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Guiding European Policy toward a low-carbon economy. Modelling sustainable Energy system Development under Environmental And Socioeconomic constraints

Annex 5: Task 2.2.d.1 Energy consumption of industry, residential and commercial sectors

Version 2.0.0

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MEDEAS
MODELING THE RENEWABLE ENERGY TRANSITION IN EUROPE

Document info sheet

Lead Beneficiary: CIRCE – Research Centre for Energy Resources and Consumption)

WP: WP2 Data Collection

Task: Annex 5: Task 2.2.d.1. Energy consumption of industry, residential and commercial sectors

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List of abbreviations and acronyms

IEA	International Energy Agency
OECD	Organisation for Economic Co-operation and Development
WIOD	World Input-Output Database
RES	Renewable Energy Resources
CHP	Combined heat and Power
CCS	Carbon Capture and Storage
BATs	Best Available Technologies
GHG	Green House Gas
ETS	Emissions Trading System
2DS	According to IEA publication: Energy Technology Perspectives 2012. Pathways to a Clean Energy System, scenario that will lead to a 2ºC increase in the temperature in 2050.
4DS	According to IEA publication: Energy Technology Perspectives 2012. Pathways to a Clean Energy System, scenario that will lead to a 4ºC increase in the temperature in 2050.
6DS	According to IEA publication: Energy Technology Perspectives 2012. Pathways to a Clean Energy System, scenario that will lead to a 6ºC increase in the temperature in 2050.

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Introduction

The industry sector accounts for about one-third of total final energy consumption and almost 40% of total energy-related CO_2 emissions. Residential and commercial sectors account for approximately 32% of global energy use and almost 10% of total direct energy-related CO_2 emissions. These sectors have an undoubted importance in the energy panorama and in the possible future scenarios.

In this document firstly we analyse the different sources that provide data about the energy consumption of industry, residential and commercial sectors. An overview of the scope and availability of these sources is done in order to facilitate a detailed study to develop a future possible scenario. Furthermore, the most relevant information concerning the sectors of study is detailed. According to the results previously obtained in this project the main variables to quantitatively set-up scenarios and pathways are the energy intensity of each sector and the industrial final energy consumption by type of final energy in each sector; it is also included the residential final energy consumption mandatory share from renewable energy systems.

The second part of this document makes a general outlook of the different trends that are expected in these sectors in the future and which aspect can favour or disfavour a transition towards a low carbon based economy.

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Sources of information, data analysis and availability

International Energy Agency (IEA)

The IEA is an autonomous organization which has 29 member countries. The IEA has four main areas of focus: energy security, economic development, environmental awareness and engagement worldwide. The IEA produces priced and free publications with wide data about energy.

According to IEA data published in its free report "Energy Technology. Perspectives 2012" (IEA 2012) **Industry** accounts for about one-third of total final energy consumption and almost 40% of total energy-related CO_2 emissions. From 2000 to 2009, production and energy consumption in all industry sectors increased mainly due to China and India (China doubled its energy demand and India increased it a 50%). OECD member countries experienced a major downturn in production, due in part to the economic recession since 2008.

Residential and commercial buildings account for approximately 32% of global energy use and almost 10% of total direct energy-related CO_2 emissions. Including electricity generation emissions (plus district heat), buildings are responsible for just over 30% of total end-use energy-related CO_2 emissions.

From 1980 to 2010 in the **commercial sector**, buildings decreased the use of coal from 21% to 3% and the use of oil from 28% to 15%; the use of natural gas remained constant at about 24% and the use of electricity and heat increased from 26% to 54%. In the residential sector during the same period the use of coal decreased from 10% to 4%, the use of oil decreased from 15% to 10% and the use of electricity and heat increased from 16% to 25% while the use of natural gas and of renewable stayed almost constant (17% to 20% and 41% to 42%). Space heating accounts meanwhile for 32% in residential and commercial buildings and domestic hot water represents 24% in residential building and 12% in commercial building.

Another IEA free publication is the **Headline Energy Data** (last update from 2016). This database contains 14 energy balance flows for 9 energy products, electricity output for 4 energy products and total CO_2-emission from fuel combustion. It contains data for the industry, residential and commercial and public sector for each country (IEA 2016).

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OCDE database obtained most of its energy related data from IEA. Due to this, this database has not been added to this report.

World Input-Output Database (WIOD)

The first version of WIOD was constructed within a project funded by European Commission as part of the 7th Framework Programme from May 2009 to April 2012. Afterwards there have been updates. The last one, the 2016 release, was financially supported by the Dutch Science Foundation (NWO) (grant number 453-14-012) and European Commission Services (project ECFIN 2015/019B).

The database covers 27 European Union (EU) countries and 13 other major countries in the world for the period from 1995 to 2009. They combine and process different background data to achieve a final database of energy and air emissions satellite accounts. The next table summarises the main sources of data used.

COUNTRY	NAMEA- (energy and air (Eurostat, NSts) 1995-2008	UNFCCC Inventory submissions 1990-2009	EDGAR emission data 1970-2008	IEA data (energy balances, fuel prices 1960-2009)	MFA (SERI, Eurostat) 1980-2008	FAO land data 1961-2008	EU FP6 EXIOPOL 2000 only
EU27	x	x	x	x	x	x	x
Canada	x	x	x	x	x	x	x
Japan		x	x	x	x	x	X
Australia	x	x	x	x	x	x	X
Turkey		x	x	x	x	x	x
USA		x	x	x	x	x	x
India			x	x	x	x	x
China			x	x	x	x	X
Brazil			X	x	x	x	x
Mexico			x	x	x	x	x
Indonesia			x	x	x	x	X
South Korea			x	x	x	x	x
Taiwan			x	x	x		X
Rusia		x	x	x	x	x	x

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Concerning environmental issues, WIOD reports data for energy use, energy use emission relevant, CO_2 emissions, emissions to air, land use, materials use and water used. The Energy Use data details for each country the amount of each different type of energy used in each economical sector. Data are free and can be download as an excel file for each country.

In order to estimate the quality of the method they compared its results, obtained from the information that is available for all countries, with the information that is given by some countries and is considered of good quality (Austria, Denmark, Germany and Netherlands) and estimates the error. In these cases only small deviations are obtained. Another data integrity issue of this database is the concordance between the information on inputs of energy in money terms from the use tables and the same information in physical terms from the energy satellite accounts.

Enerdata

Enerdata is an independent information and consulting firm specialising in the global energy industry and carbon market. They collect energy related data from different sources resulting in a priced quantitative database and models (Enerdata Webpage).

Europe

The European Commission provides a wide range of statistics on the energy market including oil, coal, gas and electricity prices, data on energy imports and exports, and energy trends up to 2050 (European Commission Webpage. Data analysis. Energy).

Eurostat is the main source of statistical data of the European Union. Its database has a specific section dedicated to energy (EUROSTAT webpage).

Another relevant publication in the energy topic is the **energy statistical pocketbook** that proves an annual overview of energy related statistics in the EU and in individual EU countries. It includes, amongst other information, data on production, consumption, greenhouse gas emissions, imports, and energy sector employment (Energy statistical pocketbook webpage).

Odyssee-Mure is a project co-funded by the horizon 2020 program of the European Union that gathers data from the 28 EU Member States plus Norway. It uses two complementary internet databases: Odyssee and Mure

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Odyssee contains data on energy efficiency and CO_2 indicators. Odyssee use data provided by EUROSTAT and other sources and is regularly updated by national representatives from all the participant states. Energy efficiency data is available from 1990 to 2014.

Mure contains data on energy efficiency policy measures and their impacts.

Access to the database is free for EU universities and research centres for non-commercial uses and via subscription for other uses (Odyssee-Mure webpage).

Furthermore, the data are gathered in free reviews as "Energy Efficiency Trends and Policies in the Household and Tertiary Sectors" (Odyssee-Mure September 2015) and "Energy Efficiency Trends and Policies in Industry" (Odyssee-Mure June 2015). Data from these reports concerning energy consumption of industry, residential and commercial sectors are summarised as follows.

"Energy Efficiency Trends and Policies in Industry- Industry sectors"

Between 2000 and 2007 the **industrial energy consumption** was stable in the EU due to the balance between the increase in industrial activity and energy savings. Since 2007 it decreased rapidly due mainly to the industrial recession. Subsequently industrial consumption was in 2013 17% below its 2000 level representing 25% of the energy used by final consumers, compared to 29% in 2000. However, the energy efficiency progress has been much slower since the recession.

Natural gas and electricity are the dominant sources of energy for industry with respectively 32% and 31% of the market in 2012. Electricity, biomass and heat have experienced a rapid growth between 2000 and 2012 and the contribution of all fossil fuels has decreased.

The chemical industry was responsible of 19% of total energy consumption of industry in 2013 being the main energy consuming sector. Steel is the second consumer with an 18% share, followed by non-metallic mineral and paper (12% each) and food (10%). The share of chemicals, paper and food is increasing, while the share of steel is declining.

"Energy Efficiency Trends and Policies in the Household and Tertiary Sectors" Residential and commercial sectors.

In EU buildings accounted for about 40% of total final energy consumption and around 55% of electricity consumption in 2012 being the largest end-use sector, followed by transport (32%), industry (26%) and agriculture (2%). Buildings represent even more than 45% of final energy

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consumption in countries such as Estonia, Latvia or Hungary. At the EU level, around two thirds of the consumption of buildings is for residential buildings.

However, in some countries such as Luxembourg, Malta, the Netherlands, Italy or Portugal, non-residential buildings (i.e. services) are dominant and represent more than half of the total consumption of buildings. The consumption of residential buildings is above 70% in Denmark, Latvia, Poland and Austria and even reaches 80% in Romania.

The average electricity use of EU households is around 4000 kWh. Around a 60% is due to captive uses of electricity, i.e., electrical appliances, lighting and air conditioning. Coal and oil for heating have been replaced by electricity and to a lesser extent wood. The gas market represents around 9% and remains roughly stable. In some countries, such as Ireland, Spain or the Czech Republic, solid fuels (i.e. peat, coal or biomass) have been replaced by more efficient fuels, such as oil and/or gas.

Consumption for lighting represented around 10% of total household electricity consumption in 2012 at EU level (12% in 2000). The specific consumption per dwelling for lighting has decreased since 2000 in half of the EU countries and at the EU level thanks to the diffusion of CFLs and LEDs.

The energy consumption of **services,** or tertiary sector, comprises the energy used in public and private buildings including the energy used for lighting. Energy consumption in the tertiary sector increased rather rapidly until 2008 decreasing since the economic downturn. Electricity consumption has slowly grown since 2008.

The electricity consumption per unit of value added is increasing due to the growing number of new appliances, such as IT devices, and air conditioning. At EU level, electricity intensity has increased by 0.9%/year since 2008, although in about 10 countries it is decreasing.

Large use of electricity for space heating in Nordic Countries Norway, Sweden, Finland and Luxembourg use by far the largest amount of electricity per employee (more than twice the EU average); for Norway and Finland and, to a lesser extent, Sweden, it is has to do with electric heating. Electricity consumption per employee is increasing in most countries. This is because the penetration of air conditioning electricity consumption is increasing in all southern countries.

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Comparison

The next table compares the main characteristics of the different data sources.

	IEA	WIOD	ENERDATA	EUROSTAT	ODYSEE-MURE
Scope	World	27 EU countries and 13 other major countries	World	Europe	Europe
Access	Priced (some publications free)	Free	Priced	Free	Free
Reliability[1]	0.6-1*	0.6**	No available	0.6-1	1
Data	Energy balance flows for different energy products and electricity output for each country	Energy use and emissions, land use, materials use and water used for each country. Combines IEA data with other sources.	No available	Supply, transformation, consumption, import, export and infrastructure.	Energy efficiency and CO_2 indicators. Combines EUROSTAT data with other sources.

[1] Based on the reliability calculation procedure as proposed in MEDEAS project and described in D.2.3.

* Considering that the length of time reported in the open document "Energy Technology Perspectives 2012" is 9 years resulting reliability is 0,6. In other cases, as the Headline Energy database the length of the data is longer and the reliability increases to 1.

** Considering that the length of time reported is from 1995-2009

WIOD source aggregates NACE sectors that do not coincide with the **IEA** sectors. More detailed information of the sectors used by WIOD can be found in its technical report (WIOD 2012). Due to that, a direct comparison between these sources of data is difficult because a desegregation of some sectors would be needed.

For the European countries **Odyssee-Mure** can be compared with other data sources. Odyssee-Mure obtains its data from different sources, for example in the case of the *final consumption of industry* the different sources can be observed in the next table:

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Country	Source
European Union	Eurostat
Austria	stat 3
Belgium	ODYSSEE
Bulgaria	NSI
Croatia	EIHP
Cyprus	National data
Czech Rep.	EUROSTAT
Denmark	Danish Energy Agency: Annual Statistics
Estonia	Estonia Annual Questionnaire IEA-Eurostat-UNECE
Finland	STFIN
France	OEBIL
Germany	AGEBISI
Greece	YPEKA
Hungary	Eurostat
Ireland	ODYSSEE
Italy	MAP
Latvia	CSB
Lithuania	LITSO
Luxembourg	ODYSSEE
Malta	Enemalta
Netherlands	CBS
Norway	SSB
Poland	EUROST
Portugal	DGEG
Romania	National statistics
Slovakia	EUROSTAT
Slovenia	SORS
Spain	MINETUR
Sweden	STEM
UK	DECC

In the IEA source, data are reported from 1971 while in Odyssee-Mure only from 2000. The next plot compares the data about final consumption of industry obtained in the case of Spain reported from Odyssee-Mure and the IEA:

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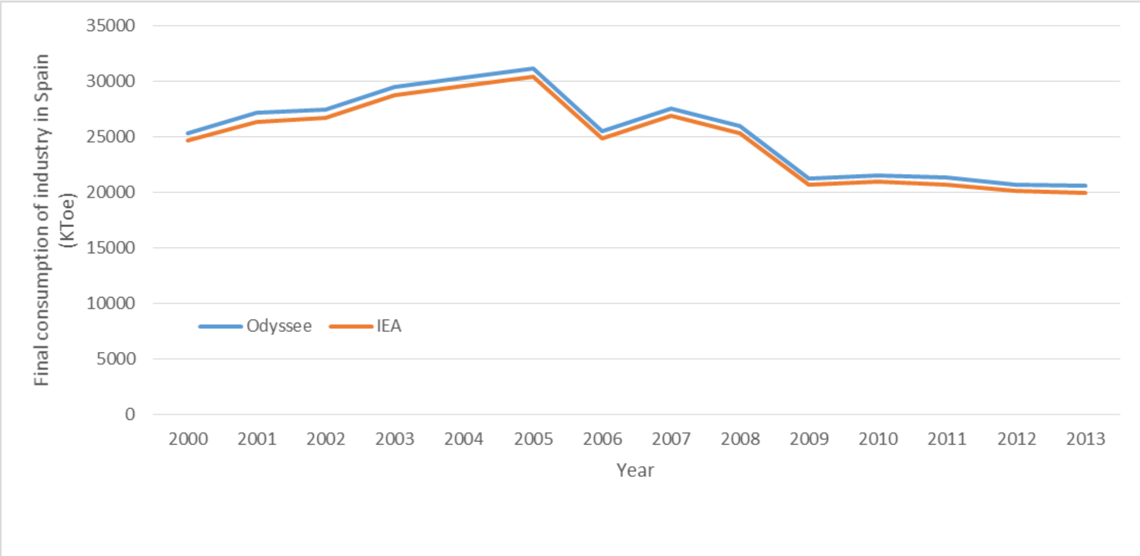

Comparison between the data reported by Odyssee and IEA for the final consumption of energy of industry in Spain

As can be observed data are around 1000 KToe lower in the case of the IEA but the tendency is the same.

All the sources of information are reliable and the choice of a source is going to depend mainly on its scope but also on the information needed because it differs from one source to another.

Future scenarios and pathways

Europe

Energy roadmap 2050

The European Commission's 2011 Energy Roadmap (European Commission 2011) creates and analyses different possible scenarios for 2050 combining four main routes: energy efficiency, renewable energy, nuclear energy and carbon capture and storage.

The different possible scenarios are:

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Reference scenario: it includes current trends and long-term projections on economic development. It takes into account policies adopted by March 2010, including the 2020 targets for RES share and GHG reductions as well as the Emissions Trading Scheme (ETS) Directive.

Current Policy Initiatives (CPI): it updates measures adopted after the Fukushima events and being proposed in the Energy 2020 strategy, it also includes proposed actions concerning the "Energy Efficiency Plan" and the new "Energy Taxation Directive".

High Energy Efficiency: it is based on political commitment to very high energy savings, for example more stringent minimum requirements for appliances and new buildings, high renovation rates of existing buildings or establishment of energy savings obligations on energy utilities. This scenario achieves a decrease in energy demand of 41% by 2050 compared to the peaks in 2005-2006.

Diversified supply technologies: in this scenario all energy sources compete with no specific support measures. Decarbonisation is driven by carbon pricing assuming public acceptance of both nuclear and CCS.

Delayed CCS: similar to the previous scenario but assuming that CCS is delayed.

High Renewable Energy Sources (RES): it includes strong support measures for RES leading to 75% share of RES in 2050 in gross final energy consumption and a share of RES in electricity consumption reaching 97%.

Low nuclear: similar to diversified supply technologies scenario but assuming that no new nuclear is built and including higher penetration of CCS.

The last four scenarios are the decarbonisation scenarios that have the objective to reach 80% GHG reductions by 2050 (as compared to 1990), provided that industrialised countries as a group undertake similar efforts. They are based on the same demographic and macroeconomic assumptions as the Reference scenario and Current Policy Initiatives scenario. Such an assumption also facilitates comparison of the energy results across scenarios. The share of renewable energy rise at least to 55% in all scenarios, being 64% in a High Energy Efficiency scenario and 97% in a High Renewables Scenario that includes significant electricity storage to accommodate varying RES supply even when the demand is low.

All the decarbonisation scenarios, except the High-RES scenario, rely partly on CCS and nuclear power. Nowadays these two technologies are unlikely to make a significant impact on emission

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reduction. CCS plants have not yet become commercially viable and are not currently being promoted. Nuclear power have suffered a shift in public and political opinion and several countries have decided to phase out nuclear. So it is difficult for these technologies to make a significant contribution to decarbonisation before 2050.

In general it is necessary to take into account that the economic growth is combined with more favourable conditions for improving energy efficiency leading to a primary energy demand rising much less than GDP. On the contrary, lower capital turnover with lower economic growth limits the opportunities for investing in energy efficient items, this results in a decrease in energy consumption significantly less than GDP. Thus, the economic growth is not proportional to the energy consumption.

In the **reference scenario** there is a decrease in the GDP that is associated to a lower decrease in the energy demand. Comparing CPI scenario with the reference scenario, households show the greatest decrease in energy demand by 6, 1% below 2005 level up to 2020, as well as by 8, 5% and 10% until 2030 and 2050, respectively. This is due to the energy measures linked to eco-design regulations and savings obligations on energy providers. Moreover, the effects on final consumer prices stemming from the proposed energy taxation directive contribute towards reducing energy consumption. Eco-design measures and faster renovation rates also brings savings to the public buildings. Energy consumption in industry also declines from 2005 levels: by 2.3% up to 2020 and by 3.7% up to 2030. Thereafter, industrial energy demand starts growing slightly without reaching again the current level. Industrial energy demand stays below Reference scenario levels: by 5.5% in 2030 and 5.1% in 2050. Energy service companies, eco-design and energy savings obligations are the main responsible for these savings.

Concerning the **decarbonisation scenarios**, energy savings in the High RES scenario are almost as high as in the Energy Efficiency case (minus 38% for energy consumption in 2050 compared to 2005 instead of minus 41%); however, this is achieved by different means: the energy efficiency scenario focuses on direct impacts on final demand, whereas energy savings in the high RES case come largely through highly efficient RES technologies replacing less efficient nuclear and fossil fuel technologies.

Primary energy consumption is significantly lower in all decarbonisation scenarios as compared to the Reference scenario. The biggest decline of primary energy consumption comes in Energy Efficiency scenario (-16% in 2030 and -38% in 2050) showing effects of stringent energy efficiency policies and smart grid deployment. Energy efficiency is an essential building block in all decarbonisation scenarios.

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It is important to note that these levels of reduced primary energy demand do not come from reduced activity levels or reduce GDP or sectoral production levels (which remains the same across all scenarios). Instead they are mainly the result of technological changes on the demand and also supply side: from more efficient buildings, appliances, heating systems and vehicles and from electrification in transport and heating, which combines very efficient demand side technologies (plug-in hybrids, electric vehicles and heat pumps) with a largely decarbonised power sector.

Regarding **heating and cooling,** the distributed heat/steam and RES demand for distributed heat in the decarbonisation scenarios rises compared to current level but is 2%-10% lower by 2030 as compared to the Reference scenario, with the greatest decline occurring in the high RES scenario. The decrease is more pronounced towards 2050 with 46% decrease as compared to Reference scenario in the High RES scenario. The High RES scenario shows lowest distributed heat demand after 2025 due to the highest penetration of RES in power generation which leads to decrease of CHP and due to the shift towards electricity use for heating reducing especially district heating from fossil fuels.

The biggest decrease in heat demand as compared to the Reference scenario in 2050 occurs in the **residential sector** (-63% in High RES scenario and -32 -42% in all other decarbonisation scenarios), this is due to the implementation of energy efficiency policies in buildings. Demand stays at current levels of around 240 TWh until 2015 and then gradually declines to 69 TWh in the High RES scenario and 126 TWh in the Low nuclear by 2050, showing the higher distributed heat demand among the decarbonisation cases.

Industrial demand for heat increases massively from 160 TWh in 2005 to reach 503 TWh in High RES scenario and up to 733 TWh in Low nuclear/High CCS scenario by 2050. Industrial demand is still lower as compared to Reference scenario by at least 17% in all decarbonisation scenarios and by -43% in High RES scenario. However, industry needs steam for some processes that can hardly be substituted by other fuels. Heat consumption is also rising in the energy branch from 54 TWh in 2005 to 71-77 TWh in 2050, with the Energy Efficiency and delayed CCS scenarios at the lower end of the range and the Low Nuclear scenario at the upper one.

The share of distributed heat in total heating in the residential, services and agriculture sectors rises somewhat from current level of slightly over 11% in most scenarios, except for the High RES scenario. This decrease in the share of distributed heat is compensated by the increased direct use of biomass for heating, which soars from approx. 13.5% in 2010 to approx. 33% in 2050 in the High RES scenario.

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There is very significant progress in all decarbonisation cases regarding the share of RES in heating and cooling. The RES share in heating and cooling doubles between 2005 and 2020 in all scenarios, reaching at least 44% by 2050 under decarbonisation. The highest share of well over 50% in 2050 is achieved in the High RES scenario.

Thus concerning residential and commercial sectors achieving a renewable heating and cooling is vital to decarbonisation. Heat pumps, storage heaters, and renewable energy through district heating systems (for example: solar heating, geothermal, biogas, biomass) are required. In all scenarios, including current trends, expenditure on energy and energy-related products (including for transport) is likely to become a more important element in household expenditure. Energy related expenditures for heating and cooling of households as well as for lighting and appliances almost double from today to 2015 in the Reference and CPI scenarios and this increase is even bigger in most decarbonisation scenarios and above all in the high RES scenario this is due to the higher costs for energy appliances, boilers and insulation. While these costs might be affordable by an average household, vulnerable consumers might need specific support to cope with increased expenditures due to decarbonisation.

Higher carbon prices can benefit low-carbon technologies. However, it may increase the risk of carbon leakage, in particular in those industry sectors subject to global competition. A well-functioning carbon pricing system should include incentive cost-effective emission reductions outside Europe and free allowances based on benchmarks to prevent significant risks of carbon leakage.

EU Reference Scenario 2016. Energy, transport and GHG emissions. Trends to 2050

The EU Reference scenario 2016 (European Commission 2016) projects EU and Member States energy, transport and greenhouse gas (GHG) emission-related developments up to 2050. It takes into account global and EU market trends and the energy and climate policies adopted by the EU and its Member States up to the end of 2014.

The projection is based on a set of assumptions, including population growth, macroeconomic and oil price developments, technology improvements, and policies. Only one scenario considered as a reference is developed in this projection.

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The policies included in the Reference Scenario, the agreed policies at EU and Member State levels until December 2014 including the legally binding GHG and RES targets for 2020, are expected to lead to considerable changes in the energy system.

The Reference Scenario analyses key policies aiming at reducing GHG emissions (e.g. EU ETS, CO_2 standards for light duty vehicles), at increasing the RES share (e.g. RES targets and implementing policies), and at improving energy efficiency (e.g. Energy Efficiency Directive, Eco-design). The increase in RES and improvements in energy efficiency also lead to the reduction of GHG emissions. The modelling captures these policy interactions.

The **industrial activity** has not yet recovered from the economic downturn suffered in 2010. The activity of the industrial sector is projected to recover and follow a slowly increasing pace in the future, with the non-energy intensive sectors growing faster and the industrial sectors moving towards higher value added and lower energy intensity products. This implies that energy consumption of the sector will grow at a slower rate relative to the activity of the sector.

Since 1995 the overall trend in energy intensity has been downwards due to market forces that drive the renovation of equipment. This trend is persisting, that means that energy intensity of the industrial sectors continues to slightly decline but there can be observed an additional energy demand due to the more than proportionate increase in production activity. In the medium term energy demand decreases and stabilises in the long term, even though activity in terms of value added progresses. This is due to two main drivers:

- The energy efficiency embedded in the new capital vintages which replaces old equipment.
- Structural changes in the activity which is assumed to shift towards higher value added and less energy intensive production processes.

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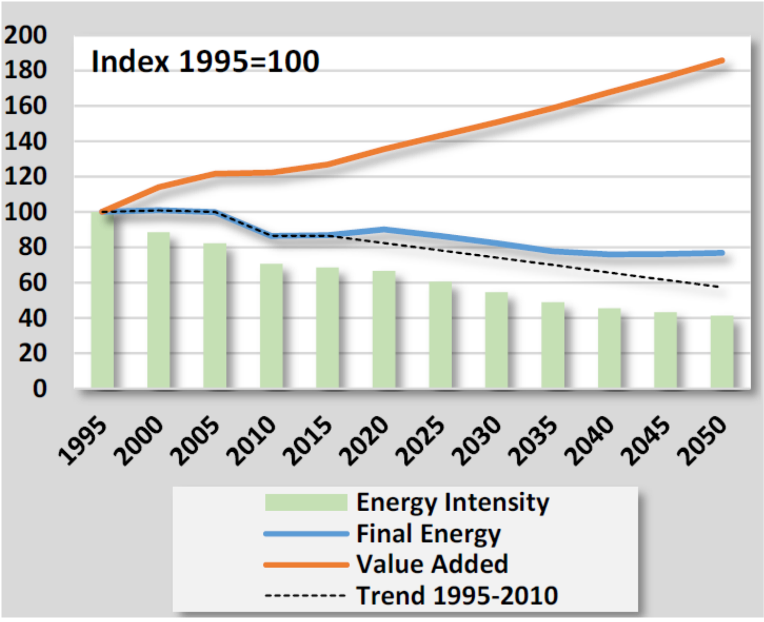

Industrial energy demand versus activity. EU reference scenario 2016.

The recovery of activity growth in the short term implies that industries mainly use existing equipment, including the less efficient ones. The low activity growth discourage investment and left part of capacities unused. This explains the shown slowdown of energy efficiency improvement in industry in the short term. However, persistence of economic recovery leads to investment in new productive equipment, to mitigate impacts of increasing cost of energy, implemented in the medium term, mainly between 2020 and 2030. This explains the acceleration of efficiency improvement in industry during the same period. The strong investment which includes strong energy efficiency, necessarily implies a cycle with lower investment in the longer term. This projection considers an absence of additional policies after 2030 that do not provide incentives form maintaining the pace of efficiency improvement.

The macro-economic projection made in this Scenario implies that significant part of the energy intensive industrial productions will remain in the EU territory, due to advantages of maintaining industrial integration and to technology progress offsetting effects of energy costs and competitiveness. The projection considers the potential of using recycled materials thus avoiding unnecessary primary production which is highly energy consuming. However, the yet untapped potential is not very high in the European Union. Therefore, the projected energy efficiency improvements primarily comes from energy efficient technologies and secondarily from changing the mix of industrial outputs towards less energy intensive production. However, this is only true for some sectors, such as iron and steel, nonferrous metals, glass, etc. but it is not true when looking at industry as a whole. The macroeconomic projection foresees significantly stronger

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growth of activity in industrial sectors of low energy intensity, such as the engineering sectors, than in energy intensive ones.

The European Commission´s Circular Economy Package was adopted after the cut-off date for the policies to be reflected in this Reference Scenario and thus is not assumed, otherwise this would be expected to have noticeable effects on overall efficiency.

Final energy consumption of the industrial sector shifts towards less carbon intensive fuels due to an increase in the ETS carbon prices after 2020 and by a shift towards products of higher quality with higher value added which often require cleaner fuels. These facts, together with the different directives for industrial efficiency, as well as, national renewable support policies, leads to a decline in solid and petroleum fuels that is compensated with an increase in RES (mainly biomass and waste fuels), as well as, an increase in the share of electricity. The share of gas remains approximately constant. Industrial boilers and CHP become more efficient over time and the share of industrial CHP slightly increases in the future, substituting boilers. Finally, the provisions on cogeneration in the Energy Efficient Directive promote the penetration of highly efficient cogeneration and the use of waste heat for steam generation in industrial sites. Also industrial boilers and CHP follow similar trends regarding fuel split.

The developments across countries within the various industrial sectors are very similar. However varying structures in industry may lead to aggregate results differing.

The energy demand in the **residential sector** decouples from the income growth, as the efficiency policies drive energy intensity improvements in the medium term, and it remains below 2015 levels throughout the projection period.

Energy used for heating maintains the highest share of energy consumption, but the share decreases from 65% in 2010 to 58% in 2050 due to improvements in efficiency driven by renovation of buildings that has to comply with energy efficiency obligation on buildings and strict building codes.

Energy demand for electric appliances continues to increase but there is a decoupling between appliance stock and energy consumption due to the technological progress facilitated by Eco-design regulations. Regarding the fuel mix, the consumption of solids and oil decline following policies to improve air quality, complying with the EU Air Quality Directive. Gas is projected to approximately maintain its market share, whereas electricity increases its share due to the uptake

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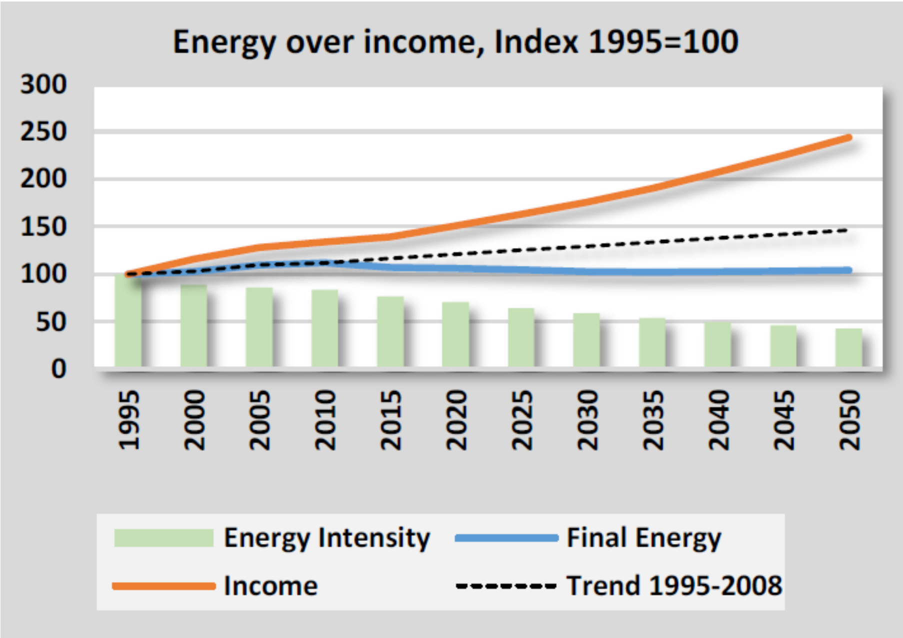
of appliances and a slow penetration of electricity in heating uses. The share of RES increases mainly to 2020.



Energy over income for residential energy demand, Index 1995=100. EU reference scenario 2016

Although the overall EU trends are generally similar across Member States, there is some differentiation among them due to the different starting points: the majority of EU13 Member States have lower average energy consumption than EU15 Member States, pointing to lower comfort levels. This is due to lower heating levels. In such Member States, an increase in comfort level is assumed together with the projected energy efficiency developments.

Although the dwelling will have a better efficiency overall, the increase in the heated space may compensate for the higher efficiency, effectively achieving no efficiency gains or even increasing energy consumption.

The same may apply to electric appliances where although the appliances (per unit) become more efficient, an initial low penetration of appliances will lead to overall higher electricity consumption from appliances.

Projection of final energy demand in the **commercial sector** (in this scenario included into the tertiary sector) follow similar trends as for the residential sector: demand is projected to decouple from activity growth. In the short to medium term, despite high growth in services, demand for energy decreases driven by energy efficiency policies and eco-design policies. In the long term,

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due to the lack of additional policies, energy consumption slightly increases. Different policies over-compensate the effects of increasing sectorial activity up to 2030, driving final energy demand below 2010 peak levels throughout the entire projection period. Marked efficiency progress is observed both for heating and for specific electricity consumption, in particular in the medium term (2020-30), driving energy consumption downwards in the period 2010-30, contrasting past increasing trends. Beyond 2030, where no additional energy efficiency policies are implemented, energy consumption increases with a slow pace of growth.

Due to the application of heat pump electricity share increases. The share of RES increases up to 2020, but thereafter this pace reduces considerable.

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World

Energy Technology Perspectives 2012. Pathways to a Clean Energy System

This is an International Energy Agency publication (IEA 2012) where three different energy futures are projected. The 6ºC Scenario (6DS), which is where the world is leading if the current trends persist. The 4ºC Scenario (4DS), which takes into account the policies that were already announced in 2012 and step up efforts to improve energy efficiency; this is already an ambitious scenario that requires significant changes in policy and technologies. The 2ºC Scenario (2DS) describes an energy system consistent with an emission trajectory that would give an 80% chance of limiting average global temperature increase to 2ºC. This scenario sets the target of cutting energy-related CO_2 emissions by more than half in 2050 (compared with 2009) and continuing to decrease thereafter.

The scenarios take an optimistic view of technology development and assume that technologies are adopted as they become cost-competitive and that non-technical barriers, such as social acceptance, proper regulatory framework and information deficits, are overcome.

These scenarios are not predictions. They are internally consistent analyses of the pathways that may be available to meet energy policy objectives, given a certain set of optimistic technology assumptions.

To achieve a 2ºC scenario (2DS):

Energy efficiency will play a major role in industry, driven by deployment of new technologies, better system integration and closed-loop processes. Renewable energy sources will replace fossil fuels in almost all direct uses. Emissions of CO_2 from industry fall to approximately 6.5 Gt by 2050, a 20% reduction compared to 2009. This is lower than average across the economy as a whole, due to very costly abatement options in some industrial processes such as cement and steel production.

In buildings, better building shells will improve energy efficiency and reduce energy demand, as will more efficient heating and cooling systems. This entails a substantial increase in the use of heat pumps, expanded use of district heating. All new construction would have to meet high performance standards, particularly in non-OECD countries where most new construction will take

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place. OECD countries will need to focus on refurbishing the existing building stock; financing of such measures, however, is expected to be a central challenge.

To analyse the longer-term potential contribution of new technologies for emission reduction in the **industrial sector**, it was developed a modelling framework that examines three different scenarios and two variants in the industrial sector to the year 2050.

For industry the 6DS scenario results in CO_2 emissions that are 45% to 65% higher in 2050 than they were in 2010. While autonomous energy efficiency is observed, no major shifts in technology or energy consumption mix are expected in this scenario.

The 4DS in industry means increase the adoption of BATs in new facilities. Use of biomass and other alternative energy sources also increases. Industrial CO_2 emissions under this scenario would increase 20% to 30% between 2010 and 2050.

In the 2DS scenario, global energy-related CO_2 emissions in 2050 are half the current level. Achieving this goal also requires deep cuts in other greenhouse-gas emissions. The 2DS explores the technical options that need to be exploited to halve global CO_2 emissions by 2050. This does not mean that industry necessarily needs to reduce its emissions by 50% instead each economic sector would have to make contribution based on its costs of abatement. Under this scenario, industrial CO_2 emissions would be between 6.7 $GtCO_2$ and 6.8 $GtCO_2$ in 2050, about 20% less than current levels.

To take into account the uncertainties about projection long-term growth in consumption two variants were developed for each scenario: a low-materials demand case and a high-materials demand case. The difference in global materials production between the low and high demand cases to 2050 varies between 15% and 35% but with the same level of CO_2 emission reduction.

In the three scenarios analysed materials consumption and production are assumed to be the same, the differences are found in the different primary resources and the processes used in material production. IEA scenarios assumes that growth in China´s material will flatten or even decline in the case of cement. But in most non-OECD regions, industry development accelerates. Materials production in Asia (excluding China), and Africa and the Middle East more than triples over the 2010 to 2050 period. Most of the growth in North America occurs within the next decade, as industry will be recovering from the heavy impact of the recent economic recession. Other OECD countries are expected to show relatively flat production or only modest increases as

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consumption levels for materials in these countries are already mature and population growth is expected to be relatively stable or declining.

A significant reduction in CO_2 emissions in industry, to between 6.7 $GtCO_2$ and 6.8 $GtCO_2$, is only possible if all sub-sectors contribute. The reductions envisaged under the 2DS in industry can be achieved by deploying existing BATs, by improving production techniques, and by developing and installing new technologies that improved energy efficiency, enable fuel and feedstock switching, promote more recycling, and increase capture and storage of CO_2. Many of this technologies are currently being developed, demonstrated and adopted by industry. Additional research, development and demonstration is needed to develop process technologies for the CO_2-free production of materials and to advance understanding of system approaches, such as the optimisation of life cycles through recycling and developing new materials that contribute to emissions reductions in other sectors.

To achieve the 2DS objectives, the five most energy intensive industrial sectors need to make marked progress in incorporating energy efficient technologies, recycling and energy recovery, CCS, alternative materials use, and fuel and feedstock switching. In the short term, these sectors must increase efficiency by steadily adopting the most efficient BATs to reduce emissions significantly. After 2020, the introduction of CCS and the deployment of new technologies become crucial. These energy-intensive sectors have significant untapped potential for delivering the CO_2 emissions reduction needed to achieve the 2DS objectives.

In the 2DS, investment needs by 2050 in the five most intensive sectors are estimated to be between USD 10.7 trillion and USD 12.5 trillion between 2010 and 2050; this represents USD 1.5 trillion to USD 2.0 trillion above the investments required by the 6DS and 4DS. Most of the additional investment is needed in the cement, iron and steel, and chemical and petrochemical sectors. These sectors account for the largest share of emissions in industry. The additional investments in best available technologies will yield significant savings in fossil-fuel consumption. The total fuel savings in the 2DS compared with the 6DS are estimated to be around USD 7.8 trillion for the 2010-50 period. Overall, the net cumulative savings are estimated at USD 5 trillion to USD 6 trillion.

Differences are found from one sector to another. The main conclusion obtained for the 5 most important industry subsectors are summarised as follows:

- There has been a 67% growth of the steel production between 2000 and 2010 affecting positively the energy efficiency of the **iron and steel industry**. The iron and steel sector still

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has the technical potential to further reduce energy consumption by approximately 20%. In order to reach the targets set out in the 2DS, multiple technology options need to be developed and deployed in the iron and steel sector. No one single option can yield sufficient reductions in direct CO2 emissions.

- The thermal energy consumption of the **cement industry** is strongly linked to the type of kiln used and the production process. There has been recent improvements in energy and emissions intensity but there is still significant room for improvement. If all plants used BATs, the global intensity of cement production could be reduced by 1.1 GJ/t of cement, or about 30% (from an intensity of 3.5 GJ/t of cement today). However, efficiency improvements in the 2DS would account for only approximately 20% of total emissions reduction. Given the large share of process emissions, CCS is essential to reducing CO_2 emissions in the cement sector. By 2050, CCS is the most important option, accounting for more than 50% of the reduction. Without the implementation of CCS in this sector, CO_2 emissions in 2050 will be higher than their 2009 level, even if all other technology options are implemented.
- It is expected a substantial growth in **the chemical and petrochemical sector** in the coming decades and it have to be sustainable so steps will need to be taken to bring to fruition many of the technological developments envisaged in the 2DS. Implementing BPT in the short term and applying new technologies in the long term can enable the sector to significantly reduce its energy needs and its CO_2 intensity as well as reach the emissions levels implicit in the 2DS. Ambitious R&D can lead to substantial energy and/or CO_2 emission savings. All countries should strive to achieve current BPT levels by 2030 and additional improvements are needed which will further reduce energy intensity.
- The application of BAT in the **aluminium industry** can help further reduce energy use in aluminium production by approximately 10% compared with current levels. Energy efficiency improvements in both refining and smelting have an important role to play. Realising these savings in refineries will require improved controls and processes to increase yields of alumina, combined with reduced heat loss, better heat transfer and improved waste-heat recovery, including the introduction of more co-generation. In smelting, the main savings will come from improved process controls, reduced heat losses, and electricity savings in auxiliary uses. The per capita consumption of finished aluminium will almost double between 2010 and 2050 under a low-demand case and will increase 2.8 times in the high-demand case. This substantial increase is explained by higher aluminium consumption in a wide range of sectors, especially transport, construction and engineering. To meet the increased demand, the primary production of aluminium will increase from 41

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Mt in 2010 to 89 Mt in the 2DS low-demand case and 122 Mt in the high-demand case. The lower production in 2DS, compared with the 4DS and 6DS, is explained by the increased use of recycled aluminium that requires 3% to 8% of the energy having large benefits in the energy consumption. Furthermore using low carbon electricity is needed. Measures to create a global carbon price would encourage new aluminium plants to be sited where they have access to available and competitively priced, low-carbon electricity. Future technological developments could also provide an opportunity to reduce the direct emissions of CO_2 from aluminium smelting.

- Most of the **pulp and paper** sector's efficiency improvements have come from integrated pulp and paper mills that use recovered heat in the production process. Additionally, the production of recovered paper pulp uses 10 GJ to 13 GJ less energy per tonne than the production of virgin pulp. Recycling rates can be increased in most regions, especially in many non-OECD countries. The per capita consumption of paper and paperboard is expected to double between 2010 and 2050. This growth will be driven by higher demand for paper in developing countries and will be different for each type of paper. While paper and paperboard production is assumed to be the same in the three different scenarios, the use of recovered paper is about 8% higher in the 2DS than in the 6DS in 2050, this improves energy intensity although is more CO_2-intensive than production of chemical pulp because the latter uses biomass for energy, which is considered CO_2 neutral. Total direct CO_2 emissions are 54% lower in the 2DS low-demand case, and 64% lower in the high-demand case, than in the 4DS. Energy efficiency and fuel switching represent the largest contribution to reducing direct emissions. Carbon capture and storage begins to have an impact in the sector by 2030, accounting for 4% of the reductions in 2050 in the 2DS low-demand case, and 9% in the 2DS high-demand case. Deploying a wide range of BATs and newly emerging technologies will enable the sector to reduce significantly both its energy needs and its CO_2 intensity and achieve the emissions reduction implicit in the 2DS. Government policies are needed to facilitate a transition to more efficient and/or lower carbon technologies.

Energy demand from the **buildings sector** will more than double by 2050. Much of this growth is due to the rising number of residential and commercial buildings in response to the expanding global population. In the residential sector, mounting energy demand was further exacerbated as the number of people per household decreased in many economies and the size of dwellings increased. To achieve energy-savings potential in the buildings sector, stringent energy-saving

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requirements for new buildings plus retrofits of existing buildings is necessary. The efficiency of the building shell must be upgraded and buildings need to incorporate more energy-efficient building technologies for heating, ventilation and air conditioning systems; high-efficiency lighting, appliances and equipment; and low-carbon or carbon free technologies, such as heat pumps and solar energy, for space and water heating and cooling.

Energy demand in the buildings sector is driven by population, geographic region, climatic conditions, incomes, energy prices, services sub-sector value added, services sub-sector floor area and cultural factors. These elements have an impact on the number and size of households, the heating or cooling load, the number and types of appliances owned, and their patterns of use. A number of parameters are key to the buildings-sector scenario, and different considerations have been done in these projections:

- Population: the world's population will increase 35% to 9.3 billion in 2050 with Africa outgrowing all other continents, followed by Asia (114% and 23% respectively). The population increase translates into a higher number of households and houses, and the corresponding increased demand for services.
- Urbanisation: today, slightly more than half the world's live in urban areas. By 2050, 70% of the world population will live in urban areas, while 86% of the world's population will live in less developed countries. Increased urbanisation will bring greater access to commercial energy sources.
- Number of households: the global number of households is projected to grow 88% between 2009 and 2050, a rate that exceeds that of population growth because of the continuing trend of fewer people per household. It is accompanied by a recent trend towards larger floor area per household which will likely continue.
- Gross domestic product (GDP) and value added growth: GDP will be four times higher in 2050 than in 2009. The growth in the sector's value added reflects the increased demand for services, which will require more buildings.
- Services floor area: this will increase to 1.7 times the 2009 estimated levels in 2050, as the services sub-sector value added continues to grow more rapidly than GDP, particularly in developing countries whose economies are still maturing.
- Energy prices: crude oil import prices are expected to grow from an average of USD 78.1 per barrel (bbl) in 2010, to USD 118.5/bbl in 2050 in the 4DS, and to USD 86.6/bbl in 2050 in the 2DS. Higher prices will influence the choice of technology and, where possible, the energy source selected.

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Existing available technologies offer opportunities to significantly reduce energy use and emissions at low cost. Cutting electricity consumption may be a higher priority than reducing the direct use of fossil fuels in countries with CO_2-intensive electricity generation mixes. In the building sector the 2DS is based on the large-scale deployment of technologies with the greatest opportunities for cost-effective CO_2 reductions. A necessary first step is to implement policies to ensure the maximum uptake of existing technologies for improving the energy performance of building shells.

Developing countries face quite different policy challenges than OECD countries, non-OECD Europe and Eurasia. The latter have a large stock of residential buildings, most built before 1970, which will be retired slowly and retrofitted with measures to reduce CO_2 emissions. At the same time, the buildings sector in the OECD and non-OECD Europe and Eurasia has significant heating and cooling loads, which policy makers must reduce.

Currently, the rate of residential building refurbishment to improve energy efficiency is low. Because energy efficiency renovations are potentially expensive, urgent policy action is needed to induce building owners to schedule refurbishments or maintenance activities earlier than the average 20- to 30-year time frame when they traditionally make economic sense.

In contrast, buildings in developing countries tend to have shorter life spans, on the order of 25 to 35 years. Consequently, policies and standards should dictate the minimum energy performance of new buildings, especially for their cooling loads, lighting and appliances.

Applying all these consideration in to the model total energy demand in the buildings sector will increase from 115 EJ in 2009 to 160 EJ in 2050 in the 4DS, mainly driven by the services sub-sector, which represents 64% of this growth. The services sub-sector grows at 0.9% a year between 2009 and 2050 and the residential sub-sector at 0.6% per year. Energy from non-biomass renewables, predominantly solar, increases as a whole by 6% a year between 2009 and 2050, although it only supplies 3% of the buildings sector’s energy consumption in 2050.

In the 2DS, energy consumption in the buildings sector by 2050 is 20% lower than in the 4DS. Energy consumption in 2050 (2DS) is only 11% higher than in 2009, despite a 65% increase in the number of households and greater services sub-sector floor area (72%) over the same time period. Electricity demand grows 1.3% per year and becomes the largest single source of energy. Consumption of oil and coal declines significantly, as does the use of traditional biomass.

The energy sources and growth-demand patterns in OECD and non-OECD countries are dramatically different. While electricity and natural gas are the main energy sources for OECD

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countries, non-OECD countries continue to rely on biomass, mostly for household applications such as cooking, in each scenario. However, non-OECD countries will switch to high-efficiency cook stoves using modern types of biomass or other fuels such as liquefied petroleum gas, natural gas and electricity. Total energy savings in the buildings sector in the 2DS, compared to the 4DS, amounts to 33 EJ in 2050. Energy savings in residential space heating amount to 22% of the total savings.

In the 4DS, the 9 $GtCO_2$ in 2050 includes upstream emissions attributable to the consumption of electricity and heat in the buildings sector. This is an 11% increase over 2009 levels. The 2DS reduces CO_2 emissions from the buildings sector by 6 $GtCO_2$ from the 4DS level in 2050: 2.4 $GtCO_2$ is directly attributable to energy efficiency and fuel switching in the buildings sector, and 3.6 $GtCO_2$ is the result of decarbonisation of the electricity and heat sectors. As a result, buildings-sector CO_2 emissions in the 2DS are 67% lower than the 4DS level in 2050. This reduces the direct and indirect CO_2 emissions attributable to the buildings sector to 64% lower than the 2009 level.

The CO_2 emissions savings from the buildings sector in the 2DS can only be achieved if the entire buildings system contributes. Increased deployment of more efficient heat pumps and co-generation and solar thermal for space and water heating, as well as cooling, accounts for 21% of the savings. Co-generation plays a notable role in reducing CO_2 emissions, as well as helping balance the renewables dominated electricity system in the 2DS. More efficient lighting, appliances and miscellaneous equipment account for 17% of the total reduction. This proves the importance of electrical end-use growth and energy efficiency improvements in non-OECD countries.

In the residential sub-sector, total energy consumption grows 0.6% a year between 2009 and 2050, from 85 EJ to 108 EJ in the 4DS. Electricity demand in the residential sub-sector continues increases its share of consumption from 20% to 33% between 2009 and 2050. Non-biomass renewables, predominantly solar, grow rapidly by 5.8% a year on average but this account for only 1.5% of total energy consumption in the residential subsector by 2050. Gas consumption grows by 1.4% per year and oil consumption by 0.2% per year to 2050. Coal consumption declines by 0.3% per year between 2009 and 2050.

In non-OECD countries, the growth in electricity demand is being driven by the increasing ownership of small and large appliances, as incomes rise. In OECD countries the energy consumption of large appliances is declining due to the implementation of energy efficiency policies in many countries.

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In OECD countries, most of the building stock was constructed before the 1970s and has very high space-heating requirements. Refurbishment or renovation of these buildings will offer the largest abatement potential but this will require significant up-front costs, and their economic viability will depend heavily on energy prices. The 2DS scenario will require a 60% of the existing building stock to be renovated to a low-energy standard.

In the 2DS, energy efficiency improvements become all the more important in reducing emissions from the sector, for example high-efficiency cook stoves in developing countries and the adoption of efficiency technologies such as heat pumps.

The services sub-sector is significantly more energy-intensive in terms of electricity use than the residential sub-sector. In 2009, electricity accounted for almost 50% of the total energy consumed by the services sub-sector globally. By 2050 in the 2DS, electricity consumption represents 58% of total energy consumption in the services sub-sector. This pattern of savings is also different from that of the residential sub-sector due to the higher share of electricity-intensive end uses. By 2050 in the 2DS, space cooling, lighting and other miscellaneous end uses account for 60% of energy consumption in the services sub-sector. Energy savings in lighting and miscellaneous equipment will account for 60% of the energy-consumption reduction in 2050. Furthermore, the decarbonisation of the power sector is important to reach the goals elaborated in the 2DS.

In general, this assessment suggests that buildings require increased application of energy efficiency potential in order to achieve the 2DS objectives. Low-carbon technologies for heating and cooling systems and building energy codes must be mandatory and include minimum energy performance requirements for the overall building.

Currently most energy codes target only new buildings or extensions, and therefore do not apply to a large proportion of the existing building stock. This is especially problematic in OECD countries, where most of the efficiency potential requires retrofitting existing buildings.

World Energy Outlook 2016

The International Energy Agency provides annually analysis of the energetic situation worldwide. The last one, World Energy Outlook 2016 (IEA 2016b), reflect the post-Paris expectations for international co-operation on climate change. Three main global scenarios are developed:

Current Policies Scenario: it is based on policy announcements and plans and reflects the way that governments see their energy sectors developing over the coming decades. It takes into account

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the policies or measures already supported by specific implementation measures in place as of mid-2016.

New Policies Scenario: its starting point is the policies and measures that are already in place, but it also takes into account, the aims, targets and intentions that have been announced.

450 Scenario: it has the objective of limiting the average global temperature increase in 2100 to 2 degrees Celsius above pre-industrial levels. In this scenario it is fixed where the energy sectors needs to end up and then work back to the present.

The World Energy Model (WEM) generates the energy projections used in this report. The WEM is a database drawn primarily from IEA databases on the basis of submission from IEA member and non-member countries, supplemented by additional research and other sources.

Over the projection period to 2040, the share of **industry** is projected to increase from 38 to 39%. Energy demand in industry has increased by 2.0% per year since 1990, but this rate of growth is expected to slow to 1.2% per year over the period to 2040. While energy efficiency is projected to continue to improve over the next two-and-a-half decades, slower demand growth for most energy-intensive materials will be an important supporting factor in limiting energy demand growth. As an example, steel production has increased by 3.3% per year since 1990, but average growth over the period to 2040 slows to 0.6% per year. This is mainly a consequence of a restructuring of the Chinese economy, where steel production is projected to fall by more than 30% from 2014 to 2040. The wider application of energy efficiency measures across all industries over the period to 2040 leads to energy savings of 1.740 Mtoe in 2040. In other words, without energy efficiency, annual industrial energy demand growth would be 2.4% to 2040, instead of 1.2%, i.e. twice as high. Three-quarters of the energy efficiency savings arise in countries outside of OECD and half of worldwide savings due to energy efficiency come from only two countries: China and India. This is a consequence not only of the still relatively large potential for energy efficiency in both countries, but also of the policies that have been put in place.

Regulatory efforts to reduce the carbon intensity in the industry sector typically focus on improving energy efficiency. The degree to which regulatory action is being pursued has been mounting in recent years, in particular in China where the industry sector is responsible for one-third of its total energy demand today and uses more energy than the industry sectors of all OECD countries combined. The emissions intensity of fuel demand in the industry sector has been on the rise over much of the past 15 years. In the New Policies Scenario, the emissions intensity of fuel demand in the industry sector falls by 0.6% per year on average through 2040 as policies help

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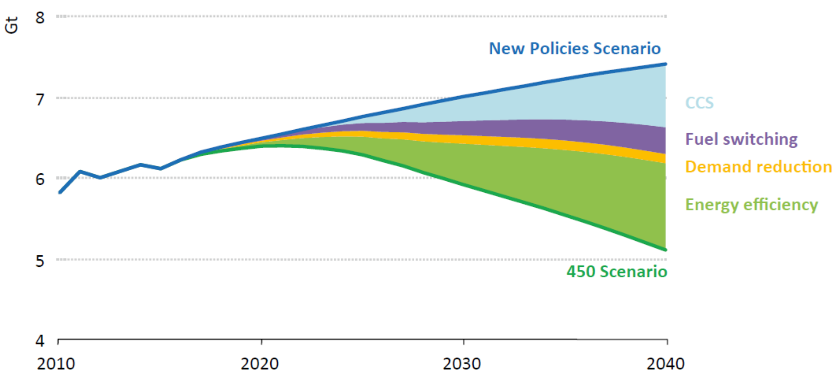
facilitate the more efficient use of coal, oil and gas, and rising fossil-fuel prices (alongside CO_2 prices in some regions) incentivise the uptake of low-carbon options. However, CO_2 emissions continue to increase in the New Policies Scenario to reach 7.4 Gt in 2040, up from 6.1 Gt today. An additional 5.0 Gt of indirect emissions occur from rising electricity and heat demand in 2040. A key reason for the further emissions increase is that in the New Policies Scenario, a significant part of the energy efficiency potential in industry remains untapped. Beyond energy and material efficiency, there is a need for further research, development and deployment to increase the uptake of renewables-based options, for example, to produce heat for use in industry, and to improve the commercialisation prospects for CCS. CCS is responsible for about 30% of the cumulative CO_2 emissions savings in the 450 Scenario, relative to the New Policies Scenario, bringing up the rate of decarbonisation in industry to 1.4% per year on average to 2040 and contributing to reducing CO_2 emissions from the industry sector to 5.0 Gt in 2040.



Global direct CO_2 emissions savings in the industry sector in the 450 Scenario relative to the New Policies Scenario. (IEA 2016b).

The share of **buildings** decrease from 31 to 30% over the projection period to 2014, this reflects a decline in the traditional use of biomass in households (today more than a third of household energy consumption worldwide). In the buildings sector, almost three-quarters of energy is consumed in households, with the rest distributed across different uses in the services sector, including public buildings, offices, shops, restaurants and water treatment and pumping. Energy demand growth in services of 1.6% annually to 2040 is more than twice as high as in households, since economic growth (and therefore the need for energy) is fastest in the services sector while, on the other hand, population declines in some parts of the world in the later part of the projection period, including China, Russia and several OECD countries.

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The realisation of efficiency measures means that energy consumption in the New Policies Scenario in the buildings sector as a whole grows by only 0.9% instead of 1.5% in the absence of action on energy efficiency. In households, over 40% of the savings are realised in space and water heating, as buildings become better insulated and heating equipment becomes more and more efficient. More efficient lighting is responsible for a third of the savings in households, as most countries have already committed to phase out the use of the least efficient incandescent light bulbs and are promoting LEDs. In geographic terms, the United States, China, the European Union and India account for two-thirds of all energy efficiency savings in buildings.

The emissions intensity per unit of energy use in the buildings sector is two-to-three-times lower than that of other sectors. But the buildings sector is also the largest consumer of electricity and district heat, responsible for half of global electricity demand today. The associated indirect CO_2 emissions, at 5.6 Gt, are almost twice as large as the direct emissions in the buildings sector itself.

In broad terms, decarbonising the buildings sector takes two principle angles: reducing energy demand or switching to low-carbon fuels for consumer goods such as appliances and lighting; and improving building insulation to reduce heating and cooling needs.

Significant progress has been made in the consumer goods area with the adoption of minimum energy performance standards in many countries. This holds back energy demand growth to 2040 in the New Policies Scenario, which increases at only about 60% of the rate than over the last two-and-a-half decades and reduces emissions intensity of fuel demand further. As a result, direct CO_2 emissions from the buildings sector stabilise at about today's level and reach 3.0 Gt in 2040, although indirect emissions continue to rise to 6.4 Gt with rising electricity and heat demand. The projections of the New Policies Scenario imply significant untapped potential to further reduce emissions from the buildings sector. Phasing out the least-efficient categories of appliances (e.g. refrigerators, freezers, washing machines and dryers) and all incandescent light bulbs (including halogens) by 2030 helps significantly to cut electricity demand growth in the 450 Scenario, which is reduced by more than one-third, relative to the New Policies Scenario. In some cases, such measures are already justified by the market, but consumers need an additional incentive.

Significant additional potential lies in improvements to the building envelope: building codes for new buildings are not yet mandatory in all countries, although more than half of the floor area worldwide in 2040 is yet to be built. Imposing such requirements helps to reduce energy demand for space heating and cooling in the 450 Scenario, which falls by around 20% in 2040 below the level of the New Policies Scenario. As a result, direct CO_2 emissions from the buildings sector fall to

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2.3 Gt in 2040 in the 450 Scenario, while indirect emissions from an increasingly decarbonised power sector fall by two-thirds below today's level.

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Conclusions

With the aim to have reference values the following table summarised and compare the energy demand estimated in the different scenarios for the accounted sectors.

	Mtoe		1990	2014 or 2015	2020	2025	2030	2035	2040	2045	2050
Europe European Commission 2011	Reference Scenario (with update world	Total Final Energy Demand	1069	1215	1227	1207	1187	1192	1202	1215	1221
		Industry Final Energy Demand	366	323	330	332	333	338	347	358	369
		Residential Final Energy Demand	264	320	318	304	299	296	293	292	288
	HIGH RES scenario	Total Final Energy Demand	1069	1215	1145	1104	1093	1039	965	886	804
		Industry Final Energy Demand	366	323	317	317	320	315	311	292	276
		Residential Final Energy Demand	264	321	290	274	273	261	241	220	190
Europe European Commission	Reference Scenario 2016	Total Final Energy Demand		1133	1134	1106	1081	1065	1068	1077	1086
		Industry Final Energy Demand		285	295	283	270	255	249	250	252
		Residential Final Energy Demand		300	298	293	288	287	288	290	292
World IEA 2016	New policies scenario	Total final Energy Demand	6161	9410	10204	10794	11392	11989	12538		
		Industry Final Energy Demand	1805	2836	3113	3335	3547	3756	3941		
		Buildings Final Energy Demand	2141	3044	3210	3343	3524	3697	3852		
	450 scenario	Total Final Energy Demand			1527		1477		1386		
		Industry Final Energy Demand			3070		3221		3316		
		Buildings Final Energy Demand			3144		3267		3378		

The activity of the industrial sector is expected to follow an increasing pace in the future because is going to be linked to the rise in population. The increase in production activity will demand additionally energy and without decisive actions the upward energy trends of the previous years will continue.

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In order to reduce this trend energy efficiency is essential. Energy efficiency must be driven by deployment of new technologies and use of the Best Available Technologies, better system integration and closed-loop processes.

It is essential to develop new technologies and use the Best Available Technologies. In accordance, regulatory efforts to reduce the carbon intensity in the industry sector typically focus on improving energy efficiency (IEA 2012). Renewable energy sources need to replace fossil fuels in almost all direct uses, there is also a need for further research in renewables-based options, for example, to produce heat for use in industry.

Another approach to improve the efficiency in industries within the scope of the circular economy is the Industrial Symbiosis. Industrial Symbiosis is based in an association between companies to exchange energy, water or materials. The wastes or by-products of one company become the raw materials for another. This approach leads to multiple environmental and economic benefits.

In spite of all the possible energy efficiency improvements, Carbon Capture and Storage is considered needed to accumulate a 30% of CO_2 emissions saving in a global scenario in which the temperature increases 2ºC in 2040 (IEA 2016). Thus, research and development in CCS are crucial to improve its commercialisation prospects or alternatively it would be needed to look for other solutions.

In Europe energy demand is expected to decrease in the medium term and stabilise in the long term, even though activity in terms of value added progresses. This is due to energy efficiency improvements and to structural changes in the activity which is assumed to shift towards higher value added and less energy intensive productions processes.

Politic measures can be very effective to foster energy efficiency measures. Higher carbon prices can benefit low-carbon technologies. However, if it is not applied worldwide it may increase the risk of carbon leakage.

Projections about the energy consumption in the **residential sector** are complex as many different drivers are implied: population, geographic region, climatic conditions, incomes, energy prices, cultural factors and energy efficiency improvements. These elements have an impact on the number and size of households, the heating or cooling load, the number and types of appliances owned, and their patterns of use.

Population is expected to increase and this is going to translate into a higher number of households. Also it is necessary to take into account that there is tendency in developed countries

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of fewer people per household and a trend towards larger floor area per house. All this is going to result in a higher demand of energy in the residential sector. Urbanisation is increasing and this will bring greater access to commercial energy sources. Energy prices will influence the choice of technology and, where possible, the energy source selected.

Regarding the **services sector** the same drivers can be applied. Furthermore, it is necessary to take into account that Gross Domestic Product is growing demanding more services. In developing countries the services sector is expected to growth faster than the GDP. According to IEA, floor area in services sector building is expected to almost double between 2009 and 2050 due to the increase in importance of this sector in developing countries. In OECD countries is expected to grow at a lower rate (IEA 2012).

Decarbonising the buildings sector takes two principle angles: reducing energy demand or switching to low-carbon fuels for consumer goods. In general, energy efficiency in the residential and commercial sectors can be improved by:

- Using more efficient equipment (lighting, appliances, heating and cooling systems).
- Upgrading energy characteristics of building by doing energy efficient improvements and increasing the use of renewable energies.
- Inducing changes in energy consuming behaviour.

For example, in Europe the increase in the number of dwelling and appliances has been counter balance by the energy efficiency improvements. Without these savings since 2000 the energy consumption of households would have been 60 Mtoe higher in 2012 (Odyssee-Mure September 2015).

In developed countries the biggest opportunities to improve energy efficiency in buildings came with space and water heating, air conditioning, ventilation, lighting and appliances. In developing countries, lighting and cooking are more important but this may change as middle-class income rise.

Today renewables satisfy 9% of heat demand in building, 50% in the form of modern bioenergy, 10% as solar heating for hot water and the remaining mainly indirect renewables through the use of electricity or district heat supplier by renewable sources (IEA 2016b). Although many technologies are now mature and can provide heat at a competitive price, the growth in renewable energy in buildings relies on support policies.

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Better building shells will improve energy efficiency and reduce energy demand. All new construction would have to meet high performance standards, particularly in non-OECD countries where most new construction will take place. OECD countries will need to focus on refurbishing the existing building stock.

In the services sector electricity accounted for almost 50% of the total energy consumed globally. The most important consumptions are space heating (accounts for 33% in 2009), space cooling, lighting and office equipment.

In summary, to achieve energy-savings potential in the buildings sector, stringent energy-saving requirements for new buildings plus retrofits of existing buildings is necessary. The efficiency of the building shell must be upgraded and buildings need to incorporate more energy-efficient building technologies for heating, ventilation and air conditioning systems; high-efficiency lighting, appliances and equipment; and low-carbon or carbon free technologies, such as heat pumps and solar energy, for space and water heating and cooling.

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