# *Potentials and prospects for renewable energies at global scale*

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## Abstract

*Renewable energies (RE)* represent a cornerstone to steer our energy system in the direction of sustainability and supply security. Generating electricity, heat or biofuels from renewable energy sources has become a high priority in the energy policy strategies at national level as well as at a global scale. Challenging goals for these 'new' supply options to meet our energy demands have been set, e.g. at European level by the commitment of meeting 20% of the overall energy demand from renewable energy sources by 2020.

A broad set of different RE technologies and resources exist today. Obviously, for a comprehensive investigation of the future RE development it is of crucial importance to provide a detailed investigation of the country- or region-specific situation – e.g. with respect to the potential of the certain RE's in general as well as the part that can be realised in the near future.

It is the core objective of this paper to fulfil above mentioned constraints, aiming to present an overview on the RE potentials and prospects globally – but based on region- and / or country-specific assessments of the resource conditions, the overall energy system boundaries and the related energy policy framework. Thereby, a topical focus is put on both the near to mid future up to 2020 as well as the long-term perspective, indicating besides theoretical and technical potentials also the realisable mid- and long-term potentials referring to the time-horizon between 2030 and 2050 and prospects for the various renewable energy options. Future prospects are discussed by means of analysing energy policy scenarios as conducted for the International Energy Agency (IEA)'s "World Energy Outlook"-series. In this context, emphasis is given on the illustration of the possible contribution of renewable energies to power supply.

Keywords: Renewable Energies, Potentials, Prospects.

# 1 Introduction

*Renewable energies (RE)* represent a cornerstone to steer our energy system in the direction of sustainability and supply security. Generating electricity, heat or biofuels from renewable energy sources has become a high priority in the energy policy strategies at national level as well as at a global scale. Challenging goals for these 'new' supply options to meet our energy demands have been set, e.g. at European level by the commitment of meeting 20% of the overall energy demand from renewable energy sources by 2020.

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As starting point, the applied method of approach is discussed in a subsequent chapter. This comprises a concise discussion of the overall approach and an explanation of the applied terminology. Next, chapter 3 illustrates the derived data on the various potentials for the individual RE options. Then, corresponding future prospects are discussed in chapter 4 by analysing energy policy scenarios on their resulting future RE deployment. These scenarios represent the outcomes of modelling work conducted for the International Energy Agency (IEA)'s "World Energy Outlook"-series. Finally, conclusions end this concise review.

# 2 Method of approach

## 2.1 Assessment of RE potentials

Mid-term and long-term potentials and prospects of renewable energies as presented in this paper build to a large extent on a series of studies as conducted by the authors themselves. In contrast, the global theoretical and technical potentials are based on an in-depth literature survey.

From a historical perspective the starting point for the assessment of realisable mid-term potentials was geographically the European Union, where corresponding data was derived for all Member States initially in 2001 based on a detailed literature survey and a development of an overall methodology with respect to the assessment of specific resource conditions of several RE options. In the following, within the framework of the study "Analysis of the Renewable Energy Sources' evolution up to 2020 (FORRES 2020)" (see Ragwitz et al., 2005) comprehensive revisions and updates have been undertaken, taking into account reviews of national experts etc.. Consequently, this paper builds directly on these consolidated outcomes as presented in the European Commission's Communication 'The share of renewable energy' (European Commission, 2004). This finally derived data on mid-term potentials for RE fits to the requirements of the model ***Green*-X**[1] – a modelling and analysis tool for the

1 The ***Green*-X** model, an independent computer programme, is the core product developed in the project Green-X in the period 2002 to 2004. Later on, an extended version with regard to the geographical and sectoral coverage for RE was produced. It covers besides all Member States of the European other European countries such as Croatia, Norway or Switzerland. It enables a comparative and quantitative

assessment of energy policy instruments in the field of renewable energy, geographically currently constraint to European countries.

Within the framework of a recent study conducted for the IEA (see Resch et al., 2008) it was envisaged to geographically extend this survey to other countries, namely the other OECD countries as well as the emerging economies classified as BRICS countries – incl. Brazil, Russia, India, China and South Africa. Thereby, long-term potentials on various RE technologies and the corresponding global RE forecast model **World*RES***[2], served as solid basis for the following steps: Applying a similar bottom-up in-depth assessment of the prospects for renewable energies in the near future for these countries as done for European countries was not feasible due to time and budget constraints. Accordingly, it was aimed to make use of the available data, i.e. the historical record and assessed long-term potentials by RE technology, as well as the corresponding modelling tool **World*RES***. This meant in particular elaborating on the mid-term realisable potentials for the various RE technologies by means of scenario projections, transferring the same level of ambition for RE's to other countries as observed for Europe.

With regard to the individual RE technologies, this potential assessment focuses on the following options for power generation: Biomass, onshore and offshore wind, hydropower, solar energy (where feasible subdivided into solar thermal electricity and photovoltaics), tidal & wave energy, and geothermal electricity.

## 2.2 Prospects for RE technologies

Prospects for RE technologies are presented in this paper at a global level, illustrating the feasible deployment of these technologies by means of scenarios depending on the applied energy policies. These future projections as published in the latest IEA "World Energy Outlook 2007" (IEA, 2007) were conducted with the above discussed model **World*RES***. Two differing cases will be discussed which aim to illustrate the feasible RE deployment exemplarily for the electricity sector: A *reference* scenario, illustrating a conservative view of the future RE deployment based on the currently applied energy policy support and the corresponding observed framework conditions that often comprise several deficits for an accelerated RE deployment. In contrast to this, an *alternative policy* scenario aims to indicate the feasible RE deployment if support measures as currently in the pipeline of political decision making will become effective. This also comprises an improvement with regard to pending non-economic obstacles.

# 3 The potential for renewable energies at global scale

## 3.1 Classification of potential categories

The possible use of RE depends in particular on the available resources and the associated costs. In this context, the term "available resources" or RE potential has to be clarified. In literature potentials of various energy resources or technologies are heavily discussed. However, often no common terminology is applied. In order to contribute to the comprehension of the derived data, we start with an introduction on the applied terminology:

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analysis of the future deployment of RE in all energy sectors (i.e. electricity, (grid-connected and non-grid) heat and transport) based on applied energy policy strategies in a dynamic context. For details regarding the project or the model Green-X we refer to www.green-x.at.

2 The projections of renewable energies of last year's "World Energy Outlook 2007" (IEA, 2007) were derived in the separate model **World*RES***, allowing assessments of the future deployment of renewable energies and the investment needs related to such deployment. This model has been developed for this purpose by the Energy Economics Group (EEG) at Vienna University of Technology in cooperation with Wiener Zentrum für Energie, Umwelt und Klima (WZE). This builds on previous work as done in a fruitful cooperation in the context of IEA's last years world energy outlook series.

- *Theoretical potential*: For deriving the theoretical potential general physical parameters have to be taken into account (e.g. based on the determination of the energy flow resulting from a certain energy resource within the investigated region). It represents the upper limit of what can be produced from a certain energy resource from a theoretical point-of-view – of course, based on current scientific knowledge;
- *Technical potential*: If technical boundary conditions (i.e. efficiencies of conversion technologies, overall technical limitations as e.g. the available land area to install wind turbines) are considered the technical potential can be derived. For most resources the technical potential must be seen in a dynamic context – e.g. with increased R&D conversion technologies might be improved and, hence, the technical potential would increase;
- *Realisable potential*: The realisable potential represents the maximal achievable potential assuming that all existing barriers can be overcome and all driving forces are active. Thereby, general parameters as e.g. market growth rates, planning constraints are taken into account. It is important to mention that this potential term must be seen in a dynamic context – i.e. the realisable potential has to refer to a certain year;
- *Mid-term potential*: The mid-term potential is equal to the realisable potential for the year 2020.

Figure 1 shows the general concept of the realisable mid-term potential up to 2020, the technical and the theoretical potential in a graphical way.

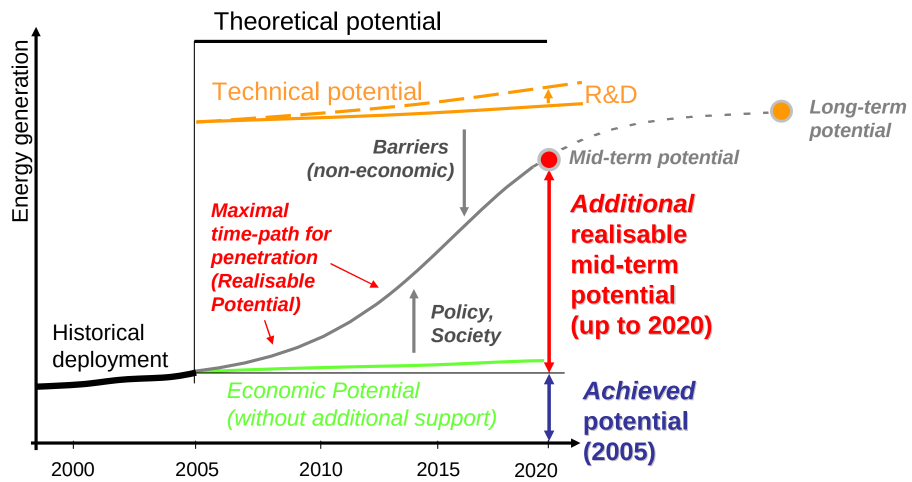


*Figure 1 Methodology for the definition of potentials*

## 3.2 Literature review: Theoretical and technical potentials for RE

The global potential for renewable energies as an indication of long term availability of the resource can be defined as a *theoretical potential* (e.g. theoretical maximums) which is compared to what is known as resources for other types of fuels. The theoretical potential, as listed in Table 1 and graphically illustrated in Figure 2 for various renewable energy sources at global scale, when demanded for energy purposes, needs to be analyzed taking into account appropriate technological possibilities in order to exploit the resources available. This is then named as the *technical potential* (see definitions given above) and can be used in a similar fashion as the concept of energy resources, and e.g. realisable potentials by 2020 as the concept of energy reserves. The fundamental difference, of course, is that renewable potentials represent flows available, in principle, on a sustainable basis indefinitely, whilst fossil energy reserves and resources, although expanding in time, are fundamentally finite quantities. Life cycle analyses remain important, because although the energy flows are sustainable they still require materials like concrete and copper and the commitment of land and other resources.

*Table 1* *Current use (2004) as well as technical and theoretical potentials for various renewable energy sources (in terms of primary energy) at global scale*

*Source: (Johansson et al., 2004; Rogner et al., 2004).*

**Global theoretical and technical potentials** (Unit: EJ)

| **Ressource** | **Current use (2004)** | **Technical potential** | **Theoretical potential** |
|---|---|---|---|
| Biomass energy | 50 | 250 | 2,900 |
| Geothermal energy | 2 | 5,000 | 140,000,000 |
| Hydropower | 10 | 50 | 150 |
| Ocean energy | - | - | 7,400 |
| Solar energy | 0.2 | 1,600 | 3,900,000 |
| Wind energy | 0.2 | 600 | 6000 |
| **Total** | **62.4** | **7,500** | **143,916,450** |

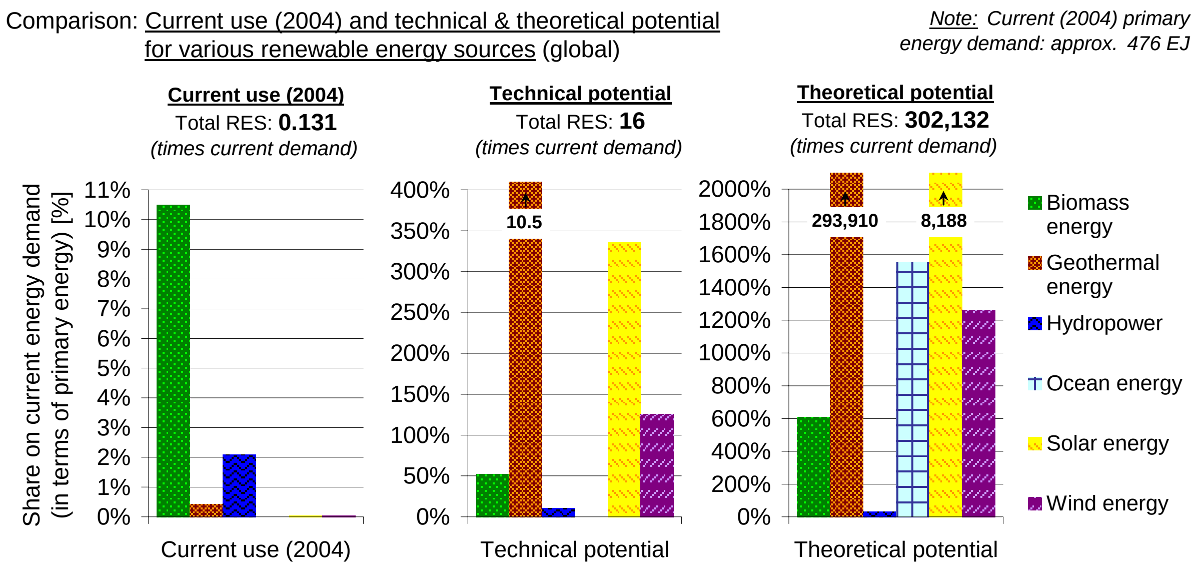


*Figure 2* *Current use (2004) as well as technical and theoretical potentials for various renewable energy sources (in terms of primary energy – compared to current energy demand) at global scale*

*Source: (Johansson et al., 2004; Rogner et al., 2004).*

Both Table 1 and Figure 2 provide a depiction of the current use (2004) as well as technical and theoretical potentials for various renewable energy sources in terms of primary energy at global scale according to (Johansson et al., 2004; Rogner et al., 2004). Thereby, Table 1 lists the data in absolute terms, whilst Figure 2 offers an expression in relative terms – i.e. by illustrating the resource potentials in comparison to current (2004) gross energy consumption. From this depiction it is getting apparent that renewable energy sources are large enough to provide several times the worldwide current primary energy needs, even when considering conceivable future growth of that. As illustrated in Figure 2, from a theoretical perspective RES could contribute to meet more than 300 thousand times the current demand at global scale, by considering technical constraints still the potential remains 16 times higher than current needs, but at present RES cover approximately only 13.1%. Observing the current RES contribution the high share of biomass and the comparatively low contribution of hydropower or wind energy are noticeable. Besides, hydropower also offers a low technical potential by way of comparison to other RES. In this context, it is important to emphasise that RES are accounted in both current use and technical potential according to the physical energy content method as nowadays commonly applied in energy statistics (e.g. by the IEA or EUROSTAT). Thereby, in the case of hydropower, wind or solar power, as electricity is the primary energy form selected, the primary energy equivalent is considered as the physical energy content of the electricity generated in the plant, assuming thus an efficiency of 100%. Applying alternatively the partial substitution method, the contribution of these RES would increase by a factor of about 2½, as the conventional fuels substituted are then taken into account.

Three general categories of *biomass energy* resources are used as energy fuels including: forestry biomass, agricultural biomass and wastes. Biomass wastes originate from farm crops, animals, forestry wastes, wood processing by-products, and municipal waste and sewage. The potential of biomass energy crops and plantations depends on the land area available, the harvestable yield, its energy content and the conversion efficiency. Theoretical biomass energy potentials as illustrated in Figure 2 or Table 1 amount to 2,900 EJ corresponding to 6 time current gross energy consumption. Especially the technical potential of energy crops and plantations is difficult to estimate as land-use patterns have a very dynamic character and as there is competition between crops for different uses, such as food, material or energy. Based on land-use capacity studies, estimates of the land available for tropical plantations range between 580 and 620 million ha (Rogner et al., 2004). Estimates of technical potentials for bioenergy are likely to be higher than 250 EJ which correspond to slightly more than 50% of current gross demand.

*Geothermal energy* offers the highest global potential among all RES from both a theoretical and a technical viewpoint worldwide as shown in Table 1 or Figure 2. The theoretical potential amounts to 140 million EJ, and a much more limited technical potential of 5.000 EJ which still is more than ten times higher as current gross energy consumption. There are four types of geothermal occurrences: hydrothermal sources, hot dry rock, magma, and geo-pressurized sources. In general it is notable that geothermal energy is widely and almost evenly dispersed across the globe. High-temperature fields used for conventional power production (with temperatures above 150 degrees Celsius) are largely confined to areas with young volcanism, seismic, and magmatic activity and geographic conditions will limit or expand its technical potential. Low-temperature resources suitable for direct use can be found in most countries. However, the technical potential given in Figure 2 is significantly reduced when only considering the easily accessible layers of the crust and a limitation of the drilling depth. The long-term technical potential based on these limitations could be greater than 21 EJ per year, especially if deep drilling costs can be reduced, as these represent a major deficit for this energy source. Thus, the technological availability rather than the availability of geothermal resources will determine its future share (Rogner et al., 2004, World Energy Council, 1994; Palmerini, 1993; Sørensen, 1979).

*Hydropower* is the form of mechanical conversion to produce energy from water falling from high to low altitudes. The geographical conditions of the regions as well as detailed information on water conditions, such as available head, flow volume per unit of time among others, play a direct and important role in assessing the potential of hydropower. According to assessments in this respect, hydropower has a theoretical potential estimated at 150 EJ per year, whilst the technical potential, taking into account technical, structural, legal and ecological restrictions, amounts to 50 EJ or a third of the theoretical potential. Dynamic changes in this potential are possible as rainfall variations across world regions could increase or decrease the yearly power output. In this respect, it is expected that climate change influences the hydropower potentials on the long term (Lehner et al., 2005).

As applicable in Table 1, *solar energy* has an immense theoretical potential over almost 4 million EJ reflecting the vast areas intercepting solar radiation across the globe. However, large scale availability of solar energy depends greatly on the regions geographical position as well as weather conditions and primarily on the assumptions regarding land availability. Additionally, the corresponding potentials in terms of final energy will depend on the efficiencies of the solar technologies applied.

The theoretical potential of *wind energy* as illustrated in Table 1 amounts to 6,000 EJ (or more than 12 times current energy needs), what seems to be enormously high when compared to its current use. A technical potential is estimated to be 10 percent of the theoretical one. The ultimate potential of wind-generated electricity worldwide could indeed be very large: Other assessments state figures of up to 50 times current global final electricity consumption (Grubb and Meyer, 1993; Rogner et al., 2004; Häfele et al., 1981). Height limitations of wind converters, coast distance of offshore sites, insufficient wind velocities and land use, and the feasible grid integration all limit the realisable potential of this promising technology option.

*Ocean energy* includes thermal energy, waves, tides, and the sea-freshwater interfaces as rivers flow into oceans. The low temperature gradients and low wave heights lead to an annual flow up to 7,400

EJ (equalling more than 15 times current energy demand). The technical potential is estimated to be about 10 to 100 times smaller (see e.g. Rogner et al., 2004; Sørensen, 1979). The ocean, tidal and wave energy resources are rather diffuse posing a very difficult challenge for commercial use and similar to geothermal energy technology advancements will determine its use in the future.

## 3.3 Realisable mid- and long-term potentials for RE technologies in the electricity sector

As illustrated in the previous section, the theoretical and technical potentials are huge compared to the status quo of energy consumption in general or the current deployment of RES respectively. The question remains open how much of these potentials can be mobilised and integrated into our energy system in the forthcoming years up to a time horizon of e.g. 2050. Accordingly, this section is dedicated to provide clarification in this respect by illustrating the future potential for renewable energies in the mid- to long-term. More precisely, it offers an overview on the realisable mid-term (up to 2020) as well as the corresponding long-term potentials in the time horizon 2030 to 2050 for a broad set of RE technologies. For practical reasons this exercise is however constraint to the electricity sector, and the selected technology basket comprises all technology options which are in an early or enhanced stage of market deployment.

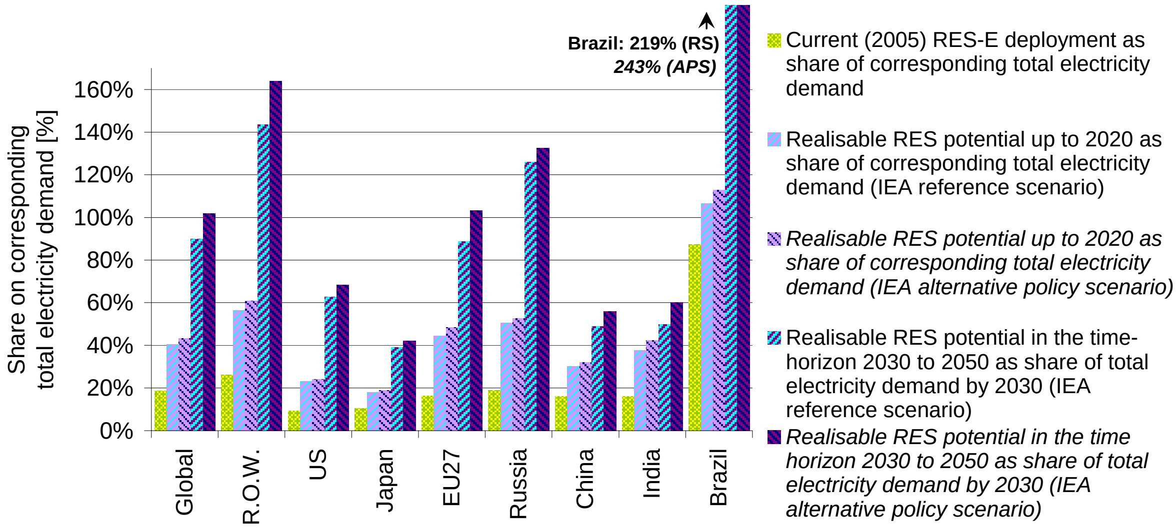


*Figure 3* *Mid- and long-term potential for RES-E (by country / global) expressed as share on corresponding total electricity demand*

*Note: R.O.W. … Rest of the World*

*Source: Own investigations.*

Figure 3 (above) to Figure 5 (below) aim to illustrate both the current (2005) deployment as well as the mid- and long-term potentials for electricity from renewable energy sources (RES-E) for selected countries / regions[3] as well as at global scale. Figure 3 starts with showing the possible contribution of RES-E to electricity supply in relative terms, by indicating the current deployment and future potentials as share of corresponding electricity demands.[4] Thereby, in case of both mid- and long-term

3 Thereby, all 27 EU countries are grouped together to one region, covering the whole European Union as of 2007. For a detailed discussion of the mid-term potentials for renewable energies in the European Union we refer to (Resch et al., 2006) and (Ragwitz et al., 2005).

4 Illustrating the potentials in relative terms, expressed as share of demand, appears suitable for a comparison of the country-specific situation.

potentials two different demand projections are applied in order to illustrate the impact of accompanying demand side measures on the feasible future RES-E contribution. Next to this, Figure 4 (below) offers a breakdown of the current (2005) RES-E deployment as well as of the total mid- and long-term potential for RES-E by country / region. In order to provide more insights to the country-specific resource conditions, Figure 5 indicates the shares of the individual RES-E options again in current (2005) overall RES-E deployment (left) as well as in the total mid- (middle) and long-term (right) RES-E potential for each country / region.

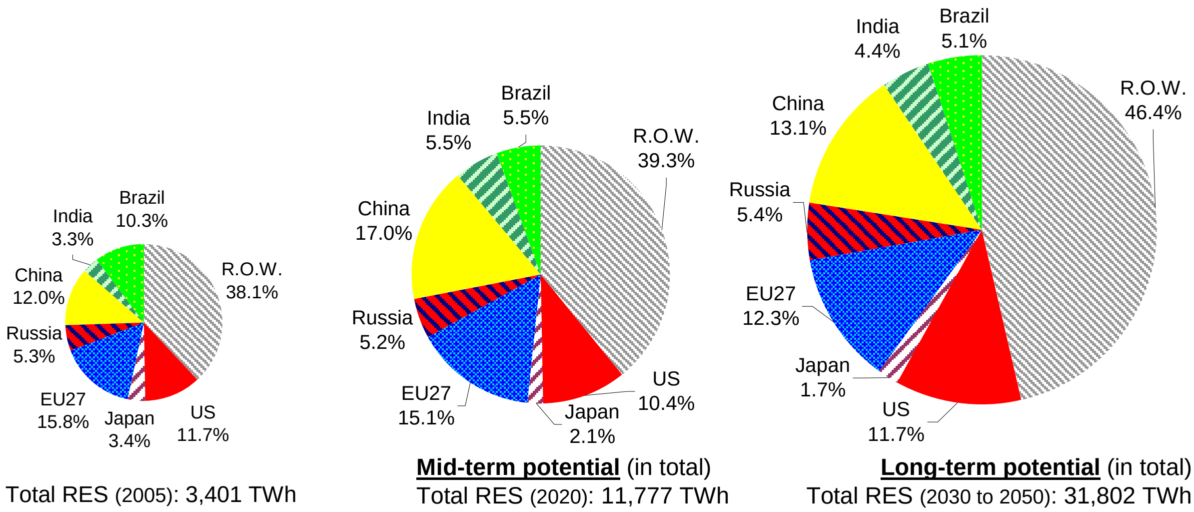


*Figure 4* *Breakdown of the current (2005) RES-E deployment as well as of the total mid- (2020) and long-term (2030 to 2050) potential for RES-E by country / region*

*Source: Own investigations.*

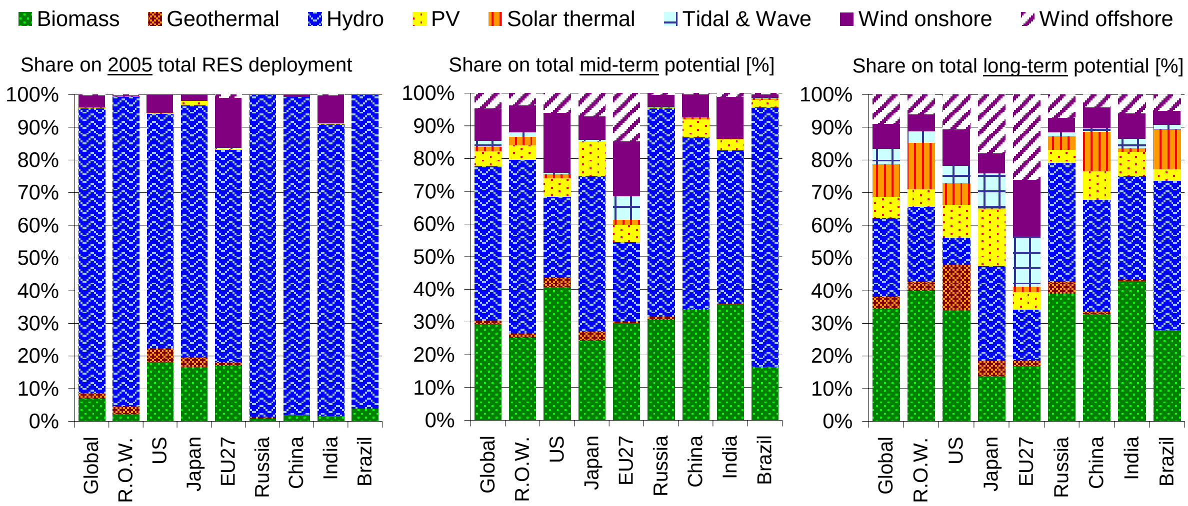


*Figure 5* *Technology-specific breakdown of the current (2005) RES-E deployment as well as of the total mid-term (2020) and long-term (2030 to 2050) potential for RES-E (by country / region)*

*Source: Own investigations.*

In the following, a closer look on the mid- to long-term potentials for RES-E as illustrated above is taken. Thereby, initially the global picture and country-specific situation is discussed, followed by technology-specific observations:

Firstly, it is worth to mention that the derived realisable RES-E potentials aim to illustrate for each technology what can be achieved if effective & efficient RE policies and measures are implemented immediately. Summing up the potentials for individual technologies at country level may indicate radical changes compared to the present situation, especially in the case of long-term potentials – see Figure 3. This emphasises the need for accompanying measures in order to overcome pending barriers in time. However, this indicates also that, even by implementing a proper energy policy mix a certain country may not achieve cumulative RES-E potentials by 2020 or later due to overall budget constraints or limitations arising from the feasible RES-E integration into the overall electricity system.

Ignoring above remarks, as illustrated in Figure 3 a full exploitation of the cumulative realisable RES-E potentials would correspond to achieve more than a doubling of the share of RES-E in total electricity demand in the mid future at global scale – i.e. an increase of the demand share from currently (2005) 18.7% up to a range of 41% to 43% by 2020, depending on the future demand development. In the long-term perspective, RES-E may allow to cover all global power needs in case of accompanying energy efficiency activities. In quantitative terms this would mean a tripling of the current RES-E exploitation in the near to mid future, whilst the long-term potentials are nine times higher than current RES-E deployment – see Figure 4. It is notable that the country-specific situation differs largely. Whilst e.g. Brazil already holds a significant RES-E share at present (87% by 2005) which may not simply be increased much in the near to mid future, a high increase appears feasible and adequate for other countries. A closer look on the long-term potentials for RES-E in Brazil indicates that domestic renewable resources would in principle allow meeting twice times the domestic demand. In contrary to Brazil, both the US and Japan are industrialised countries with a low contribution of RES-E to meet their electricity demands at present. The assessed cumulative realisable potentials indicate an increase from currently 9% in 2005 up to 24% by 2020 for the US, which could then rise further up to two thirds of overall consumption in the long term. In Japan renewable resources are less prospering – i.e. an increase from 10.5% in 2005 to less than half of the overall demand appears feasible at the maximum even in the long term. For achieving the EU's recently agreed overall 20% RE target by 2020 as defined in terms of final energy RES-E could contribute a maximum of 60%, corresponding to a share on gross electricity consumption in size of 48% or a tripling of current RES-E deployment.[5] Emerging economies such as China or India faced a huge growth of electricity consumption in the past and it can be expected that this trend will continue up to the near to mid future. In both countries the RES-E share on demand is in size of approx. 16% at present (as of 2005), which can be increased to approx. 32% in China or 42% in India in the mid-term. The domestic long-term RES-E potentials indicate a maximum contribution of RES-E to slightly more than half of overall electricity demand for both countries. As also illustrated with these country observations, renewable resources are unevenly distributed at global scale, which also do not match necessarily with current demands. Achieving a power supply that substantially builds on RES-E requires accompanying activities to tackle this issue.

At global scale as well as in most countries *hydropower* is the largest renewable contributor to meet the electricity needs of today. As indicated in Figure 5, hydropower holds a share of 87% on the total RES-E generation globally at present (as of 2005). Looking at its future potential, it can be expected that it will remain in the leading position at least up to the mid-term. For example it holds a share of 47% on the total global mid-term potential for RES-E – however, 53% of this is already exploited. In absolute terms the largest potentials among the assessed countries are identified for China, followed by Brazil and the EU 27. However, in relative terms it is observable that shares are low in the EU 27 or in the US – where potentials refer mainly to the large hydropower plants as installed in the past.

*Biomass* represents another important option at global scale. Biomass comprising products and residues from forestry and agriculture as well as biowaste refers to 29% of the overall mid-term or 35% of the long-term potential for RES-E. A large share of this – i.e. 93% (mid-term) to 98% (long-term) – is still waiting to be exploited. All countries have some forms of biomass in their resource portfolio. Obviously, large countries such as China or the US possess the highest potentials in absolutes terms. It is noticeable that not only a variety of biomass feedstocks exist, the same refers to the

5 Considering a more balanced approach for achieving the EU's 20% target where renewable energies contribute substantially besides electricity also to heat and transport fuel supply, a RES-E share of 35% on gross electricity demand appears feasible.

corresponding technology options – i.e. from cheap co-firing in conventional power plants on to small-scale CHP plant. An environmentally beneficial use as well as a consideration of possible social impacts is of key importance when striving for a massive market introduction. A delay in introducing sustainability criteria may hinder the diffusion of promising conversion technology options and consequently affects the realisable mid-term potential. Additionally, competition occurs among the usable feedstocks – e.g. with regard to energy crops as needed for biofuel or food production as well or in case of wood as traditionally used for heat supply and material / industrial uses. It is worth to mention that the indicated electricity generation potentials shall be seen as maximum achievable in the electricity sector – which would be reduced largely in the case that ambition is placed also on using biomass for heating and as transport fuel.

Similar to biomass, *wind energy* is characterised by a large future potential waiting to be exploited – i.e. more than 92% of the total wind potential refers to the additional potential as feasible up to 2020. The share of wind energy on the total mid-term RES-E potential is in size of 14% at global scale – which indicates the maturity of this technology. Whilst in Europe also offshore technology is of key importance – at least due to limited suitable onshore sites, in most other parts of the world it can be expected that onshore wind will be of dominance in the near to mid future. In line with country size and feasible resources, the largest mid-term generation potentials can be found in the European Union, the USA, China and India. In the long-term perspective wind energy may contribute substantially more to electricity supply. The limiting factor for wind energy represents the necessary grid integration. This is also reflected in the expressed long-term potentials, which can be classified as low compared to the technically exploitable resources, indicating a conservative view in this respect.

*Solar energy* is a promising future option that lacks behind past expectations. Recently, growing emphasis is given to both *photovoltaics (PV)* and *solar thermal electricity* generation – especially in Europe but also the USA or China, where a massive PV manufacturing industry is currently being built. A share of 4.4% on the cumulative mid-term potentials for RES-E can be expected for PV at global scale in the case of effective and efficient support within each country. Obviously, the long-term potentials for both RES-E options is huge, but similar to wind also PV represents a technology with a fluctuating power output in line with changing weather conditions. A massive market introduction would require tackling the hindrance of grid integration as well.

Besides offshore wind energy also other marine technologies are on the way: However, for *tidal & wave energy* a noticeable deployment is assumed mainly in Europe for the near to mid future.

*Geothermal electricity* is a proven RE option in some countries worldwide (e.g. Iceland, New Zealand, USA, Mexico or Italy). However, neglecting novel technology options such as hot-dry-rock the near to mid-term potential is constraint, limited to favourable hot-temperature geothermal resources, which comprises approx. 1% of the cumulative mid-term potential for RES-E at global scale.

# 4 Prospects for RE technologies in the electricity sector

Finally, prospects for RE technologies are presented in this section at a global level. Thereby, the feasible deployment of these technologies is discussed by means of scenarios depending on the applied energy policies. These future projections as published in the latest IEA “World Energy Outlook 2007” (WEO, 2007) were conducted with the previously discussed model **World*RES***.

Two different cases are presented which show the feasible RE deployment exemplarily for the electricity sector:

- A *reference* scenario, illustrating a conservative view of the future RE deployment based on the currently applied energy policy support and the corresponding observed framework conditions that often comprise several deficits for an accelerated RE deployment.
- In contrast to this, an *alternative policy* scenario aims to indicate the feasible RE deployment if support measures as currently in the pipeline of political decision making will become effective. This also comprises an improvement with regard to pending non-economic obstacles.

Therefore, the following part focuses on the future deployment of RES-E generation for selected countries / regions, at global scale as well as on technology level.

Figure 6 (below) provides a comparison of the future RES-E deployment up to 2030 in absolute terms by country / region. The left hand figure represents the deployment in the *reference scenario* while the right hand figure is based on the *alternative policy scenario*. Within the *reference scenario* the EU27 would maintain its leading role with regard to RES-E at global scale, whereas the contribution of Japan and Russia is comparatively small. Moreover the latter show only small increases within the regarded time period in comparison to other countries where a doubling of RES-E production is expected. On the other hand, the *alternative policy scenario* evolves stronger increases of electricity generation from renewable energy sources, especially in economically emerging regions such as China and India. Remarkable, China would then also take over the global lead by 2025. Comparing both scenarios, at global scale a higher renewable electricity exploitation of 1637 TWh can be observed in the *alternative policy case*.

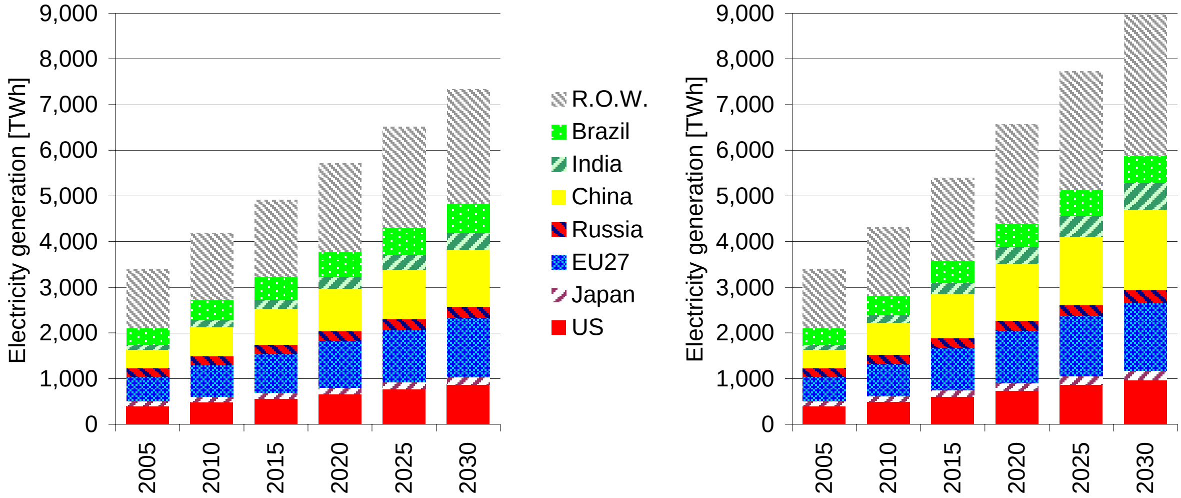


*Figure 6* *Comparison of the future RES-E deployment up to 2030 in absolute terms by country / region for both IEA scenarios – reference case (left) and alternative policy scenario (right)*

*Source: Own investigations and (IEA, 2007).*

Figure 7 (below) shows a comparison of the future RES-E deployment up to 2030 in relative terms, indicating the RES-E share on total electricity generation by country / region. The left hand figure illustrates the deployment in the *reference scenario* while the depiction on the right refers to the *alternative policy scenario*. In the *reference scenario* industrialised countries / regions achieve an increase of the electricity generation from renewable energy sources in relation to its total electricity generation except the economically emerging countries where the RES-E share slightly declines. However, for Brazil a hold of their already high RES-E share is projected. Remarkable is the comparatively strong increase of the EU27 region from currently (2005) 16.4% up to 29.5% in 2030. In comparison, discussing the *alternative policy scenario* all investigated countries / regions show an increasing share of RES-E. Besides the EU27 region with the strongest increase up to 39.0%, also the US and Japan as well as the emerging economies China and India show strong increases of about 10%. At global scale, it can be expected that 28.7% of total electricity will be generated by using RES by 2030, corresponding to an increase from currently (2005) 18.7% by 10% within the assessed period of 25 years.

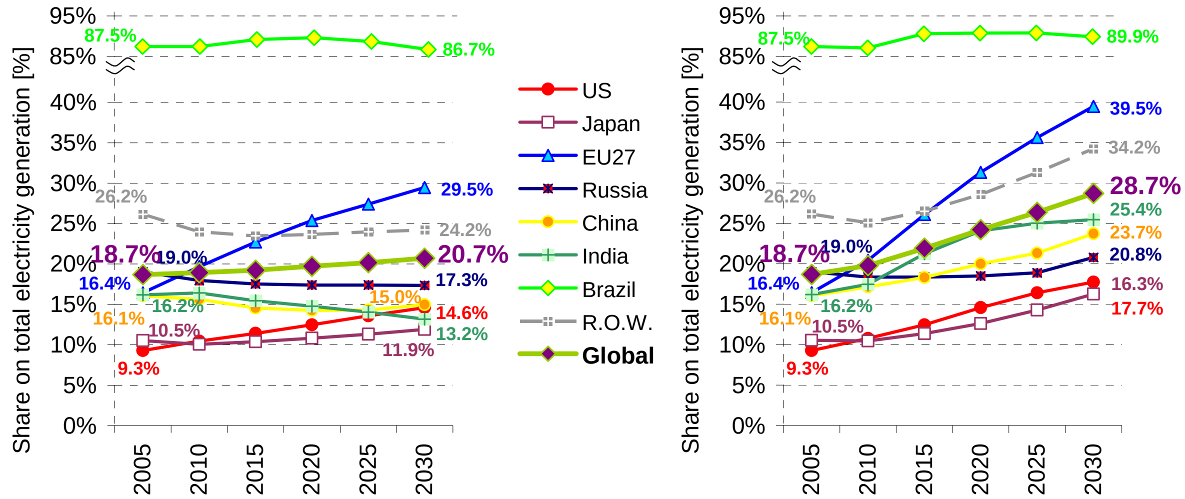


*Figure 7* *Comparison of the future RES-E deployment up to 2030 in relative terms (expressed as share on total electricity generation) by country / region for both IEA scenarios – reference case (left) and alternative policy scenario (right)*

*Source: Own investigations and (IEA, 2007).*

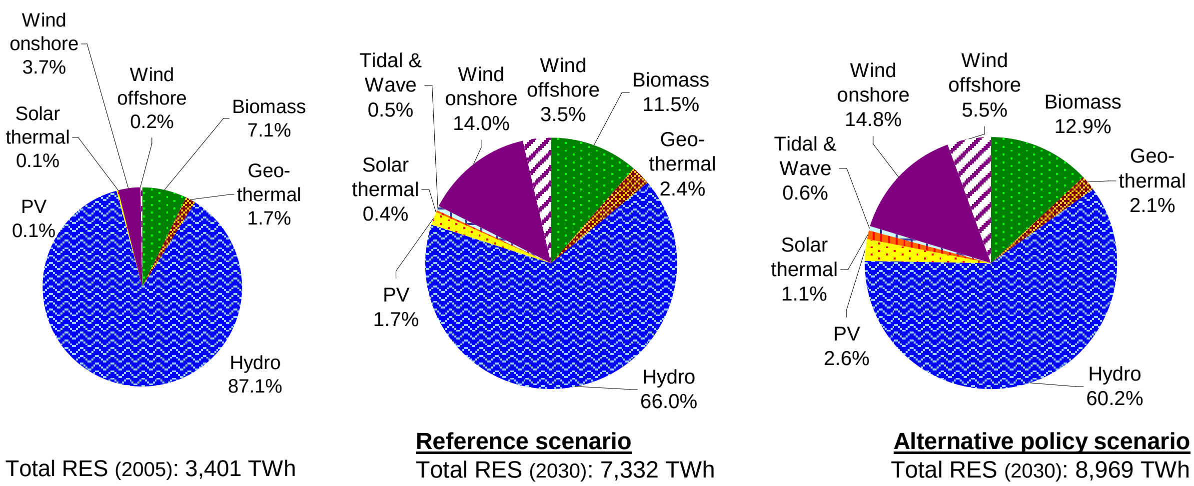


*Figure 8* *Technology-specific breakdown of the current (2005 – left) and of the expected RES-E deployment by 2030 at global scalefor both IEA scenarios – reference case (middle) and alternative policy scenario (right)*

*Source: Own investigations and (IEA, 2007).*

Figure 8 (above) indicates the technology-specific breakdown of the current (2005 – left) and of the expected RES-E deployment by 2030 in the *reference case* (middle) as well as the *alternative policy scenario* on the right hand. Firstly, a strong increase of the total electricity generation by renewable energy sources in absolute terms is notable. As already stated in prior, currently among all RES-E technologies hydropower is strongly dominating the market, whereas wind, biomass and geothermal power only contribute with 12.7% in total to renewable electricity generation. In the *reference scenario* up to 2030 the diversity of RES-E technologies is growing since major shares of the hydro potential are already exploited. Besides hydro power (66.0%), wind onshore (14.0%) as well as biomass (11.5%) and wind offshore (3.5%) will play an important role. Additionally, geothermal, solar thermal and photovoltaics will also contribute to a larger extend compared to the current situation. Considering the *alternative policy scenario*, new renewables will contribute even larger in absolute as well as in relative terms due to the improvements of the support framework for these promising technology options. Although hydropower also deploys larger the share on total RES-E is expected to be smaller than in the reference case (60.2% in 2030). All “new” RES-E except geothermal electricity increase their share on total RES-E by 2030 more substantially compared to the reference case. Thereby, a significant amount of currently novel technology options including offshore wind (5.5%), photovoltaics (2.6%), solar thermal electricity (1.1%) and tidal & wave power (0.6%) is observable.

# 5 Conclusions

Renewable energies sources have been facing a growing importance in the European and global energy markets due to various benefits associated with their use: RE technologies help decreasing import dependency, diversifying sources of production, and contribute to a sustainable development. A broad set of technology options and resources exists today. In this paper an investigation of their future development was undertaken by discussing their potentials and prospects globally with special emphasis on the electricity sector.

As illustrated in section 3.2, the theoretical and technical potentials are huge compared to the status quo of energy consumption in general and the current deployment of RES respectively. From a theoretical perspective RES could contribute to meet more than 300 thousand times the current overall primary energy demand at global scale, by considering technical constraints still the potential remains 16 times higher than current needs, but at present RES cover approximately only 13.1%.

Subsequently, clarification was given on the question how much of these potentials can be mobilised and integrated into our energy system in the forthcoming years up to a time horizon of 2050. Realisable mid-term (up to 2020) and corresponding long-term potentials in the time horizon 2030 to 2050 were presented for a broad set of RE technologies in section 3.3. For practical reasons this exercise was however constraint to the electricity sector, and the selected technology basket comprised all technology options which are currently in an early or enhanced stage of market deployment. The derived realisable RES-E potentials show for each technology what can be achieved if effective & efficient RE policies and measures are implemented immediately. Summing up the potentials for individual technologies at country level partly may indicate radical changes compared to the present situation, especially in the case of long-term potentials. This emphasises the need for accompanying measures in order to overcome pending barriers in time.

A full exploitation of the cumulative realisable RES-E potentials would correspond to achieve more than a doubling of the share of RES-E in total electricity demand in the mid future at global scale – i.e. an increase of the demand share from currently (2005) 18.7% up to a range of 41% to 43% by 2020, depending on the future demand development. In the long-term perspective, RES-E may allow to cover all global power needs in case of accompanying energy efficiency activities. In quantitative terms this would mean a tripling of the current RES-E exploitation in the near to mid future, whilst the long-term potentials are nine times higher than current RES-E deployment. As shown with more thorough country observations, renewable resources are unevenly distributed at global scale, and do not necessarily match with current demands. Achieving a power supply that substantially builds on RES-E requires accompanying activities to tackle this issue.

Finally, prospects for RE technologies at a global level were presented in section 4, illustrating the feasible deployment of these technologies by means of scenarios depending on the applied energy policies. According to IEA’s recent *alternative policy* scenario (as of 2007) it can be expected that 28.7% of total electricity will be generated by using RES by 2030 at global level, corresponding to an increase from currently (2005) 18.7% by 10% within the period of 25 years. This underpins that even if all support measures as currently in the pipeline of political decision making will become effective the realisable mid- and long-term potentials of most promising RE technology options will still not be exploited largely. Combating climate change effectively might however require faster actions worldwide that go far beyond these alternative policies currently in the queue.

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