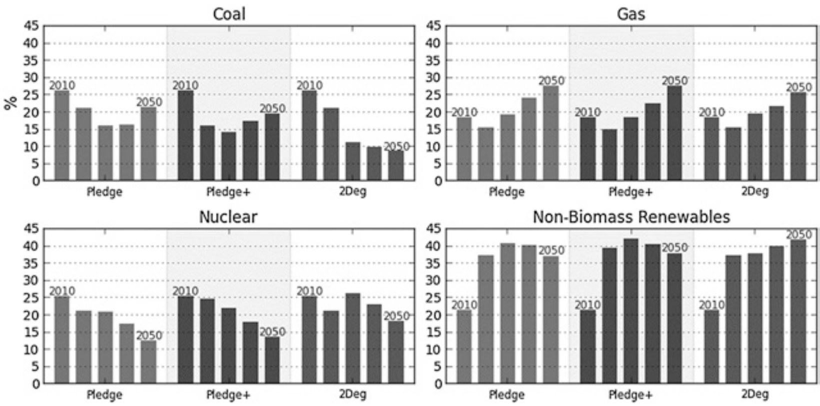

Fig. 2.13 Power generation shares by fuel—Pledge, Pledge+ and 2Deg scenarios

capacity of nuclear has been fixed to reflect a partial phase out nuclear of within western Europe.

In terms of TWh, increased demand for gas wrt 2010 tends to occur in all but the HEE scenario and when the renewable target has an impact (i.e. 2020 within 2Deg, but not within 2Deg/NoRET). In comparison with the Pledge and Pledge+ cases, there is a lower demand for natural gas with the 2050 amount in 2Deg being 976 TWh in comparison with 1276 TWh in Pledge and 1245 TWh in Pledge+. Policy costs within the 2Deg scenario are significant irrespective of global action, and in 2050, costs are over three times larger than in the other policies considered (6.27% in comparison with 1.47% in Pledge and 1.85% in Pledge+).

2.4 Conclusions

This chapter used WITCH, an integrated assessment energy-economic model, to assess a range of energy and climate policy scenarios, as a way to pin down the prospects for natural gas within the welfare-maximising energy mix in Europe for the next four decades. In doing so, it reviewed the role of natural gas within various climate efforts and policy schemes. Two main conclusions can be highlighted. The first is the importance of setting a suitable and sustained carbon price, which ensures that the right incentives are given to energy markets so that the welfare-maximising energy mix can be achieved. This would also reduce the policy costs related to all of the climate policy targets reviewed within the analysis. The second is that natural gas is very likely to be the key transitional fuel within the cost-effective achievement of a range of climate policy targets.

2.4.1 Carbon Pricing

In this chapter, we have shown that even a moderate and fragmented climate policy is sufficient to provide the appropriate incentives for realigning energy markets dynamics with climate objectives. This would require a carbon price of above 15 $/t$CO_2$ which grows to 60–70 $/t$CO_2$ over time. This can be achieved at moderate economic cost by a 2030 emission reduction target in the range of 25–35%, and a 2050 target of 40–60% (all relative to 2005).

The 2050 Energy Roadmap (reduction targets of 60% in 2030 and 80% in 2050 which are consistent with a global objective of 2 °C in 2100) would have significantly higher economic impacts (much higher GDP losses) than the fragmented carbon policy scenarios identified as Pledge and Pledge+, even with global action consistent with the Durban Action Platform.

In relation to providing appropriate incentives for energy markets via a carbon price, it is important to note that modern renewables, such as solar and wind, are becoming competitive due to the existing targets and incentives. Modern renewables would continue to play an important role after 2020 as long as carbon prices are sufficiently high (e.g. 20–50 $/t$CO_2$), and this will occur even without additional incentives or subsidies.

Energy efficiency regulation could play an important role by reducing overall electricity demand; however, the policy design will matter with a notable impact in terms of policy costs, depending on whether it is implemented through improved intensity or reduced demand. Indeed, if the energy efficiency target is designed as a target on energy demand reduction (as done in the EU Energy Efficiency Directive), then costs and the demand for offsets are notably higher.

2.4.2 Gas as a Transition Technology

Due to slow growth in demand and the growing role of renewables which has been induced by the EU target and related incentives/subsidies, natural gas use in power generation is expected to slightly decline until 2020 (unless important changes in gas supply related to shale gas production occur).

Irrespective of a decrease in the share of natural gas until 2020 due to the renewable target, the share of natural gas rises after 2020 and an increase in gas is consistent with the cost-effective achievement of a range of climate targets—refer to the discussion surrounding Fig. 2.6 for further details. In other words, although natural gas's share falls through 2020, it will rise after 2020 if climate targets are to be met cost effectively.

After 2020, both the Pledge and Pledge+ climate policies would induce an increase in gas consumption, while the use of coal decreases. After 2020, increases in gas consumption and a phase out of coal would be enhanced by promoting climate policies which sustain carbon prices above 15 \$/tCO_2 and up to 50–70 \$/tCO_2 in the following decades.

Gas demand would increase after 2020 in all simulated policy scenarios, including the 2Deg scenario through linkages to CCS. The growth of renewables is likely to slow down after 2020 due to limitations of system integration. This will enhance the role of gas as a transition fuel. However, to achieve the 2 °C target, a further development of renewables is required, even at high electricity storage costs, which explains the high policy cost of the 2Deg scenario.

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