Les Cahiers de la Chaire Economie du Climat

Working Paper Series

n° 2014-04

Interactions between CO_2 and RES targets: A cost assessment of European Energy Climate Policies with POLES model

Florent Le Strat[1], Elaine Pelourdeau[1], Benoît Peluchon[1], Jean-Yves Caneill[1], Yasmine Arsalane[2], Kimon Keramidas[2]

In 2008, Europe chose to commit to multiple targets with the Climate Energy Package (CEP). This package of European texts (mainly Directives & Decisions) set targets for different policies, all for the 2020 time horizon. In March 2013, European Commission issued the Green Paper on "A 2030 Framework for climate and energy policies" initiating the discussions about the extension of the CEP to 2030, and its possible targets. EC explicitly stated that the different policy instruments have to be coherent because they "interact with one another". The present study was performed in 2013 by EDF R&D and ENERDATA, in order to quantify the effects of overlapping policies with POLES model, and compare the costs generated by those interactions in the framework of CEP and Energy Roadmap. The two binding targets (CO_2 and RES) were considered in this approach. In particular the results are used to identify the impact of the different targets on European electricity retail prices considering different financing options.

1. EDF

2. Enerdata

Climate Economics Chair
Paris-Dauphine University
CDC Climat

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A cost assessment of European Energy Climate Policies with POLES model

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Working paper

February 2014

Abstract

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EDF

Florent LE STRAT

Elaine PELOURDEAU

Benoît PELUCHON

Jean-Yves CANEILL

ENERDATA

Yasmine ARSALANE

Kimon KERAMIDAS

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Introduction

Climate change is one of the most challenging issues our societies will have to face with. Since the beginning of industrial revolution and the use of fossil fuels (firstly coal, then oil and gas), greenhouse gas (GHG) emissions have been so quickly increasing that future climate conditions will be strongly impacted according to IPCC experts. Mean temperature increase and sea level rise are part of the phenomena human beings will be exposed to, if no action is rapidly and clearly undertaken. In order to prevent such environment disorders, policies have to be put in place to reduce GHG emissions.

Among GHG, CO2 accounts for around two thirds of anthropogenic emissions. Those emissions are directly linked with the combustion of fossil fuels (oil, gas and coal) that are used to respond to the world increasing energy demand. Climate policies which have been defined until now (Kyoto Protocol, EU-ETS, other emission reduction target around the world), mainly address CO2 emissions because of their share in the global emissions.

In 2008, Europe chose to commit to multiple targets with the Climate Energy Package (CEP). This package of European texts (mainly Directives & Decisions) set targets in different topics, all for the 2020 time horizon. The first target is to reach a GHG emissions 20 % lower than 1990 level (⇔ -14 % / 2005), with different targets for ETS (-21 % / 2005) and non ETS sectors (-10 % / 2005). The second goal is to increase RES to a share of 20 % in final consumption; targets were declined on a country by country basis. The last target, which is not binding, is to improve energy efficiency by 20 %.

In 2011, with the Energy Roadmap 2050, Europe set an ambitious GHG emission reduction target by committing to reduce its emissions in 2050 by at least 80 % compared to 1990. Impact assessment study detailed different options but their interactions were not really investigated.

More recently, in March 2013, European Commission (EC) issued the Green Paper on “A 2030 Framework for climate and energy policies” initiating the discussions about the extension of the CEP to 2030, and its possible targets. In this document, EC explicitly mentioned that the different policy instruments have to be coherent because they “interact with one another”. Moreover, the competitiveness of European economy is the key issue which has to be integrated in the debate about Climate Energy Policy.

The present study was performed in 2013, in order to quantify the effects of overlapping policies, and compare the costs variations generated by those interactions in the framework of CEP and Energy Roadmap. The two binding targets (CO2 and RES) were considered in the approach. Some elements were complemented with the objectives proposed in the Green Paper for 2030.

The first part of this study presents the main assumptions that were used in the calculations which were processed with the POLES model in collaboration with Enerdata (see Annex 1: POLES model for a short description of the model). The second part describes the results concerning the energy and power generation mixes. In the last part, the costs of the different options were assessed by considering different options in costs transmission.

1 Assumptions

1.1 Macroeconomic projections from CEPII

POLES model describes 179 countries regrouped in 57 country-regions and uses GDP PPP, in $2005. CEPII's GDP/capita projections[1] have been combined with UN population projection (medium scenario) to project five year CAGR between 2010 and 2050 for each modeled country[2].

	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	2035-2040	2041-2045	2046-2050
EU30	1.48%	1.70%	1.62%	1.54%	1.53%	158%	1.63%	1.67%
NOAM	1.76%	1.37%	1.63%	1.65%	1.68%	1.66%	1.62%	1.60%
ANZC	2.72%	3.07%	3.05%	2.82%	2.62%	2.38%	2.23%	2.01%
Other OECD	3.32%	2.68%	2.83%	2.54%	2.31%	2.10%	2.06%	2.07%
OECD	**1.79%**	**1.92%**	**1.92%**	**1.84%**	**1.80%**	**1.76%**	**1.75%**	**1.75%**
China	8.46%	6.94%	6.14%	5.42%	4.76%	4.22%	3.82%	3.42%
India	7.08%	6.24%	3.06%	5.75%	5.43%	5.07%	4.72%	4.40%
Russia	4.74%	4.63%	4.33%	4.23%	4.08%	3.79%	3.51%	3.50%
Brazil	3.41%	3.39%	3.16%	2.91%	2.73%	2.55%	2.43%	2.33%
South Africa	3.38%	3.46%	3.49%	3.32%	3.13%	2.92%	2.66%	2.46%
Indonesia	4.92%	3.80%	3.65%	3.44%	3.21%	2.99%	2.73%	2.65%
Other Asia	4.97%	5.10%	4.98%	4.78%	4.57%	4.38%	4.16%	3.95%
Other non-OECD	4.72%	4.52%	4.36%	4.24%	4.20%	4.10%	3.98%	3.91%
Non-OECD	**6.10%**	**5.54%**	**5.18%**	**4.86%**	**4.53%**	**4.22%**	**3.94%**	**3.70%**
WORLD	**3.82%**	**3.80%**	**3.74%**	**3.65%**	**3.52%**	**3.38%**	**3.25%**	**3.13%**

Table 1 – GDP assumption, CAGR

At this step, the study did not model macro-economic effects. Therefore, GDP remains unchanged for all calculations, and does not take into account neither effects of carbon on GDP growth (energy costs increases and recycling opportunities), nor adaptation costs in the absence of carbon policy as could be done in an Integrated Assessment Model.

1.2 Different stringencies in emission constraint

1.2.1 Carbon budgets

Three levels of climate policies have been represented, each one corresponding to emission trajectories for each geographical area

- "No climate policy" (or **NoCV**, for No Carbon Value) is the baseline case, where emissions are not constrained.
- "Limited climate policies" (or **LCV,** for Low Carbon Value) represents a world where all countries decide to limit their GHG emissions, however without big ambition.
- "Stringent climate policies" (or **HCV,** for High Carbon Value) is the most ambitious case, though to be in line with international political recommendations to limit the temperature rise to 2°C. All countries decide to reduce their emissions quickly, with strong objectives.

[1] Jean FOURE, Agnès BENASSY-QUERE & Lionel FONTAGNE (2012) *The Great Shift: Macroeconomic projections for the world economy at the 2050 horizon*, CEPII Working paper 2012-03

[2] When both datas are available, otherwise growth rate from corresponding regional aggregation : EU30 (EU27 + Switzerland + Norway + Liechtenstein) , NOAM (USA + Canada), ANZC (Australia + New Zealand + South Korea), Other OECD, China, India, Russia, Brazil, South Africa, Indonesia, Other Asia or Other non-OECD

	2020	2030	2050
EU30	-20% /2005		LCV : -43% /2005 HCV : -80% /2005
OECD	-11% /2005		LCV : -34% /2005 HCV : -80% /2005
Non-OECD	+73% /2005	LCV : +99% /2005 HCV : +67% /2005	LCV : +66% /2005 HCV : -50% /2005

Table 2 – Emission targets

In the study, we chose to translate climate policies and emissions trajectories in a "carbon budget" for each area in order to take into account banking flexibility (see Annex 2: Modeling for further explanation). The emission reductions compared to the NoCV policy are detailed hereafter. They take into account the possibility for OECD areas to use a 10% offset of their initial allocation through non-OECD credit.

		NoCV	LCV	HCV
EU30	(2012-2050)	146 595 $MtCO_2$	133 967 $MtCO_2$ -9%	109 116 $MtCO_2$ -26%
OECD	(2015-2050)	488 406 $MtCO_2$	414 558 $MtCO_2$ -15%	316 089 $MtCO_2$ -35%
Non-OECD	(2015-2050)	1 170 187 $MtCO_2$	884 284 $MtCO_2$ -24%	666 952 $MtCO_2$ -43%

Table 3 – Cumulated emissions targets

EU carbon policies classify economic sectors in two categories, ETS sectors (energy production and industry) and non-ETS sectors (transport, services and agriculture). As this classification seems to be used in countries putting in place climate policies, we integrated it in the four OECD areas (EU30, NOAM, ANZC and Other OECD) and China. Hereafter are the cumulated emission targets in the case of EU30:

		NoCV	LCV	HCV
EU30 ETS	(2012-2050)	86 990 $MtCO_2$	75 669 $MtCO_2$ -13%	59 559 $MtCO_2$ -31%
EU30 non-ETS	(2012-2050)	59 605 $MtCO_2$	58 298 $MtCO_2$ -2%	49 517 $MtCO_2$ -17%

Table 4 – Detailed cumulated emissions targets (EU30)

To stay in its budget, each area sees a carbon value (in €12/tCO_2) growing each year. The growth rate has been chosen to represent the behavior of actors of the two groups of sectors (who can be industrial or financial ones).

- Concerning ETS sectors, a 7% growth rate can represent both the WACC of industrial actors and the sum "risk free rate + market equity risk premium" used by financial actors.
- As investment in non-ETS sectors is mainly driven by public policies, a growth rate of 4% has been chosen in concerned areas to represent a "risk free rate" used by public investors.
- When the emission reduction targets are not set apart for ETS and non-ETS sectors (in non-OECD areas, excluding China) we chose a 7% growth rate.

1.2.2 Nuclear and CCS development

CCS and nuclear are two technologies whose development is highly reliant on political decision. To consider this non-economic factor, nuclear and CCS developments were bounded on the upside by ETP 2012 capacities in all cases.

	(GW)	2020	2030	2050
Nuclear	Europe	130	130	140
	China	70	150	345
	World	525	755	1090
CCS	Europe	5	37	70
	China	3	97	345
	World	15	271	960

Table 5 - CCS and nuclear capacities in ETP 2012

1.3 Different RES support scenarios in Europe

In POLES model, RES support is modeled through FiT for each technology and each country/area. For further explanations on FiT modeling, see Annex 3: Modeling the RES support through Feed in Tariffs.

1.3.1 Three gradual RES targets

Three levels of RES support policies have been represented:

- "Present FiT" is the baseline case, were there is no additional RES policy: FiT slowly decrease from their current level.
- "20%" is a case where present FiT increase to reach the European objective from Climate Energy Package (20% of RES in final energy in 2020) on a country by country basis according to national development plans, and decrease after 2020.
- "30%" is a more ambitious case, where the previous objective is reached (20% in 2020) and then the RES objective proposed in the EC Green Paper (30% en RES in final energy in 2030). As there are no details on potential national targets, we modeled a convergence of FiT in 2030 for each technology.
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1.3.2 Two funding possibilities

For each RES target, two funding alternatives are modeled concerning RES.

- RES subventions are financed by consumers, through electricity prices, with a mechanism similar to present ones in Europe (CSPE in France). In this case, we focused on RES in electricity production (e-RES).
- RES subventions are not financed by consumers. We focused on the possibility to finance RES subventions through CO_2 revenues from the ETS sector[3].

[3] According to the Directive 2009/29/EC (amending Directive 2003/87/EC, article 10.3), member states should use at least half of the ETS auctions revenues to help reducing GHG emissions, including support of RES

Another option that could have been considered is to finance RES support within fiscal revenues. A macro-economic approach would be necessary which was not integrated in the present study as described in section 1.

1.4 Summary of scenarios

This leads to 18 scenarios for EU, combining an assumption of CO2 emission reduction target, an assumption of RES development and a choice of RES support financing.

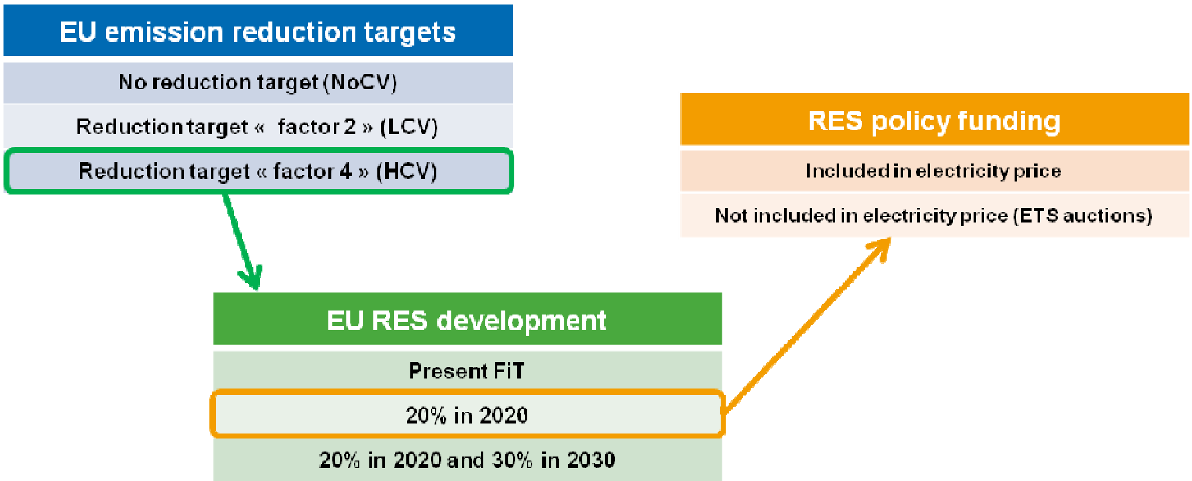

Figure 1 - Summary of scenarios

2 Energy mixes

An emission reduction target directly affects the energy mixes in order to decarbonize the consumption. Dedicated to Europe, we focused the result analysis for EU27, even if, as described before in the assumptions chapter, the cases depict situations where the different areas of the world have coherently committed to reduction pledge.

After describing the main results when only CO2 emission targets are imposed, the interactions between RES and CO2 will be investigated.

2.1 Carbon constraint only

2.1.1 Carbon constraint has a limited impact on power generation increase

When no reduction target is imposed on European energy system, the electricity consumption increases by around 50 % between 2010 and 2050, from 3302 TWh in EU30, to 4885 TWh over the EU27.

In order in comply with the CO2 budget in the LCV and HCV case, carbon values must be imposed on the energy system in order for production to evolve toward a less emitting energy mix. As described before, targets were imposed separately on ETS and non ETS sectors, which imply different carbon values.

	EU-ETS sectors				Non EU-ETS sectors			
€12/tCO2	2012	2020	2030	2050	2012	2020	2030	2050
LCV	7	12	25	95	11	15	22	48
HCV	28	48	96	367	43	87	128	282

Table 1 - Carbon values

In HCV case, noticeable differences appear between ETS and non ETS values. Non ETS sectors which gather Building, Transportation and Services, have less means to reduce emissions than ETS ones (Energy and Industry). Furthermore, a lower discount rate implies a flatter price curve, all other things being equal. As a result, the starting values for non ETS sectors are higher than for ETS sectors.

As a result of those values, carbon content of energy consumption drops in Europe as seen in the following graph, reflecting the shift to less emitting energy production technologies:

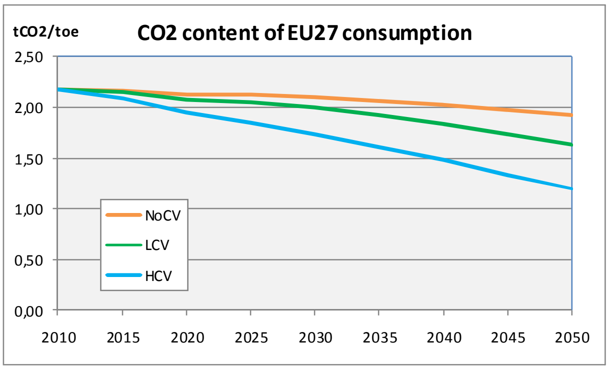

Figure 2 - Evolution of CO2 content of EU27 energy consumption

	2020	2030	2050
NoCV	22%	23%	28%
LCV	22%	23%	28%
HCV	23%	24%	32%

Table 2 - Share of electricity in final consumption

Decarbonizing the energy consumption is achieved by increasing the share of electricity consumption, especially in HCV Case.

These two effects (decrease of CO_2 content of energy consumption and increase of the share of electricity consumption) lead to antagonist trends, and finally, the price of CO_2 has limited impact on electricity consumption at European Level:

-3 % for power generation for LCV compared to NoCV in 2050

-4 % for power generation for HCV compared to NoCV in 2050.

2.1.2 European power mix based on carbon free technologies

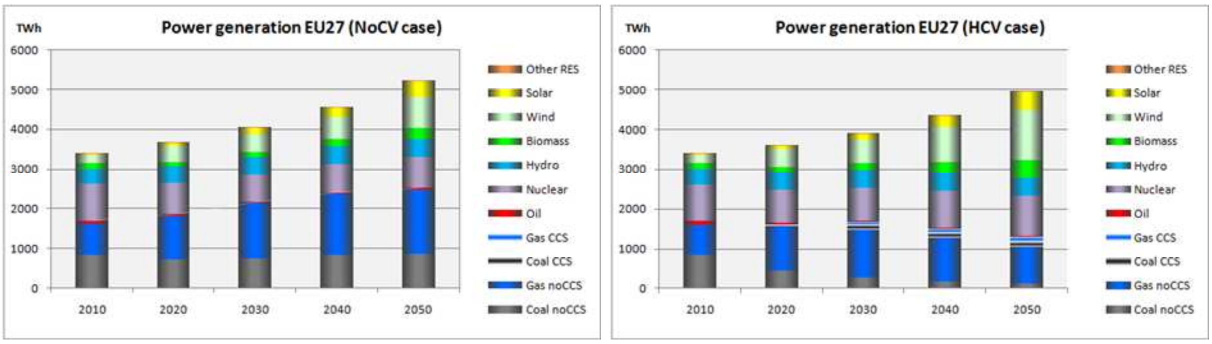

Figure 3 - European generation mixes

Without a carbon constraint, the generation mix is based on the cheapest technologies: Coal, Gas and Nuclear account for around two thirds of electricity production in 2050. RES increase their share in power generation from 23% in 2010, to 37% in 2050.

When the reduction target increases, the mix moves to a lower emitting structure: fossil fuel based generation only represents 27 % of generation in 2050, and coal almost disappears (only 4 % of generation including CCS power plants). Nuclear and RES plants represent 73 % of generation mix in 2050.

Carbon value makes the no emitting technologies more competitive than the fossil fuel based ones, inducing an improvement of the carbon factor of the European electricity sector which is improved by 65 % in 2050 in HCV case compared to the case without reduction target.

Those results are in line with the expected trends that are usually observed in all the long term energy prospect studies.

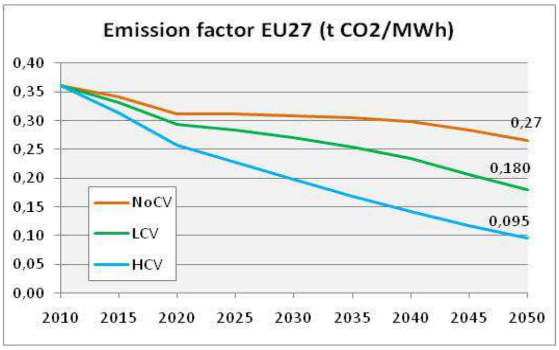

Figure 4 - CO2 content of EU27 power generation

2.1.3 Carbon policy has a limited impact on electricity retail price

In order to quantify the impacts of these changes from the consumer's point of view, we studied the evolution of the electricity retail price at EU27 level for both class of consumers (Industry and Residential)[4].

2012-2030 EU27	2012	2030		
		NoCV	LCV	HCV
CO2 ETS price	7,5 €/t	0 €/t	25 €/t	96 €/t
		-	+ 230 %	+ 1180 %
Elec. price Industry	115 €/MWh	- 7,3 %	+ 0,5 %	+ 16,2 %
Elec. Price Residential	188 €/MWh	- 8,3 %	- 2,5 %	+ 8,9 %

Table 3 - Comparison of 2030 electricity retail price to 2012 levels for different CO2 targets

Without carbon constraint, as a consequence of the natural technologies improvement, old and low efficient power stations are progressively replaced by new and more efficient ones. The electricity system gets more cost efficient, which produces a decrease of retail prices (energy taxes remain unchanged from the last observed level in 2011).

When an emission reduction target has to be reached, a carbon value is introduced in electricity production costs, and its impact is then passed in retail prices. That naturally leads to a price increase compared to the case without carbon value. Indeed, in LCV case, electricity retail prices remain globally at the same level as in 2012. In the HCV case, retail prices increase for both types of consumers, but the impact is stronger for the Industry whose prices are linked to baseload production costs in POLES. Actually, CO2 price impacts more coal-fueled plants than CCGT since the latter has a lower emission factor.

Nevertheless, electricity retail price increases (+16,2 % for Industry in HCV case) look rather limited in comparison with the CO2 price increase.

[4] In POLES, Power taxes (excluding RES support financing) remain at the last observed values over the calculation period

2.2 Interactions between RES and CO2

In CEP, two main targets were defined on GHG emissions and RES, which implies interactions with each other, and leads to competing effects. On the one hand, for a given amount of emissions, enhanced RES development limits reductions to be achieved through a carbon price. As compared to the default renewable deployment case, a lower carbon price is therefore needed, with less impact on electricity retail prices. To compensate with this CO2 price decrease, RES subsidies must get higher, driving up retail price. On the other hand, for a given RES target, more stringent emission reductions targets will increase carbon price, and then electricity retail prices. Since RES competitiveness is improved by higher carbon price, subsidies can be limited to comply with the RES target, which can relax electricity retail prices.

2.2.1 Share of RES in 2050 does not depend on the intermediary targets

As described before, RES can develop with carbon price only and reach 53% of generation mix in 2050. When intermediary RES targets are imposed by increasing Feed In Tariffs, higher share of RES are met earlier as can be seen in the following chart for HCV case:

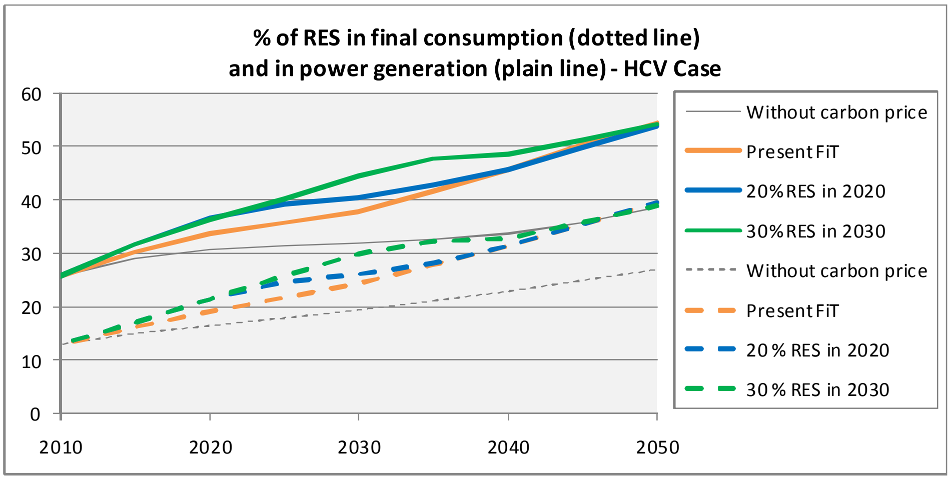

Figure 5 - Share of RES in HCV cases

RES targets in 2020 or 2030 have a clear impact on RES development pathway, accelerating their penetration in energy mix and power generation. More surprising, is that the 2050 point is not sensitive to the enhanced FiT in 2020 or 2030. Similarly to the HCV case with present FiT, the share of RES in 2050 accounts for 53 %, indicating that RES development can mainly be driven through carbon price independently from transitory goals.

2.2.2 Carbon price depreciated by RES development

When RES target are imposed in the energy system, emission reductions are achieved thanks to the development of those no emitting technologies.[5]

€12/tCO2	2020	2030	2050	Diff. / present FiT
LCV present FiT	12	25	95	
LCV 20% RES in 2020	9	18	71	-25 %
HCV present FiT	48	95	367	
HCV 20% RES in 2020	45	89	344	-6 %
HCV 30% RES in 2030	42	83	320	-13 %

Table 4 - Impact of RES targets on EU-ETS price

Considering that carbon budget is fixed in LCV and HCV cases, the enhanced implementation of RES tends to reduce emissions. Emissions reductions induced by RES support are all the more important than emissions targets are less ambitious. In LCV case, 20% RES target would be responsible for a reduction of 1618 MtCO2 over the 2012-2050, but in HCV case, only for 1108 MtCO2.

2.2.3 RES support has no impact on 2050 carbon factor of EU27 power generation

A noticeable result is that carbon content of power generation is adversely affected by RES promotion:

2010 = 100	2010	2020	2030	2050
LCV Present FiT	100	81	75	50
LCV 20% RES	100	77	73	54
HCV Present FiT	100	71	55	26
HCV 20% RES	100	68	53	29
HCV 30% RES	100	69	52	29

Table 5 - EU27 power generation CO2 emission factor evolution

As can be observed, in 2020 and 2030, CO2 emission factor of power generation slightly decreases in RES supported scenarios. But the impact appears quite limited. More surprisingly, in 2050, the opposite effect appears:

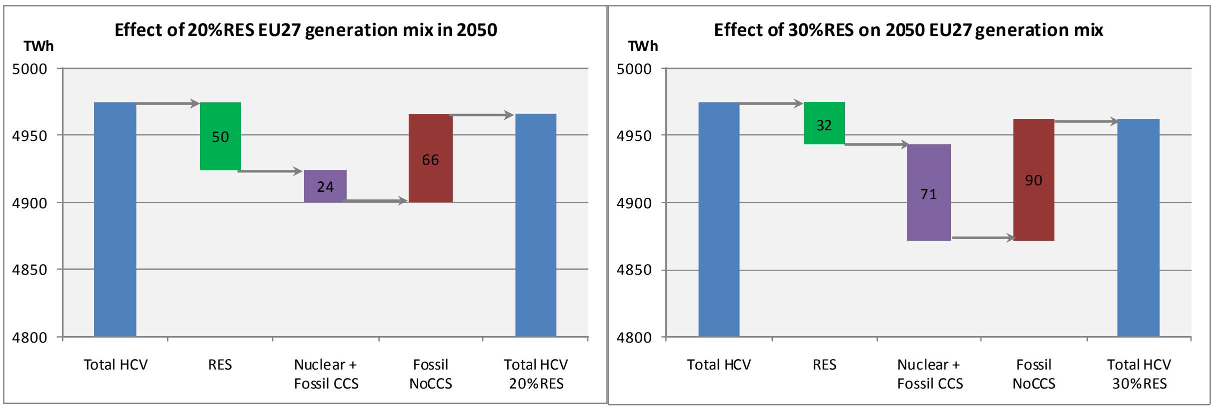

Figure 6 - Impact of RES targets on 2050 generation mix - HCV case

[5] The LCV case with 30 % RES target in 2030 was not simulated because that configuration appears to be unrealistic in term of political acceptance.

In 2050, due to the impact of RES on carbon price which gets lower and the absence of FiT (since we assumed a phase-out after reaching the RES target), fossil fuel based power plants profitability is less worsened compared to no emitting technologies. In this case, the non CCS fossil fuel generation gets higher than in the present FiT HCV case. The effect is naturally all the more important in 2050 than the support of RES was large in 2020 and 2030. Despite intermediary RES targets, transitory RES support does not help to decarbonize power generation in the very long term.

2.2.4 RES subsidies generate a strong increase of electricity retail price

Complying with RES target is simulated through increasing FiT in European countries so that they match their RES targets. Those FiT could be financed through different provisions. The first effect that was studied is the potential impact on electricity retail price, by considering that electricity RES subsidies are transmitted in electricity prices.[6] At EU27 level, we compared the electricity prices in LCV and HCV cases, with different RES targets:

2012-2030 EU27	LCV		HCV		
	Present FiT	20% RES	Present FiT	20% RES	30% RES
Elec. price Industry	0,5%	22,0%	16,2%	26,0%	34,0%
Elec. Price Residential	-2,5%	9,1%	8,9%	13,3%	18,9%

Table 6 - Comparison of 2030 electricity retail price to 2012 levels for different RES targets

Firstly, the electricity retail prices impact of a higher RES target is larger when emissions reduction target is less ambitious, especially in Industry sector considering POLES retail price modeling. RES substitute to baseload generation capacities, especially coal, which has the highest CO2 emissions factor. As a result, the share of RES in baseload generation gets higher, which implies that large part of electricity RES subsidies are transmitted to that type of consumers. In comparison, Residential sector consumption is less relying on coal generation. The penetration of RES is lower, with a lower impact of FiT on electricity prices.

Secondly, compared to the situation with present FiT, electricity retail prices increase could appear as not sustainable in a macro-economic configuration where energy prices issues are dominant. In the climate policies scenarios we considered, carbon constraints are coherent all around the world, making the impact of carbon price limited with regard to the regions. On the opposite, RES target would be imposed on Europe, affecting electricity prices only in European countries compared to outside EU countries, harming European production costs.

3 Balancing the costs of Climate Policy: RES financing depending on carbon constraint stringiness

As seen in the former section, electrical RES support transfer would induce an important rise of electricity retail prices. Other options still exist to finance RES support.

3.1 In Climate Energy Package, EC recommend to use EU-ETS auctioning revenues to address climate issues, of which RES support

The first possibility would be to rely on fiscal revenues to compensate for the subsidies needed to increase RES share in energy mix. As a matter of fact, if electricity retail price is considered as a strategic issue, state budget could take care of financing RES support: it would not be paid by consumers, but by taxpayers. However,

[6] The financing of non electricity RES (biofuels, biomass heating,...) is not transmitted in electricity price.

considering the debt reduction issue in Euro zone Member States, it looks unlikely that domestic budgets could absorb new expenditures.

The second option would be to allocate the revenues of EU-ETS auctions to finance RES subsidies. The approach would be in line with the ETS Directive in which is stated that "at least 50 % of the revenues generated from the auctioning of allowances (...) should be used for one or more of the following: (...) (b) to develop renewable energies to meet the commitment of the Community to using 20 % renewable energy by 2020 (...)"[7]. This recommendation is not binding since EU has no legal responsibility to impose such a use of ETS auctions revenues. Nevertheless, let's consider that Member States follow this guideline[8]. In this case, we will compare the amount of RES subsidies needed to match RES targets in different carbon constraint scenarios to the auctioning revenues.

3.2 With a low ambition of emission reductions, 20% RES target cannot be financed with EU-ETS auctioning revenues

As presented in the precedent section, RES development has a clear impact on carbon price, and *vice versa*. Those interactions have then an influence on the ETS auctioning revenues.

In NoCV case, no carbon value is imposed. The evolution of RES generation is only linked to the evolution of generation costs and the present competitive advantage given to RES through FiT. With present FiT, and their progressive disappearance, RES develop increasing RES subsidies. In this case, 25 G€ would have to be found in 2020.

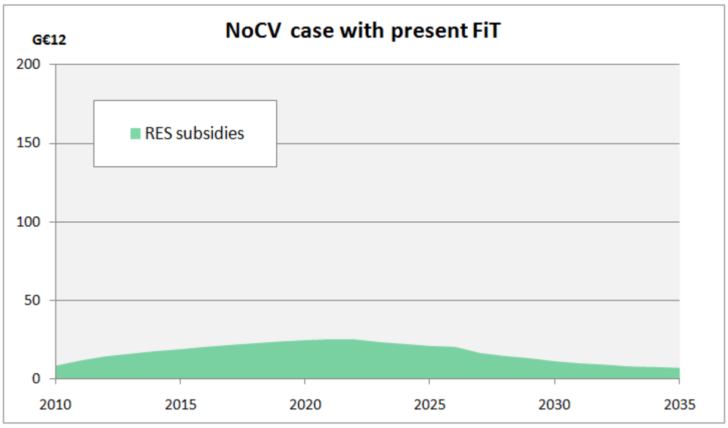

Figure 7 - RES subsidies vs. ETS auctioning - NoCV

If the LCV carbon target is then imposed on Europe, a carbon price has to be imposed on the EU-ETS generating auctioning revenues, which are enough to finance present RES support.

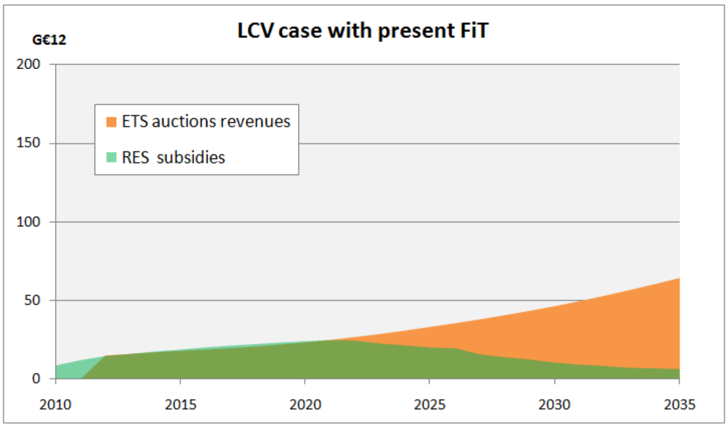

Figure 8 - RES subsidies vs. ETS auctioning - LCV

[7] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:140:0063:0087:en:PDF

[8] Free allocations are not considered here since the configurations suppose coherent international climate policies: carbon leakage risks are not an issue, since all countries are supposed to have carbon prices.

If 20% RES share has then to be reached in LCV case in 2020, a dramatic increase of RES subsidies is necessary to comply with the target (140 G€ in 2020). This amount cannot be financed by ETS revenues, all the more since these revenues have decreased because of the depreciated CO2 price, as an impact of RES development.

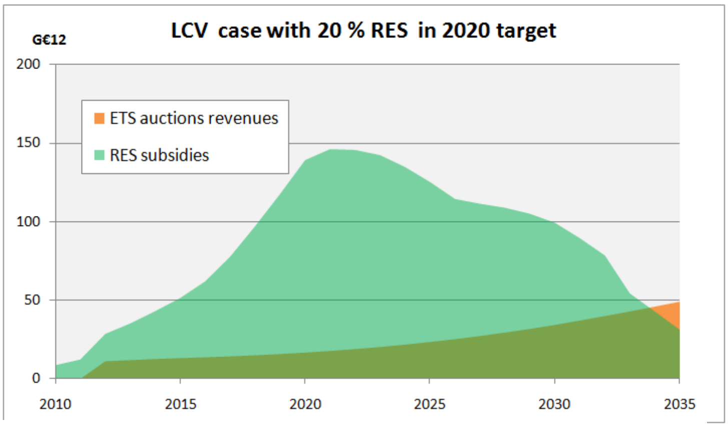

Figure 9 - RES subsidies vs. ETS auctioning - LCV 20% RES

3.3 2020 RES target can only be funded if stringent 2050 target is imposed

The HCV case depicts a configuration where 2050 targets are consistent with Energy Roadmap. Stringent reductions are then to be achieved over the 2012-2050 period. Carbon values are much higher than in LCV case (see §0), implying larger auctioning revenues. Meeting the 20% RES target in 2020 appears to be possible with far less subsidies than with a lower carbon constraint. Integrating long term Roadmap emission reductions endowment appears to be financially consistent with 20% RES target.

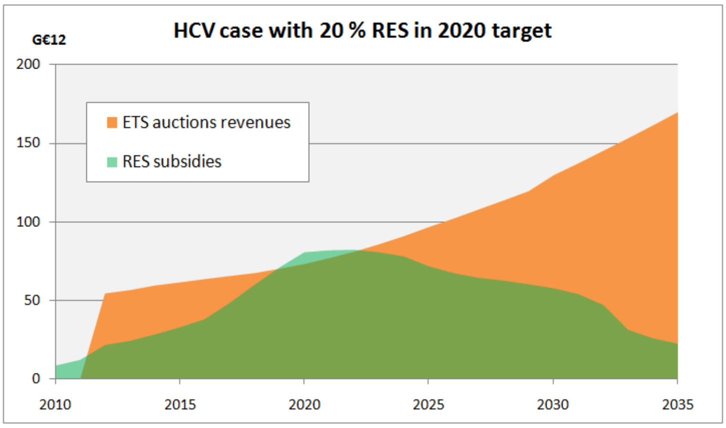

Figure 10 - RES subsidies vs ETS auctioning - HCV 20% RES

3.4 30% RES target costs would not be covered by EU-ETS auctioning revenues

If Green Paper's RES targets have to be reached, supplementary support to RES induces new carbon price drop, diminishing auctioning revenues. Simultaneously, RES subsidies grow until 2030, challenging the financial balance of the target. It appears that ETS revenues cannot compensate for Green Paper's RES target costs.

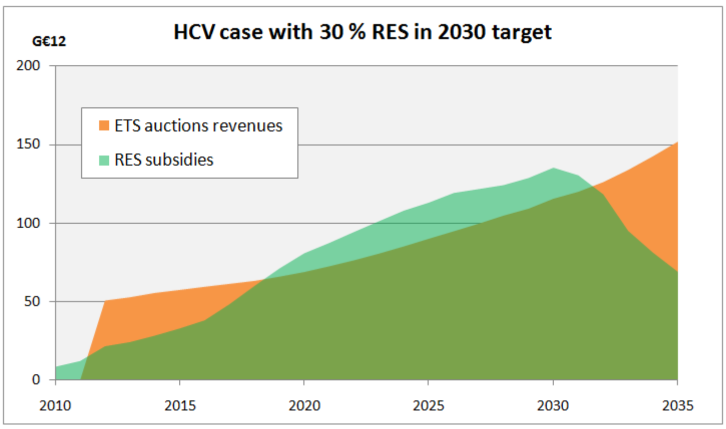

Figure 11 - RES subsidies vs ETS auctioning - HCV 30% RES

3.5 Carbon price is the main signal which limit climate policy costs

The results clearly show that EC's will to impose 30% RES target for 2030 could have heavy consequences on finance balance of the Package. EU-ETS auctioning revenues will not be sufficient to finance this target and Member States would have to levy new tax to subsidize RES development. Even if carbon price is back on track with values consistent with Energy Roadmap targets, costs will be too high to be covered only by EU-ETS auctioning revenues[9].

3.6 Impact of RES energy trade balance appears very limited

By limiting fossil fuel consumption, energy-climate policies have an impact on energy balance. Climate policies introduced in the HCV case impact both the level and the structure of the energy demand. By 2050 global energy intensity is reduced by 2%/year and the competitiveness of fossil fuels is significantly affected, leading to reduced fossil fuel consumption (only 50% of Primary Demand in 2050 as compared to 67% in the NoCV case). Non Fossil fuels share in Europe more than double between 2010 and 2050 whereas reductions in fossil consumption reaches -42% for oil and -74% for coal. With much less tensions on fossil markets, the increase of fossil fuel prices is contained. Oil price in 2050 reaches in this configuration 108 €/bbl, 75 €/bbl smaller than in the NoCV case.

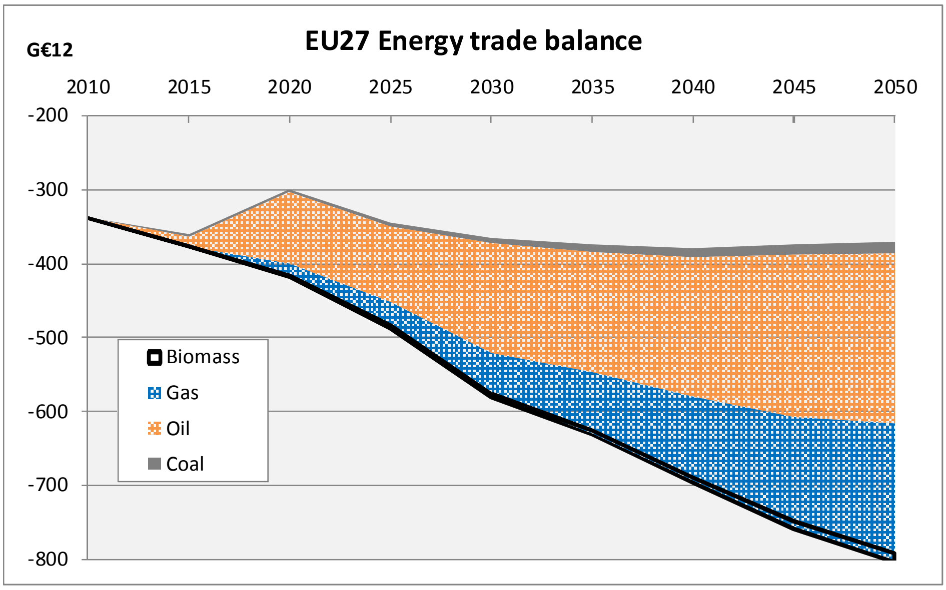

Figure 12 - EU27 Energy trade balance

The fossil fuels consumption reductions translate into a reduction of imports and, combined with lower prices, the oil balance drops by 35% between 2010 and 2050. For gas, imports are significantly reduced. In comparison with the NoCV scenario, cumulated balance savings by 2050 could represent 4000 G€ as can be observed in the following chart:

	NoCV	HCV		
	Present FiT	Present FiT	20% RES	30% RES

[9] Present debate at European level focuses on impact of electricity RES support on electricity retail prices. If we then consider that among EU-ETS sectors, RES are mainly dedicated to power generation. It could be asked whether electric RES support could be compensated with auctioning revenues from power generation alone. The former conclusions remain valid for this sector specific approach:

- Electric RES subsidies needed to reach 20% RES 2020 target cannot be compensated with power generation auctioning revenue in LCV case
- Auctioning revenues from power generation can only finance the 20% RES target if stringent emission reduction target is implemented
- 30% RES target induces costs concerning power generation sector, that auctioning revenues are not sufficient to compensate with.

Cum. Import Bill G€ (2012 - 2050)				
Biomass	676	772	845	848
Oil	8697	5978	5944	5947
Coal	228	68	66	62
Gas	2882	1529	1470	1430
Total	**12484**	**8347**	**8324**	**8287**
change vs NoCV				
Biomass		14%	25%	25%
Oil		-31%	-32%	-32%
Coal		-70%	-71%	-73%
Gas		-47%	-49%	-50%
Total		**-33%**	**-33%**	**-34%**

Table 7 - Impact of RES targets on EU27 Energy balance

Concerning RES, it appears that their impact is very limited on energy import balance. If HCV carbon constraint is able to reduce the European energy balance by 33 % over 2012-2050, the 30% RES scenario improves the balance only by less than 1% in HCV configuration. With a lower carbon price induced by RES support, oil and coal tend to be more competitive, and import costs increase. Simultaneously, biomass imports have to increase to match European RES targets. As a consequence, RES support does not improve European energy costs in a significant way.

4 Conclusions and Follow up

The present study was performed to assess the interactions between CO2 and RES targets of European Climate energy policies. The different cases clearly show that carbon targets play a central role in the transition to low emission energy mixes. RES targets appear to increase transition costs, and do not have a notable impact on European energy independency or on 2050 power mix. The effect of 2020 CEP RES target on electricity retail prices could be limited if ETS auctioning revenues were dedicated to support the 20% RES target.

On the 22th of January, European Commission issued the project of Climate Energy package for 2030. It will be useful to study the effects of those new targets (binding or not), on European decarbonization costs. As a matter of fact, the intermediary targets which Europe will commit to, on the way toward a 2050 low carbon energy system, could have an impact on European economy energy prices. An assessment of the macro-economical feedback of the different options could be a useful complement to the present approach taking into account the proposed targets.

Annex 1: POLES model

POLES (European Commission, 1996) is a world energy-economy simulation model for the development of long-term energy supply and demand scenarios. The POLES model uses a dynamic partial-equilibrium framework, specifically designed for the energy sector but also including other GHG emitting activities (e.g., the six GHG's of the "Kyoto basket"). Macro-economic drivers, such as population and GDP growth, are included through exogenous assumptions from external forecasting groups (UNDP, IMF and CEPII). The simulation process uses dynamic (year-by-year) recursive modeling, with endogenous international energy prices and lagged adjustments of supply and demand by world region, which allows for describing full development pathways to 2050. Atmospheric carbon concentrations and temperature modeling can be included through exogenous forecasts from the IMAGE model (MNP, 2006).

The POLES model has been developed using a hierarchical framework of interconnected sub-modules at the international, regional, and national levels. A high degree of detail for technological components of the energy system is combined with a strong economic consistency through feedbacks on key components via relative price changes at the sectoral level driven by international energy prices. Endogenous model parameters are calibrated on the period 2000-2010 to include observed preferences and actor behaviour in future forecasts.

The current geographic disaggregation of the model incorporates 57 demand countries/regions and 80 supplying countries/regions, defining the major and most commonly used areas of energy supply, demand, and trade. For each region, POLES articulates four main modules:

- Final energy demand by sector;
- New and renewable energy technologies diffusion;
- Conventional energy and electricity transformation system; and
- Fossil fuel supply (conventional and non-conventional sources).

While the simulation of the different energy balances allows for the calculation of import demand or export capacities by region, the world integration is ensured through the energy markets module. Only one world market is considered for oil (the "one great pool" concept), while three regional markets are identified for gas and coal (Americas, Europe & Africa, and Asia), in order to take into account different cost, market, and technical structures. Conventional and non-conventional oil and gas resources are included in POLES.

The model provides technological change through dynamic cumulative processes such as the incorporation of two-factor learning curves, which combine the impacts of "learning by doing" and "learning by searching" on technologies' development. Price induced mechanisms, such as feed-in tariffs, drive technology diffusion under conditions of sectoral demand and inter-technology competition based on relative costs and merit orders, and allow for consideration of key drivers to future development of new energy technologies.

The description of wind and solar power in the POLES model incorporates land surfaces available for power production based on wind speed potential and annual solar irradiation. Limits to the development of wind and solar capacity also exist based on minimum dispatchable back-up capacity (e.g., gas turbine) due to the intermittency of renewable electricity generation. Renewables compete with other technologies to fill a "demand gap" created each year due to total generating stock retirement and electricity demand increase.

Nuclear power is the net result of capacity additions from new plants and subtractions due to retirement of existing generating stock based on vintages. Mid-term (next 5-15 years) capacity additions are calibrated to Enerdata's Power Plant Tracker service, which follows global announced, planned, and in-construction nuclear power plants. Long-term new nuclear additions compete with other technologies for market share as for renewables. Nuclear capacity is removed from the system based on plant lifetimes and installation date.

Carbon capture and storage technology offers the possibility to generate electricity with fossil fuels, but avoid emitting CO_2 to the atmosphere. In POLES, gas and coal electricity generation using CCS competes with conventional technologies when determining new generating capacity (i.e., the CCS-equipped technology only takes market share away from the non-CCS version). A premium is applied to conventional technologies variable costs for CCS to account for capture, transport, and sequestration costs; therefore, non-emitting fossil fuel technology will only appear in simulations that include a price for carbon emissions.

Annex 2: Modeling the carbon constraint

A very important feature of the EU-ETS is the possibility to use permits distributed in a given year for compliance in the following years (so called "banking"). This implies that even though the market is oversupplied, a permit keeps some value because of the possibility that the market becomes short in the future. In a market with a decreasing cap and a growing economic activity, it is rational for firms to bank some permits until they equalize the expected discounted prices with the spot price. It is indeed rational to buy permits now if their discounted expected future price is higher than the spot price. Because borrowing is forbidden, if the discounted expected future price is lower, no reverse arbitrage is possible. But as we mentioned, the EU-ETS design is such that available permits decrease each year and our scenarios are based on a growing economic activity. Taking into account the already existing permit surplus, it is straightforward to conclude that banking intertemporal arbitrage is done by regulated companies. As a result, the discount rate is the growth rate of the permit price, as in a Hotelling setting, and the relevant carbon constraint in the sum of all distributed allowances, what we have dubbed "carbon budget". The model finds the initial price (and thus the whole price curve) that allows emissions to stay within that budget.

The discount rate of a regulated firm is its cost of capital plus any premium that it deems relevant in order to decide if a new investment is worth engaging. The cost of capital is given by the Weighted Average Cost of Capital (WACC), in the spirit of the Capital Asset Pricing Model, widely used in finance department for capital budgeting. The difficulty is that in the EU-ETS different sectors are regulated, all with different betas, and that firms have different equity / debt ratios. The discount rate of firms is often considered confidential information, and as such, is not known.

In the case of utilities, which are the main participants of the emissions market, financial reports may contain some data regarding their cost of capital. Using utilities financial reports, we find that the nominal post-tax WACC is around 6 % in power generation activities, the ones emitting and as thus relevant for our choice. But companies report that the effective discount rate they use when assessing investment opportunities is higher, because of a "value creation" premium. In some public documents, a 300 basis point order is acknowledged for investment decisions. Since that kind of premium seems standard practice in the sector, we have chosen to use this value. On a nominal post-tax basis, the discount rate of electricity producers can be computed as around 9 %. Since POLES only use real economic values, with a further long-term inflation hypothesis of 2 % a year, in line with the European Central Bank target, we can retain a 7 % real post-tax discount rate as a reasonable value for the permit price growth rate implied by optimal banking.

For non-ETS sectors, a 4 % discount rate is used, since carbon values are more representative of taxes chosen by public entities. Its value is thus aligned with a long-term risk free interest rate. The carbon budget approach is also used, since even if non-ETS objectives are not given on an annual basis, the path leading to the objective must be specified in order to compute yearly tax levels.

Annex 3: Modeling the RES support through Feed in Tariffs

Direct subsidies to power production for renewable technologies can be included in POLES for the following technologies: Biomass, Wind (offshore and onshore), Solar (centralized and decentralized PV, Concentrating Solar Power (CSP) Technologies), small and large hydro, Geothermal, Tide & Wave and Combined Heat & Power (CHP).

New and Renewable technologies in power generation are subsidized through technology-specific Feed-in Tariffs. In a given year, the feed-in tariff is applied to the newly installed capacity. This tariff remains fixed for the contract duration for the technology. Figure 13 show how they reduce the apparent costs of the technology, thus improving their economic viability in the electricity production and capacity investments competition processes.

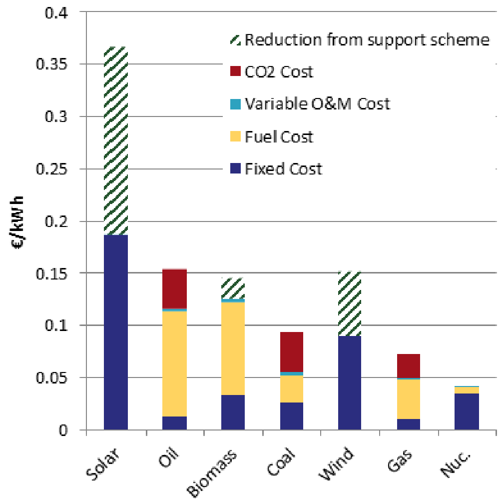

Figure 13 - EU baseload production costs in 2020

Total subsidies to RES in power generation can thus be calculated as the difference between the overhead price compared to the overall cost of electricity.

As seen in the figure below, historical Feed-in-tariff by country and by technology are used, followed, by default, by a 2%/y reduction (HCV case). In this particular example, the FIT procures no effect as it doesn't compensate for an increasing electricity market price. Reaching RES 20% and 30% targets requires an important support.

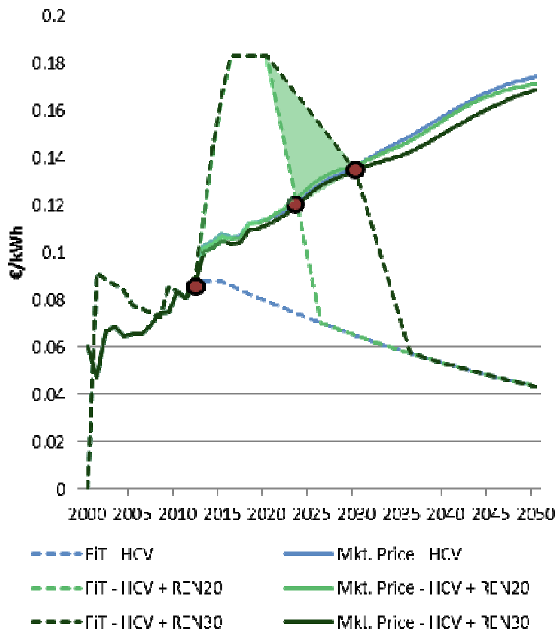

Figure 14 - FiT of wind offshore in Germany

Annex 4: Fossil fuel prices

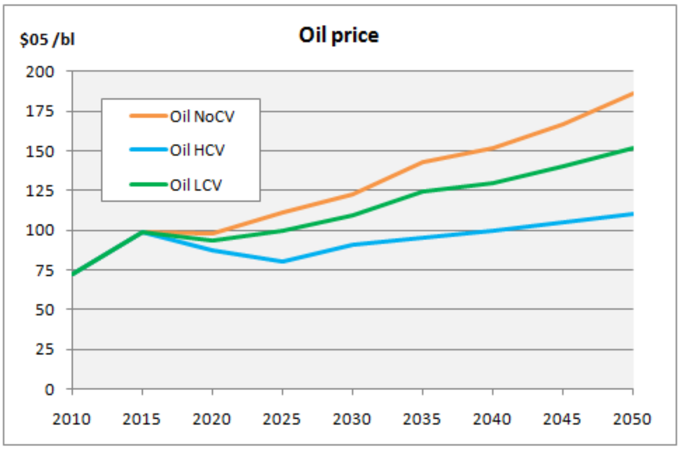

Figure 15 - World oil price

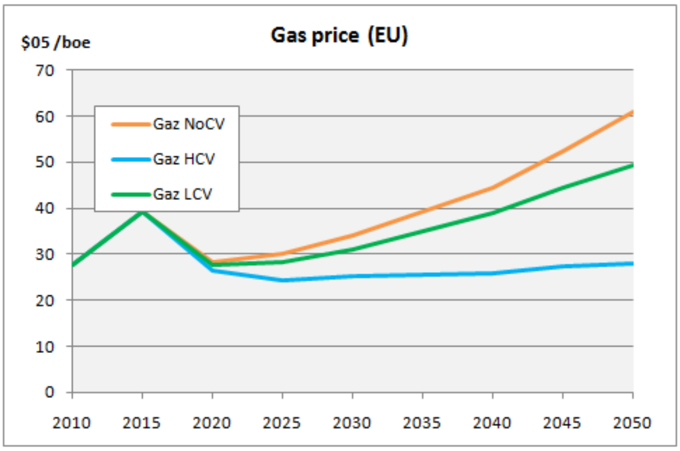

Figure 16 - European gas price

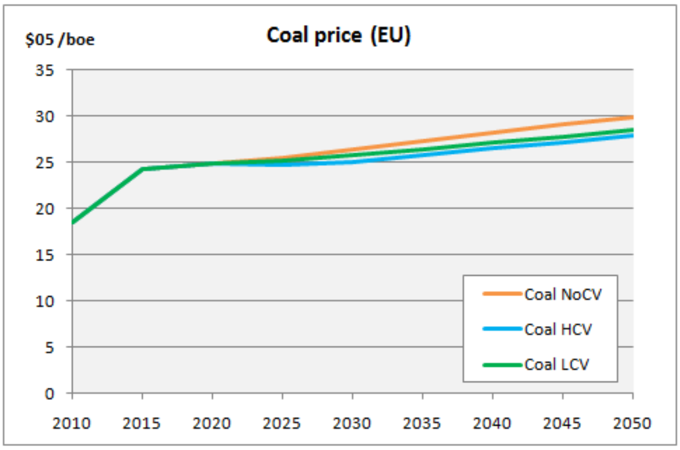

Figure 17 - European coal price

Working Paper Series

n° 2014-04

Contact us :
Chaire Economie du Climat - Palais Brongniart (4e étage)
28 Place de la Bourse, 75 002 Paris
Tel : +33 (0)1 73 01 93 31

Email : contact@chaireeconomieduclimat.org

Working Papers Publication Director: Pierre-André Jouvet

La Chaire Economie du Climat est une initiative de CDC Climat et de l'Université Paris-Dauphine sous l'égide de la Fondation Institut Europlace de Finance

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