RESEARCH REPORT

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Comments on the EU Commission’s document “A Roadmap for moving to a competitive low carbon economy in 2050”

Authors: Tomi J. Lindroos, Tommi Ekholm

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Summary

This report comments the greenhouse gas reduction scenarios reported by the European Commission in the document *A Roadmap for moving to a competitive low carbon economy in 2050*, *COM(2011) 112 final*; and the associated *Impact assessment*, *SEC(2011) 288 final*. The report outlines the main results from the roadmap, and clarifies the division between assumptions that have been made in the scenarios, and the results that follow from these assumptions.

The main driver for the emission reductions in the scenarios is an assumed price for emissions, and the emission levels in different years and sectors are then a consequence of this assumption. However, the roadmap is not clear on what the price assumption is based on. The roadmap also claims erroneously that the resulting emission pathway between 2020 and 2040 as the cost-efficient path to reach the 2050 targets, even though the emission level of e.g. 2020 affects 2050 emissions only very indirectly. This is our main concern with the roadmap, as this might cause considerable confusion when interpreting the roadmap's scenarios.

This report also provides further analysis and comments on sectoral emission pathways for the roadmap's scenarios, which clarify the underlying technology assumptions behind the results. We find that the sectoral reduction potentials mainly correspond to previous emission reduction scenarios. The reduction potentials are, however, relatively dependent on two assumptions: the deployment and price of CCS and electric vehicles. If the emission pathway is examined from the ETS/non-ETS perspective, we find that the majority of reductions would fall to the ETS, although non-ETS holds also important reduction potential in and after 2020.

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Written by	Accepted by
Tomi J. Lindroos	Seppo Hänninen

VTT's contact address
VTT Technical Research Centre of Finland, PL 1000, 02044 VTT, Finland

Distribution (customer and VTT)
Ministry of Environment, VTT

Preface

This report comments the greenhouse gas reduction scenarios reported by the European Commission in the document *A Roadmap for moving to a competitive low carbon economy in 2050, COM(2011) 112 final*; and the associated *Impact assessment, SEC(2011) 288 final*.

The report has been written by Tomi J. Lindroos (sectoral emission reductions, sensitivity scenarios) and Tommi Ekholm (overall approach and emission price assumptions) between March and May, 2011. The work was commissioned by Finnish Ministry of the Environment, and the steering group for the report comprised Counsellor Magnus Cederlöf, Environment Counsellor Jaakko Ojala and Counsellor Harri Laurikka. The authors wish to thank the steering group for their helpful comments regarding the report.

The views expressed in this report are those of the authors, and do not necessarily represent the view of Finnish Ministry of the Environment.

Espoo, 1.6.2011

Tomi J. Lindroos,
Tommi Ekholm

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1 A summary of main observations

The Roadmap portrays a number of separate energy-climate scenarios which aim at ambitious greenhouse gas emission reductions in the EU by 2050. When interpreting these scenarios, however, one has to be careful with separating the assumptions and the results from these assumptions.

The **main assumptions** include:

- The pricing of emissions in the EU between 2020 and 2050
- The pricing of emissions outside the EU: globally equal prices by 2050
- Carbon capture and storage (CCS) available on a large scale by 2030
- Electric vehicles introduced in 2015, prevalent by 2030
- The future price of oil
- Increases in energy efficiency

The **main results** *following from these assumptions* include:

- The emission pathway in the EU, due to the assumed emission price. This approach doesn't, however, mean that this resulting emission *path* would be the most cost efficient.
- The EU doesn't acquire international emission credits, due to the assumption of globally equal prices in 2050.
- The emissions from the power and industrial sectors are reduced to near zero by 2050.
- Passenger cars are mainly electric by 2050, and biofuels are needed only for heavy road transport and aviation.
- The cost effectiveness of the technologies that are used in the scenarios
- Improved energy efficiency lowers the emission reduction costs and required reductions

For some assumptions a sensitivity analysis has been made, and for some not:

- The effect of assumed emission pricing on emissions (i.e. the marginal abatement curve, MAC) has not been published
- The effect of lower emission prices in developing countries and the acquisition of emission credits on the reduction costs has not been analyzed
- The effects of delayed and costlier CCS have been analyzed as a separate scenario
- The effects of delayed and costlier electric cars have been analyzed as a separate scenario

- The effects of a spiking oil price have been analyzed
- Assumptions and effects of improved energy efficience have not been comprehensively reported

The assumptions described above are used in a number of models which describe the development of energy use and emissions. Based on these and other assumptions in the models, the models are used to calculate e.g.

- that the -80% reductions of the EU by 2050 are achievable internally
- emission levels for the years 2020, 2030, 2040 and 2050 that follow from the assumed emission prices
- the cost optimal portfolio of energy technologies, as a response to the emission pricing and considering existing policies (e.g. the biofuels target)
- the sectoral distribution of emissions and thus also emission reductions
- the required investments and economic effects of the emission reductions, including changes in GDP, employment and energy imports

The scenarios treat all economic sectors equally after 2020, and e.g. don't separate between the ETS and non-ETS sectors starting from 2030. Therefore the sectors respond to the price of emission, which is uniform across all sectors from 2020. This results with the selection of cost effective reduction technologies across the economy, and the following patterns for sectoral reductions (from 1990 levels):

- The power sector reduces emissions by 98% by 2050.
- The residential and service sectors reduce by 88% by 2050, following electrification in their energy use.
- Industrial emissions are reduced only by 30% in 2030, after which CCS is used to attain rapid reductions, reaching 85% by 2050.
- In the Road Map transportation sector is very different to other sectors. Transport emissions grow in the beginning and are still 10% above 1990 levels at 2030. After 2030 they would reduce quickly and end 60% below 1990 levels by 2050. This very fast change is achieved with electrification of passenger transport and biofuels in heavy transport and aviation.
- Agricultural emissions are reduced by some 50%, following a considerable increase in agricultural productivity. Agricultural output is yet increased, as the biomass feedstock for e.g. energy use needs to be produced along with food production.

2 Emission prices and international climate policy

The roadmap[1] assesses emission reductions in the global and the EU contexts using two modelling frameworks: the POLES model is used to analyze emission reductions and the energy system on the global level, while the PRIMES, GAINS and CAPRI models focus on energy, emission and agricultural projections in the EU. In both frameworks, the starting point is an assumed price for emissions to which the economy responds to. Based on this emission price, the models estimate how actors in the markets would react, carrying out emission reduction measures that are cost efficient with this assumed emission pricing. Separate sectoral targets (e.g. separately for the ETS and non-ETS sectors) have not been assumed, and the models have been free to choose the overall cost-optimal response to the emission price, separately for each modelled year.

The main driver of the emission reductions, the emission price assumption, is set in a way that the EU would reach emission reductions of roughly 80% from 1990 levels by 2050. The actual reduction level in 2050 varies somewhat between the scenarios, being 78% in the POLES scenario and between 74% and 83% in the PRIMES-GAINS-CAPRI scenarios. In the EU context, the development of the emission price between 2020 and 2050 is very uneven between different scenarios in the roadmap, as can be seen from Figure 1[2]. No justification for the assumed values of emission prices between 2020 and 2050, or reasons for the differences between different scenarios, were given in the roadmap.

Moreover, even though the roadmap doesn't justify its assumptions for the path of the emission price, the text claims that the emission pathway that results from this price assumption is cost efficient. This is rather confusing. The price for 2050 is presumably set so that the 80% target endorsed by e.g. the European Council and Parliament is met. However, the 2050 target doesn't set a solid level at which emissions in 2030 or 2040 should be. Therefore it is not possible to claim that the overall emission pathways in the roadmap would be cost efficient. They merely present the emission levels that would follow from the assumed emission prices.

In the majority of the reduction scenarios the EU emission level in 2020 is 25% below 1990 levels, which may result from improved energy efficiency or emission price assumptions, but it happens to equal the amount of domestic reductions relating to the 30% target that has been previously assessed by the Commission[3]. With all the assumptions in the Roadmap, the 25% target can not be described as being any more cost-efficient than any other emission target, e.g. the current 20% target. Although a more ambitious target for 2020 could indeed be worthwhile, the roadmap does not provide any valid justification for such increase in the ambition level of emission reductions in the EU.

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[1] European Commission: *A Roadmap for moving to a competitive low carbon economy in 2050*, COM(2011) 112 final; and the associated Impact assessment, SEC(2011) 288 final.

[2] The roadmap presents the EU emission price in the POLES scenario only relative to the price in 2012, i.e. not in absolute €/t values. For the figure a price of 20 €/t was assumed for 2012, which incidentally roughly equalizes the 2020 price between the POLES and main PRIMES-GAINS-CAPRI scenarios.

[3] European Commission: *Analysis of options to move beyond 20% greenhouse gas emission reductions and assessing the risk of carbon leakage*, COM(2010) 265 final.

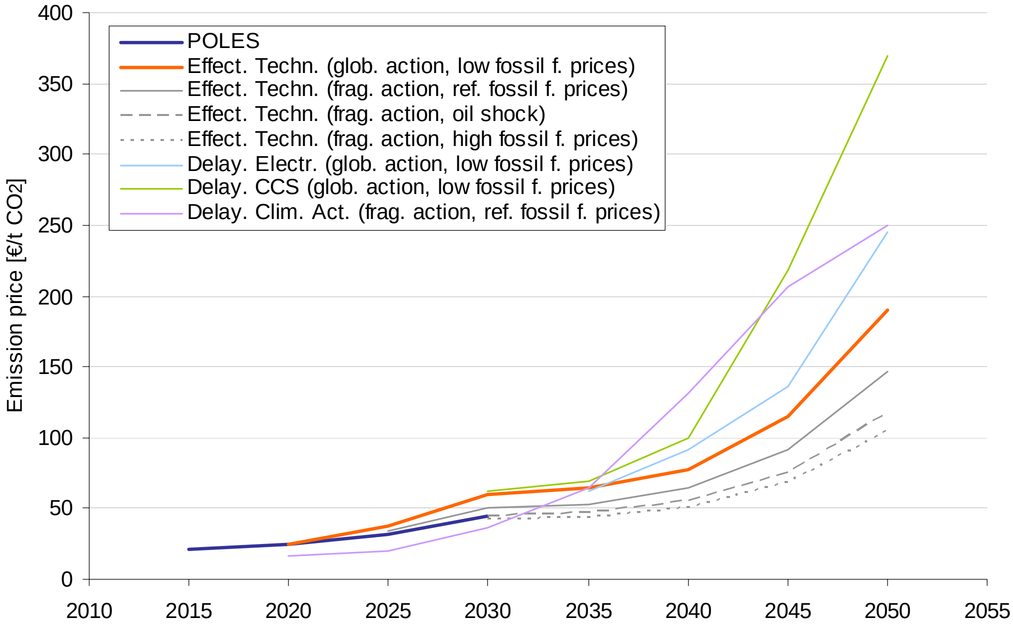

Figure 1. Emission price assumptions in various scenarios of the roadmap.

If we look at emission reductions in the global context, a globally cost effective mitigation strategy would require that the emissions are reduced in a manner that the marginal reduction costs (i.e. emission prices) are equal across all countries. This is also what has been assumed in the roadmap, and based on this assumption to the roadmap claims that it would be cost efficient for the EU to reach the 80% by internal reductions only, i.e. that a cost-effective strategy could not involve any purchases of emission credits from outside the EU. This conclusion is, however, valid only if the underlying assumption on equal emission prices is valid.

Globally equal emission prices could be achieved through either a) globally harmonized emission taxes or b) a global cap-and-trade system, in which globally emission trading would then equalize the prices across all counties. The option a) might not be very realistic, as it would require commitments to deep emission reductions also from the developing countries. With the option b) the equalization of emission prices is achieved though global emission trading, i.e. that global effort sharing is used to set national caps; the countries carry out emission reduction measuress that are less expensive than the global emission price; and countries then finally either sell their surplus or purchase the deficit quota on the global emission credit market.

Therefore the assumption of globally equal emission prices is valid perhaps only if there will actually be emission trading between countries, and most likely with the developed countries purchasing credits from the developing ones. This is, however, directly against the conclusions of the roadmap that credit purchases by the EU would not be part of a cost-optimal solution. Indeed, the credit purchases by the EU and other developed countries would be the very mechanism which would even out the emission prices between countries. Therefore, the possibility of importing emission credits from outside the EU should not be disregarded, let alone that internal-only-reductions could be stated to be a cost efficient strategy.

What the scenarios in the roadmap in effect tell is that reaching reduction levels around 80% from 1990 levels by 2050 is technically possible, and how the reductions might be realized in different sectors. Regarding these results, the roadmap scenarios fit well to the previous, recent mitigation scenario studies.

3 Emission reductions by sector

The main EU mitigation scenario in the roadmap, "Effect. techn. (glob.action, low. fossil f. prices)", projects a reduction of 80% from 1990 by 2050. At a sectoral perspective, the cost optimal solution presented in the roadmap is the following:

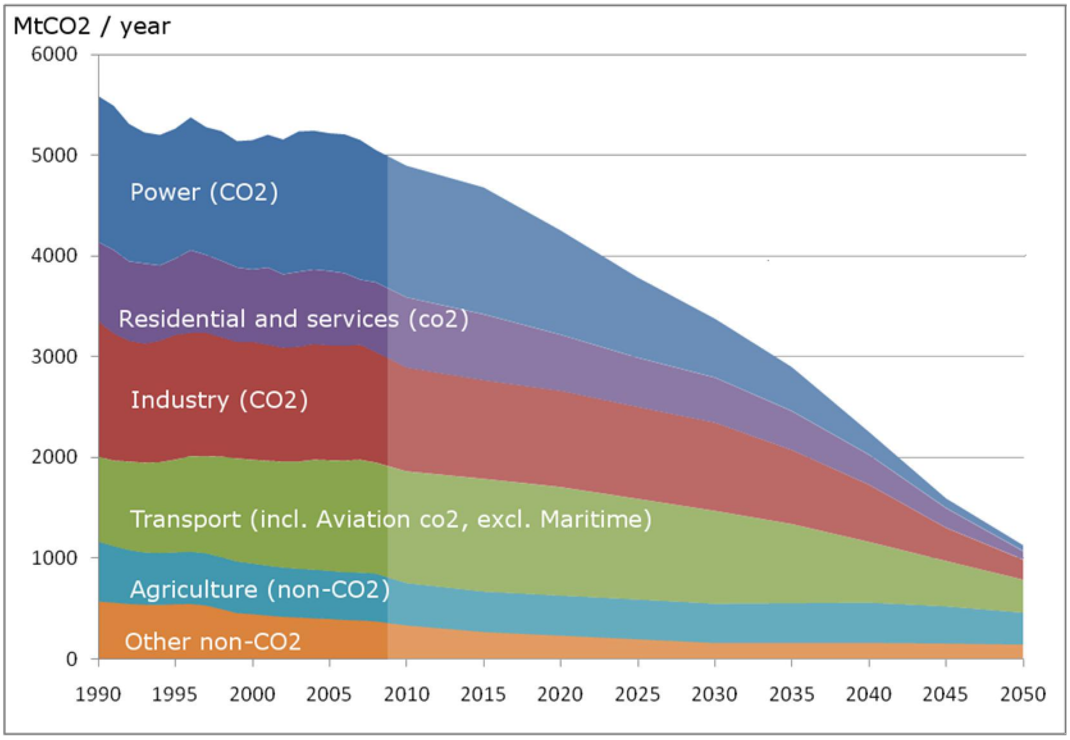

Figure 2. Sectoral greenhouse gas emissions in the EU between 1990 and 2050 in a scenario where total EU emissions are reduced by 80% by 2050.

Currently the **power sector** is the main contributor to the total emissions of the EU, but in the presented scenario the power sector emissions would become close to negligible by 2050. Another source of deep reductions would be the residential and commercial sectors, resulting from a shift in heating to heat pumps, district heating and renewables, e.g. solar panels. The scenarios involve a large share of electricity, between 50% and 55%, from renewable sources in 2050, while the remaining would be from nuclear and fossils combined with CCS.

Industrial emissions in the roadmap's scenarios are the most dependent on the technology assumptions. The sector remains relatively stable until 2030, after which heavy investments to CCS will prompt the industrial emissions to fall rapidly during the next 20 years to roughly 85% below 1990 levels. The roadmap portrays also a scenario in which the deployment of CCS is delayed and the technology is costlier than in the base case. These changes that affect only this one particular technology cause the required emission price to almost double between 2040 and 2050, when compared to the main mitigation scenario. Despite this cost increase, CCS is deployed in large amounts even in the delayed-CCS scenario, and it might therefore be concluded that the model's mitigation options depend very heavily on CCS. The issue is discussed more extensively in section 5.

Transportation emissions have been recently growing considerably. The scenarios project that the growth trend would turn to a decreasing one around 2015, and that the 1990 level would be reached in 2030. Finally in 2050, due to an extensive shift to electric vehicles, the emissions would be 60% below 1990. The traffic volume is expected to rise, but increases in fuel efficiency are assumed to be even more rapid, decrease the effect of the volume growth. As a practical example on the latter, the average fuel consumption of passenger cars is assumed to be below 3 l / 100 km in 2050.

Although the electrification of passenger car transport by 2050, as portrayed in the roadmap's scenarios, can be seen as a cost optimal mitigation strategy, this result is obviously dependent on the assumptions regarding the price and efficiency of electric vehicles. Delayed electrification was analyzed as a separate scenario in which the required level of emission pricing was notably higher than in the main mitigation scenario, although not as high as in the delayed CCS case. Nevertheless, the roadmap's main mitigation scenario seems to depend highly also on the assumed pace of electrification in the transport sector.

Non-CO_2 emissions in **agriculture** and **other sectors** are assumed to hold some cost-efficient reduction potential that would be utilized by 2020 (non-agriculture) or 2030 (agriculture). After this, the scenarios assume only very limited reductions to be feasible, and the emissions remain relatively flat. It is worthy to note that large improvements in agricultural emission-intensity are required to reduce emissions effectively with agriculture-based biofuels.

The sectoral contributions to the roadmap's emission target may be observed better if the emissions from Figure 2 are displayed as an index time series, as in Figure 3. The sectoral reduction potentials may be summarized as:

- nearly 100% reductions would be possible in the power sector
- deep reductions possible in industrial, residential and commercial sectors
- transportation emissions would peak later and have only limited potential
- limited potential in agriculture and other non-CO_2 emissions

This pattern is very much what also past mitigation scenario studies[4] have already outlined, and the roadmap's scenarios confirm past observations about the cost-effective emission reduction potentials in various sectors.

[4] E.g. Ekholm, T. et al., "Assessing the effort sharing for greenhouse gas emission reductions in ambitious global climate scenarios", *VTT Research Notes* 2453, 2008;
Ekholm, T. et al., "Effort sharing in ambitious, global climate change mitigation scenarios", *Energy Policy* 38, pp. 1797-1810, 2010;
Rao, S. and Riahi, K. "The Role of Non-CO2 Greenhouse Gases in Climate Change Mitigation", *The Energy Journal*, Special Issue #3, pp. 177-200, 2006;
van Vuuren, D. et al., "Stabilizing greenhouse gas concentrations at low levels: an assessment of reduction strategies and costs", *Climatic Change* 81, pp. 119–159, 2007.

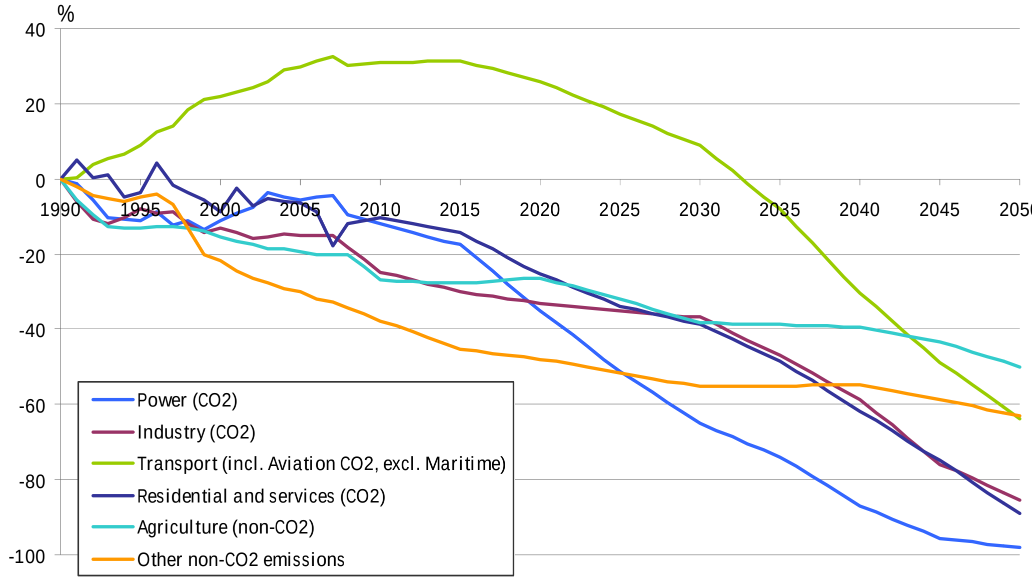

Figure 3. Sectoral greenhouse gas emissions, *relative to 1990 levels*, in the EU between 1990 and 2050 in a scenario where total EU emissions are reduced by 80% by 2050.

4 Emission reductions using the ETS and non-ETS division

Although the roadmap doesn't much discuss the currently set division between the Emission Trading Sectors (ETS) and non-ETS sectors, a comparison of emission reductions between these sectors might be illustrative if this division is to remain in place also after 2020. The roadmap's impact assessment presents reductions from 2005 for ETS and non-ETS sectors only for the years 2030 and 2050, and only as ranges from all assessed scenarios. These figures are reproduced in Table 1 below.

Table 1 – Emission reductions in the ETS and non-ETS sectors relative to their 2005 levels, as presented in the impact assessment's Table 9.

	2030	2050
Total	-35 to -40%	-77 to -81%
ETS	-43 to -48%	-88 to -92%
Non-ETS	-24 to -36%	-66 to -71%

The roadmap is not explicit on whether it uses the currently effective ETS coverage or what will be effective from 2013, and here we assume that it is the latter. We also assume that the coverage will remain same after 2020. Based on the sectoral emissions, the reductions for ETS and non-ETS can be estimated also for other years, and this is presented for the roadmap's main scenario in Table 2. Details for this estimation are provided in Appendix 1.

Table 2 – Emission reductions in the ETS and non-ETS sectors relative to their 2005 levels in the roadmap's main reduction scenario, as estimated from the sectoral reductions.

	1990	2005	2020	2030	2040	2050
Total	0	-7%	-25%	-40%	-60%	-80%
Total		0	-19%	-36%	-57%	-79%
ETS		0	-23%	-40%	-64%	-88%
Non-ETS		0	-18%	-33%	-51%	-71%

As the total reductions in 2020, 25% below 1990, are larger than the current target of 20%, so are the emission levels of both ETS and non-ETS. The current targets are 21% and 10% below 2005 levels, respectively; whereas in the roadmap's main scenario the reductions would be roughly 23% and 18%. A comparison between the roadmap's scenarios and current sectoral targets therefore suggest that the additional reductions would fall mainly to the non-ETS sector. At least three reasons may be found for this:

1. The reductions in the non-ETS sector are due to "emission leakage" from non-ETS to the ETS sector.
2. Energy efficiency measures are assumed to be take place mainly in the non-ETS sector, e.g. in transportation.and residential sector.
3. Technology assumptions have been changed after the impact assessment for the current target so that further reductions in the non-ETS sector are more cost efficient.

It is probable that all three factors are taking place. Yet, as the roadmap doesn't discuss the ETS and non-ETS emissions in 2020, it is difficult to analyze how much each factor contributes to the overall figure. This is especially hard for the two latter factors, the effect of which might, in addition, vary greatly between different Member States.

The first factor, the shifting of emissions from the non-ETS to the ETS sector, can be examined to some extent by using the sectoral emissions reported in the roadmap. The sectoral shifting is mainly due to a) the electrification of some non-ETS sectors and b) biofuel use in transportation.

a) The roadmap doesn't report the heating emissions prior to 2020, and therefore the effect of electrification of heating systems (e.g. heat pumps) can't be estimated. In transportation, the share of electricity in 2020 is roughly 2%, which would reduce non-ETS emissions by 1%. The increase in the ETS is dependent on how the marginal increase is electricity output is produced.

b) Producing biofuels inside the EU increases agricultural, LULUCF and also slightly refinery emissions. From these, only agriculture is a non-ETS sector, and therefore the biofuel use shifts emissions from non-ETS to LULUCF and ETS sectors. The amount of shifting emissions can be anything from 10 to 100 % depending on raw material and product. Due to the considerable level of ambition with the EU's biofuel target, this might reduce non-ETS emissions by several percentage points.

Last, Figure 4 presents the total EU emissions to 2050, split between ETS and non-ETS sectors. Table 3 also presents sectoral emissions for 2030 and 2050.

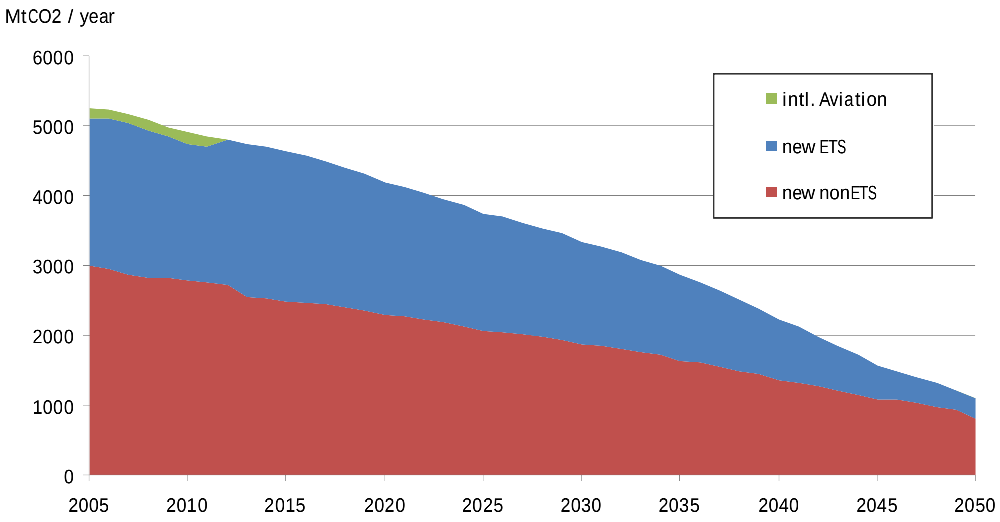

Figure 4. An estimate on the emissions in the ETS and non-ETS sectors in the roadmap's main reduction scenario. ETS sector expands in 2012 and 2013. We assume here that sectors definitions will remain same after 2013.

Table 3 – Emissions (Mt CO_2-eq.) split between different sectors in 2030 and 2050 in the roadmap's main reduction scenario.

	2030	2050
Total (incl. intl. aviation)	3380	1127
New ETS	1481	298
New non-ETS	1869	817
Power (CO_2)	507	27
Industry (CO_2)	848	198
Transportation (incl. intl. aviation CO_2, not incl. intl. maritime)	918	307
- of which aviation:	*190*	*75*
Residential and services (CO_2)	483	87
Agriculture (ei- CO_2)	367	298
Other non- CO_2emissions	255	210

5 The effects of delayed CCS (sensitivity analysis)

The roadmap presents sensitivity analysis in the form of separate scenarios where selected assumptions are varied. From these sensitivity scenarios, the scenario with delayed and more expensive CCS differs most from the main reduction scenario. The possibility of delays and higher costs with critical technologies, i.e. CCS and electric vehicles, has not been taken into account in the main reduction scenario, meaning that the sensitivity scenarios are entirely separate scenario cases. The possibility of delays and higher costs should be therefore borne in mind by the reader when interpreting the main reduction scenario.

The most visible effect from the assumed delay is a significant increase in the emission price that is required to meet the 80% reduction target in 2050. In 2050 the required price is nearly doubled (from 190 €/t to 370 €/t), as can be observed from Figure 1. With the higher price, emission reductions are higher in sectors that do not use CCS than in the main reduction scenario, but this additional reduction potential in non-CCS-using sectors seems to be rather limited. Therefore the emission price has to be increased to such a high level that also the now more expensive CCS will be utilized.

Such high price of emission allowances would, most likely, increase the price of electricity and some industrial products and decrease the European competitiveness unless the industry in other countries would have similar burden or the European industry would get free allowances.

In the sectoral emission profiles the largest difference between the main scenario and the delayed-CCS scenario occurs in 2040 only just before the delayed CCS can be put to use. **Error! Reference source not found.** below presents this difference in sectoral emission reductions, measured in percentage points. In 2040, the reductions in the power sector would be considerably lower as the reduction potential would be notably reduced without CCS. Due to the high emission price, industry and other sectors would increase emissions more than in the main case.

Interestingly, the total amount of emissions during the period of 2030-2050 is the same in main scenario and delayed CCS scenario. This implies that, as we assumed in chapter 1, the total amount of emission reductions is decided and modelling is used only to find out how that could be possible.

Table 4 – Change in the sectoral reduction levels, in percentage points, between the main and delayed-CCS scenarios. A negative figure indicates that the reductions in that sector are higher in the delayed-CCS scenario.

	2005	2020	2030	2040	2050
Total	0	0	0	1	-2
Power (CO_2)	0	0	1	11	-1
Industry (CO_2)	0	0	1	-8	-3
Transportation (incl. intl. aviation CO_2, not incl. intl. maritime)	0	0	0	-2	-3
Residential and services (CO_2)	0	0	0	-1	-2
Other non- CO_2emissions	0	0	0	-1	-3

Appendix I – an estimate on the size of the extended ETS

In the division of emissions between ETS and non-ETS it has been assumed that

- International aviation (130 Mt CO_2 in 2005) is included in the ETS from 2012
- Domestic aviation (25 Mt CO_2 in 2005) is included in the ETS from 2012
- The ETS is extended as set in the directive 2009/29/EC. The directive estimates that some 150 Mt CO_2 of emissions would be shifted from the non-ETS to the ETS starting from 2013.
- The emissions in the base year (2005) of both the non-ETS to the ETS will be recalculated to reflect the above changes. For aviation emission inventories exist. For industry the emissions that will be shifted from the non-ETS to the ETS are assumed to develop similarly to other industry.

As a result, the ETS will expand by some 300 Mt CO_2 by 2013, which equals roughly 15% of total emissions, and this expansion is also accounted in the base year emissions. Due to this correction of base year emissions, the expansion of the ETS doesn't much affect the numbers presented in Table 2.

Including international aviation in the ETS reduces the relative cost-effective reduction potential of the ETS somewhat. Conversely, the removal of domestic aviation from the non-ETS increases its reduction potential in relative terms. The effect in the latter, though, is only minor due to the small emissions from domestic aviation. In absolute terms, however, the non-ETS sector needs to carry out smaller reductions as the base year level is smaller. On the other hand, the measures available for the reductions are also affected, as e.g. the majority of industrial N_2O emissions, which are estimated to hold large cost-effective reduction potential, are moved to the ETS.