



Renewable energy deployment potentials in large economies

Wolfram Krewitt, Sonja Simon, Thomas Pregger
with contributions from Paul Suding, REN21

Stuttgart, April 2008



Contact:

Dr. Wolfram Krewitt
German Aerospace Center (DLR)
Institute of Technical Thermodynamics
Department Systems Analysis and Technology Assessment
Pfaffenwaldring 38-40
D-70569 Stuttgart
Germany
wolfram.krewitt@dlr.de

Table of Contents

1	Introduction.....	1
2	Renewable energy potentials	2
3	Assessment of renewable energy deployment potentials.....	4
4	Renewable energy potentials for electricity generation in large economies	5
4.1	Current situation.....	5
4.2	Deployment potential	6
5	Renewable energy potentials for heat production in large economies.....	9
5.1	Current situation.....	9
5.2	Deployment potentials.....	9
6	Renewable energy potentials for the production of transport fuels in large economies	12
6.1	Current situation.....	12
6.2	Deployment potentials.....	12
7	Conclusions	15
8	References.....	16
9	Annex - Energy demand projections and renewable energy deployment in large economies	
	17	

1 Introduction

This report provides background on the methodology and results of the assessment of the long term 'deployment potential' of renewable energy sources in large economies. This analysis has been carried out as part of the report *Opportunities for the rapid deployment of renewable energy in large economies*, which was published by REN21 as an input to the third Ministers Meeting in the Gleneagles dialogue on Climate Change in 2007. The work described in this report relies on the assessment of global and regional technical potentials of renewable energy sources performed by Ecofys on behalf of REN21 (Hoogwijk and Graus, 2008).

2 Renewable energy potentials

Information on renewable energy potentials need to be carefully put into context. In the literature, various types of potentials are defined, and there is no one single definition of the various types of renewable energy potentials. In accordance with Hoogwijk and Graus (2008) we differ between the following five types of potentials (Figure 1):

- **Theoretical potential:** The theoretical potential is derived from natural and climatic parameters (e.g. total solar irradiation on a continent's surface). The theoretical potential can be quantified with a reasonable accuracy, but the information is of little relevance. The theoretical potential of renewable energy sources is huge compared to global energy demand, and there are various constraints in exploiting the theoretical potential.
- **Technical potential:** The technical potential takes into account geographical restrictions (e.g. land use cover that reduces the theoretical potential) as well as technical and structural constraints. Due to technical progress of energy conversion technologies the technical potential may change over time.

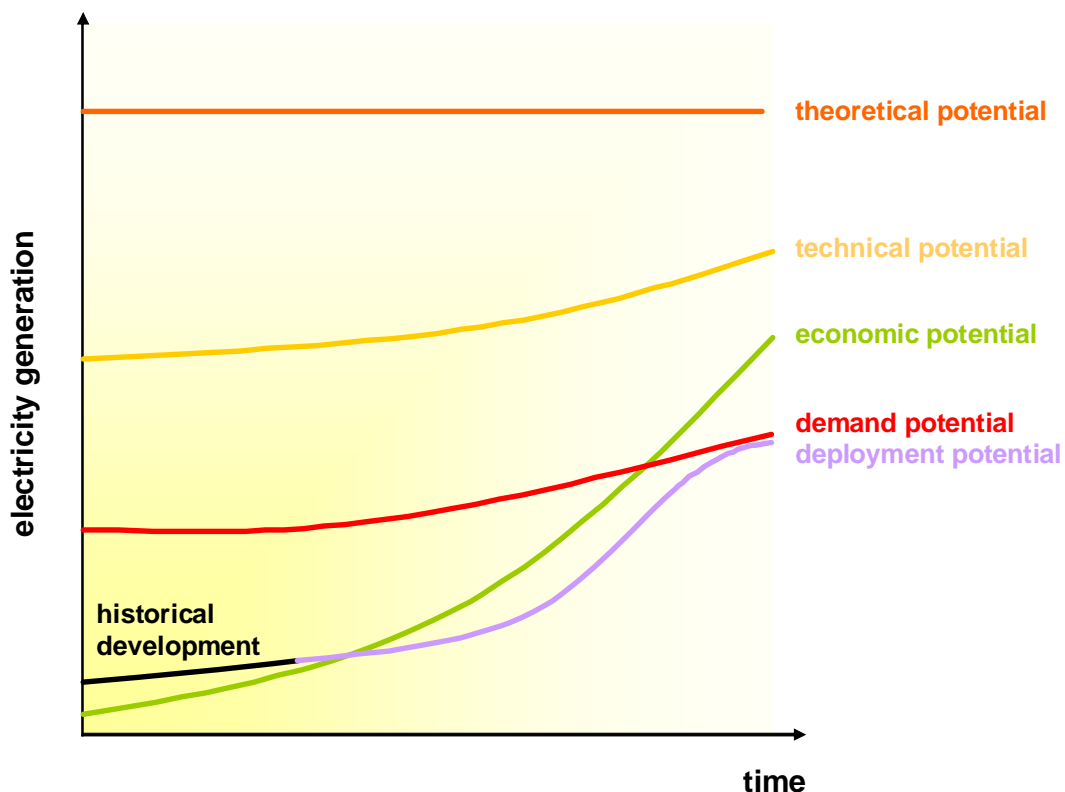


Figure 1: Concepts of renewable energy potentials

- **Economic potential:** The economic potential is the technical potential that can be exploited at competitive costs. As the break even between renewable energy technologies and conventional technologies change over time (rise in fossil fuel prices, reduction in renewable energy generation costs), the economic potential is highly dependent on framing conditions.
- **Deployment potential:** The deployment potential characterises the potential market uptake of renewable energy technologies under pre-defined framing conditions. It depends on e.g. the structure of the existing supply system, the development of energy demand, and on energy policy targets and instruments in place.
- **Demand potential:** With increasing competitiveness of renewable energies, in the future the economic potential may exceed the energy demand. In such a case the deployment potential of renewable resources is of course limited by the energy demand.

3 Assessment of renewable energy deployment potentials

This report makes an attempt to quantify the renewable energy deployment potential in large economies. Given the technical potential and the prospective cost of producing electricity, transport fuel and heat from renewable energy, the question arises, how much of this could realistically be tapped during the coming decades. This depends not only on the quality and quantity of the renewable energy sources and on the state of technologies to tap it, but also on the size of the markets and the current supply structure. The market penetration takes time, in particular with the longevity of energy supply and consumption structures. Thus the deployment potential can only be estimated for a given market, practically in the form of a potential market share in a given economy.

Today, various support schemes created a dynamically growing market for renewable energy technologies in several countries around the world. Our assessment of the long term renewable energy deployment potentials assumes a strong growth in these technologies within the framework of each individual countries' demand, taking into account the technical and economic potentials of the respective renewable energy resources as well as potential structural constraints, which include the country's current supply structure, the time lags in the energy supply stock turnover and the implementation of renewables. The deployment of these potentials requires a reasonable strong and continuous policy support to foster the market introduction of renewable energies and to stimulate market dynamics that are required to run through the economic learning curve of these technologies. In all cases, a much improved energy efficiency of the economies is assumed, which is a prerequisite for achieving a high share of renewable energies in the supply system. However, the necessary institutional and behavioural changes are not described nor are the barriers that must be overcome.

The renewable energy deployment potentials in the 20 large economies are assessed based on projections of the energy demand (strongly influenced by population and GDP development) and the technical and structural options for transforming the respective countries' energy supply structure towards a low carbon supply system with a high share of renewables. In each case we assume favourable policy conditions that support the continuous market deployment and cost-effective exploitation of domestic renewable energy resources. Results thus by no means describe a 'business-as-usual' trajectory, but give an indication of which share of renewables can be reasonably achieved in each country, taking into account the national or regional renewable energy resources available, and assuming strong policy actions supporting renewable energy deployment and the implementation of energy efficiency measures.

Deployment potentials are presented in the form of potential market shares for each renewable energy source in the supply of electricity, heat, and transportation fuels in the large economies. Starting from current conditions, deployment potentials are quantified for an intermediate term (~ 2030) and long term (~ 2050) time horizon in order to visualize the dynamics required.

4 Renewable energy potentials for electricity generation in large economies

4.1 Current situation

The contribution of renewable energy to electricity generation in large economies, and the development since 2000 are extremely diverse (Figure 2). In 2004, the range of renewable energy shares in power production ranges from below 2% in South Africa and South Korea to almost 90% in Brazil. Hydropower is by far the principal contributor. Other renewables, whose investment growth was rapid since a number of years, are becoming visible also in power production market shares in Spain, Germany, Brazil, Indonesia, Italy and Mexico.

There has been significant growth of electricity generation from renewable energy in absolute terms also in China and India, but the overall growth of electricity generation leaves share growth slow. In some cases, the absolute growth trend of new renewable energy use would be more evident if it were not masked by lower hydro energy production due to low rainfall.

The decades of hydropower development have made it a well established source of electricity, supplying 16% of global electricity production in 2004. The top five producers are Canada, China, Brazil, the United States and Russia. Hydropower is dominant power source in Brazil and Canada, very considerable in Russia, China and Nigeria, and significant in most other large economies, including France, Germany, India, Indonesia, Italy, Iran, Japan, Mexico, Spain, and the US.

In Germany, Indonesia, Italy, Japan, Mexico, Spain, UK and US, wind, geothermal, biomass capacity are diversifying the production of power from renewable sources.

The generation of electricity from solar PV is yet barely noticeable in power production statistics despite very high growth rates.

Small amounts of electricity from concentrating solar power (CSP) projects have been found in a few countries in the past, particularly in the US. The first significant new capacity additions are now being installed mainly in Spain and the US.

Ocean power was first used in France (tidal power) a few decades ago and is only now being trialled in the form tidal and wave power by other countries, including the UK and the US.

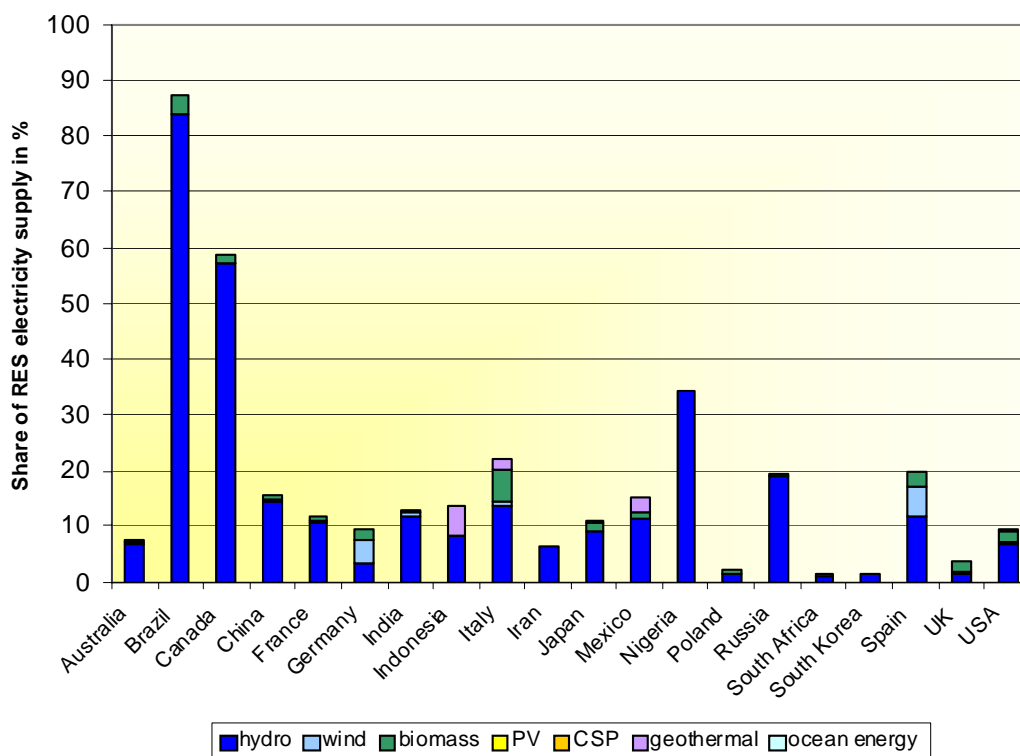


Figure 2: Share of renewable electricity supply in large economies in 2004 (source: IEA 2006 a, b)

4.2 Deployment potential

By 2050, the picture may change completely. Renewable energy could contribute at least half of all electricity generation in most of the large economies. In some cases, that percentage could climb to over 90 percent, even with an expected significantly higher electricity demand in most of the countries considered (Figure 4).

A wide variety of renewable energy resources can realistically be deployed in electricity generation. While the hydropower potential becomes gradually developed, additional demand will be covered by other renewable energy technologies. Even taking into account intermittency, wind, biomass, concentrating solar thermal power (CSP) and solar PV are expected to become equal to hydro in their importance. Due to the possibility of heat storage, CSP will be able to provide dispatchable solar bulk power. Geothermal power may be significantly expanded in a number of countries, with ocean energy available in only a few countries.

Countries will focus their efforts on the renewable energy technologies that are available to them. For example, Australia may concentrate on solar and wind, Canada on hydro and wind, Russia on hydro and biomass, UK on wind and ocean energy, Indonesia, Mexico and Italy may add considerable amounts of geothermal power.

Not all the renewable energy contributions are produced in the respective countries. There is e.g. a significant potential for European countries to import electricity produced in concentrating solar thermal power plants in North Africa and the Middle East (very good solar conditions).

In the intermediate term to 2030, the overall deployment potential of renewable energy in the electricity generation sector is somewhat lower. However, wind energy may already achieve a considerable market share in addition to hydropower, which would tend to reach its full potential during this period. With new grid management technologies and operational approaches, intermittent resources such as wind already today can achieve shares in excess of 30 percent, as has been accomplished in Denmark.

Biomass power, CSP and PV as well as geothermal in some countries, may contribute significantly in the mid-term, with more potential to be developed after 2030. The deployment of ocean energy in countries like the UK and South Africa is more likely after 2030.

Various renewable energy technologies are available now to meet a high proportion of incremental electricity demand and replace outgoing fossil capacity. The contributions from renewable energy can be widely diversified already in 2030.

If renewable energy technologies are deployed rapidly, it is possible to increase their shares in all countries already in the medium term, including those currently with a high share like Brazil and Canada, in particular when combined with energy efficiency to reduce demand. This strategy puts renewable energies on the path to attaining high market shares by 2050.

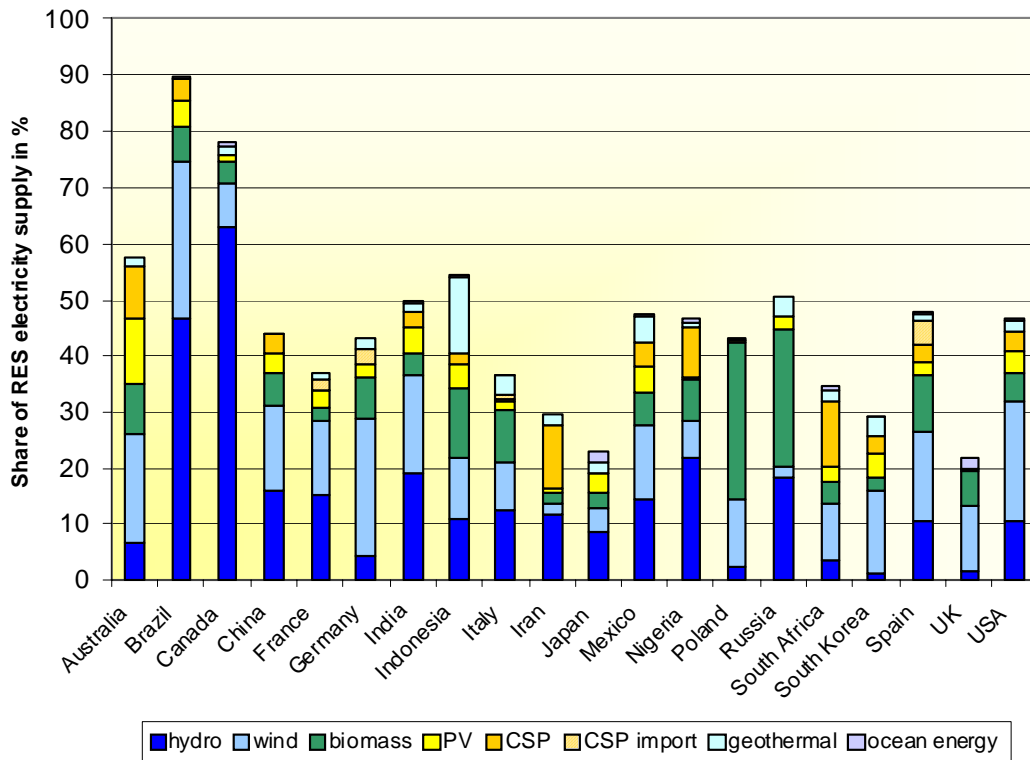


Figure 3: Renewable energy deployment potentials in electricity generation in ~ 2030

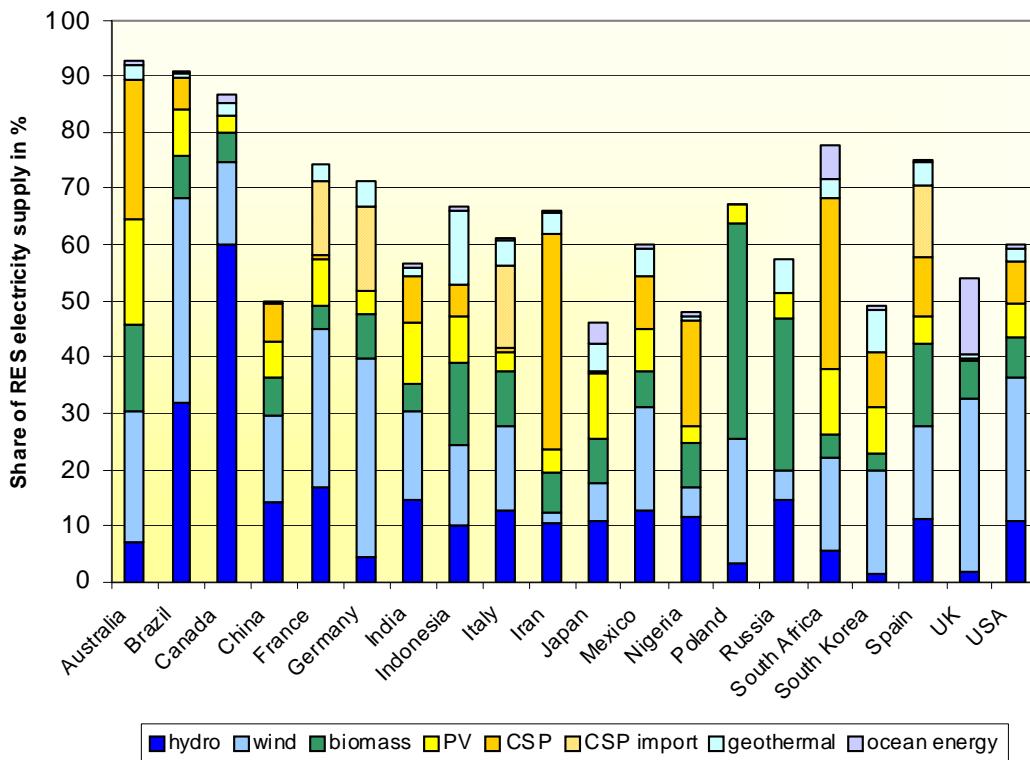


Figure 4: Renewable energy deployment potentials in electricity generation in ~ 2050

5 Renewable energy potentials for heat production in large economies

5.1 Current situation

The share of renewable energy in the heat market of large economies for heating and cooling, cooking, and industrial process heat can be divided into two very distinct sub-markets:

- Consumption of traditional forms of biomass
- Significant use of biomass in modern forms

Figure 5 is a reminder that renewable energy from traditional biomass is still a dominant fuel for heating and cooking in many developing countries, such as Brazil, China, India, Indonesia, Nigeria, and South Africa. According to IEA statistics, the high renewable energy consumption in heat markets of developing countries - most from traditional forms - was still rising from 2000 to 2004.

However, biomass is also significant source of heat energy in Australia, Canada, France, Germany, Italy, Mexico, Poland and Spain. Biomass is also the dominant source for this market with solar water heating a minor player, even though in absolute terms it is quite significant in China. Even the high dissemination of solar water heaters in China, however, seems not to constitute a significant market share in overall heating and cooling markets.

5.2 Deployment potentials

For the heating and cooling markets renewable energy technologies can realistically achieve very high market shares by 2050. Apart from biomass, solar water heating and geothermal can contribute significantly (Figure 7). However, the large market shares can only be achieved when very energy-efficient heating and cooling systems are utilized, and when heat demand is reduced by implementing energy efficiency measures. The introduction of low energy or passive house standards will drastically reduce space heat demand. More than in any other sector energy efficiency works hand in hand with renewable energy in building and industrial heat energy. Combined heat and power from biomass, or biogas additions to the gas supply systems, may jointly serve electricity and heat markets.

The year 2030 presents a transitional situation. In some countries, there will still be quite high use of traditional forms of biomass, although less than at present (Figure 6). Their replacement by modern forms of biomass, solar heat and geothermal energy resources requires time.

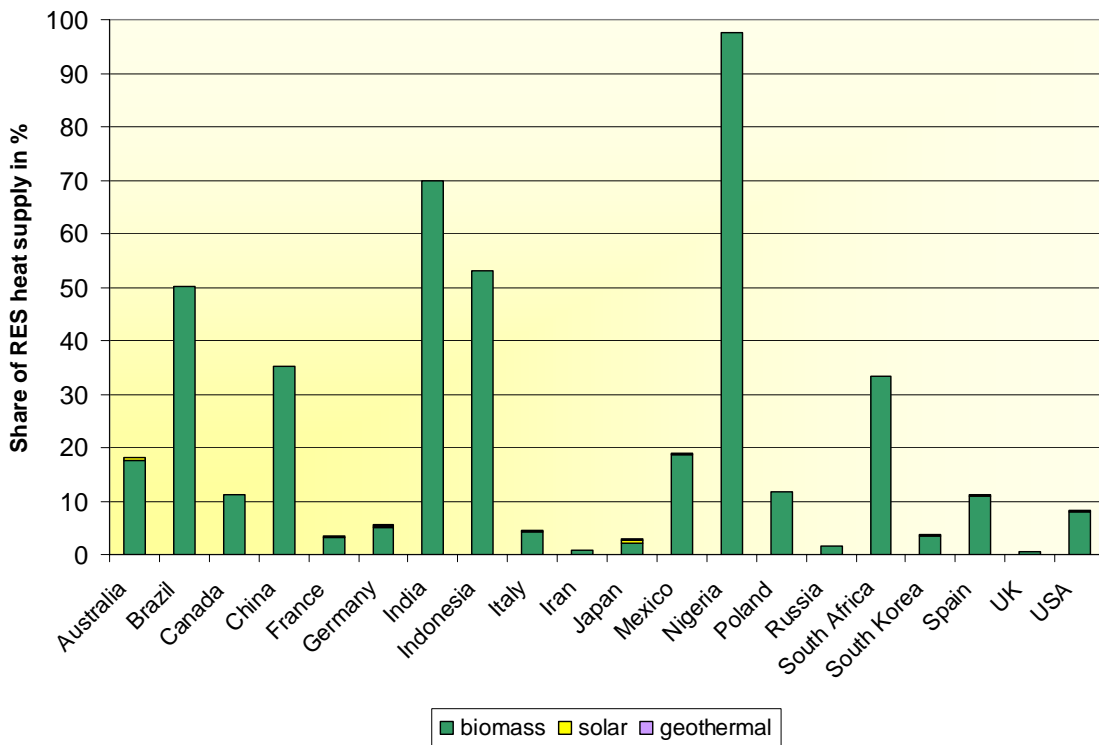


Figure 5: Share of renewable energies for heat supply in large economies in 2004 (source: IEA 2006a, b)

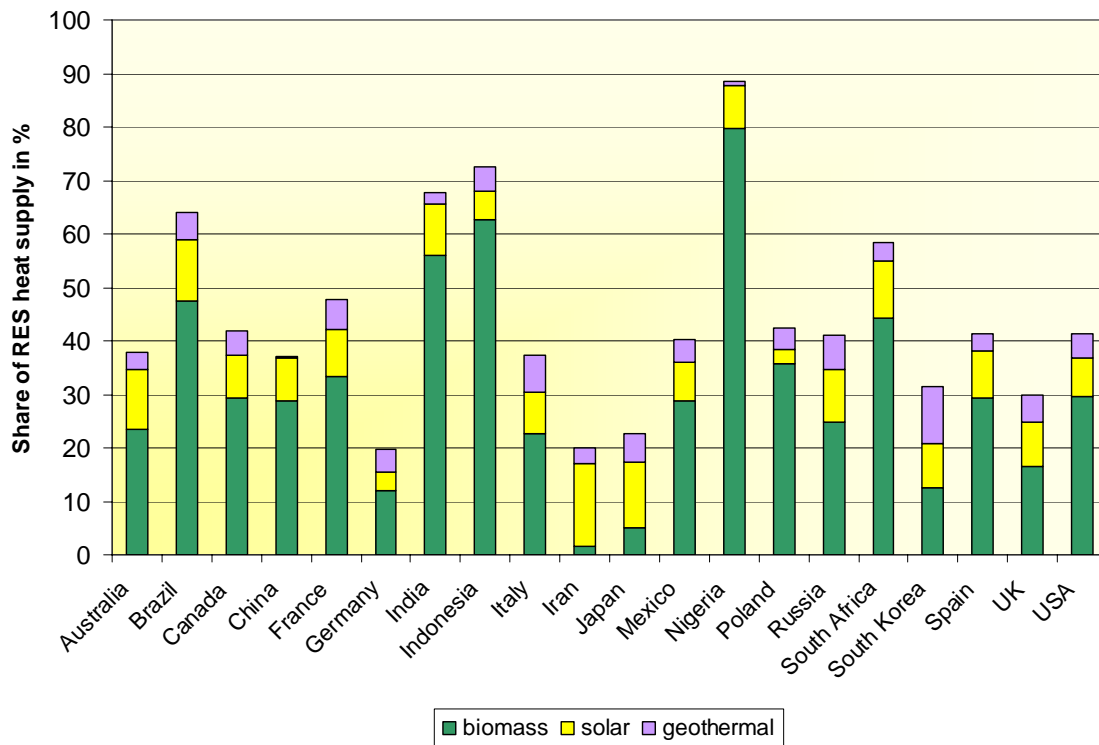


Figure 6: Renewable energy deployment potentials for heat production in ~ 2030

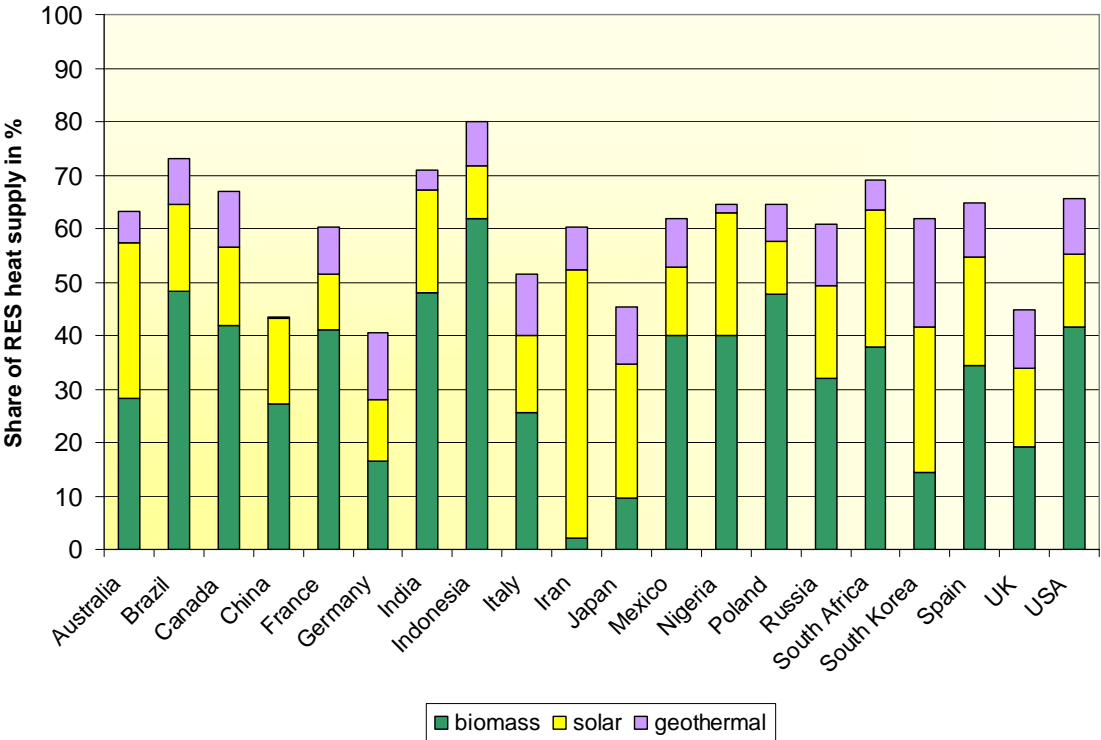


Figure 7: Renewable energy deployment potentials for heat production in ~ 2050

6 Renewable energy potentials for the production of transport fuels in large economies

6.1 Current situation

Until recently, the only country with a substantial market share of transport fuel from biomass energy sources has been Brazil, although biofuel use is growing in other large economies (figure 3.21).

According to the REN21 Renewable Global Status Report, total ethanol production in 2007 reached over 40 billion liters, with US and Brazil accounting for almost 90% of this total. This compares with about 1200 billion liters of gasoline production worldwide annually.

Brazil has been the world's largest producer and consumer of fuel ethanol for more than 25 years. Importantly, ethanol from sugarcane is fully competitive with gasoline in Brazil and provided over 40% of the non-diesel motor vehicle fuel. The United States ethanol fuel market is expanding quickly - moving from 4 billion liters per year in 1996 to 18 billion liters per year in 2006 and overtaking the volume produced by Brazil. By 2006, about 3 percent of the 140 billion gallons of non-diesel vehicle fuel being consumed annually in the US was ethanol. Other large energy economies producing some ethanol fuel include: Australia, Canada, China, Germany, India, South Africa and Spain.

Biodiesel is growing more rapidly than ethanol in terms of growth rates, but is starting from a much lower base, reaching 6 billion liters principally in US, Germany and other EU countries. Biodiesel grew by 50% in Germany in 2004, bringing total world production to more than 2 billion liters. France and Italy are also following the biodiesel path.

6.2 Deployment potentials

The potential for renewable fuels in transport fuel markets in 2050 are more limited than for electricity (and heat) as bioenergy sources must be shared with electricity and domestic markets for heat¹. If biomass is used preferably for heat and electricity because of its higher CO₂ reduction impact in considerable quantities, bioenergy will be able to supply 5%-45% of the transport fuel demand in the large economies. Brazil would have the largest share followed by Canada, Germany, Mexico and USA with shares of around 30 percent. In some countries domestic biomass may not be used for biofuels at all (Figure 9). Imports from third countries would increase the market share.

¹ In this analysis, no biofuel trade is assumed. Potentials are deployed in their country of origin.

When priority is given to electricity and heat, in most countries biofuels can only cover 15 percent of the transport fuel market in 2030 (Figure 8). If priority is given to the transport market, market shares may be higher by 2030, particularly in Brazil.

Competition for land, water and food supply and the success of new technologies will ultimately determine the biomass available for biofuel uses. What transport technology and infrastructure will ultimately be chosen for the future remains unknown. Biomass fuels could support the transition from the current carbohydrate fuel-based system but not replace it. In the long run, it could be largely replaced by either electricity or hydrogen-based systems. Both alternatives can use renewables as the primary energy input. Any breakthrough in electricity storage technologies favouring electric vehicles or hydrogen/fuel cell technologies will allow solar and wind energy to be used in the transport sector, for which the potential is expected to be large enough to satisfy future transport demand based on highly efficient transportation technologies.

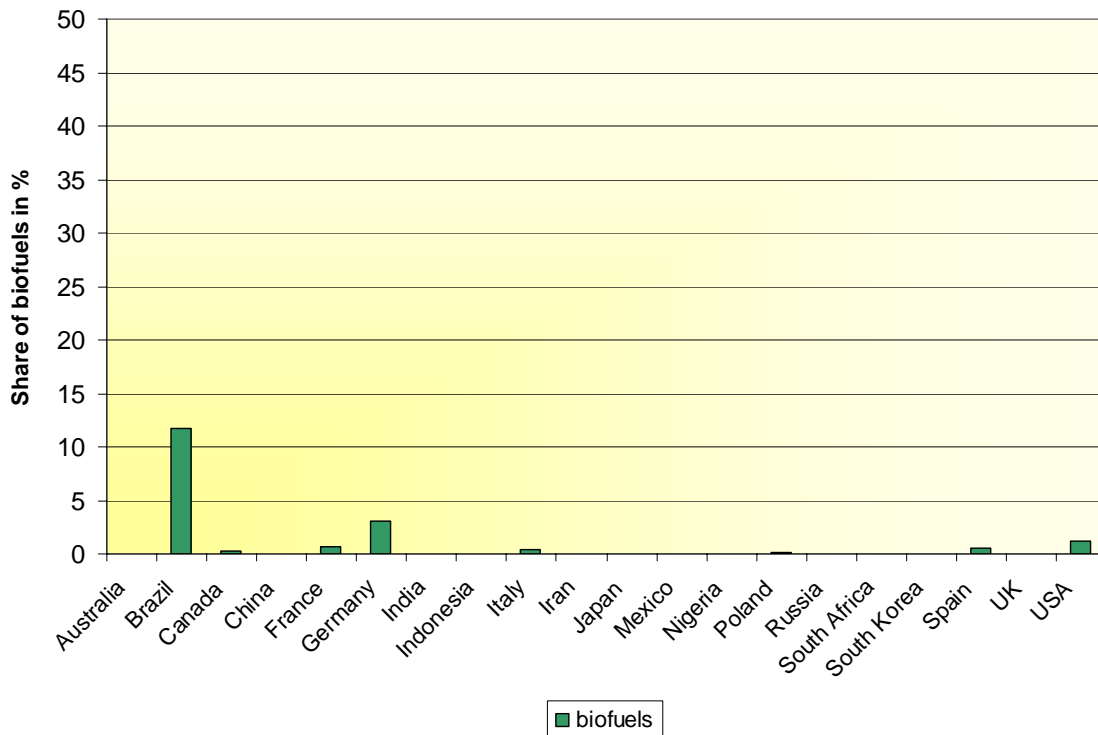


Figure 8: Biofuel use in large economies in 2004 (source: IEA 2006a, b)

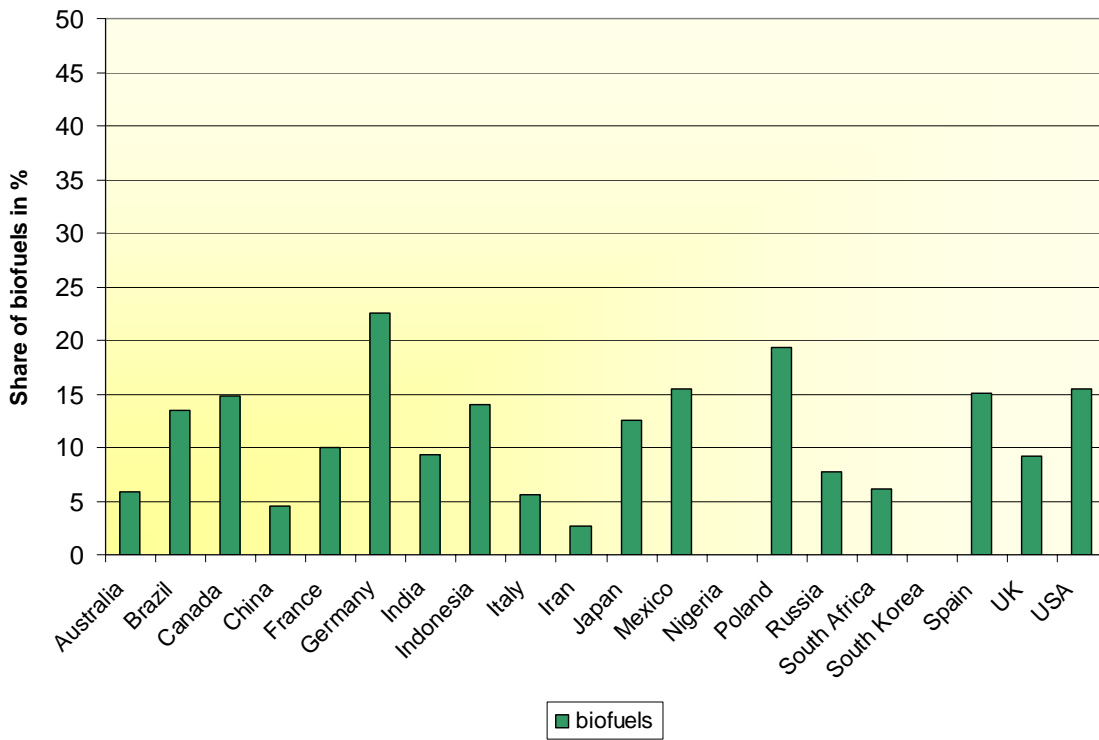


Figure 9: Renewable energy deployment potentials in transport fuel markets in ~ 2030

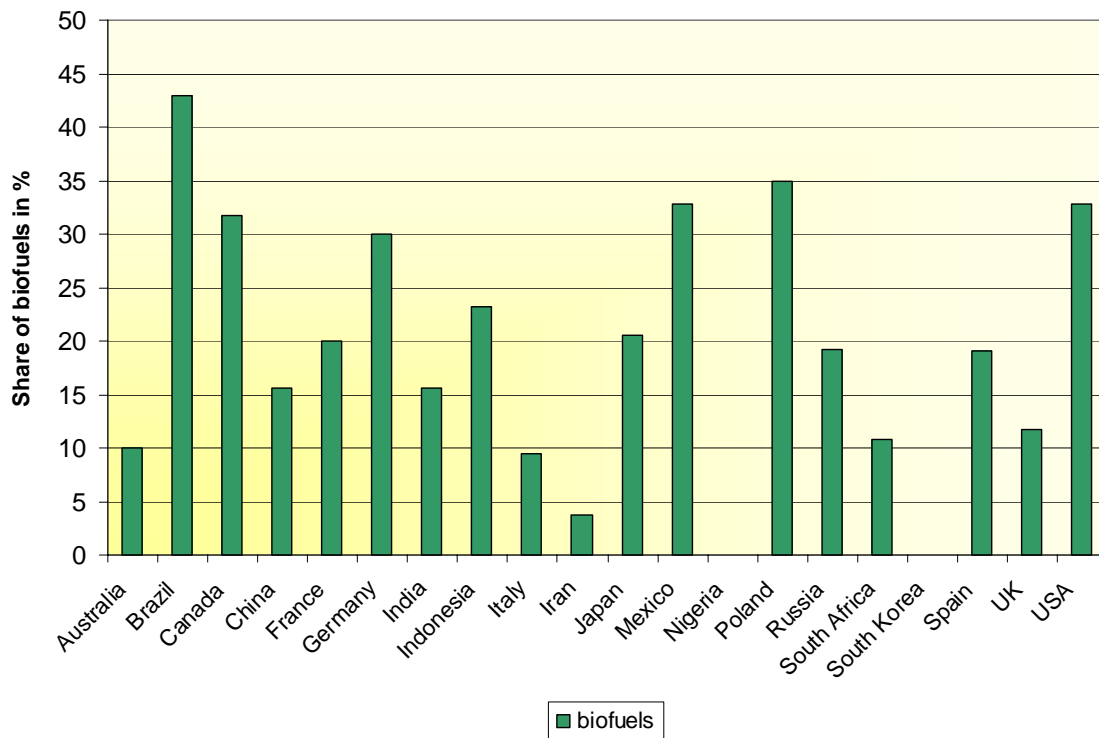


Figure 10: Renewable energy deployment potentials in transport fuel markets in ~ 2050

7 Conclusions

The renewable energy deployment potentials outlined above present significant opportunities for the respective economies, not only for addressing the challenge of mitigating climate change, but also for attaining higher energy security and fostering innovation and employment. The deployment potential in this analysis assumes a rapid structural change towards realizing the technical and economic potentials of renewable energy and energy efficiency as the demand for energy services in each economy grows. The exploitation of the renewable energy deployment potentials however requires targeted policy support to foster the market uptake of renewable energy technologies in the electricity, the heat and the transport fuel markets, and the implementation of energy efficiency measures to reduce energy demand.

Accelerating the deployment of renewable energy technologies can make significant contributions to domestic energy security. Many countries are facing a growing dependence on imported fossil fuels. Renewables provide alternative, mostly domestic sources of electric power and can displace electricity demand through direct heat production. Renewables increase the diversity of electricity and fuel sources, providing a buffer against rising prices and resulting price shocks. Local power generation contributes to grid flexibility and reduced risks of supply disruption.

Results from the study underline that

- Renewable energy can potentially supply a very large part of the resource mix in the electricity sector in large economies, with various renewable technology portfolios in the different countries.
- Bioenergy sources have wide applications in all main energy markets. Apart from competing for food, bioenergy will not be sufficient for all demands - even with newer, second generation technologies. Choices must be made according to CO₂ abatement potentials, market value, a country's priorities, the cost of the particular technology, and broader social and sustainability criteria.
- In view of the huge technical and increasing economic potential, renewable energy can contribute much more to electricity production and heat energy supply beyond 2050.

8 References

Hoogwijk, M., Graus, W. (2008): Global potential of renewable energy sources: a literature assessment. Background report prepared by order of REN21. Ecofys, PECSNL072975, 2008.

IEA (2006a): Energy balances of OECD countries. IEA Statistics, 2006 Edition, International Energy Agency, Paris

IEA (2006b): Energy balances of Non-OECD countries. IEA Statistics, 2006 Edition, International Energy Agency, Paris

9 Annex - Energy demand projections and renewable energy deployment in large economies

Australia

	2004	2030	2050
Electricity	TWh		
Electricity generation	239	Increase by 1 to 1.5	Increase by 1 to 1.5
Share renewables	7,7%	50 - 60%	>90%
- hydro	6,8%	5 - 10%	5 - 10%
- wind	0,293%	15 - 20%	20 - 25%
- PV	0,002%	10 - 15%	15 - 20%
- CSP	0%	5 - 10%	25 - 30%
- biomass	0,6%	5 - 10%	15 - 20%
- geothermal	0,0000003%	0 - 5%	0 - 5%
- ocean Energy	0%	0 - 5%	0 - 5%
Heat	PJ		
Heat demand	777	Decrease by 0.9 to 1	Decrease by 0.9 to 1
Share renewables	18,0%	30 - 40%	60 - 70%
- biomass	17,7%	20 - 25%	25 - 30%
- solar	0,32%	10 - 15%	25 - 30%
- geothermal	0,0000003%	0 - 5%	5 - 10%
Transportation	PJ		
Transport energy demand	1229	Increase by 1 to 1.5	Increase by 1 to 1.5
Share biofuels	0,00%	5 - 10%	10 - 15%

Brazil

	2004	2030	2050
Electricity	TWh		
Electricity generation	365	Increase by 2 to 2.5	Increase by 3 to 3.5
Share renewables	87,4%	>90%	>90%
- hydro	83,8%	40 - 50%	30 - 40%
- wind	0,027%	25 - 30%	30 - 40%
- PV	0,0%	0 - 5%	5 - 10%
- CSP	0%	0 - 5%	5 - 10%
- biomass	3,5%	5 - 10%	5 - 10%
- geothermal	0,00%	0 - 5%	0 - 5%
- ocean Energy	0%	0 - 5%	0 - 5%
Heat	PJ		
Heat demand	2557	Increase by 1 to 1.5	Increase by 1.5 to 2
Share renewables	50,2%	60 - 70%	70 - 80%
- biomass	50,2%	40 - 50%	40 - 50%
- solar	0,0%	10 - 15%	15 - 20%
- geothermal	0,0%	5 - 10%	5 - 10%
Transportation	PJ		
Transport energy demand	2048	Increase by 1.5 to 2	Increase by 2.5 to 3
Share biofuels	11,7%	10 - 15%	40 - 50%

Canada

	2004	2030	2050
Electricity	TWh		
Electricity generation	598	Increase by 1 to 1.5	Increase by 1 to 1.5
Share renewables	58,7%	70 - 80%	80 - 90%
- hydro	57,0%	60 - 70%	60 - 70%
- wind	0,230%	5 - 10%	10 - 15%
- PV	0,004%	0 - 5%	0 - 5%
- CSP	0%	0 - 5%	0 - 5%
- biomass	1,5%	0 - 5%	5 - 10%
- geothermal	0%	0 - 5%	0 - 5%
- ocean energy	0,006%	0 - 5%	0 - 5%
Heat	PJ		
Heat demand	3019	Decrease by 0.9 to 1	Decrease by 0.9 to 1
Share renewables	11,1%	40 - 50%	60 - 70%
- biomass	11,1%	25 - 30%	40 - 50%
- solar	0,000000001%	5 - 10%	10 - 15%
- geothermal	0%	0 - 5%	10 - 15%
Transportation	PJ		
Transport energy demand	2329	Increase by 1 to 1.5	Increase by 1 to 1.5
Share biofuels	0,26%	10 - 15%	30 - 40%

China

	2004	2030	2050
Electricity	TWh		
Electricity generation	1943	Increase by 2.5 to 3	Increase by 4 to 4.5
Share renewables	15,4%	40 - 50%	40 - 50%
- hydro	14,6%	15 - 20%	10 - 15%
- wind	0,062%	10 - 15%	15 - 20%
- PV	0,0%	0 - 5%	5 - 10%
- CSP	0%	0 - 5%	5 - 10%
- biomass	0,8%	5 - 10%	5 - 10%
- geothermal	0%	0 - 5%	0 - 5%
- ocean energy	0,0%	0 - 5%	0 - 5%
Heat	PJ		
Heat demand	20881	Increase by 1 to 1.5	Decrease by 0.9 to 1
Share renewables	35,2%	30 - 40%	40 - 50%
- biomass	35,2%	25 - 30%	25 - 30%
- solar	0,0%	5 - 10%	15 - 20%
- geothermal	0%	0 - 5%	0 - 5%
Transportation	PJ		
Transport energy demand	4050	Increase by 2.5 to 3	Increase by 4 to 4.5
Share biofuels	0,00%	0 - 5%	15 - 20%

France

	2004	2030	2050
Electricity	TWh		
Electricity generation	567	Decrease by 0.5 to 1	Decrease by 0.5 to 1
Share renewables	11,6%	30 - 40%	70 - 80%
- hydro	10,5%	15 - 20%	15 - 20%
- wind	0,2%	10 - 15%	25 - 30%
- PV	0,0%	0 - 5%	5 - 10%
- CSP	0%	0 - 5%	10 - 15%
- biomass	0,9%	0 - 5%	0 - 5%
- geothermal	0%	0 - 5%	0 - 5%
- ocean energy	0%	0 - 5%	0 - 5%
Heat	PJ		
Heat demand	3310	Decrease by 0.9 to 1	Decrease by 0.6 to 0.7
Share renewables	3,4%	40 - 50%	60 - 70%
- biomass	3,3%	30 - 40%	40 - 50%
- solar	0,09%	5 - 10%	10 - 15%
- geothermal	0,0%	5 - 10%	5 - 10%
Transportation	PJ		
Transport energy demand	2175	Decrease by 0.5 to 1	Decrease by 0.5 to 1
Share biofuels	0,69%	5 - 10%	20 - 25%

Germany

	2004	2030	2050
Electricity	TWh		
Electricity generation	609	Decrease by 0.5 to 1	Decrease by 0.5 to 1
Share renewables	9,4%	0 - 5%	70 - 80%
- hydro	3,4%	0 - 5%	30 - 40%
- wind	4,200%	20 - 25%	30 - 40%
- PV	0,090%	0 - 5%	0 - 5%
- CSP	0%	0 - 5%	5 - 10%
- biomass	1,7%	5 - 10%	5 - 10%
- geothermal	0%	0 - 5%	0 - 5%
- ocean energy	0%	0 - 5%	0 - 5%
Heat	PJ		
Heat demand	5258	Decrease by 0.5 to 1	Decrease by 0.5 to 1
Share renewables	5,5%	15 - 20%	40 - 50%
- biomass	5,2%	10 - 15%	15 - 20%
- solar	0,2%	0 - 5%	10 - 15%
- geothermal	0,13%	0 - 5%	10 - 15%
Transportation	PJ		
Transport energy demand	2608	Decrease by 0.5 to 1	Decrease by 0.5 to 1
Share biofuels	3%	20 - 25%	25 - 30%

India

	2004	2030	2050
Electricity	TWh		
Electricity generation	633	Increase by 2 to 2.5	Increase by 4 to 4.5
Share renewables	12,8%	40 - 50%	50 - 60%
- hydro	11,9%	15 - 20%	15 - 20%
- wind	0,569%	15 - 20%	15 - 20%
- PV	0,0%	0 - 5%	10 - 15%
- CSP	0%	0 - 5%	5 - 10%
- biomass	0,3%	0 - 5%	0 - 5%
- geothermal	0,0%	0 - 5%	0 - 5%
- ocean energy	0%	0 - 5%	0 - 5%
Heat	PJ		
Heat demand	9809	Increase by 1 to 1.5	Increase by 1 to 1.5
Share renewables	70,0%	60 - 70%	70 - 80%
- biomass	70,0%	50 - 60%	40 - 50%
- solar	0,0%	5 - 10%	15 - 20%
- geothermal	0,0%	0 - 5%	0 - 5%
Transportation	PJ		
Transport energy demand	1457	Increase by 2 to 2.5	Increase by 3 to 3.5
Share biofuels	0,00%	5 - 10%	15 - 20%

Indonesia

	2004	2030	2050
Electricity	TWh		
Electricity generation	121	Increase by 2 to 2.5	Increase by 3.5 to 4
Share renewables	13,9%	50 - 60%	60 - 70%
- hydro	8,0%	10 - 15%	10 - 15%
- wind	0,0%	10 - 15%	10 - 15%
- PV	0,0%	0 - 5%	5 - 10%
- CSP	0%	0 - 5%	5 - 10%
- biomass	0,3%	10 - 15%	10 - 15%
- geothermal	5,5%	10 - 15%	10 - 15%
- ocean energy	0%	0 - 5%	0 - 5%
Heat	PJ		
Heat demand	2949	Increase by 1 to 1.5	Increase by 1 to 1.5
Share renewables	53,1%	70 - 80%	80 - 90%
- biomass	53,1%	60 - 70%	60 - 70%
- solar	0,0%	5 - 10%	5 - 10%
- geothermal	0,0%	0 - 5%	5 - 10%
Transportation	PJ		
Transport energy demand	1162	Increase by 2 to 2.5	Increase by 3 to 3.5
Share biofuels	0,0%	10 - 15%	20 - 25%

Italy

	2004	2030	2050
Electricity	TWh		
Electricity generation	293	Increase by 1 to 1.5	Increase by 1 to 1.5
Share renewables	21,9%	30 - 40%	60 - 70%
- hydro	13,5%	10 - 15%	10 - 15%
- wind	0,630%	5 - 10%	10 - 15%
- PV	0,010%	0 - 5%	0 - 5%
- CSP	0%	0 - 5%	15 - 20%
- biomass	5,9%	5 - 10%	10 - 15%
- geothermal	1,9%	0 - 5%	0 - 5%
- ocean energy	0%	0 - 5%	0 - 5%
Heat	PJ		
Heat demand	2501	Decrease by 0.9 to 1	Decrease by 0.8 to 0.9
Share renewables	4,5%	30 - 40%	50 - 60%
- biomass	4,2%	20 - 25%	25 - 30%
- solar	0,03%	5 - 10%	10 - 15%
- geothermal	0,32%	5 - 10%	10 - 15%
Transportation	PJ		
Transport energy demand	1880	Increase by 1 to 1.5	Increase by 1 to 1.5
Share biofuels	0,42%	5 - 10%	5 - 10%

Iran

	2004	2030	2050
Electricity	TWh		
Electricity generation	164	Increase by 1.5 to 2	Increase by 2.0 to 2.5
Share renewables	6,5%	25 - 30%	60 - 70%
- hydro	6,5%	10 - 15%	0 - 5%
- wind	0,0%	0 - 5%	0 - 5%
- PV	0,0%	0 - 5%	0 - 5%
- CSP	0%	10 - 15%	30 - 40%
- biomass	0,0%	0 - 5%	5 - 10%
- geothermal	0,0%	0 - 5%	0 - 5%
- ocean energy	0%	0 - 5%	0 - 5%
Heat	PJ		
Heat demand	2190	Increase by 1.5 to 2	Increase by 1.5 to 2
Share renewables	0,8%	15 - 20%	60 - 70%
- biomass	0,8%	0 - 5%	0 - 5%
- solar	0,0%	15 - 20%	50 - 60%
- geothermal	0,0%	0 - 5%	5 - 10%
Transportation	PJ		
Transport energy demand	1350	Increase by 1 to 1.5	Increase by 1 to 1.5
Share biofuels	0,0%	0 - 5%	0 - 5%

Japan

	2004	2030	2050
Electricity	TWh		
Electricity generation	1068	Increase by 1 to 1.5	Decrease by 0.5 to 1
Share renewables	11,0%	20 - 25%	40 - 50%
- hydro	8,8%	5 - 10%	10 - 15%
- wind	0,123%	0 - 5%	5 - 10%
- PV	0,0002%	0 - 5%	10 - 15%
- CSP	0%	0 - 5%	0 - 5%
- biomass	1,7%	0 - 5%	5 - 10%
- geothermal	0,32%	0 - 5%	0 - 5%
- ocean Energy	0%	0 - 5%	0 - 5%
Heat	PJ		
Heat demand	4161	Increase by 1 to 1.5	Decrease by 0.9 to 1
Share renewables	2,9%	20 - 25%	40 - 50%
- biomass	2,1%	5 - 10%	5 - 10%
- solar	0,58%	10 - 15%	20 - 25%
- geothermal	0,22%	5 - 10%	10 - 15%
Transportation	PJ		
Transport energy demand	3940	Decrease by 0.5 to 1	Decrease by > 0.5
Share biofuels	0,0%	10 - 15%	20 - 25%

Mexico

	2004	2030	2050
Electricity	TWh		
Electricity generation	224	Decrease by 0.5 to 1	Increase by 1 to 1.5
Share renewables	15,3%	40 - 50%	60 - 70%
- hydro	11,2%	10 - 15%	10 - 15%
- wind	0,007%	10 - 15%	15 - 20%
- PV	0,0156%	0 - 5%	5 - 10%
- CSP	0%	0 - 5%	5 - 10%
- biomass	1,1%	5 - 10%	5 - 10%
- geothermal	2,93%	0 - 5%	5 - 10%
- ocean Energy	0%	0 - 5%	0 - 5%
Heat	PJ		
Heat demand	1328	Decrease by 0.9 to 1	Decrease by 0.9 to 1
Share renewables	18,8%	40 - 50%	60 - 70%
- biomass	18,6%	25 - 30%	40 - 50%
- solar	0,23%	5 - 10%	10 - 15%
- geothermal	0,0%	0 - 5%	5 - 10%
Transportation	PJ		
Transport energy demand	1890	Increase by 1 to 1.5	Increase by 1 to 1.5
Share biofuels	0,0%	15 - 20%	30 - 40%

Nigeria

	2004	2030	2050
Electricity	TWh		
Electricity generation	20	Increase by 2 to 2.5	Increase by 5 to 6
Share renewables	34,2%	40 - 50%	40 - 50%
- hydro	34,2%	20 - 25%	5 - 10%
- wind	0%	5 - 10%	5 - 10%
- PV	0%	0 - 5%	0 - 5%
- CSP	0%	5 - 10%	15 - 20%
- biomass	0%	5 - 10%	5 - 10%
- geothermal	0%	0 - 5%	0 - 5%
- ocean energy	0%	0 - 5%	0 - 5%
Heat	PJ		
Heat demand	2722	Increase by 1 to 1.5	Increase by 1.5 to 2
Share renewables	97,5%	80 - 90%	80 - 90%
- biomass	97,5%	70 - 80%	40 - 50%
- solar	0%	5 - 10%	20 - 25%
- geothermal	0%	0 - 5%	0 - 5%
Transportation	PJ		
Transport energy demand	359	Increase by 1.5 to 2	Increase by 2.5 to 3
Share biofuels	0,0%	0 - 5%	0 - 5%

Poland

	2004	2030	2050
Electricity	TWh		
Electricity generation	152	Increase by 1 to 1.5	Increase by 1 to 1.5
Share renewables	2,2%	40 - 50%	60 - 70%
- hydro	1,4%	0 - 5%	20 - 25%
- wind	0%	10 - 15%	20 - 25%
- PV	0%	0 - 5%	0 - 5%
- CSP	0%	0 - 5%	0 - 5%
- biomass	1%	25 - 30%	30 - 40%
- geothermal	0%	0 - 5%	0 - 5%
- ocean energy	0%	0 - 5%	0 - 5%
Heat	PJ		
Heat demand	1239	Decrease by 0.5 to 1	Decrease by 0.5 to 1
Share renewables	11,8%	40 - 50%	60 - 70%
- biomass	11,8%	30 - 40%	40 - 50%
- solar	0%	0 - 5%	5 - 10%
- geothermal	0%	0 - 5%	5 - 10%
Transportation	PJ		
Transport energy demand	492	Increase by 1 to 1.5	Increase by 1 to 1.5
Share biofuels	0,12%	15 - 20%	30 - 40%

Russia

	2004	2030	2050
Electricity	TWh		
Electricity generation	932	Increase by 1 to 1.5	Increase by 1.5 to 2
Share renewables	19,1%	50 - 60%	50 - 60%
- hydro	18,9%	15 - 20%	5 - 10%
- wind	0,001%	0 - 5%	5 - 10%
- PV	0%	0 - 5%	0 - 5%
- CSP	0%	0 - 5%	0 - 5%
- biomass	0,2%	20 - 25%	25 - 30%
- geothermal	0,04%	0 - 5%	5 - 10%
- ocean energy	0%	0 - 5%	0 - 5%
Heat	PJ		
Heat demand	10496	Increase by 1 to 1.5	Increase by 1 to 1.5
Share renewables	1,7%	40 - 50%	60 - 70%
- biomass	1,7%	20 - 25%	30 - 40%
- solar	0%	5 - 10%	15 - 20%
- geothermal	0%	5 - 10%	10 - 15%
Transportation	PJ		
Transport energy demand	3977	Increase by 1 to 1.5	Increase by 1.5 to 2
Share biofuels	0,0%	5 - 10%	15 - 20%

South Africa

	2004	2030	2050
Electricity	TWh		
Electricity generation	240	Increase by 1 to 1.5	Increase by 1.5 to 2
Share renewables	1,3%	30 - 40%	70 - 80%
- hydro	0,9%	0 - 5%	15 - 20%
- wind	0,013%	10 - 15%	15 - 20%
- PV	0,009%	0 - 5%	10 - 15%
- CSP	0%	10 - 15%	30 - 40%
- biomass	0,1%	0 - 5%	0 - 5%
- geothermal	0%	0 - 5%	0 - 5%
- ocean energy	0%	0 - 5%	5 - 10%
Heat	PJ		
Heat demand	989	Increase by 1 to 1.5	Increase by 1.5 to 2
Share renewables	33,2%	50 - 60%	60 - 70%
- biomass	33,2%	40 - 50%	30 - 40 %
- solar	0,0%	10 - 15%	25 - 30 %
- geothermal	0,0%	0 - 5%	5 - 10%
Transportation	PJ		
Transport energy demand	643	Increase by 1.5 to 2	Increase by 2.5 to 3
Share biofuels	0,0%	5 - 10%	10 - 15%

South Korea

	2004	2030	2050
Electricity	TWh		
Electricity generation	366	Increase by 1 to 1.5	Increase by 1 to 1.5
Share renewables	1,3%	25 - 30%	40 - 50%
- hydro	1,2%	0 - 5%	0 - 5%
- wind	0,013%	10 - 15%	15 - 20%
- PV	0,003%	0 - 5%	5 - 10%
- CSP	0%	0 - 5%	10 - 15%
- biomass	0,1%	0 - 5%	0 - 5%
- geothermal	0,0000003%	0 - 5%	5 - 10%
- ocean energy	0%	0 - 5%	0 - 5%
Heat	PJ		
Heat demand	1565	Increase by 1 to 1.5	Increase by 1 to 1.5
Share renewables	3,7%	30 - 40%	60 - 70%
- biomass	3,6%	10 - 15%	10 - 15%
- solar	0,08%	5 - 10%	25 - 30%
- geothermal	0,000005%	10 - 15%	20 - 25%
Transportation	PJ		
Transport energy demand	1434	Increase by 1 to 1.5	Increase by 1 to 1.5
Share biofuels	0,02%	0 - 5%	0 - 5%

Spain

	2004	2030	2050
Electricity	TWh		
Electricity generation	275	Increase by 1 to 1.5	Increase by 1 to 1.5
Share renewables	19,6%	40 - 50%	70 - 80%
- hydro	11,5%	10 - 15%	10 - 15%
- wind	5,7%	15 - 20%	15 - 20%
- PV	0,020%	0 - 5%	0 - 5%
- CSP	0%	5 - 10%	20 - 25%
- biomass	2,4%	10 - 15%	10 - 15%
- geothermal	0%	0 - 5%	0 - 5%
- ocean energy	0%	0 - 5%	0 - 5%
Heat	PJ		
Heat demand	1337	Decrease by 0.9 to 1	Decrease by 0.8 to 0.9
Share renewables	11,1%	40 - 50%	60 - 70%
- biomass	10,9%	25 - 30%	30 - 40%
- solar	0,16%	5 - 10%	20 - 25%
- geothermal	0,02%	0 - 5%	10 - 15%
Transportation	PJ		
Transport energy demand	1637	Increase by 1 to 1.5	Increase by 1 to 1.5
Share biofuels	0,53%	15 - 20%	15 - 20%

UK

	2004	2030	2050
Electricity	TWh		
Electricity generation	392	Increase by 1 to 1.5	Increase by 1 to 1.5
Share renewables	3,8%	20 - 25%	50 - 60%
- hydro	1,3%	0 - 5%	30 - 40%
- wind	0,493%	10 - 15%	30 - 40%
- PV	0,001%	0 - 5%	0 - 5%
- CSP	0%	0 - 5%	0 - 5%
- biomass	2,0%	5 - 10%	5 - 10%
- geothermal	0%	0 - 5%	0 - 5%
- ocean energy	0%	0 - 5%	10 - 15%
Heat	PJ		
Heat demand	2559	Decrease by 0.9 to 1	Decrease by 0.8 to 0.9
Share renewables	0,6%	25 - 30%	40 - 50%
- biomass	0,5%	15 - 20%	15 - 20%
- solar	0,04%	5 - 10%	10 - 15%
- geothermal	0%	5 - 10%	10 - 15%
Transportation	PJ		
Transport energy demand	2296	Increase by 1 to 1.5	Increase by 1 to 1.5
Share biofuels	0,03%	5 - 10%	10 - 15%

USA

	2004	2030	2050
Electricity	TWh		
Electricity generation	4047	Increase by 1 to 1.5	Increase by 1 to 1.5
Share renewables	9,5%	40 - 50%	60 - 70%
- hydro	6,9%	10 - 15%	25 - 30%
- wind	0,279%	20 - 25%	25 - 30%
- PV	0,0%	0 - 5%	5 - 10%
- CSP	0%	0 - 5%	5 - 10%
- biomass	1,9%	5 - 10%	5 - 10%
- geothermal	0%	0 - 5%	0 - 5%
- ocean energy	0%	0 - 5%	0 - 5%
Heat	PJ		
Heat demand	19618	Increase by 1 to 1.5	Decrease by 0.9 to 1
Share renewables	8,4%	40 - 50%	60 - 70%
- biomass	7,9%	25 - 30%	40 - 50%
- solar	0,28%	5 - 10%	10 - 15%
- geothermal	0%	0 - 5%	10 - 15%
Transportation	PJ		
Transport energy demand	23103	Increase by 1 to 1.5	Increase by 1 to 1.5
Share biofuels	1,23%	15 - 20%	30 - 40%