How to trigger low carbon technologies by EU targets for 2030?

An assessment of technology needs

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Executive Summary

The current EU framework for energy and climate policies up to 2020 consists of three headline targets: 20% reduction of GHG emissions compared to 2005, a 20% share of renewable energy in final energy consumption, and 20% primary energy savings compared to baseline developments. While progress on these 2020 targets is mixed, discussions in the EU about climate and energy policies and targets for the period after 2020 have started. Given the long cycles associated to energy and climate investments, agreement on a clear longer-term policy framework is critical to improve visibility for investors and avoid lock-in effects in inefficient or polluting technologies. Therefore, the European Commission published a Communication on 6 June 2012 on the need for a long term policy framework for renewable energy, and a Green Paper on the 2030 climate and energy policy framework on 27 March 2013.

Against this background, the Dutch Ministries of Infrastructure and Environment and the Ministry of Economic Affairs requested PBL[1] to create input for the European debate on climate targets and policies until and beyond 2030. Ecofys supported PBL by addressing the following two questions:

1. What steps are needed for selected key technology groups to achieve long term GHG emission reductions and what climate and energy policies are likely to trigger these steps?
2. What are the pros and cons of a 2030 policy framework with a) a GHG reduction target only, and b) targets for GHG reduction, renewable energy, and energy efficiency?

The focus of the first question was on four technology groups, namely (1) energy efficiency in the built environment, notably for heat; (2) solar PV and wind energy; (3) advanced biofuels; (4) CO_2 carbon capture and storage (CCS). An analysis of the steps needed for the deployment of the full GHG mitigation potential of the discussed technology groups shows that this will largely depend on the adoption of a wide range of policy instruments by EU Member States:

- In the **built environment**, the widespread deployment of energy efficiency measures is usually obstructed by non-economic barriers such as high upfront investments, split-incentives, as well as information barriers and asymmetries. Deployment of policy instruments that pay due regard to these obstacles e.g. minimum energy efficiency standards, innovative financing schemes, consumer information campaigns and professional capacity building, will be critical to speed up progress in this sector.

- **Solar PV and wind** power generation rely progressively less on economic support schemes. However, policy interventions will still be required to enable deeper integration of renewable sources in the power grids and markets. Likewise, policy packages will need to provide stable and clear administrative and regulatory conditions that improve access of project developers to competitive financing.

[1] Netherlands Environmental Assessment Agency (Planbureau voor de Leefomgeving) http://www.pbl.nl/

- The deployment of **biofuels** increased significantly, stimulated by blending targets and mandates for transport fuels. Currently, production of ethanol from sugar crops and biodiesel from vegetable oils are mature technologies. Advanced biofuels could become competitive with conventional transport fuels by 2030. Deployment of advanced biofuels may be triggered by a combination of blending obligations and standards for life-cycle GHG emissions.

- **Carbon capture and storage** technology is still far from maturity and current CO_2 prices are clearly insufficient to trigger the necessary investments in the short term. Even when CCS reaches a mature stage, additional policy measures will be required such as emission performance standards, fossil fuel taxes, and/or bonus allowances.

The second question is: what set of targets at EU level would trigger the adoption of the necessary policy interventions? Agreeing on an ambitious EU wide GHG reduction target for 2030 is certainly an important step in the right direction. However, our analysis shows that a policy framework with dedicated, complementary targets and policies for energy efficiency, renewable energy, and greenhouse gas reduction may be more effective than a framework with a GHG target only, at least for the following reasons:

- Firstly, both renewables and energy efficiency have proven to be not only useful as GHG mitigation options but also key elements for the **competitiveness of the EU economy** by driving the development of new domestic industries and the creation of employment. Moreover, renewable energy and energy efficiency constitute the main instrument to EU's security of supply.

- Secondly, a GHG target and the EU-ETS on their own will not necessarily lead to **GHG emission reductions in all economic sectors**. It will be very difficult to bring the residential, commercial and transport sectors under the EU ETS and therefore, the effects of a CO_2 price signal on energy efficiency of the built environment and on the deployment of biofuels in transport are likely to be limited. Moreover, the CO_2 price signal generated by the EU ETS may be insufficient to trigger the deployment of less mature technologies such as offshore wind or CCS, despite their great long-term mitigation potential.

- Finally, the four technology groups discussed in this paper face **very specific non-economic barriers**. Overcoming these barriers requires equally specific policies and measures that are unlikely to be triggered by a single GHG reduction target.

We conclude that regardless of the ambition of the GHG target, a single target framework addresses the relevant economic and non-economic barriers for the four technology groups only to a limited extent, and has only a limited impact on the development and deployment of these technologies. As a result, economic and public policy objectives, other than GHG reduction, (e.g. security of supply, economic development and employment) are therefore missed out on.

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1 Introduction

1.1 Background

The need for a long-term climate policy framework

Discussions in the EU about climate and energy policies and targets for the period after 2020 have started. Until recently, discussions on EU climate and energy policy were focused on the period until 2020, which helped to avoid undue postponement of climate action in the years until 2020. As a consequence, a policy framework for the period after 2020 is currently non-existing and targets for a sustainable and low-carbon energy supply have not yet been defined and set.

However, clarity on a policy framework post-2020 that can drive the transition of the European energy system is much needed in the short term. A transition of the European energy system is desirable for various reasons, including security of the European energy supply, climate change, economic development as well as employment. The transition will take several decades and requires a supra-national framework. Clarity for the mid- and long-term perspective is therefore needed. Otherwise, necessary investments in technologies that have a lifetime of 20-40 years will not be made (either in renewable, fossil, or nuclear energy, and/or in infrastructure). Also the exact definition of 2030 targets is critical, as it can have huge impact on the position of individual groups of technologies, such as renewables.

For this reason, the Renewable Energy Directive already referred to a post-2020 roadmap in 2018, which is quite late. The European Commission (EC) has therefore made some first steps in addressing this issue. It has recently published a roadmap of the EU's energy system until 2050. In this roadmap the objective of reducing GHG emissions by 80-95% compared to 1990 was laid down, together with an indication of a required -40% in GHG reduction by 2030. It has also published a Communication on renewable energy, outlining policy options for renewable energy for the period beyond 2020.

Progress on 2020 targets

The background of these discussion on long term climate policy is progress to date on the climate and energy targets set for 2020. In 2007, the European Council set its ambitious energy and climate targets including a 20% reduction of GHG-emissions over 2005 level (under the condition of a shared international ambition this target was raised to 30%), 20% renewable energy in final energy consumption, and 20% reduction of primary energy use as compared to 2020 projection[2]. These targets have been supported by the European Parliament from the start.

[2] Council Conclusions 8/9 March 2007, 7224/1/07

Currently, the majority of the EU Member States are on schedule (or even ahead) in meeting their 2020 targets for renewable energy. However, most of the progress (35%) has been scheduled for the period 2018 – 2020. Also, the relative low energy consumption as a result of the economic crisis, strongly influences the progress on the renewable energy share. Meeting the targets for renewable energy therefore remains a challenge.

On energy efficiency, European and national policies have been proven insufficient to meet the 20% target. The impact of these policies must be tripled to meet the set target[3]. In 2011, the European Commission reacted by composing an Energy Efficiency Plan. This resulted in binding targets that were established in June 2012 in the new Guideline for Energy Efficiency.

The debate on a post-2020 policy framework
Against this background the European Commission published an anouncement and an impact assessment[4] on 6 June 2012 concluding that in order to meet the 2050 targets, a stable investment climate should be established much earlier than 2018 (when post-2020 targets should be determined). The impact assessment considers the following policy options:

1. Business as usual.
2. Decarbonisation, without renewable energy target.
3. National level post-2020 renewable energy targets including coordinated support.
4. EU-level post-2020 renewable energy targets including harmonised measures.

An important part of the European debate on targets and policies for 2030 and 2050 will be on the balance between short term emission reductions and technological developments to establish long term emission reductions.

1.2 Objective

Against this background, the Dutch Ministries of Infrastructure and Environment and the Ministry of Economic Affairs have requested PBL to create input for the European debate on climate targets and policies until and beyond 2030. This project intends to support PBL by creating insight into the steps needed to achieve long term emission reductions. More specifically, the following questions will be answered:

1. What steps are needed for selected key technology groups to achieve long term GHG emission reductions in the long term, what climate and energy policies are likely to trigger these steps?
2. What are the pros and cons of a 2030 policy framework with a) a GHG reduction target only, and b) targets for GHG reduction, renewable energy, and energy efficiency?

[3] Ecofys and Fraunhofer ISI, 2010. Energy savings 2020. A Contributing study to Roadmap 2050. European Climate Foundation.
[4] SDW/2012/149 and SDW/2012/164 and COM/2012/271

The first question we will answer in four dedicated chapters of this report dealing with required action and necessary policies for:

- Energy efficiency in the built environment, notably for heat
- Solar PV and wind energy
- Advanced biofuels
- CO_2 capture and storage.

For each of these we will discuss status of the relevant technologies, costs, non-cost barriers, and policy options.

In the final chapter we will bring together findings from the preceding sections, and conclude on requirements for an EU framework for climate and energy policies until 2030. In particular, we will focus on comparing the extent to which the adoption of a GHG target only (either for ETS only or for ETS and non-ETS jointly) would be sufficient and adequate to trigger the required actions in the market and advance up scaling of the four technology groups or, a more specific policy framework with additional targets and policies for renewable energies and energy efficiency would be required.

We emphasize here that conclusions on the effectiveness of any policy or policy framework will depend very much on the details of the policy design. A framework is not effective or efficient only because of the number of policy targets in it. Effectiveness and efficiency of a framework are determined to a large extent by the stringency of targets, and by the design of specific policy measures that are based on it.

2 Energy efficiency for heat in buildings

2.1 Status and costs

The European Union aims at drastic reductions in domestic greenhouse gas emissions of at least 80% by 2050 compared to 1990 levels. Representing approximately 40% of EU's final energy consumption and being responsible for a major share of GHG emissions and being expected to have above average savings potentials, the building sector should achieve even higher reductions of at least 88% 91% by 2050[5] in the context of the overall 80% target.

In order to tap the full energy- or carbon savings potential respectively in the buildings sector, swift action will be required to ensure that new stock is built according to ambitious energy standards as well as to speed up renovation rates and increase renovation depths of the old building stock up to rates compatible with the 2050 target.

Table 1 shows a list of available measures to reduce carbon emissions from heating and/or cooling of buildings. Most of them also result in a reduction of heating or cooling energy in buildings both for new buildings and retrofit – and their GHG abatement costs. There is a wide range of (heat) efficiency and GHG mitigation measures available that can be implemented in the built environment. These include improving the energy performance of the building shell (e.g. wall and roof insulation, double/triple glazing windows) incorporate more efficient energy systems (e.g. condensing boilers, highly efficient heat pumps for heating and cooling, demand driven ventilation with heat recovery) as well as e.g. installing solar thermal panels or PV systems for on-site production or switching to fuels with lower emission factors (gas/biomass/low carbon electricity). The relevance for long term GHG reduction depends to a large extent on the life time of the measures. Typical lifetimes for systems for heating, ventilation and air-conditioning are between 15 and 20 years, while insulation measures live 30 to 40 years. It is important to consider lock-in effects in this respect: investments for deep renovation (e.g. triple glazing) may be discouraged if recently shallower measures have been taken (for double glazing).

[5] European Commission Communication: COM(2011) 112 final, A Roadmap for moving to a competitive low carbon economy in 2050.

Table 1 Heat efficiency measures in the built environment and associated abatement costs. Source: Ecofys, 2009[6]

Technical measures	Residential /Non Residential	New/Retrofit	Specific costs €/t-C02	Emission reduction potential in 2020 Mton C02-eq
Improved regulation & heat distribution	Non-Res.	Retrofit & New	-356	9
Efficient tap water	Residential	Retrofit & New	-168	6
Improving building shell: roof insulation	Residential	Retrofit	-155	68
Heating: condensing boilers	Residential	Retrofit	-155	92
Heating: condensing boilers	Non-Res.	Retrofit	-149	66
Improving building shell: ground floor	Residential	Retrofit	-146	51
Heating: heat pumps	Non-Res.	Retrofit	-136	5
Improving building shell: roof insulation	Non-Res.	Retrofit	-135	21
Improving building shell: ground floor	Non-Res.	Retrofit	-128	16
Heating: heat pumps	Non-Res.	New	-103	2
Improved regulation & heat distribution	Residential	Retrofit	-98	30
Improving building shell: wall insulation	Non-Res.	Retrofit	-87	20
Improving building shell: windows	Non-Res.	Retrofit	-81	30
Improving building shell: windows	Residential	Retrofit	-80	40
Heating: Biomass (Pellets etc.)	Non-Res.	Retrofit	-72	8
Heating: Biomass (Pellets etc.)	Non-Res.	New	2	4
Passive Houses/zero energy houses	Residential	New	22	3
Passive House Non-res	Non-Res.	New	37	1
Heating: Biomass (Pellets etc.)	Residential	Retrofit	39	14
Ventilation system with heat recovery	Non-Res.	New	114	1
Solar water heater	Residential	Retrofit & New	143	16
Ventilation system with heat recovery	Residential	New	153	4
Heating: heat pumps	Residential	Retrofit	153	7
Heating: Biomass (Pellets etc.)	Residential	New	202	10
Heating: heat pumps	Residential	New	223	5
Heating: Micro CHP	Non-Res.	Retrofit	284	8
Heating: Micro CHP	Residential	Retrofit	378	15
Heating: Micro CHP	Residential	New	928	2
Heating: Micro CHP	Non-Res.	New	1415	1

CO_2 prices to trigger commercialization

The residential and commercial building sectors fall outside the EU Emissions Trading Scheme. For this reason CO_2 prices have not provided so far a direct economic incentive to trigger the implementation of efficiency measures. However, CO_2 abatement costs for efficiency measures in the built environment are often negative (see Figure 1), meaning that investment costs can be paid back by savings in the energy bill. In other words, a wide number of energy efficiency measures are cost-competitive without additional revenue from avoided CO_2 emissions.

[6] Ecofys, 2009: Sectoral Emission Reduction Potentials and Economic Costs for Climate Change (SERPEC-CC), for European Commission.

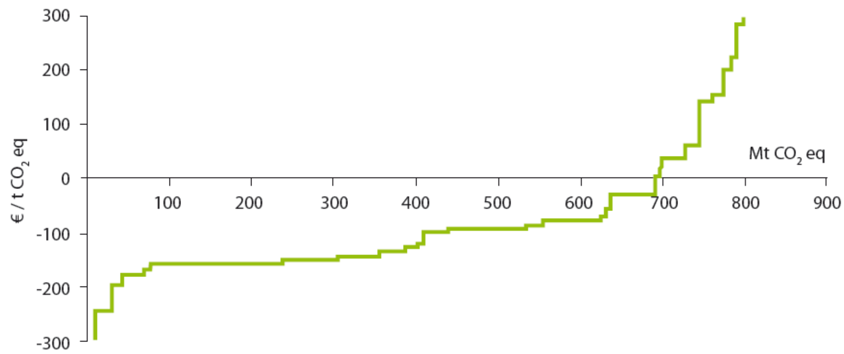

Figure 1 CO_2 mitigation options in the building sector, reduction potentials and mitigation costs up to 2020.

Source: Ecofys, 2009Error! Bookmark not defined..

Outlooks for improvements and cost reductions

The Energy Performance of Buildings Directive[7] (EPBD) establishes that by the end of 2020 'all new buildings are nearly zero- energy buildings'. The Directive defines nearly zero-energy buildings (nZEB) as '*a building that has a very high energy performance […]. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby;'*

Concepts and examples for nearly zero-energy buildings already exist in various countries. However, the translation of this concept into national regulations and standards is yet to be decided by the Member States.

A recent study[8] estimates that in order to meet the 2050 targets for CO_2 reduction, nZEB requirements for new buildings also have to include nearly zero carbon emissions below approx. $3kgCO_2/m^2yr$. The same study[8] concluded that nearly zero-energy buildings – with emissions below the 3kg $CO_2/(m^2yr)$ threshold, consistent with the EU low-carbon roadmap for 2050 - are already achievable with existing technologies.

However, generally there is still an economic gap between cost-optimal building approaches and nearly zero-energy buildings (figure below) today. Experts suggest that this economic gap can be substantially bridged before 2020, the moment when nZEB approaches will become mandatory within the EU. This is e.g. because learning curves for high efficiency and renewable energy components as well as their large diffusion from a niche to a mass product lead to significant price decreases which make them a standard practice. Several examples can be found, e.g. PV panels, condensing boilers, triple glazing, highly insulating window frames etc.

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[7] Directive 2010/31/EU. Available from: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:153:0013:0035:EN:PDF

[8] Buildings Performance Institute Europe (2011) "Principles for nearly Zero-Energy Buildings. Paving the way for effective implementation of policy requirements". Available from: http://www.bpie.eu/

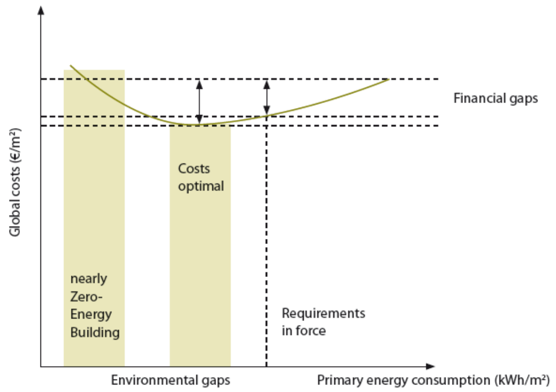

Figure 2 Cost-Optimality vs nearly Zero-Energy Building in 2011. Source: BPIE[8]

Another recent study[9] shows that some key technologies for improving energy efficiency in the built environment show promising potential for substantial cost reductions beyond 2020:

Table 2 Estimated reductions in costs of delivered energy for some key technologies. Source: IEA

Technology	2030		2050	
Active solar thermal	**-50% to -60%**		**-50% to -65%**	
Heat pumps	Space/water heating	Cooling	Space/water heating	Cooling
	-20% to -30%	**-10% to -20%**	**-20% to -30%**	**-10% to -20%**
CHP	Fuel cells	Microturbines	Fuel cells	Microturbines
	-45% to -65%	**-10% to +5%**	**-45% to -65%**	**-10% to +5%**

2.2 Non-cost barriers

Even in those cases in which building efficiency measures are cost-effective, their widespread adoption is still hindered to a great extent by a diversity of barriers for implementation.

One of the most common barriers for efficiency in the built environment is the 'split incentive' that is usually created between landlords and tenants. Landlords have to bear the capital investment costs required for the efficiency upgrades, while the tenant is usually the one who benefits from the reduced energy costs.

[9] IEA (2011) Technology Roadmap Energy-efficient Buildings: Heating and Cooling Equipment.

Incentives are also often misaligned in the relationship between energy retailers and end-consumers. Retailers tend to have easier access to finance, qualified professionals, as well as information on available efficiency measures and their savings potential, but they lack the incentive to take action in reducing energy demand.

Information barriers are also an important obstacle for the deployment of energy efficiency measures. End-consumers usually lack sufficient technical knowledge about available options in order to take rational decisions. But also architects, engineers and craftsmen do not yet have the know-how to build nZEB as a standard and need time to align to this construction level.

High upfront capital investments required for some measures and a tendency to focus on short-term rather than life-cycle costs are also common obstacles preventing higher levels of adoption. When energy costs represent a too small fraction of total costs, particularly in the business sector, this may also shift attention – and investment capacity - to other areas where higher returns on investment can be expected.

2.3 Policy options

More than one quarter of the 2050's building stock in Europe is still to be built[10]. In order to ensure consistency with the EU's ambitious decarbonization targets[11] , the energy consumption and associated GHG emissions of this new stock need to be close to zero. For this purpose, it is critical that the concept of nearly zero-energy buildings advanced in the EPBD Directive[12] materializes in **highly ambitious national plans (regulations, finance, information) for new buildings and major renovations**. The EPBD requires Member States to set up national plans for increasing the number of nearly zero buildings.

On the other hand, the existing building stock represents the single biggest potential for energy savings[13]. Acknowledging this, the newly adopted Energy Efficiency Directive[13] requires EU Member States to establish long-term strategies for the renovation of their national stock of public and private residential and commercial buildings. Policy packages should aim at incentivising an increase in renovation rates as well as in the energy ambition level of the retrofits, in order to avoid a 'lock-in' in moderate energy performance levels.

[10] Buildings Performance Institute Europe (2011) "Principles for nearly Zero-Energy Buildings. Paving the way for effective implementation of policy requirements". Available from: http://www.bpie.eu/

[11] European Commission Communication: COM(2011) 112 final, A Roadmap for moving to a competitive low carbon economy in 2050.

[12] Directive 2010/31/EU. Available from: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:153:0013:0035:EN:PDF

[13] Directive 2012/27/EU. Available from: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ%3AL%3A2012%3A315%3A0001%3A0056%3AEN%3APDF

A recent study[14] shows that a 'deep renovation[15]' strategy – characterized by an increased renovation rate and high levels of ambition on the efficiency improvements – seems the most appropriate to tap this potential. This strategy would not only contribute to achieve EU's decarbonisation targets, but also to create additional employment. It has been estimated[16] that such a 'deep renovation' strategy could create 1.4 million jobs[14] within the EU.

Policy instruments that may be successful in incentivising a path consistent with a 'deep renovation' scenario include **tax exemptions for investments in energy efficiency, subsidies, soft loans, or energy efficiency obligations with ambitious targets**.

Policy packages must pay due regard to non-cost barriers as those discussed in the previous section. There is some experience in Europe with the implementation of **financial schemes** (e.g. KfW in Germany, 'Green Investment Bank and Green Deal' in the UK) that can help investors overcome the barrier of high upfront costs by subsidising interest rates or by enabling the end-consumer to repay the investment through the energy bill. The latter may also prove effective in overcoming landlord-tenant barriers.

Other 'soft' measures such as **consumer information campaigns** and **professional capacity building** are also an important component to overcome non-cost barriers. Energy efficiency should become a major criterion in the perception of investors and users for a building's value, which increases their willingness to pay for this feature. Energy certificates must become a much more visible feature of buildings that helps increasing awareness for energy efficiency. What works for e.g. cars and white goods with the energy labelling schemes should also become common knowledge and practice relative to building energy efficiency.

The implementation of **energy efficiency obligation schemes** may also be used as a mechanism to align the interests of energy suppliers and consumers towards energy efficiency while incentivising the development of a market for energy service companies (ESCO's).

[14] Ecofys 2012. Renovation tracks for Europe up to 2050. Building renovation in Europe: What are the choices?
[15] 'Deep Renovation' scenario is defined as: Renovation rate 2.3% (approximately double that current rates of renovation), high level of energy efficiency improvement (~80% reduction in energy use for space heating) high focus on energy efficiency of the building envelope; advanced systems (high use of renewable energy and heat recovery ventilation).
[16] Assuming 17 jobs created and maintained per M€ of investment. Based on: Urge-Vorsatz, D. (2011) et al. Employment Impacts of a Large-Scale Deep Building Energy Retrofit Programme in Hungary. Center for Climate Change and Sustainable Energy Policy - Central European University & European Climate Foundation.

The table below shows the relative importance of different policy instruments required to tap the full potential of energy efficiency in buildings from now until 2050:

Table 3 Perceived role of policy instruments for a technology until 2050 (++ = very important, + = important, 0 = moderately important, - = unimportant)

Energy Efficiency in Buildings	2010-2020	2020-2030	2030-2040	2040-2050
Regulation or standards	++	++	+	+
Externality pricing	0	0	0	0
Subsidies (Financial Incentives)	+	+	+	+
Addressing Non-Economic barriers	++	++	++	++
Capacity building	+	+	+	+

3 Solar PV and wind energy

3.1 Status and costs

Wind and solar power generation technologies have achieved remarkable market expansion in Europe in the last years. In the year 2000, a total of 3.5 GW of new renewable power generating capacity were deployed in Europe. Installation of renewable power has been constantly growing over the past 11 years, to reach 32 GW in 2011[17].

Wind and PV alone accounted for more than two thirds of the new installed capacity in Europe in 2011. Of the 35,468 MW of new generating capacity, 21,000MW (47%) corresponded to PV and 9,616 MW (21%) to wind power[17].

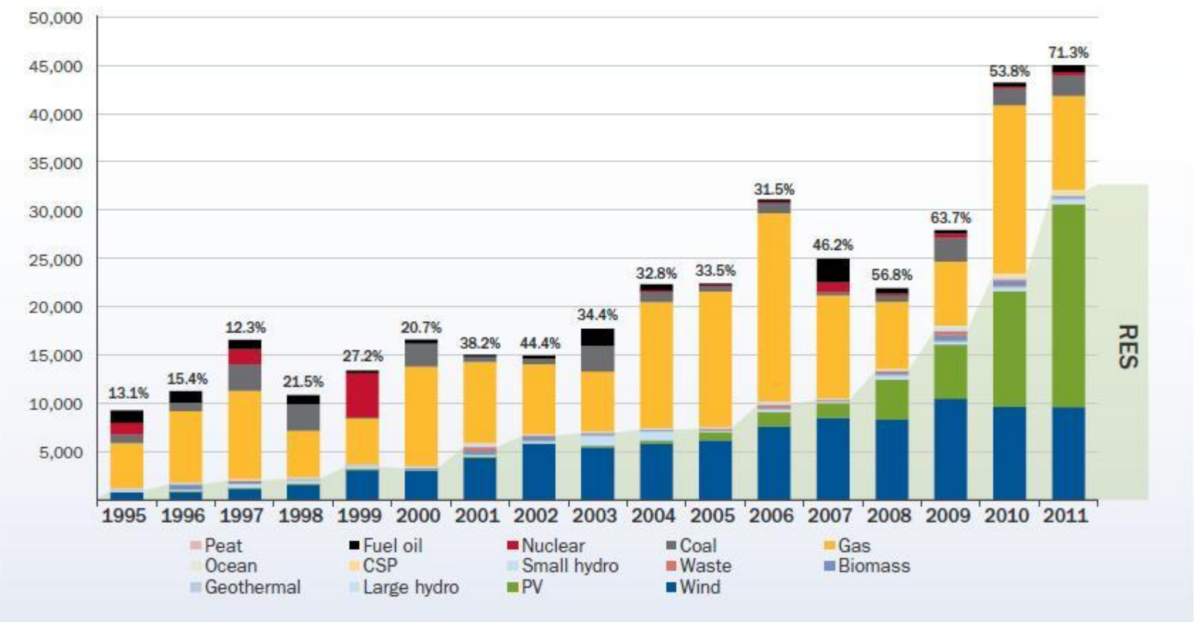

Figure 3 New power generation capacity (MW) installed in the EU per year and RES share. Source: EWEA, 2012

[17] EWEA, 2012. Wind in Power: 2011 European Statistics. Available from: http://www.ewea.org/fileadmin/files/library/publications/statistics/Wind_in_power_2011_European_statistics.pdf

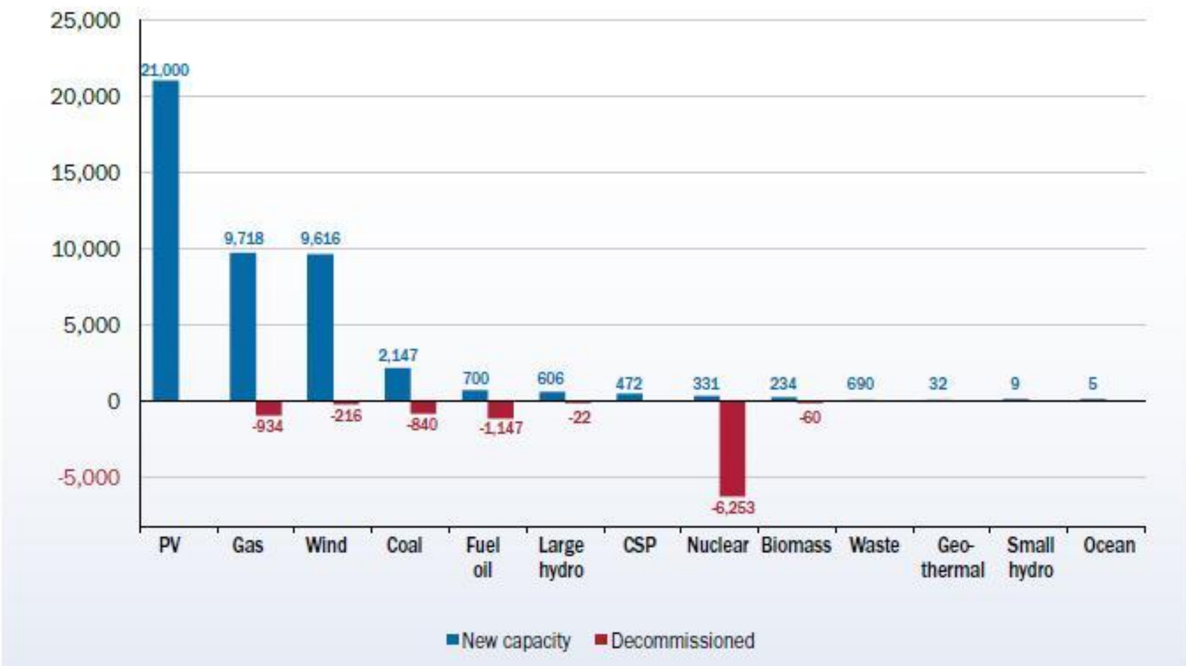

Figure 4 New power generation capacity (MW) installed in the EU in 2011. Source: EWEA, 2012

The expansion of installed renewable power has been accompanied by substantial cost reductions. Generation costs for wind and solar power are very sensible to project-specific factors such as the renewable resource available on the site, project size, as well as the administrative and financial environment of the region, which in turn affects financial costs. For this reason, an accurate assessment of the economic competitiveness of these technologies – and therefore any decision about the required economic support – needs to take these factors into account very carefully.

Onshore wind power is becoming cost-competitive in a broad range of circumstances. According to the International Renewable Energy Agency (IRENA), the typical levelled cost of electricity (LCOE)[18,19] for new onshore wind farms in Europe was in the range of 61-106 €/MWh in 2010[20]. Offshore wind power has higher costs and still requires sustained economic and institutional support in most circumstances. Also according to IRENA, typical LCOE for new offshore wind farms in Europe was in the range of 106-144 €/MWh in 2010[20].Realistic short-term cost reductions by 2015 are in the order of 6-7% for onshore and 8-10% for offshore[20].

[18] LCOE: Ratio of lifetime costs to lifetime electricity generation.
[19] Assuming a 10% cost of capital
[20] Prices in Euro assume a 0,76 Euro/USD exchange rate. Source: IRENA (2012) Renewable Energy Technologies: Cost Analysis Series. Volume 1: Power sector. Issue 5/5. Wind Power. Available from: http://www.irena.org/DocumentDownloads/Publications/RE_Technologies_Cost_Analysis-WIND_POWER.pdf.

Solar PV generation has shown dramatic price reductions over the last years. According to EPIA (European Photovoltaic Industry Association) the price of PV modules has decreased by over 20% every time the cumulative sold volume of PV modules has doubled[21], and there is still a great potential for further reductions in generation costs. According to industry estimations, the cost of PV electricity generation in Europe could decrease from a range of 0.16-0.35 €/kWh in 2010 to a range of 0.08-0.18 €/kWh in 2020 depending on system size, application (e.g. land-based or building-integrated) and irradiance level[21].

Figure 5 compares estimated[22] levelled costs of electricity from renewables[23], with coal and natural gas power plants in 2010 and 2020.

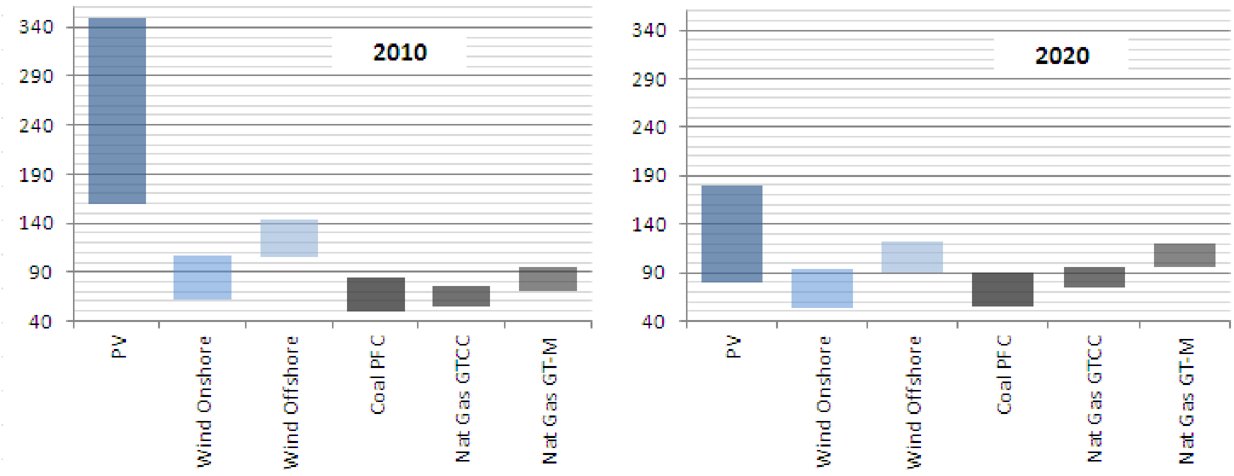

Figure 5 Estimated LCOE (€/MWh) of different technologies in 2010 and 2020

[21] EPIA – European Photovoltaic Industry Association (2011) *Solar Photovoltaics: Competing in the Energy Sector. On the Road to Competitiveness*. September 2011.
[22] Projections for LCOE for coal and natural gas were created using the SETIS model from the Joint Research Center. Available from: https://odin.jrc.ec.europa.eu/SETIS/SETIS1.html#app=9a5c&73f1-selectedIndex=0 . The following assumptions were used: 10% discount rate, 3% inflation rate. The "High DG Tren" fuel price scenario was used (this assumption is considered conservative given that oil prices are already higher in 2012 than those estimated under this scenario for 2020). Lower and higher price ranges correspond to a CO2 price of 10€/ton and 60 €/ton respectively.
[23] LCOE ranges for renewables according to IRENA (2012). IRENA estimates costs reductions of 6% and 8% for onshore and offshore wind respectively for the period 2010-2015. Similar cost reductions for the period 2015-2020 were assumed.

Lower and higher price ranges for coal and natural gas power plants correspond to a 10€/tCO_2 and 60€/tCO_2 scenarios respectively. Prices for coal and natural gas prices are expected to rise until 2020. This is in line with the latest projections of the International Energy Agency[24]. Prices for coal and natural gas in Figure 5 are based on worldwide energy modelling done for the European Commission (see Table 4). In the graph we assumed the high price scenario[25].

Table 4 Price assumptions for the EU-27 for Coal and Natural Gas (€/bbl)[26]

	2010		2020	
€/barrel of oil equivalent	Moderate	High	Moderate	High
Gas	33.2	37.0	36.8	62.0
Coal	11.0	12.6	11.8	19.4

Regardless the CO_2 price in 2020, wind onshore is expected to be competitive with Natural Gas GTCC and GT-M, and Coal PFC.

Wind-offshore is expected to be competitive with natural gas GTCC generation at relatively high CO_2 prices (40-60 €/tCO_2 and higher), but is competitive with natural gas GT-M irrespective of the CO_2 price. The costs for electricity production from offshore wind are expected to be still higher than the LCOE of coal fired generation at a CO_2 prices of 60 €/tCO_2 and below and therefore not yet competitive at these CO_2 price levels.

The LCOE range for solar-PV is broad, reflecting the large uncertainties that exist with regards to expected future price and market developments. It is therefore difficult to predict how high the CO_2 price would need to be in order to make this technology competitive. Figure 5 shows that when CO_2 prices are high at 60 €/tCO_2, solar-PV could be competitive with the fossil fuel generation options that we considered in this report, but only when considering the most ambitious cost reductions of solar-PV until 2020. In other cases, solar-PV is expected to remain a relatively expensive option and not yet competitive at prices at or below 60 €/tCO_2.

[24] International Energy Agency 2012. World Energy Outlook 2012. Prices are expected to rise under a Current Policy Scenario (embodies the effects of only those government policies and measures that had been
enacted or adopted by mid-2012) as well as a New Policy Scenario. The New Policy Scenario takes into account renewable energy and energy efficiency targets, programmes relating to nuclear phase-out or additions, national targets to reduce greenhouse-gas emissions communicated under the 2010 Cancun Agreements and the initiatives taken by G-20 and Asia-Pacific Economic Cooperation (APEC) economies to phase out inefficient fossil-fuel subsidies. IEA also defines a ‚450 Scenario' that is consistent with actions having around a 50% chance of meeting the goal of limiting the global increase in average temperature to two degrees Celsius (2 °C) in the long term, compared with pre-industrial levels. Under this scenario prices for gas and coal are assumed to decline. Because the world has not committed to meeting this objective, we disregarded this scenario.

[25] Coal PFC: Coal Pulverised Fuel Combustion; Nat Gas GTCC: Combined Cycle Gas Turbine; Nat Gas GT-M - Open Cycle Gas Turbine - Medium

26 Source: EC 2008 Second Strategic Energy Review
http://ec.europa.eu/energy/strategies/2008/doc/2008_11_ser2/strategic_energy_review_wd_future_position2.pdf . These figures are used in the SETIS model from the Joint Research Center.

3.2 Non-cost barriers

Even in those conditions where renewable power generation technologies are already competitive or deemed to reach cost-competitiveness in the coming years, deployment is still at risk of being inhibited by other barriers such as:

Regulatory and policy instability:
Lack of long-term policy commitments or unexpected changes in the regulatory framework drive financing costs up dramatically and undermine investors' trust.

Long and costly administrative processes:
Lengthy, costly and intransparent permitting and grid connection procedures are widely considered one of the key non-economic barriers for the deployment of renewable energy sources (RES) across Europe.

Grid infrastructure and market integration:
Wind and solar power are supply-driven technologies characterized by fluctuations of the electricity output. A high share of intermittent resources in the power grid poses a crucial challenge for system operation and a barrier to reach high market penetration levels of these technologies. Renewable electricity sources are becoming mainstream and should hence not be treated as niche-applications. Electricity infrastructure and markets need to be adjusted.

High up-front investments required and associated financial costs:
Capital costs of RES technologies are typically higher than conventional sources, while usually the marginal costs are very low. Even when technologies reach competitiveness, high financing requirements (debt, equity) may represent an insurmountable barrier for project developers, notably under economic uncertainty. Access to affordable finance is therefore a key element for the successful deployment of RES. This barrier is becoming particularly important due to the financial crisis.

3.3 Policy options

Economic Support

The European deployment of RES policy support instruments[27] has been instrumental in increasing RES market penetration by bridging the competitiveness gap between RES electricity and conventional sources. As discussed in the previous section, this competitiveness gap has been substantially narrowed in the last years due to technology development, economies of scale and progress towards market maturity. This trend is likely to continue in the near future. Provided that the right steps are taken for the integration of RES power in the electricity grids and markets, wind and solar power are expected to rely progressively less on these dedicated financial support schemes in an increasing number of circumstances. However, specific economic support may still be required beyond 2020 in certain situations where technologies will still not be fully competitive (e.g. incentives for solar PV in central and north european countries or offshore wind).

Even when the costs of the technology are competitive, high upfront costs and the associated financial costs may still be a barrier for investors in RES power. Instruments that may reduce the cost of financing for project developers include publicly backed loans, loan guarantees, investment subsidies and soft loans, public investment in private equity and public-private partnerships, among others.

We have recently witnessed how some Member States have suddenly removed economic support schemes for renewables due to concerns about their economic sustainability (e.g. Spain, Portugal, Latvia, Bulgaria, Czech Republic). These sudden changes in policy undermine investors confidence and increase financing costs dramatically. A dynamic and flexible approach to economic support is therefore desirable, i.e an approach in which the policy instruments adapt to the maturity of the technologies. For this purpose, it is critical to monitor market trends periodically and adjust the amount of support accordingly. This is particularly important in times of economic crisis.

Convergence of national schemes is another important aspect to be taken into account in order to reduce the costs of RES support across Europe. Increased cooperation between Member States can reduce the costs of reaching the European RE targets substantially e.g by tapping low-cost potentials through RE trade. Harmonisation of national support schemes (i.e. going beyond coordination) has the potential to further reduce support costs through efficiency gains. However, uniform support payments across Europe could lead to limited RES deployment (compared to nationally binding targets) and high producer rents (wind fall profits) for producers of least cost-RES and high costs to society[28].

[27] Including investment subsidies, Feed-in Tariffs (FiT), Feed-in Premium (FiP) and Quota Obligation schemes; often in combination with fiscal measures (accelerated depreciation, investment tax deduction, green loans, etc.).
[28] According to the analysis done by the European Commission in the Energy Roadmap 2050.

Well-designed uniform support schemes can however reduce this risk to acceptable levels though technology and location-dependent support (e.g. where solar-PV support depends on irradiance levels and wind support depends on average wind speeds)[29].

Non Economic Policy Support

In addition to provide economic support to bridge the gap to cost-competitiveness, a comprehensive policy package needs to tackle other important barriers for RES deployment.

The top priority of RES support is to create a predictable, transparent and comprehensive policy package that removes regulatory uncertainty by giving a strong, clear, long-term signal for project developers. This applies not only to the reliability of economic support – where required – but also to permitting processes and other regulations that affect the investor's visibility and ultimately the feasibility of RES projects. Policy actions needed to improve administrative and grid connection procedures and reduce regulatory uncertainty include[30]:

- Streamlining procedures towards transparent and non-discriminatory processes ("one-stop shop" approaches, maximum response periods for authorities, clear guidelines and capacity building for civil servants, limiting administrative requirements to the relevant elements, simplified procedures for small plants, etc.)
- Guaranteed and possibly priority grid access
- Improved spatial planning rules
- Definition of RES priority areas
- Regulations to limit grid connection costs

Wind and solar power are supply-driven generation technologies. For this reason, both the grid infrastructures and the operation of the electricity markets will need to evolve in order to accommodate increasing levels of these sources in the system. Sometimes new, sometimes upgraded, modern electric infrastructure will be required in order to ensure the connection of the full cost-effective potential of renewable power. In particular, expanding cross-national interconnection capacities within Europe would improve the overall stability of the systems and their capacity to absorb increasing amounts or intermittent power. Alongside with appropriate and interconnected grids, power market design, regulations and operation practices will need to evolve in order to provide a fair framework for an increasing share of variable renewable sources.

Policy instruments that may be required to increase the integration of wind and solar in the power systems and markets include incentives for (flexible) demand-side management and decentralized energy storage, as well as support for R&D of smart-grids.

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[29] Klessman, C. de Lovinfosse, I. (2012) Converging Support Schemes in Europe? Best practice design criteria for effective and efficient future RES-E support. Available from: http://www.erec.org/fileadmin/erec_docs/Events_Documents/EREC-Ecofys_Workshop_19.09.12_Ecofys_Converging_RES-E_support.pdf

[30] Klessmann, C., Held, A., Rathmann, M., Ragwitz, M., 2011. Status and perspectives of renewable energy policy and deployment in the European Union– what is needed to reach the 2020 targets? Submitted to Energy Policy in February 2011.

The tables below show the relative importance of different policy instruments for RES deployment for the different technologies discussed from now until 2050:

Table 5 - Perceived role of policy instruments for a technology until 2050 (++ = very important, + = important, 0 = moderately important, - = unimportant)

SOLAR PV		2010-2020	2020-2030	2030-2040	2040-2050
Category	***Policy instrument***				
Regulation or standards	Guaranteed /priority grid access	++	+	+	+
Economic Support	Externality pricing	+	0	0	0
	Feed-in tariffs, subsidies, tax exemptions	+	0	-	-
Addressing Non-cost barriers	Streamlining Administrative Procedures	+	+	+	+
	Grid Infrastructure Development				
	Mechanisms for low-cost finance of high upfront capital costs				
	Electricity Market Integration				
Capacity building	Research & Development	+	0	0	0
	Public acceptance, Information Programmes, etc.				

WIND ONSHORE		2010-2020	2020-2030	2030-2040	2040-2050
Category	***Policy instrument***				
Regulation or standards	Guaranteed /priority grid access	++	+	+	+
Economic Support	Externality pricing	+	+	0	0
	Feed-in tariffs, subsidies, tax exemptions	+	+	0	-
Addressing Non-cost barriers	Streamlining Administrative Procedures	++	++	++	++
	Grid Infrastructure Development				
	Mechanisms for low-cost finance of high upfront capital costs				
	Electricity Market Integration				
Capacity building	Research & Development	+	+	+	+
	Public acceptance, Information Programmes, etc.				

WIND OFFSHORE		2010-2020	2020-2030	2030-2040	2040-2050
Category	***Policy instrument***				
Regulation or standards	Guaranteed /priority grid access	++	+	+	+
Economic Support	Externality pricing	+	+	0	0
	Feed-in tariffs, subsidies, tax exemptions	++	++	0	-
Addressing Non-cost barriers	Streamlining Administrative Procedures	++	++	++	++
	Grid Infrastructure Development				
	Mechanisms for low-cost finance of high upfront capital costs				
	Electricity Market Integration				
Capacity building	Research & Development	+	+	+	+
	Public acceptance, Information Programmes, etc.				

4 Biofuels

4.1 Status and costs

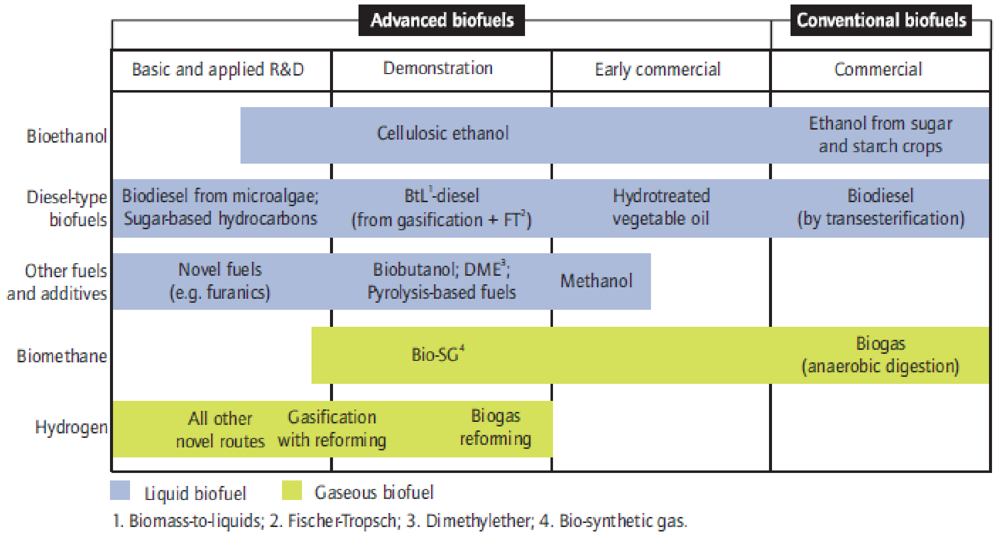
Status

Between 2000 and 2010, the worldwide produced volume of biofuels increased from 16 billion litres to 100 billion litres. The biofuel market was stimulated by blending targets and mandates for transport fuels that were set in many countries, including the EU27, Brazil, United States, and some Chinese provinces. These mandates were mainly triggered by emission reduction ambitions in the transport sector, but security of supply and agricultural development also played a role.

Currently, production of ethanol from sugar crops and biodiesel from different vegetable oil (e.g. from oil palm and sunflower) are mature technologies, although some efficiency improvements in the production process are possible. The production costs of these biofuel types are very sensitive to the feedstock costs. Many types of advanced biofuels are under development, as shown in the figure below. With advanced we indicate biofuels produced either from lingo-cellulose biomass, or from waste-residues via advanced technologies, that go beyond the technologies commonly used for biofuel production. The use of other types of feed stocks could increase the efficiency and yields for biofuel production. Sustainability of biofuels is an important aspect that should improve with the development of advanced biofuels (IEA, 2011)[31].

The sustainability of biofuels has been a subject of public discussion in recent years and is high on the agenda of policy makers. Sustainability generally refers to the life-cycle greenhouse gas (GHG) balance of biofuels and the impact of feedstock production on food production and other types of land-use. The life-cycle GHG balance represents the sum of absorption of GHG by feedstock growth, emissions from production and transport, as well as emissions from the combustion of biofuels. Apart from this GHG balance, indirect land-use change (ILUC) impacts are at the centre of the biofuel debate as well: biofuel feedstock production might displace food, feed and fibre production. This might result in additional GHG emissions as the food production might move to areas where production is less efficient or replace forests. Deploying cellulosic ethanol and Btl diesel might reduce GHG emission with more than 50%, compared to fossil fuels. The reduction can exceed 100% because co-products from biofuel production might be used for power and heat production (IEA, 2011).

[31] IEA, 2011. Technology Roadmap Biofuels for Transport. International Energy Agency (IEA), Paris.



Source: Modified from Bauen *et al.*, 2009.

Figure 6 Overview of the development stages of different types of advanced and conventional biofuels. Source IEA (2011)

Figure 7 gives an overview of operational advanced biofuels initiatives in the EU until 2011. The majority of the volume stems from the BioMCN biomethanol facility in the Netherlands, which came on stream in July 2008 and was enlarged in 2009. Inbicon/Dong in Denmark commissioned a significant but still small cellulose ethanol plant at the end of 2009. The figure shows that advanced biofuel production in Europe is still in the pilot/demonstration phase.

Finland
1. Chempolis (5 ktonne/yr cellulose ethanol demonstration, since 2008)
2. NSE Biofuels (0.7 ktonne/yr FT-diesel demonstration, since 2009)

Sweden
3. SEKAB (0.2 ktonne/yr cellulose ethanol pilot, 2004 – 2012 - Halted)

Norway
4. Borregaard ChemCell (16 ktonne cellulose ethanol, commercial, since 1930)
5. Weyland (0.2 ktonne/yr cellulose ethanol, pilot, since 2010)

Denmark
6. Inbicon/DONG (4.3 ktonne cellulose ethanol, demonstration, since 2009)

the Netherlands
7. BioMCN (20 ktonne biomethanol, pilot, since 2008)
BioMCN (200 ktonne biomethanol, commercial, since 2009)

Germany
8. CHOREN (methanol and FT liquids, pilot, 1998 – 2004 - Halted)
CHOREN (15 ktonne FT-diesel, commercial, 2009 – 2011 - Halted)

France
9. PROCETHOL 2G Futurol (0.2 ktonne bioethanol, pilot, since 2010)

Spain
10. Abengoa (4 ktonne cellulose ethanol, demo, since 2008)

Italy
11. Chemtex Mossi & Ghisolfi (0.2 ktonne cellulose ethanol, pilot, 2009)
Chemtex Mossi & Ghisolfi (60 ktonne cellulose ethanol, commercial, 2012 Q4 expected)

Figure 7. Pilots and demonstrations of advanced biofuel production from residues and ligno-cellulose biomass.

NER300 projects

In December 2012, the European Commission made a decision on the awarding of the first round of NER300 funding.[32] Eight projects were shortlisted (excluding biogas, including projects on the reserve list) and of these eight projects, six were awarded the NER funding. The table shows that lignocellulosic/woody feedstock is the main feedstock in all of these projects. The first projects are planned to be operational at the end of 2015. If we compare this with the main milestones in the IEA Roadmap31, this is late: the industry should have established "commercial-scale cellulosic-ethanol, BtL and bio-SG plants by 2015". According to the roadmap, advanced biofuel production capacity has to ramp up rapidly after 2015, and the projects in the table below are not sufficient to achieve this growth.

Table 6 Overview of project that are awarded NER300 funding (excluding biogas)

Project name	Feedstock	Output
SE Bioenergy Pyrogrot	Forest residues	Pyrolysis oil
IT Bioenergy BEST	Lignocellulosic biomass from energy crops	Bio-ethanol
FI Bioenergy Ajos BTL	Woody feedstock	Biodiesel, bionaphta
FR Bioenergy UPM Stracel BTL	Woody feedstock (from paper and pulp industry)	Biodiesel, bionaphta
PL Bioenergy CEG Plant Goswinowice	Straw, corn	Bio-ethanol
NL Bioenergy Woodspirit	Wood chips	Bio-methanol

Costs

Cost and prospective costs of conventional and advanced biofuels are very sensitive to the type of feedstock that is used. Apart from the feedstock type, the global feedstock demand is also an important determinant of the costs: the higher the demand, the higher the cost. The estimated production costs are estimations from the IEA Energy Technology Perspectives (ETP) 2012 in 2030 (IEA, 2012)[33].

[32] Commission implementing decision – Award Decision under the first call for proposals of the NER300 funding programme. http://www.ner300.com/wp-content/uploads/2012/12/Award-Decision-1st-call-scan.pdf

[33] IEA, 2012. Energy Technology Perspectives 2012. International Energy Agency (IEA), Paris

Table 7 Overview of biofuel prices in IEA's Energy Technology Perspectives 2012 (IEA, 2012) by 2030.

Source/biofuel type	Costs (EUR/GJ) Min	Costs (EUR/GJ) Max
IEA ETP cellulosic ethanol 2030	16	24
IEA ETP BTL Biodiesel 2030	16	24
IEA ETP cellulosic ethanol 2030	19	22
IEA ETP BTL Biodiesel 2030	19	23
Current spot *prices* ethanol	20[34]	24[35]

To compare, current Brent crude oil prices are around 110 $/barrel, which translates to about EUR 14 per GJ. This would translate to EUR 18 per GJ of 'production costs' for gasoline and diesel[36]. The IEA (2011)[31] expects that advanced biofuels could reach parity with conventional transport fuels by 2030.

Because there are large uncertainties in the future GHG performance of advanced biofuels, as well as in future costs of conventional transport fuels (or other reference technologies, e.g. electric cars) it is very difficult to estimate the required CO_2 price to make advanced biofuels competitive.

4.2 Non-cost barriers

First of all, the discussion about sustainability of biofuels creates uncertainties in the market: Investors might be hesitant to invest in production capacity because the sustainability of a particular biofuel is debated. Therefore, it is of great importance to design and implement sustainability criteria and set up a clear monitoring/certification scheme. This will create clarity in the market and improves prospects for investors. To create prospects for investors, long term mandates on blending targets is also of pivotal importance (IEA, 2011).

Furthermore, the lack of knowledge of agricultural/land-use policies threat the sustainability of biofuel production. In order to safeguard sustainability of biofuels, a consistent policy on land-use in general is preferred, so a policy that is not only focussed on biofuels but includes other agricultural and forestry activities as well.

A third challenge is that feedstock production will take place in rural areas of which many are still underdeveloped and should be developed to unlock those areas for the biofuel market (IEA, 2011).

At the end-use side of the biofuel chain, the so-called "blending wall" is a barrier for biofuels to achieve high shares in the transport sector. This means that only a limited share of ethanol in gasoline is technically possible, ranging between 10 and 15%. In for example Brazil vehicles are introduced that allow higher shares.

[34] http://www.indexmundi.com/commodities/?commodity=cbot-denatured-fuel-ethanol - Accessed 21-12-2012
[35] http://www.cepea.esalq.usp.br/english/ethanol/ - Accessed 21-12-2012
[36] This is a estimate, as exact costs of gasoline and diesel production are not publicly available

4.3 Policy options

Regulation or standards
First of all, biofuels can be stimulated with blending mandates, as part of a renewable energy target in transport. In the EU, biofuels have been stimulated in many member states with a combination of tax exemptions and obligations (EC,2012)[37]. The tax exemptions are being phased out in most member states, making obligations the main support instrument. In order to stimulate advanced biofuels, some types of advanced biofuel (with feedstock from waste, residues or lignocellulosic materials) can be counted double in fuel blends.

Clear sustainability criteria that are recognised internationally should be developed, along with appropriate indicators. These criteria should at least involve ILUC and GHG emissions. Ideally, these criteria should extend to other (food, feed and material related) biomass production as well in order to prevent indirect negative effects from biofuel production. Minimum GHG emission reduction targets should be set, so that biofuel deployment will contribute to the global effort to reduce GHG emissions. In the EU, the first sustainability criteria are set as well: biofuels should not be produced from feedstock that grew on land that used to be (before 2008) forest or other carbon rich reservoirs.

Externality pricing/tax measures
To bridge the price gap with conventional transport fuels, taxation to fuels could be introduced, preferably related to CO_2 emissions (externality pricing). Alternatively, tax exemption for (sustainable) biofuels could be implemented to level the playing field. These exemptions were in place in many EU member states (most successfully in combination with obligations (EC, 2012) 37. But, as mentioned above, tax exemption will be phased out in most member states, and blending obligation will become the main instrument to stimulate biofuels (in combination with sustainability criteria).

Subsidies
In the near future R&D and pilot funding could be provided for the development of advanced biofuels, as well as to improve the efficiency of the production of conventional biofuels. However, previous initiatives in R&D support have been diffused and the effectiveness of this support is debated. A combination of blending obligations with clear sustainability criteria will probably be sufficient to stimulate developments of (advanced) biofuels, if well defined. What could remain a barrier is the investment risk related to the first commercial advanced biofuel production facilities. Governments could help to reduce those risks by providing sufficient support (e.g.through grants and loan guarantees) (IEA, 2011)[31]

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[37] EC, 2012.Biofuel baseline 2008. European Commission (EC), implemented by Ecofys. http://ec.europa.eu/energy/renewables/studies/renewables_en.htm

Capacity building/addressing non-financial barriers
The IEA recommends consumer countries to collaborate financially and as well as technically support with producer countries to plan and map sustainable land-use (IEA, 2011). Preferable, this should not only include biofuel production, but sustainability (environmental and socio-economic) of a wide range of agricultural projects. This broader perspective will probably be more effective in mitigating negative impacts such as indirect land-use change and land-grabbing. Some consumer countries are already involved in these projects: The Netherlands for example collaborates with Mozambique and Sweden with Tanzania.

Secondly, life cycle assessment methodologies and sustainability certification and monitoring schemes, especially for indirect land-use change, have to be developed, cooperation with industry and research institutes. Because the agricultural and forestry sectors will remain dynamic, knowledge should be updated and shared regularly and the collaboration of consumer with producer countries will remain important.

Table 8 Perceived role of policy instruments for advanced biofuels until 2050

Advance biofuels		**2010-2020**	**2020-2030**	**2030-2040**	**2040-2050**
Category	***Policy instrument***				
Regulations/ Standards	Blending obligations	++	++	++	++
	Sustainability criteria	++	++	++	++
Economic Support	Externality pricing	+	+	+	+
	Tax exemptions	+	0	0	0
Non-economic Barriers/ Capacity Building	Supporting producer countries	++	++	++	++
	Stimulate development of sustainability criteria and monitoring processes	++	++	++	++

5 CO_2 capture and storage

5.1 Status and costs

The individual components of the CCS technology are to a large extent commercially available. However, integrated operations combining CO2 capture, transport and technology on a large scale still needs to be demonstrated. CCS is not only aimed at fossil based thermal power production, but also on industrial CO_2 streams, biomass combustion as well as biofuel and hydrogen production. R&D is still needed to treat these different CO_2 -streams. While CO_2 transport by pipelines is a proven technology, the development of a large scale infrastructure strategy is needed to optimize the future CO_2 transport.

The first full-scale post-pilot projects are expected to be commissioned after 2030, if sufficient pilot and demonstration projects are realised in the years before.

At this moment, only six integrated CCS demonstration projects are planned (but definitely not certain) in Europe[38] and two large projects (related to natural gas production) are operational: the Sleipner project and the Snøhvit project[39].

The European Commission recently made an awarding decision under the first call for proposals of the NER300 funding programme.[40] Only one CCS projected is being awarded NER300 funding: the Ultra Low-CO_2 Steelmaking (ULCOS) project in France. However, the realisation of this project is also uncertain: ArcelorMittal, which is in a consortium with nine other steelmakers, told the European Commission that it cannot proceed immediately because of "the current state of research and the technical difficulties". Another reason behind the postponement of investment decisions, is the low CO_2 price, which is currently below €7/tonne. This is also the main reason behind the decision of GDF Suez and E.On to postpone an investment decision on their capture installations, creating uncertainty around the ROAD ('Rotterdam Opslag en Afvang Demonstratieproject') project in Rotterdam.[41]

To summarize, there is currently no certainty on any CCS pilot project in Europe, mainly caused by a low price for emissions allowances and the absence of prospects of higher prices in the future. The subsidies were mainly determined when CO_2 prices, or expected future prices, where much higher: while CO_2 prices dropped, subsidies were not adjusted, creating a less attractive business case.

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[38] ZEP, 2012. EU CCS demonstration projects map. Zero Emissions Platform (ZEP). http://www.zeroemissionsplatform.eu/projects/eu-projects.html

[39] GCCSI , 2012. Large-scale Integrated CCS Projects – Map. http://www.globalccsinstitute.com/projects/browse

[40] Commission implementing decision – Award Decision under the first call for proposals of the NER300 funding programme. http://www.ner300.com/wp-content/uploads/2012/12/Award-Decision-1st-call-scan.pdf

[41] Volkskrant, 28 November 2012: Eon en GDF Suez willen niet meer investeren in CO2 afvang. http://www.utilities.nl/eon-en-gdf-suez-willen-niet-meer-investeren-in.96646.lynkx

The IEA (2009)**Error! Bookmark not defined.** outlined the actions and milestones that are needed in order to achieve the targets set in its CCS Roadmap. In this memo, we will address a number of actions listed in the CCS Roadmap that would need to be taken by national governments. The CCS roadmap was published in 2009 and the IEA and others argue that the more action is needed to keep on track with the targets in the roadmap.[42] The first issue that has to be addressed is the (abovementioned) financial gap for CCS projects.

Costs

Levelled cost of electricity have been provided by ZEP (2011). The costs are estimations for post-pilot (i.e. early commercial) projects (in the mid-2020's). A summary of these costs are provided in Table 9.

Table 9 Overview of costs of electricity production with and without CCS in the mid-2020's. Source: ZEP (2011)

Fuel	wCCS (EUR/MWh)	w/o CCS (EUR/MWh)
Coal	72	48
Lignite	65	45
Natural gas	92	68

The levelled fuel cost will depend on the future fuel prices. In the estimations in the table above, medium fuel prices are assumed (with moderate fuel price growth). Furthermore, onshore storage is assumed.

CO_2 price needed to trigger commercialization

According to ZEP (2011)[43], the price of Emission Unit Allowances (EUAs) should range between €34/tonne (for lignite) and €90/tonne (for natural gas) to break even (compared to similar power stations without CCS), these numbers apply to early commercial plants. The GCCSI estimated mitigation costs associated with CCS to range between €18/tonne (23US$/tonne) and €69/tonne (90US$/tonne) (GCCSI, 2012) , this number applies to current technologies (but with developed infrastructure). IEA, (2009) estimates the costs of CCS applied to power production to range between €27/tonne (35 US$2009 /tonne) and €56/tonne (70 US$2009/tonne) (IEA, 2009) . Cost could increase if the average transport distance increases, where the lower end of the cost range refers to a full-scale commercial plant.

The prospects for further costs reductions are limited as a large share of the costs is associated with energy costs to compress the CO_2. Before abovementioned cost levels are reached, pilot and demonstration projects are needed and deep infrastructural investments have to be made. Since a CO_2 pipeline transport infrastructure requires substantial investments, a stable investment climate should be present on the long term (decades).

[42] IEA/GCCSI, 2012. Tracking Progress in Carbon Capture and Storage. Global CCS Institute (GCCSI)/International Energy Agency (IEA). http://www.iea.org/publications/freepublications/publication/IEAandGlobalCCSInstituteTrackingProgressinCarbonCaptureandStoragereporttoCEM3FINAL.PDF
[43] ZEP, 2011. the costs of CO2 Capture, Transport and Storage. Zero Emissions Platform (ZEP). http://www.zeroemissionsplatform.eu/library/publication/165-zep-cost-report-summary.html

Since the costs of CCS are also sensitive to transport costs (increasing costs of offshore transport over increasing distances), CCS costs could exceed the abovementioned cost. If CO_2 storage takes place offshore, transport costs could increase from the by ZEP (2011) assumed costs of 5.4 €/tonne to 10-20 €/tonne for an offshore location 500 km away from the source.

5.2 Non-cost barriers

The main (non-cost) barrier for CCS is the absence of a stable investment climate, i.e. long term certainties on climate policies, CO_2 prices (also after 2020), governmental support and regulation. Without a stable investment climate the needed pilot and demonstration projects and investments in infrastructure will not be realised.

Secondly, public opposition against onshore storage is a problem that should be addressed. This public opposition might result in a shift towards offshore storage locations, which would increase CO_2-transport costs.

Another non-cost barrier is the lack of dissemination of knowledge, on reservoirs, but also on the technology. This is currently concentrated in the oil & gas sector, while for example governmental agencies need to build capacity as well in order to properly monitor CCS activities as well properly support pilot and demonstration projects (IEAGHG, 2012)[44]. Because these projects involve deep investments, public investments and funding is probably needed to realise these projects. In order to make investment decisions by public institutions, capacity building is very important.

5.3 Policy options

In the paragraph below, we distinguish important instruments to promote the deployment of CCS. As mentioned before, the main barrier is the absence of a long term stable investment climate, partly caused by the absence of long term climate policies. It is thus of pivotal importance for CCS that the enacted combination of instruments[45] offers sufficient investment security. We will mention a number of important instruments in the paragraphs below, but we cannot isolate one particular instrument that would stimulate CCS: Even a combination of EU-ETS and EPS will not necessarily stimulate CCS. Other instruments, subsidies and financial support and the abovementioned long term stable investments climate are all needed.

[44] IEAGHG, 2012. Barriers to implementation of CCS: Capacity constraints. IEA Greenhouse Gas Programme (IEAGHG), implemented by Ecofys.
[45] Most importantly a combination of a minimum CO_2 price, combined with either additional financial support/penalties or emission performance standards.

Regulation and standards

On top of a CO_2 price, additional standards might be needed to guarantee CO_2- capture in case the CO_2 price is insufficient to make a business case for CCS, or, for operational installations, to compensate the operational costs. One could think of emission performance standards (EPS) for coal plants, or fossil fuel plants, as are currently being developed in the UK, the USA and Canada[46]. An EPS would 'duplicate' legislation, and for this reason greenhouse gas emission standards for installations under the ETS have notbeen included in the Industrial Emissions Directive (IED)[47]. Member States are free to set more stringent standards, and the UK has used this room to develop EPS legislation that applies to new fossil fuel power plants. Opponents to EPS argue that a duplication of policies is not effective. , Overall greenhouse gas emissions achieved under the EU ETS will not be reduced by introducing these standards. Along this line an impact analysis by Bloomberg New Energy Finance (2011)[48], concludes that EPS will not contribute to a wider deployment of CCS because it would result in fewer coal plants being built, rather than in more capture installations.

Externality pricing

Because the costs of CCS will remain higher than reference technologies (predominantly fossil fuel combustion without CCS), a tax or cap on CO_2-emissions is important to make CCS cost-effective.

The price level of emission allowances might not be sufficient to make a business case for CCS, either caused by low CO_2 prices or increased costs for CCS. In that case, regulation is needed (e.g. an emission performance standards) and/or additional taxation on fossil fuel combustion without CCS. Alternatively, bonus allowances could be given to CCS projects in order to stimulate commercialisation.

Subsidies

Before full-scale carbon capture installations are operational, experience has to be gained with pilot projects and later on demonstration projects. To stimulate these projects financial support is needed, as the price of emission allowances is low and the first projects are expensive. Subsidies are an option, but it is more likely that public private parties will invest jointly in the first projects.

Subsidies are also needed to (IEA, 2009)**Error! Bookmark not defined.**:

- fund longer-term CCS R&D;
- finance CO_2 transport infrastructure;
- fund RD&D programmes to target gaps in knowledge on different aspects of CCS technology development

[46] Hanly, D. 2012. Emission performance standards - Old option, new incentive for CCS http://www.globalccsinstitute.com/insights/authors/davidhanly/2012/12/04/emission-performance-standards-old-option-new-incentive-ccs

[47] EC, 2010. The Industrial Emissions Directive (2010/75/EU). http://ec.europa.eu/environment/air/pollutants/stationary/ied/legislation.htm

[48] Bloomberg New Energy Finance, 2011 Emission performance standards Impacts of power plant CO2 emission performance standards in the context of the European carbon market. http://ec.europa.eu/clima/policies/lowcarbon/ccs/docs/impacts_en.pdf

Capacity building
The first projects are very likely to be funded in public private partnerships. This means investment decisions have to made by public institution or governments. Capacity building is needed in order to make informed decisions, while most of the information and knowledge is currently concentrated in the oil & gas sector.

In order to address public opposition against storage the government should, apart from convincing safeguarding environment and health, address the public. Informing the public should involve information about the risks and benefits of carbon capture and storage, as well as the necessity of climate policies in general. If support for the latter is absent, it will be difficult to gain support for CCS.

Other capacity building activities should cover (IEA, 2009)**Error! Bookmark not defined.**:

- cooperate internationally to harmonise CO_2 storage monitoring and verification (M&V) methodologies;
- develop national CO_2 storage capacity estimates using approved methodologies and share this information widely;
- expand the number of geologists who are trained in CO_2 storage site assessments;

Table 10 Perceived role of policy instruments for Carbon Capture and Storage until 2050

Category	*Policy instrument*	2010-2020	2020-2030	2030-2040	2040-2050
Regulation or standards	Emission performance standards	++	++	++	++
	Define the different responsibilities and roles	++	++	0	0
	Health and safety standards	++	++	0	0
	Develop comprehensive CO_2 transport and storage permit frameworks	++	++	0	0
Economic Support	Externality pricing	++	++	++	++
	Other subsidies	++	++	+	0
Capacity building	Public acceptance, Information Programmes, etc.	++	++	+	0
	Capacity building at governmental bodies, harmonize M&V programmes	++	++	+	0
	Knowledge development and sharing on CO_2 storage	++	++	+	+

6 What 2030 targets may trigger low carbon policies?

In the preceding chapters we discussed the required components of the comprehensive policy packages that need to be implemented by Member States in order to tap the full potential of the four technology groups. This chapter discusses the extent to which these policy interventions/instruments are likely to be triggered by the different EU-wide policy frameworks, namely a CO_2 target, a RES target and an energy efficiency (EE) target. Each of the tables in the following sections provides an answer to the question as to whether a GHG target, a RE target or an EE target on their own are likely to trigger the deployment of the technology at hand.

6.1 How to trigger energy efficiency measures for heat in buildings?

A wide number of energy efficiency measures in the built environment are already cost-competitive without the need for economic support; however, they are to a great extent obstructed by non-economic barriers. Addressing these obstacles, such as high upfront investments, split-incentives (e.g. the landlord-tenant issue), or information barriers is of particular importance in order to speed up progress in this sector. It is expected that the establishment of a specific EE target will more likely lead to the mitigation of these barriers, than a GHG target only.

There is some experience within the EU[49] in the implementation of energy efficiency obligation schemes[50] backed by annual energy savings targets and flaking instruments. These schemes have shown results overcoming some of the prevailing barriers and achieving high levels of implementation of energy efficiency measures.

The building sector currently does not participate in the EU ETS. A GHG reduction target per se would not provide additional incentives for the implementation of efficiency measures, unless specific policy instruments are implemented aimed at exposing the building sector to a CO_2 price, through ETS for example. This is however not foreseeable in the near future and will be difficult to establish due to the highly diverse nature of the sector. It would also unlikely lead to the deployment of instruments that address the non-economic barriers.

[49] E.g. Denmark, UK, Italy, France, Belgium.
[50] For further info: ECEE (2012) Energy efficiency obligations– the EU experience. March 2012.

Table 11 Assessment[51] of the effects of specific targets in triggering different policy instruments required for the deployment of energy efficiency measures in the built environment.

Energy Efficiency in the Built Environment		CO_2 Target	RES Target	EE Target
Category	*Policy instrument*			
Regulations/ Standards	Energy performance standards for new buildings and major renovations	Maybe	N.R.	Likely
Economic Support	Externality pricing	Surely (but built environment not under ETS)	N.R.	Unlikely
	Subsidies, tax exemptions, efficiency obligation schemes	Unlikely	N.R.	Likely
Non-cost barriers	Providing low-cost finance instruments	Unlikely	N.R.	Maybe
	Addressing landlord – tenant barriers	Unlikely	N.R.	Maybe
	Addressing other non-economic barriers e.g. lack of information	Unlikely	N.R.	Maybe
Capacity Building	Research & Development	Unlikely	N.R.	Maybe

6.2 How to trigger the deployment of solar PV and wind energy?

The current renewable energy framework with legally binding RES targets for MS has proven to be successful in triggering the implementation of critical policies for the deployment of RES at the Member State level, such as the provision of economic support through feed-in tariffs or similar mechanisms, simplification of administrative procedures, better development and infrastructure planning or support for R&D for immature technologies such as PV or offshore wind.

A CO_2 target only, is unlikely to provide an incentive to Member States to keep in place or implement other equally important supporting measures such as targeted economic support for those technologies that will still need it (e.g. PV in central and northern European countries or offshore wind power). The CO_2 price would have to be substantially high and stable in order to trigger investments in these options. This will prove difficult to achieve with ETS. Also, a CO_2 reduction target does not necessarily address any of the non-economic barriers for deployment of renewable power.

[51] Assessment levels: Unlikely/Maybe/Likely/Surely/ N.R.(not relevant)

Table 12 Assessment[52] of the effects of specific targets in triggering different policy instruments required for the deployment of PV and Wind Power.

PV and Wind Power		CO_2 Target	RES Target	EE Target
Category	*Policy instrument*			
Regulations/ Standards	Guaranteed/priority grid access	Unlikely	Likely	N.R.
Economic Support	Externality pricing	Surely/(partly)	Unlikely	N.R.
	Feed-in tariffs, subsidies, tax exemptions	Unlikely	Likely	N.R.
Non-cost barriers	Streamlining Administrative Procedures	Unlikely	Likely	N.R.
	Mechanisms for low-cost finance of high upfront capital costs	Unlikely	Maybe	N.R.
	Grid Infrastructure Development	Unlikely	Likely	N.R.
	Electricity Market Integration	Unlikely	Likely	N.R.
Capacity Building	Research & Development	Maybe	Likely	N.R.
	Public Acceptance, Information Programmes, etc.	Maybe	Maybe	N.R.

6.3 How to advance the deployment of sustainably sourced biofuels?

Biofuel policies could be triggered by RES targets (blending obligations) and CO_2 targets (setting standards for life-cycle GHG emissions). Economic support to advance biofuels could consist of externality pricing or tax exemptions. As tax exemptions tend to be easier to implement at the national level, it seems unlikely that a dedicated target for renewable energy would trigger externality pricing.

To advance the deployment of sustainably source biofuels, pilot and demonstration projects are needed and a ramp up of advanced biofuel production capacity is needed from 2015 onwards. First of all, long term prospects are needed for investors: blending targets should be set on the long term (until 2030) and clear sustainability criteria and indicators should be developed. Secondly, risks related to investing in the first commercial advanced biofuel plants could be reduced through for example loan guarantees. To guard the sustainability of the biofuels, international collaboration and knowledge exchange is needed between producer and consumer countries. Sustainability should not only be evaluated and assessed from an energy or climate perspective but in a broader context which involves food security and biodiversity as well. Necessary sustainability policies will thus be triggered by other objectives as well (i.e. not CO_2, RES or EE related but for example related to international development or food security).

[52] Assessment levels: Unlikely/Maybe/Likely/Surely/ N.R.(not relevant)

Table 13 Assessment[53] of the effects of specific targets in triggering different policy instruments required for the deployment of sustainably sourced biofuels

Advance biofuels		**CO2 Target**	**RES Target**	**EE Target**
Category	*Policy instrument*			
Regulations/ Standards	Blending obligations	Maybe	Likely	N.R.
	Sustainability criteria	Maybe	Likely	N.R.
Economic Support	Externality pricing	Likely	Unlikely	N.R.
	Tax exemptions	Maybe	Likely	N.R.
Non-economic Barriers/ Capacity Building	Supporting producer countries	Maybe	Maybe	N.R.
	Stimulate development of sustainability criteria and monitoring processes	Maybe	Maybe	N.R. N.R.

6.4 How to trigger large scale deployment of CO_2 capture and storage?

CCS will only be stimulated by a CO_2 target. However, a CO_2 price is not sufficient, because the technology is immature and the CO_2 price might be too low. Additional measures are probably needed, even after CCS reached a mature stage, for example emission performance standards, fossil fuel taxes, and/or bonus allowances.

In order to successfully deploy CCS, many steps have to be taken (e.g. on capacity building, the development of regulation, R&D), but the main barrier in the realisation of the first pilot project is the absence of a minimum level of investment security: CO_2 prices are very low and there is no prospect of increasing prices or complementary regulation that improve the business case for CCS.

[53] Assessment levels: Unlikely/Maybe/Likely/Surely/ N.R.(not relevant)

Table14 Assessment[54] of the effects of specific targets in triggering different policy instruments required for large scale CCS.

Carbon capture and storage		CO2 Target	RES Target	EE Target
Category	*Policy instrument*			
Regulations/ Standards	Emission performance standards	Likely	N.R.	N.R.
	Define the different responsibilities and roles	Likely	N.R.	N.R.
	Health and safety standards	Likely	N.R.	N.R.
	Develop comprehensive CO2 transport and storage permit frameworks	Likely	N.R.	N.R.
Economic Support	Externality pricing	Likely	N.R.	N.R.
	Other subsidies	Likely	N.R.	N.R.
Non-economic Barriers/ Capacity Building	Public acceptance, Information Programmes, etc.	Likely	N.R.	N.R.
	Public acceptance, Information Programmes, etc.	Likely	N.R.	N.R.
	Knowledge development and sharing on CO_2 storage	Likely	N.R.	N.R.

6.5 Argumentation and conclusions

An ambitious EU wide GHG reduction target for 2030 is an important step for further and deeper reduction in the period until 2050. A sustained CO_2 price signal would have a positive effect in improving investor's trust in low carbon technologies, including the four technology groups discussed in this paper. However, there are a number of considerations that need to be taken into account.

Argument 1: Both renewables and energy efficiency have proven to be key elements for the competitiveness of the EU economy by driving the development of new domestic industries and the creation of employment. The required policy packages for scaling-up the deployment of these technologies are more likely to be implemented at the Member State level when the full spectrum of their advantages is reflected in the EU policy objectives.

[54] Assessment levels: Unlikely/Maybe/Likely/Surely/ N.R.(not relevant)

- For instance, it is estimated by the European Commission[55] that **meeting the 20% renewable energy target could have a net effect of creating around 417, 000 additional jobs**, while getting on track to achieve the 20% energy efficiency improvement in 2020 is forecast to boost net employment by some 400,000 jobs.
- The European Commission estimates[56] that the **implementation of the Energy Performance in Buildings Directive (EPBD) will create a minimum of 280,000 (to 450,000) potential new jobs by 2020**, mainly in the construction sector, energy certifiers and auditors and inspectors of heating and air-conditioning systems.
- **Moreover, renewable energy and energy efficiency constitute the main instrument to EU's security of supply** by reducing our dependence on fossil fuel imports and moderating the level and volatility of fossil fuel prices. On top, they are not characterized by the serious safety and environmental risks and externalities associated to other low-carbon technologies such as nuclear and gas-fired power generation to a lesser extent.

Argument 2: A GHG target and an EU-ETS on their own will not necessarily lead to GHG emission reductions in all economic sectors.

- An important reason is that it will be **difficult to bring a number of key economic sectors under the EU ETS**. This regards in particular the residential sector, but also the commercial and transport sectors. For this reason the effects of a CO_2 price signal on energy efficiency of the built environment and on the deployment of biofuels in transport are likely to be limited. In order to fully tap these potentials, additional policy objectives are required, and specific supporting policy instruments need to be in place.
- In addition, **the CO_2 price level may be insufficient for less mature technologies**. Under an emission trading system, less mature and therefore more expensive technologies, including CCS and less mature renewable energy technologies such as offshore wind, solar-PV, wave and tidal power and concentrated solar power (CSP) are likely to be picked last, and investors may still prefer to build gas fired stations even in the presence of a carbon pricing system that equalises levelised costs[57]. The short-term horizon of the market players under the ETS and uncertainty over the long-term carbon price poses an investment risk for mitigation options that only have a long-term effect, in particular costlier options that have a high decarbonisation potential. This makes projects more risky, which drives up the cost of capital, and discourages investment. Investment risks cannot be removed by the carbon market alone for more immature technologies[58].

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[55] http://ec.europa.eu/clima/policies/package/index_en.htm

[56] COM(2008) 780 final/2: Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the energy performance of buildings.

[57] Ibid (p.13).

[58] Ross, R. et al. 2012. *On picking winners: The need for targeted support for renewable energy*, Imperial College London for WWF UK.

Argument 3: Dedicated renewable energy and energy efficiency policies are unlikely to be triggered by a GHG reduction target only. The four technology groups discussed in this paper face very specific non-economic barriers. Overcoming these barriers requires equally specific policies and measures. As we have seen, a carbon target addresses the majority of these barriers only to a limited extent, for three reasons:

- To start with, in absence of dedicated policies for these sectors it could be argued that emission reductions in the residential, services, or transport sector could be realized by **bringing cost-effective potential in these non-ETS sectors under the ETS**. If the overall ceiling of emissions is not adjusted however, this will lower the overall ambition level of the ETS, and possible action in traditional ETS sectors is frustrated.
- Furthermore, CDM/JI or other **project-based mechanisms may allow for offsetting** domestic GHG emissions. although these mechanisms arguably lead to a more cost-optimal fulfilment of GHG reduction targets by developing projects in less advanced economics (and counting the generated credits towards meeting the EU target), this does not contribute to the development of low-carbon technologies and improvement of resource efficiency within Europe as would be the case without such mechanism.
- Finally, the ETS is highly **sensitive to economic developments** that have an effect on carbon prices. For example in case of negative or low economic growth, such has been the case in recent years, emissions will also decrease as a result of reduced demand for power due to lower industrial activity. This will lead to an oversupply of carbon permits and has a lower carbon price as a result. Governments have proven to respond slow to such developments and have encountered much resistance to adjust the ETS accordingly to meet its GHG objectives.

In conclusion

For a low-carbon economy, technologies have to be developed that allow reaching very low emission levels in line with the long-term decarbonisation goal in the EU. It is important to implement higher cost options (i.e. certain renewables and CCS) together with lower cost options, as the deployment of the former has the potential to reduce the longer-term costs of mitigation. Our analysis shows that a policy framework with dedicated targets and policies for energy efficiency, renewable energy, and greenhouse gas reduction may well turn out more effective than a framework with a GHG target only. Regardless of the ambition of the GHG target, a single target framework addresses the relevant economic and non-economic barriers for the four technology groups only to a limited extent, and has only a limited impact on the development and deployment of these technologies. As a result, economic and public policy objectives, other than GHG reduction, (e.g. security of supply, economic development and employment) are therefore missed out on.

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