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Why and How the European Union Can Get a (Near To) Carbon-Free Energy System in 2050?

by

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Why and How the European Union Can Get a (Near To) Carbon-Free Energy System in 2050?

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Abstract

Reducing the European Union GHG emissions by at least 80% by 2050 will require a near zero carbon electricity, road and rail transport industry, and heating and cooling in buildings. As compared to "business as usual" the amount of energy required will basically vary according to the level of energy efficiency: it is the "system scale". Then it is the "system design" which will provide the needed carbon-free technologies consisting of renewable, nuclear and fossil fuels with carbon capture and storage.

A zero carbon energy system by 2050 is then demonstrated to be feasible. However it is far from easy and requires immediate and substantial policy action. The main policy implications are addressed in this paper. The 5 years 2010-2015 will be decisive in establishing a regulatory environment whereby the EU will be in a position, by 2020, to take the next steps to achieve the 2050 goal.

1 Introduction

The present pace of carbon emission is not sustainable. Human societies need to react and to change. A rational responsive policy to deliver the required carbon emission reduction can be delineated if the key objective parameters are identified and addressed[3]. That is the purpose of this paper; intending to suggest a feasible and viable carbon energy policy for Europe[4].

1.1 Climate change

Sufficient evidence has been presented to acknowledge that the use of fossil fuels in the way and at the pace we do today will rapidly make the planet significantly less suited for living. As a result of changing precipitation patterns and the disappearance of the 160,000 land glaciers on which today over 2 billion people rely for fresh water supply, large areas will experience water shortage. This will cause land to become infertile and other ecosystem services we depend on to end. The concern that will affect every European's life the most directly and painfully concerns rainfall. Global warming will have profound consequences on rainfall, especially in areas such as Africa and Southern Europe. It will cause agricultural failures on a massive scale, creating deserts where we have fertile land

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[4] This paper expresses the personal view of its authors and does not constitute any kind of official statement of the institutions hosting these authors.

today. This will cause starvation and migration towards the EU, even within the EU, that will completely dwarf existing problems. The EU accepts unconditionally the science of climate change and that it has an absolute obligation to play its fair part in dealing with it[5]. It equally accepts that the current course on which we are - that would lead to an increase in global temperatures of as much as 5°C by the end of this century - would be truly disastrous not just for the world's poorest countries (it would be especially disastrous for them), but also for the EU's citizens.

Climate change has not, however, been the only driver of the EU's energy policy. Indeed, the EU has always been clear that its new energy policy has three, equally important aims: sustainability, security of supply, and competitiveness. The EU, as is the case in many developing countries, is becoming increasingly reliant on imported fossil fuels; its indigenous resources of oil and gas are rapidly running out. Furthermore, energy security has many elements, including, e.g., the reliability of the EU's electricity grid. The real test for the EU's emerging energy policy is how the EU can meet the dual challenges of climate change and energy security, which will require investments in terms of billions of € every year for decades, in a manner that will improve its competitiveness and the standard of living of its citizens.

1.2 Required reduction

In its 2007 Climate Change Report, the IPCC considers that a cut of between 85% and 50%, compared to the emissions in 2000, in 2050 is necessary to limit warming to between 2.0 and 2.4 degrees. A 50% cut of global emissions by 2050 can be distributed amongst regions in different ways. Any distribution works as long as the numbers add up. Independent of the exact distribution, for the EU, this basically results in an emission reduction of at least 80%, probably more. Furthermore, as developing countries will also have to make significant efforts, there will be no "low hanging fruits" in terms of actions to reduce greenhouse gas emissions in the developing world that the EU could undertake to achieve its own reduction target cheaply; it will have to realize an 80% or more cut *in* Europe.

Emissions from several sectors will be very difficult (if not impossible) to significantly reduce. These are emissions from agriculture, several non-CO_2 emissions from industry and emissions from air travel, maritime and possibly freight. Furthermore, these emissions can be reasonably expected to account, in 2050, for at least 20% of our current Greenhouse gas (GHG) emissions (even with significant efforts in these areas in terms of energy efficiency). Therefore, the conclusion for the EU is abundantly evident: it will have to move to a carbon-free EU internal energy system by 2050, or at least to a system very close to it.

[5] See for example conclusions of the European Council;
http://register.consilium.europa.eu/pdf/en/08/st07/st07652-re01.en08.pdf
http://www.consilium.europa.eu/uedocs/cms_data/docs/pressdata/en/ec/103441.pdf , and
http://www.consilium.europa.eu/ueDocs/cms_Data/docs/pressData/en/ec/104692.pdf .

1.3 Determining parameters

The emission of GHG is determined by the product of four factors: population, wealth, energy intensity and the GHG intensity of energy[6]:

$$[GHG\ emissions] = [population] \cdot [wealth] \cdot [energy\ intensity] \cdot [GHG\ intensity]$$

A carbon-free energy system implies that the left-hand side of this equation is zero. Therefore, for the equation to hold, one of the four factors on the right-hand side should be zero. Given a non-zero population, wealth, or energy intensity, the only remaining possibility is the GHG intensity of energy. With this GHG intensity equal to zero, the equation holds, irrespective of what the product of the other three factors results in[7]. Note that the product of these three factors (population, wealth, and energy intensity) determines the amount of energy that has to be provided [MWh].

Therefore, a carbon-free energy system in fact allows splitting the discussion in what we could refer to as **system scale** (a certain amount of energy being consumed) on the one hand, and **system design** (a design delivering a zero GHG intensity) on the other hand. In what follows these two issues and their interactions are discussed to identify the rational structure shaping a feasible zero carbon policy in Europe.

2 System scale

The system scale, i.e., the amount of energy consumed (let say in [MWh]), is determined as the product of population, wealth and energy intensity.

The EU's population is expected to remain more or less stable to 2050, according to Eurostat[8] increasing from 495 million today to 520 million in 2035 and then decreasing to 510 million in 2050. Furthermore, it is reasonable to assume a GDP growth of on average 2% per year to 2050. This then only leaves the energy intensity [MWh/GDP] as a parameter which can be modified. This can be accomplished by improving the energy efficiency.

Figure 1[9] plots the energy consumption of the EU today, and a number of different scenarios regarding how much one can reasonably expect that it will need in 2050. Obviously, this is far from simple, but it is possible to plot some reasonable scenarios.

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[6] When writing these factors in [capita], [GDP/capita], [MWh/GDP] and [GHG/MWh], respectively, one can see that it matches with [GHG].

[7] The product of these factors, however, determines the scale of the system, and hence, which possibilities (given certain potentials) exist for the carbon-free technologies to accomplish this.

[8] Population and social conditions, Konstantinos Giannakouris, EUROSTAT, Statistics in Focus 72/2008 http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-SF-08-072/EN/KS-SF-08-072-EN.PDF

[9] Study for the new Energy Efficiency Action Plan. Preliminary data.

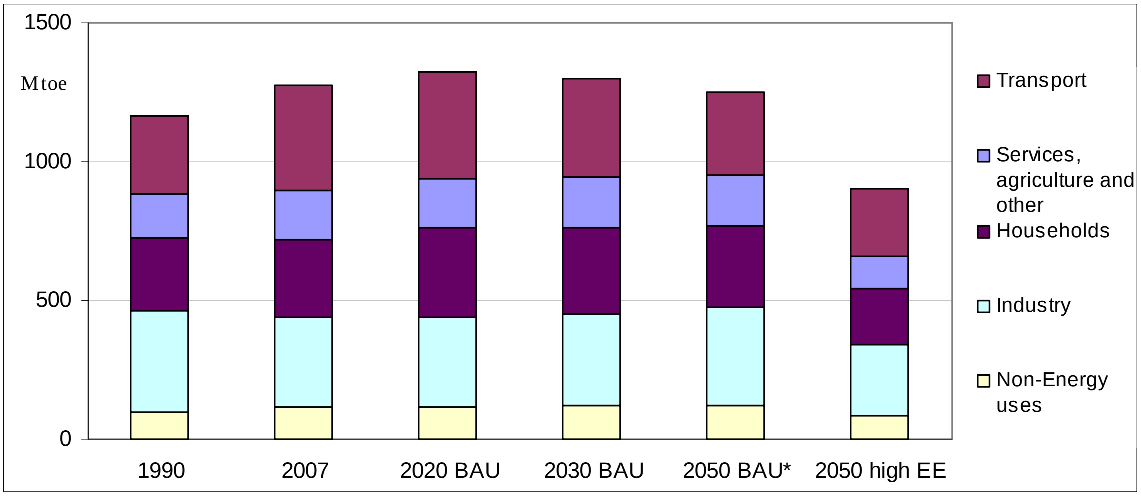

Figure 1. Final energy consumption for EU-27 (Note: including energy resources consumption for energy and non-energy use, BAU: business-as-usual scenario, *data for 2050 are extrapolation of the reduction between '20 and '30).
Source: Study for the new Energy Efficiency Action Plan.

The first two bars in the graph show historic (1990) and current (2007) energy consumption. The third, fourth and fifth bars predict EU future energy demand in 2020, 2030 and 2050. The fifth bar thus indicates that if the EU only continues the energy efficiency policies already announced, one can expect that in 2050 EU will need about 10% more energy than it uses today (energy efficiency improvements will cancel out most of the growth that would have otherwise resulted from GDP growth during the period).

The final column (2050 high EE) indicates what might be possible in 2050 on the basis of a very (very) aggressive approach to improving energy efficiency over the next 40 years; delivering a 37% reduction in energy demand compared to today. It assumes that existing demand from industry can be reduced by 30%, for households 40%, services, agriculture and other 35%, and finally for transport by 40% compared to 2007, even though GDP is assumed to continue growing.

- In terms of buildings, low energy houses could be constructed at or below the cost of normal ones taking into account projected savings in energy costs over the lifetime of the building. Notice that refurbishing an existing house to very low energy standards is much more difficult than equipping a new building. However, even with existing options a great deal can profitably be done.

- Cogeneration (or combined heat and power - CHP) is a more efficient way to generate heat and electricity compared to separate generation of both. Common district heating is another possible more efficient way for heating vis-à-vis individual heating. District heating could also be CHP.

- In terms of energy using products, such as washing machines, motors, boilers, TVs and computers, considerable savings can be made. Also regarding the energy used in manufacturing the goods that we consume, again, considerable efficiencies can be expected in the coming decades.

- In agriculture, over the past 20 years, overall energy consumption has reduced by around 20%, indicating a further efficiency improvement that might be expected.

- In transport, given the wide spread on fuel consumption of current cars, the potential for energy savings is evident. Furthermore, in the event of a massive shift to electric vehicles as argued later in this article, further efficiency gains are possible.

Thus, by concentrating on all the areas outlined above, it is reasonable to believe that, even with a GDP growth of on average 2% per year to 2050, the EU could significantly reduce the energy that it uses by 2050. With determined action it might even reduce it to the high energy efficiency scenario in the above graph. From the EU's viewpoint (and that of the remainder of the developed world), it is vital to underline that improving energy efficiency is a priority.

3 System design

This section covers the so-called “system design” (recall that we need a carbon-free energy system, i.e., zero carbon intensity in terms of energy, in terms of [GHG/MWh]). In this area the carbon-free energy options are threefold:

- Renewables

- Nuclear

- Fossil fuels with carbon caption and sequestration (CCS)

3.1 Renewables

Wind energy already contributes significantly to the electricity generation in various European countries, and is further expected to grow substantially in the future. Offshore wind is currently in its very initial state, but could constitute a large share of the upcoming deployment of wind. **Photovoltaics** (PV) have faced an important growth over the past years, and the possibilities to use PV would increase as prices come down further. For **Concentrated Solar Power** (CSP), direct sunlight is required, which limits the geographic potential. In absolute terms, however, the expected potential is significant and comparable with PV. **Solar panels** on buildings can be used to warm the water used for hot water and space heating. In fact, this form of renewable energy can already be competitive with other energy sources today. If the EU were to adopt a program of ensuring, over the next 40 years, that every single European dwelling covered its southfacing roof with solar heaters, this would permit the EU to save, in a cost-effective manner, 5% of its energy use. Not huge, but significant and cost effective. **Wave and tidal** energy can further provide a certain potential for the EU. Considering **hydro**, there are considerable difficulties in expanding large hydro facilities, which are the most competitive, to a very great extent, because a lot of the largest potentials have been exploited and because they are very land intensive due to flooding of large areas. Small hydro (facilities with a capacity typically less than 10 MW), however, has an important potential, because of its relatively limited environmental impact (minimal change to the water flow or surrounding areas). With respect to **biomass and bio fuels**, linkages between biomass use and food supplies, water use and biodiversity need to be carefully considered, and agro-economic and GHG effects have to be taken into account. In terms of security of supply, the EU might want to rely on domestic biomass resources. This potential can be increased from technical progress (e.g. second generation bio fuels and more productive agricultural systems). Whilst high temperature **geothermal** resources for generating electricity are limited in Europe, shallow geothermal energy, that can provide heat for household heating, is almost everywhere and can be harvested using heat pumps in households or via district heating systems for districts or whole cities.

Concerning the cost of renewables, support is currently required in most cases to make these technologies competitive with fossil fuels and nuclear.

3.2 Nuclear

As we are still at least several decades away from a full-sized working nuclear fusion reactor, it is clear that fusion will not solve climate change. If we were to meet all the world's energy needs in 2050 from nuclear fission on the assumption that we will need the same amount of energy as we use today (due to enormous energy efficiency efforts preventing increase), some 5500 average sized nuclear power reactors (being 1000 MW each) would be needed. This compares to the 436 units that are in operation today: US 104 (1 under construction), Japan 53 (2 under construction), Russia 31 (9 under construction), China 11 (16 under construction), India 17 (6 under construction), France 59 (1 under construction), UK 19, Germany 17, other EU countries 50 (5 under construction)[10].

In terms of cost, it is very difficult, in fact impossible, to find universally agreed figures. Some include risk premiums, others do not; the way in which one calculates storage and dismantling costs varies, etc.

3.3 CCS

CCS can reduce CO_2 emissions from power plants by more than 85%. The first difficulty in making CCS work is separating the CO_2 from the rest of the air in flue emissions. The second difficulty is finding somewhere safe to bury that CO_2. In some cases this is rather

[10] IAEA. PRIS database, cited at: http://www.iaea.or.at/programmes/a2/

simple, an empty oil or gas well; the gas in it hasn't leaked for millions of years, so there is no reason why CO_2 should leak when re-injected to refill the space created when we extract the oil/gas. Furthermore, the CO_2 can be injected to keep up the pressure in the well, ironically enough allowing us to extract even more oil, producing hydrocarbons from the well, and create more CO_2 that we can later put back. Other storage places include salt aquifers.

In terms of the technology necessary to separate the CO_2, this is advanced. Indeed, the EU has committed to building up to 12 demonstration plants by 2015 to bring this technology to the level to permit its wide scale roll-out. It has already committed 1,050 million € over the next two years to the initial stage of these demonstration plants in its European Energy Program for Recovery, and has agreed to set aside up to an additional 6-9 billion € from auctioning revenues from the EU Emission Trading Scheme (EU ETS) to ensure their completion.

In terms of storage, it is stated that, at least technically and theoretically, there is plenty of storage sites for the CO_2 emissions at least for this century, and probably until the fossil fuels really do run out.

CCS may be a rather expensive option compared to renewable energy sources in the future, as well as nuclear. However, it is vitally important to ensure its development, particularly at the world global level. It is highly questionable whether the EU will be able to (or more accurately choose to) generate all the energy we need from renewable energy sources or nuclear for local environmental (or "nimby": “not in my back yard”) reasons, both in the EU and in the developing world, where there is hundreds of years of coal reserves (like India or China). As a result CCS could need to be an important part of the solution to climate change.

3.4 Feasible scenario

The first and most obvious conclusion from above is that replacing all of our current energy system with low carbon alternatives will be far from easy, and will require great political determination. However, there is a lot of good news. There are plenty of options for fuelling the EU that will not produce lots of CO_2. If one adds up the reasonable potentials for the different low-carbon energy sources examined above, one finds that there is no reason whatsoever why the EU should ever be short of largely indigenously produced energy. Figure 2 below looks at the economic potential[11] for EU produced renewable energy in 2050 based on an oil price of 100-110 $ per barrel. The first bar shows the model “*Primes*” predictions of our energy mix on a “Business As Usual” scenario. The second bar shows that there are reasonable grounds to believe that there are renewable resources in the EU to produce pretty much all of the needs. The third bar shows that with the same nuclear capacity as today, and a limited amount of CCS, we could easily produce all the energy we need from very close to zero carbon sources. The

[11] Green X model policy scenario of cost effective potential extrapolated to 2050; growth capped at 10% p.a. (excluding biofuel imports).

final two columns are on the basis of expected EU energy needs in 2050 with the very aggressive energy efficiency policy referred to in the previous section. In such a scenario, as the last bar shows, we can achieve a zero carbon energy system using only a part of the economic potential for renewable energy in the EU.

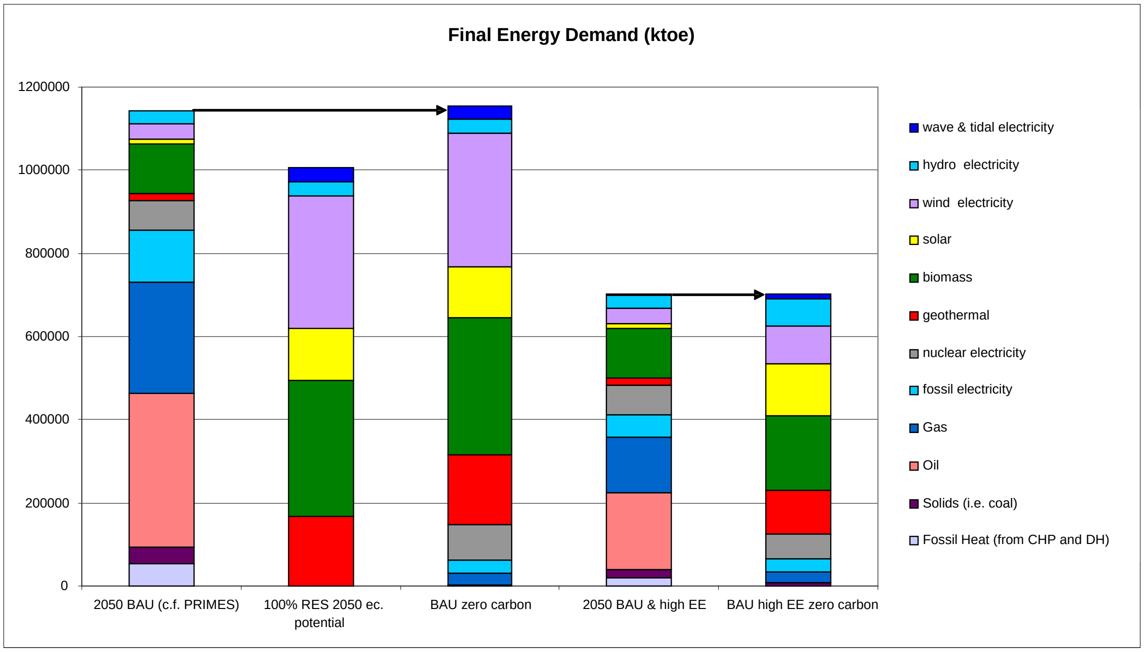

Figure 2. Economic potential of RES and final energy demand, under different scenarios.
Source: Green X model policy scenario of cost effective potential

Furthermore, as we improve the technology and above all manufacturing processes, these technologies would not result in unaffordable energy prices. The following table (Table 1) from the IEA "Energy Technology Perspectives Report" (2008), shows the expected costs of the available alternatives, confirming the view on expected price developments figuring above (given that average retail market price for electricity in the EU was 120 €/MWh for households and 90 €/MWh for industrial users in 2008[12]):

Table 1. Estimates of power generation costs by technology type: current and future.

	Current €/MWh	Future €/MWh

[12] Source EMOS, DG TREN both retail price averages are calculated without tax while incl. network charges.

Coal	18 – 42	depends on fuel costs
Gas	28 – 42	depends on fuel costs
CCS	n/a	premium of 14 – 28
Nuclear	21 – 53	no significant reduction
Wind	Onshore: 46 – 95	37 – 56 in 2015
	Offshore: 53 – 78	25% reduction by 2020
Solar PV	212 – 247	64 – 85 by 2030
(areas of good irradiation)		35 – 49 by 2050
Concentrated Solar Power	88 – 159	25 – 42
Wave and Tidal	106 – 212	28 – 56
Biomass	42 – 127	35 – 85

Source: IEA (2008), Energy Technology Perspectives 2008, Paris.

4 Policy implications

This section will again distinguish between system scale and system design to identify a feasible and viable frame for a low carbon energy policy in the EU.

4.1 System scale

Buildings consume about 40% of the EU's energy. A massive reduction in energy use in this sector is possible at zero net cost. Thus, all new buildings will have to be subject to rapidly increasing and very stringent minimum efficiency requirements that are as close to low energy buildings as is "cost-reasonable". Provisions on these issues are already foreseen in the new Buildings Directive. However careful monitoring will be necessary to determine whether it is adequate to achieve the necessary results.

Even more challenging is the fact that the EU is going to have to ensure that every single existing building is "deep" refurbished by 2050, and that many are refurbished as quickly as possible to meet the 2020 and any 2030 target in any economically sensible way and to ensure that the industry develops sufficiently to meet the challenge. Indeed, to get the "deep" refurbishment necessary, most existing buildings will have to be refurbished twice by 2050. Schemes such as cheap loans and subsidies have been having already some effect, but success has been limited. It therefore needs to be considered whether such 'soft' approaches need to be accompanied, for example, by a prohibition on re-letting and reselling a property that has not been refurbished to the cost-effective standard established by a registered energy auditor. Such an approach would be politically unpopular. An alternative is to prohibit the re-letting of a property until it meets a given standard, and to require anyone who purchases a building to bring it up to a defined standard before they resell it (as it exists for second-hand car resale). Yet another alternative is to reduce taxable capital gains and/or inheritance tax for those that bring a property to a high level of energy efficiency before sale. Such issues, however, will certainly remain for Member States to decide upon, not the EU.

Standards will also increasingly be set on electric and other devices under the EU's Ecodesign legislation, or equivalently, energy inefficient products might be taxed more. Towards this aim, the present taxation system might be reformed to push customers towards a more energy efficient lifestyle. This taxation could also account for the energy used to construct or transport the good or product.

The Commission's forthcoming third Energy Efficiency Action Plan will be crucial in setting the EU on the path it needs to be. Experience to-date indicates that rules, many of which will need to be determined at the national rather than Community level given the subsidiarity principle, are going to have to be much more prescriptive and effective if the EU is to harvest the available opportunities. This third Energy Efficiency Action Plan should be another step along what will have to be a long road.

In transport, the existing approach of the EU, which includes requiring automobile companies to reduce the average carbon emissions of their fleet, can be extended and stricter limitations on emissions progressively implemented (i.e., when using fossil fuels, this is equivalent with energy use)[13].

4.2 System design

4.2.1 Sector specific reflections

It is useful to first reflect upon the implication for the transport and heating/cooling in buildings, when assuming a carbon-free energy system. For transport, basically three options exist: bio fuels, hydrogen and electricity. Bio fuels will play a role, but the share in transport is unlikely to be very large, given the existence of a large demand, the concerns related to sustainable production, the possible conflicts with food production and for reasons of security of supply (if it would be imported from outside the EU). The possible role of hydrogen is still very uncertain. Although hydrogen has several advantages (it has a very high energy density and can be converted using a hydrogen combustion engine or using a fuel cell (electricity)), currently a hydrogen economy does not seem to be close. Hydrogen is, after all, an energy carrier or vector (as electricity), not an energy source, and has to be produced, either from electricity or directly from natural

[13] This will help the EU along the way but it will not lead towards a zero carbon road transport industry by 2050. In principle, by 2050 all cars on EU roads will need to be fuelled by bio fuels, renewable electricity or renewably produced hydrogen. This will be discussed in the following section.

gas (in a carbon-free scenario this implies with CCS). Therefore, given these considerations, it can be expected that a very substantial share of the energy demand in transport will be preferably met by electric vehicles (using electricity as energy source).

In the heating and cooling sector, several options exist: biomass (incl. district heating), solar heat, and heat pumps/air conditioning (the option of hydrogen in heating is not considered). A substantial contribution of biomass and solar heat can certainly be expected, but the remainder will also here have to result from heat pumps and hence, electricity.

The above implies a substantial shift from both the transport and the heating and cooling sector to the electricity sector. For policy making, it might be relevant to implement specific targets for, e.g., bio fuels in transport and biomass in heating, but also for a shift towards electricity. The next section presents the policy measures that might be required for a carbon-free electricity system.

Furthermore, if we are to have an electricity system that relies to a very significant extent on renewable energy, notably, wind, solar and PV, we will also have to find cheap and effective ways to store energy when the wind is blowing and the sun is shining to permit its use when it is not. Traditional ways to solve the problem of intermittent wind, notably a gas fired electricity plant is an option, but the CO_2 that it produces will need to be sequestrated, which will be expensive. Alternative options do exist, such as pumping water uphill so that it can drive turbines when allowed to flow back down-like any hydro electricity plant (the world has been using this form of energy pretty much since the Archimedes screw was invented). Furthermore, other storage systems such as a "smart grid" combined with electric vehicles can play an important role.

4.2.2 Electricity system

EU Emission Trading Scheme

The ETS system alone cannot solve the EU's climate change objectives, but it can go a long way on that road. It is an important instrument developed in the EU that has the potential to put us on a path towards an 80% GHG cut. The ETS system currently covers around 50% of energy use, but is arguably unsuited to small industry and individual citizens due to the transaction costs it would produce. However, given the likely shift of the other sectors towards electricity, this share is likely to grow.

It is submitted that a clear ETS framework is necessary up to 2050, or at least has to be ready to be put into place as soon as an effective global agreement on combating climate change is reached. The system as agreed today (fixing rules up to 2020) may be insufficient to lead to a transformation of the electricity industry quickly enough for it to be in a place by 2020 (and thus 2030) where it will physically be able to reach carbon neutrality by 2050. Unless, for example, it is clear how severe the reductions are that the electricity industry will face, it will continue to make investments in carbon positive generating production facilities in the foreseeable future. If the energy system will indeed have to be carbon-free by 2050 (and as seen above it is difficult to see any alternative), such investments make no economic sense and will lead to very significant 'stranded cost' claims by the industry further down the road. It seems therefore essential to provide a definitive and binding ETS approach that could lead to (near) zero carbon credits being available to the electricity industry by 2050.

Are specific targets and support required?

The first and most important question is whether specific targets (for, e.g., renewable energy or CCS, together with corresponding subsidy schemes) are needed, or, whether a long-term stable ETS system is adequate to provide the appropriate price signal to a carbon-free EU energy system.

Economic theory suggests that it would be more beneficial from a cost point of view to rely solely on the ETS mechanism. If the EU commits to gradually reducing the number of ETS certificates available to the electricity industry so that by 2050 there are none, the market would, goes the argument, decide how much energy efficiency, nuclear, renewable energy, CCS, etc… should result.

However, there are several arguments to indicate that the ETS alone may not be enough. First, the ETS system has some questions on an imperfect electricity market, i.e., a market constrained by planning/environmental constraints. Difficulties in getting planning permission for new, large projects are clearly an issue. Most importantly, permission to build new overhead lines is also often necessary. Also a number of very large, multi-Member State projects, such as a North Sea offshore grid and, almost certainly, desert-based PV will be necessary. The ETS approach further possibly provides a high level of market risk, both in terms of cost (uncertainty regarding future price levels) and in terms of its ability to actually deliver the desired amount of, e.g., renewable energy, CCS and nuclear needed. An ETS system also lacks the ability to differentiate between the costs of different forms of energy, with possibly some very high windfall profits (price set by the marginal, most expensive technology).

Whether the uncertainty inherently coupled with the ETS will lead to the commitment to install the very large, more expensive installations in due time without additional governmental action, is an important question given the carbon policy risk that would result.

ETS will play an important role. However, given the arguments outlined above, it is very likely that specific targets and support for renewables, grid development (including smart grid standards), balancing and storage options, amongst other, may well be necessary.

Support for renewable energy

Under any scenario, as seen earlier, it is difficult to envisage a future zero-carbon energy industry that does not figure at minimum 50% renewable energy.

If the current situation remains, renewable energy is produced nationally, with national support schemes. Then that volume of renewable will be removed from the competitive Internal Energy Market, making it, it is submitted, so distorted in 2050 (given the substantial amount of renewably generated electricity) as to be incapable of operating reasonably efficiently. The question therefore arises whether to shift towards a non-distorting and harmonized EU support scheme.

A possible route may be to first move to a regional support, and then, over time, to an EU wide feed-in tariff. It is submitted that work should now commence on the development of an EU-wide renewable support mechanism, which enables renewable energy to be traded across borders as an integral part of the Internal Energy Market. This should have certain preconditions from the start in order that it does not result in a "wait and see" approach to investments in the meanwhile.

Grid and energy security issues are also a clear point of concern. A new approach to infrastructure planning is foreseen in the third “Internal Energy Market Package”. ACER, the EU Energy Regulators' Cooperation Agency, has to regularly adopt a 10-year rolling infrastructure plan on the basis of a proposal prepared by the Transmission companies through their new EU bodies (ENTSO-E and ENTSO-G). This will go a long way to prepare such a planned approach. It will, notably, need to be followed up by real determination at the national political level to ensure that the necessary planning permission is granted sufficiently quickly, either for overhead lines or for 'undergrounding' financed through transparent and expensive public subsidies, before permission is given to construct renewable capacity.

A further aspect of grid security worth touching on here is the question of the impact of high penetration of renewables and the impact on costs, balancing and system stability. Building storage capacity is one immediately available solution, through new technologies or expanding existing ones such as pumped hydropower. Improving pricing signals and market pricing technology to speed up balancing market trade will also be possible as metering and other demand management technology improves. And of course building up interconnection capacity such that a single pan-European grid evolves (and helps variable sources to balance each other out) will also play a big role.

A number of vital issues therefore need to be addressed by a new and comprehensive 'Regulatory Framework for Renewable Energy’: (i) the need for common regulatory rules concerning grid access for projects wider than a single Member State; (ii) the need to develop a smart grid that will permit the effective integration and balancing of a great deal of intermittent generation; (iii) the need to create the regulatory framework for the construction of the balancing capacity (who pays? whose responsibility is it to provide the balancing capacity: the renewable producer, the transmission company, the national energy regulator?); (iv) the need to ensure that large multi Member State projects such as large-scale offshore wind parks develop in a way that makes sense (i.e. a single integrated project rather than many, scarcely "joined-up" national projects).

Finally, a wider-Europe agreement on renewable energy should be aimed for. This needs to be developed in a way that avoids providing disincentives for renewable energy development by third countries neighboring the EU to power their own needs.

5 Conclusion

This brief tour of the EU's energy challenges to 2050 is far from exhaustive, but one can draw some tentative conclusions. In the context of a global agreement on climate change, which will surely come sooner or later – global warming is not going away - it is assumed that the EU will have to reduce its GHG emissions by at least 80% through action within in the EU. This will require, in effect, a near zero carbon electricity, road and rail transport industry, and heating and cooling in buildings. Given this zero-carbon target, one can distinguish between the scale of the system, determined by energy efficiency (and population and wealth), and the design of the system (near to zero-carbon technologies). Action on these two fronts will be required, resulting in a high priority for improving energy efficiency, and the definition of a framework to moving to a system with solely zero carbon technologies. For the latter, this implies an increasingly important role for the electricity system (as part of transport and heating and cooling will be electrified).

Whilst this is a huge challenge, it also gives enormous opportunities for the EU[14]. With determined action, it is perfectly possible to develop a near-zero carbon energy industry in the EU by 2050 in a manner that would provide major benefits to EU citizens[15]. It is clear that the next 5 years will be decisive in establishing a regulatory environment whereby the EU will be in a position, by 2020, to take the next steps to achieve the 2050 goal, and that it is vital that these measures start to be developed in earnest, so that they can be implemented once agreement is reached at the international level on effective action to deal with climate change. If we wait until, say 2025, to start putting into place the changes to enable these developments to take place, notably with respect to infrastructure and the long-term predictable and clear regulatory incentives for industry, we will wake up in the late 2020's to realize it is now too late to take the necessary action, at least without taking the types of measures that would then lose every European politician the next election.

[14] Andris Piebalgs, "*Europe's new energy policy*", Clayes & Casteels Publishers, January 2009.
[15] Andris Piebalgs "How the European Union is preparing the "Third Industrial Revolution" with an innovative energy policy", European University Institute in Florence, Loyola de Palacio Working Paper Series N°7 2009 (available at http://cadmus.eui.eu/dspace/handle/1814/10747).