THE WORLD OUTLOOK FOR BIOMASS TO PRODUCE HEAT AND POWER

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(Tutorial paper)

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Abstract

Ancient way of converting biomass into energy is just burning to produce heat, practiced for thousands of years. Still this is the most common way for conversion of biomass into energy elsewhere. The heat generated from biomass can be used for heating, cooking, and industrial processes, or for producing electricity.

Biomass energy is derived from five distinct energy sources: garbage, wood, waste, landfill gases, and alcohol fuels. Wood energy is derived both from direct use of harvested wood as a fuel and from wood waste streams. Waste energy is the second-largest source of biomass energy. The main contributors of waste energy are municipal solid waste, manufacturing waste, and landfill gas. Biomass alcohol fuel, or ethanol, is derived almost exclusively from corn. Its principal use is as an oxygenate in gasoline.

Biomass can be converted to other usable forms of energy like methane gas or transportation fuels like ethanol and biodiesel. Methane gas is the main ingredient of natural gas. Smelly stuff, like rotting garbage, and agricultural and human waste, release methane gas - also called "landfill gas" or "biogas." Crops like corn and sugar cane can be fermented to produce the transportation fuel, ethanol. Biodiesel, another transportation fuel, can be produced from left-over food products like vegetable oils and animal fats. Also, Biomass to liquids (BTLs) and cellulosic ethanol are still under research.

Although biomass-based generation is assumed to yield no net emissions of CO_2 because of the sequestration of biomass during the planting cycle, there are environmental impacts related to sulfur and nitrogen in the combustion process. However, the rate of emissions is significantly lower than that of coal-based generation.

Biomass played a significant role among renewables in 2000 providing 48% of the energy coming from all renewable sources. However, ever since in EIA's AEO2002 reference case projection, growth in demand for biomass is expected to be modest. The subsequent reports of OECD / IEA also consider a reference scenario not increasing very much the importance of biomass in the context of renewable energy sources till 2050.

However the climate change threat is deriving new focus to biomass to be converted into energy or electricity for being part of the worldwide effort on carbon dioxide abatement in atmosphere and of the streamline to sustainable development (SD). The report of EREC/Greenpeace from June 2010 evidences that.

Thermal plants burning biomass in connection to different steam power processes are now receiving emphasis. Most of biomass sources can be used, however the sugarcane bagasse, the agricultural and forestry residues and wastes, wood chips and logs are by far the most envisaged ones. Pelletizing Biomass

Biomass pelletized is becoming welcome in EU due to process of reducing the bulk volume of the material, by mechanical means for easy handling, transportation and storage of material. In addition to the practical advantage of increased convenience, putting biomass in pellet form also decreases the moisture content, increases the density and maintains a high heating value.

In many countries biomass surpassed hydropower as the largest domestic source of renewable energy and consumption in electric utilities is expected to increase significantly till 2030.

This paper is referred to present the state of art for biomass power plants for producing only power or combined heat and power (CHP) which raw materials would be woody products and sugar cane bagasse, while presenting a summary of differences between the two most relevant outlooks for renewable energy (including biomass) issued by reputable international institutions or organizations: OECD/IEA on a more conservative approach, and EREC/Greenpeace on a more radical one, both presenting their reasons for that.

1 - The biomass outlook

It is interesting to present the outlook for energy of IEA/OECD (annually reviewed, the WEO reports, last in November 2009) and compare it to the outlook recently released by EREC/Greenpeace (June 2010). The OECD/UEA scenario for biomass (as well as for all types of renewable energy sources) by 2050 has been considered not satisfactory for many experts to soon approach a low carbon economy. The EREC/Greenpeace now emerges as the most relevant answer against conservative ideas. These conservative ideas still accept long-term changes depending on findings in technology just pressed by market opportunities disregarding threats from climate change.

The EREC/Greenpeace merely considers the OECD/IEA a reference scenario and suggests new ones in which the conveyance to reducing GHGs would fast and more effective. Following is presented a summary of them focused to biomass. For other considerations on alternative renewable energy sources one must read both reports which are excellent in presentation.

- OECD/IEA - World Energy Outlook 2030 - the latest one issued in 2009
- EREC/Greenpeace - Energy (R)evolution: A Sustainable World Energy Outlook - issued in 2010

OECD / IEA - Since the WEO-2008 report, the economic downturn has led to a drop in energy use, CO_2 emissions and energy investment. For a while this has been an opportunity to face climate change defining the possible economic upturns without inflicting losses to environment and living standards with special focus on the energy and fuel systems.

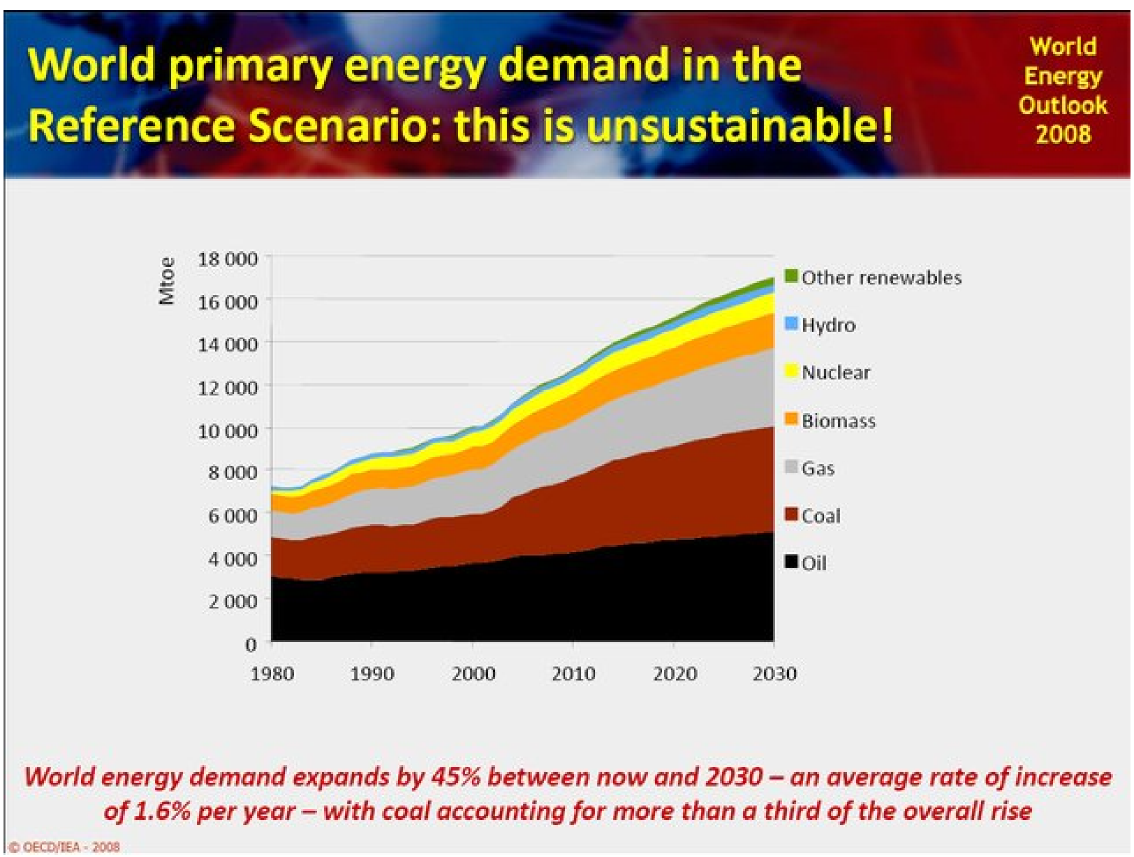
The IEA WEO-2009 released its Annual World Energy Outlook with stern warnings for the international community in advance of Copenhagen conference (COP 15) stating that "the time has come to make the hard choices needed to combat climate change and enhance global energy security."

These warnings are nothing new and are already impacting minds of world leaders. WEO-2009 notes that as one of the consequences of the financial crisis, global energy use is set to fall this year, but projects that it will soon resume its upward trend if government policies don't change. Specifically, the report calls for a profound transformation of the energy sector, identifies higher oil prices as a major threat to the world economy, and points to growing demand in Southeast Asia as an indicator pointing to a refocusing of the global energy landscape increasingly towards Asia.

WEO-2009 also states that it is possible to contain climate change, but only insofar as a "profound transformation of the energy sector" takes place. This includes fossil fuel demand peaking by 2020 and energy-related carbon dioxide emissions falling to 26.4 Giga tons in 2030 from 28.8 in 2007. While energy efficiency must play a vital role, the report also calls on increasing development of low-carbon energy technologies to create downward pressure on GHG emissions. 2030 projections for global electricity production include 60% from renewables (37%), nuclear (18%), and plants fitted with carbon capture and storage (5%) as well as 60% market penetration for PHEVs and EVs, up from 1% of sales today. From that biomass is projected to play in increased role.

Nevertheless, climate negotiators at the UN Climate Change Conference (COP 15) in Copenhagen have failed and world testifies the possible birth of an era without regulations for GHGs emissions. Many questions were tentatively answered in the WEO-2009 report with extensive data, more detailed projections which include the role of renewable resources and energy, in which biomass for heat and power takes place.

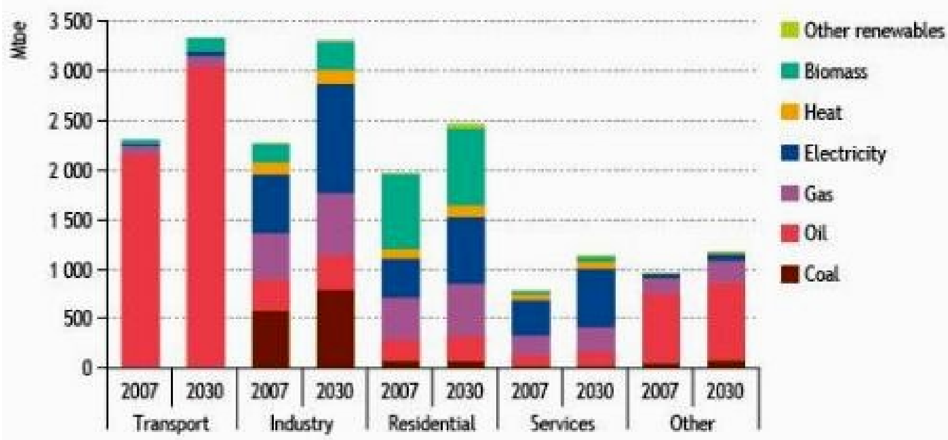
According to IEA / OECD WEO series the use of biomass growth as a renewable energy will play a growing role in the world's primary energy mix. Poor people in developing countries rely heavily on traditional biomass – wood, agricultural residues and dung – for their basic energy needs. According to information specifically collected for this WEC study (World Energy Outlook 2002 and on till 2009), 2.4 billion people in developing countries use only such fuels for cooking and heating. Many of them suffer from ill-health effects associated with the inefficient use of traditional biomass fuels. Over half of all people relying heavily on biomass live in India and China, but the proportion of the population depending on biomass is heaviest in sub-Saharan Africa. The share of the world's population relying on biomass for cooking and heating is projected to decline in most developing regions, but the total number of people will rise. Most of the increase will occur in South Asia and sub-Saharan Africa. Over 2.6 billion people in developing countries will continue to rely on biomass for cooking and heating in 2030. That is an increase of more than 240 million, or 9%. In developing countries, biomass use will still represent over half of residential energy consumption in 2030. Figure below shows the participation of biomass in the world primary demand from 1980 to 2030.



Despite the predicted progress of Renewable Energy projects, fossil fuels will still account for 80% of the world's primary energy mix in 2030.

Regarding the allocation of final biomass energy by sector in the reference scenario one in 2007 and later in 2030 can see the above projections. There it is clear the important role of biomass in residential and industry sectors which tends to increase in percentage.

Figure 1.4 • **World final energy consumption by fuel and sector in the Reference Scenario**



EREC / **Greenpeace** - The European Renewable Energy Council (EREC) and Greenpeace International recently released an updated second edition of "Energy (R)evolution: A Sustainable World Energy Outlook" as a blueprint for reducing carbon dioxide emissions and moving the world towards more sustainable energy practices. Biomass is one of the renewable energy markets highlighted in the report as offering an "increasingly attractive option" to accomplish this outcome. The report claims that an energy revolution is necessary to reverse climate change and alter the way energy is produced. The report lists five principles necessary for the shift to happen:

a) Implement renewable solutions, especially through decentralized energy systems.
b) Phase out nuclear and coal energy sources.
c) Create greater equity in the use of resources.
d) Decouple economic growth from the consumption of fossil fuels.

According to this report, biomass is currently the main renewable energy source used throughout the world. Renewable energy sources in total provide approximately 13% of the world's energy demands. If measures recommended are taken, renewable energy contributions could jump to 56% of the world's total energy supply by 2050, according to the study. The report's "development pathway" includes the expanded use of biomass for combined heat and power (CHP) as well as heat supply in order to reach the 56% goal by 2050.

The crucial factor for the economics of biomass is the cost of the feedstock, which today ranges from a negative cost for waste to the more expensive energy crops. One of the most economic options is the use of waste wood in steam turbine combined heat and power (CHP) plants. Gasification of solid biomass, on the other hand, is still relatively expensive. In the long term it is expected that favorable electricity production costs will be achieved by using wood gas both in micro CHP units (engines and fuel cells) and in gas-and-steam power plants. Great potential for the utilization of solid biomass also exists for heat generation in both small and large heating centers linked to local heating networks. Converting crops into ethanol and 'bio diesel' made from rapeseed methyl ester (RME) has become increasingly important in recent years, for example in Brazil, the USA and Europe.

Processes for obtaining synthetic fuels from biogenic synthesis gases will also play a larger role. A large potential for exploiting modern technologies exists in Latin and North America, Europe and the Transition Economies. In the long term Europe and the Transition Economies will realize 20-50% of the potential for biomass from energy crops, whilst biomass use in all the other regions will have to rely on forest residues, industrial wood waste and straw. In Latin America, North America and Africa in particular, an increasing potential value will be available. In other regions, such as the Middle East and all Asian regions, increased use of biomass is restricted, either due to a generally low availability or already high traditional use.

The figures for the biomass outlook of this report are related to two different scenarios; *a) the Energy (R)Evolution scenario; b) The Advance Energy (R)Evolution scenario*, both compared to a Reference scenario from IEA. It has been understood that those scenarios are important in describing possible development paths for decision-makers in order to inform them how far they can shape the future energy system. Two different kinds of scenario are used here to characterize the wide range of possible pathways for a future energy supply system: a Reference Scenario, reflecting a continuation of current trends and policies, and the Energy [R]evolution Scenarios, which are designed to achieve a set of dedicated environmental policy targets.

The Reference Scenario is based on the reference scenario published by the International Energy Agency (IEA) in World Energy Outlook 2009 (WEO 2009).31 This only takes existing international energy and environmental policies into account. Its assumptions include, for example, continuing progress in electricity and gas market reforms, the liberalization of cross-border energy trade and recent policies designed to combat environmental pollution. The Reference scenario does not include additional policies to reduce greenhouse gas emissions. As the IEA's projection only covers a time horizon up to 2030, it has also been extended by extrapolating its key macroeconomic and energy indicators forward to 2050. This provides a baseline for comparison with the Energy [R]evolution scenario.

The Energy [R]evolution Scenario has a key target to reduce worldwide carbon dioxide emissions down to a level of around 10 Giga tons per year by 2050 in order to keep the increase in global temperature under +2°C. A second objective is the global phasing out of nuclear energy. First published in 2007, then updated and expanded in 2008, this latest revision also serves as a baseline for the more ambitious "advanced" Energy [R]evolution scenario. To achieve its targets, the scenario is characterized by significant efforts to fully exploit the large potential for energy efficiency, using currently available best practice technology. At the same time, all cost-effective renewable energy sources are used for heat and electricity generation as well as the production of bio fuels.

The Advanced Energy [R]evolution Scenario is aimed at an even stronger decrease in CO_2 emissions; especially given the uncertainty that even 10 Giga tons might be too much to keep global temperature rises at bay. All general framework parameters such as population and economic growth remain unchanged. The efficiency pathway for industry and "other sectors" is also the same as in the basic Energy [R]evolution scenario. What is different is that the advanced scenario incorporates a stronger effort to develop better technologies to achieve CO_2 reduction. So the transport sector factors in lower demand (compared to the basic scenario), resulting from a change in driving patterns and a faster uptake of efficient combustion vehicles and – after 2025 – a larger share of electric and plug-in hybrid vehicles.

In all sectors, the latest market development projections of the renewables industry have been taken into account. In developing countries in particular, a shorter operational lifetime for coal power plants, of 20 instead of 40 years, has been assumed in order to allow a faster uptake of renewables. The fast introduction of electric vehicles, combined with the implementation of smart grids and faster expansion of super grids (about ten years ahead of the basic Energy [R]evolution scenario) - allows a higher share of fluctuating renewable power generation (photovoltaic and wind) to be employed. The 30% mark for the proportion of renewables in the global energy supply is therefore passed just after 2020 (ten years ahead of the basic Energy [R]evolution scenario). The global quantities of biomass and large hydro power remain the same in both *Energy [R]evolution* scenarios, for reasons of sustainability.

Energy (R)Evolution						
Biomass (electricity only)	**2007**	**2015**	**2020**	**2030**	**2040**	**2050**
Global installed capacity (GW)	28	48	62	75	87	**107**
Investment costs ($/kW)	2,818	2,452	2,435	2,377	2,349	**2,326**
O&M costs ($/kW/a)	183	166	152	148	147	**146**
Biomass (CHP)	**2007**	**2015**	**2020**	**2030**	**2040**	**2050**
Global installed capacity (GW)	18	4,255	150	261	413	**545**
Investment costs ($/kW)	5,250	348	3,722	3,250	2,996	**2,846**
O&M costs ($/kW/a)	404	50	271	236	218	**207**
Advanced Energy (R) Evolution						
Biomass (electricity only)	**2007**	**2015**	**2020**	**2030**	**2040**	**2050**
Global installed capacity (GW)	28	50	64	78	83	**81**
Investment costs ($/kW)	2818	2,452	2,435	2,377	2,349	**2,326**
O&M costs ($/kW/a)	183	166	152	148	147	**146**
Biomass (CHP)	**2007**	**2015**	**2020**	**2030**	**2040**	**2050**
Global installed capacity (GW)	18	65	150	265	418	**540**
Investment costs ($/kW)	5,250	4,255	3,722	3,250	2,996	**2,846**
O&M costs ($/kW/a)	404	348	271	236	218	**207**

Table presented on the Greenpeace report

2 - Highlight on the European Commission contribution

Recently European Commission issued the report "World Energy Technology Outlook 2050 – WETO H2 -which is focused to a low carbon economy but with a different approach driven to a near hydrogen (H2) economy.

WETO-H2 is structured around a BAU (business-as-usual) case, and features two specific scenarios that reflect the political will of Europe to be at the forefront of the struggle against climate change and to promote new clean energy technologies:

The "reference case" describes the developments of the world energy system up to 2050, and the related CO_2 emissions assuming a continuation of existing economic and technological trends. Without determined action, energy demand will double and electricity demand will quadruple, resulting in an 80% increase in CO_2 emissions.

The "carbon constraint case" explores the consequences of more ambitious carbon emissions policies that aim at the long-term stabilization of the CO_2 concentration in the atmosphere. Early action is assumed in industrialized countries, while more time is allowed for the emerging and developing countries. It reflects a state of the world with moderately ambitious climate targets, aiming at an emission profile that is compatible in the long-term with concentration levels below 550 ppm for CO_2. This scenario is not intended to depict the climate policy of the EU that is now in preparation and that will be presented to the UNFCCC "post-2012" negotiation process;

The "hydrogen case" is then derived from the need to implement the "carbon constraint case" but also assumes (and depends on) a series of technology breakthroughs that significantly increase the cost effectiveness of hydrogen technologies, in particular in end use. This hydrogen scenario considers alternative technological and socio-economic pathways that illustrate possible ways of incorporating hydrogen into the world energy system. It implies a certain number of technology breakthroughs to make hydrogen technologies, mainly on the end-use side, more cost effective.

Results of the WETO-H2 report may be the first step to create a global awareness about a possible hydrogen parallel economy replacing the high carbon economy and moving it to a low carbon economy. That could be of considerable interest for decision and policy makers at different levels.

The report is fully based on outputs for a computer simulation model with several portfolios reflecting hypothesis considered for the H2 case. Due to the present state of knowledge the report has been prudent for not stating definite conclusions. One can only find key-messages reporting the findings through the interpretation of model outputs which are herein transcribed.

2.1 - Drivers and constraints in the H_2 case

- *Hydrogen technologies* - The Reference case is characterized by BAU (business-as-usual) trends in cost and performance data for hydrogen technologies. It shows a small penetration of hydrogen into the energy system; by 2050, the share of hydrogen in final energy consumption is 2% of the world total and 3% for Europe. Given the many ongoing initiatives to facilitate and accelerate the development and deployment of cost-competitive hydrogen technologies, an alternative scenario – the H_2 case – was elaborated. The H2 scenario assumes technological breakthroughs based on the indicative targets outlined by the International Platform for the

- *Hydrogen Economy* - These breakthroughs show that improvements in technical performance and costs are predominantly required in the distribution and consumption segments of the hydrogen economy. Fuel cell technologies have to undergo a decrease in cost by a factor 100 to become competitive. The technical and economic characteristics of the transport and distribution of hydrogen must also be improved significantly. On the production side, fossil fuel based technologies are already close to the competitiveness threshold.

- *Climate policy* - The assumptions on climate policy are similar to those made in the Carbon Constraint case and are expressed in the same time-path of carbon values. However, the emission profiles of CO_2 differ because of differences in technical performance and cost in the two cases.

2.2 - The world energy system in the H_2 case

- *Primary energy demand* - The primary energy demand in 2050 is 1.7 Gtoe (8%) less than the Reference and change to the fuel mix is significant. The share of fossil fuels in 2050 is slightly less than 60% in the H2 case compared to 70% in the Reference. Coal is affected more than other fossil fuels. The demand for coal drops dramatically by 49% in 2050 compared to the Reference despite the assumed lower cost of carbon capture and storage. The share of nuclear and renewable energy grows more strongly in the H2 case than in the Reference. The fastest increase is between 2030 and 2050; it is caused partly by the high carbon values across the world and partly by the rapidly growing demand for hydrogen.

- CO_2 *emissions* - World emissions of CO_2 in 2050 fall by 18 Gt (about 40%) compared to the Reference. Of this reduction, about three quarters are achieved in the generation of electricity. This result shows that the deployment of hydrogen in the world energy system is compatible with ambitious climate policies consistent with a trajectory of long-term stabilization of greenhouse gas emissions at 550 ppm. World emissions of CO_2 are, however, somewhat higher in the H2 case than in the Carbon Constraint case. Between 2020 and 2050, the gap is from 5 to 6%. This difference is the direct consequence of slightly higher global primary energy demand that in turn results from an overall cheaper energy system.

- *Electricity production* - The growth of electricity generation and the share of fossil energy sources are reduced compared to the Reference. Generation in the H2 case evolves much like in the Carbon

- Constraint case - The move to a hydrogen economy induces further change in the structure of generation; the share of nuclear increases to 38%, compared to 33% in the CC case, at the expense of both fossil fuels and renewables. The volume of production of thermal electricity continues to grow because it is associated with the development of carbon capture and storage (CCS) systems. In 2050, 66% of electricity generation from fossil fuels is in plants equipped with CCS against 12% in the Reference.

- *Hydrogen production - The* production of hydrogen in the world takes-off after 2030, driven by substantial reductions in the cost of the technology and the demand-pull in the transport sector. From 2030 to 2050 production increases by a factor of 10 to reach 1 Gtoe. By 2050, hydrogen provides 13% of final energy consumption, compared to 2% in the Reference and the share of production from coal and natural gas is only 10%, although the volume is increasing. The share of renewable energy is 50% and of nuclear is 40%.

- *Energy consumption in transport* - The critical finding for hydrogen consumption is that around 90% is used in transport. The 'optimistic' characterization of hydrogen technology and the demand-pull from transport assumed in the H2 case contributes to this result. By 2050, the consumption of hydrogen in transport is five times as great as in the Reference, with a share of 35% of the energy consumption of the sector. Hydrogen cars represent 30% of total passenger cars: about 80% are fuel cell cars; 15% are hydrogen hybrid vehicles and 5% are hydrogen internal combustion engines.

2.3 - The European energy system in the H_2 case

- *Primary energy demand and* CO_2 *emissions* - As at world level, the H2 case has significant effect on the dynamics of the energy system in Europe. Primary energy demand in 2050 is 2% lower than in the Reference and there is a significant change in the fuel mix. Nuclear energy provides one third of the primary energy consumption in Europe. Oil, natural gas and renewables each provide roughly one fifth and coal 6%. Emissions of CO_2 fall steadily and are 35% lower than now.

- *Electricity and hydrogen production* - Electricity generation in Europe grows strongly from 2030 and 2050. It increases on average by 2.1% per year compared to 1.8% in the Reference. The fuel mix in power generation changes markedly compared to the balanced structure of the Reference. The share of fossil fuels decreases steadily and significantly. The use of CCS systems develops greatly; by 2050, more than 50% of thermal electricity production is from plants with CCS.

- The production of hydrogen increases rapidly after 2030 to reach 120 Mtoe/yr by 2050; this is 12% of world hydrogen production. Hydrogen provides 7% of final energy consumption in Europe, against 3% in the Reference. In Europe, hydrogen is produced mainly from the electrolysis of water using nuclear electricity. Nevertheless, the share of renewables is not negligible and by 2050 represents 40% of total hydrogen production.

- *Energy consumption in transport* - In 2050, about three quarter of the hydrogen produced in Europe goes to transport. Energy consumption in transport is projected to be stable from 2001 to 2050, showing only a 4% increase over 49 years. The mix of hydrogen technologies for hydrogen passenger cars reflects that described for the world.

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