PÖYRY

COMPLIANCE COSTS FOR MEETING THE 20% RENEWABLE ENERGY TARGET IN 2020

A report to The Department for Business, Enterprise and Regulatory Reform

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EXECUTIVE SUMMARY

This study was commissioned from Pöyry Energy Consulting by the Department for Business, Enterprise and Regulatory Reform (BERR) to investigate the impact of the commitment, made at the Spring Council in March 2007, to deliver 20% of EU primary energy consumption from renewable sources by 2020. A 20% target implies a significant increase in the contribution of renewable sources compared to recent projections[1] and as such the main objectives of the study were:

- to understand the relative costs and renewable resource availability across the EU Member States; and
- to investigate the costs for the United Kingdom and the European Union of achieving a target of delivering 20% of primary energy consumption from renewable sources by 2020.

The study was originally commissioned to be undertaken over a 6 week period and given this tight timeframe no new original research was envisaged. Thus, the results are dependent on the validity of existing publicly available data sources on renewable energy potential and costs reviewed by Pöyry. These have been used as the basis for construction of a pan-European renewable energy supply curve (incorporating the renewable electricity and heat sectors (RES-E and RES-H)).

Because of a lack of credible data on the transport biofuels market, a separate modelling exercise has been undertaken on the cost of meeting the specific 10% transport biofuels obligation. This is not a definitive analysis of the transport sector but the outputs produce indicative compliance trajectories and costs fit for purpose.

The results of these complementary analyses on the RES-E, RES-H and RES-T sectors have been combined in a mechanistic way to produce supply curves of potential renewable resource that have been used to answer several key questions relating to the costs of compliance with the 20% target. More subjective assessment of consistency with existing domestic policies, impacts on diversity of the renewables mix or specific aims for development of a domestic renewables industry are outside the scope of this analysis.

Is there sufficient renewable potential in the EU27?

Pöyry has used publicly available data sources on technical potential of renewable technologies out to 2020. In the electricity and heat sectors, this is primarily based on Green-X data that reports a maximum technical renewable electricity and heat potential in the EU27 by 2020 of 2870TWh.

Taken in conjunction with assumptions on transport biofuel production potential and total energy consumption, the analysis suggests that there is sufficient resource for the 20% target to be achieved, but this is dependent on four main conditions being realised:

- reported biomass potential is realisable – there is a heavy reliance on biomass-based heat technologies in the resultant fuel mix. Since the biomass resource is based on estimates of resource potential data produced by Green-X and has not been

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[1] The baseline scenario presented in the European Commission publication ‘European Energy and Transport: Trends to 2030 (Update 2005)’, projects renewable energy sources accounting for around 12% of final energy demand by 2020.

independently validated, an audit of reported biomass resource potential may be advisable;

- sustainability and land-use competition considerations do not adversely affect assumed global biofuel supply volumes – the Pöyry analysis is, of necessity, high-level and further research of supply constraints on solid biomass and transport biofuels should be included in any further work on this market;
- all technologies must be capable of implementing a step change in build rates if the resource is to be delivered by 2020. This may require additional action to ensure any material regulatory, institutional, legal and supply chain barriers can be overcome; and
- additional support is provided to incentivise incremental investment above that in projected baselines.

What is the cost to the EU of meeting the 20% target?

The relevant cost for the purposes of this analysis is the incremental resource cost. That is, we investigate the resource cost of additional volumes of renewable energy to meet the 20% target, over and above those included in our baseline.[2]

Resource cost measures the cost to the economy from using higher cost renewable technologies in place of their conventional alternative. Some costs, such as additional network investment or reinforcement costs for heat and electricity grids, and hidden costs affecting demand side take-up are not included. Therefore, costs are likely to be an indication of minimum resource cost. Distributional effects – i.e. on whom the burden of cost falls – are a function of the instrument used to support faster deployment of these technologies and are outside the scope of this study.

The Central Case least-cost scenario estimates the efficient annual incremental cost of meeting the target in 2020 to be €18.8bn, with the total lifetime cost of the policy (the 'lifetime costs')[3] being €259bn.[4]

This estimated resource cost is sensitive to:

- the costs of the conventional technologies replaced; and
- the overall renewable potential and the assumed costs of each renewable technology.

The Central Case cost is calculated on an energy output (production) basis against a measure of final energy demand (FED). When the analysis was being developed, there was still uncertainty over the precise definition of the target and as such the target was based on the Final Energy Demand figure reported in European Energy and Transport Trends. This differs from the definition of final energy consumption as set out in the

2 Thus, the costs of existing policies are assumed to be sunk and are not assumed to add to the cost of complying with the 20% target.

3 This lifetime cost calculation captures the fact that additional resource costs are incurred over each year of the economic lifetime of the renewable investment. It does not account for additional investment that may be required post 2020 to maintain a 20% renewable energy position. It assumes that the transport resource costs and the cost of permit purchases are held constant at 2020 levels until 2030.

4 All costs are discounted to 2006.

European Commission proposed Directive[5] in that it does not include energy branch consumption. Thus, it is possible that the level of effort required, and the associated costs of compliance, may differ from the estimates presented in this study.

Alternative assumptions on renewable technology costs and availability tested during this study can increase annual incremental cost in 2020 by up to 20%. Factors affecting the biomass-based technologies are the most important determinants of this cost for the EU as a whole given their prominence in total incremental investment. However, the results are extremely sensitive to the assumed cost of the conventional alternative technology. Applying low (high) counterfactuals consistent with fuel price assumptions in the most recent BERR Updated Energy Projections increases (decreases) the 2020 annual incremental cost by 38% (19%).

What is the cost to the UK?

Business as usual projections for UK renewable energy consumption in 2020 stand at around 5% of final energy consumption, but the UK's burden share, as set out in the Draft Directive, is 15% of final energy consumption, Thus, there will be an additional resource cost to the UK in order to deliver this incremental renewable energy.

The annual cost to the UK in 2020 of meeting its burden share is between €5.0bn (least-cost trading) and €6.7bn (domestic-constrained), the range reflecting the options available to the UK for complying with its burden share.

Under the least cost solution for the EU as a whole, the UK invests in additional domestic renewable sources consistent with meeting a 10.4% share of UK FED. This imposes an additional cost of €2.6bn (of which 70% is attributable to transport sector compliance). However, the UK has to supplement domestic production through trading with other countries (leading to a redistribution of costs between countries) thereby increasing the annual incremental cost to the UK by €2.5bn.[6]

While the draft Directive allows for trading of renewable energy (through guarantees of origin), if no market were to develop then the UK would be required to comply through domestic action. In these circumstances, the UK would have to meet the target through the use of more expensive domestic technologies, which would be more costly for the UK and less efficient for the EU as a whole. For the UK, the €6.7bn annual 2020 resource cost represents the central domestic constrained scenario.

Importantly, the differential between the least cost (trading) and domestic action costs are not just a redistribution, as a requirement for domestic action imposes a real cost across the EU preventing the most efficient resources being developed.

The lifetime resource costs likewise vary according to the option available. With trading, the lifetime costs are in the order of €59.0bn, whereas under the domestic constrained scenario they are €93.1bn.

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5 Proposal for a Directive of the European Parliament and of the council on the promotion of the use of energy from renewable sources, 23/01/2008.

6 The marginal cost of each traded guarantee of origin is derived from the renewable supply curves generated in the modelling. This simplistic representation of the trading market may introduce some additional producer surplus or rent.

How sensitive is the mix between the different sectors (electricity, heat and transport)?

The modelling assumes that the separate 10% share of biofuels in transport fuel consumption (equivalent to 1.6% of FED) is met in the Central Case and therefore any variation would be observed between the electricity and heat sectors. The overall mix appears to be sensitive to changes in relative costs, as the cost sensitivities investigated result in transfers between heat and electricity shares of up to 8 percentage points.

How sensitive is the UK's share of the least cost solution?

In the Central Case scenario the UK's contribution to the least cost delivery of the 20% target is 10.4% of UK's FED (equivalent to 6.4% of total EU renewable production, whereas UK FED is 12.4% of EU27 FED). This changes relatively little as a result of alternative cost assumptions because while it lowers the relative cost differential between the UK's marginal resource wind and the cheaper biomass technologies, it does not fully remove the cost differential and therefore serves mainly to raise the overall cost of meeting the target.

How do constraints on trading affect the overall costs of compliance?

As the example from the UK above has illustrated, requiring all action to be domestic will generally raise the cost of compliance for any given burden share allocation.[7] This is because, unless the burden shares match exactly the least cost renewable energy mix across countries, some countries will have to employ a more expensive renewable technology mix if they are constrained to invest domestically and other countries will have no incentive to exploit relatively low cost renewable resource because they have already met their target.

The analysis undertaken in this study indicates this may be a costly distortion to market operation. Using the European Commission proposed burden shares, without trading the annual incremental cost to the EU in 2020 from €18.8bn to €25.6bn, and the lifetime cost from €259bn to €351.7bn.

What are the carbon savings as a result of the policy?

The carbon savings achieved are significant. The annual savings in 2020 across the EU are 388 $MtCO_2$ (32 $MtCO_2$ in the UK) and the total lifetime savings are in the order of 9,834 $MtCO_2$ in the EU (1,034 $MtCO_2$ in the UK). Around 10% of the 2020 carbon savings in the EU are attributed to the transport sector but it should be noted that the analysis has assumed biofuels are a zero-carbon technology, while there is ongoing debate regarding the actual carbon savings generated from the use of biofuels.

Compared with the EU27 baseline projections used in the study, these carbon savings are around 45% of the total required to meet the EU's stated 20% reduction in CO_2 emissions by 2020.

The incremental abatement cost in 2020 is €49/tCO_2 for the EU and €82/tCO_2 in the UK, with the incremental cost of transport sector abatement being an order of magnitude higher (€276/tCO_2 for the EU and €259/tCO_2 for the UK) than that of abatement activity in the electricity and heat sectors (€23/tCO_2 and €35/tCO_2 in the EU and UK respectively). The incremental lifetime carbon abatement cost is lower than this annual cost, being €26/tCO_2

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7 Indeed, the initial analysis suggests that Belgium, Netherlands, Romania, Cyprus and Malta have insufficient domestic potential to meet their proscribed burden shares.

for the EU as a whole and €57/tCO_2 in the UK, as future carbon savings are not discounted, unlike costs.[8]

What further analysis is required?

In the timeframe available, this study inevitably had to rely on existing data sources and some additional high-level modelling of the transport sector as a means of delivering the project. The analysis has highlighted key sensitivities and uncertainties surrounding the emerging conclusions that merit further analysis. These include:

- an audit of available biomass resource potential across the EU;
- detailed modelling of the global biofuel supply market;
- insight into the carbon savings generated through biofuel use;
- review of potential supply chain constraints on increased renewable deployment across the EU; and
- assessment of any missing or hidden costs. In particular, additional network investment[9] or reinforcement costs associated with major renewable investment programmes; infrastructure costs[10] that may result from further penetration of renewable heat grids; and costs arising from any demand-side distortions affecting take-up.

8 It should be remembered that what is being analysed is the incremental cost of policy support above that already provided from existing policies in the Business as Usual baseline.

9 This analysis only includes the cost of connecting the renewable electricity facility to the main transmission grid.

10 This would include premature scrapping of current network infrastructure and development of new heat grids.

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1. INTRODUCTION

1.1 Background

At the Spring Council in March 2007, European Union leaders agreed to a package of measures aimed at strengthening the EU's contribution to the problem of global climate change. One of the measures was a commitment to deliver 20% of the EU's primary energy consumption from renewable sources by 2020. Currently, renewable energy accounts for only 7% of EU primary energy consumption and publicly available projections by the European Union[11] suggest this share would rise to 12% on a business as usual basis by 2020, still substantially below the 20% target.

Moreover, there is significant variation by country, reflecting the available resource, local cost differentials and infrastructure constraints. For example, in the UK, the current share of renewables is just over 2% (which represents less than 2% on the revised Commission definition) with 2020 projections of an increase to around 5.6%. This is in contrast to a country like Sweden, where renewable energy sources already account for 20% of primary energy consumption and this share is anticipated to grow to around 35% by 2020.

Thus, not only will achieving the 20% target be potentially costly for the European Union as a whole, but the nature of compliance with the burden sharing agreement will affect the overall cost of delivering the commitment and the distribution of this cost among Member States.

The draft directive published on 23 January 2008[5] sets up the basis for the implementation of the 20% target for 2020. The main aspects relevant to this report are the following ones:

- Each country will have an individual target, expressed in terms of the percentage of its share of energy from renewable sources in final consumption of energy. These shares are given in Table 2 and were calculated on a flat rate approach, modulated by GDP and by the early progress in developing renewables. A path of compliance is also set with interim targets every two years.
- There is a 10% minimum share of biofuels in the use of gasoline and diesel for each country. The use of biofuel is conditional to minimum carbon savings and sustainability criteria.
- Trading of Guarantees of Origin (GoO) is allowed between member states, the trading parties will be the governments of the EU27. A country is only allowed to trade its GoOs additional to its interim target, but there is no obligation to do so.

1.2 Objectives

Against this background, Pöyry Energy Consulting was commissioned by BERR to undertake an initial analysis of the cost of compliance, the objective of which was two-fold:

- to understand the relative costs and potential for renewable energy in each of the EU27 countries; and
- to assess the overall cost of meeting the target for the EU and the UK.

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11 European Energy and Transport: Trends to 2030 (Update 2005), European Commission

The overall cost to the EU of meeting the target depends on the ability to access and develop the least cost renewable technologies. Consequently, the study investigates the effect of constraints on the flexibility to meet individual commitments through trading of renewable energy certificates as opposed to domestic action. For the UK, the issue is the proportion of the EU cost it bears. This is a function of its assumed burden share and the extent to which this exceeds the implied contribution under a least-cost solution. While the study does not estimate appropriate burden sharing contributions it considers how the UK's cost varies with commitment levels and analyses in detail the effects of specific the European Commission's proposed burden sharing arrangements.

1.3 Structure of Report

This report summarises the key results and conclusions of the study and is structured as follows:

- Chapter 2 outlines the approach to the analysis and the methodology employed;
- Chapter 3 presents the main results;
- Chapter 4 provides some initial conclusions and suggestions for further analysis; and
- Annex A contains more detail on the input assumptions and modelling methodology underlying the results.

1.4 About Pöyry Energy Consulting

Pöyry Energy Consulting is Europe's leading energy consultancy providing strategic, commercial, regulatory and policy advice to Europe's energy markets. Part of Pöyry Plc, the global engineering and consulting firm, Pöyry Energy Consulting merges the expertise of ILEX Energy Consulting, ECON and Convergence Utility Consultants with the management consulting arms of Electrowatt-Ekono and Verbundplan. Our team of 250 energy specialists, located across 14 European offices in 12 countries, offers unparalleled expertise in the rapidly changing energy sector.

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2. APPROACH

The focus of this study is on assessing the incremental resource cost of meeting a 20% renewable energy target through action across three main sectors – electricity generation, heat and transport. The approach centres on the construction of a supply curve of potential incremental renewable electricity and heat resource across technologies, countries and time.[12] Imposing a renewable demand target[13] on the supply curve then enables least-cost technology mixes to be identified and analysed.

The underlying methodology behind this approach is expanded upon below. In addition, further detail is provided on supplementary modelling of the transport biofuels target that Pöyry had to undertake within the timeframe of the project when it became apparent that there was insufficient publicly available data.

2.1 Methodology

There are essentially four integral steps to implementing the methodology:

- identify the baseline renewable growth that would occur without the policy (i.e. the business as usual position);
- research the costs and resource potential of the different technologies and countries;
- construct a supply curve of technologies to determine the incremental renewable supply curve; and
- calculate the costs of compliance for each member state against a pre-defined policy position (in terms of the country burden shares and the degree to which action is constrained to occur domestically).

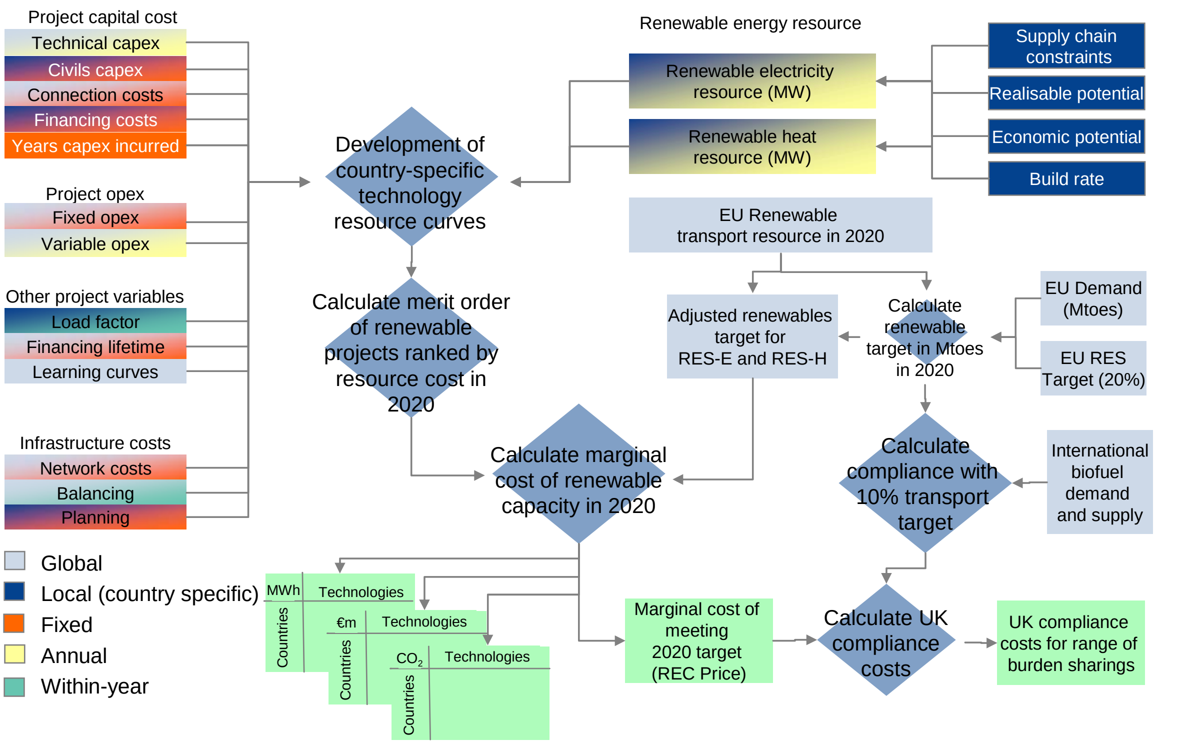
Each step is outlined below, with further detail contained in the annexes to this report. Pöyry has been reliant on existing data sources for the analysis presented. Where there is uncertainty surrounding these figures we have tried to include these in sensitivity analysis, but there are several areas identified that would benefit from further analysis.

The project methodology is summarised in Figure 1.

12 The supply curve is incremental as maximum resource potentials for each technology/country have baseline renewable consumption figures netted off. That is, the supply curve represents the resource available to meet the gap between the 20% target and the business as usual position.

13 The demand target is calculated from assumptions on total primary energy consumption, business as usual renewable electricity and heat consumption and transport biofuel consumption. It can also specify minimum constraints on contributions from Member States to reflect domestic compliance requirements.

Figure 1 – Project Methodology



Source: Pöyry Energy Consulting

2.2 Determining the baseline

The analysis covers the period 2010 to 2020 and differentiates renewable energy supply across:

- the three main sectors – electricity (E), heat (H) and transport (T);
- the 27 member states; and
- 17 individual renewable electricity and heat technologies.

The Business as Usual (BAU) position has been constructed from data contained in the European Commission publication European Energy and Transport Trends to 2030 (2005 Update) to ensure a consistent treatment across all countries and sectors. Figure 2 shows the baseline growth in renewable energy supply between 2010 and 2020. By 2020, renewable energy supply (RES) is expected to account for around 12% of EU final energy demand. 59% of this volume will be from electricity generation, 32% from renewable heat and 9% from transport.

In terms of individual technologies, by 2020, biomass-based electricity and heat technologies[14] account for just over half (52%) of the business as usual renewable energy mix, completely dominating the renewable heat sector (over 95% of the RES-H mix) and making up 35% of the RES-E mix. In RES-E, wind and hydro resource together account for 39% of the mix.

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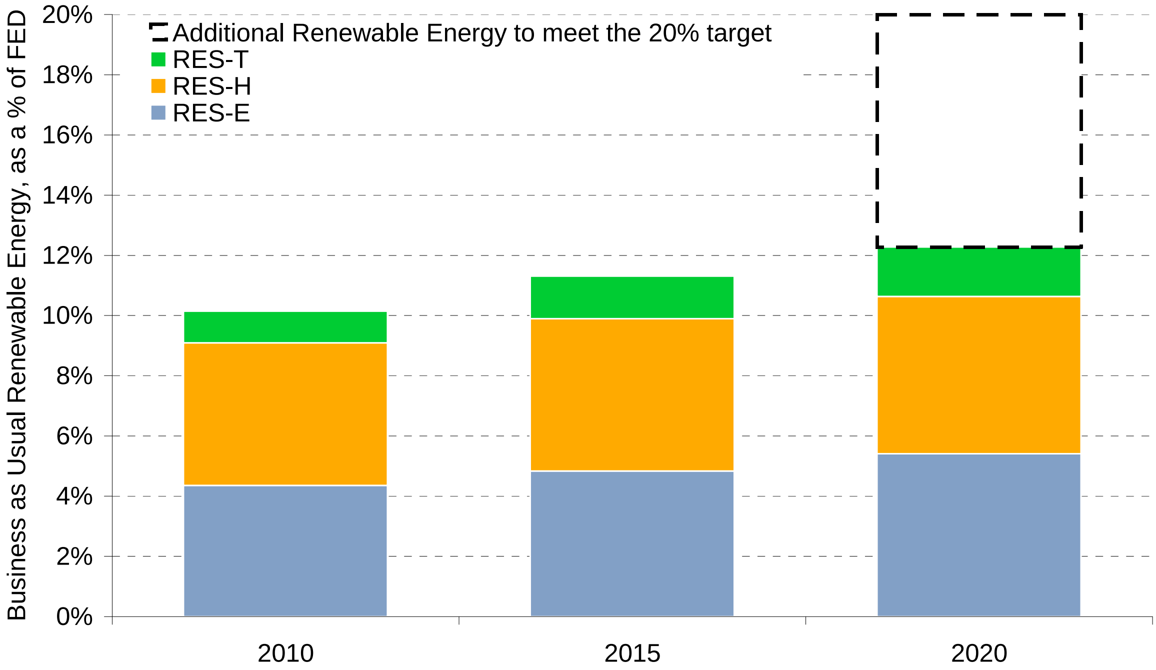
14 These are biomass, biowaste and biogas electricity and grid and non-grid connected biomass heat technologies.

Figure 2 – EU baseline renewable energy supply by sector (2010 – 2020, ktoe)



Source: Pöyry Energy Consulting

The consistent 2005 EU dataset used to derive this BAU position in the Central Case differs from the most recent BERR projections of UK renewables. The extent of this difference is shown in Table 1. An additional sensitivity was run applying this more recent view of the UK renewables BAU, details of which can be found in section 3.4.

Table 1 – Comparison of UK Business as Usual position (Central Case and current BERR forecast)

	(TWh)	Pöyry Baseline	BERR baseline
2010	Electricity	31	33
	Heat	18	*7*
	Transport	12	12
	Total RES	**62**	**53**
	Assumed FED	*1910*	*1826*
2020	Electricity	50	57
	Heat	37	7
	Transport	25	25
	Total RES	**112**	**89**
	Assumed FED	*2020*	*1940*

Source: DG/TREN and BERR

2.3 Technology costs and resource availability

In order to understand the differences in national resource potential and costs of renewable heat and power, a broad literature review was undertaken, supplemented by a workshop with regional renewable energy experts drawn from across Pöyry's European offices. Details of the sources used in this research are included in the annexes, together with the final set of assumptions Pöyry has used as the basis for its Central Case renewable energy supply curve.

2.3.1 Technology cost database

A technology cost database was constructed that disaggregated the following elements needed to calculate the levelised cost of a renewable energy project (where available):

- capital costs – including technical capex, civils capex, connection costs and financing costs;
- operating costs – fixed and variable opex;
- infrastructure costs – network costs, balancing costs and planning costs; and
- operating characteristics – load factor and operational lifetime.

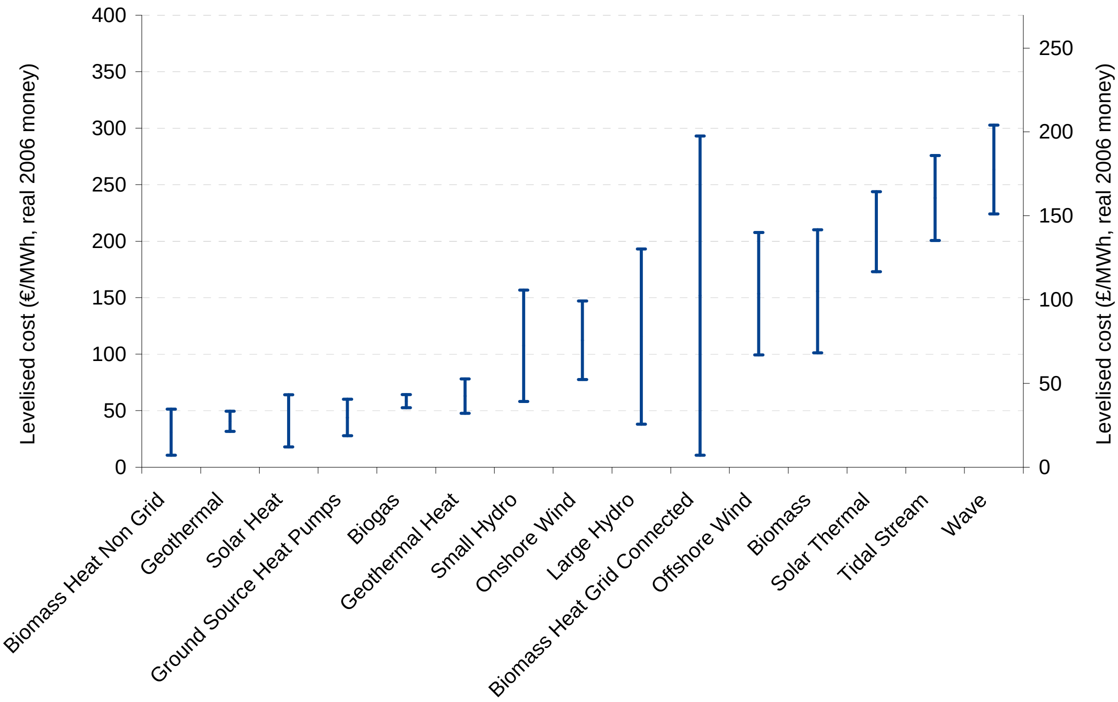
These costs were further differentiated along the following lines:

- global or local costs – whether there were elements of local costs (e.g. civils capex, financing costs, etc) or costs were equal across countries (e.g. technical capex costs); and
- fixed or time variable – in particular, taking account of dynamic effects on capital costs associated with learning by doing and on variable opex associated with changing fuel input prices.

The range of levelised costs by technology (across countries and time) derived from the Central Case assumptions described in Annex A is shown in Figure 3.[15]

[15] The costs used are individual project costs. They do not reflect additional network investment or other hidden costs (e.g. transactions costs) that may affect take-up or total resource cost to the economy.

Figure 3 – Levelised project cost ranges (€/MWh, 2006 prices)



Source: Pöyry Energy Consulting Analysis. The levelised cost for Solar PV is between €360/MWh to €960/MWh

2.3.2 Resource potential

Projections of additional resource potential by 2020 were taken from analysis published from the Green-X project. Business as Usual projections have been netted off the reported maximum potentials and annual build constraints have been applied to the remaining potential dependent on the maturity of the technology and views on realistic build rates for some technologies (e.g. biowaste). The biomass potential figures reflect domestic production potential and do not account for any additional potential that could be achieved through importation of suitable feedstocks.[16]

2.4 Supply curve

The main modelling output was the construction of a renewable energy supply curve detailing the volume and cost of a range of renewable technologies across time and accounting for cost differences and availability across countries. Within a year, additional cost differentiation was introduced through assumptions on proportions of annual volume that would come to market at, above or below, the central levelised cost.

For the purposes of this policy analysis, the relevant cost measure is the resource cost (i.e. the additional cost incurred above that of the conventional technology that has been replaced). For example, the counterfactual cost for biodiesel is the cost of diesel and for bioethanol is that of gasoline. In the electricity sector, to be consistent with existing BERR analysis, the counterfactual is the cost of a CCGT, whereas in the heat sector the

16 This differs from the transport biofuels analysis, where a global assessment of feedstock potential is undertaken.

counterfactual depends on the alternative heating fuel mix available. All these counterfactual cost calculations are presented in the annexes.

The model was set up to enable a range of sensitivities affecting the supply curve to be tested. These covered resource volumes, technology costs and the costs of the counterfactual technology.

2.5 Costs of compliance and impact of burden sharing

When a known renewable energy target is applied to the supply curve it is possible to identify the cost of achieving the target. Throughout the analysis the cost of compliance has been calculated on two bases:

- a least-cost basis – representing the optimised allocation of renewable energy development across the EU to achieve the 20% target; and
- a domestic compliance basis – assuming that each Member State must deliver a minimum level of renewable energy through domestic action. The scenario agreed with BERR for this was 100% domestic compliance in line with burden shares included in the proposed Directive shown in Table 2.

Table 2 – European Commission burden share proposals

	Burden Share (as % of national FED)		Burden Share (as % of national FED)
Austria	34%	Latvia	42%
Belgium	13%	Lithuania	23%
Bulgaria	16%	Luxembourg	11%
Cyprus	13%	Malta	10%
Czech Republic	13%	Netherlands	14%
Denmark	30%	Poland	15%
Estonia	25%	Portugal	31%
Finland	38%	Romania	24%
France	23%	Slovakia	14%
Germany	18%	Slovenia	25%
Greece	18%	Spain	20%
Hungary	13%	Sweden	49%
Ireland	16%	United Kingdom	15%
Italy	17%		

Source: European Commission

The costs are reported both as an incremental cost in 2020 and on a total project lifetime. All costs are discounted back to 2006. Similar comparable carbon abatement figures are provided from which the incremental carbon abatement costs can be calculated.

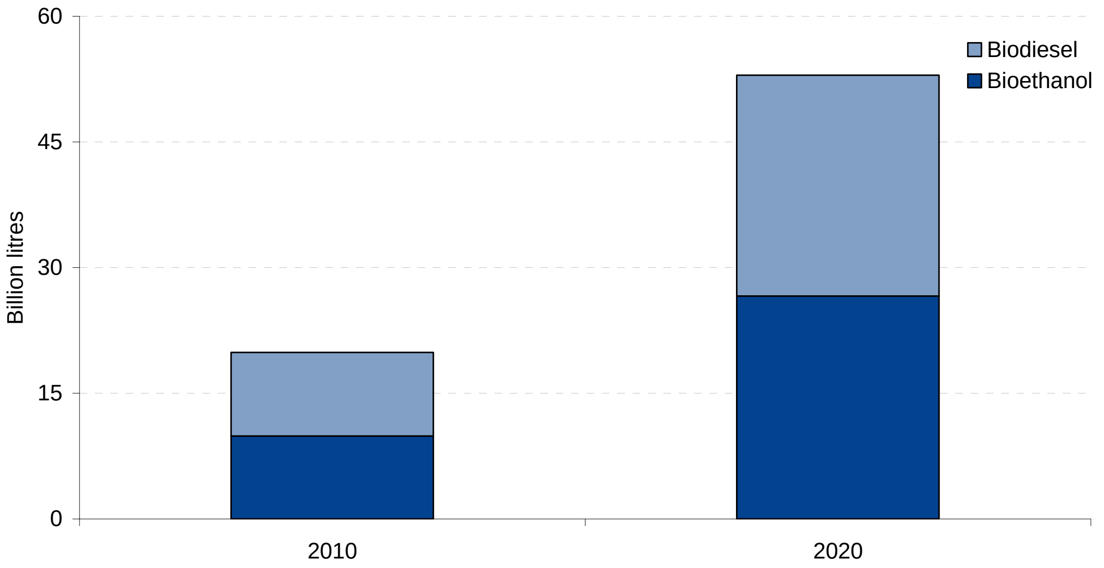
2.6 Modelling of the transport biofuels market

While the overall assessment incorporates renewable energy consumption across all the sectors, the transport sector has been modelled separately to ascertain the costs of complying with the separate target of 10% biofuels use in transportation fuel consumption (excluding aviation) by 2020. The modelling analyses the demand, resource availability and cost of biofuels in a global market – the main elements of which are described below.

2.6.1 Demand for biofuels

The demand for biofuel is split between bioethanol and biodiesel. The volume in the EU is based on an assumed trajectory from a 2010 business as usual position derived from current EU predictions of biofuel shares, to a 2020 position that assumes compliance with the 10% biofuels target for each member state.[17] Figure 4 illustrates the assumed growth in demand from 2010 to 2020, by fuel type. In total, demand is expected to increase from 20 billion litres to 53 billion litres.

Figure 4 – Total biodiesel and bioethanol demand in 2010 and 2020



Source: Pöyry Energy Consulting

2.6.2 Biofuel supply

The supply for biofuels is calculated from 2020 production estimates of key domestic feedstocks and their crop fuel yield. The same analysis is conducted for each country around the world to ascertain total global supply. We net off local demand to arrive at a net supply available for export, which is then apportioned in order of priority between the EU and the US.[18][19]

Prior to the supply calculations, we net off domestic crop consumption for food to establish the amount available for biofuels in each country. A second constraint further limits this net

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17 Sources: EU Commission, DG Transport, *European Energy and Transport Trends to 2030* – update 2005; US Department of Energy, *International Energy Outlook 2007*; World Resources Institute EarthTrends Database; International Energy Agency (IEA) Energy Balances of OECD Countries, 2006 edition; IEA, Extended Balances and Energy Balances of Non-OECD Countries, 2006 edition.

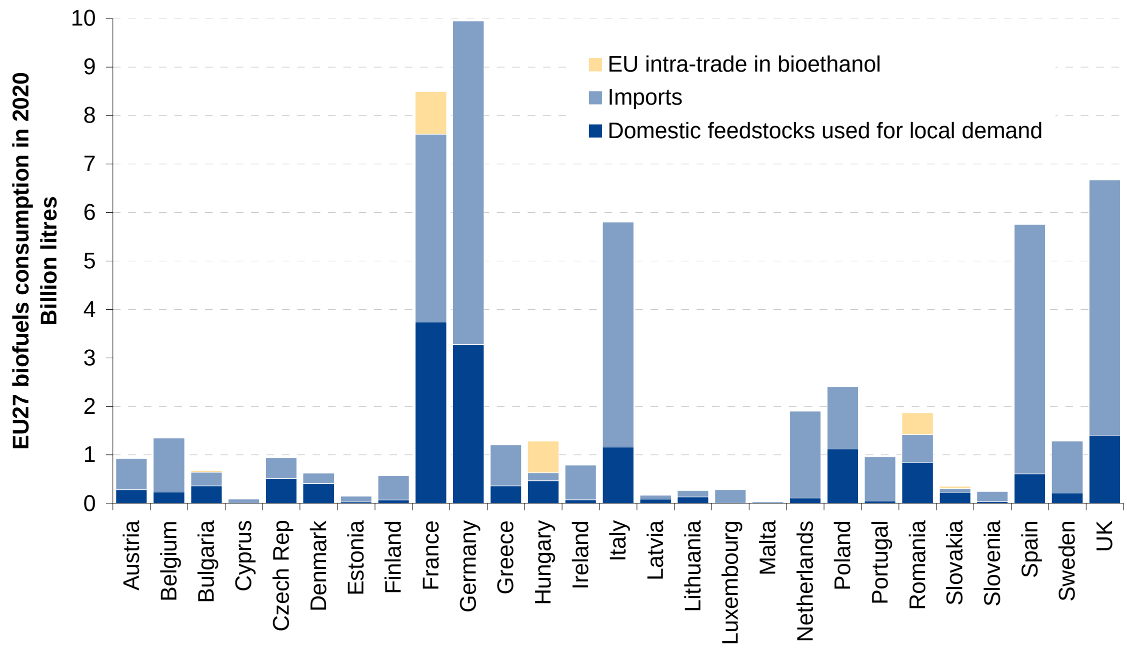
18 Sources: UN FAO Stat Database, for feedstock production estimates; OECD/FAO, *OECD-FAO Agricultural Outlook, 2007-2016* for production and consumption forecasts; IEA/OECD, *Biofuels for Transport: An International Perspective,* 2004, for crop fuel yields.

19 For biodiesel, the EU is assumed to have priority access, due to its dominant position in the market and a high willingness to pay due to the legally binding target. For bioethanol, the US and EU are given equal 50:50 priority access

amount to 50% biofuel use – to take into account of other current non-food uses, such as soaps and detergents, which are unlikely to change significantly.

The supply analysis indicates that the EU will be able to meet its 10% target for biofuels consumption in 2020, although it does indicate that this may be at the expense of other countries compliance with their own targets. Figure 5 below presents our central scenario results for the demand and supply of biofuels in Europe in 2020. Total EU demand is estimated at 53 billion litres, of which 18 billion litres will come from domestic production, while the rest will be imported.

Figure 5 – EU 27 biofuels demand and supply and percentage domestic sourcing



Source: Pöyry Energy Consulting

On average, domestic biofuel production in Europe is limited due to relative scarcity of land, high diversion to food and non-food consumption. In addition, it is less competitive compared to large scale biodiesel exporters such as Malaysia and Indonesia, and bioethanol exporters notably Brazil. Romania, Slovakia, France, Hungary and Bulgaria are the only countries in our analysis capable of meeting their bioethanol 2020 demand from domestic sources.

At the other end of the spectrum, Malta, Cyprus, Luxembourg, Portugal and the Netherlands are all likely to import more than 85% of their demand. UK domestic production is likely to meet 28% of ethanol consumption, far less than the EU average of 55%. For biodiesel, only Latvia at 41%, Slovakia at 45% and Hungary at 46% come close to self-sufficiency. The UK will meet 10% of its demand, while the EU average for domestic production according to our estimates is 12%.[20]

20 It is likely that the processing and refining sector will decouple from domestic feedstock production, which may lead to different patterns of final supply. The more mature markets such as Germany are already seeing a concentration in capacity and significant substitution between domestic raw feedstock, and imported semi-processed cake or final refined product for blending according to price sensitivities and other criteria.

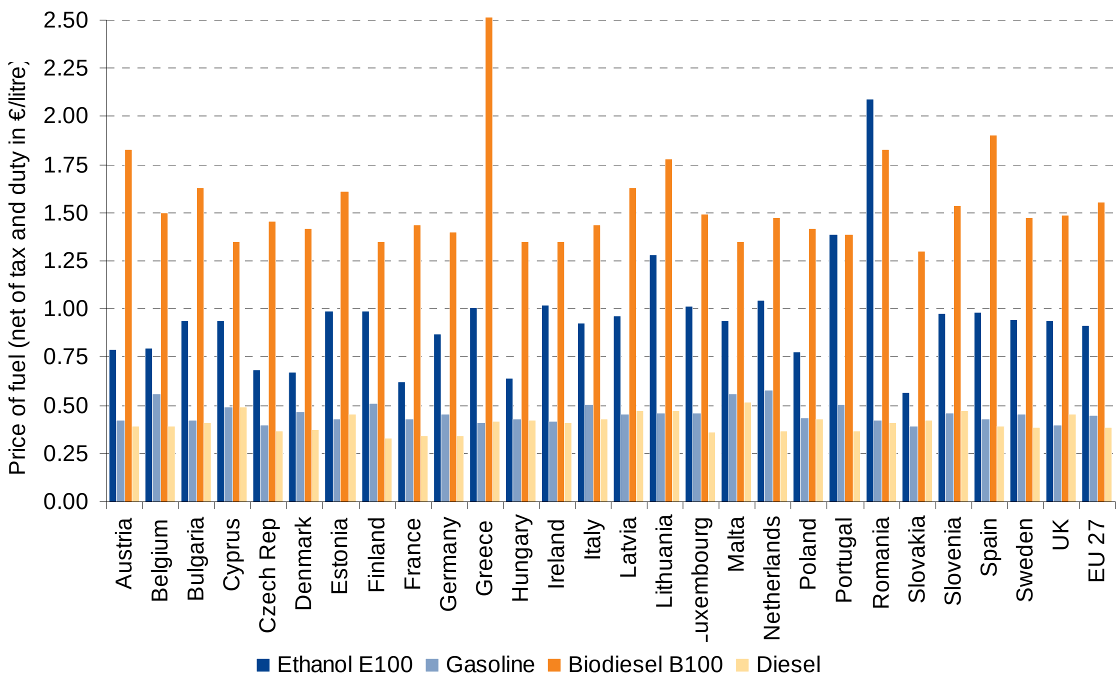
It should be noted that competition for set-aside land for energy crops (where transport and electricity/heat demand may overlap) is not modelled explicitly within this study as it is assumed that priority is given to energy crop production for transport biofuel use given higher anticipated returns from this sector.

2.6.3 Biofuel costs

Costs of production are calculated as the sum of feedstock costs (producer prices), international transport costs derived from ocean freight charges, and processing and refining costs (assumed to be a percentage of feedstock costs). Other costs considered include tariffs and subsidies (included at current levels) and blending and distribution costs (assumed to be a percentage of feedstock costs based on historic ratios).[21]

Biofuels are more expensive compared to conventional fuels and are unlikely to become competitive, absent very high sustained oil prices. However, on average, bioethanol is more cost competitive than biodiesel, as illustrated in Figure 6.

Figure 6 – Cost of fossil fuels vs. biofuels in 2020 (in € per litre, real 2006 money)



Source: Pöyry Energy Consulting

21 Sources: UN FAO Stat Database, for producer prices; OECD/FAO, *OECD-FAO Agricultural Outlook, 2007-2016* for Personal Consumption Expenditure (PCE) inflator; IEA/OECD, *Biofuels for Transport: An International Perspective*, 2004, for processing cost estimates.

Other sources include CIF/FOB Bands used to calculate international transport costs based on Jeffrey Sachs, Steven Radelet, *Shipping Costs, Manufactured Exports, and Economic Growth*, mimeo Harvard Institute for International Development, 1998; FAO *Food Outlook June 2007*, Global Market Analysis/ International Grains Council Grains Market Report Ocean Freight Survey for ocean freight rates; EUBIA, the European Biomass Industry Association, *Average biodiesel production costs in the EU-2*5, EUBIA, *Average biodiesel production costs in the EU-25*

Combining the costs of production and quantities demanded, it is estimated that the annual cost of biofuel use in the EU will rise from an estimated €19bn in 2010 to €40bn in 2020. The resource cost, defined as the difference between the cost of fuel displaced and the cost of biofuel used, is likely to rise from an estimated €14bn to €30bn for the same period. For the UK, gross expenditures will rise from an estimated €1.6bn in 2010 to 4.8bn in 2020, as the rate of incorporation increases. The UK resource cost is likely to rise from €1.1bn in 2010 to €3.4bn in 2020. Table 3 below provides additional cost estimates for the EU and for selected countries, discounted to 2006.

Table 3 – Gross costs and resource expenditures on biofuels 2010-2020 (€bn, discounted to 2006)

	France	Germany	Italy	Spain	UK	Others	EU-27
Gross Costs							
Business As Usual + Incremental	41	52	31	41	32	93	290
Business As Usual	33	41	22	33	20	72	220
Incremental	8	11	9	9	12	21	70
Counterfactual Costs							
Business As Usual + Incremental	11	14	9	9	9	25	77
Business As Usual	8	11	7	7	6	20	58
Incremental	2	3	3	2	3	6	18
Resource costs							
Business As Usual + Incremental	30	38	22	33	23	68	213
Business As Usual	24	30	15	26	14	53	162
Incremental	6	8	6	7	9	16	51

Source: Pöyry Energy Consulting

2.6.4 Limitations

The cost and volume estimates provided in this analysis are a baseline attempt to quantify compliance and are meant as a starting point. The original intent was to use publicly available data, and absent useful data, we have had to resort to original research. Despite these constraints the assumptions made are reasonable and supported by numerous external sources. However the final results are very sensitive to the assumptions made. The most important driver is global demand for biofuels. A one percentage point change in global demand yields about 0.7% change in supply to the EU, assuming the EU has priority access to global export volume and higher depending on the assumptions on competition for supply. In absolute terms dropping the cap on diversion to allow for possible 100% of a crop to be utilised for transport fuels, enables the EU to theoretically meet 73% of its biofuel consumption from domestic sources.

3. KEY RESULTS

The main results presented here describe the cost of compliance with the renewable energy target on the following basis:

- business as usual volumes are derived from the baseline projections contained in European Energy and Transport Trends to 2030 (Update 2005);
- central technology cost assumptions (i.e. the Central Case) underlie the RES-E and RES-H supply curve;
- full compliance with the 10% biofuels target is achieved in 2020 and costs are as reported in section 2.6 above; and
- burden sharing commitments are as set by the European Commission and presented in Table 2.

In addition, the impact of variations in these core assumptions are shown through a range of sensitivities addressing the definition of the target (the manner in which member states are able to comply), technology costs, counterfactual costs and resource availability.

3.1 Costs of compliance

The cost of compliance with the proposed burden shares presented in Table 1 depend on whether the most efficient renewable energy mix is available (i.e. there is some means of facilitating trading amongst Member States) or not (i.e. each country must meet its own burden share through domestic action). Since uncertainty remains over whether a workable system of trading Guarantees of Origin will emerge, the cost of compliance may vary substantially. To capture the range of costs, the central case has been run on two bases:

- least cost; and
- domestic constrained

reflecting the situation where trading is or is not available as a means of meeting an individual Member State's burden share respectively.

A summary of the key results for the EU and UK under each scenario is shown in Table 4, which highlights the extent of differences in cost between the least cost and domestic constrained options:

- for the EU, the annual incremental cost (for electricity, transport and heat) in 2020 rises from €18.8bn under the least cost option to €25.6bn under the domestic constrained scenario and the lifetime cost[22] increases from €259bn to €351.7bn; and
- for the UK, the annual incremental cost (for electricity, transport and heat) in 2020 rises from €5.0bn under the least cost option to €6.7bn under the domestic constrained scenario and the lifetime cost increases from €59bn to €93.1bn.

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22 This lifetime cost calculation captures the fact that additional resource costs are incurred over each year of the economic lifetime of the renewable investment. It does not account for additional investment that may be required post 2020 to maintain a 20% renewable energy position. It assumes that the transport resource costs and the cost of permit purchases are held constant at 2020 levels until 2030.

Table 4 – Main results for the EU and the UK

	EU 27		UK	
	Least Cost	Domestic compliance	Least Cost	Domestic compliance
2020 RES volumes (TWh)	**3,250**	**3,250**	**303**	**303**
of which RES-E	*1,253*	*1,258*	*84*	*150*
of which RES-H	*1,580*	*1,574*	*74*	*102*
of which RES-T	*417*	*417*	*51*	*51*
of which permits			*94*	
2020 Compliance (%FED)	**20.0%**	**20.0%**	**15.0%**	**15.0%**
of which RES-E	*7.7%*	*7.7%*	*4.1%*	*7.4%*
of which RES-H	*9.7%*	*9.7%*	*3.7%*	*5.0%*
of which RES-T	*2.6%*	*2.6%*	*2.5%*	*2.5%*
of which permits			*4.6%*	
2020 incremental cost (€bn, discounted back to 2006)	**18.8**	**25.6**	**5.0**	**6.7**
of which RES-E	*6.1*	*10.8*	*0.8*	*3.6*
of which RES-H	*2.1*	*4.2*	*0.1*	*1.4*
of which RES-T	*10.6*	*10.6*	*1.7*	*1.7*
of which permits			*2.5*	
Lifetime cost (€bn, discounted back to 2006)	**259.0**	**351.7**	**59.0**	**93.1**
of which RES-E and RES-H	*114.1*	*206.8*	*12.1*	*69.3*
of which RES-T	*144.9*	*144.9*	*23.9*	*23.9*
of which permits			*23.1*	
Carbon savings of the incremental renewable capacity (MtCO2)	**388**	**388**	**32**	**67**
of which RES-E	*151*	*153*	*14*	*40*
of which RES-H	*199*	*197*	*11*	*20*
of which RES-T	*38*	*38*	*7*	*7*
Abatement cost of the incremental renewable capacity (€/tCO2)	**49**	**66**	**82**	**101**
of which RES-E and RES-H	*23*	*43*	*35*	*84*
of which RES-T	*276*	*276*	*259*	*259*
Lifetime carbon savings (MtCO2)	**9,834**	**9,659**	**1,034**	**1,628**
of which RES-E	*4,653*	*4,548*	*371*	*1,046*
of which RES-H	*4,604*	*4,534*	*314*	*481*
of which RES-T	*577*	*577*	*101*	*101*
of which permits			*247*	
Lifetime abatement cost (€/tCO2)	**26**	**36**	**57**	**57**
of which RES-E and RES-H	*12*	*23*	*18*	*45*
of which RES-T	*251*	*251*	*236*	*236*
of which permits			*93*	

Source: Pöyry Energy Consulting Analysis

3.2 Least cost compliance scenario

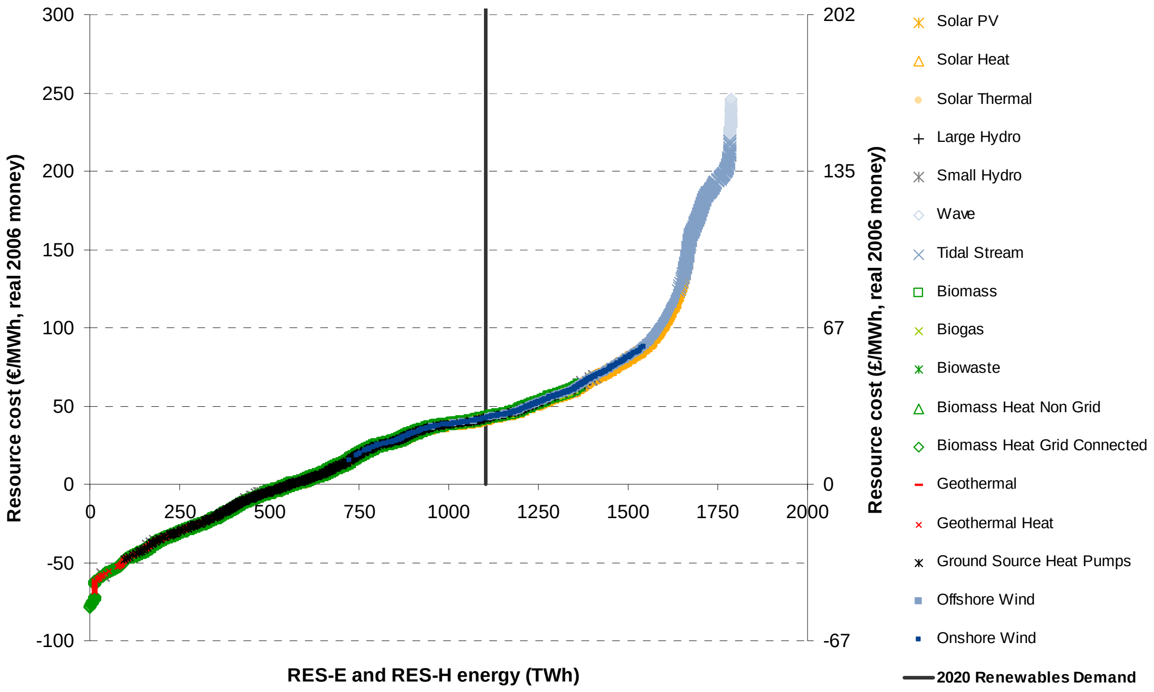
In the least cost scenario, it is assumed that the EU target is met through the most efficient deployment of renewable heat and electricity technologies across the member states, given assumed compliance with the 10% transport target, as discussed in section 2.6.

3.2.1 *Projected renewable mix*

The EU supply curve for renewable electricity and heat is shown in Figure 7. One important feature of this curve is the concentration of low cost biomass-based technologies (in particular in the heat sector) in the lower part of the curve. This reflects several factors including:

- the relatively low cost of biomass heat and electricity technologies compared to competing renewable technologies (see Figure 3); and
- the large biomass potential identified in the Green-X reports used as the basis for resource potentials in this study.

Figure 7 – Incremental EU renewable electricity and heat supply curve

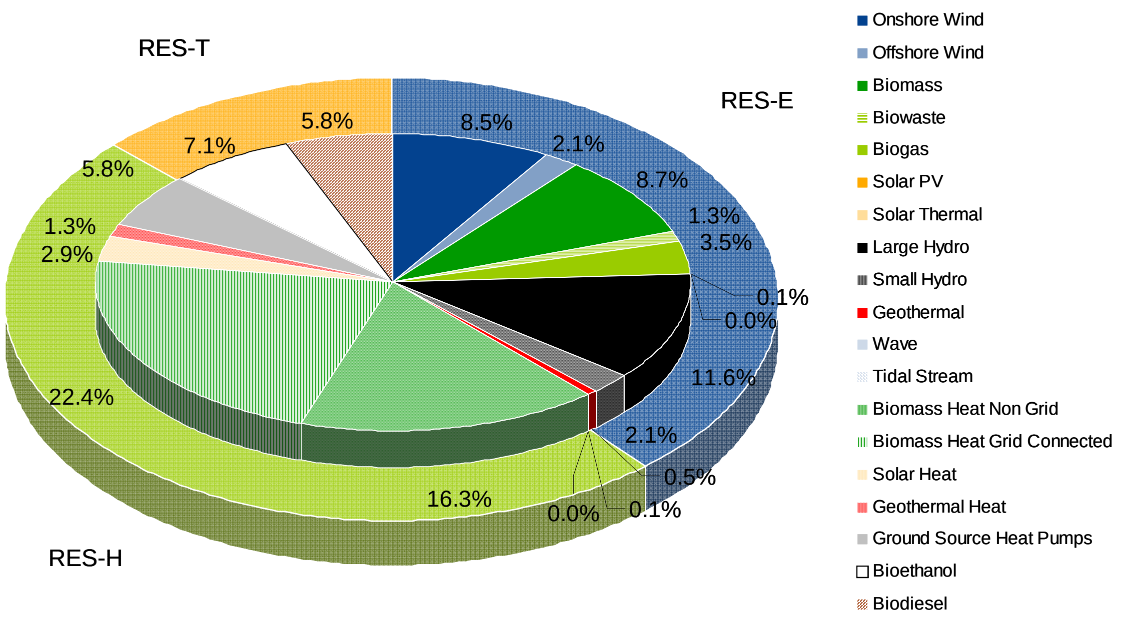


Source: Pöyry Energy Consulting Analysis

The EU renewable mix in 2020 illustrates the effect of this dominance of biomass in the renewable supply curve. As Figure 8 shows, biomass heat and electricity sources account for around 52% of total renewable energy in 2020. As such, it is to be expected that countries with larger biomass potential would, on a least cost basis, contribute a higher proportion of total renewable energy to meet the 20% target. This is evident in Figure 9, which shows the volume of renewable generation (as a % of national FED) that each member state would optimally contribute to the target. The UK's least cost contribution would be 10.4%, compared with almost 50% for Sweden.

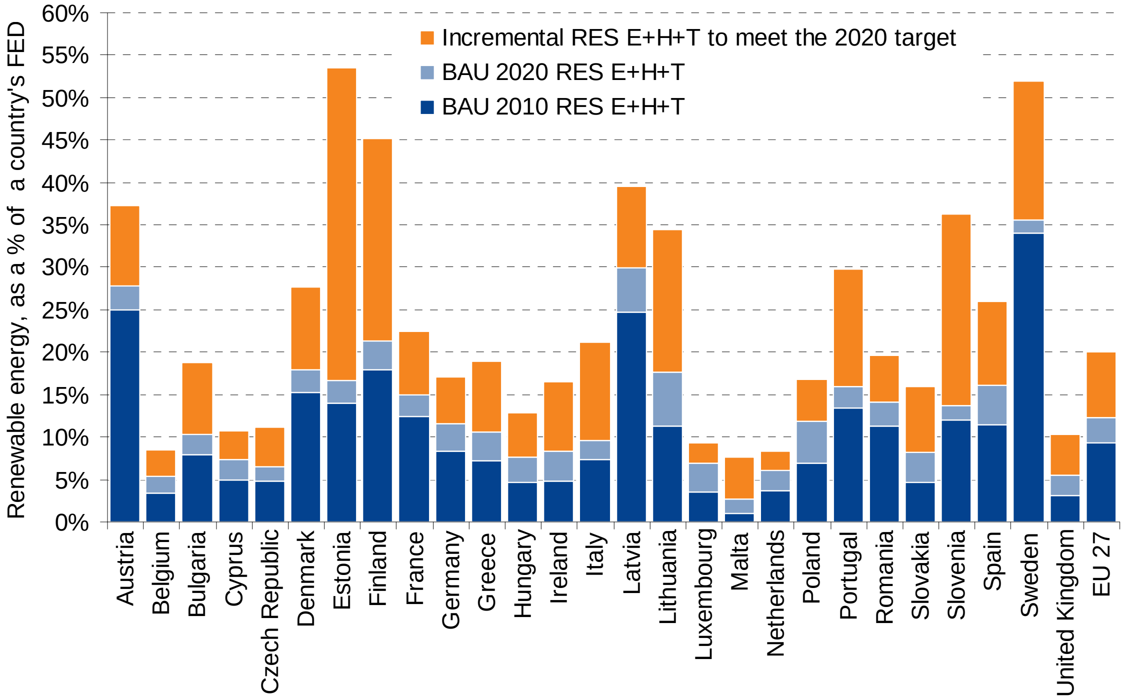
However, while there is a significant variation in the shares of member states, the 20% target implies a large shift in renewable energy supply across the EU, with incremental growth (i.e. above that already projected for each country) in many countries being of the same order of magnitude as the business as usual production. While some resource constraints have been imposed in this analysis, the underlying assumption has been that reported Green-X resource potentials can be met. As Figure 10 highlights, this will require a step change in renewable energy deployment and investment, and failure to do so would raise the cost of, or jeopardise the delivery of, the 20% renewable energy target.

Figure 8 – EU total renewable energy mix in 2020



Source: Pöyry Energy Consulting

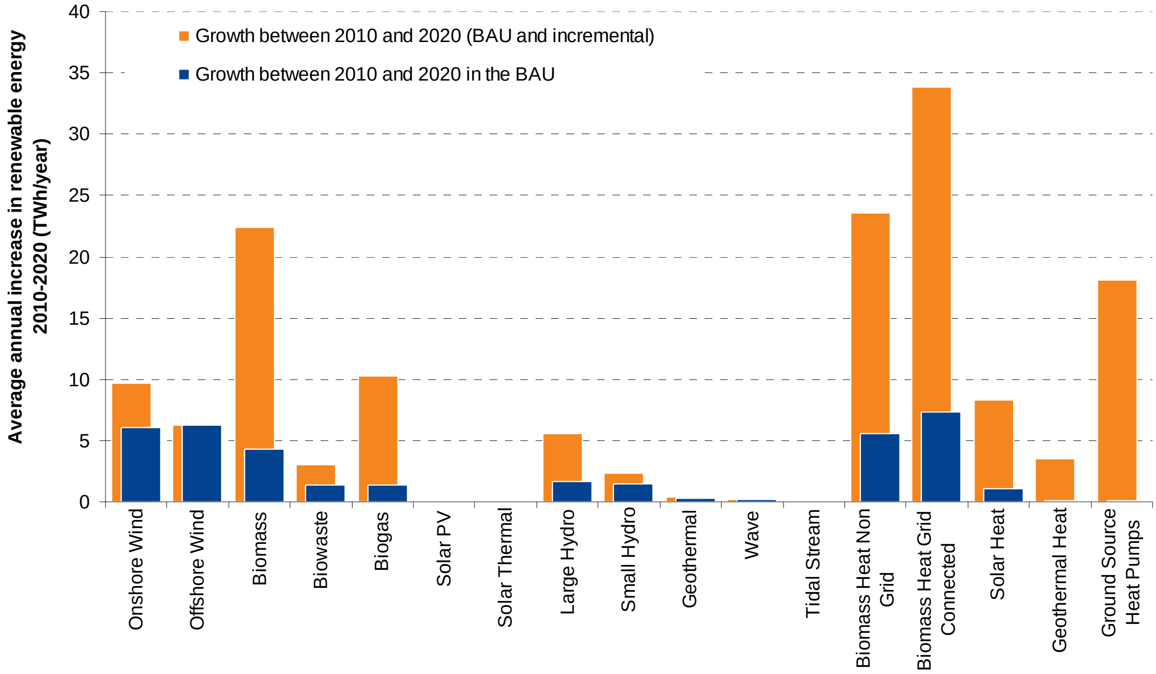
Figure 9 – Least cost compliance volumes



Source: Pöyry Energy Consulting

This is particularly true for biomass electricity and heat technologies, where growth rates would need to increase five- to ten-fold within the time period, as illustrated in Figure 10, which shows the annual growth rates in renewable volumes by technology under the business as usual baseline and the implied growth rates to deliver the 2020 renewable mix from Figure 8.

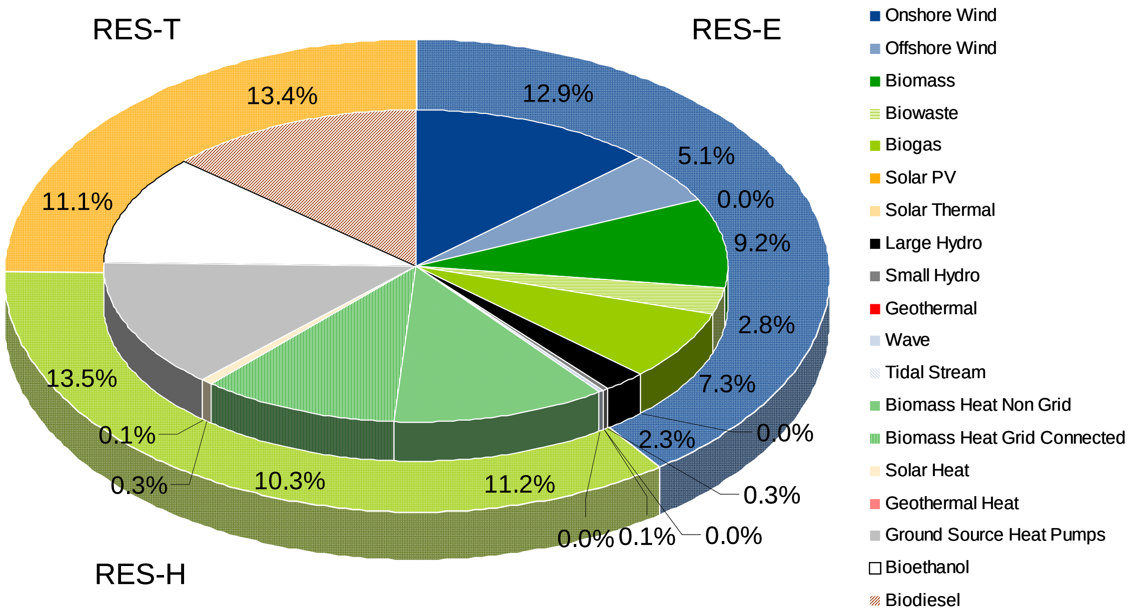
Figure 10 – Business as usual and required technology growth rates (TWh pa)



Source: Pöyry Energy Consulting

Within its 10.4% contribution, the UK exhibits a similar pattern to that shown in the EU as a whole, with biomass-based technologies contributing 65% of renewable energy in 2020, compared with 18% for wind energy for example (see Figure 11).

Figure 11 – UK total renewable energy mix in 2020



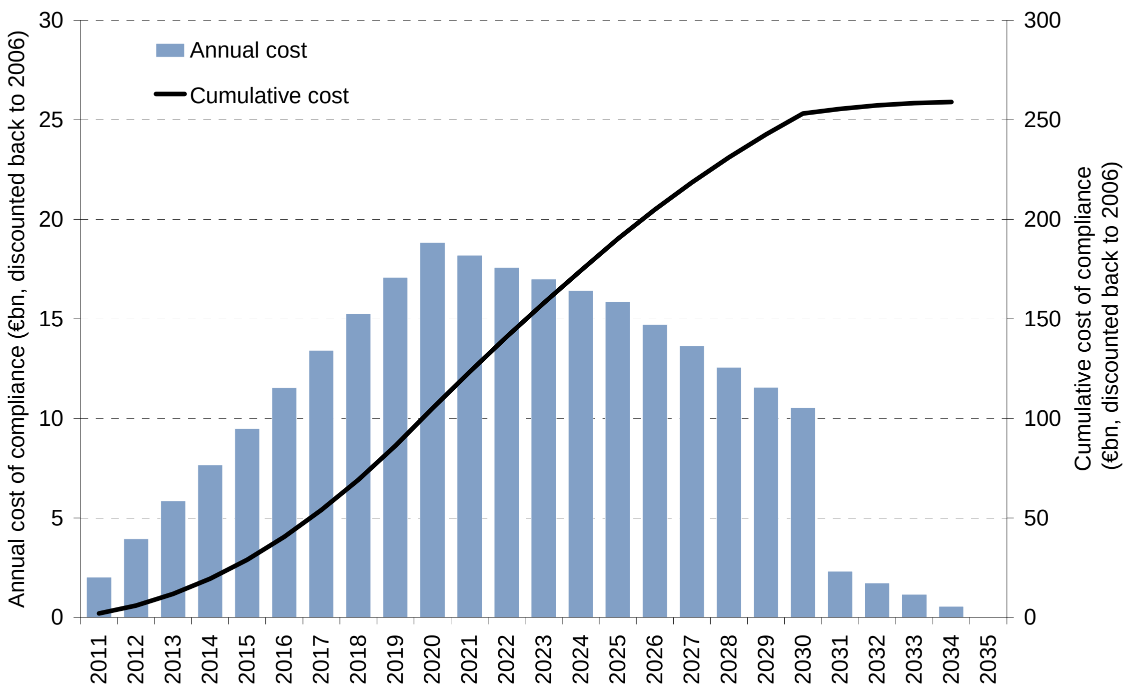
Source: Pöyry Energy Consulting Analysis

This characteristic of the UK's potential resource has two interesting implications. First, as already stated, it means that the UK is likely to contribute a relatively lower proportion of renewable energy on a least cost basis because it has a relatively low proportion of biomass heat potential and a higher volume of wind-based electricity potential, the latter being higher up the supply curve of EU renewable potential. Second, the UK's costs will be higher as its burden share exceeds this optimal contribution (implying the need to purchase credits from other countries or to deliver more expensive renewable technologies to meet the gap).

3.2.2 Projected costs of compliance

The cost impacts for the EU and the UK are shown in Table 4. As can be seen, the annual incremental cost to the EU of meeting the target in 2020 is €18.8bn (discounted to 2006). Projects are expected to commission from 2011 and have project lifetimes of around 20 years (specific assumptions on lifetimes for individual technologies are in Annex A). Incremental support will be needed throughout this period to ensure investment in these technologies. Taking this into account, the total lifetime cost of investment up to 2020 is €259bn (discounted to 2006). The distribution of the lifetime cost is illustrated in Figure 12, reflecting the growth in investment over the period.[23]

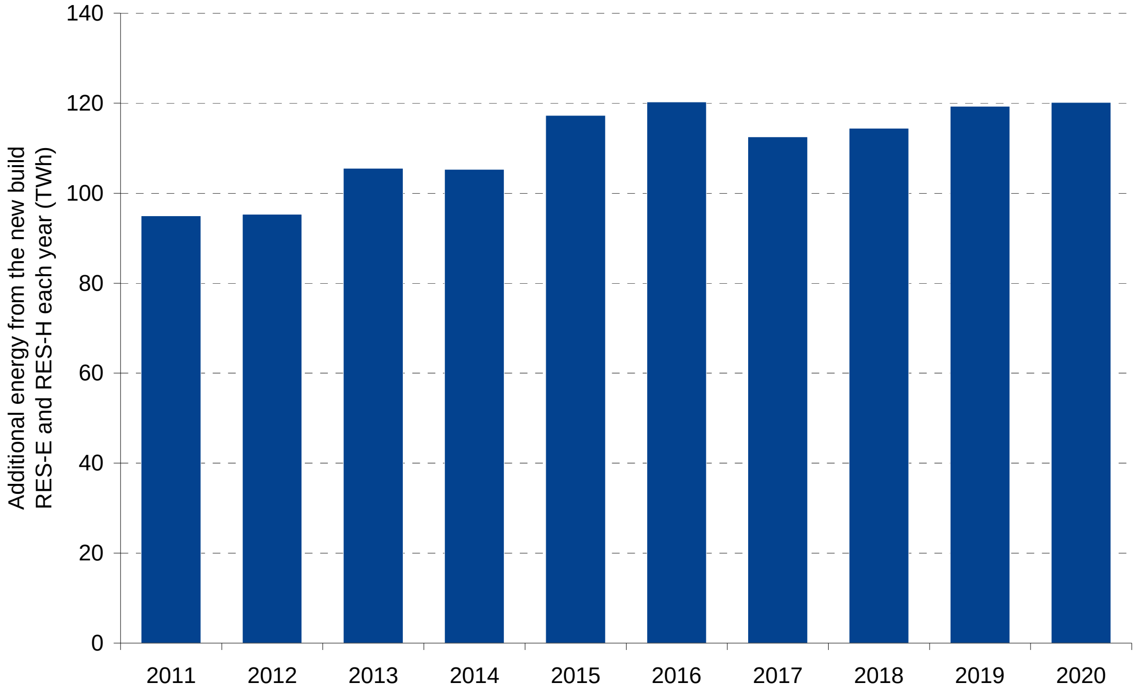
Figure 12 – Distribution of EU resource cost over time (discounted to 2006)



Source: Pöyry Energy Consulting

[23] The drop-off in cost in 2031 is a consequence of the assumption that lifetime transport resource costs continue to 2030 but not beyond.

Figure 13 – New build evolution in the EU throughout the analysed period



Source: Pöyry Energy Consulting Analysis

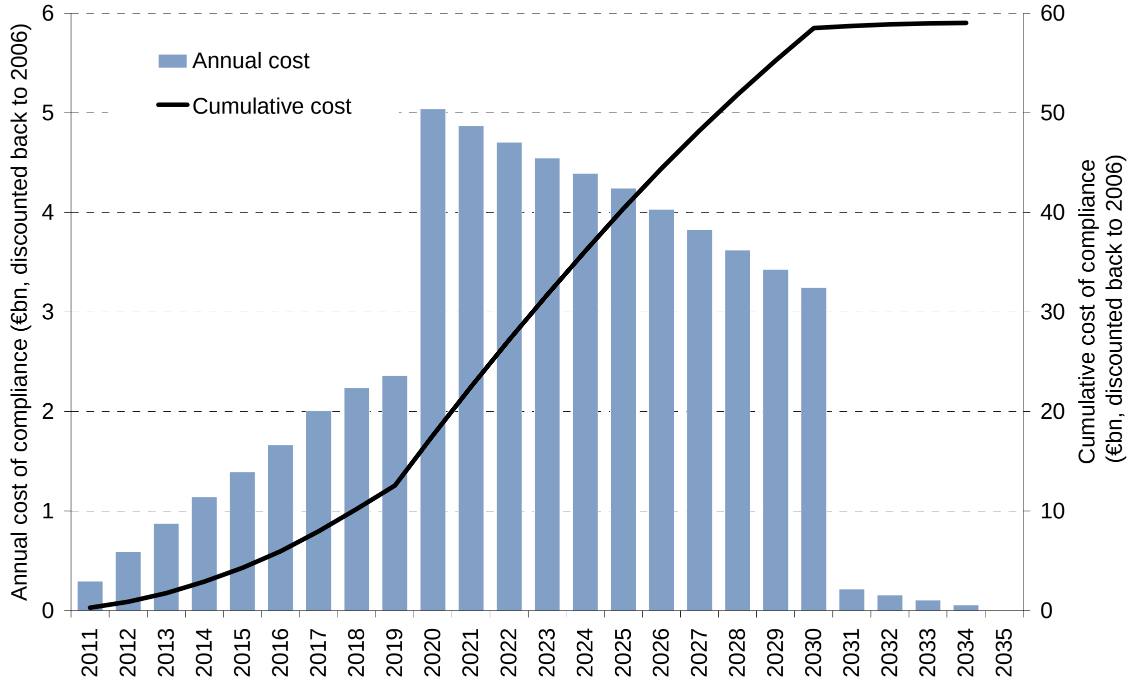
Using the 15% burden share , the UK's least cost annual incremental cost in 2020 is €5.0bn, consisting of €2.6bn of domestic renewable energy production (to deliver the 10.4% of UK FED predicted by the least cost modelling) and €2.5bn of purchases of permits to cover the additional 4.6% burden share.[24] The cost of UK domestic action in 2020 amounts to a total lifetime cost of €59bn, with a distribution similar to that of the EU, as illustrated in Figure 14.[25]

The costs in Figure 14 are underpinned by the pattern of new build shown in Figure 15. As can be seen, the annual incremental growth is not flat but varies over time. The model optimises the renewable investment over the period, reflecting changes in the cost of technologies and in the available volumes across time, the latter determined by the different build rate profiles assumed by technology (see the detailed descriptions in the annex).

24 The cost of the renewable energy permit is assumed to be the marginal renewable resource cost in 2020, as derived from the EU supply curve.

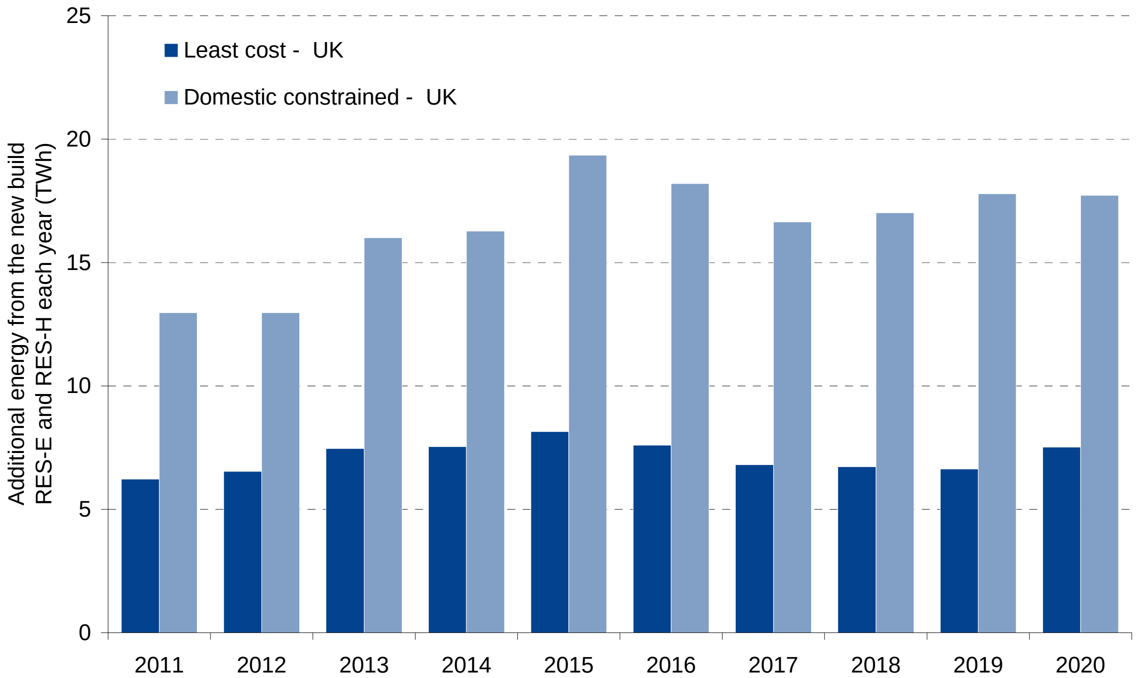
25 The jump in 2020 reflects the jump in permit purchase price as the 2020 target approaches.

Figure 14 – Distribution of UK resource cost over time (discounted to 2006)



Source: Pöyry Energy Consulting

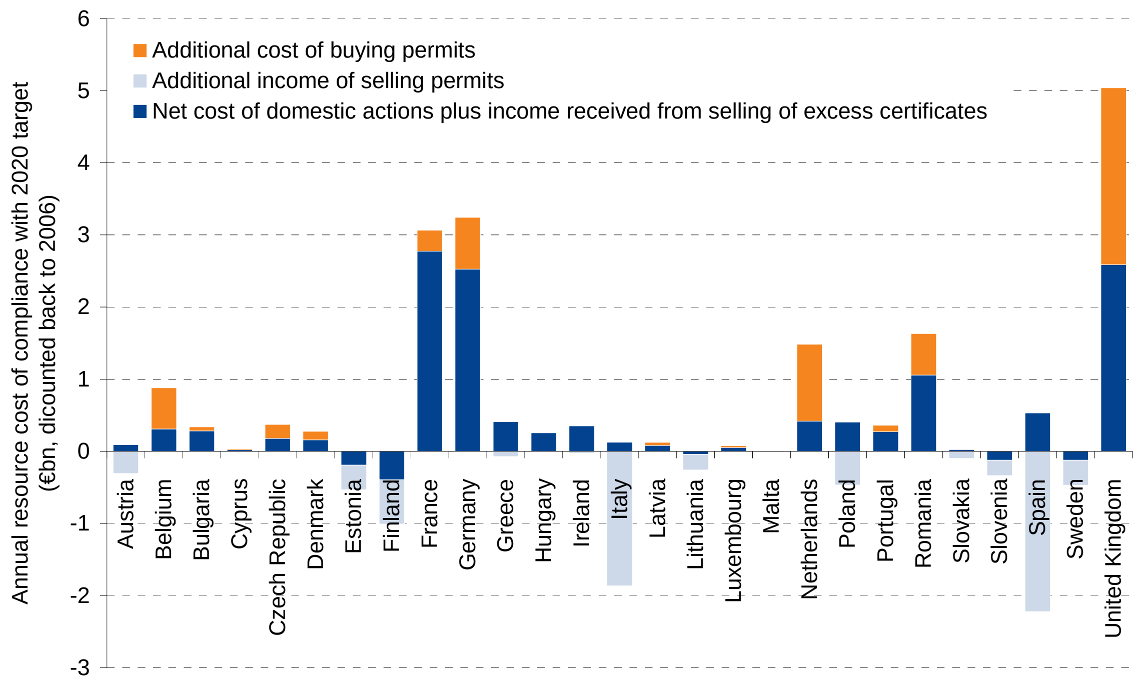
Figure 15 – New build evolution in the UK throughout the analysed period



Source: Pöyry Energy Consulting Analysis

The implication is that, under the least cost scenario, the UK bears a significant portion of the total cost of compliance across the EU (around 19% of the annual 2020 cost). Figure 16 shows that the European Commission burden sharing implies a wide variation in total costs incurred. Like the UK, there are several countries who will incur large additional costs through the need to purchase permits (these include Germany, the Netherlands, Belgium, France and Romania). By contrast, the model suggests there will be a concentration of surplus permits among a few countries, namely Italy, Spain, Finland, Austria and Poland.

Figure 16 – Distribution of costs across Member States



Source: Pöyry Energy Consulting

3.2.3 *Impact on carbon savings*

Table 4 also shows the implied carbon savings as a result of the policy. On the basis of the carbon counterfactual assumptions described in detail in the annexes, the annual carbon savings in 2020 for the EU are 388 MtCO2 and for the UK are 32 MtCO2.[26] Over the lifetime of the electricity and heat sector projects developed as part of this policy, there will be total lifetime carbon savings of 9,834 MtCO2 and 1,034 MtCO2 in the EU27 and UK respectively.

The annual incremental carbon abatement cost in 2020 shows the average support required for each unit of emission reduction, though it should be noted that the marginal support required may be significantly higher. One of the more striking factors here is the large difference between the cost of compliance across the sectors. Specifically, the incremental carbon abatement cost in the transport sector is around 10 times the cost in the electricity

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26 These figures assume that biofuels are carbon neutral, a point that is widely debated at present and therefore the overall savings are sensitive to the treatment of the transport contribution.

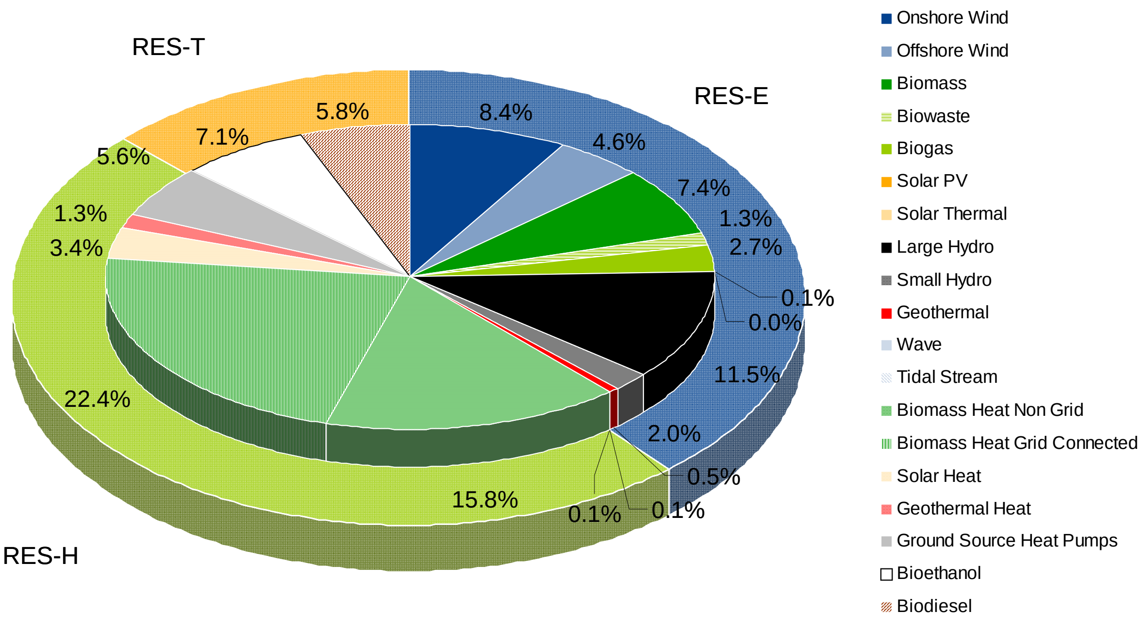
and heat sectors. On a lifetime analysis, the incremental carbon abatement cost in the electricity and heat sectors is in the order of €26/tCO2 and €57/tCO2, in the EU27 and UK respectively.

3.3 Domestic constrained scenario

The least cost results presented above assume that some form of renewable certificate trading exists, enabling the most efficient deployment of renewable resources to be achieved. The alternative scenario has investigated the impact on costs of constraining each country to meet its burden share through domestic action. Since this may prevent some low cost renewable resource being deployed, it can be expected to raise the cost of compliance with the target to the EU as a whole. To illustrate the extent of this impact, an additional scenario has been run using the same burden sharing assumptions, but imposing a domestic action constraint. The results are also shown in Table 4.

Compared to the least cost scenario, an outcome where all action has to be taken domestically (but the same burden shares apply) raises the EU cost of compliance by €6.8bn (or 36%), and the cost to the UK increases by €1.7bn (or 34%). From Table 4, it can be seen that the majority of the increase in cost arises from higher electricity costs (an increase in the 2020 incremental cost from €6.1bn to €10.8bn, compared with an increase of €2.1bn in renewable heat costs). A proportion of this is a result of a growth in wind volumes in the mix from 10.6% to 13.0%, as shown in Figure 17.

Figure 17 – EU renewable energy mix 2020 for the domestic constrained scenario



Source: Pöyry Energy Consulting

3.4 Sensitivity analysis

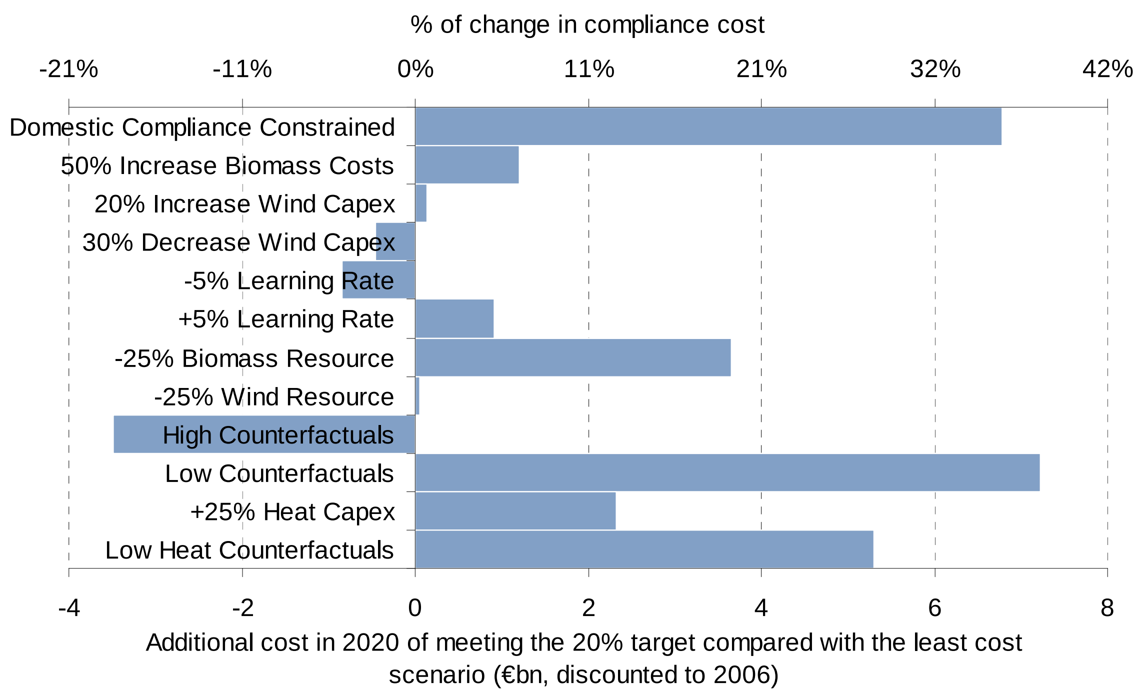
There are a number of uncertainties surrounding the construction of the supply curve, as the more detailed analysis contained in the Annex shows.

Three further types of sensitivity have therefore been run on the assumptions underlying the supply curve:

- technology cost sensitivities – applying to base year costs and the rates of learning applicable across time;
- resource availability sensitivities – focussed on biomass resource availability across all three sectors; and
- counterfactual cost sensitivities – reviewing high and low counterfactual costs consistent with the high and low UEP fuel price projections.

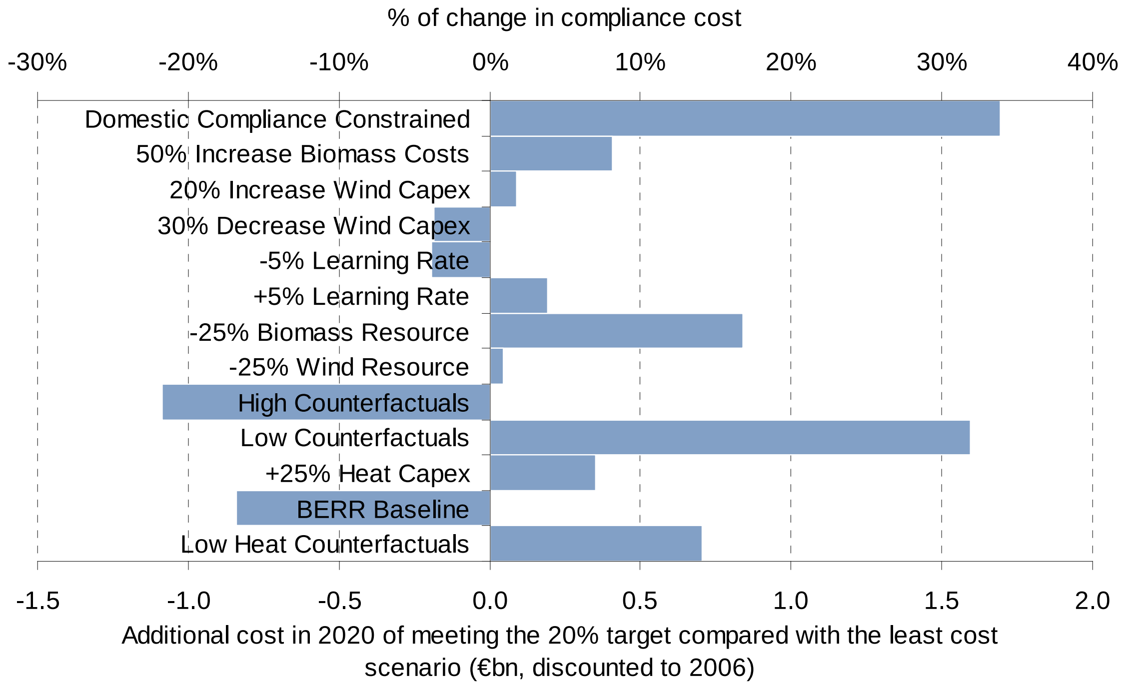
The impact on annual incremental costs in 2020 for the EU and the UK are shown in Figure 18 and Figure 19 respectively. In both, the most important sensitivity (around twice the impact on costs of other sensitivities) is in relation to the cost counterfactual assumed for the conventional technology. Since the cost counterfactual is largely a function of underlying fossil fuel price assumptions, the wide variation in the Updated Energy Projections can result in substantial changes.

Figure 18 – EU compliance cost sensitivities



Source: Pöyry Energy Consulting Analysis

Figure 19 – UK compliance cost sensitivities



Source: Pöyry Energy Consulting Analysis

A similar pattern of variability in total resource cost is also observed, with cost and resource sensitivities causing fluctuations up to ±20% but variability in the counterfactual costs having a substantially greater impact, in the order of -19% to +38% for high and low counterfactual assumptions respectively.

The biomass sensitivities looked at both cost and available biomass resource. These factors have significant impacts on the renewable supply curves and hence on the overall cost of compliance. As noted in section 2.3.2, the biomass resource potential was taken from Green-X and does not include allowance for imported biomass that may increase realisable output, albeit at a higher cost in a globally traded market.

One final sensitivity was run to assess the impact of an alternative baseline renewable energy position in the UK, consistent with the 2007 Energy White Paper projections. The change in the mix and in the level of the baseline, along with a different assumption for the growth in FED as reported in Table 1 reduced the cost by 17%.

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4. CONCLUSIONS

4.1 Implications for the EU

The following key conclusions for the EU as a whole can be drawn from the analysis undertaken to date.

- If the resource assumptions are correct, then there is sufficient resource in the EU to meet the target. However, if the target is actually to be met then:
  - the deployment/growth rates in the electricity and heat sectors would need to increase substantially; and
  - further research would be required into the likely availability of, and competition for, biofuel feedstocks as Pöyry has had to undertake primary research not originally anticipated as part of this study due to lack of credible publicly available data sources.
- The resultant renewable resource mix is dominated by biomass-based technologies which increase their share relative to wind and hydro technologies.
- The cost to the EU of achieving the target efficiently (i.e. the least cost consumption basis scenario) varies between €15.2bn and €25.9bn per annum in 2020 under a range of sensitivities on cost and resource availability, with a central estimate of €18.8bn (corresponding to a total lifetime cost of €259bn). The more significant cost impacts are as a result of the changes in the cost counterfactual that determines the overall resource cost associated with each technology.
- There is a wide variation in action by country under the least cost outcome reflecting available resource and local cost differentials.
- These resource and cost differentials mean that if countries are constrained to achieving compliance by domestic action this may increase the cost relative to a least cost outcome as a more expensive technology mix is employed. In the scenario analysed in this study, the increase in cost for the EU was of the order of €6.8bn/year (i.e. an annual resource cost in 2020 of €25.6bn), with a corresponding increase in total lifetime cost of €93bn.
- The incremental carbon abatement cost in 2020 of complying with the transport obligation is 10 times higher than the cost of meeting the RES-E and RES-H targets (and the carbon savings themselves are far less certain).

4.2 Implications for the UK

For the UK, there are further conclusions to draw.

- Under the least cost scenario the UK would almost double its renewable energy production relative to business as usual, with the majority of the growth occurring in the wind, biomass, waste and heat sectors.
- The cost to the UK is higher, in general, because of lack of access to cheap biomass resource in the electricity and heat sectors and greater reliance on higher cost electricity technologies such as wind and wave/tidal. However, it is also dependent on how it is able to meet any potential shortfall. On the basis of the Commission burden sharing, the cost to the UK increases by around 34%, from €5.0bn to €6.7bn, if trading is not a viable alternative.

- As for the EU, the cost to the UK is sensitive to biomass assumptions and the level of the cost counterfactual. However, wind costs have a greater impact due to greater reliance on wind energy in the UK's renewable resource potential.

4.3 Areas for further work

This study has also highlighted several areas of data inadequacy or lack of information that BERR should investigate further in order to substantiate these results. In particular, the following primary research would improve our understanding of the risk on compliance costs.

- An audit of available biomass resource potential across the EU.
- Analysis of the sensitivity of transport biofuels assumptions to views on food/non-food substitution, crop substitution, sustainability conditions and the interaction with solid biomass resource and electricity and heat sector demand (especially in relation to second generation biofuel production).
- Review of the carbon footprint associated with biofuel use and hence the effective carbon savings generated through biofuel use.
- Investigation of potential supply chain and other constraints on increased renewable deployment across the EU and the additional cost of overcoming them.
- Investigation of other barriers to deployment which could affect the extent to which the least cost mix of technologies could be deployed and their effect on:
  - total compliance costs;
  - the deliverable renewables mix; and
  - the structure and form of renewable support mechanisms to minimise barriers whilst targeting deliverable technologies.
- The form and scope of a European green certificate trading system to facilitate cost savings identified in the least cost solution, which is reliant on trading, and the extent to which such a scheme could sit alongside existing domestic support mechanisms.

ANNEX A – DETAILED ASSUMPTIONS FOR RENEWABLE ENERGY MODELLING

The following slides present our detailed input assumptions used in the modelling of the renewable heat and electricity sector technologies for the EU27 member states considered for this project.

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Detailed assumptions for renewable electricity and heat modelling

Department for Business, Enterprise and Regulatory Reform

February 2008

Agenda

Introduction

- This set of slides provides a detailed summary of the input assumptions used in the modelling of the renewable heat and electricity sector technologies for the 27 EU member states in this project.
- The assumptions presented in this slide pack were used to create a core “Central Case”, against which a number of sensitivities were run to test the significance of certain cost and resource variables.
- Volumetric and cost assumptions for the period 2010 – 2020 were agreed with BERR after review of publicly available data sources.
- Assumptions for the modelling of the transport bio-fuels market are presented in a separate slide pack.
- Unless otherwise stated, all monetary values are presented in real 2006 prices.

Country groupings

- While the analysis undertaken allowed for renewable energy output for each EU-27 Member State to be projected, lack of data or similarity in country characteristics meant that for some assumptions, broader country groupings were used.

- **United Kingdom**
- **Ireland**
- **Austria and Italy**
- **Poland+** (Poland, Bulgaria, Romania, Hungary, Czech Republic)
- **Iberia** (Spain and Portugal)
- **France**
- **Benelux** (Belgium, the Netherlands, Luxembourg)
- **Germany**
- **Greece+** (Greece, Malta, Cyprus)
- **Slovakia+** (Slovakia, Slovenia, Lithuania, Estonia, Latvia)
- **Finland and Sweden**
- **Denmark**

Technologies represented

- Renewable electricity and heat resource for each EU member state are broken down into the following technologies.

Renewable electricity technologies

- Onshore wind
- Offshore wind
- Biomass
- Biowaste
- Biogas
- Solar PV
- Solar thermal
- Large Hydro (>100MW)
- Small Hydro (<10MW)
- Geothermal
- Wave
- Tidal stream

Renewable heat technologies

- Biomass heat (grid connected)
- Biomass heat (non-grid connected)
- Solar heat
- Geothermal heat
- Ground source heat pumps (GSHP)

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We used five key steps to determine the relative costs and potential for renewable energy across the EU27

1. Identifying the baseline renewable growth that would occur without the policy (i.e. the business as usual position).

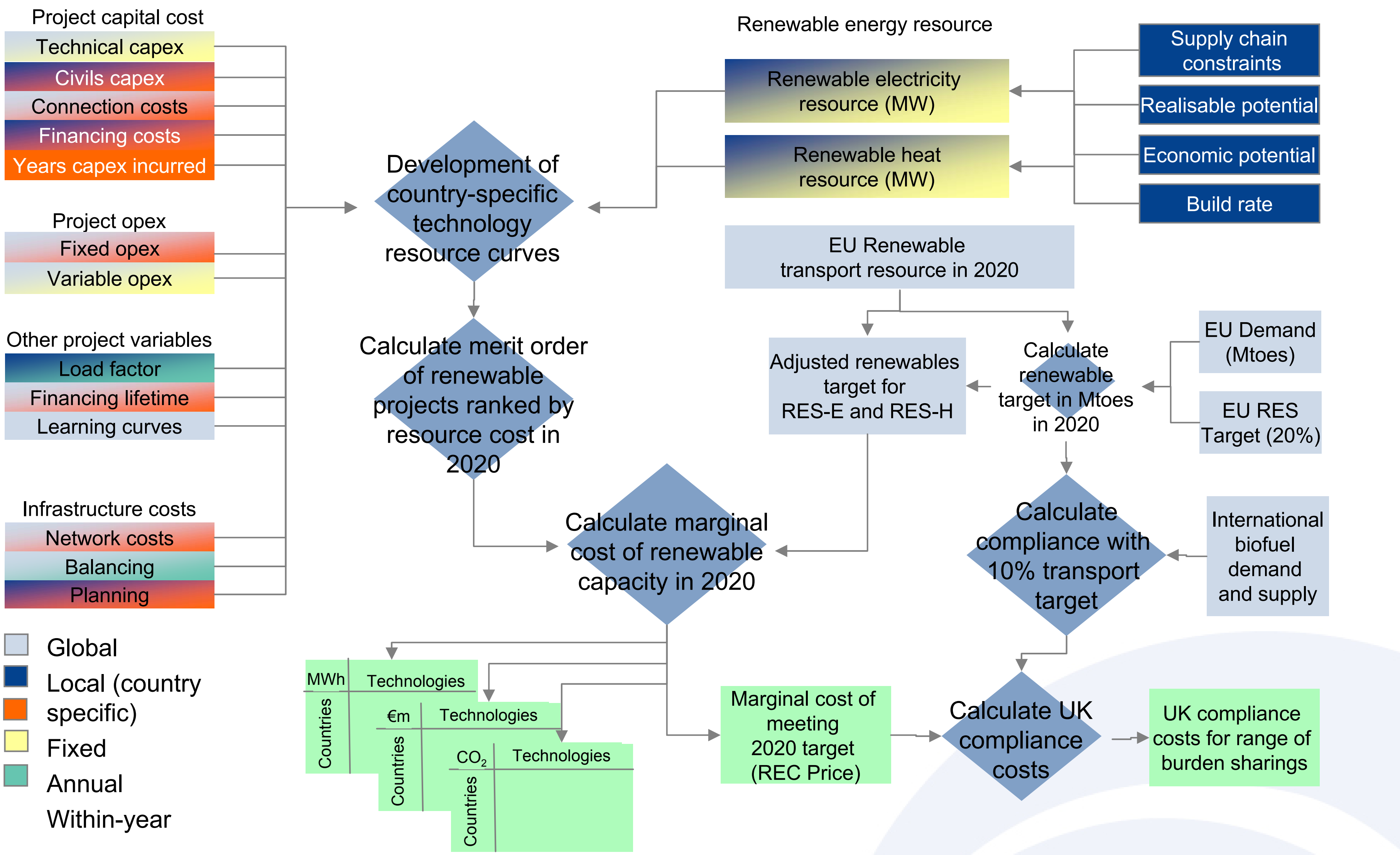
2. Defining the target for renewable energy supply against which to measure compliance with the target (and hence determine the additional volumes that are required).

3. Researching the costs and resource potential of the different technologies and countries.

4. Constructing a supply curve of technologies to determine the incremental renewable supply curve.

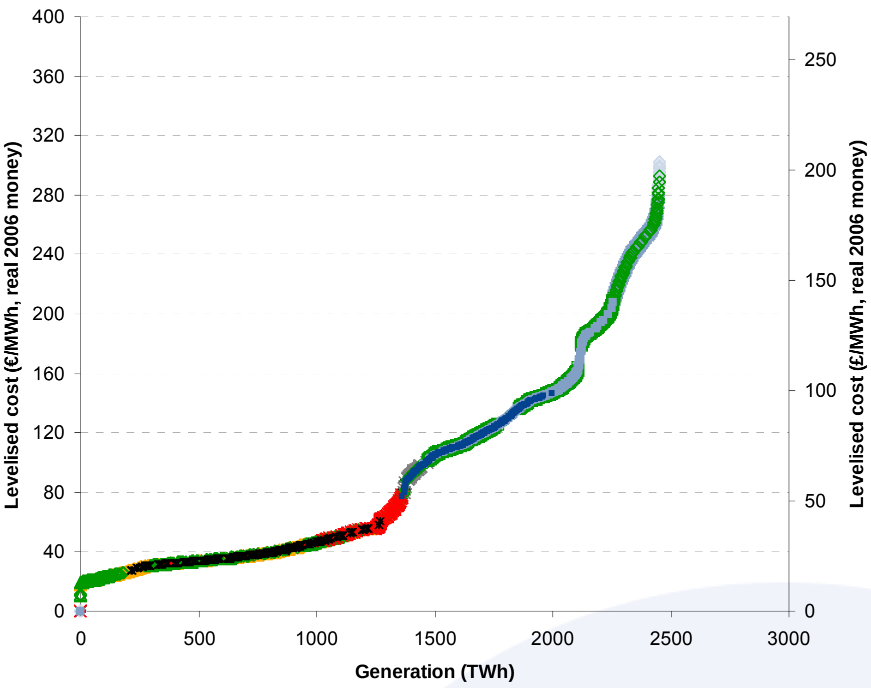
5. Calculating the costs of compliance for each member state against a pre-defined policy position (in terms of the country burden shares and the degree to which action is constrained to occur domestically).

These five steps were implemented using the following methodology



One of the main modelling outputs was to create a renewable energy supply curve

- Using the volume and cost data researched for this project, we have constructed a merit order of renewable resource which are ranked by levelised cost and resource cost.
- The merit order enables the comparison of costs across countries, RES-E and RES-H technologies and time periods.
- For each year that resource is projected to be built, we have also introduced additional cost differentiation (High, Low and Central points on the curve) through assumptions on proportions of annual volume that would come to market at, above or below, the central levelised cost.



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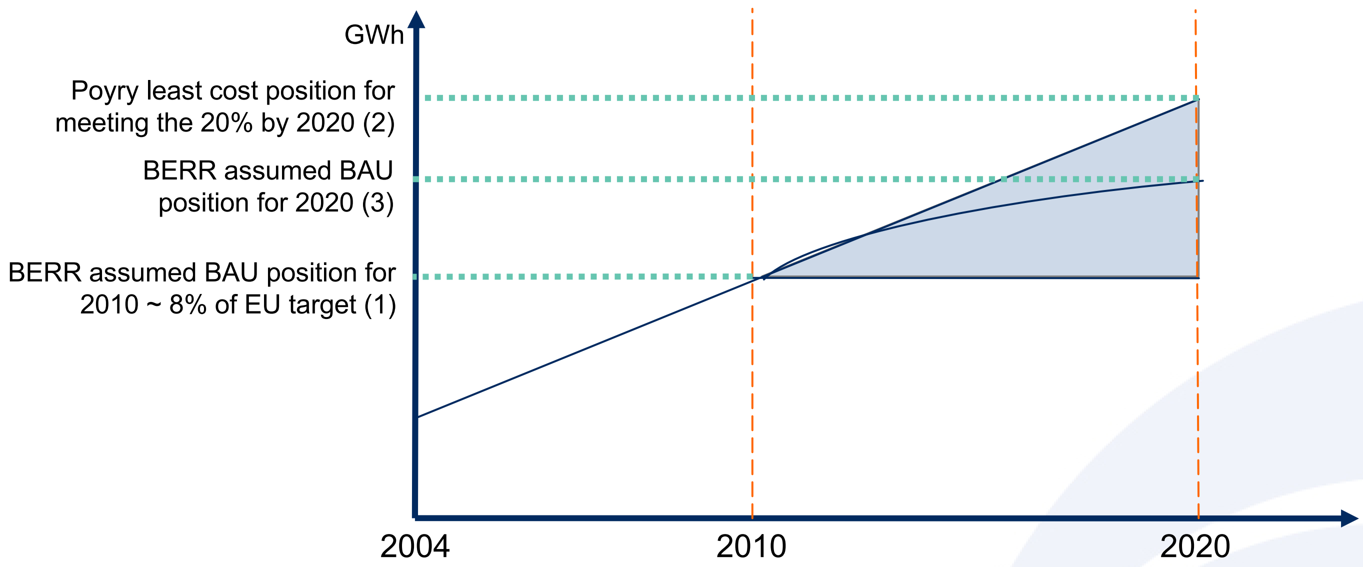
Renewable energy resource – principles

- In assessing the cost of meeting the 2020 renewable energy target, we split resource into:
  - Business As Usual (BAU) – resource which would have been built under existing renewable policies post 2010; and
  - Additional – resource built as a response to the new 2020 renewable energy target.
- Our BAU for the electricity and heat sectors is taken from the “Baseline” scenario as detailed in the EC European Energy and Transport: Trends to 2030 – update 2005.
- Figures are provided for each country for 2010, 2015 and 2020. Our BAU assumes linear interpolation between these points.
- Volumes are allocated across technologies according to their share of total maximum additional potential, as presented in the Green-X analysis from ISI, EEG and Ecofys “Economic analysis of reaching a 20% share of renewable energy sources in 2020”).
  - For 2010 it is assumed wave and tidal make no contribution
- We have considered the renewable target as corresponding to the ratio between renewable energy production (i.e. on an ‘output’ basis) and the Final Energy Demand (FED).

Renewable energy resource – methodology

- The 2010 baseline (1) and the projected business as usual (BAU) growth in renewable energy over the period 2011 to 2020 (3) is based on the EC “Baseline” scenario.
- The additional volume required to meet the 2020 target is derived from the least cost resource curve as projected by Poyry Energy Consulting.
- The BAU renewable growth (3) is netted off the total growth (2) to produce the incremental volume associated with meeting the 2020 target.
- The incremental resource costs by 2020 are then calculated on the basis of the incremental renewable growth volumes.



Baseline RES-E and RES-H volumes 2010 and 2020 (output basis, TWh)

BAU in 2010

	RES-E TWh	RES-H TWh	RES-T TWh	Total TWh	Total % of FED
Austria	55	29	4	88	26.6%
Belgium	5	6	5	16	3.5%
Bulgaria	4	8	1	13	10.6%
Cyprus	0	1	0	1	5.3%
Czech Republic	4	11	4	18	5.4%
Denmark	13	15	1	29	15.8%
Estonia	1	5	0	6	17.0%
Finland	29	28	1	59	18.4%
France	90	144	26	259	13.0%
Germany	95	112	33	240	8.7%
Greece	10	9	4	23	8.1%
Hungary	1	10	1	12	5.4%
Ireland	4	3	2	9	5.6%
Italy	70	40	16	126	7.9%
Latvia	4	13	1	17	31.7%
Lithuania	1	7	1	8	14.6%
Luxembourg	0	1	1	2	4.0%
Malta	0	0	0	0.1	1.1%
Netherlands	13	7	6	26	4.0%
Poland	10	53	6	69	8.8%
Portugal	21	11	3	36	15.2%
Romania	19	36	2	57	15.3%
Slovakia	5	3	1	9	5.8%
Slovenia	4	4	1	9	13.4%
Spain	81	62	18	162	13.0%
Sweden	78	69	5	152	36.0%
United Kingdom	31	18	13	63	3.3%
EU27	**649**	**706**	**157**	**1512**	**10.1%**

BAU in 2020

	RES-E TWh	RES-H TWh	RES-T TWh	Total TWh	Total % of FED
Austria	62	30	5	98	27.8%
Belgium	7	11	8	26	5.4%
Bulgaria	5	9	3	18	10.3%
Cyprus	0	1	0	2	7.3%
Czech Republic	5	14	6	25	6.6%
Denmark	19	13	2	34	18.0%
Estonia	1	6	1	8	16.6%
Finland	33	35	2	70	21.4%
France	123	146	42	311	14.9%
Germany	133	147	52	332	11.6%
Greece	17	11	7	34	10.6%
Hungary	4	13	3	20	7.6%
Ireland	6	5	4	15	8.3%
Italy	87	52	26	165	9.6%
Latvia	5	15	1	20	29.9%
Lithuania	2	9	1	13	17.6%
Luxembourg	0	2	2	4	6.9%
Malta	0	0	0	0.2	2.7%
Netherlands	19	14	10	43	6.1%
Poland	25	82	12	118	11.9%
Portugal	27	10	5	42	15.9%
Romania	24	42	6	72	14.1%
Slovakia	9	5	2	16	8.1%
Slovenia	5	4	1	10	13.7%
Spain	123	73	32	227	16.2%
Sweden	89	62	8	159	35.5%
United Kingdom	50	37	26	112	5.6%
EU27	**879**	**848**	**268**	**1995**	**12.3%**

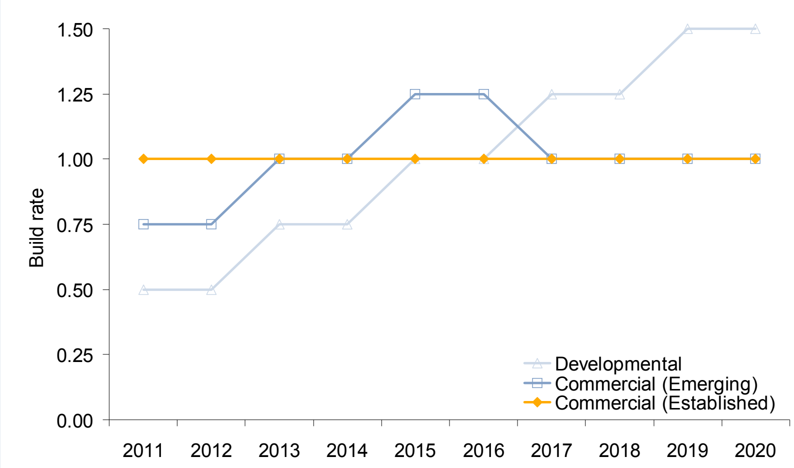
Build rate profiles

- The maximum available resource is assumed to be released to the market according to build rate profiles relative to an annual average build rate that would enable the maximum potential to be reached.

- A number of different build rate profiles are used that reflect the state of development of the technology and the maturity of the national market:
  - Commercial established;
  - Commercial emerging; or
  - Developmental.

- For some technologies, where the maximum available resource would never be reached, we have assumed a portion of the three main build rate types.

Assumed build rates



Build rate type assumed per technology

	UK, Germany, France, Denmark, Iberia, Ireland, Benelux, Finland+, Italy+	Poland+, Slovakia+	Greece+
Commercial (Established)	Onshore Wind, Biomass, Biogas, Hydro, Geothermal (Heat and Electricity), Biomass Heat (Grid and Non-Grid Connected)	Biogas, Hydro, Geothermal (Heat and Electricity)	Onshore Wind, Biomass, Biogas, Hydro, Geothermal (Heat and Electricity), Biomass Heat (Grid and Non-Grid Connected)
Commercial (Emerging)	Offshore Wind, Solar PV	Onshore Wind, Offshore Wind, Biomass, Solar PV, Biomass Heat (Grid and Non-Grid Connected)	Offshore Wind, Solar PV
Developmental	Solar Thermal, Wave, Tidal Stream	Solar Thermal, Wave, Tidal Stream	Solar Thermal, Wave, Tidal Stream
1/2 Commercial (Emerging)	Heat Pumps	Heat Pumps	Heat Pumps
1/2 Developmental	Solar Heat	Solar Heat	Solar Heat
1/4 Commercial (Established)	Biowaste		Biowaste
1/4 Commercial (Emerging)		Biowaste	

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Main studies used for the cost input assumptions

- A wide range of sources have been investigated as part of this study, with the following sources used for the final set of cost assumptions. In deciding which sources to use, we have chosen those which allow for consistency across the EU within this study.

Report reference	Author	Publication title	Year of report
DEA	Danish Energy Authority	Technology Data for Electricity and Heat Generating Plants	2005
DTI	Enviros	The costs of supplying renewable energy	2005
E&Y	Ernst and Young	Impact of banding the Renewables Obligation – Costs of electricity production	2007
EC_WETO	European Commission Director-General for Research	World energy, technology and climate policy outlook (WETO)	2003
EEE	Energy Saving Trust, Econnect, and Element Energy	Potential for Microgeneration Study and Analysis	2005
F/E/E	Fraunhofer ISI, Energy Economics Group and Ecofys	Economic analysis of reaching a 20% share of renewable energy sources in 2020- Annex 1 to the final report	2005
Green-X	Green-X	Deriving Optimal Promotion Strategies for Increasing the Share of RES-E in a Dynamic European Electricity Market	2003
IEA	NEA, IEA, OECD	Projected Costs of Generating Electricity - Update 2005	2005
RECaBS	IEA	Renewable Energy Costs and Benefits for Society (RECaBS)	2007
Vattenfall	Vattenfall	Global Mapping of Greenhouse Gas Abatement Opportunities up to 2030: Power sector deep-dive	2007

Choice of cost elements for building up supply curves

- The cost curves for each technology are derived from a bottom-up cost calculation with the following costs differentiated for each technology type.

- Project costs:
  - Technical CAPEX – costs of the actual technology used e.g. turbine
  - Civils CAPEX – construction costs involved in developing a project
  - Connection CAPEX – costs involved in connecting the project to the electricity or heat grid
  - Planning CAPEX
  - Finance – costs involved in financing the project
  - Fixed Operation and Maintenance (O&M)
  - Variable O&M – mainly fuel costs

- Infrastructure costs:
  - System integration costs – network and balancing costs

Each of the cost elements have been distinguished as to whether they are global, local, fixed, annual or proportional

- Global or local
  - cost element is set by the global market (e.g. cost of a turbine) or is affected by local economics (e.g. costs involved in installing GSHP within a particular country)
- Fixed or Annual
  - whether the cost is fixed over time or changes over time, taking into account learning curves
- Proportional
  - cost is proportional to deployment (e.g. system balancing costs increase as more intermittent generation is connected to the electricity network)

	Time variability		Country variability		Propotional to Deployment
	Fixed	Annual	Global	Local	
Projects					
Technical CAPEX		✓	✓		
Civils CAPEX	✓			✓Wage relativity	
Connection CAPEX	✓		✓ ←	?	
Planning CAPEX	✓		✓ ←	?	
Finance Costs	✓			✓	
Opex					
- fixed	✓ ←	?	✓		
- variable		✓Fuel cost assumptions		✓	
Load Factor				✓	✓
Project Life	✓		✓		
Infrastructure					
System integration					
- Network costs	✓		✓		
- Balancing			✓System costs		✓

Notes:
- Finance costs are localised through country specific discount rates
- Fixed opex is predominantly related to technology rather than location.
- Network costs and connection are more of an influence of local regulatory regimes, but the project assumes a harmonised approach by 2020

We have broken down, where possibly, the total CAPEX into the various elements using the following splits for RES-E

- We have based the breakdown of the various capex elements using the splits as provided by the recent E&Y analysis “Costs of electricity production” undertaken for the DTI as part of the RO banding review.

- This split was applied to the total capex numbers for the year 2010 for the UK as a basis.

- Various local factors, for example, Civils CAPEX and finance costs together with technology-specific factors, such as learning rates, were then applied to the various elements to derive a country-specific total technology capex cost.

	Technical	Civils	Connection	Planning
Onshore Wind	66%	17%	14%	3%
Offshore Wind	52%	46%	0%	2%
Biomass	60%	28%	8%	4%
Biowaste	64%	28%	4%	4%
Biogas	55%	10%	30%	5%
Solar PV	65%	10%	15%	10%
Solar Thermal	No data available			
Large Hydro	50%	30%	15%	5%
Small Hydro	60%	20%	10%	10%
Geothermal	No data available			
Wave	50%	20%	20%	10%
Tidal Stream	55%	20%	20%	5%

Source: Ernst & Young, Pöyry analysis

For RES-E, reductions in technical CAPEX are calculated through applying a learning rate for every doubling of global capacity

- We have considered a number of sources for our learning rates, with the final selection of learning rates generally reflecting the mid-range of the various sources.
- For technologies where CAPEX breakdowns were not available, the learning rates were applied to the total capex:
  - solar thermal; and
  - geothermal
- The assumed increase in global capacity was sourced from the International Energy Agency's (IEA) World Energy Outlook for 2006 for the majority of renewable electricity technologies.

Learning Rates	Green X	Vattenfall	DTI (Enviros)	Pöyry Assumption
Onshore Wind	91%	89%	92%	**91%**
Offshore Wind	91%	89%	85%	**91%**
Biomass	95%	95%	85%	**85%**
Biowaste	95%	-	-	**95%**
Biogas	95%	-	85-92%	**95%**
Solar PV	85-90%	82%	85%	**85%**
Solar Thermal	85-90%	97.5%	-	**90%**
Large Hydro	100%	-	-	**100%**
Small Hydro	100%	95%	90%	**100%**
Geothermal	95%	-	-	**95%**
Wave	-	-	85%	**85%**
Tidal	-	-	85%	**85%**

Notes:

The learning curves for onshore and offshore wind are considered to be the same since the learning curve for these two technologies relates solely to the turbine element of wind costs, where onshore and offshore cost reductions can be expected to be comparable

Global Installed Capacity (GW)	2004	2015	2030
Hydro	851	1079	1373
Biomass and Waste	36	68	129
Wind	48	168	430
Geothermal	8	15	25
Solar Thermal	4	20	87
Tidal and Wave	0	0	3

Source: IEA World Energy Outlook 2006

This provided us with the following reductions in technical CAPEX for the various RES-E technologies to 2020

Technical Capex in €/kW for RES-E technologies

€/kW	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Onshore Wind	1040	1040	1040	1040	997	953	909	865	822	778	734	691	647	603
Offshore Wind	1161	1161	1161	1161	1100	1039	978	917	857	796	735	674	613	552
Biomass	1563	1563	1563	1563	1542	1523	1505	1488	1471	1456	1442	1428	1415	1402
Biowaste	3475	3475	3475	3475	3461	3448	3436	3424	3413	3403	3393	3383	3374	3365
Biogas	1911	1911	1911	1911	1903	1896	1888	1882	1875	1869	1863	1857	1852	1847
Solar PV	3900	3900	3900	3900	3784	3684	3596	3518	3449	3386	3329	3276	3228	3183
Solar Thermal	3119	3119	3119	3119	3059	3006	2960	2918	2880	2846	2815	2786	2759	2734
Large Hydro	800	800	800	800	800	800	800	800	800	800	800	800	800	800
Small Hydro	1188	1188	1188	1188	1188	1188	1188	1188	1188	1188	1188	1188	1188	1188
Geothermal	1626	1626	1626	1626	1620	1614	1608	1602	1597	1592	1587	1583	1578	1574
Wave	1990	1990	1990	1990	1920	1860	1810	1766	1727	1692	1660	1632	1606	1581
Tidal Stream	2388	2388	2388	2388	2304	2233	2172	2119	2072	2030	1992	1958	1927	1898

Source: Pöyry

Technical Capex in £/kW for RES-E technologies

£/kW	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Onshore Wind	701	701	701	701	672	642	613	583	554	524	495	465	436	406
Offshore Wind	782	782	782	782	741	700	659	618	577	536	495	454	413	372
Biomass	1054	1054	1054	1054	1040	1026	1014	1003	992	981	972	962	954	945
Biowaste	2342	2342	2342	2342	2333	2324	2316	2308	2301	2294	2287	2280	2274	2268
Biogas	1288	1288	1288	1288	1283	1278	1273	1268	1264	1260	1256	1252	1248	1245
Solar PV	2629	2629	2629	2629	2550	2483	2424	2371	2325	2282	2244	2208	2176	2145
Solar Thermal	2102	2102	2102	2102	2062	2026	1995	1967	1941	1918	1897	1878	1860	1843
Large Hydro	539	539	539	539	539	539	539	539	539	539	539	539	539	539
Small Hydro	801	801	801	801	801	801	801	801	801	801	801	801	801	801
Geothermal	1096	1096	1096	1096	1092	1088	1084	1080	1076	1073	1070	1067	1064	1061
Wave	1341	1341	1341	1341	1294	1254	1220	1190	1164	1140	1119	1100	1082	1066
Tidal Stream	1610	1610	1610	1610	1553	1505	1464	1428	1396	1368	1343	1320	1299	1279

Source: Pöyry

Civils CAPEX figures vary according to local wage relativities

- We have assumed civils costs proportional to reported labour costs by country.
- This is based on data published by the Eurostat on hourly labour costs for the various EU member states.
- For those technologies where a cost breakdown was available, which due to the availability of public data was based on sources with UK values, a percentage was applied to the technology's civils CAPEX element to derive a non-UK country specific civils CAPEX cost.
- This percentage was based on an Index using the hourly labour costs with UK=100.

	Average hourly labour costs (€)	Index UK = 100
Austria	24.53	100%
Belgium	30.73	113%
Bulgaria	1.55	53%
Cyprus	8.35	67%
Czech Republic	6.63	64%
Denmark	31.98	115%
Estonia	4.67	60%
Finland	26.39	104%
France	29.29	110%
Germany	26.43	104%
Greece	8.35	67%
Hungary	6.14	63%
Ireland	24.47	100%
Italy	24.53	100%
Latvia	2.77	56%
Lithuania	3.56	57%
Luxembourg	31.1	114%
Malta	8.35	67%
Netherlands	27.41	106%
Poland	5.55	61%
Portugal	10.6	72%
Romania	2.33	55%
Slovakia	4.8	60%
Slovenia	10.76	72%
Spain	15.22	81%
Sweden	26.39	104%
United Kingdom	24.47	100%

Source: Eurostat, Pöyry

The other capex elements – Connection and Planning CAPEX - were kept fixed throughout the period (2010-2020) for RES-E

Connection Capex in €/kW for RES-E technologies*

€/kW	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Onshore Wind	221	221	221	221	221	221	221	221	221	221	221	221	221	221
Offshore Wind	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biomass	208	208	208	208	208	208	208	208	208	208	208	208	208	208
Biowaste	217	217	217	217	217	217	217	217	217	217	217	217	217	217
Biogas	1043	1043	1043	1043	1043	1043	1043	1043	1043	1043	1043	1043	1043	1043
Solar PV	900	900	900	900	900	900	900	900	900	900	900	900	900	900
Solar Thermal	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Large Hydro	240	240	240	240	240	240	240	240	240	240	240	240	240	240
Small Hydro	198	198	198	198	198	198	198	198	198	198	198	198	198	198
Geothermal	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wave	796	796	796	796	796	796	796	796	796	796	796	796	796	796
Tidal Stream	868	868	868	868	868	868	868	868	868	868	868	868	868	868

Source: Pöyry

Planning Capex in €/kW for RES-E technologies*

€/kW	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Onshore Wind	47	47	47	47	47	47	47	47	47	47	47	47	47	47
Offshore Wind	45	45	45	45	45	45	45	45	45	45	45	45	45	45
Biomass	104	104	104	104	104	104	104	104	104	104	104	104	104	104
Biowaste	217	217	217	217	217	217	217	217	217	217	217	217	217	217
Biogas	174	174	174	174	174	174	174	174	174	174	174	174	174	174
Solar PV	600	600	600	600	600	600	600	600	600	600	600	600	600	600
Solar Thermal	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Large Hydro	80	80	80	80	80	80	80	80	80	80	80	80	80	80
Small Hydro	198	198	198	198	198	198	198	198	198	198	198	198	198	198
Geothermal	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wave	398	398	398	398	398	398	398	398	398	398	398	398	398	398
Tidal Stream	217	217	217	217	217	217	217	217	217	217	217	217	217	217

Source: Pöyry

*CAPEX breakdowns were not available for Solar thermal and Geothermal

BERR - Estimating costs of renewables for the 2020 target

We have combined these various elements to derive the total CAPEX for each RES-E technology for all EU27 member states

- Example of how the total capex various between two selected countries – UK and Germany

Total Capex in €/kW for RES-E technologies for the UK

€/kW	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Onshore Wind	1576	1576	1576	1576	1533	1489	1445	1401	1358	1314	1270	1226	1183	1139
Offshore Wind	2232	2232	2232	2232	2171	2110	2050	1989	1928	1867	1806	1745	1685	1624
Biomass	2605	2605	2605	2605	2585	2565	2547	2530	2514	2498	2484	2470	2457	2444
Biowaste	5430	5430	5430	5430	5416	5403	5391	5379	5368	5358	5348	5338	5329	5320
Biogas	3475	3475	3475	3475	3467	3459	3452	3445	3439	3433	3427	3421	3416	3411
Solar PV	6000	6000	6000	6000	5884	5784	5696	5618	5549	5486	5429	5376	5328	5283
Solar Thermal	3119	3119	3119	3119	3059	3006	2960	2918	2880	2846	2815	2786	2759	2734
Large Hydro	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600
Small Hydro	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980
Geothermal	1626	1626	1626	1626	1620	1614	1608	1602	1597	1592	1587	1583	1578	1574
Wave	3981	3981	3981	3981	3910	3851	3800	3756	3717	3682	3651	3622	3596	3572
Tidal Stream	4342	4342	4342	4342	4258	4187	4126	4073	4026	3984	3946	3912	3881	3852

Source: Pöyry

Total Capex in €/kW for RES-E technologies for Germany

€/kW	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Onshore Wind	1587	1587	1587	1587	1543	1500	1456	1412	1368	1325	1281	1237	1193	1150
Offshore Wind	2273	2273	2273	2273	2212	2152	2091	2030	1969	1908	1847	1787	1726	1665
Biomass	2635	2635	2635	2635	2614	2594	2576	2559	2543	2528	2513	2499	2486	2474
Biowaste	5491	5491	5491	5491	5477	5464	5452	5440	5429	5418	5408	5399	5390	5381
Biogas	3489	3489	3489	3489	3481	3473	3466	3459	3453	3447	3441	3435	3430	3425
Solar PV	6024	6024	6024	6024	5908	5808	5720	5642	5573	5510	5453	5400	5352	5307
Solar Thermal	3119	3119	3119	3119	3059	3006	2960	2918	2880	2846	2815	2786	2759	2734
Large Hydro	1632	1632	1632	1632	1632	1632	1632	1632	1632	1632	1632	1632	1632	1632
Small Hydro	1996	1996	1996	1996	1996	1996	1996	1996	1996	1996	1996	1996	1996	1996
Geothermal	1626	1626	1626	1626	1620	1614	1608	1602	1597	1592	1587	1583	1578	1574
Wave	4012	4012	4012	4012	3942	3883	3832	3788	3749	3714	3682	3654	3628	3604
Tidal Stream	4377	4377	4377	4377	4292	4221	4161	4108	4061	4019	3981	3947	3916	3887

Source: Pöyry

For RES-H technologies there was a lack of information regarding the breakdown of the total capex

- We have applied learning rates, or similar, to the total capex to calculate how the costs change over time for RES-H technologies.

- For Solar Heat, Ground Source Heat Pumps (GSHP) and Geothermal Heat we have applied learning rates for every doubling of global capacity.

- The assumed increase in geothermal global capacity was sourced from the IEA's World Energy Outlook for 2004, whilst for solar heat and GSHP we used the views of E/E/E's "Potential for Microgeneration Study".

- For Biomass Heat technologies, where learning rates were not available, we have assumed an annual capex reduction factor based on F/E/E's "Economic analysis of reaching a 20% share of renewable energy sources in 2020"

Learning Rates	E/E/E	F/E/E	DEA	Pöyry Assumption
Solar Heat	82%	95%		**95%**
GSHP	85%		100%	**91%**
Geothermal Heat		95%		**95%**

Source:

- Energy Saving Trust, Econnect and Element Energy (E/E/E)
- Fraunhofer ISI, Energy Economics Group and Ecofys (F/E/E)
- Danish Energy Agency (DEA)

	Global Growth Rates
Solar Heat	Growth rate based on E/E/E's views of the global growth in the use of solar heat
GSHP	Growth rate based on E/E/E's views of the global growth in the use of GSHP
Geothermal Heat	Growth rate based on IEA's views of the global growth in the use of geothermal heat

Source:

- Energy Saving Trust, Econnect and Element Energy (E/E/E)
- International Energy Agency (IEA)

	Annual capex reduction factor
Biomass Heat Non Grid	Annual 1.5% reduction
Biomass Heat Grid Connected	Annual 1.5% reduction

Source:

- Fraunhofer ISI, Energy Economics Group and Ecofys (F/E/E)

This provides us with the following reductions in total CAPEX for the various RES-H technologies to 2020

- Due to capex breakdowns not being available for RES-H technologies, the “local factor” has been applied through the use of country-specific discount rates (see slide 35).

Total Capex in €/kW for RES-H technologies

€/kW	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Biomass Heat Non Grid	470	470	470	470	463	456	449	442	436	429	423	416	410	404
Biomass Heat Grid Connected	425	425	425	425	419	412	406	400	394	388	382	377	371	365
Solar Heat	1336	1336	1336	1336	1317	1298	1281	1263	1246	1230	1213	1198	1183	1168
GSHP	1366	1366	1366	1366	1331	1296	1264	1232	1202	1173	1145	1118	1092	1067
Geothermal Heat	1533	1533	1533	1533	1477	1441	1415	1394	1377	1363	1350	1339	1329	1320

Source: Pöyry

Total Capex in £/kW for RES-H technologies

£/kW	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Biomass Heat Non Grid	317	317	317	317	312	307	303	298	294	289	285	281	276	272
Biomass Heat Grid Connected	286	286	286	286	282	278	274	270	266	262	258	254	250	246
Solar Heat	900	900	900	900	888	875	863	851	840	829	818	807	797	787
GSHP	921	921	921	921	897	874	852	831	810	790	772	753	736	719
Geothermal Heat	1033	1033	1033	1033	996	971	954	940	928	918	910	903	896	890

Source: Pöyry

We have assumed a single global value to be applied to the fixed Opex element for each RES-E and RES-H technology

- We have assumed a fixed annual Opex cost for each of the RES-E and RES-H technologies, since Opex is predominantly related to the technology rather than where the resource is located.
- RES-E Opex costs have been sourced from the recent E&Y analysis "Costs of electricity production" undertaken for the DTI as part of the RO banding review; Green-X's "Deriving Optimal Promotion Strategies for Increasing the Share of RES-E in a Dynamic European Electricity Market" and Poyry analysis.
- RES-H Opex costs have been sourced from F/E/E's "Economic analysis of reaching a 20% share of renewable energy sources in 2020"

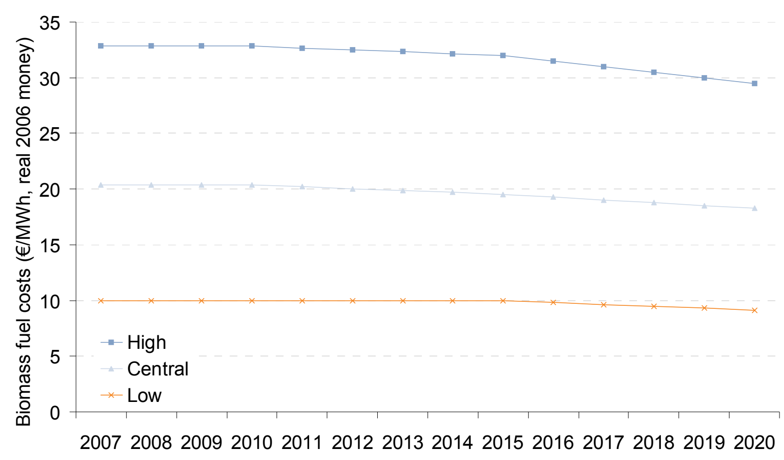
€/kW	Opex	Source
Onshore Wind	59	E&Y Central
Offshore Wind	117	E&Y Central
Biomass	90	E&Y Central
Biowaste	141	Green X Central
Biogas	195	E&Y Central
Solar PV	72	E&Y Central
Solar Thermal	206	Green X Central
Large Hydro	36	E&Y Central
Small Hydro	58	E&Y Central
Geothermal	54	Pöyry
Wave	119	E&Y Central
Tidal	109	E&Y Central

€/kW	Opex	Source
Biomass Heat Non Grid	8	F/E/E
Biomass Heat Grid Connected	19	F/E/E
Solar Heat	13	F/E/E
GSHP	68	F/E/E
Geothermal Heat	56	F/E/E

Our variable fuel costs for biomass reflect the local sourcing of materials in each country

- Our High, Central and Low biomass fuel costs were sourced from the recent E&Y analysis “Costs of electricity production”.
- These were assigned to each EU member state based on an indexation using cost and volume data in EUBioNet2’s “Biomass fuel trade in Europe: Summary Report VTT-R-03508-07”.
- This indexation was calculated using a volume-weighted average price of a country’s biomass resource to determine whether the country used mainly cheap, mid-priced or expensive sources of biomass.

Biomass fuel costs assumed for each cost band



Country groupings for biomass fuel costs

Cost band	Countries included in the cost band
High	Denmark, France, Hungary, Netherlands, Spain.
Central	Austria, Belgium, Finland, Germany, Ireland, Luxembourg, Sweden, UK.
Low	Bulgaria, Czech Republic, Cyprus, Estonia, Greece, Italy, Latvia, Lithuania, Malta, Poland, Portugal, Romania, Slovakia, Slovenia.

Annual average load factors assumed in modelling the additional RES-E resource that would generate in response to the 2020 target

Assumed annual average load factors for RES-E projects

Load factors (%)	Onshore Wind	Offshore Wind	Biomass	Biowaste	Biogas	Solar PV	Solar Thermal	Large Hydro	Small Hydro	Geothermal	Wave	Tidal Stream
Austria	21%	0%	73%	73%	59%	9%	0%	44%	50%	85%	0%	0%
Belgium	21%	31%	73%	73%	63%	8%	0%	34%	20%	0%	30%	35%
Bulgaria	23%	34%	73%	73%	61%	8%	0%	38%	42%	85%	30%	35%
Cyprus	22%	29%	73%	73%	58%	11%	0%	0%	0%	0%	30%	35%
Czech Republic	23%	0%	73%	73%	61%	8%	0%	38%	42%	0%	0%	0%
Denmark	24%	34%	73%	73%	62%	8%	0%	0%	0%	0%	30%	35%
Estonia	23%	34%	73%	73%	61%	9%	0%	0%	40%	0%	30%	35%
Finland	22%	31%	73%	73%	60%	7%	0%	52%	47%	0%	30%	35%
France	24%	33%	73%	73%	61%	9%	0%	36%	42%	85%	30%	35%
Germany	20%	34%	73%	73%	61%	8%	0%	68%	32%	0%	30%	35%
Greece	22%	29%	73%	73%	58%	11%	34%	16%	32%	85%	0%	35%
Hungary	23%	0%	73%	73%	61%	8%	0%	38%	42%	0%	0%	0%
Ireland	28%	39%	73%	73%	60%	8%	0%	41%	35%	0%	30%	35%
Italy	21%	27%	73%	73%	59%	9%	33%	44%	50%	85%	0%	35%
Latvia	23%	34%	73%	73%	61%	9%	0%	50%	40%	0%	30%	35%
Lithuania	23%	34%	73%	73%	61%	9%	0%	50%	40%	0%	30%	35%
Luxembourg	21%	0%	73%	73%	63%	8%	0%	0%	0%	0%	0%	0%
Malta	22%	29%	73%	73%	58%	11%	0%	0%	0%	0%	30%	35%
Netherlands	21%	31%	73%	73%	63%	8%	0%	0%	20%	0%	30%	35%
Poland	23%	34%	73%	73%	61%	8%	0%	38%	42%	0%	30%	35%
Portugal	22%	31%	73%	73%	59%	13%	34%	26%	24%	85%	30%	35%
Romania	23%	34%	73%	73%	61%	8%	0%	38%	42%	85%	30%	35%
Slovakia	23%	0%	73%	73%	61%	9%	0%	50%	40%	0%	0%	0%
Slovenia	23%	0%	73%	73%	61%	9%	0%	50%	40%	0%	0%	0%
Spain	22%	31%	73%	73%	59%	13%	34%	26%	24%	85%	30%	35%
Sweden	22%	31%	73%	73%	60%	7%	0%	52%	47%	0%	30%	35%
United Kingdom	27%	37%	73%	73%	61%	8%	0%	37%	37%	0%	30%	35%

Source: Green-X, Pöyry assumptions for geothermal and E&Y for wave and tidal

Notes:

Where 0% exists, this should be inferred as no resource of this particular technology type is available in this country

Annual average load factors assumed in modelling the additional RES-H resource that would generate in response to the 2020 target

Assumed annual average load factors for RES-H projects

Load factors (%)	Biomass Heat Non Grid	Biomass Heat Grid Connected	Solar Heat	Geothermal Heat	Ground Source Heat Pumps
Austria	17%	51%	18%	50%	30%
Belgium	38%	65%	13%	50%	30%
Bulgaria	0%	0%	13%	50%	30%
Cyprus	17%	51%	18%	0%	30%
Czech Republic	38%	65%	13%	50%	30%
Denmark	51%	74%	10%	50%	30%
Estonia	19%	53%	16%	0%	30%
Finland	51%	74%	10%	0%	30%
France	19%	53%	16%	50%	30%
Germany	38%	65%	13%	50%	30%
Greece	17%	51%	18%	50%	30%
Hungary	38%	65%	13%	50%	30%
Ireland	51%	74%	10%	50%	30%
Italy	17%	51%	18%	50%	30%
Latvia	19%	53%	16%	0%	30%
Lithuania	19%	53%	16%	50%	30%
Luxembourg	38%	65%	13%	0%	30%
Malta	17%	51%	18%	0%	30%
Netherlands	38%	65%	13%	50%	30%
Poland	38%	65%	13%	50%	30%
Portugal	17%	51%	21%	50%	30%
Romania	0%	0%	13%	50%	30%
Slovakia	19%	53%	16%	50%	30%
Slovenia	19%	53%	16%	50%	30%
Spain	17%	51%	21%	50%	30%
Sweden	51%	74%	10%	50%	30%
United Kingdom	38%	65%	13%	50%	30%

Source: Green-X

Notes:

Where 0% exists, this should be inferred as no resource of this particular technology type is available in this country

To calculate the levelised costs we have also taken account of project and economic lifetimes

- Economic lifetime is defined as the period over which the project's total capex is recovered
- Project lifetime is defined as the period over which the project is operational

Economic and project lifetimes for RES-E technologies

Years	Onshore Wind	Offshore Wind	Biomass	Biowaste	Biogas	Solar PV	Solar Thermal	Large Hydro	Small Hydro	Geothermal	Wave	Tidal Stream
Economic lifetime	15	15	15	15	15	15	15	15	15	15	15	15
Project lifetime	25	25	30	30	25	25	30	50	50	30	25	25

Source: Green-X

Economic and project lifetimes for RES-H technologies

Years	Biomass Heat Non Grid	Biomass Heat Grid Connected	Solar Heat	GSHP	Geothermal Heat
Economic lifetime	15	15	15	15	15
Project lifetime	20	20	20	20	30

Source: Green-X

Our discount rates take account of the different risks associated with the country and the type of technology assumed

- Chosen discount rate differentiates according to country and technology risk factors.
- Our discount rates do not assume any particular support mechanism, hence the discount rate applied to a particular technology in a specific country are neutral to this.
- The discount rates assumed for this analysis do not distinguish between types of investors i.e. utilities, banks, developers.
- Individual investors may require discount rates ±2% around the average assumption used for this analysis.

		Country banding		
	Discount rate (%) – pre-tax real	High	Medium	Low
Technology status	Developmental	18	16	14
	Commercial (Emerging)	16	14	12
	Commercial (Established)	14	12	10
	Mature	12	10	8

Source: Pöyry

We have categorised our country/country groupings and renewable technologies into the following bands

- Country risk relates to
  - size/strength of established renewables markets
  - economic stability
- Country risk does not account for differences in support mechanisms or tariff systems for renewable technologies
- Technology risk related to
  - maturity of technology
  - cost uncertainty

How countries have been assigned to a risk band

Risk band	Country/country groupings
High	Poland+, Slovakia+
Medium	Greece+
Low	UK, Germany, Denmark, Iberia, Ireland, Italy+, France, Benelux, Finland+

How technologies have been assigned to a risk band

Risk band	Technology type
Developmental	Wave, Tidal,
Commercial (Emerging)	Biomass (RES-E and RES-H), Offshore Wind
Commercial (Established)	Onshore Wind, Solar PV, Solar Thermal, Solar Heat Geothermal, GSHP
Mature	Biogas, Biowaste, Large Hydro, Small Hydro

Using these risk bands we have derived our local technology discount rate assumptions (%, real pre-tax) for RES-E

Discount rate (%)	Onshore wind	Offshore wind	Biomass	Biowaste	Biogas	Solar PV	Solar thermal	Large Hydro	Small Hydro	Geothermal	Wave	Tidal
UK	10	12	12	8	8	10	10	8	8	10	14	14
Germany	10	12	12	8	8	10	10	8	8	10	14	14
France	10	12	12	8	8	10	10	8	8	10	14	14
Denmark	10	12	12	8	8	10	10	8	8	10	14	14
Iberia	10	12	12	8	8	10	10	8	8	10	14	14
Ireland	10	12	12	8	8	10	10	8	8	10	14	14
Benelux	10	12	12	8	8	10	10	8	8	10	14	14
Finland+	10	12	12	8	8	10	10	8	8	10	14	14
Italy+	10	12	12	8	8	10	10	8	8	10	14	14
Poland+	14	16	16	12	12	14	14	12	12	14	18	18
Slovakia+	14	16	16	12	12	14	14	12	12	14	18	18
Greece+	12	14	14	10	10	12	12	10	10	12	16	16

Source: Pöyry

And RES-H

Discount rate (%)	Biomass Heat Non Grid	Biomass Heat Grid Connected	Solar Heat	Geothermal Heat	Ground Source Heat Pumps
UK	12	12	10	10	10
Germany	12	12	10	10	10
France	12	12	10	10	10
Denmark	12	12	10	10	10
Iberia	12	12	10	10	10
Ireland	12	12	10	10	10
Benelux	12	12	10	10	10
Finland+	12	12	10	10	10
Italy+	12	12	10	10	10
Poland+	16	16	14	14	14
Slovakia+	16	16	14	14	14
Greece+	14	14	12	12	12

Source: Pöyry

PÖYRY

Balancing cost assumptions

- As a general rule, balancing system costs increase as the share of intermittent generation – onshore wind, offshore wind, tidal and wave – to total generation increases.

- We have therefore assumed the following balancing costs:
  - Below 20% share of output of intermittent sources we assume a balancing cost of €1.5/MWh; and
  - Above 20% we assume a balancing cost for intermittent generation of €3.6/MWh.

- These figures are based on the findings of the ILEX Energy Report for the DTI “System Costs of Additional Renewables”.

Agenda

Main studies used for the cost input assumptions

- A wide range of sources have been investigated as part of this study, with the following sources used for the final set of cost assumptions. In deciding which sources to use, we have chosen those which allow for consistency across the EU within this study.

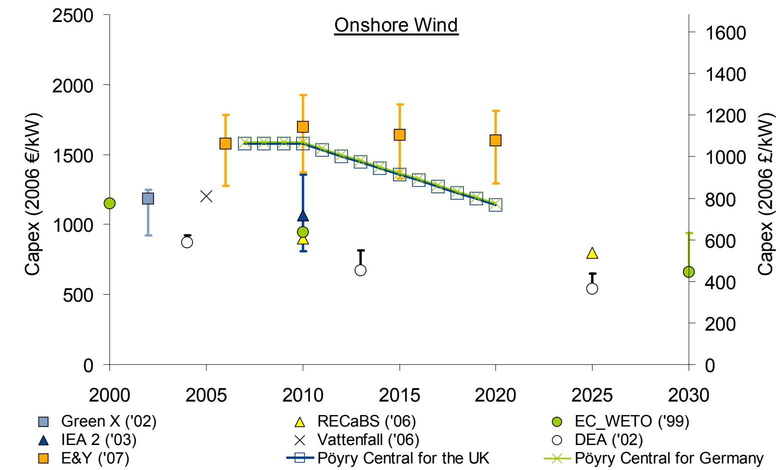
Report reference	Author	Publication title	Year of report
DEA	Danish Energy Authority	Technology Data for Electricity and Heat Generating Plants	2005
DTI	Enviros	The costs of supplying renewable energy	2005
E&Y	Ernst and Young	Impact of banding the Renewables Obligation – Costs of electricity production	2007
EC_WETO	European Commission Director-General for Research	World energy, technology and climate policy outlook (WETO)	2003
EEE	Energy Saving Trust, Econnect, and Element Energy	Potential for Microgeneration Study and Analysis	2005
F/E/E	Fraunhofer ISI, Energy Economics Group and Ecofys	Economic analysis of reaching a 20% share of renewable energy sources in 2020- Annex 1 to the final report	2005
Green-X	Green-X	Deriving Optimal Promotion Strategies for Increasing the Share of RES-E in a Dynamic European Electricity Market	2003
IEA	NEA, IEA, OECD	Projected Costs of Generating Electricity - Update 2005	2005
RECaBS	IEA	Renewable Energy Costs and Benefits for Society (RECaBS)	2007
Vattenfall	Vattenfall	Global Mapping of Greenhouse Gas Abatement Opportunities up to 2030: Power sector deep-dive	2007

PÖYRY

Onshore Wind – Global Capex

- Learning curve assumptions for the onshore wind technical capex based on:
  - Learning Rate of 91%
  - Future worldwide capacity growth assumption from International Energy Agency's (IEA) World Energy Outlook for 2006
  - Assuming that 99% of wind capacity is onshore until 2015, and that 95% is onshore thereafter

Poyry capex assumptions vs. other sources



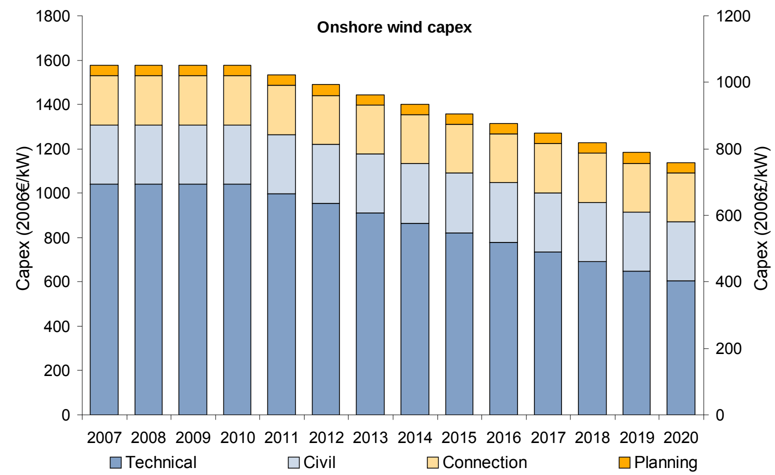
Onshore wind capex assumptions in 2010 and 2020

	2010 Costs (€/kW)	Capex Split in 2010	2020 Costs (€/kW)
Technical CAPEX	1040	66%	603
Civils CAPEX	268	17%	268
Connection CAPEX	221	14%	221
Planning CAPEX	47	3%	47
Total CAPEX	1576	100%	1139

Notes:

The Civils CAPEX costs in the above table apply to the UK, hence for other countries the Civils will vary by the labour costs (see Slide 25).

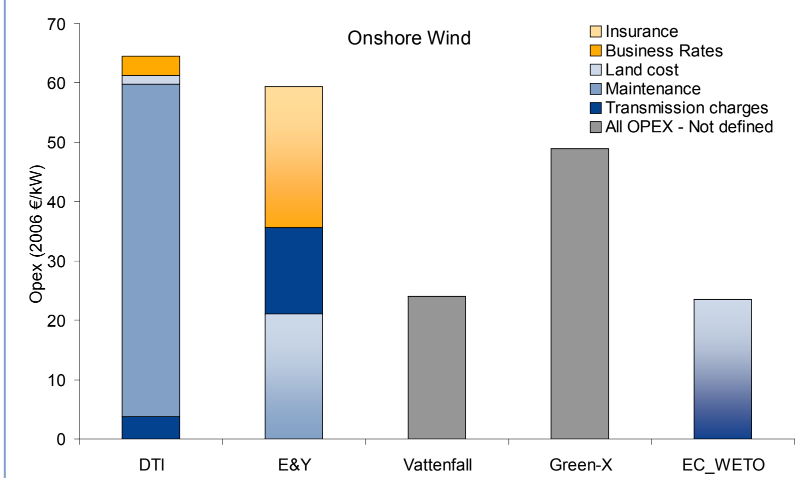
How UK onshore wind total capex changes over time



Onshore Wind – Other Assumptions

- Pöyry Central scenario Fixed Opex:
  - €59/kW/yr,
  - E&Y 2007
- Project lifetime: 25 years, Green-X 2003
- Economic lifetime: 15 years, Pöyry
- Fixed Opex includes: Turbine O&M, Use of System charges, Insurance, Rates and Rent
- Discount rates range between 10-14% real pre-tax, depending on the location of the onshore wind resource.

Poyry opex assumptions vs. other sources



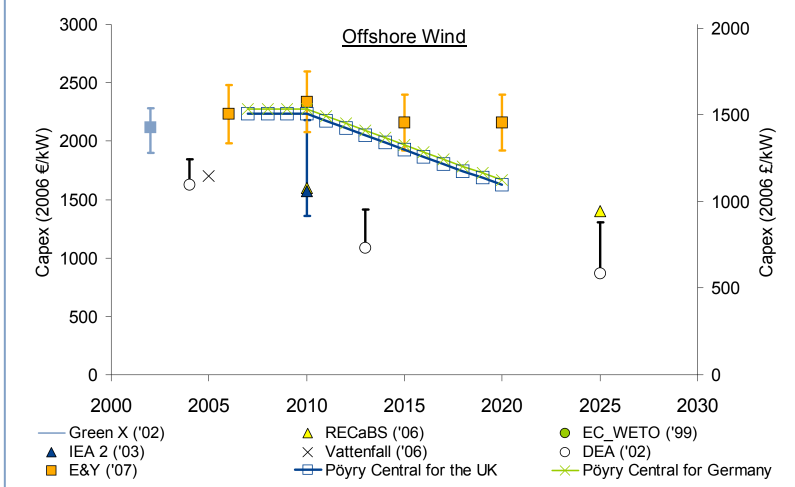
Load factor assumptions

	Average Load Factor	
	Current ('04)	New Build
UK	27%	27%
Germany	19%	20%
France	27%	24%
Denmark	25%	24%
Iberia	25%	22%
Ireland	30%	28%
Benelux	22%	21%
Finland+	21%	22%
Italy+	21%	21%
Poland+	22%	23%
Slovakia+	22%	23%
Greece+	25%	22%

Offshore Wind – Global Capex

- Learning curve assumptions for the offshore wind technical capex based on:
  - Learning Rate of 91%
  - Future worldwide capacity growth assumption from International Energy Agency's (IEA) World Energy Outlook for 2006
  - Assuming that 99% of wind capacity is onshore until 2015, and that 95% is onshore thereafter

Poyry capex assumptions vs. other sources



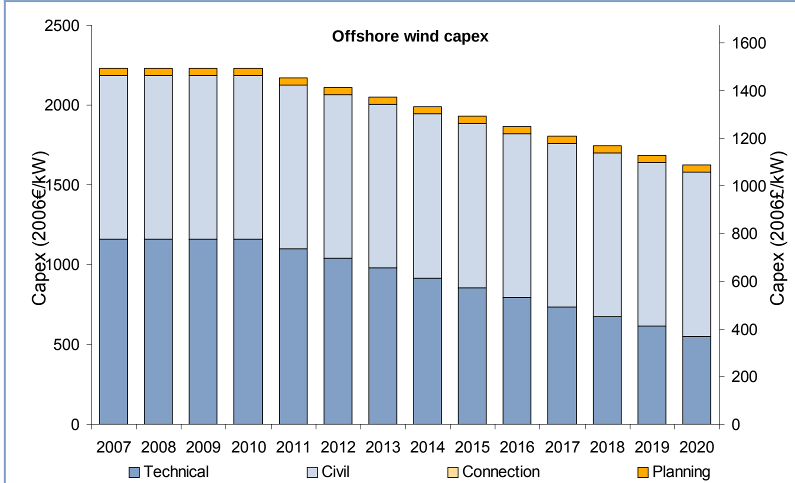
Offshore wind capex assumptions in 2010 and 2020

	2010 Costs (€/kW)	Capex Split in 2010	2020 Costs (€/kW)
Technical CAPEX	1161	52%	552
Civils CAPEX	1027	46%	1027
Connection CAPEX	0	0%	0
Planning CAPEX	45	2%	45
Total CAPEX	2232	100%	1624

Notes:

The Civils CAPEX costs in the above table apply to the UK, hence for other countries the Civils will vary by the labour costs (see Slide 25).

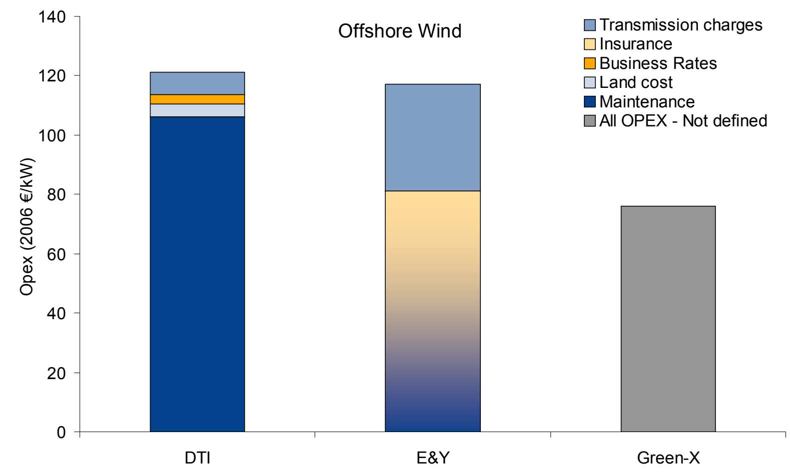
How UK offshore wind total capex changes over time



Offshore Wind – Other Assumptions

- Pöyry Central scenario Fixed Opex
  - €117/kW/yr
  - E&Y 2007
- Project lifetime: 25 years, Green-X 2003
- Economic lifetime: 15 years, Pöyry
- Fixed Opex includes: Turbine O&M, Use of System charges, Insurance, Rates, and Rent.
- Discount rates range between 12-16% real pre-tax, depending on the location of the offshore wind resource.

Poyry opex assumptions vs. other sources



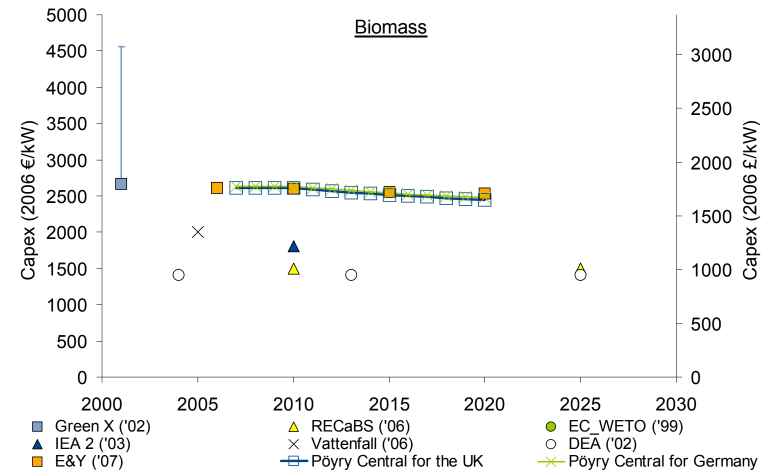
Load factor assumptions

	Average Load Factor	
	Current ('04)	New Build
UK		37%
Germany		34%
France		33%
Denmark	35%	34%
Iberia		31%
Ireland		39%
Benelux	35%	31%
Finland+	40%	31%
Italy+		27%
Poland+		34%
Slovakia+		34%
Greece+		29%

Biomass – Global Capex

- Learning curve assumptions for the biomass technical capex based on:
  - Learning Rate of 85%
  - Future worldwide capacity growth assumption from International Energy Agency's (IEA) World Energy Outlook for 2006

Poyry capex assumptions vs. other sources



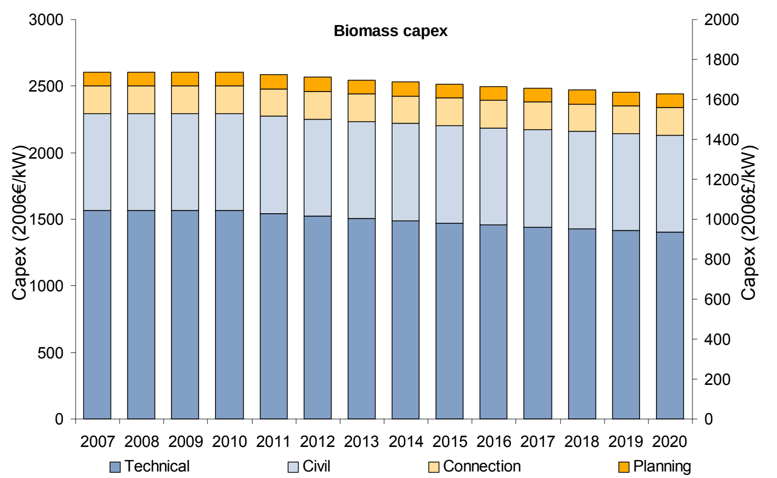
Biomass capex assumptions in 2010 and 2020

	2010 Costs (€/kW)	Capex Split in 2010	2020 Costs (€/kW)
Technical CAPEX	1563	60%	1402
Civils CAPEX	730	28%	730
Connection CAPEX	208	8%	208
Planning CAPEX	104	4%	104
Total CAPEX	2605	100%	2444

Notes:

The Civils CAPEX costs in the above table apply to the UK, hence for other countries the Civils will vary by the labour costs (see Slide 25).

How UK biomass total capex changes over time

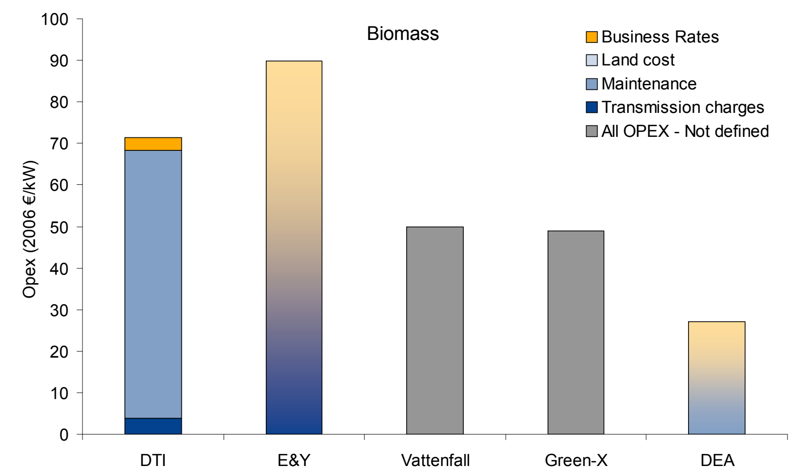


PÖYRY

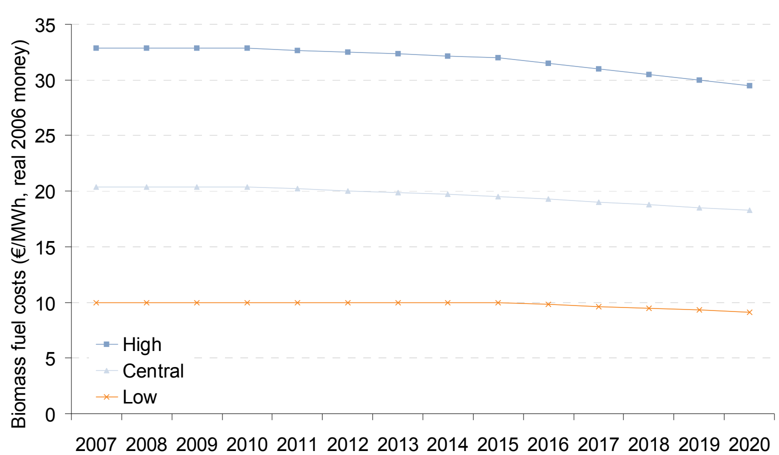
Biomass – Other Assumptions

- Pöyry Central scenario Fixed Opex:
  - €90/kW/yr
  - E&Y 2007
- Project lifetime: 30 years, Green-X 2003
- Economic lifetime: 15 years, Pöyry
- No information available on individual elements of fixed opex
- Discount rates range between 12-16% real pre-tax, depending on the location of the biomass resource

Pöyry fixed opex assumptions vs. other sources



Biomass fuel costs assumed for each cost band



Load factor assumptions

	Average Load Factor	
	Current ('04)	New Build
UK	73%	73%
Germany	73%	73%
France	73%	73%
Denmark	73%	73%
Iberia	73%	73%
Ireland	73%	73%
Benelux	73%	73%
Finland+	73%	73%
Italy+	73%	73%
Poland+	73%	73%
Slovakia+	73%	73%
Greece+	73%	73%

Biowaste – Capex and Opex assumptions

- Learning curve assumptions for the biowaste technical capex based on:
  - Learning Rate of 95%
  - Future worldwide capacity growth assumption from International Energy Agency's (IEA) World Energy Outlook for 2006
  - Assuming that 85% of the IEA's classification "Biomass and Waste" consists of waste
- Pöyry Central scenario Fixed Opex:
  - €141/kW/yr
  - Green-X 2003
- Project lifetime: 30 years, Green-X 2003
- Economic lifetime: 15 years, Pöyry
- No information available on individual elements of fixed opex
- Discount rates range between 8-12% real pre-tax, depending on the location of the biowaste resource.

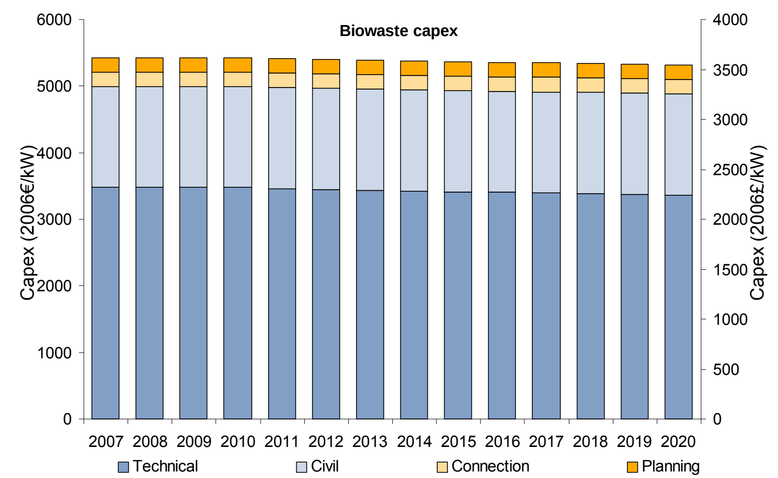
Biowaste capex assumptions in 2010 and 2020

	2010 Costs (€/kW)	Capex Split in 2010	2020 Costs (€/kW)
Technical CAPEX	3475	64%	3365
Civils CAPEX	1520	28%	1520
Connection CAPEX	217	4%	217
Planning CAPEX	217	4%	217
Total CAPEX	5430	100%	5320

Notes:

The Civils CAPEX costs in the above table apply to the UK, hence for other countries the Civils will vary by the labour costs (see Slide 25).

How UK biowaste total capex changes over time

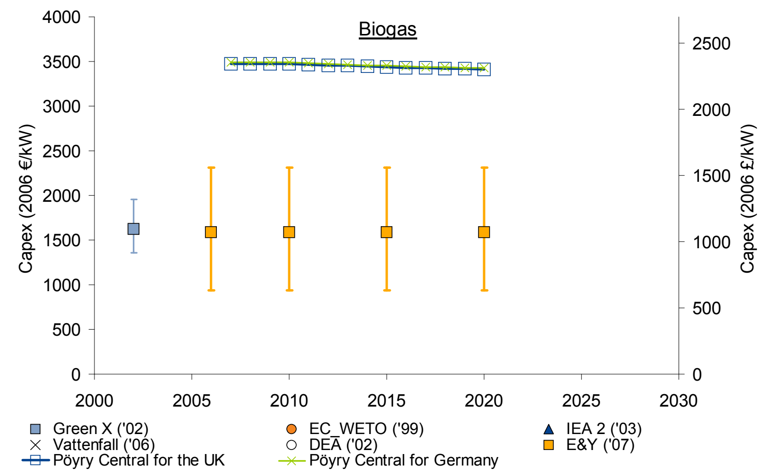


PÖYRY

Biogas – Global Capex

- Learning curve assumptions for the biogas technical capex based on:
  - Learning Rate of 95%
  - Future worldwide capacity growth assumption from International Energy Agency's (IEA) World Energy Outlook for 2006
  - Assuming that 85% of the IEA's classification "Biomass and Waste" consists of waste

Poyry capex assumptions vs. other sources



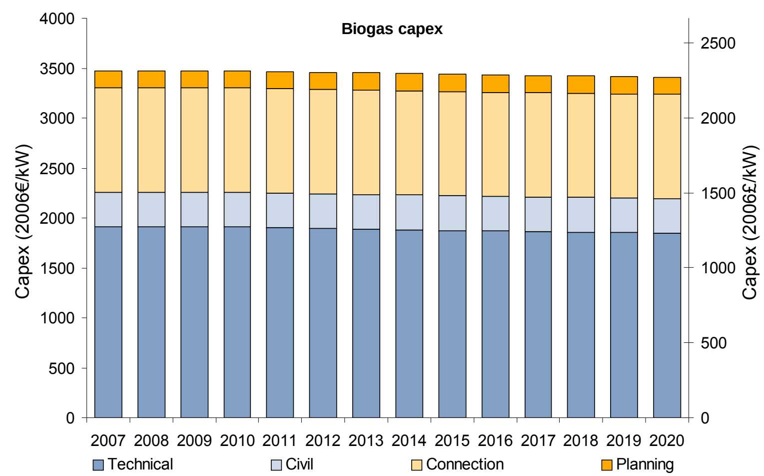
Biogas capex assumptions in 2010 and 2020

	2010 Costs (€/kW)	Capex Split in 2010	2020 Costs (€/kW)
Technical CAPEX	1911	55%	1847
Civils CAPEX	348	10%	348
Connection CAPEX	1043	30%	1043
Planning CAPEX	174	5%	174
Total CAPEX	3475	100%	3411

Notes:

The Civils CAPEX costs in the above table apply to the UK, hence for other countries the Civils will vary by the labour costs (see Slide 25).

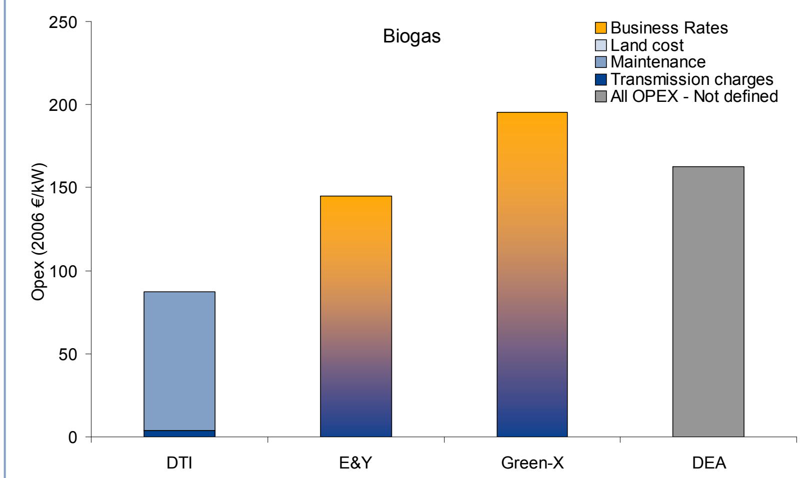
How UK biogas total capex changes over time



Biogas – Other Assumptions

- Pöyry Central scenario Fixed Opex:
  - €195/kW/yr
  - E&Y 2007
- Project lifetime: 25 years, Green-X 2003
- Economic lifetime: 15 years, Pöyry
- No information available on individual elements of fixed opex
- Discount rates range between 8-12% real pre-tax, depending on the location of the biogas resource.

Poyry opex assumptions vs. other sources



Load factor assumptions

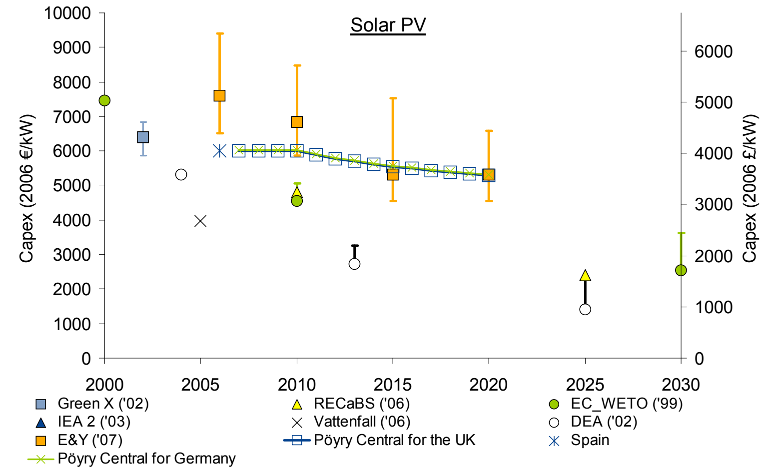
	Average	
	Current ('04)	New Build
UK	61%	61%
Germany	61%	61%
France	61%	61%
Denmark	62%	62%
Iberia	59%	59%
Ireland	60%	60%
Benelux	63%	63%
Finland+	60%	60%
Italy+	59%	59%
Poland+	61%	61%
Slovakia+	61%	61%
Greece+	58%	58%

PÖYRY

Solar PV – Global Capex

- Learning curve assumptions for the Solar PV technical capex based on:
  - Learning Rate of 85%
  - Future worldwide capacity growth assumption from International Energy Agency's (IEA) World Energy Outlook for 2006

Poyry capex assumptions vs. other sources



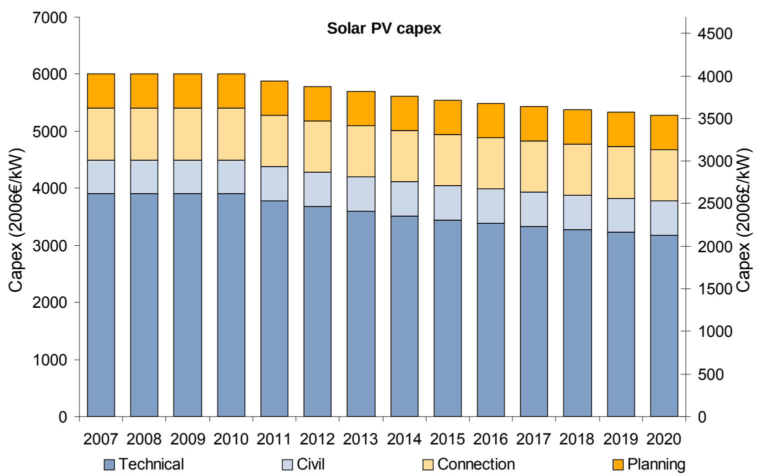
Solar PV capex assumptions in 2010 and 2020

	2010 Costs (€/kW)	Capex Split in 2010	2020 Costs (€/kW)
Technical CAPEX	3900	65%	3183
Civils CAPEX	600	10%	600
Connection CAPEX	900	15%	900
Planning CAPEX	600	10%	600
Total CAPEX	6000	100%	5283

Notes:

The Civils CAPEX costs in the above table apply to the UK, hence for other countries the Civils will vary by the labour costs (see Slide 25).

How UK solar PV total capex changes over time



Solar PV – Other Assumptions

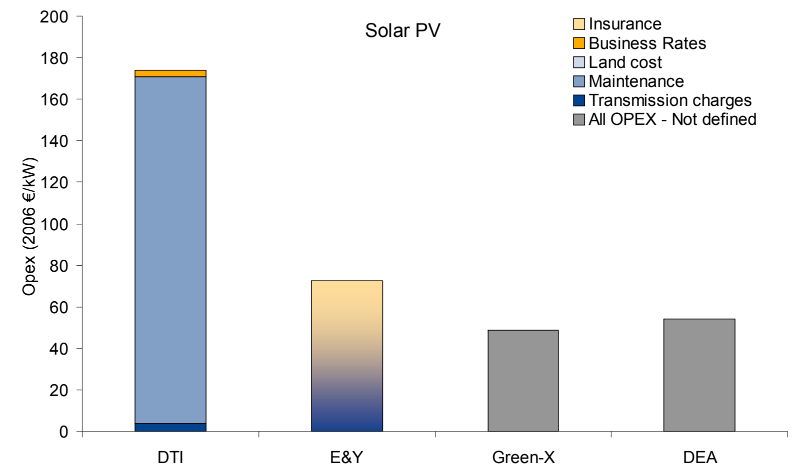
- Pöyry Central scenario Fixed Opex:
  - €72/kW/yr
  - E&Y 2007

- Project lifetime: 25 years, Green-X 2003
- Economic lifetime: 15 years, Pöyry

- No information available on individual elements of fixed opex

- Discount rates range between 10-14% real pre-tax, depending on the location of the solar PV resource.

Poyry opex assumptions vs. other sources



Load factor assumptions

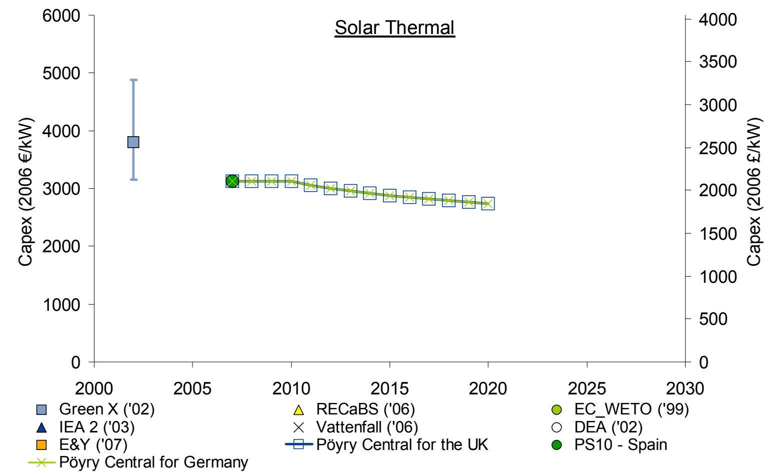
	Average Load Factor	
	Current ('04)	New Build
UK	8%	8%
Germany	9%	8%
France	10%	9%
Denmark	8%	8%
Iberia	13%	13%
Ireland	8%	8%
Benelux	8%	8%
Finland+	7%	7%
Italy+	10%	9%
Poland+	9%	8%
Slovakia+	10%	9%
Greece+	12%	11%

PÖYRY

Solar Thermal – Global Capex

- Learning curve assumptions for the Solar Thermal technical capex based on:
  - Learning Rate of 90%
  - Future worldwide capacity growth assumption from International Energy Agency’s (IEA) World Energy Outlook for 2006
- No information available on individual elements of capex, hence learning rate applied to total capex value

Poyry capex assumptions vs. other sources



Solar Thermal capex assumptions in 2010 and 2020

	2010 Costs (€/kW)	2020 Costs (€/kW)
Technical CAPEX	3119	2734
Civils CAPEX	0	0
Connection CAPEX	0	0
Planning CAPEX	0	0
Total CAPEX	3119	2734

Solar Thermal – Other Assumptions

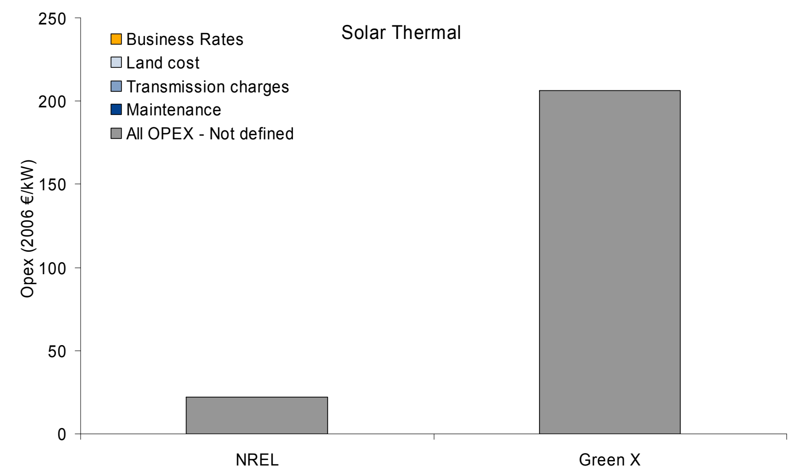
- Pöyry Central scenario Fixed Opex:
  - €206/kW/yr,
  - Green-X 2002

- Project lifetime: 30 years, Green-X 2003
- Economic lifetime: 15 years, Pöyry

- No information available on individual elements of fixed opex

- Discount rates range between 10-14% real pre-tax, depending on the location of the solar thermal resource.

Poyry opex assumptions vs. other sources



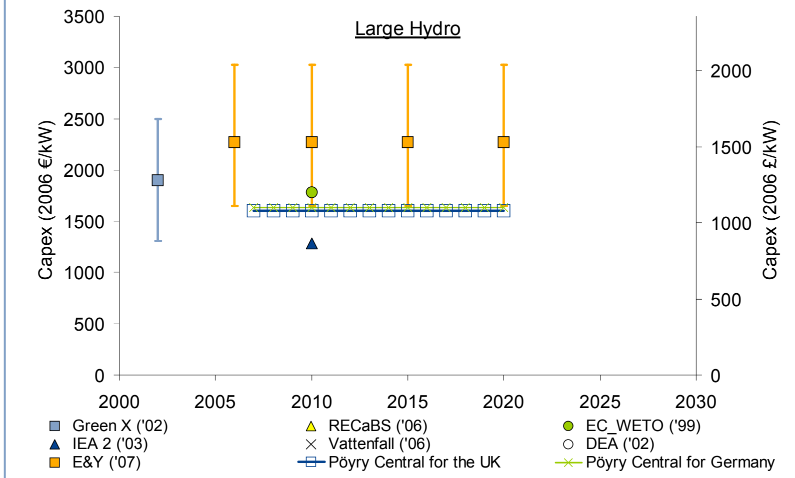
Load factor assumptions

	Average Load Factor	
	Current ('04)	New Build
UK		
Germany		
France		
Denmark		
Iberia		34%
Ireland		
Benelux		
Finland+		
Italy+		33%
Poland+		
Slovakia+		
Greece+		34%

Large Hydro – Global Capex

- Learning curve assumptions for the Large Hydro technical capex based on:
  - Learning Rate of 100%
  - Future worldwide capacity growth assumption from International Energy Agency's (IEA) World Energy Outlook for 2006

Poyry capex assumptions vs. other sources



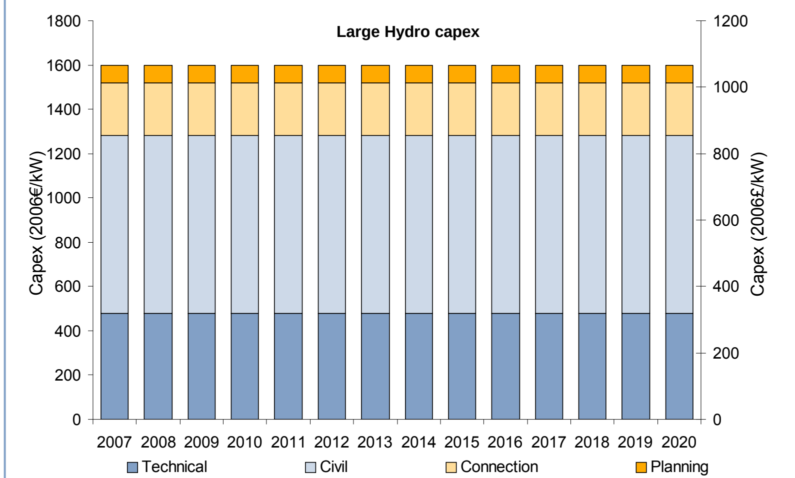
Large hydro capex assumptions in 2010 and 2020

	2010 Costs (€/kW)	Capex Split in 2010	2020 Costs (€/kW)
Technical CAPEX	800	50%	800
Civils CAPEX	480	30%	480
Connection CAPEX	240	15%	240
Planning CAPEX	80	5%	80
Total CAPEX	1600	100%	1600

Notes:

The Civils CAPEX costs in the above table apply to the UK, hence for other countries the Civils will vary by the labour costs (see Slide 25).

How UK large hydro total capex changes over time



Large Hydro – Other Assumptions

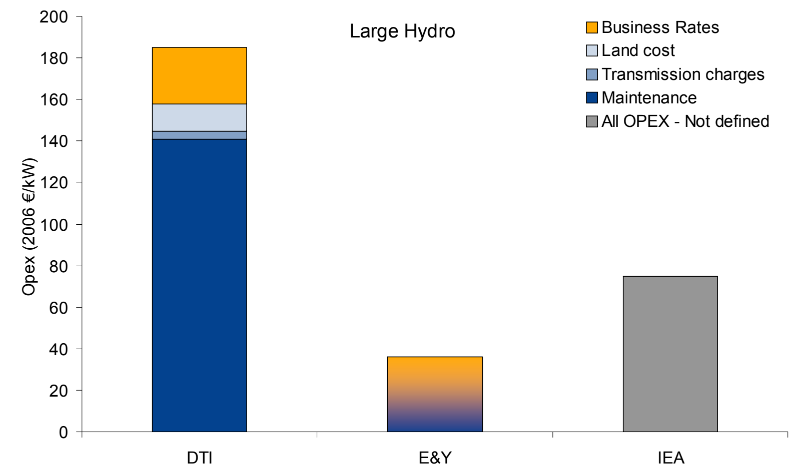
- Pöyry Central scenario Fixed Opex:
  - €36/kW/yr,
  - E&Y 2007

- Project lifetime: 50 years, Green-X 2003
- Economic lifetime: 15 years, Pöyry

- Fixed Opex includes: Turbine O&M, Use of System charges, Insurance, Rates and Rent

- Discount rates range between 8-12% real pre-tax, depending on the location of the large hydro resource

Poyry opex assumptions vs. other sources



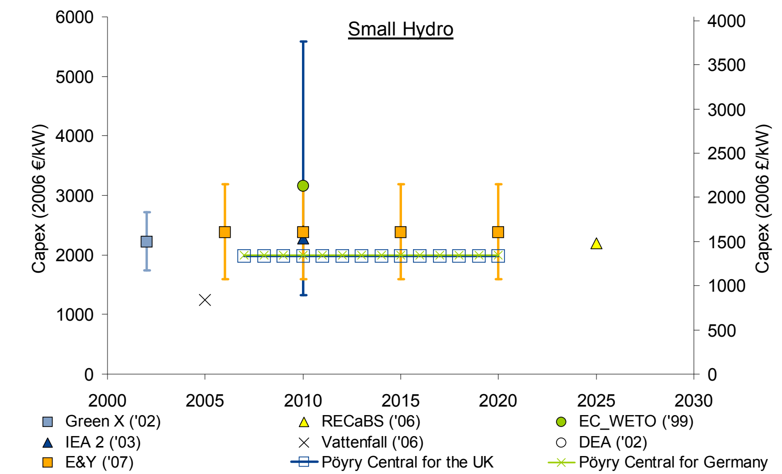
Load factor assumptions

	Average Load Factor	
	Current ('04)	New Build
UK	37%	
Germany	68%	68%
France	36%	
Denmark		
Iberia	26%	26%
Ireland	41%	41%
Benelux	34%	
Finland+	52%	52%
Italy+	44%	
Poland+	38%	
Slovakia+	50%	
Greece+	16%	

Small Hydro – Global Capex

- Learning curve assumptions for the Small Hydro technical capex based on:
  - Learning Rate of 100%
  - Future worldwide capacity growth assumption from International Energy Agency's (IEA) World Energy Outlook for 2006

Poyry capex assumptions vs. other sources



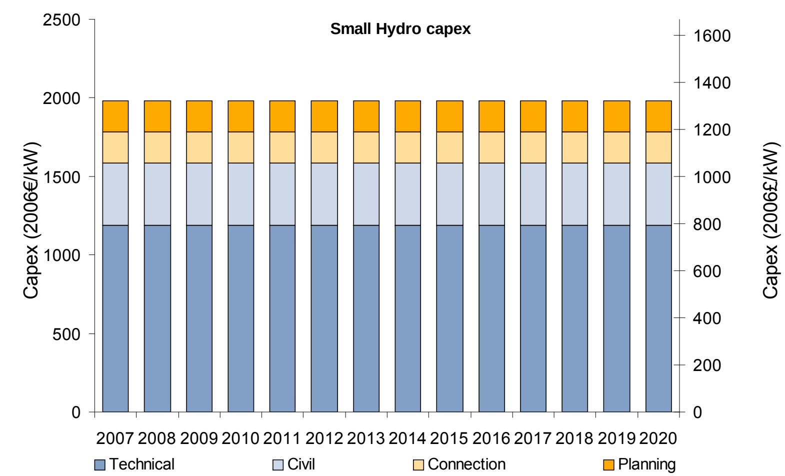
Small hydro capex assumptions in 2010 and 2020

	2010 Costs (€/kW)	Capex Split in 2010	2020 Costs (€/kW)
Technical CAPEX	1188	60%	1188
Civils CAPEX	396	20%	396
Connection CAPEX	198	10%	198
Planning CAPEX	198	10%	198
Total CAPEX	1980	100%	1980

Notes:

The Civils CAPEX costs in the above table apply to the UK, hence for other countries the Civils will vary by the labour costs (see Slide 25).

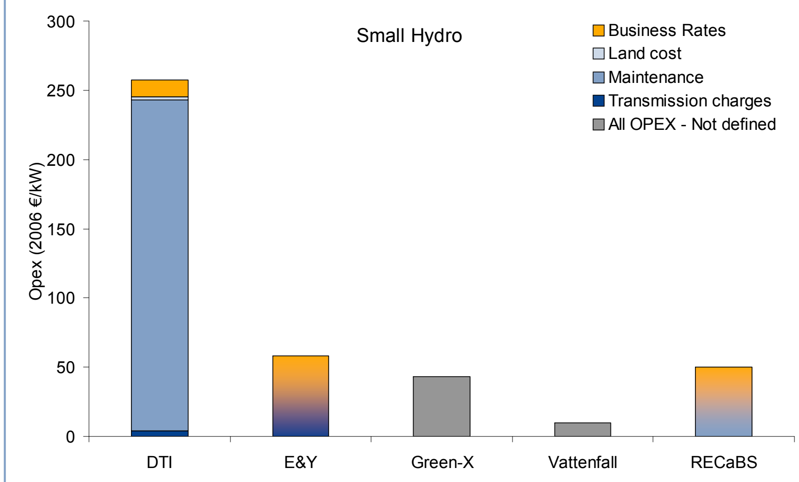
How UK small hydro total capex changes over time



Small Hydro – Other Assumptions

- Pöyry Central scenario Fixed Opex:
  - €58/kW/yr
  - E&Y 2007
- Project lifetime: 50 years, Green-X 2003
- Economic lifetime: 15 years, Pöyry
- Fixed Opex includes: Turbine O&M, Use of System charges, Insurance, Rates and Rent
- Discount rates range between 8-12% real pre-tax, depending on the location of the small hydro resource

Poyry opex assumptions vs. other sources



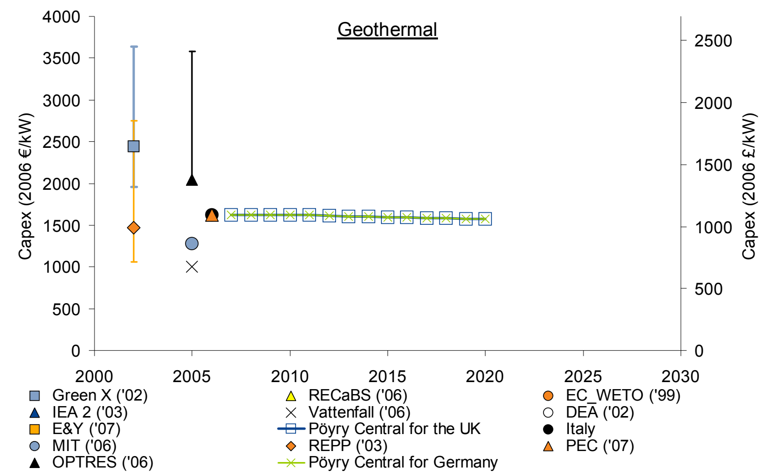
Load factor assumptions

	Average Load Factor	
	Current ('04)	New Build
UK	37%	37%
Germany	32%	32%
France	42%	42%
Denmark	32%	
Iberia	24%	24%
Ireland	35%	35%
Benelux	24%	20%
Finland+	47%	47%
Italy+	50%	50%
Poland+	42%	42%
Slovakia+	40%	40%
Greece+	32%	32%

Geothermal – Global Capex

- Learning curve assumptions for the Geothermal technical capex based on:
  - Learning Rate of 95%
  - Future worldwide capacity growth assumption from International Energy Agency's (IEA) World Energy Outlook for 2006
- No information available on individual elements of capex, hence learning rate applied to total capex value

Poyry capex assumptions vs. other sources



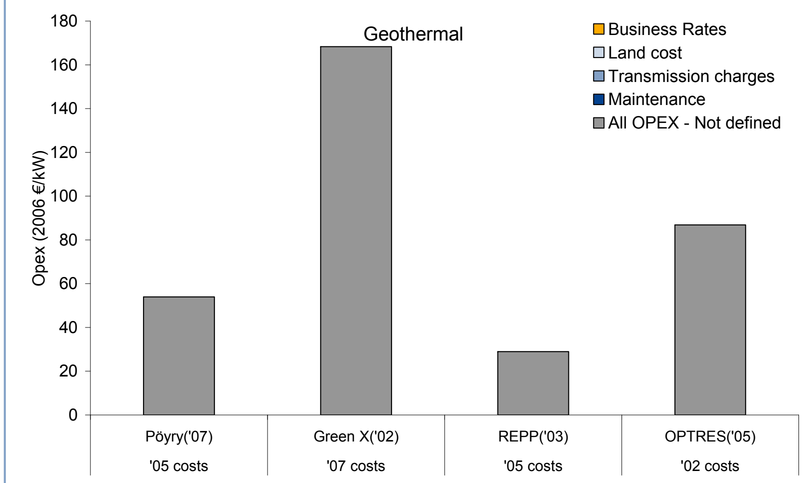
Geothermal capex assumptions in 2010 and 2020

	2010 Costs (€/kW)	2020 Costs (€/kW)
Technical CAPEX	1626	1574
Civils CAPEX	0	0
Connection CAPEX	0	0
Planning CAPEX	0	0
Total CAPEX	1626	1574

Geothermal – Other Assumptions

- Pöyry Central scenario Fixed Opex
  - €54/kW/yr
  - Pöyry 2007
- Project lifetime: 30 years, Green-X 2003
- Economic lifetime: 15 years, Pöyry
- No information available on individual elements of fixed opex
- Discount rates range between 10-14% real pre-tax, depending on the location of the geothermal resource

Poyry opex assumptions vs. other sources



Load factor assumptions

	Average Load Factor	
	Current ('04)	New Build
UK		
Germany		
France	85%	85%
Denmark		
Iberia		85%
Ireland		
Benelux		
Finland+		
Italy+	85%	85%
Poland+		
Slovakia+		
Greece+		85%

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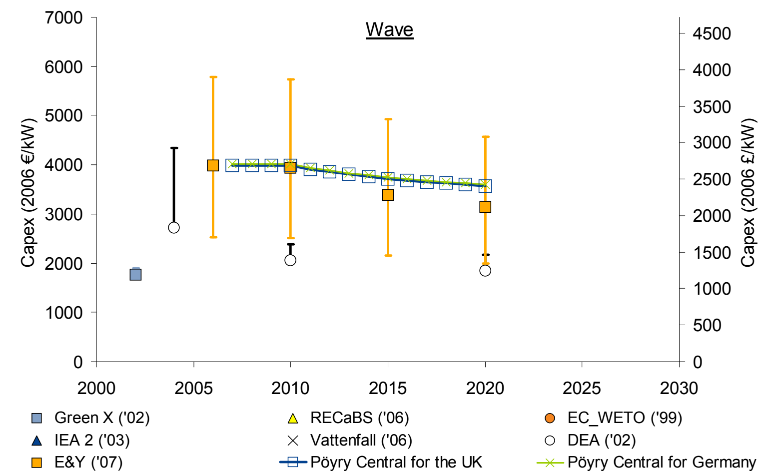
Wave – Global Capex

- Learning curve assumptions for Wave technical capex based on:
  - Learning Rate of 85%
  - Future worldwide capacity growth assumption from International Energy Agency's (IEA) World Energy Outlook for 2006

Poyry capex assumptions vs. other sources



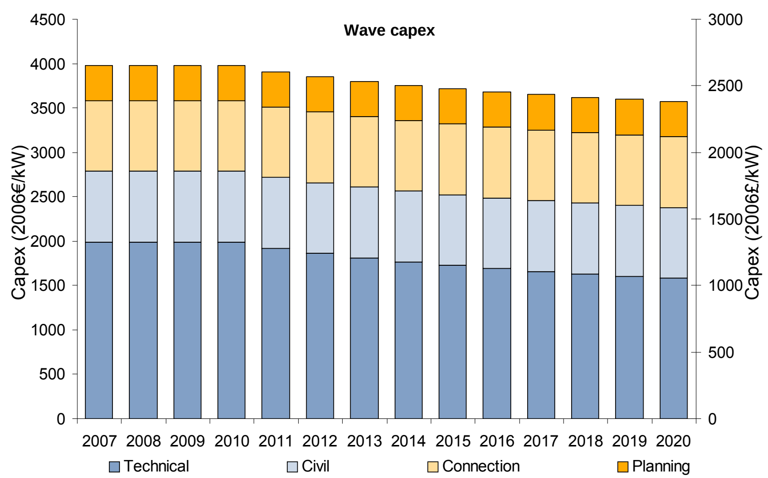
Wave capex assumptions in 2010 and 2020

	2010 Costs (€/kW)	Capex Split in 2010	2020 Costs (€/kW)
Technical CAPEX	1990	50%	1581
Civils CAPEX	796	20%	796
Connection CAPEX	796	20%	796
Planning CAPEX	398	10%	398
Total CAPEX	3981	100%	3572

Notes:

The Civils CAPEX costs in the above table apply to the UK, hence for other countries the Civils will vary by the labour costs (see Slide 25).

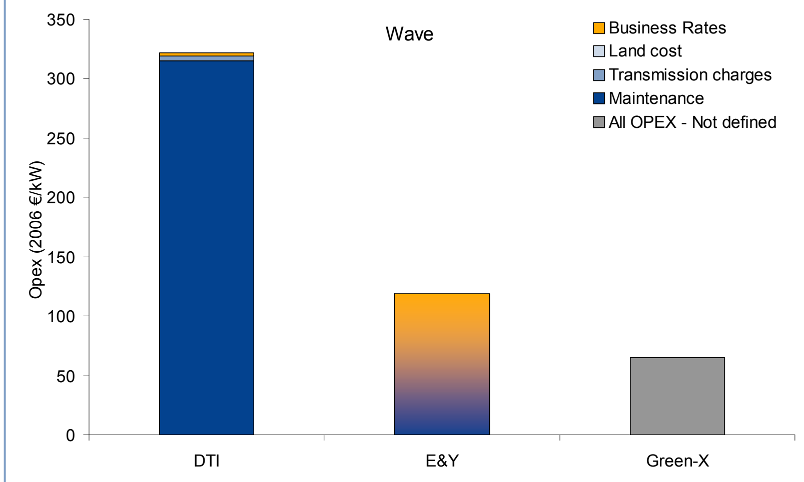
How UK wave total capex changes over time



Wave – Other Assumptions

- Pöyry Central scenario Fixed Opex
  - €119/kW/yr
  - E&Y 2007
- Project lifetime: 25 years, Green-X 2003
- Economic lifetime: 15 years, Pöyry
- No information available on individual elements of fixed opex
- Discount rates range between 14-18% real pre-tax, depending on the location of the wave resource

Poyry opex assumptions vs. other sources



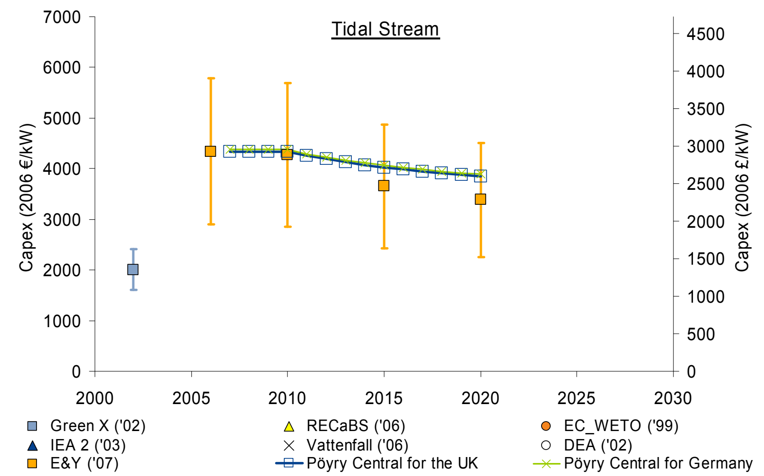
Load factor assumptions

	Average Load Factor	
	Current ('04)	New Build
UK	0%	30%
Germany	0%	30%
France	0%	30%
Denmark	0%	30%
Iberia	0%	30%
Ireland	0%	30%
Benelux	0%	30%
Finland+	0%	30%
Italy+	0%	30%
Poland+	0%	30%
Slovakia+	0%	30%
Greece+	0%	30%

Tidal Stream – Global Capex

- Learning curve assumptions for Tidal Stream technical capex based on:
  - Learning Rate of 85%
  - Future worldwide capacity growth assumption from International Energy Agency's (IEA) World Energy Outlook for 2006

Poyry capex assumptions vs. other sources



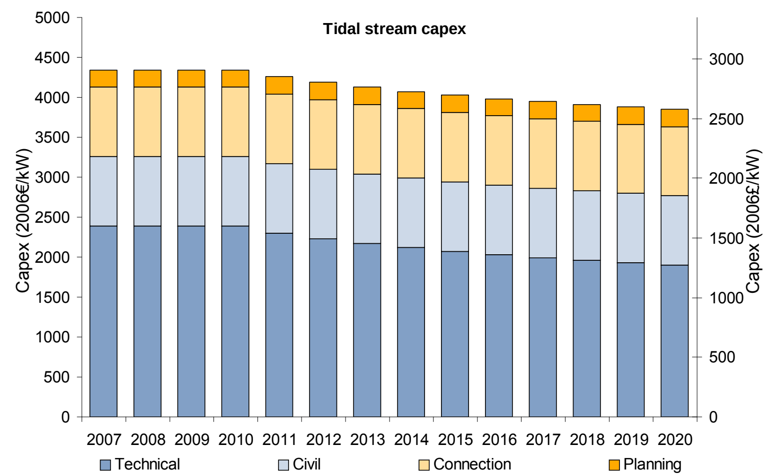
Tidal stream capex assumptions in 2010 and 2020

	2010 Costs (€/kW)	Capex Split in 2010	2020 Costs (€/kW)
Technical CAPEX	2388	55%	1898
Civils CAPEX	868	20%	868
Connection CAPEX	868	20%	868
Planning CAPEX	217	5%	217
Total CAPEX	4342	100%	3852

Notes:

The Civils CAPEX costs in the above table apply to the UK, hence for other countries the Civils will vary by the labour costs (see Slide 25).

How UK tidal stream total capex changes over time



Tidal Stream – Other Assumptions

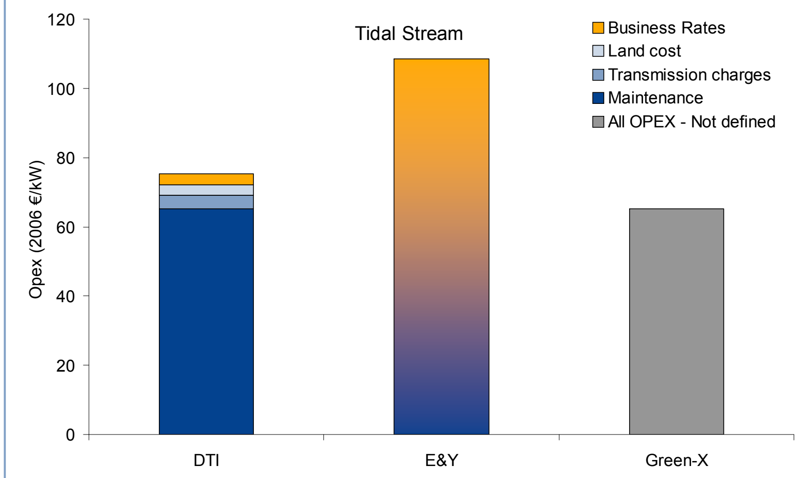
- Pöyry Central scenario Fixed Opex:
  - €109/kW/yr
  - E&Y 2007

- Project lifetime: 25 years, Green-X 2003
- Economic lifetime: 15 years, Pöyry

- No information available on individual elements of fixed opex

- Discount rates range between 14-18% real pre-tax, depending on the location of the tidal stream resource

Poyry opex assumptions vs. other sources



Load factor assumptions

	Average Load Factor	
	Current ('04)	New Build
UK	0%	35%
Germany	0%	35%
France	0%	35%
Denmark	0%	35%
Iberia	0%	35%
Ireland	0%	35%
Benelux	0%	35%
Finland+	0%	35%
Italy+	0%	35%
Poland+	0%	35%
Slovakia+	0%	35%
Greece+	0%	35%

Agenda

1. Introduction
2. Methodology overview
3. Resource assumptions
   - Definition of the 2020 target
   - Baseline renewable energy growth
   - Maximum potential
   - Build rate profiles
4. Technology cost assumptions
   - Summary
   - Renewable electricity technologies
   - **Renewable heat technologies**
5. Counterfactuals
   - Cost
   - Carbon
6. Renewable transport assumptions
7. Sensitivities

Main studies used for the cost input assumptions

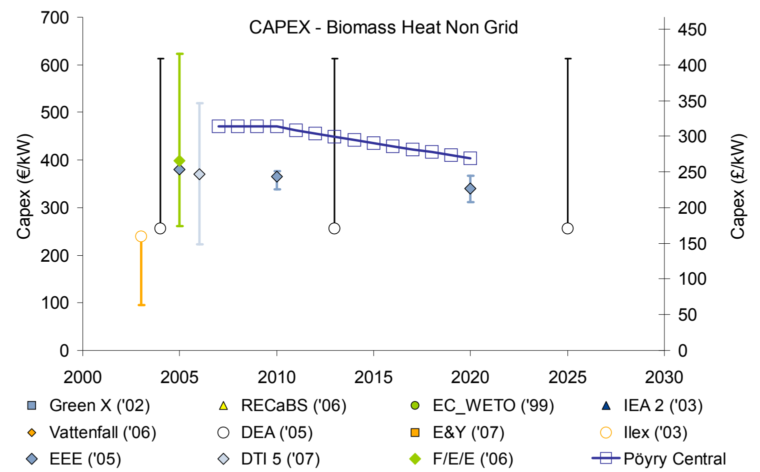
- A wide range of sources have been investigated as part of this study, with the following sources used for the final set of cost assumptions. In deciding which sources to use, we have chosen those which allow for consistency across the EU within this study.

Report reference	Author	Publication title	Year of report
DEA	Danish Energy Authority	Technology Data for Electricity and Heat Generating Plants	2005
DTI	Enviros	The costs of supplying renewable energy	2005
E&Y	Ernst and Young	Impact of banding the Renewables Obligation – Costs of electricity production	2007
EC_WETO	European Commission Director-General for Research	World energy, technology and climate policy outlook (WETO)	2003
EEE	Energy Saving Trust, Econnect, and Element Energy	Potential for Microgeneration Study and Analysis	2005
F/E/E	Fraunhofer ISI, Energy Economics Group and Ecofys	Economic analysis of reaching a 20% share of renewable energy sources in 2020- Annex 1 to the final report	2005
Green-X	Green-X	Deriving Optimal Promotion Strategies for Increasing the Share of RES-E in a Dynamic European Electricity Market	2003
IEA	NEA, IEA, OECD	Projected Costs of Generating Electricity - Update 2005	2005
RECaBS	IEA	Renewable Energy Costs and Benefits for Society (RECaBS)	2007
Vattenfall	Vattenfall	Global Mapping of Greenhouse Gas Abatement Opportunities up to 2030: Power sector deep-dive	2007

Biomass Heat Non Grid – Global Capex

- Biomass Heat Non Grid is small scale domestic and commercial heat boilers fired by biomass
- Technical capex reductions for Biomass Heat Non Grid based on:
  - 1.5% annual capex reduction between 2010 and 2020
  - F/E/E's "Economic analysis of reaching a 20% share of renewable energy sources in 2020"
- No information available on individual elements of capex

Poyry capex assumptions vs. other sources



Biomass Heat Non Grid capex assumptions

	2010 Costs (€/kW)	2020 Costs (€/kW)
Technical CAPEX	470	404
Civils CAPEX	0	0
Connection CAPEX	0	0
Planning CAPEX	0	0
Total CAPEX	470	404

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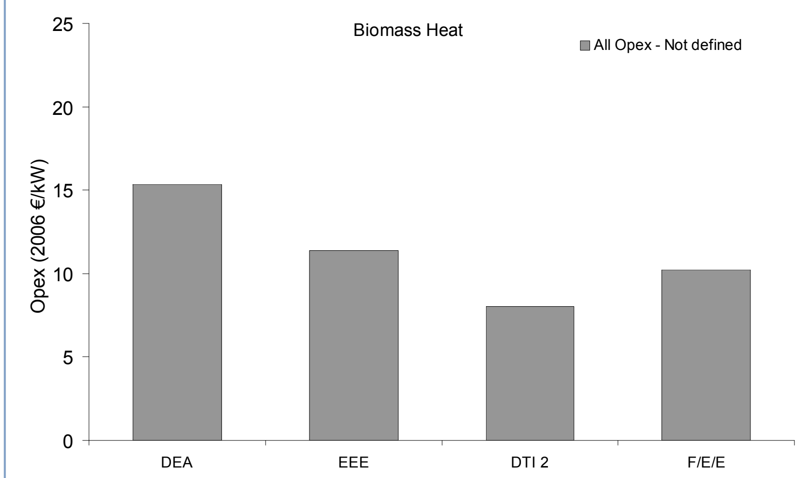
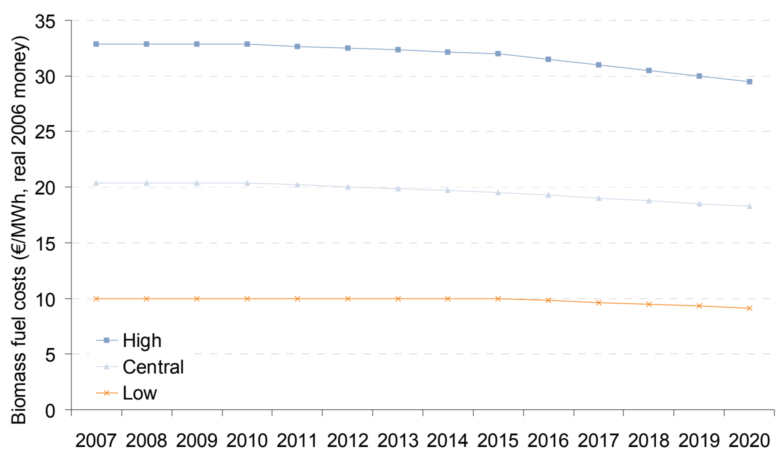
Biomass Heat Non Grid – Other Assumptions

- Pöyry Central scenario Fixed Opex:
  - €8/kW/yr
  - F/E/E, 2005
- Project lifetime: 20 years, DEA 2005
- Economic lifetime: 15 years, Pöyry
- No information available on individual elements of fixed opex
- Discount rates range between 12-16% real pre-tax, depending on the location of the biomass heat non grid resource

Poyry opex assumptions vs. other sources



Biomass fuel costs assumed for each cost band



Load factor assumptions

	Average Load Factor	
	Current ('04)	New Build
UK	38%	38%
Germany	38%	38%
France	19%	19%
Denmark	51%	51%
Iberia	17%	17%
Ireland	51%	51%
Benelux	38%	38%
Finland+	51%	51%
Italy+	17%	17%
Poland+	38%	38%
Slovakia+	19%	19%
Greece+	17%	17%

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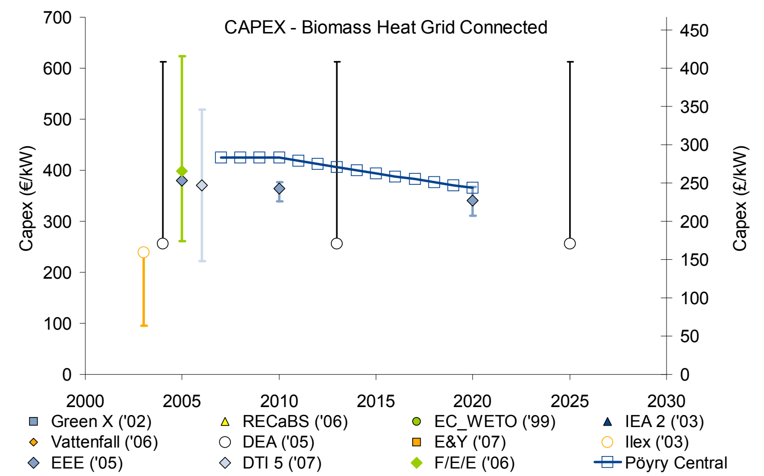
Biomass Heat Grid Connected – Global Capex

- Biomass Heat Grid Connected is district heating and large-scale heat facilities fired by biomass
- Technical capex reductions for Biomass Heat Grid Connected based on:
  - 1.5% annual capex reduction between 2010 and 2020
  - F/E/E's "Economic analysis of reaching a 20% share of renewable energy sources in 2020"
- No information available on individual elements of capex

Poyry capex assumptions vs. other sources



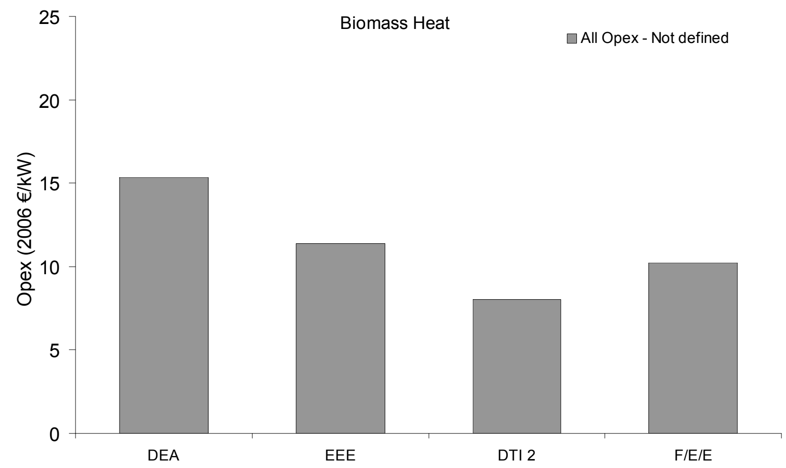
Biomass Heat Grid Connected capex assumptions

	2010 Costs (€/kW)	2020 Costs (€/kW)
Technical CAPEX	425	365
Civils CAPEX	0	0
Connection CAPEX	0	0
Planning CAPEX	0	0
Total CAPEX	425	365

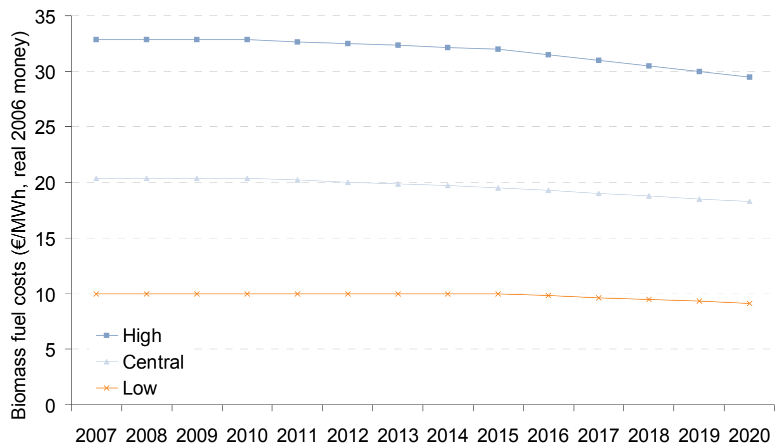
Biomass Heat Grid Connected – Other Assumptions

- Pöyry Central scenario Fixed Opex:
  - €19/kW/yr
  - F/E/E, 2005
- Project lifetime: 20 years, DEA 2005
- Economic lifetime: 15 years, Pöyry
- No information available on individual elements of fixed opex
- Discount rates range between 12-16% real pre-tax, depending on the location of the biomass heat non grid resource

Poyry opex assumptions vs. other sources



Biomass fuel costs assumed for each cost band



Load factor assumptions

	Average Load Factor	
	Current ('04)	**New Build**
UK	65%	65%
Germany	65%	65%
France	53%	53%
Denmark	74%	74%
Iberia	51%	51%
Ireland	74%	74%
Benelux	65%	65%
Finland+	74%	74%
Italy+	51%	51%
Poland+	65%	65%
Slovakia+	53%	53%
Greece+	51%	51%

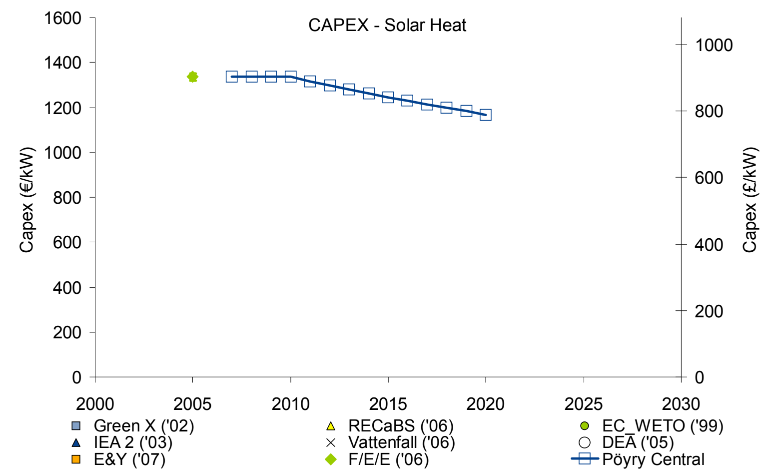
PÖYRY

Solar Heat – Global Capex

- Learning curve assumptions for Solar Heat technical capex based on:
  - Learning Rate of 95%
  - Future worldwide capacity growth assumption sourced from E/E/E's "Potential for Microgeneration Study"

- No information available on individual elements of capex

Poyry capex assumptions vs. other sources



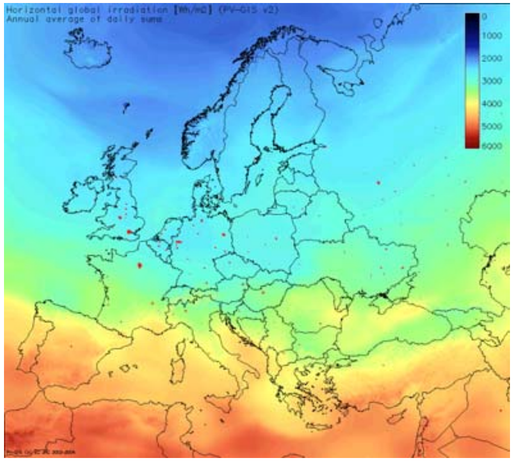
Solar Heat capex assumptions

	2010 Costs (€/kW)	2020 Costs (€/kW)
Technical CAPEX	1336	1168
Civils CAPEX	0	0
Connection CAPEX	0	0
Planning CAPEX	0	0
Total CAPEX	1336	1168

Solar Heat – Other Assumptions

- Pöyry Central scenario Fixed Opex:
  - €13/kW/yr
  - F/E/E, 2005
- Project lifetime: 20 years, DEA 2005
- Economic lifetime: 15 years, Pöyry
- No information available on individual elements of fixed opex
- Discount rates range between 10-14% real pre-tax, depending on the location of the biomass heat non grid resource
- The EC's PVGIS solar map is used to imply load factor assumptions for each member state

Annual irradiance map



Load factor assumptions

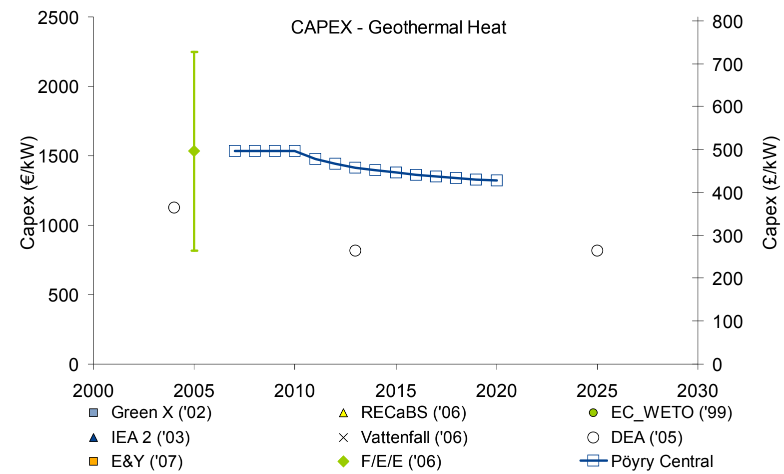
	Average Load Factor	
	Current ('04)	New Build
UK	13%	13%
Germany	13%	13%
France	16%	16%
Denmark	10%	10%
Iberia	21%	21%
Ireland	10%	10%
Benelux	13%	13%
Finland+	10%	10%
Italy+	18%	18%
Poland+	13%	13%
Slovakia+	16%	16%
Greece+	18%	18%

PÖYRY

Geothermal Heat – Global Capex

- Learning curve assumptions for Geothermal Heat technical capex based on:
  - Learning Rate of 95%
  - Future worldwide capacity growth assumption from International Energy Agency's (IEA) World Energy Outlook for 2004*
- No information available on individual elements of capex

Poyry capex assumptions vs. other sources



Geothermal Heat capex assumptions

	2010 Costs (€/kW)	2020 Costs (€/kW)
Technical CAPEX	1533	1320
Civils CAPEX	0	0
Connection CAPEX	0	0
Planning CAPEX	0	0
Total CAPEX	1533	1320

* Information not reproduced in WEO '05 or WEO '06: this is the most recent IEA figure available for geothermal capacity growth.

Geothermal Heat – Other Assumptions

- Pöyry Central scenario Fixed Opex:
  - €56/kW/yr
  - F/E/E, 2005

- Project lifetime: 30 years, DEA 2005
- Economic lifetime: 15 years, Pöyry

- No information available on individual elements of fixed opex

- Discount rates range between 10-14% real pre-tax, depending on the location of the biomass heat non grid resource

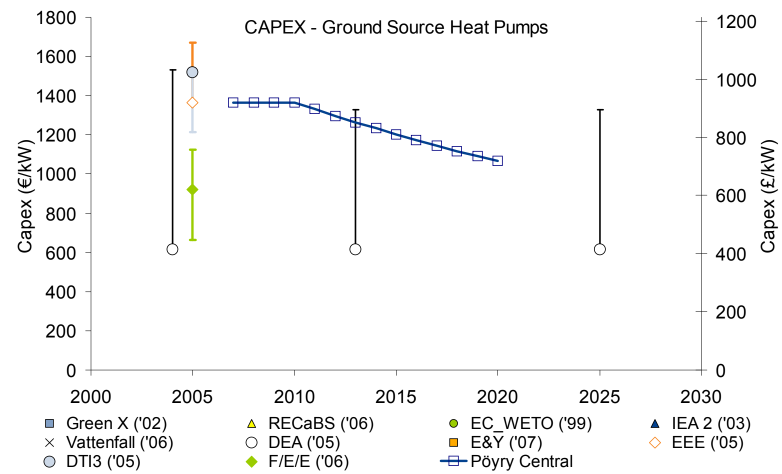
Load factor assumptions

	Average Load Factor	
	Current ('04)	New Build
UK	50%	50%
Germany	50%	50%
France	50%	50%
Denmark	50%	50%
Iberia	50%	50%
Ireland	50%	50%
Benelux	50%	50%
Finland+	50%	50%
Italy+	50%	50%
Poland+	50%	50%
Slovakia+	50%	50%
Greece+	50%	50%

Ground Source Heat Pumps – Global Capex

- Learning curve assumptions for Ground Source Heat Pumps technical capex based on:
  - Learning Rate of 91%
  - Future worldwide capacity growth assumption sourced from E/E/E's "Potential for Microgeneration Study"
- No information available on individual elements of capex

Poyry capex assumptions vs. other sources



Ground Source Heat Pumps capex assumptions

	2010 Costs (€/kW)	2020 Costs (€/kW)
Technical CAPEX	1366	1067
Civils CAPEX	0	0
Connection CAPEX	0	0
Planning CAPEX	0	0
Total CAPEX	1366	1067

Ground Source Heat Pumps – Other Assumptions

- Pöyry Central scenario Fixed Opex:
  - €56/kW/yr
  - F/E/E, 2005
- Project lifetime: 30 years, DEA 2005
- Economic lifetime: 15 years, Pöyry
- No information available on individual elements of fixed opex
- Discount rates range between 10-14% real pre-tax, depending on the location of the biomass heat non grid resource

Load factor assumptions

	Average Load Factor	
	Current ('04)	New Build
UK	50%	50%
Germany	50%	50%
France	50%	50%
Denmark	50%	50%
Iberia	50%	50%
Ireland	50%	50%
Benelux	50%	50%
Finland+	50%	50%
Italy+	50%	50%
Poland+	50%	50%
Slovakia+	50%	50%
Greece+	50%	50%

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   - Renewable heat technologies
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   - Cost
   - Carbon
6. Renewable transport assumptions
7. Sensitivities

For the purposes of this study, the relevant cost measure was the resource cost

- A resource cost is the additional cost incurred above that of the conventional technology that has been replaced.
- This is determined by taking an assumed cost counterfactual and subtracting this from the calculated levelised cost for each RES-E and RES-H technology type.
- The counterfactual cost for RES-E represents the cost of a conventional electricity installation used to produce the same electricity output as that from a renewable electricity plant, whilst for RES-H it represents the cost of a conventional heat installation used to produce the same heat output as that from a renewable heat plant.

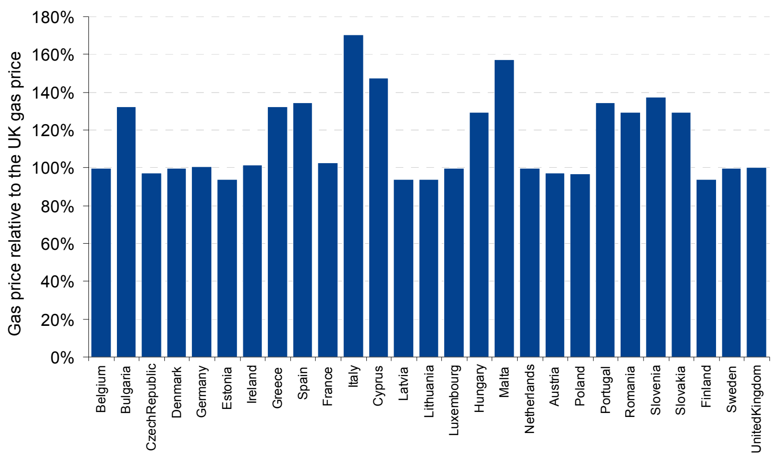
Our cost counterfactuals for RES-E technologies were based on Pöyry assumptions for a CCGT plant

- The conventional technology assumed for RES-E was a CCGT.
- We have assumed the same technical and financial characteristics across all 27 EU Member States.
- Gas prices are based on the DTI's Central projection as taken from their May 2007 report "Updated Energy and Carbon Emission Projections – The Energy White Paper" and a country specific differential applied to create a relative gas price for each member state.

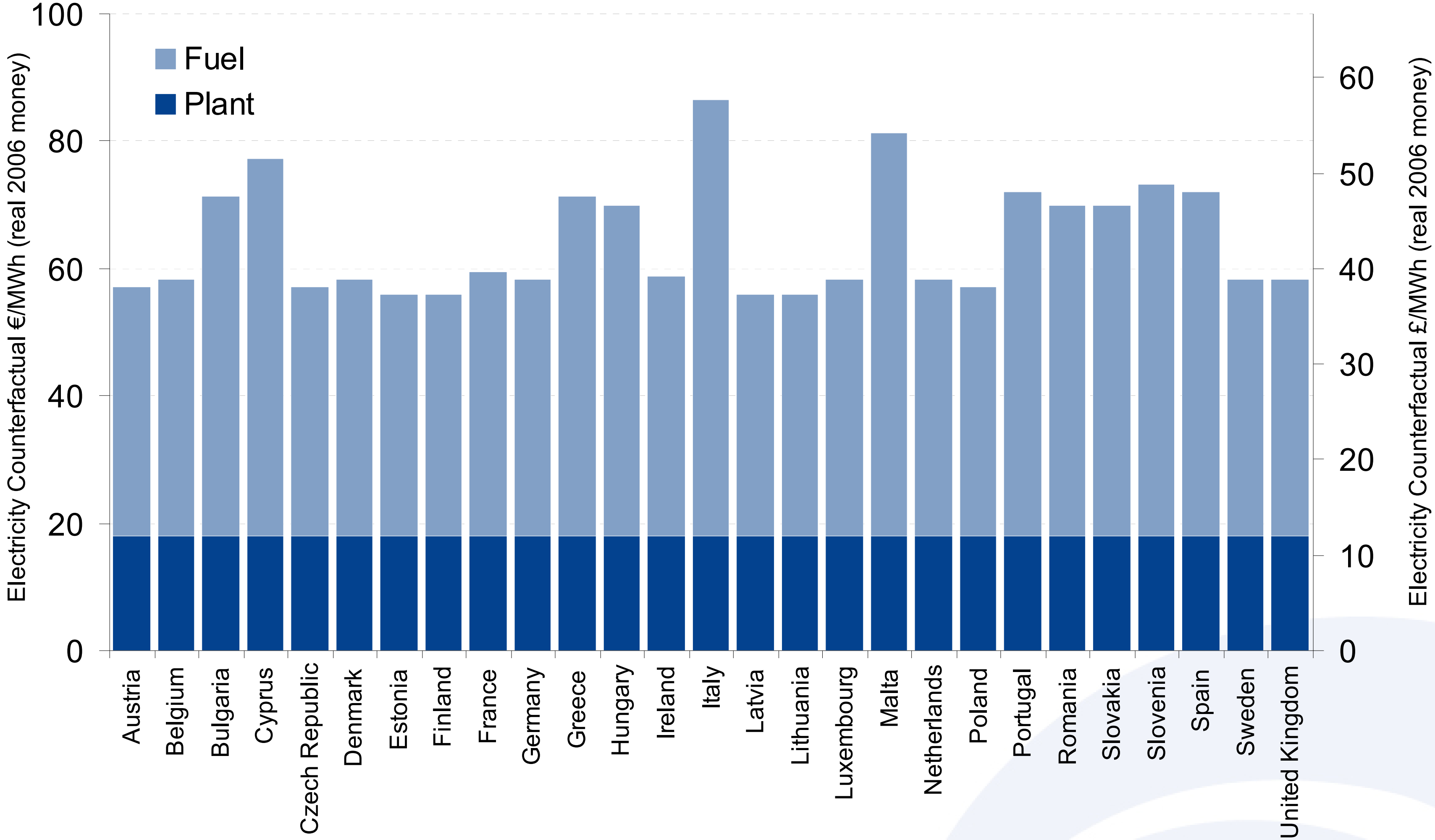
Pöyry assumptions for a new CCGT plant

Parameter		
Capex	£500/kW	€742/kW
Fixed Opex	£25/kW	€37/kW
Discount Rate	11%	11%
Load Factor	85%	85%
Efficiency (HHV basis)	55%	55%
Economic lifetime	15 years	15 years
Project lifetime	25 years	25 years

Relative gas price by country in 2010



Using these CCGT parameters, we derive a RES-E cost counterfactual of £39.3/MWh (€58.3/MWh) for the UK



Our approach to our RES-H cost counterfactuals takes into account load types and fuel

- Whereas it is possible to assume a single conventional electricity generation technology to use as a counterfactual, the heat counterfactual must account for the customer type (small or large load) and the input fuel used.

- The cost of conventional heat technologies include a Capex element for the boiler (except for electricity), fixed opex and a fuel element. The capex and fixed opex costs are assumed to be constant all 27 EU member states.

Assumptions for a small load boiler

Parameter			
Capex	£65/kW	€96/kW	E/E/E, 2005
Fixed Opex	£3.3/kW	€4.8/kW	E/E/E, 2005
Discount Rate	10%	10%	E/E/E, 2005
Load Factor	10%	10%	E/E/E, 2005
Efficiency (HHV basis)	87%	87%	Pöyry
Economic lifetime	15 years	15 years	E/E/E, 2005
Project lifetime	15 years	15 years	E/E/E, 2005

Assumptions for a large load boiler

Parameter			
Capex	£65/kW	€96/kW	E/E/E, 2005
Fixed Opex	£3.3/kW	€4.8/kW	E/E/E, 2005
Discount Rate	10%	10%	E/E/E, 2005
Load Factor	80%	80%	DTI*
Efficiency (HHV basis)	87%	87%	Pöyry
Economic lifetime	15 years	15 years	E/E/E, 2005
Project lifetime	15 years	15 years	E/E/E, 2005

* UK Biomass Strategy 2007, DTI, May 2007.

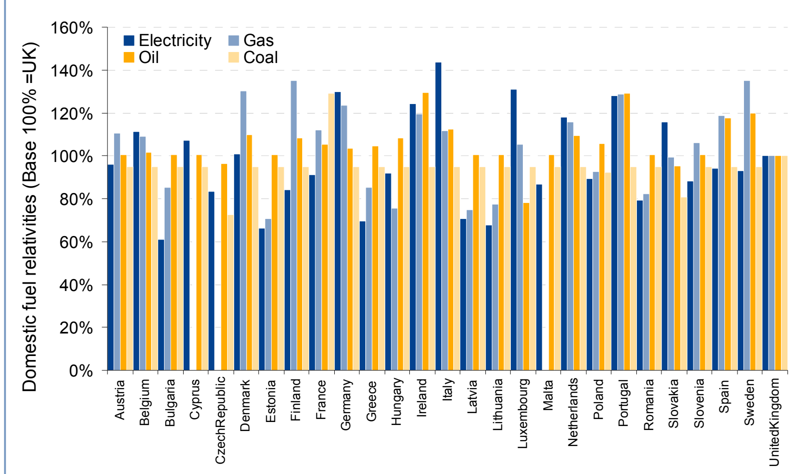
Our end-user tariffs for the different load types are assumed to differ for each EU member state

- Fuel costs (ie, end-user tariffs) are differentiated by customer type and by country. The UK tariffs are taken from the DTI's May 2007 report "UK Biomass Strategy" for gas and oil products, Eurostat end-user tariffs for electricity and IEA Statistics for coal. We assumed that small load corresponds to residential customers and large load to industrial customers.

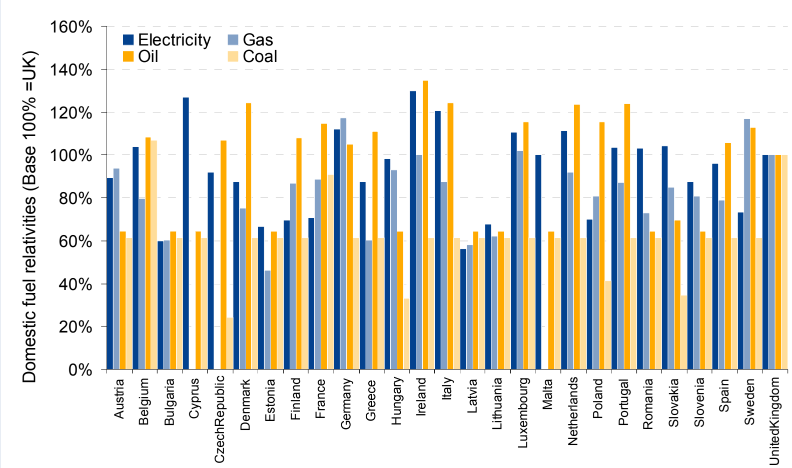
- Country specific tariffs are assumed to maintain the 2004 to 2006 average relativity to the UK tariff from Eurostat publications for gas and electricity and IEA statistics for oil.

- We assume that fuel costs are constant in real terms during the 2010-2020 period.

Small load fuel tariffs relative to the UK



Large load fuel tariffs relative to the UK



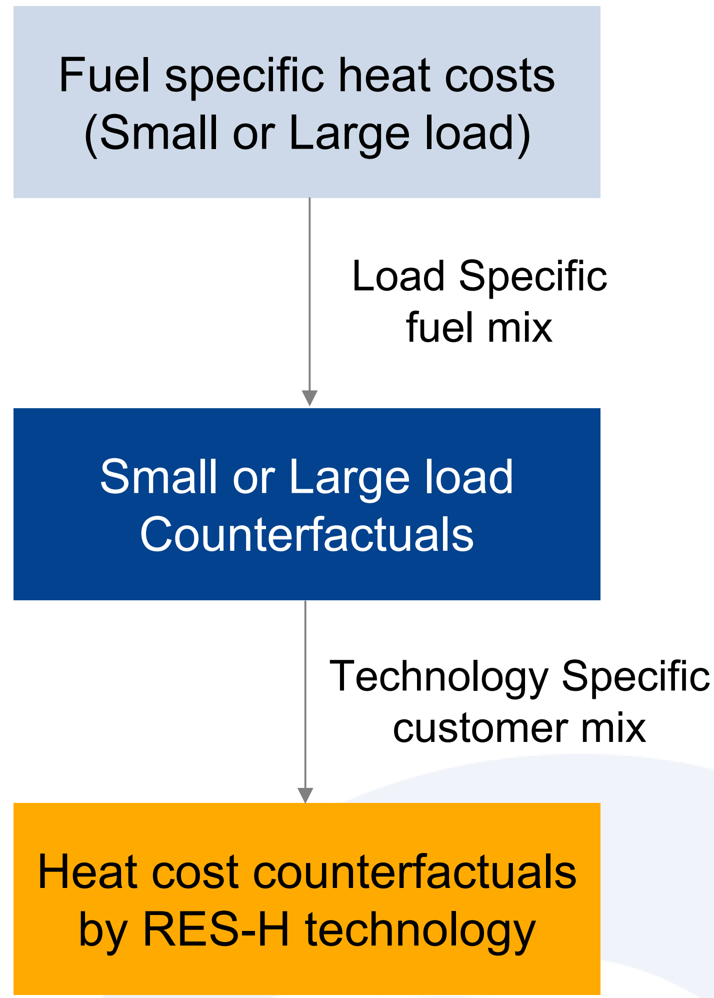
We have used the following methodology to calculate our RES-H cost counterfactuals

- The counterfactual cost for renewable technologies differs according to assumed customer mix between small load and large load

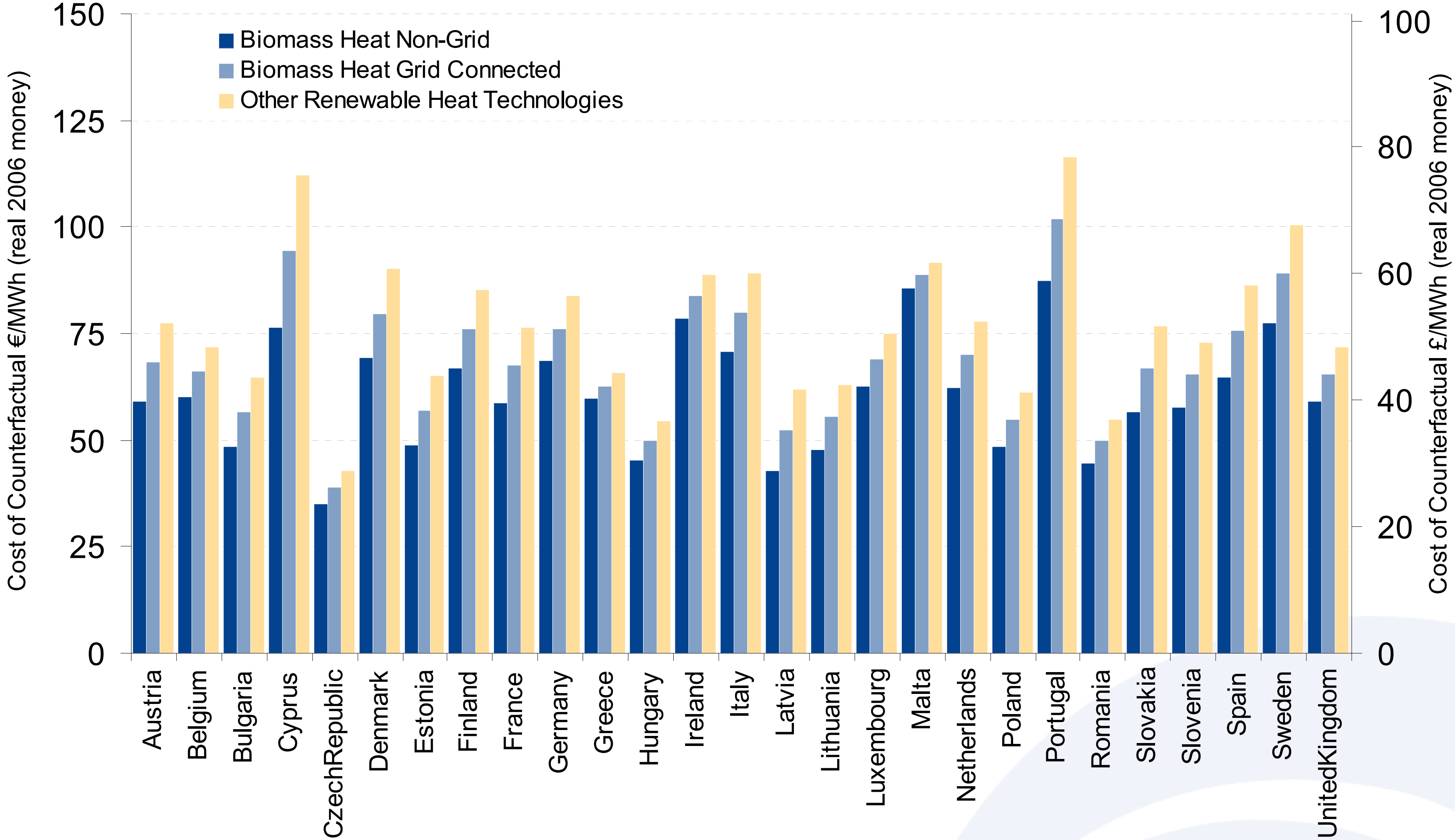
- Our assumed customer mix for the different heat technologies:

	Small load	Large load
Biomass Heat Non-Grid	75%	25%
Biomass Heat Grid Connected	50%	50%
Solar Heat	100%	
Geothermal Heat	100%	
Ground Source Heat Pumps	100%	

- The costs across countries differ according to the assumed heat fuel mix. Fuel mixes by country and customer type have been sourced from Euroheat & Power's 2005 report "Ecoheatcool Work Package 1 – The European Heat Market".



Using these different parameters, we derive technology specific RES-H cost counterfactuals



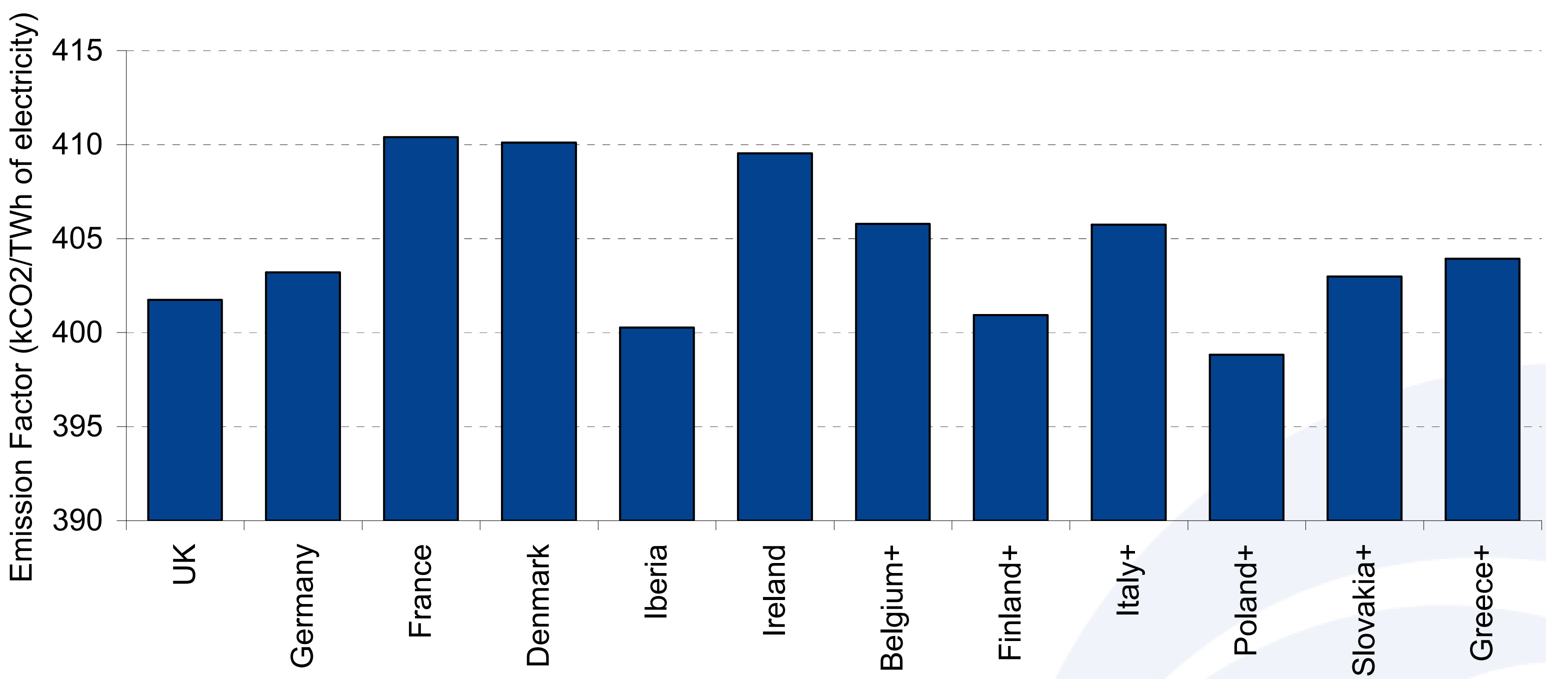
BERR - Estimating costs of renewables for the 2020 target

Agenda

We have taken the following approach in calculating our carbon counterfactuals for RES-E

- The volume of carbon abated by each additional unit of renewable electricity depends on the carbon emissions of the marginal unit of generation displaced. In order to be consistent with previous BERR analyses, the methodology assumes that the marginal generation technology will be a CCGT throughout the period.

- The country's natural gas emission factors are derived from country specific emission factors reported in the National Greenhouse Gas Inventory Reports, as shown below:



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Our carbon counterfactual for RES-H is based on the country-specific heat fuel mix

- The volume of carbon abated by each unit of renewable heat depends on the carbon intensity of the conventional heat source that is replaced. It is assumed that renewable heat displaces the average carbon emissions of the baseline heat fuel mix (the Heat Emission Factor).

- Each country's heat fuel mix is based on the EcoHeatCool Work Package 1 report. This gives a heat production mix for each country in 2003. As we have no credible sources projecting the heat mix over the period 2010 – 2020 we have assumed this mix is fixed throughout the period modelled.

Methodology: Calculating a country's Heat Emission Factor

$$EF_{H(mix)} = \sum \frac{H_i}{H_{mix}} \times EF_{H(i)}$$

$$EF_{H(i)} = \frac{EF_{F(i)}}{\eta_i}$$

- A country's Heat Emission Factor ($EF_{H(mix)}$) is the amount of CO2 emitted by an average unit of heat produced in that country.

- The Heat Emission Factor (EF_H) of heat generated from fuel i is given by dividing the fuel's Fuel Emission Factor (EF_F) by the average efficiency of heat plant burning that type of fuel, ηi .

- The overall Heat Emission Factor of the country for each category of heat is given by multiplying each heat source's Heat Emission Factor by that technology's contribution (by output volume) *Hi* to the total volume of heat produced, *Hmix*.

Based on this methodology we derive the following carbon counterfactuals for RES-E and RES-H technology type

Emission Factors tCO2/GWh	RES-E technologies	Biomass Heat Non Grid	Biomass Heat Grid Connected	Solar Heat	Geothermal Heat	Ground Source Heat Pumps
Austria	404	198	203	192	192	192
Belgium	402	274	274	273	273	273
Bulgaria	402	388	387	390	390	390
Cyprus	404	550	497	604	604	604
Czech Republic	404	367	370	363	363	363
Denmark	410	324	325	323	323	323
Estonia	404	419	425	412	412	412
Finland	396	213	206	221	221	221
France	410	178	185	171	171	171
Germany	403	345	360	331	331	331
Greece	404	431	427	434	434	434
Hungary	404	277	287	267	267	267
Ireland	410	369	364	375	375	375
Italy	406	316	323	310	310	310
Latvia	402	178	188	169	169	169
Lithuania	410	253	262	245	245	245
Luxembourg	396	290	293	286	286	286
Malta	404	716	745	688	688	688
Netherlands	409	305	312	298	298	298
Poland	391	420	429	411	411	411
Portugal	404	294	284	305	305	305
Romania	404	273	288	258	258	258
Slovakia	404	265	272	259	259	259
Slovenia	396	279	281	277	277	277
Spain	400	274	273	276	276	276
Sweden	404	125	123	126	126	126
United Kingdom	402	307	312	302	302	302
Average EU 27	**403**	**320**	**322**	**317**	**317**	**317**

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Renewable transportation fuels target in context

- The element of this study is to review compliance with the EU 2020 target of 10% biofuel use in transportation.

  To this end, we:
  - assess compliance with the biofuel target separately from renewable heat and generation targets;
  - assume a uniform target for both diesel and gasoline consumption in 2020 with no view on substitution between the two.

- The overall project scope anticipated utilizing existing data and information. Faced with limitations in publicly available data, we have had to supplement this with original Pöyry analysis:
  - the time and resource constraints of this project do not permit a comprehensive assessment of the global transport fuel market and biofuel supply chain.

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Emerging issues arising from the analysis

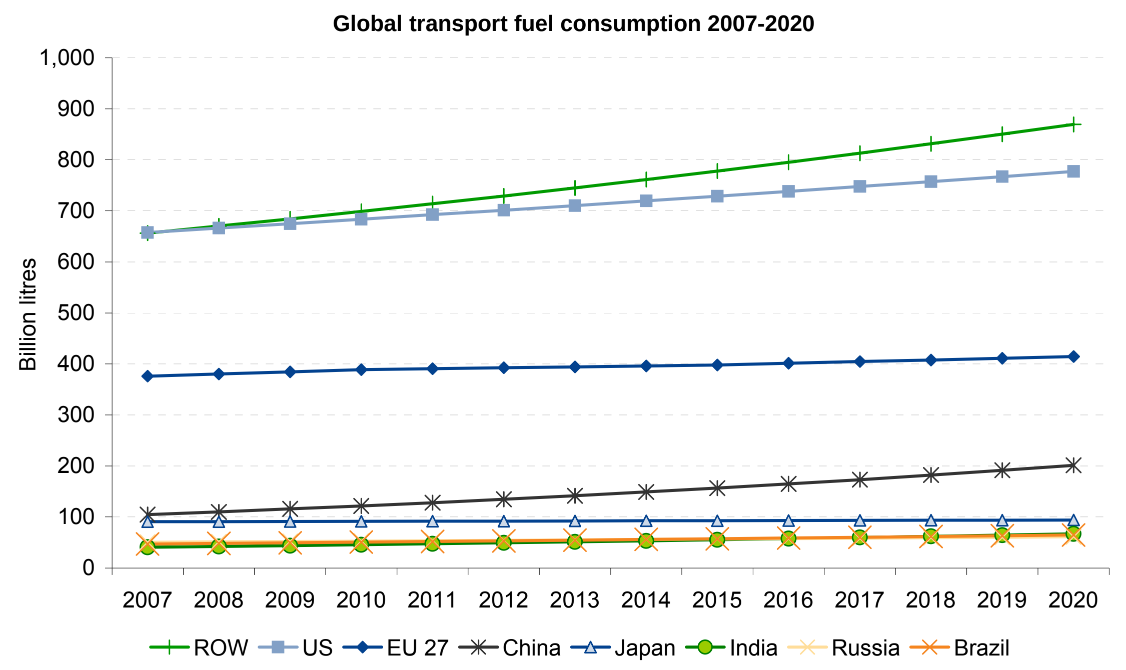
- To assess compliance with the EU 2020 target, we have analysed demand, supply and costs of biofuels in 2020. Our analysis suggests that there is sufficient supply to meet the 10% EU target in 2020.

- The results suggest that on a cost basis, the EU is likely to import significant volumes. However this raises a few issues:
  - Diversion of production meant for food consumption to biofuels
    - In assessing biofuel supply we have netted off food consumption from crop production
  - Diversion of production meant for non-food use
    - On a cost basis, Malaysian/Indonesian palm oil is capable of supplying 100% of EU biodiesel demand in 2020. However most of the production is currently used for other non-food uses e.g. soaps, oils, detergents
  - Competition for set-aside land with biomass/ energy crops for generation and heat depends on the level of import of biofuels, as solid biomass are more likely to be locally sourced

Global transport fuel consumption is the principal driver for biofuel demand and supply

- Global transport fuel consumption will increase by 18% between 2007 and 2020, driven by significant growth outside the EU and the US
- ROW increase driven primarily by consumption in China and India
- EU 2020 transport fuel consumption is estimated at 174 billion litres of gasoline and 240 billion litres of diesel

Gasoline and diesel transport consumption 2007- 2020 (billion litres)



Source: European Energy and Transport: Trends to 2030; IEA Energy Balances of OECD Countries 2004/ Key World Energy Statistics

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Assessing global demand

Demand = **Transport fuel consumption in 2020 x % displacement with biofuels**

Assumptions and calculations:

• Volumes for transport fuel consumption in 2020 are projections based on recent gasoline and diesel consumption figures;

• Demand scenarios are built on estimated or targeted % displacement of conventional fuels:

Low demand scenario:	**EU – 10% ; ROW – 1% ; US ethanol – 15% ; Brazil ethanol – 20%**
Central demand scenario:	**EU – 10% ; ROW – 2% ; US ethanol – 15% ; Brazil ethanol – 25%**
High demand scenario:	**EU – 10% ; ROW – 5% ; US ethanol – 15% ; Brazil ethanol – 30%**

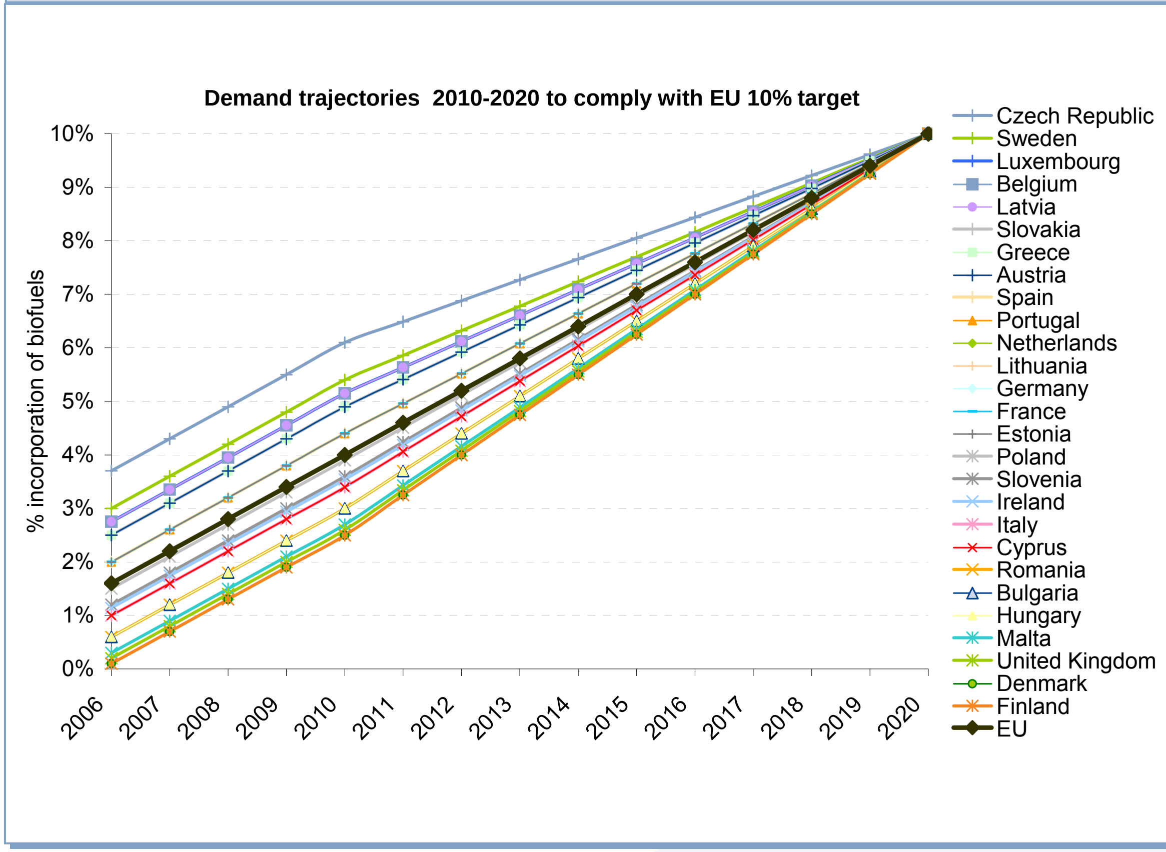
• Biofuel demand is calculated on the basis of energy content rather than direct volume displacement (energy contents: 1.53 for ethanol, 1.1 for biodiesel).

Source: European Energy and Transport: Trends to 2030; IEA Energy Balances of OECD Countries 2004/ Key World Energy Statistics; US Twenty In Ten Programme at http://www.whitehouse.gov/stateoftheunion/2007/initiatives/energy.html

A snapshot of the global biofuel demand picture between 2006 and 2020

- Global biofuel demand in 2020 ranges from 214 – 287 billion litres, with a central scenario at 234 billion
- EU biofuel demand is estimated at 53 billion litres – 26.3 billion of biodiesel and 26.6 billion of bioethanol
- US biofuel demand ranges from 138 – 146 billion litres

Biodiesel and bioethanol demand trajectories to compliance



Source: Pöyry estimates, based on data from theEU Biofuels Progress Report, 10.1.2007

Assessing global supply

Bioethanol feedstocks: Maize, wheat, sugar beet, sugarcane

Biodiesel feedstocks: Rapeseed, sunflower, palm oil, oilseeds, cottonseeds, soybean

domestic crop production

food consumption

50% of surplus, for non-food consumption

food security and arable land

constraints

domestic crop production diverted to biofuels

Global supply = Σ domestic crop production diverted to biofuels (tons) x yield (litres/ton)

= Σ domestic yield (litres)

Estimated or targeted % of fuel displacement

domestic demand for biofuels

Global supply available for export = Σ (Domestic yield (litres) – domestic demand (litres))

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Constraints on biofuel supplies

Our supply analysis includes conservative constraints to account for concerns on sustainability and to reflect economic reality:

- **<u>Sustainability in land use</u>: major concerns include the destruction of rainforest and the intensive use of fertilizers:**
  - for countries that are already using 100% or more of their rain-fed arable land either through extensive irrigation such as Egypt, or scarcity of land e.g. Luxembourg, we assumed zero annual growth rates of crop production;
  - for countries using 50% or more of rain-fed arable land such as France, Bulgaria, we assumed minimal growth rate projections;
  - the arable land definition/ constraint used expressly excludes any current forests, natural reserves etc from being diverted to agriculture.

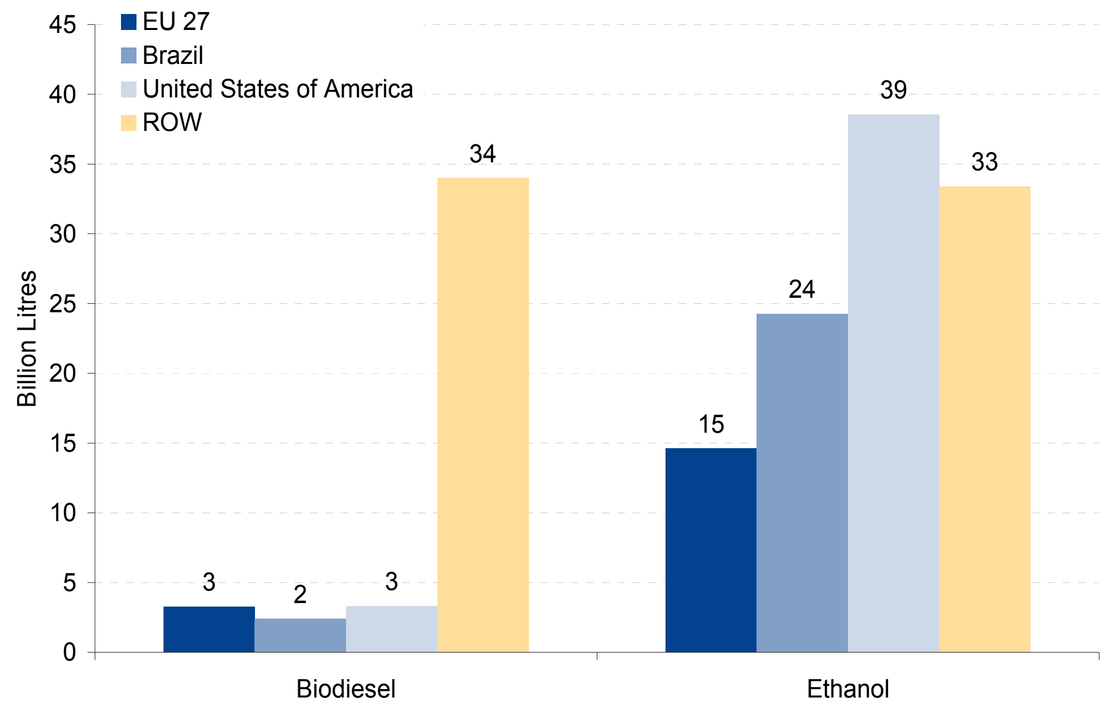
- **<u>Sustainability in food consumption</u>: there is concern that feedstocks originally destined to food consumption will be diverted to biofuels production:**
  - we expressly netted off food consumption from the feedstocks used in the supply calculation;
  - for countries with a high prevalence of poverty and under-nourishment, we capped biofuel supplies to avoid any diversion of wheat or maize to biofuel use.

- **<u>Other uses of feedstocks</u>: a significant amount of feedstocks are already currently used for non-food purposes such as soap production which is unlikely to change:**
  - we have put a cap on diversion of feedstocks from current non-food use at 50%.

A snapshot of the global biofuel supply picture at 2020

- Global supply is likely to fall short of demand. Our 2020 estimates are 154 billion litres supplied -111 billion of bioethanol, 43 billion biodiesel
- EU supply is estimated at 17.9 billion litres – 3.3 billion of which is biodiesel
- The US is likely to supply 38.6 billion litres in bioethanol and 3.3 billion in biodiesel
- Setting cost aside, the EU is unlikely to meet its own biodiesel or bioethanol demand and is likely to be a net importer
- Palm oil accounts for more than 80% of the Rest of the world supply of biodiesel
- The supply volumes are considerably conservative allowing for significant continued use of feedstocks in food and non-food use, and sustainability concerns

Biodiesel and bioethanol global supply in 2020 (billion litres)



Source: Pöyry estimates, based on data from FAO Stat; OECD-FAO Agricultural Outlook 2007-2016

Methodology for distribution of supplies available for export

- We analysed four assumptions on the distribution of biofuel supplies net of domestic consumption:

  Assumption 1: EU gets priority over the US: EU imports the volumes of biofuels necessary to achieve the 10% target

  Assumption 2: Supplies are distributed between the EU and US in proportion to their needs (US gasoline consumption represents over 80% of the total EU+US gasoline consumption whereas diesel consumption proportions are more balanced)

  Assumption 3: US gets priority over the EU

  Assumption 4: Each region imports 50% of the supplies available

- Assumption 1 was chosen for biodiesel and assumption 4 was chosen for bioethanol

- Choices for assumptions were based on our reading of the priorities of both regions (the US seem to be more reliant on bioethanol in achieving fuel displacement) and of the different level of obligation behind the targets (EU countries are likely to be willing to pay more for imports because of the binding/mandatory nature of the target)

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Assessing costs of imported and locally produced biofuels

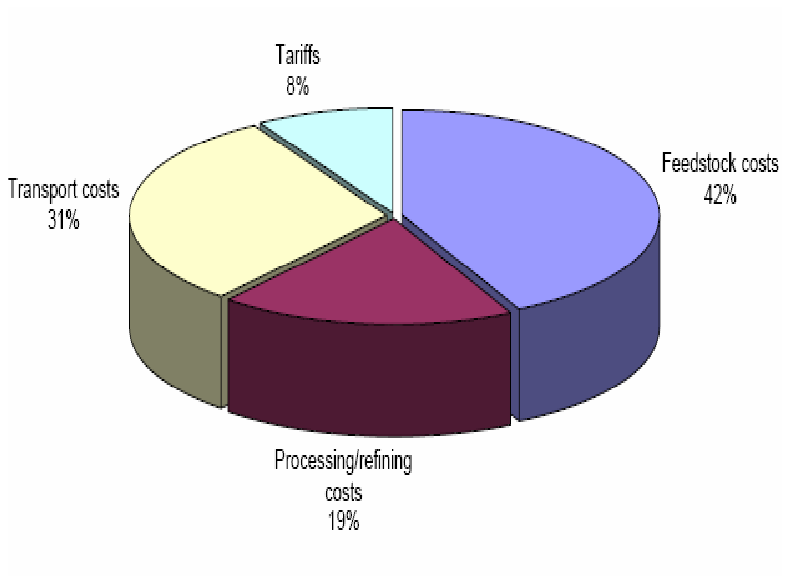
Cost of biofuels	=	**feedstock costs**	=	**producer prices**
		international transport costs	=	**ocean freight charges**
		processing & refining costs	=	**% of feedstock costs**
		tariffs & subsidies	=	**as currently instituted**
		blending & distribution costs	=	**% of feedstock costs based on historic ratios**

- There is significant variation between countries on the composition of various cost elements, however feedstock prices are consistently the largest component

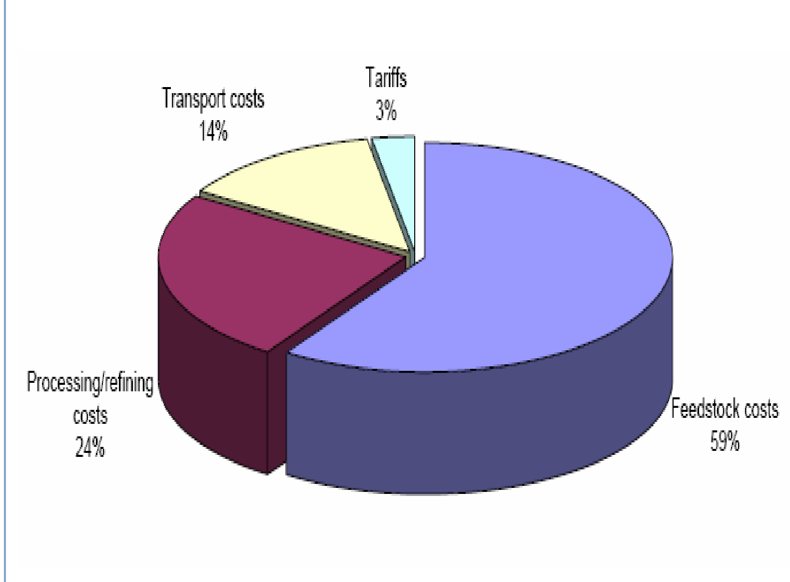
- Processing costs also vary due to differing technology (vendors and scale of production); and tradability of product (biodiesel feedstock can be imported as raw feedstock, refined product for blending, or as semi-processed tallow). Biodiesel refining is one average more expensive than bioethanol processing.

Breakdown of biodiesel and bioethanol costs

Costs of biodiesel



Costs of bioethanol



Source: Pöyry estimates

Methodology for determination of supply curves: merit orders

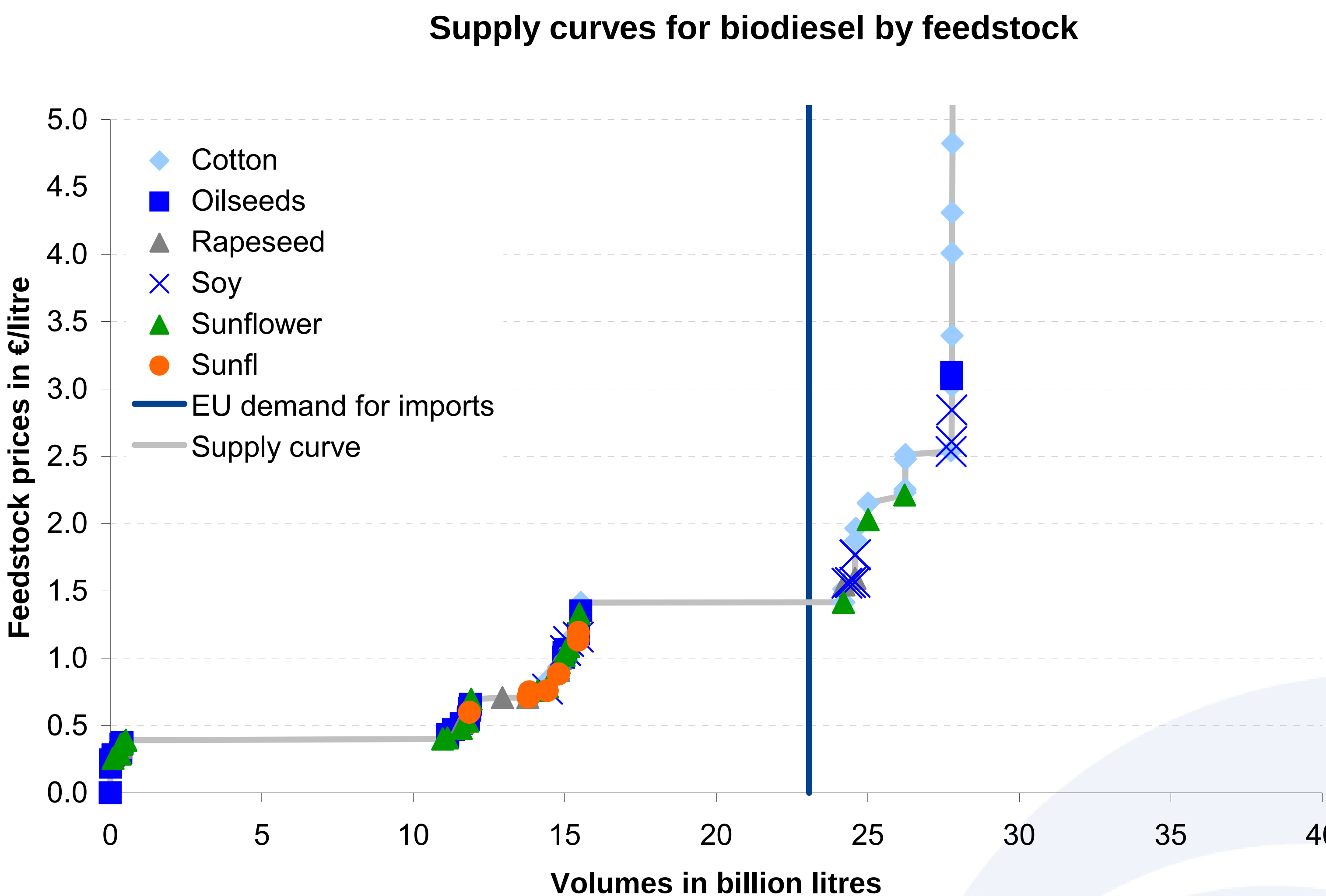
Biodiesel merit order (in €/litre and 1000 litres)

Feedstock	Volume	Price/l	Merit order
Guinea Palm	77,658	0.26	88,070
Thailand Palm	224,026	0.29	331,388
Guatemala Palm	37,892	0.36	393,225
Honduras Palm	122,312	0.39	516,375
Malaysia Palm	10,455,112	0.40	10,971,486
Cameroon Palm	157,798	0.41	11,129,285
China Oilsd	188,085	0.47	11,329,404
Côte d'Ivoire Palm	255,516	0.48	11,584,920
Russia Rpsd	25,450	0.52	11,610,458
Ecuador Palm	192,306	0.53	11,802,764
Moldova Sunfl	21,901	0.60	11,853,316
Malaysia Oilsd	27,617	0.66	11,889,242
Angola Palm	22,052	0.70	11,911,294
Canada Rpsd	1,028,797	0.71	12,940,091
China Rpsd	846,065	0.71	13,786,156
Paraguay Sunfl	5,270	0.71	13,791,426
China Sunfl	35,664	0.71	13,827,090
Benin Cotton	7,371	0.72	13,834,460
Ghana Palm	268,244	0.76	14,103,064
Ukraine Sunfl	322,487	0.76	14,425,551
Uzbekistan Cotton	75,207	0.83	14,508,799
Russia Sunfl	283,406	0.88	14,792,458
Australia Rpsd	21,165	0.96	14,821,330
Ukraine Rpsd	36,452	1.00	14,857,782
Nigeria Oilsd	106,312	1.01	14,964,094
Bolivia Soy	56,949	1.06	15,033,975
Costa Rica Palm	84,656	1.09	15,125,731
Argentina Sunfl	319,657	1.14	15,449,512
Solomon Isl Palm	22,786	1.33	15,479,320
Indonesia Oilsd	50,326	1.35	15,529,646
Indonesia Palm	8,669,025	1.42	24,198,706
Canada Soy	94,603	1.56	24,308,865
Brazil Soy	121,329	1.56	24,430,194

Source: Pöyry estimates

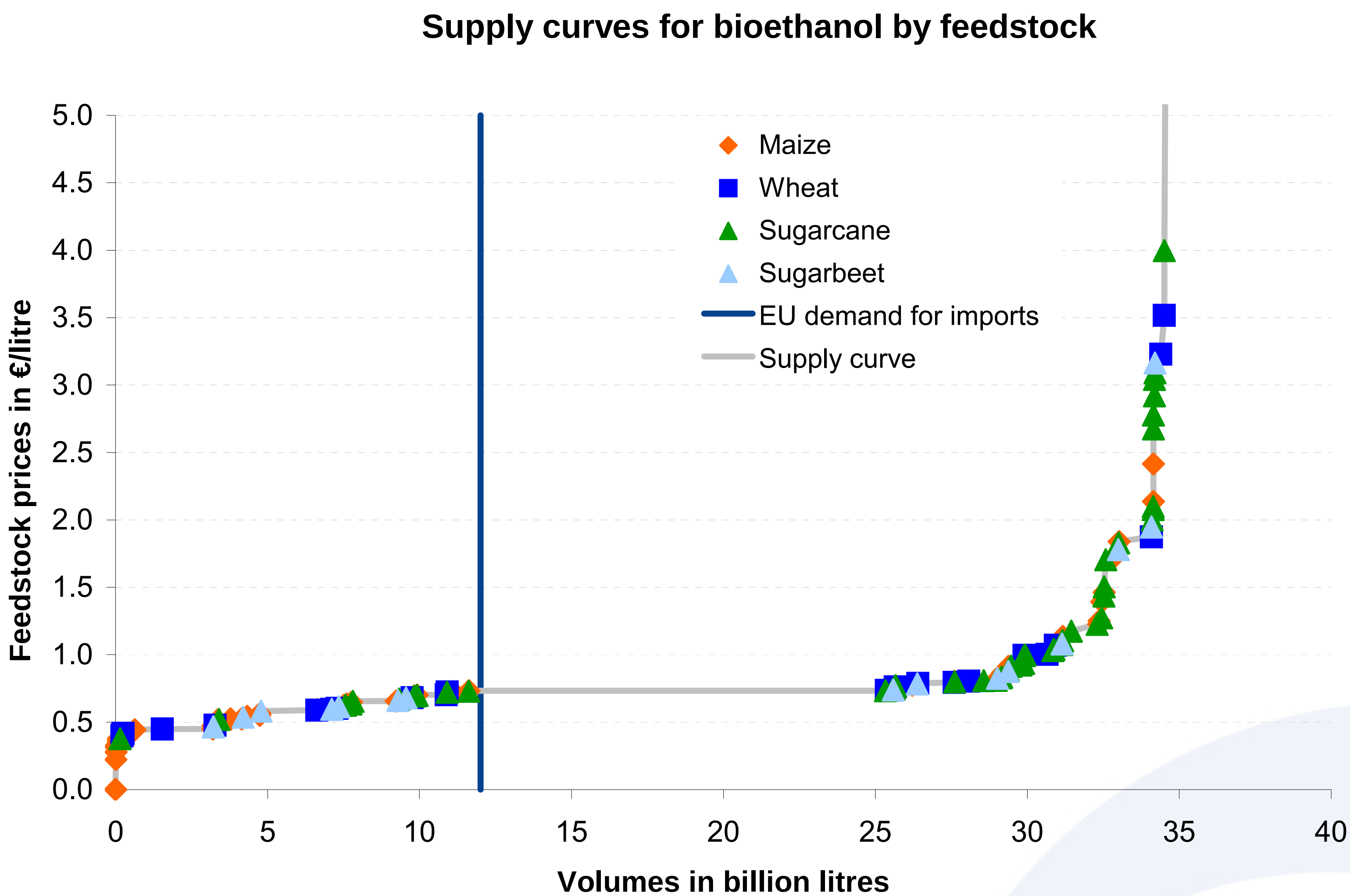
- Combining the supply and cost estimates by country and by feedstock enables us to build a 2020 picture of likely supply curves
- The merit order allows us to see the origin and costs of the various feedstocks imported into the EU
- The ranking is very sensitive to the assumptions made on prices - transport costs, tariffs and set-aside payments
- Costs of imports are calculated as the sum of the product of volume and prices for each row of the merit order

Palm oil from South East Asia will dominate EU imports and global biodiesel supply in 2020



Source: Pöyry Energy Consulting

Maize and wheat will be the most important bioethanol feestocks in the EU and worldwide



Source: Pöyry Energy Consulting

Assessing the cost of compliance with EU 2020 10% targets

Resource cost of compliance = cost of 10% biofuels use – cost of displaced fossil fuel

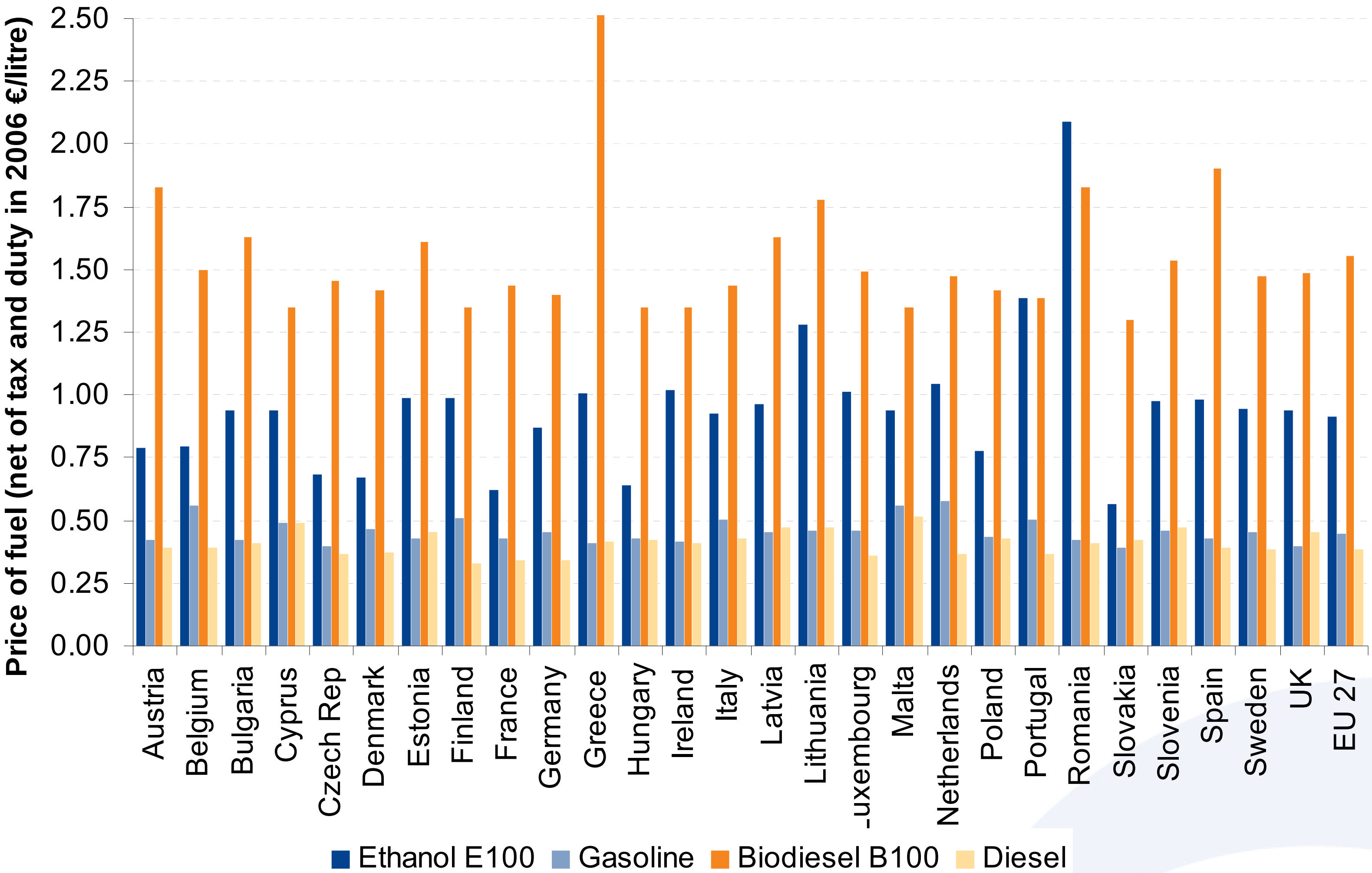
- **The cost 10% biofuels use is the sum of the cost of production within the EU and the cost of imported biofuels as determined in the merit order**

- **Our estimates for costs of production within the EU show that:**

  - bioethanol is more competitive than biodiesel:
  average cost of bioethanol = €0.58/l, average cost of biodiesel = €0.73/l;
  - costs vary widely across EU countries;
  - the cheapest bioethanol in Europe is likely to be maize and wheat based;
  - the cheapest biodiesel in Europe is likely to be rapeseed based;
  - European-produced biofuels are overall less competitive than biofuels from large exporters such as Malaysia and Indonesia for biodiesel;
  - biofuels are unlikely to be competitive with fossil fuels in 2020, absent very high oil prices.

- **The cost of displaced fossil fuel is based on our estimation of 2020 gasoline and diesel prices net of taxes**

Biofuels will remain consistently more expensive than conventional fuels in 2020



Source: Pöyry Energy Consulting

Gross and resource costs of compliance 2010-2020

Costs of compliance with 10% biofuels target over 2010-2020, (in €Bn, discounted to 2006)

Biofuel cost estimates for 2010-2020 (€bn, discounted to 2006)

	France	Germany	Italy	Spain	UK	Others	EU-27
Gross Costs							
Business As Usual + Incremental	41	52	31	41	32	93	290
Business As Usual	33	41	22	33	20	72	220
Incremental	8	11	9	9	12	21	70
Counterfactual Costs							
Business As Usual + Incremental	11	14	9	9	9	25	77
Business As Usual	8	11	7	7	6	20	58
Incremental	2	3	3	2	3	6	18
Resource costs							
Business As Usual + Incremental	30	38	22	33	23	68	213
Business As Usual	24	30	15	26	14	53	162
Incremental	6	8	6	7	9	16	51

Source: Pöyry estimates

2020 resource cost estimates suggest significant subsidies may be necessary to maintain long run compliance with 10% target

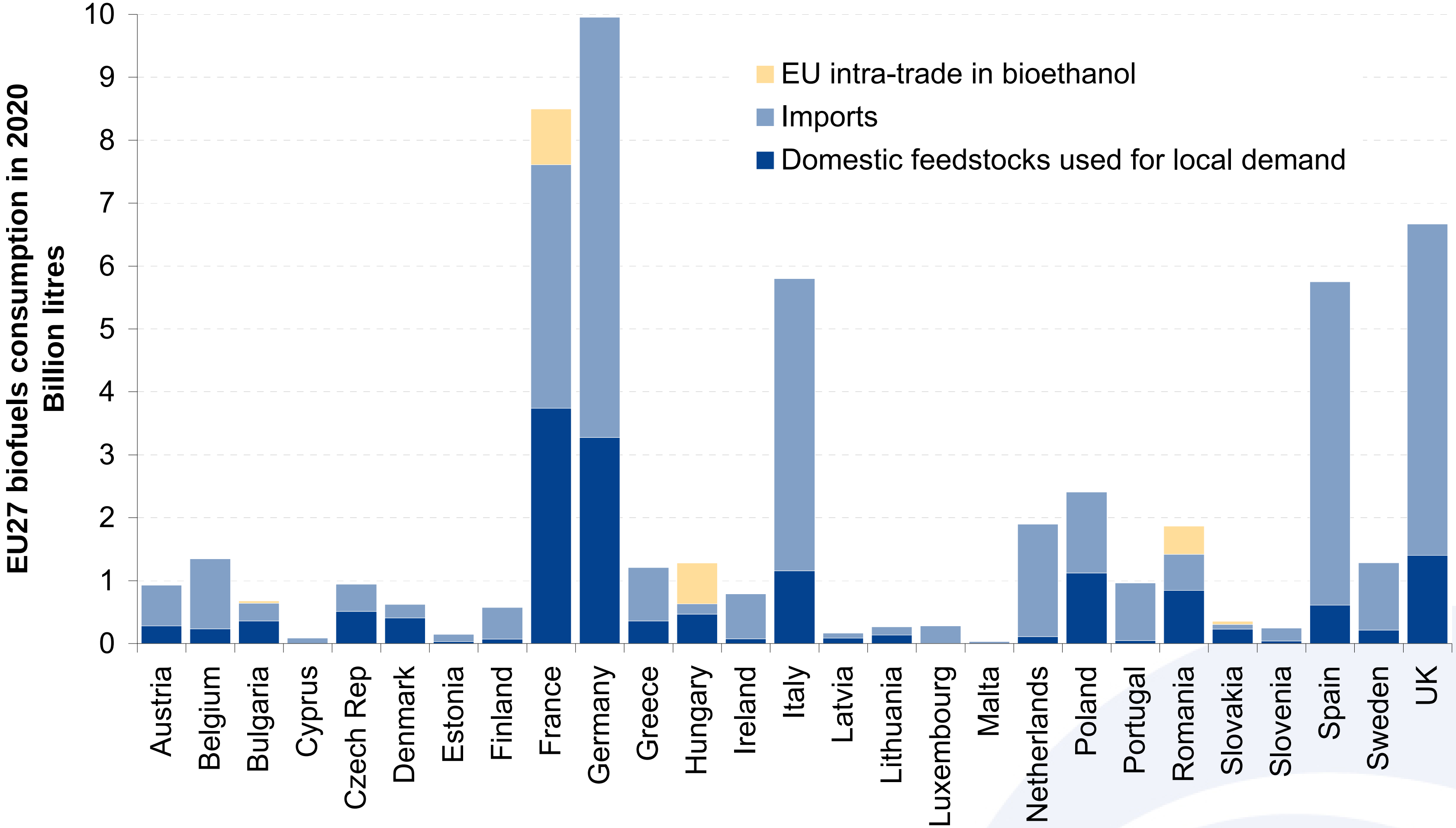
Costs of compliance with 10% biofuels target in 2020, in €Billion

Biofuel cost estimates in 2020 (€bn, discounted to 2006)

	France	Germany	Italy	Spain	UK	Others	EU-27
Gross Costs							
Business As Usual + Incremental	5.4	6.7	4.2	5.7	4.8	13.7	40.5
Business As Usual	3.6	4.5	2.4	3.9	2.4	9.1	26.0
Incremental	1.7	2.1	1.8	1.8	2.4	4.6	14.5
Counterfactual Costs							
Business As Usual + Incremental	1.4	1.9	1.3	1.2	1.3	3.5	10.6
Business As Usual	1.0	1.3	0.7	0.8	0.7	2.3	6.8
Incremental	0.5	0.6	0.5	0.4	0.7	1.2	3.8
Resource costs							
Business As Usual + Incremental	3.9	4.8	2.9	4.5	3.5	10.2	29.9
Business As Usual	2.7	3.3	1.7	3.1	1.7	6.8	19.2
Incremental	1.3	1.5	1.2	1.4	1.7	3.5	10.7

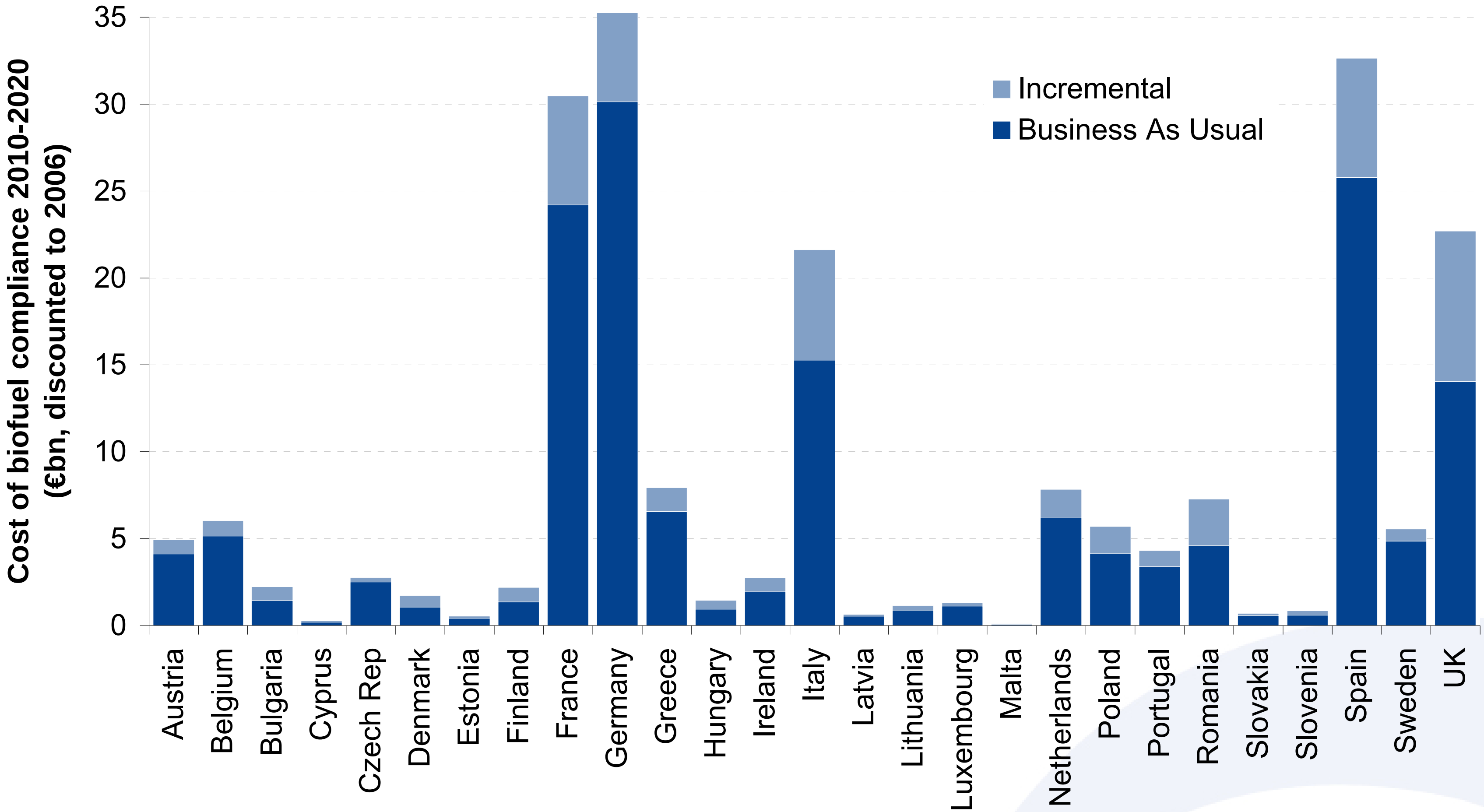
Source: Pöyry estimates

Conclusion I: The EU 27 will import 70% of biofuels consumed in 2020 - 53% of bioethanol and 88% of biodiesel demand



Source: Pöyry Energy Consulting

Conclusion II: Biofuels uptake of 10% may require up to €29.9 billion in annual support measures post 2020, and €213 billion between 2010-2020

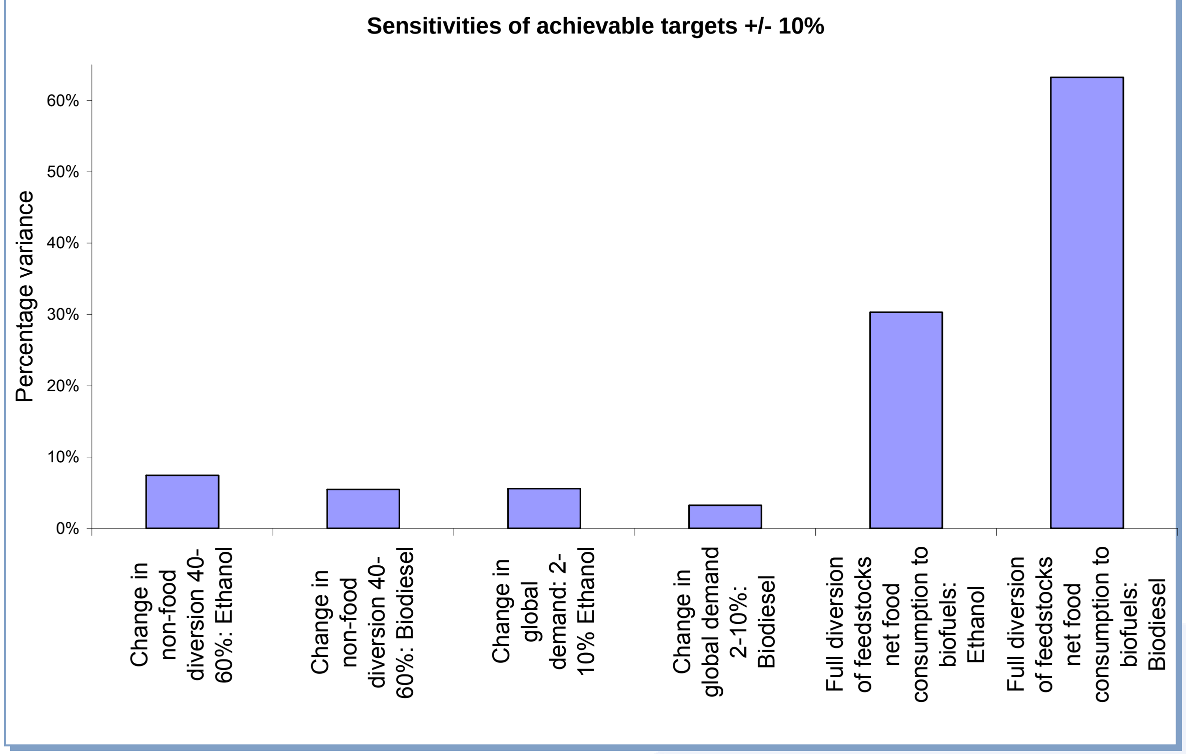


Source: Pöyry Energy Consulting

Issues arising for further consideration

- Due to significant limitations in publicly available data in the biofuels sector we have had to supplement available information with original in-house analysis.
- Level of global demand is the most important driver to the EU/UK complying with 10% target
- Analysis is sensitive to share of non-food crop diverted to biofuels

Sensitivity of compliance to changes in key variables



Source: Pöyry estimates

Issues arising from biofuels

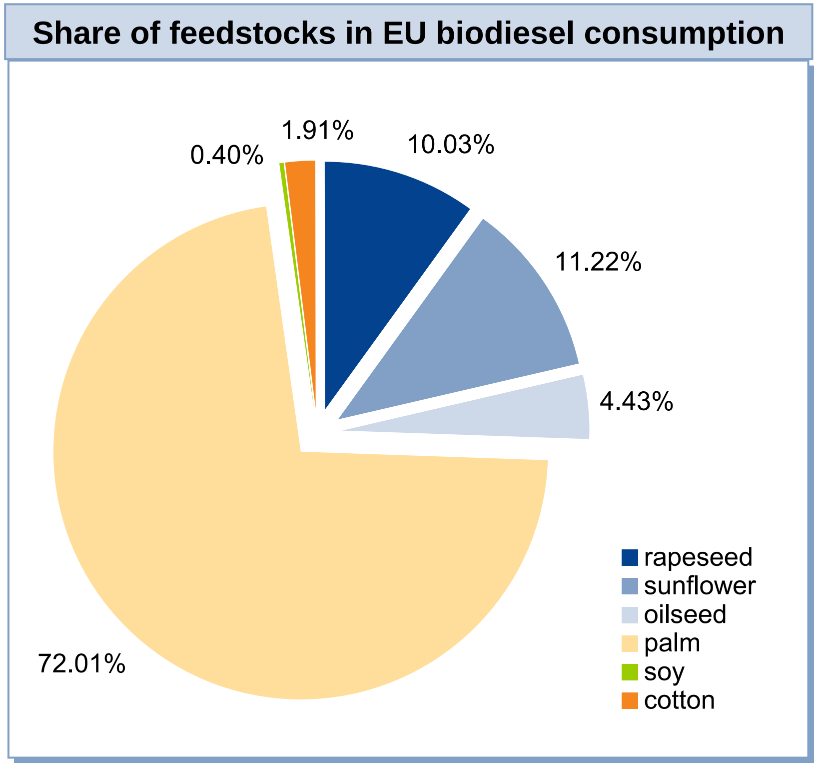
- There is potential **loss of fuel duty revenue** due to 10% displacement of fossil fuel transportation consumption. Is it reasonable to assume the current preferential tax treatment will remain?

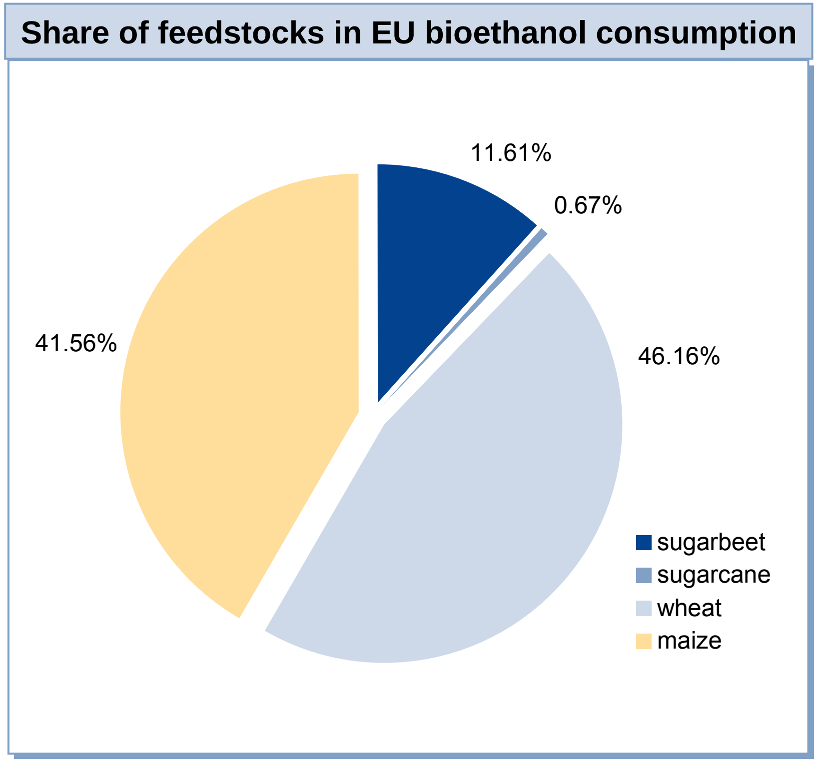
- We have excluded **second-generation technologies** from this analysis. In our opinion they are unlikely to become commercially viable and cost effective by 2020 to contribute to supply

- **Competition for land**
  - Given our indicative expectations of substantial biofuel imports, we believe that biofuels are unlikely to compete for set-aside land with biomass for generation and power
  - Set-aside payments and other subsidies however are likely to distort global biofuel market and will influence the merit order costs, and therefore the level of importation. This in turn affects the competition for land with solid biomass. Is it reasonable to assume subsidies and other existing barriers to trade will remain in 2020

- **Costs of production**
  - Producer prices are used as a proxy for feedstock prices, is there a better proxy we should be using?
  - There is no definitive source for processing costs. We have assumed these at 30% of feedstock costs based on other studies
  - EU import tariffs are assumed to continue as they are to 2020, is this reasonable?

Issues arising from imports

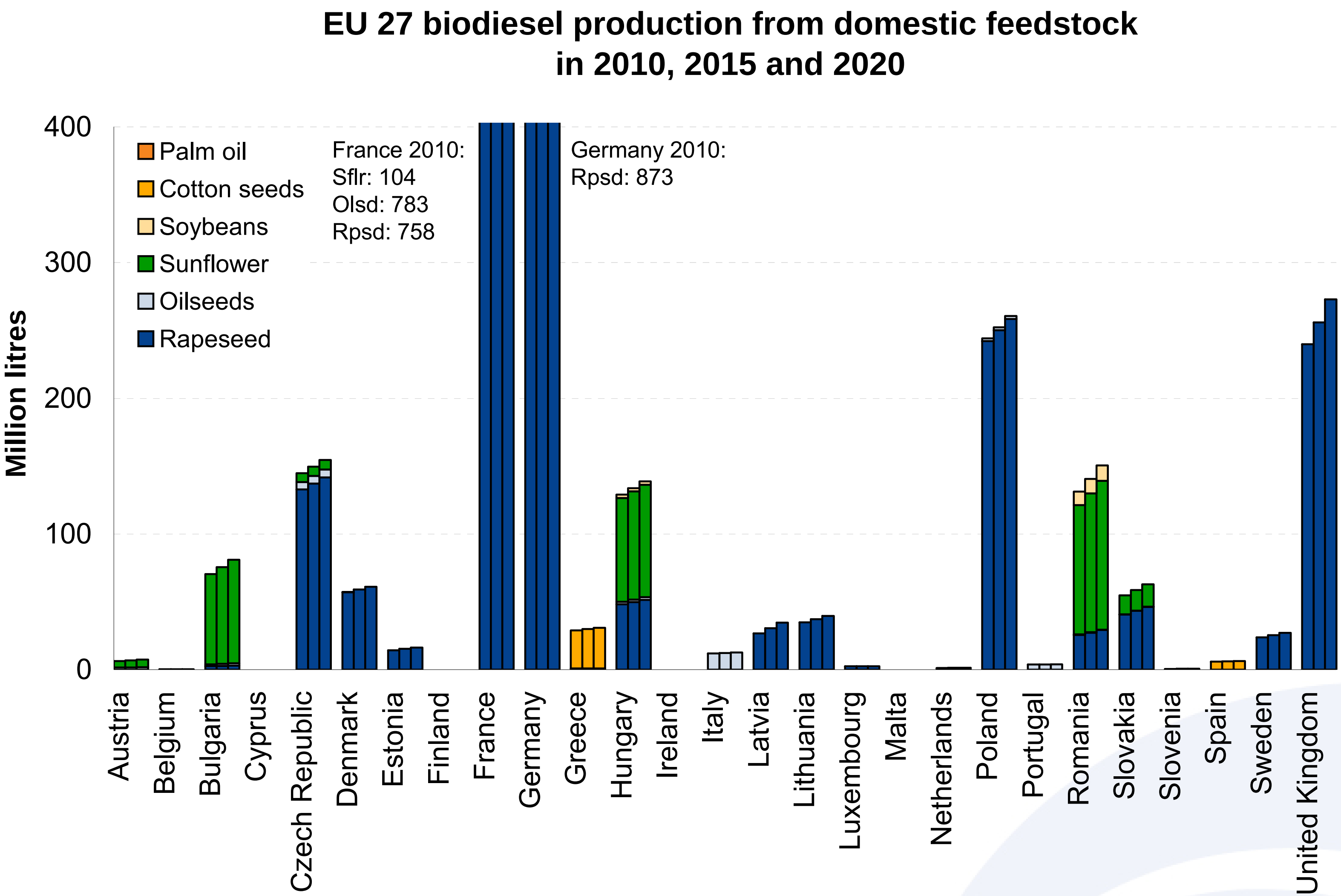




Source: Pöyry estimates

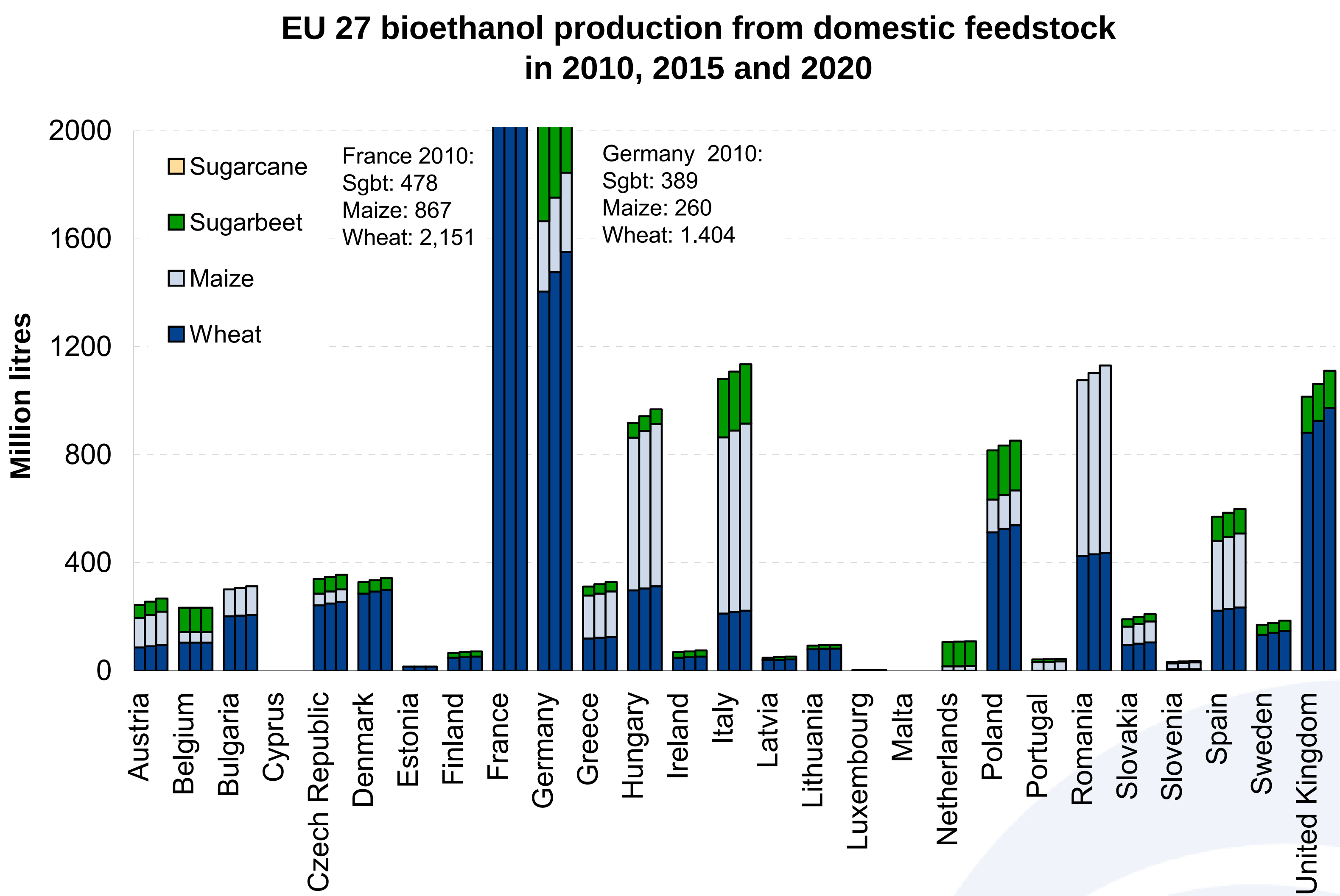
- Palm oil is likely to be the dominant biodiesel feedstock in 2020. With a high Cold Filter Plug Point, its performance in cold weather conditions is worst of the feedstocks considered, which raises issues on its uptake as a blend
- Palm oil and biofuels from developing countries raise concerns about sustainability – the destruction of rainforest to create farm land for biofuels. Other sustainability concerns include monocropping and extensive use of fertilizers to expand cultivation of feedstocks for biofuels

Projected biodiesel domestic production in EU 27 countries



Source: Pöyry Energy Consulting

Projected bioethanol domestic production in EU 27 countries



Source: Pöyry Energy Consulting

Agenda

1. Introduction
2. Methodology overview
3. Resource assumptions
    - Definition of the 2020 target
    - Baseline renewable energy growth
    - Maximum potential
    - Build rate profiles
4. Technology cost assumptions
    - Summary
    - Renewable electricity technologies
    - Renewable heat technologies
5. Counterfactuals
    - Cost
    - Carbon
6. Renewable transport assumptions
7. **Sensitivities**

A number of BERR sensitivities were undertaken to test the impact of certain input assumptions used for this project

1. Onshore and offshore wind cost and resource sensitivities
   – A 20% uplift to the assumed level of technical capex for onshore and offshore wind technologies to reflect continuing supply side constraints
   – A 30% reduction in the assumed level of technical capex for onshore and offshore wind technologies
   – A 25% reduction in the availability of onshore and offshore wind resource
2. Biomass cost and resource sensitivities
   – A 50% increase in the assumed level of biomass costs
   – A 25% reduction in the availability of biomass resource for RES-E, RES-H and RES-T
3. RES-H cost sensitivities
   – A 25% increase in the assumed level of total capex for all RES-H technologies starting in 2010
4. Cost counterfactual sensitivities
   – Use of the DTI's High and Low projections as taken from their Updated Energy Projections to test the impact of the cost counterfactuals
5. Learning rate sensitivities
   – A 5% increase and decrease in the assumed learning rate to test the sensitivity of our technical capex assumptions for certain RES-E and RES-H technologies

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