ENERGYWATCHGROUP

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Renewable Energy Outlook 2030

Energy Watch Group Global Renewable Energy Scenarios

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About Energy Watch Group

Energy policy needs objective information.

The Energy Watch Group is an international network of scientists and parliamentarians. The supporting organization is the Ludwig-Bölkow-Foundation. In this project scientists are working on studies independently of government and company interests concerning

- the shortage of fossil and nuclear energy resources,
- development scenarios for regenerative energy sources

as well as

- strategic deriving from these for a long-term secure energy supply at affordable prices.

The scientists are therefore collecting and analysing not only ecological but above all economical and technological connections. The results of these studies are to be presented not only to experts but also to the politically interested public.

Objective information needs independent financing.

A bigger part of the work in the network is done unsalaried. Furthermore the Energy Watch Group is financed by donations, which go to the Ludwig-Boelkow-Foundation for this purpose.

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Content

Executive Summary

The objective of this study is to present an alternative and - from our point of view - more realistic view of the chances of the future uses of renewable energies in the global energy supply. The scenarios in this study are based on the analysis of the development and market penetration of renewable energy technologies in different regions in the last few decades. The scenarios address the question of how fast renewable technologies might be implemented on a worldwide scale and project the costs this would incur. Many factors, such as technology costs and cost-reduction ratios, investments and varying economic conditions in the world's regions, available potentials, and characteristics of growth have been incorporated in order to fulfil this task.

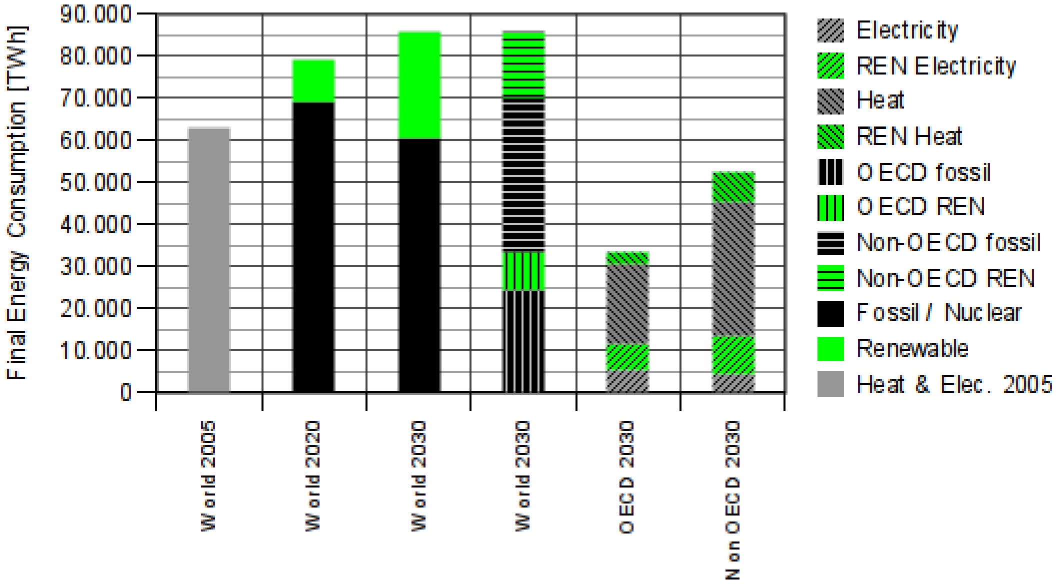
The scenarios describe only two possible developments among a range of prospects, but they represent realistic possibilities that give reason for optimism. The results of both scenarios show that – until 2030 – renewable capacities can be extended by a far greater amount and that it is actually much cheaper than most scientist and laypeople think. The scenarios do explicitly not describe a maximum possible development from the technological perspective but show that much can be achieved with even moderate investments. The scenarios do not pay attention to the further development of Hydropower, except for incorporating the extensions that are planned actually. This is not done to express our disbelief in the existence of additional potentials or to ignore Hydropower, but due to the fact that reliable data about sustainable Hydropower potentials were not available. Consequently, the figures in this study show how much can be achieved, even if Hydropower remains on today's levels more or less. Higher investments into single technologies,e.g. Hydropower or Biomass, or in general than assumed in the "REO 2030" scenarios will result in higher generating capacities by 2030.

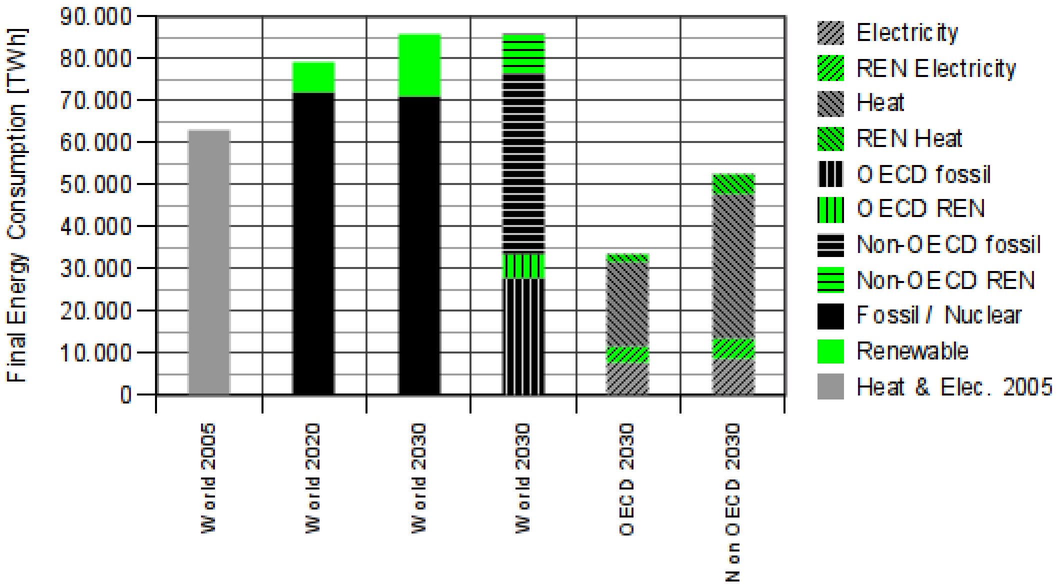
On the global scale, scenario results for 2030 show a 29% renewable supply of the heat and electricity (final energy demand) in the "High Variant". According to the "Low Variant", over 17% of the final electricity and heat demand can be covered by renewable energy technologies.

Presuming strong political support and a barrier-free market entrance, the dominating stimulus for extending the generation capacities of renewable technologies is the amount of money invested. Within the REO scenarios we assume a growing *"willingness to pay"* for a clean, secure, and sustainable energy supply starting with a low amount in 2010. This willingness to pay is expressed as a target level for annual investments per inhabitant (capita) that will be reached by the year 2030. The targeted amounts differ for the various regions of the world (see Table 1). On a global average 124 $€_{2006}$ are to be spent in 2030 per capita in the "High Variant". In the "Low Variant" the target for 2030 is half that amount (62 $€_{2006}$ per capita and year).

This scenario approach requires considering the reduction of technology costs due to the growing market and the capability of industry to learn. To achieve this, cost-progression ratios for each technology, calculated from the total amount of investments into a specific technology and the resulting development of production volumes, are considered in the scenarios.

The scenarios primarily address the development of the electricity capacities, heat supplied by renewable energies is only partially analysed. Fuels are not part of the study.





The first bar shows the final energy demand in 2005 (grey), without breakdown to fossil or renewable sources. Bars 2 an d 3 show the development of final energy demand up to 2030, the renewables contribution (always green) according to the scenarios and the fossil & nuclear contribution (always black or grey). The remaining bars provide more details on the figure for 2030. Bar 4 shows the values for OECD (vertically hatched, black is fossil, green is renewable) and non-OECD (horizontally hatched). Bars 5 and 6 show details for OECD (bar 5) and non-OECD (bar 6), broken down to electricity (hatched lower left to upper right) and heat (hatched upper left to lower right). Again renewewables are green but fossils are grey this time.

Figure 1: Final electricity and heat demand and renewable shares in 2030 in the "High Variant" (upper figure) and the "Low Variant" scenario (lower figure) [EWG; 2008]. Final Energy Demand: [IEA; 2006]

The future energy demand is taken from the “Alternative Policy Scenario” of the IEA's Study ”World Energy Outlook 2006” (WEO 2006).[1]

The OECD region will be able to cover more than 54% of its electricity and more than 13% of heat requirements from renewables in 2030, totalling a final energy share of 27% (low variant: almost 17%). In the non-OECD region, the share of renewables rises to 30% in the “High Variant” (“Low Variant” 18%). Increases due to renewables account for almost 68% in regard to electricity, while renewable heat contributes about 17% of final heat demand (“Low variant”: 36% of electricity and 11% of heat).

The scenarios show that renewable energy technologies have huge potential to help in solving the climate change problem, lowering dependence on fossil fuels, and making it possible to phase out nuclear energies. In both scenarios, the contribution of fossil and nuclear technologies increases until 2020. By that time, energy production by fossil and nuclear fuels exceeds the total final energy demand that existed in 2005. In the “Low-variant scenario”, this figure is only somewhat lower again in 2030. Looking at the “High-variant scenario”, the drop after 2020 is remarkable: in 2030 fossil and nuclear technologies have to contribute less to energy supply than the total level of energy demand in 2005.

World Region	Investment per capita per year in 2030 [€2006/cap*a]		Total investment budgets in 2030 [billion €2006]	
	Low Variant	High Variant	Low Variant	High Variant
OECD Europe	111	223	60	121
OECD North America	110	220	59	118
OECD Pacific	112	224	22	44
Transition Economies	91	180	31	60
China	102	204	149	299
East Asia	41	81	33	66
South Asia	35	71	73	147
Latin America	46	91	26	52
Africa	20	41	30	59
Middle East	101	202	28	55
Global Scale	**62**	**124**	**510**	**1021**

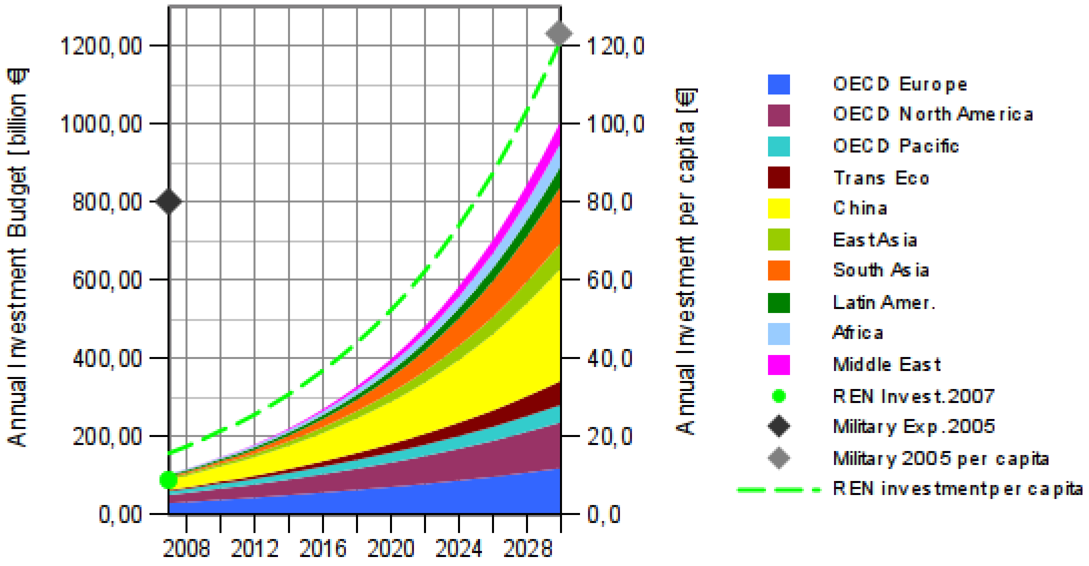
Table 1: Target investment 2030 per capita per year in various regions considered in the scenarios. All regions start with a low amount in 2010. [EWG; 2008]

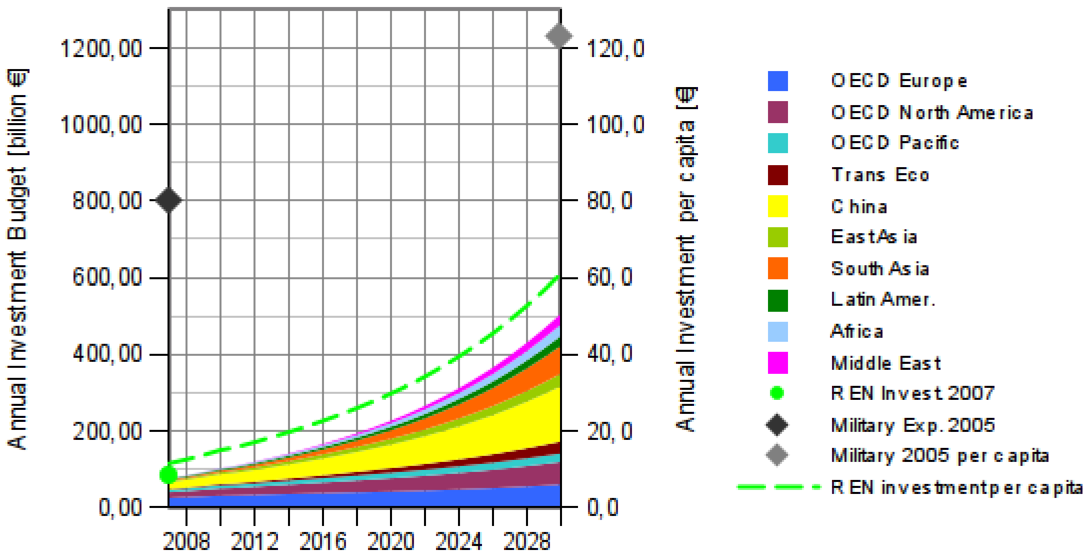
Absolute investments in 2030 are approximately 510 billion $€_{2006}$ in the ”Low Variant Scenario” and about 1,021 billion $€_{2006}$ in the ”High Variant”. The biggest single investor in both scenarios is China, followed by South Asia – both regions having a high percentage of the world population – and OECD Europe, which is less populated but shows considerably higher

1 Although an updated WEO appeared in 2007, the team continued to refer to the WEO 2006 data because differences in the development of energy demand portrayed in the two publications are only marginal. Global primary energy supply (PES) projections in the “Alternative Policy Scenario” differ by about 1.6% when comparing WEO 2006 and WEO 2007.

spendings per inhabitant in 2030. OECD Pacific has the lowest investment figure, behind Africa, the Middle East, and Latin America.

Investment sums of the dimension given here tend to be somewhat abstract and quickly appear to present an insurmountable barrier. To provide a better feeling for what such investment figures really mean with regard to today's real world, Figure 2 compares the renewable investments of this study to the global military expenditures in 2005 [SIPRI; 2006]. Only the ”High Variant” shows renewable per capita investments coming close to the military expenditures of 2005. Another illustrative comparison is the amount of money spent by each German in 2005 for culture-related activities - on the magnitude of 100€ annually [DESTATIS; 2008].





Coloured areas and markers on the left ordinate (Y-axis) show the absolute annual investments, while the dotted line and markers on the right ordinate show annual investments per capita as global average.

Figure 2: Development of investment budgets in the world regions in the "High Variant" (upper figure) and "Low Variant Scenario" (lower figure) [EWG; 2008]. Data on military expenditures: [SIPRI; 2006]. Data on REN investment 2007 [UPI; 2008].

According to an article published by United Press International in February 2008, the global investments in the renewable energy sector in 2007 (green dot in Figure 2) were about 117 billion US$, or 84 billion €; a figure closely approximates the investments in the "Low Variant Scenario".

The difference in the development of installed renewable generating capacities in both scenarios is even greater than the difference in investment budgets. With about 4,450 GW of "new" renewable electricity generating capacity in 2030, the "High Variant Scenario" is much more than double the capacity reached in the "Low Variant Scenario" (1,840 GW)[2].

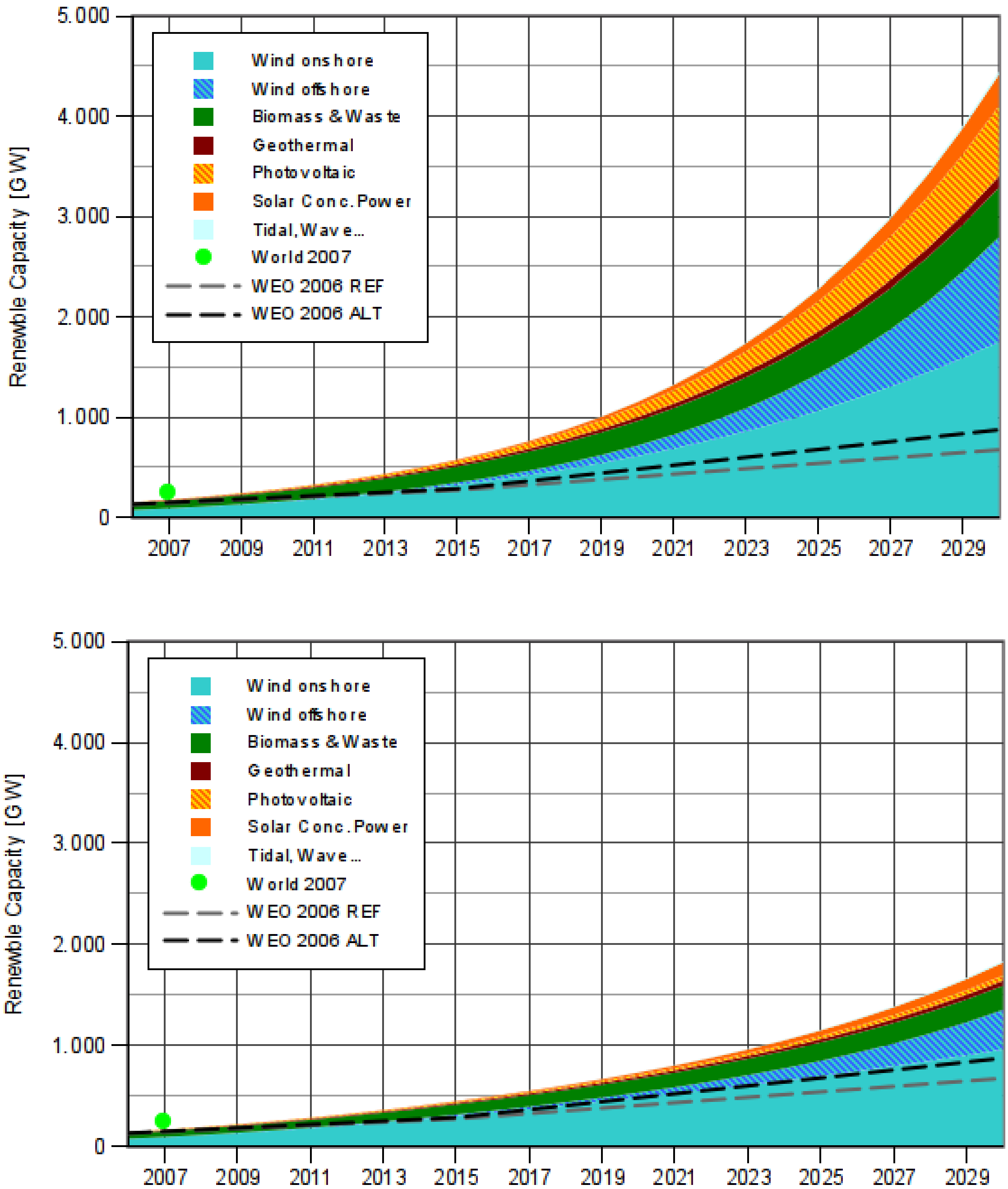


Figure 3: Development of "new" renewable electricity generating capacities in the world regions in the "High Variant" (upper figure) and "Low Variant Scenario" (lower figure) [EWG; 2008].Data on renewable capacity 2007: [REN 21; 2007].

2 Hydropower is not part of capacity extensions in the scenarios as there is no clear figure of the sustainable potential for the further increase in hydropower capacities.

The vast majority of the generating capacity in 2030 in both scenarios is onshore and offshore Wind Energy. Technologies in general develop much better in the ”High Variant Scenario”, but Photovoltaic can be seen as the big winner when the two scenarios are compared. PV, in fourth place in the ”Low Variant”, is the second-biggest contributor in the ”High Variant” (2030). Biomass & Waste follows in third place (second in the ”Low Variant”). Minor contributions come from Geothermal Power and Tidal, Wave and other Maritimes (“Tidal, Wave...” in Figure 3).

The scenarios deal with the extension of “new” renewables, i.e. hydropower is not part of the investment-budgets in the scenarios, but planned extensions of hydropower capacities (from about 762 GW today to about 856 GW in 2030) are considered because hydropower is the most important component of renewable electricity supply today and will still be important in 2030. Be that as it may, Hydropower loses its predominant role in both scenarios.

Electricity generation from “new” renewables increases with growing capacities. Starting with about 3,300 TWh in 2005, electricity generation increases to about 8,600 TWh in the “Low” and to about 15,200 TWh in the ”High Variant Scenario” (see bars in Figure 4).

Most of the “new” renewables production comes from Wind Energy, but the production share is not as high as the share in capacities[3]. Nevertheless, in 2030 electricity production from Wind Energy comes close to Hydropower in the ”Low Variant”. In the ”High Variant” Wind Energy outpaces Hydropower by about 2,000 TWh. The second-biggest source among the “new” renewables is Biomass & Waste, followed by Geothermal and Solar Concentrating Power.

For a better comparison of what the scenarios mean with regard to the WEO 2006 “Alternative Energy Scenario”, the development of renewables in this scenario is represented by marked lines and transparent areas. It is easy to see that the WEO 2006 assumes a far greater extension of Hydropower capacities (purple markers and area in Figure 4), but the development of “new” renewables (green markers and area stacked onto Hydropower) definitely even falls behind the development in the “Low Variant Scenario”.

3 This was to be expected, as wind energy (and also PV) depends on climate conditions and potentially is not as productive as Biomass or Geothermal power.

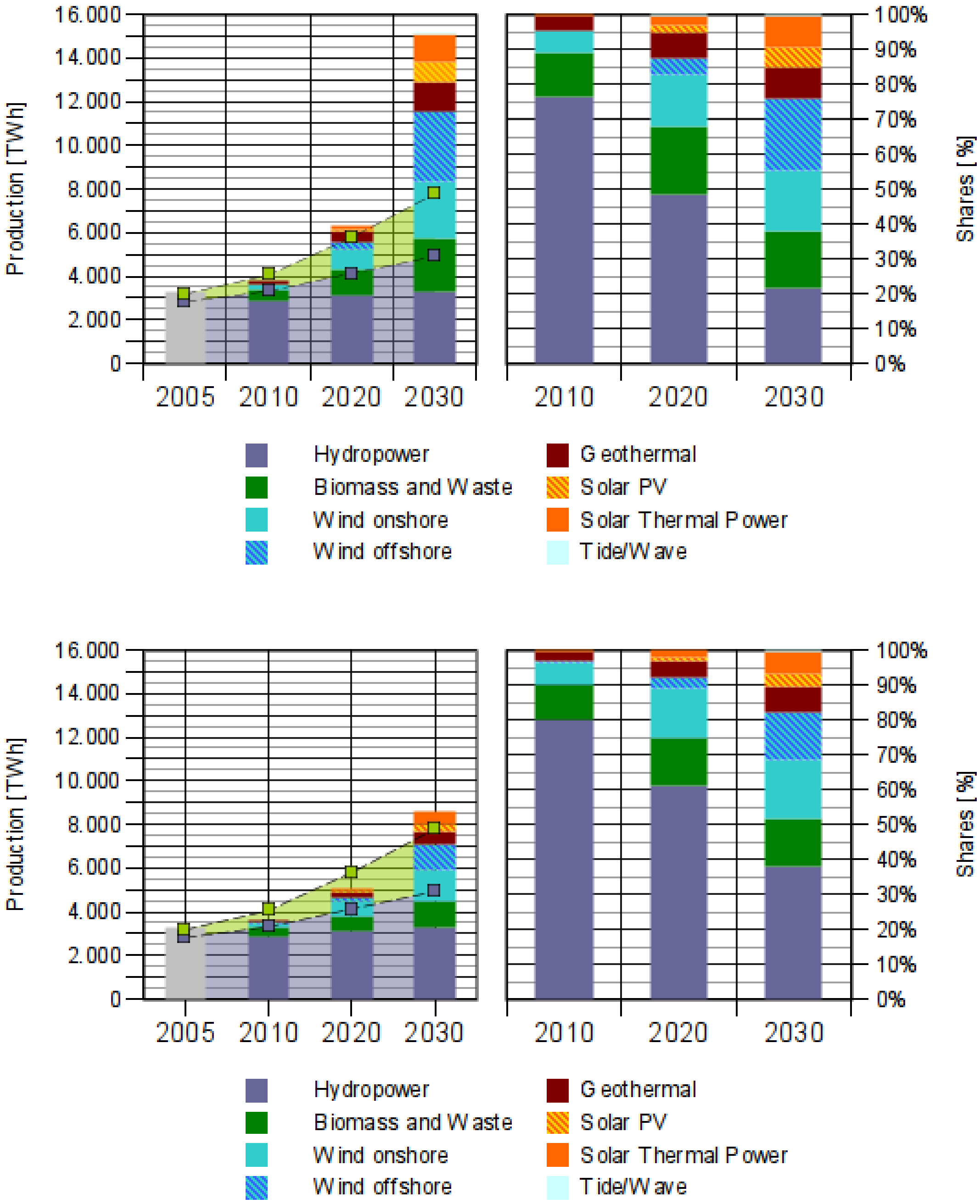


Figure 4: Development of electricity production from renewables in the "High Variant" (upper figure) and the "Low Variant Scenario" (lower figure), 2010 to 2030 [EWG; 2007]. Data 2005: [IEA; 2007b]

So far, only the electricity sector has been described, but heat supply also forms part of the scenarios. On one side, heat comes from cogeneration. Half of the Biomass & Waste and half of the Geothermal plants in the scenarios are cogeneration plants, producing heat and electricity simultaneously. Another heat producer in the scenarios is the solar thermal collectors, which account for a considerable percentage of investments in both scenarios. In fact, there is a bigger focus on solar thermal collectors in the ”Low Variant” than in the ”High Variant”. The reason for this is that solar thermal collectors are comparably cheap, and the ”Low Variant” has to get by with substantially lower investments.

The capacity of solar thermal collectors increases from 137 GW (2006) to almost 2,900 GW (2030) in the ”Low Variant”. The ”High Variant” shows an increase to about 3,800 GW. The difference between Biomass & Waste and Geothermal heat capacities in the two scenarios is proportional to the differences in electricity capacities, thus both are far lower in the ”Low Variant”.

Coming to final energy supply, about 30% of the final electricity and heat stem from renewable sources in the ”High Variant”. Consequently the percentage of renewables in the ”Low Variant” is less (more than 17 %).

Generally, renewables' share in electricity is considerably higher than in heat. Comparing the figures for 2030, renewable energy technologies contribute about 62% to final electricity and about 16% to final heat in the ”High Variant”. The related figures in the ”Low Variant” scenario are 35% of final electricity and 10 % of final heat originating from renewables.

Coming to a conclusion, both scenarios show an extension of renewable generating capacities that is far greater than the picture drawn even in the IEA's WEO 2006 “Alternative Policy Scenario”[4]. Necessary investments into renewable generating capacities – often seen as the predominant problem – are relatively low, not only in the face of ongoing and accelerating climate change, but also in comparison to today's investment figures in other sectors. To achieve a level of development as described in the “High Variant Scenario”, it would be sufficient to raise investments in renewable generating capacities to 124€$_{2006}$ per capita of the world's population until 2030; a per-capita investment the world has already seen for military expenditures in 2005. Half of this investment target would be sufficient for a development like in the “Low Variant Scenario”.

It took a long time to get scientific research focused on renewables and even more time was spent before renewable technologies could successfully be introduced into markets (e.g. in Europe). Once this happened and effective support mechanisms were implemented, such as the German EEG (Renewable Energy Law) with the feed-in tariff structure, renewables – and

4 From the pure technological perspective (technological development, possible increase in production capacities) a much higher growth could have been justified.

initially Wind Energy in particular – displayed dynamic development and increasingly became a “normal” part of thinking when dealing with the future energy supply.

A great deal of time was lost struggling over the reasons for climate change and the question of whether fossil energy resources would become scarce - and if so, when - before we recognised that the time to change our use patterns and supply of energy is **now**, is a task of **today's** generation. Starting sooner would of course have been more favourable. However, considering the relatively low investment figure and an almost 30% share of final energy demand, and that 62% of global electricity can be supplied by renewable technologies by 2030, there is reason for being optimistic that hummankind can come to grips with the problems of climate change and the reality of steadily depleting fossil energy sources.

Following a path of development as described in the “High Variant Scenario” would offer a substantial opportunity to reduce fossil and nuclear capacities in the global energy supply. Although the energy supply will require a striking amount of oil to fulfil energy demand until at least 2030, the problem of being strictly dependent on oil can be partially solved by a massive extension of renewables.

It is our strong conviction that nuclear power will not be needed if we undertake the types of development as proposed here. Furhtermore, we contend that there is no necessity to build new nuclear power plants, as proposed by the IEA, or to prolong the lifetime of existing ones. Using nuclear power, with all the associated problems (proliferation-prone nuclear material, final disposal of nuclear waste, severe accidents in nuclear power plants) can be discontinued - and this must take place as soon as possible. Instead of financing new nuclear plants, which definitely cannot provide a sustainable solution to our energy problems, this money should be invested in renewable technologies, which offer the only known sustainable solution to the world's energy-supply problems.

Although the scenarios demonstrate how renewable shares in energy supply can be increased significantly, they should also turn our attention to energy demand and its future development. In this study, we have referred strictly to the energy demand figures given in the IEA's World Energy Outlook 2006 “Alternative Policy Scenario”. As a result, even in the “High Variant Scenario”, the contribution of non-renewable sources to final energy supply in 2030 is almost as high as the total final energy demand was in 2005. This demonstrates impressively that we will also have to tackle energy consumption with the same level of effort we spend on the supply side. It might be questioned whether the IEA's demand projections are encouraging enough to deliver a perspective for solving the energy problems with which we will be confronted in the future. It is quite clear that there are huge potentials for energy savings, especially in the field of heat consumption, and that we will have to tap these potentials. This, however, is an issue to be addressed in future work.

Introduction

The objective of developing the scenarios of this study is to present an alternative to the prevailing thinking - which we find flawed - and a more realistic view of the role energies can play in a future global energy supply. Some of the latest global and regional scenarios do not really show the potentials renewable energy technologies have in the near future. The scenarios in this study are based on the analysis of the development and market penetration renewables have showed in different regions in recent decades. The scenarios illustrate that renewable energy technologies have huge potential to help to solve the climate change problem and to lower the dependence on fossil and nuclear energies.

With the release of the recent IPCC climate study at the very latest, there can no longer be any legitimate doubt that human activity is having a decisive influence on the changes in climate currently being observed worldwide. The possible magnitude of these climate changes appear set to reach levels that threaten our economies, the stability of ecosystems and, hence, sustainable development. Recently, Nicholas Stern, former chief economist of the World Bank, has drawn attention to the economic aspects of climate change, many of which have generally gone unnoticed though, in fact, they have already been commented upon in publications. According to Stern's analysis, climate change could cause a decrease in global GDP by at least 10%, and - in the worst case - even by 20%.

To avoid an increase in the average global temperature that exceeds a tolerable limit of 1.5 to 2°C, the atmospheric concentration of greenhouse gases (GHG) must be stabilised at a level of about 420 ppm (parts per million) of CO2 equivalents in this century.

This stabilisation can only be achieved if global greenhouse gas (GHG) emissions are reduced to less than half of current levels by the middle of this century. As today's developed countries are the predominant contributors to global GHG emissions, they have to commit themselves to making the first moves toward a clean energy supply and concurrently to reducing their GHG emission by 80% within the same time frame. Developed countries, among them the Member States of the European Union, must provide intermediate targets to keep this process revisable, transparent, and convincing to others, and will have to assist less-developed countries in ensuring a clean and secure energy supply.

The serious consequences of using fossil fuels, the risks of nuclear energy, and the foreseeable end of cheap fossil and nuclear fuels[5] show us that the use of these technologies must be discontinued. With regard to nuclear fusion, this technology has so far not functioned, and even if it did, it would involve the production of radioactive waste.

5 Additional EWG Publications on these issue can be found at: www.energywatchgroup.org/Studien.24+M5d637b1e38d.0.html

Over the medium and long terms, a sustainable energy system can only be supplied by renewable sources. Although the amount of energy offered by renewable sources exceeds the global energy demand by far, the expense to install the technical equipment in order to utilise these renewable sources should be kept at a minimum. This entails energy having to be used as efficiently as possible, i.e. renewable supply and energy-efficient technologies have to be combined.

One of the most common questions regarding the establishment of a renewable energy supply is related to the time necessary to realise such a system. Some scenarios have already addressed this question on a regional level[6]. The scenarios in this study deal with the questions of how fast renewable technologies might be implemented on a worldwide scale and the level of costs this magnitude of development would result in.

Addressing these questions cannot be separated from the questions of how, how fast, and to what extent greenhouse gas emissions can be reduced. Although it is quite clear that renewable technologies and energy efficiency will be the major keys in reducing greenhouse-gas emissions, clarifying the required time and costs makes the effort humanity has to make more apparent and more transparent. Last but not least, the outcome of the scenarios will also help in defining goals for the reduction of greenhouse-gas emissions.

6 e.g. German Parliaments Enquete Commission on sustainable energy supply [Enquete-Kommission; 2002], Solar Catalonia - A Pathway to a 100% Renewable Energy System for Catalonia [Peter et al.; 2006], Study on fossil plant substitution by renewables [Peter/Lehmann; 2005], Long Term Integration of Renewable Energy Sources into the European Energy System [LTI; 1998], Long Term Scenarios for the Sustainable Use of Energy in Germany[DLR/WI; 2002]

Methodology

We were asked to calculate the possible increase in renewable energy capacities assuming a hindrance-free development. This means that the “Renewable Energy Outlook 2030” (REO 2030) scenarios presume a strong support framework for renewables (political, financial, and administrative) to avoid further delays in market introduction and penetration.

The REO scenarios consider ten world regions, which are the same as in IEA's “World Energy Outlook 2006” (WEO 2006). This was not done arbitrarily: this approach helps in that it enables the comparison of the results of these scenarios with the “World Energy Outlook” scenarios and other scenarios.

Assuming strong political support and barrier-free market entrance, the dominating stimulus for extending the generation capacities of renewable technologies is the amount of money invested. Within the REO scenarios, we assume a *willingness to pay* for a clean, secure, and sustainable energy supply. This assumed willingness to pay is expressed as a target level for annual payments per capita that - after a period of continuously growing investments in renewable energies - will be reached by the year 2030. As incorporating estimations regarding inflation was viewed as adding unnecessary uncertainty to our results, all prices in this report are expressed on the basis of figures for the year 2006.

Because all investments in energy supply will have to be paid by the energy consumers in the end, the extension of renewable energies will impose a financial burden on societies[7]. Although a growing acceptance of and support for a clean energy supply by societies is assumed in this work, the Energy Watch Group respects the fact that that overextending financial burdens might negatively impact societies’ attitude towards renewable energy support. This would be likely to have knock-on negative effects on the investors’ trust in the continuity of political support for renewable energy, *ceteris paribus*.

The annual payments, starting in 2010 with a low amount of capital and reaching a defined amount of investment in 2030, are divided into two fractions called “basic investment” and “advancement investment”. “Basic investment” ensures the necessary technological diversification of renewable energy technologies; “advancement investment” makes it possible to adapt development to existing potentials within the regions.

In this study, we calculate two “REO 2030” scenarios, which differ in terms of their assumed acceptance, thus reflecting a low societal acceptance on one side and a high one on the other. Consequently, there is a “low variant” scenario, assuming lower investment budgets, and a “high variant” scenario with substantially higher expected investments in renewable technologies.

7 This is also true for conventional power supply, e.g. costs for erecting conventional power plants, maintenance, or the renewal of the power plant pool.

General Calculation Approach

In both scenarios, the total quantity of installed renewable energy technologies depends on the development of specific technology costs and total investment budgets (increasing towards 2030). There is a close relation between specific technology costs and the development of installed capacities. While specific technology costs determine the capacity that can be purchased for a specific amount of money, there is a strong interrelation between market development and specific costs, as product prices decrease with increasing production rates. To solve this problem, we selected an iterative process to calculate the interacting curves of future cost development and installed generating capacities.

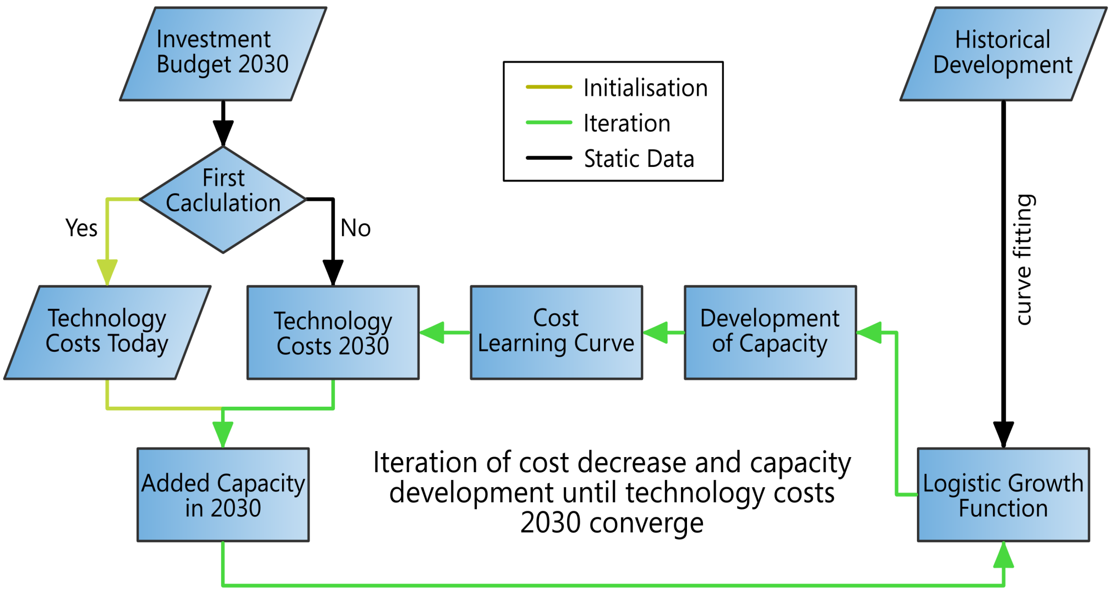


Figure 5: Flow chart of the scenario development process with iteration of technology costs and added capacities in 2030. [S. Peter, H. Lehmann; 2007]

In the scenarios, both investment budgets and specific technology costs determine the generating capacities that can be added annually up to 2030, thus providing a target mark for the development of installed capacities until that year. This is, in a first run, done using today's technology costs for the whole period up to 2030. The resulting development of the total capacities installed worldwide afterwards is used to generate technology-specific "learning-curves" for cost digression. The next run uses these decreased technology costs to recalculate installed generating capacities – with the corrected capacities-technology costs recalculated, and so forth. The execution of this calculation loop stops if technology costs for 2030 converge. The picture above (Figure 5) gives an overview of the scenario-development process.[8]

8 For more details see "Details on mapping technological and cost development" in the Annex

In the strict sense, this makes the scenario development a mixture of financial and technologically driven factors, as the fixed investment budgets in 2030 determine the preceding development in terms of installed capacities and thus the decrease of specific technology costs.

The scenarios do explicitly not describe a maximum possible development, neither from a technological nor from a financial perspective. The scenarios show what could be achieved with only moderate investments. Off course higher investments than assumed in the "REO 2030" scenarios, whether this might be for single technologies or in general, can and – likely - will allow for a much more dynamic growth and higher renewable generating capacities in 2030. There is no indication that technological aspects, such as expanding production capacities, could be a bottleneck for a faster increase of renewables.

Interaction of Investment Budget and the Decreased Cost of Technologies

The Renewable Energy Budget determines the renewable generating capacity that can be added in the course of 2030. For this purpose, the purchasable generating capacity in 2030 is calculated by dividing the investment budget by specific technology costs in 2030, which are calculated within an iteration loop (see also Figure 5 and Figure 6). On this note, in 2030 the investment budget and added capacity are equivalent by the factor of specific technology costs in that year. The decrease in specific technology costs is calculated using what are called "learning curves". Learning curves consist of a progression ratio that determines by how much costs will decrease if production doubles. For example, with a progression ratio of 0.9, costs will decrease by 10 percent for any doubling of production.

To calculate the cost decrease for each of the technologies, the following progression ratios are used:

Technology	Progress ratio
Wind Energy, onshore	0.85 up to 200 GW and 0.9 up to 2,000 GW
Wind Energy, offshore	Same as onshore but calculated as difference costs compared to onshore Wind Energy
Biomass & Waste	0.9 up to 2010, 0.93 up to 2020 and 0.95 up to 2030
Geothermal	0.95
Photovoltaic	0.8 up to 200 GW and 0.9 up to 2,000 GW
Solar Concentrating Power	0.93 up to 2020, and 0.95 up to 2030
Tidal, Wave & other Maritimes	prototype phase up to 2010, then 0.9
Solar Thermal Collectors	0.9

Table 2: Progress ratios for the technologies considered in the scenarios. [EWG; 2007]

Although there is a fixed target for the amounts that will be spent in 2030, the investment budgets in the REO scenarios are explicitly not static over the period of time considered. Annual renewable energy investments for the preceding years are a result of a technological development up to 2030, which has to fulfil the prerequisite that the overall costs of new capacities added in 2030 meet that year's investment target.

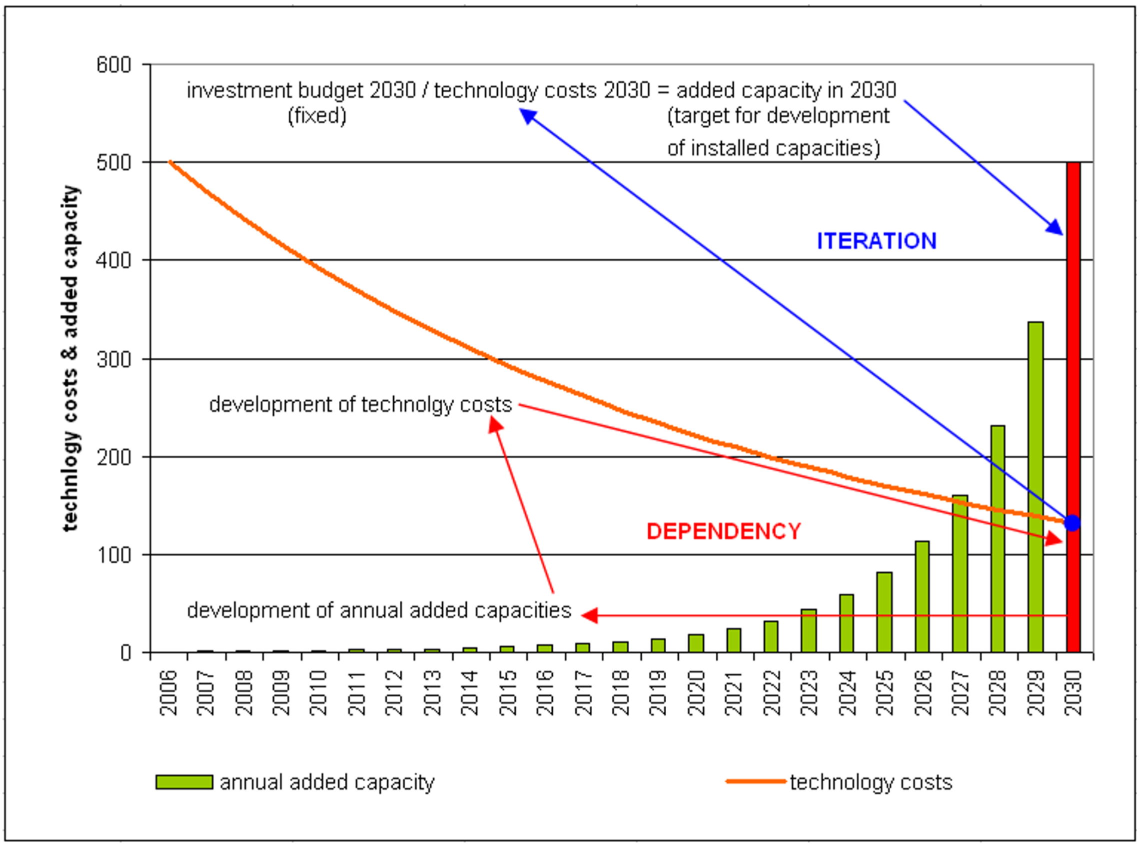


Figure 6: Example of translating the 2030 investment budget into new added capacities in 2030 with regard to degression of specific technology costs (see also Figure 5 on page 17 for more information on iterative technology cost calculation). [S. Peter, H. Lehmann; 2007]

General Growth Assumption

The general approach of mapping the development of individual renewable technologies to the time line within the various regions uses what are termed "logistic growth functions", which show a typically s-shaped curve for growth with saturation effects in the later stage of development. This reflects the underlying assumption that growth cannot be unlimited if any of the resources that growth depends on is limited. In general, logistic growth starts with an exponential development that, in the course of time, becomes increasingly dampened by saturation effects. The last phase of development shows a slow (asymptotic) approach towards a maximum value. The curve of a logistic growth function does not show the development of growth itself, but rather shows the development of inventory (growth rates follow a bell-shaped curve).

Translated, e.g. to growth of a technology, logistic growth consists of a phase of market introduction that is followed by a dynamic market growth which later declines due to market constraints. These can include, e.g., high market penetration, which makes it increasingly difficult to find new customers (e.g. in case of a product) or an increasing scarceness of available or suitable sites for installation (e.g. for Wind Energy or PV).

Generally logistic growth (or so-to-say logistic inventory development) is an idealised process of limited growth. In reality, growth might be influenced by various factors, e.g. by changes in legislation and/or financial support in the case of renewable energies.

Another issue that can be well explained by means of a logistic growth function is the advantage of starting development sooner. In the example below, the dark red curve shows the development from the start; the lighter curves started ten and twenty years earlier respectively. After twenty years of development, the curve called "logistic growth" shows a value of 10%, the curve starting ten years earlier a value of almost 30%, and the curve starting twenty years earlier a value of more than 50%. This 20% advantage per decade in the example is still present one decade later for both of the other curves (the 30th year of development for the "logistic growth" curve). Afterwards, the gap begins to close, but this happens quicker for the development starting twenty years earlier than for the one that starts ten years earlier (still almost a 20% advantage for the "ten-years-earlier" curve but "only" 35% for the "twenty- years-earlier" curve when compared to the "logistic growth" curve).

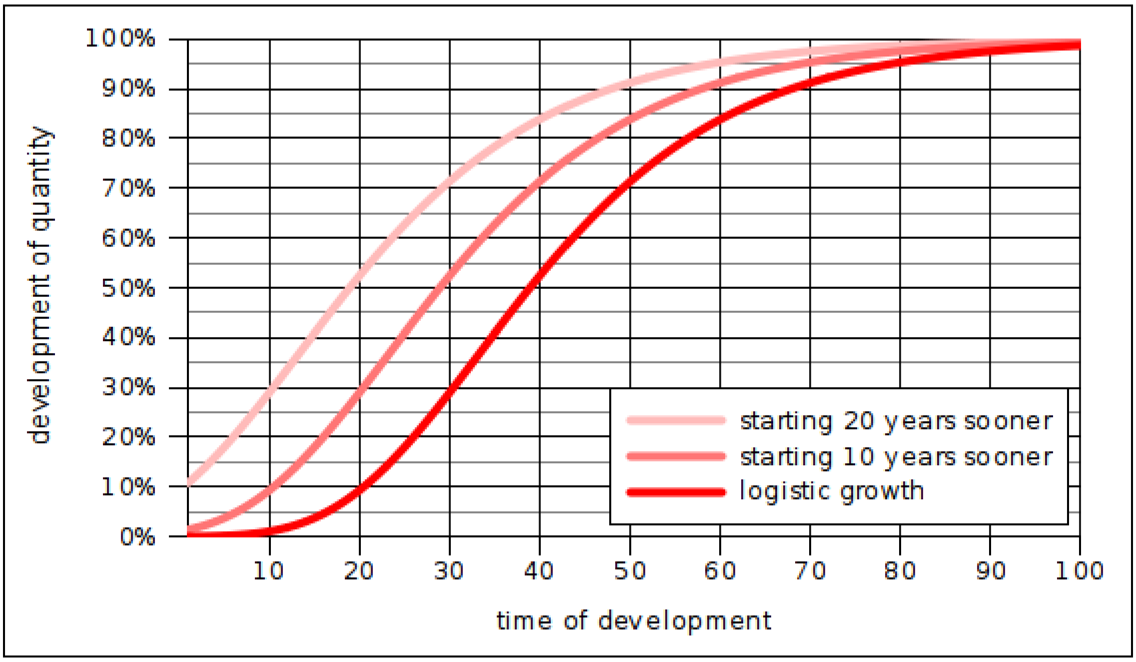


Figure 7: Example for logistic growth and the advantage of starting sooner [EWG; 2008].

One important question is whether a logistic growth function can reflect the growth characteristics of renewable energies in a way that can be seen as a valid approximation of reality (This does not mean that the logistic growth function will deliver "the right" projection for future development, but that historical development and logistic growth are sufficiently similar). Therefore, the logistic growth function used in the "REO 2030" scenarios has been applied to the German Wind Energy development (Figure 8). The result shows a good approximation of the logistic growth to historical development, which means that growth of Wind Energy in Germany has experienced logistic growth so far.

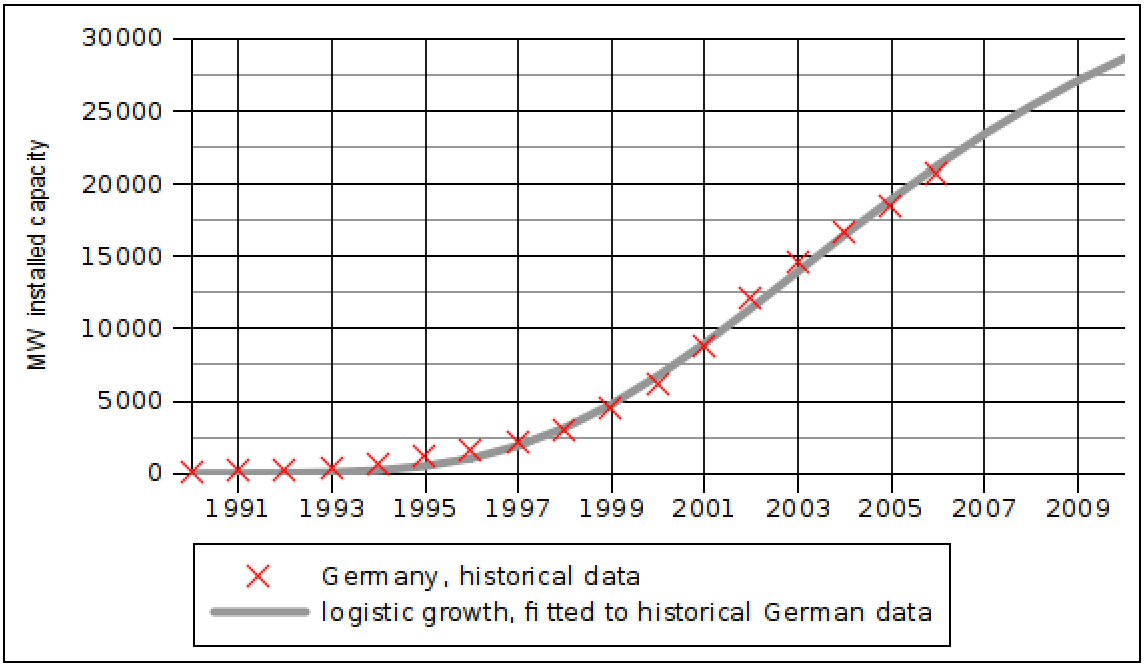


Figure 8: Example of fitting the logistic growth function used in the "REO 2030" scenarios to historical data of Wind Energy development in Germany.

Investment Budgets for Renewable Energy Technologies

Assuming strong political support and a barrier-free market entrance, the dominating stimulus for extending the generation capacities of renewable technologies is the amount of money invested. In the "REO 2030" scenarios, we assume a growing *"willingness to pay"* for a clean, secure and sustainable energy supply starting with a low amount in 2010. This willingness to pay gets expressed as a target level for annual investments per inhabitant (per capita) that will be reached by the year 2030, after a period of continuous growing investments in renewable energies.

As mentioned above, incorporating estimations regarding inflation was viewed as adding unnecessary uncertainty to the results of this report. Therefore, all prices are expressed on the basis of figures for the year 2006.

The annual payments are divided into two fractions called "basic investment" and "advancement investment", with one proportion (basic investment) being equally distributed to all the renewable energy technologies considered[9] to ensure the necessary technological diversification. The remaining budget (advancement investment) is distributed in relation to the regional potentials of the different technologies. This is done to adapt the introduction of renewable energy technologies to the existing potentials in the related regions.

The "Renewable Energy Investment Budget", i.e. the amount of money invested in renewable generating capacities, respects expectations regarding the future economic development of the different regions. Therefore, investment budgets are adapted to the economic situation of any of the regions, which results in stronger economies having higher investment targets for 2030 than weaker ones. Furthermore, rapidly developing economies are assumed to spend more money than slower ones, as they will have to improve their energy supply in any case.

This, however, is not the only criterion for the setup of the investment budgets. From the very beginning, there was some discussion about reasonable amounts per capita for the different regions. During the initial effort, investment budgets were decisively higher and showed less differentiation between the regions. As this resulted in renewable electricity shares that the working team judged as unreasonably high, investment targets were lowered region by region in order to achieve a more moderate scenario approach. The working team is aware that even higher installed capacities could have been justified from the perspective of possible technological growth, but it was decided to favour relatively low investments.

Some regions, in particular those that are currently viewed as relatively underdeveloped, will have to make stronger efforts in terms of the percentage of their Gross Domestic Product that will have to be spent to achieve the goals described in the scenarios. In the long term, the likelihood must be considered that many of the non-OECD countries will experience

9 Exceptions were made to tidal, wave and other maritime energies and solar thermal collectors.

substantially higher economic growth than most OECD countries. Some of them will even be confronted with the task of developing an energy supply that is both adequate and reliable enough to maintain the pace of their economic growth. This implies that many of the less-developed non-OECD countries will have to make massive infrastructure investments - including their energy supply - if they are to be able to participate in global economic development. This does not necessarily mean that these countries will have to bear all the related costs by themselves, as richer countries should contribute to this development, e.g. via the Clean Development Mechanism (CDM) or Joint Implementation (JI).

Investment Budgets in the REO 2030 Scenarios

In the “High Variant Scenario” (HV), per capita investments in 2030 grow to 124 € per capita per aear in global average. Investment targets differ from region to region: in 2030 220 € per capita and year (€/cap*a) are spent in the OECD regions, 200 €/cap*a in China and the Middle East; decreasing further for the Transition Economies (180 €/cap*a) and the remaining regions (all with less than 100 €/cap*a and down to about 41 €/cap*a in Africa). As the scenario is based on an iterative calculation, the estimated values do not exactly match these target values. The regions are very different in terms of population, and therefore total investment sums do not show the same distribution as the investments per capita. China and South Asia, for example, both regions with far more than one billion inhabitants, have the biggest total investments by 2030 (see Table 3 on page 24 for details).

The “Low Variant” (LV) of the “REO 2030" scenarios assumes half the investment budget of the "High Variant" (62 € per capita and year on global average in 2030), but in both the relation of investments in the various regions is the same; with the highest per-capita spendings in the OECD countries and lowest investment figures for Africa (see Table 3 for details).

Looking at the figures for 2010, investment starts with about 21 €/cap in that year in the “High Variant Scenario” (about 15 €/cap*a in the “Low Variant”). Already in 2010 the OECD regions spend most: about 60 € in OECD Pacific (“Low Variant”: 38 €/cap*a) to 70 € in OECD Europe (“Low Variant”: 56 €/cap*a) per inhabitant per year. In Africa, having the lowest investments, this figure is about 3½ € per capita.

Until 2020 investments in the “High Variant” increase to about 53 € per inhabitant per year on the global scale (about 30 €/cap*a in the “Low Variant”). By that time investments in the OECD are about 125 € to 131 € per capita (70 to 76 €/cap*a in the “Low Variant”). In China, the figure is more than half of this, while in the Transition Economies and the Middle East, it is about the half. Lowest per-capita investments fall upon East Asia, Latin America (approx. 33 €/cap*a in the “High Variant” and about 20 €/cap*a in the “Low Variant”) and, finally, South Asia (HV: 22 €/cap*a, LV: 12 €/cap*a) and Africa, with 14 (HV) and. 8 € per capita (LV) respectively.

Due to the widely differing populations of the various regions, China is already on par with OECD Europe in terms of total investments by 2010 and surpasses all other regions during the further development. By 2030, China's total investment in renewable capacities (299 billion €2006) is more than double the amount spent in South Asia (147 billion €2006, second place). OECD Europe and OECD North America are in third and fourth place, both spending about 30 billion € less than South Asia. In all other regions, total investment is lower than 70 billion euros (see Table 3 for more details).

Region	Investment budgets (€2006)					
	Per Capita			Total [bill. $€_{2006}$]		
	2010	2020	2030	2010	2020	2030
"High variant" scenario						
OECD Europe	69.2	130.9	222.8	37.0	71.1	120.9
OECD North America	62.7	126.2	220.0	28.6	62.8	118.4
OECD Pacific	59.1	124.7	223.9	11.9	25.0	43.6
Transition Economies	16.2	65.5	180.0	5.6	22.3	60.3
China	28.2	76.3	203.8	38.3	109.7	299.3
East Asia	10.3	32.2	81.3	6.8	23.9	65.6
South Asia	4.1	21.8	71.1	6.5	39.8	146.7
Latin America	12.0	32.7	91.4	5.6	17.1	51.5
Africa	3.5	14.2	40.8	3.5	17.3	59.4
Middle East	4.8	56.2	202.2	1.0	13.3	55.1
WORLD	**21.3**	**53.2**	**123.9**	**144.8**	**402.4**	**1020.8**
"Low variant" scenario						
OECD Europe	55.7	76.1	111.3	29.8	41.4	60.4
OECD North America	40.8	70.4	110.0	18.6	35.0	59.2
OECD Pacific	38.2	70.2	111.8	7.7	14.1	21.8
Transition Economies	8.9	35.0	91.1	3.0	11.9	30.5
China	18.8	43.4	101.7	25.5	62.3	149.4
East Asia	7.4	20.5	40.5	5.0	15.2	32.7
South Asia	3.0	12.2	35.4	4.7	22.2	73.1
Latin America	7.4	18.2	45.6	3.5	9.5	25.7
Africa	2.1	7.7	20.3	2.1	9.3	29.5
Middle East	2.9	26.5	101.1	0.6	6.3	27.5
WORLD	**14.8**	**30.1**	**61.9**	**100.4**	**227.3**	**509.8**
"Low variant" as percentage of "High variant"						
OECD Europe	80%	58%	50%			
OECD North America	65%	56%	50%			
OECD Pacific	65%	56%	50%			
Transition Economies	55%	53%	51%			
China	67%	57%	50%			
East Asia	72%	64%	50%			
South Asia	73%	56%	50%			
Latin America	62%	56%	50%			
Africa	60%	54%	50%			
Middle East	60%	47%	50%			
WORLD	**69%**	**57%**	**50%**			

Table 3: Development of investment per capita and total investments from 2010 to 2030 [EWG; 2008].

The development of investment budgets does not show a great difference between the "High Variant" and the "Low Variant" by 2010. On a global average, the 2010 budget in the "Low

Variant" scenario is about 70% of the “High Variant” budget. This difference grows during the further development to 57 % of the “High Variant” budget by 2020 and 50% by 2030 (see Table 4 for details).

Distribution of Investments in Various Technologies

The distribution of investments is divided into a basic investment, which is equally distributed among all technologies considered (making up half of the investment budget). The second fraction, named “advancement”, is generally oriented toward the varying potentials of the individual technologies, with some additional adjustments to add further support to specific technologies; e.g. Solar Concentrating Power in sunny regions and OECD Europe, and a general stronger support for Solar Collectors.

There is no “extra” investment in heat generation from Biomass & Waste or Geothermal Energy, which does not mean, however, that these technologies aren't used for heat supply. The scenarios assume a certain fraction of Biomass & Waste and Geothermal plants to be cogeneration facilities, producing electricity and heat simultaneously.

Distribution of investments to technologies									
Region / Technology	**Wind onshore**	**Wind offshore**	**Wind total**	**Biomass**	**Geothermal**	**PV**	**Solar Concentrating Power**	**Tide & Wave**	**Solar Collectors**
"High variant" scenario									
OECD Europe	10.5%	24.3%	34.8%	10.6%	9.2%	14.5%	11.0%	3.7%	16.2%
OECD North America	15.6%	20.1%	35.7%	13.3%	8.6%	11.0%	11.7%	3.4%	16.4%
OECD Pacific	16.7%	19.8%	36.4%	10.5%	8.6%	8.6%	16.5%	3.2%	16.1%
Transition Economies	21.3%	13.5%	34.8%	17.4%	11.4%	10.7%	0.0%	1.7%	23.9%
China	11.8%	16.3%	28.1%	11.0%	7.9%	17.1%	13.9%	2.8%	19.2%
East Asia	8.6%	21.4%	30.0%	9.8%	7.1%	13.6%	13.2%	1.4%	24.9%
South Asia	6.7%	9.4%	16.1%	8.0%	6.1%	24.1%	10.6%	1.3%	33.8%
Latin America	14.5%	20.5%	35.0%	12.4%	9.9%	10.0%	13.2%	1.6%	18.0%
Africa	12.2%	11.7%	23.9%	11.2%	6.6%	10.6%	16.0%	1.3%	30.4%
Middle East	14.3%	20.1%	34.4%	0.0%	9.5%	13.7%	21.0%	1.8%	19.6%
WORLD	**12.2%**	**17.2%**	**29.4%**	**10.6%**	**8.2%**	**15.2%**	**12.5%**	**2.4%**	**21.7%**
"Low variant" scenario									
OECD Europe	9.5%	21.9%	31.3%	9.5%	8.3%	13.1%	10.0%	3.3%	24.5%
OECD North America	14.1%	18.1%	32.1%	11.9%	7.8%	9.9%	10.5%	3.0%	24.8%
OECD Pacific	15.0%	17.8%	32.8%	9.4%	7.8%	7.7%	15.0%	2.9%	24.4%
Transition Economies	17.0%	10.8%	27.8%	14.0%	9.3%	8.7%	0.0%	1.4%	38.9%
China	10.1%	14.0%	24.1%	9.4%	6.8%	14.7%	12.0%	2.4%	30.5%
East Asia	6.6%	16.5%	23.2%	7.6%	5.5%	10.5%	10.2%	1.1%	42.0%
South Asia	5.4%	7.6%	12.9%	6.4%	4.9%	19.4%	8.5%	1.0%	46.9%
Latin America	12.7%	17.9%	30.7%	10.9%	8.6%	8.8%	11.6%	1.4%	28.1%
Africa	8.2%	7.8%	16.1%	7.5%	4.4%	7.1%	10.7%	0.9%	53.3%
Middle East	12.2%	17.2%	29.5%	0.0%	8.2%	11.7%	18.2%	1.5%	30.9%
WORLD	**10.3%**	**14.6%**	**25.0%**	**8.9%**	**6.9%**	**12.8%**	**10.6%**	**2.1%**	**33.7%**
Changes in Distribution, "Low variant" compared to "High variant"									
OECD Europe	-1,0%	-2,4%	-3,5%	-1,1%	-0,9%	-1,4%	-1,0%	-0,4%	8,3%
OECD North America	-1,5%	-2,0%	-3,6%	-1,4%	-0,8%	-1,1%	-1,2%	-0,4%	8,4%
OECD Pacific	-1,7%	-2,0%	-3,6%	-1,1%	-0,8%	-0,9%	-1,5%	-0,3%	8,3%
Transition Economies	-4,3%	-2,7%	-7,0%	-3,4%	-2,1%	-2,0%	0,0%	-0,3%	15,0%
China	-1,7%	-2,3%	-4,0%	-1,6%	-1,1%	-2,4%	-1,9%	-0,4%	11,3%
East Asia	-2,0%	-4,9%	-6,8%	-2,2%	-1,6%	-3,1%	-3,0%	-0,3%	17,1%
South Asia	-1,3%	-1,8%	-3,2%	-1,6%	-1,2%	-4,7%	-2,1%	-0,3%	13,1%
Latin America	-1,8%	-2,6%	-4,3%	-1,5%	-1,3%	-1,2%	-1,6%	-0,2%	10,1%
Africa	-4,0%	-3,9%	-7,8%	-3,7%	-2,2%	-3,5%	-5,3%	-0,4%	22,9%
Middle East	-2,1%	-2,9%	-4,9%	0,0%	-1,3%	-2,0%	-2,8%	-0,3%	11,3%
WORLD	**-1,9%**	**-2,6%**	**-4,4%**	**-1,7%**	**-1,3%**	**-2,4%**	**-1,9%**	**-0,3%**	**12,0%**

Table 4: Distribution of investments to the different technologies and differences between "Low variant" and "High variant" [EWG; 2008]

The resulting distribution favours Wind Energy, which receives about one third of all investments in all regions but South Asia and Africa. In case of Wind Energy, it has to be considered that this is the only technology that can be utilized on land and on sea, resulting in massive potentials all over the world. Almost 22% (“High Variant”) or 34% (“Low Variant”) of the total investments on the global level go to solar collectors, as this technology is considered a must for heat supply and should be implemented on every building possible (not only for heat, but also for cooling). Photovoltaic holds third place in the investment ranking (15% on average), followed by biomass (11%) and geothermal energy (8%). Tidal & Wave and other maritime sources receive the least support, as these technologies are seen as having a relatively long and slow evolution from the prototype stage to field testing and on to becoming mature technologies in the coming years or decades.

The “High Variant” and “Low Variant” scenarios manifest differences in their respective comparisons of the distribution of investment budgets among the technologies. In general, all electricity-generating technologies show lower budget shares than in the “High Variant”, while Solar Thermal Collectors show a remarkable plus in investment shares. As investments in the “Low Variant” are substantially lower than in the “High Variant”, the working team decided to favour more support to the relatively cheap Solar Thermal Collector technology.

Development of Technology Costs

Technology costs in the scenarios are calculated using progress ratios for the cost decrease. These progress ratios describe the relation between cost reduction and production capacity in such a way that the progression ratio represents the cost reduction if production capacity doubles; e.g. a progress ratio of 0.9 expresses a cost reduction of 10 % for any doubling of production capacity. Figure 9 shows an example of this relation (see also progression ratios used in Table 6 on p. 29).

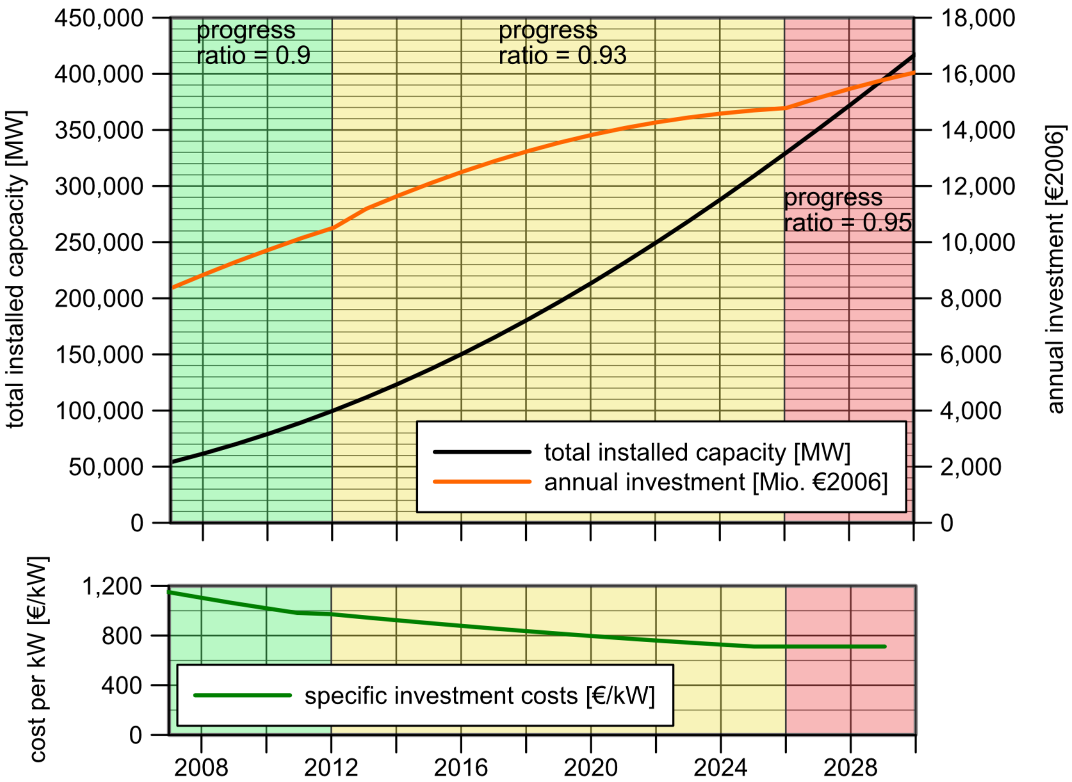


Figure 9: Example for calculating technology cost decrease by progress ratio. [EWG; 2008]

The starting point for technology costs is the same in both scenarios. Initially, the most expensive among the established technologies (which include everything but Tidal, Wave & other Maritimes) is Photovoltaic, followed by Geothermal, Biomass & Waste, Solar Concentrating Power and – substantial less costly than those technologies – offshore and onshore Wind Energy. At the very bottom, Solar Thermal Collectors are the cheapest technology (see Table 5 below for the initial technology costs).

Technology	Initial Costs [€2006/kW]	Remarks
Wind Energy, onshore	1,200	
Wind Energy, offshore	650	Additional costs compared to onshore Wind, resulting to initial cost of 1,850 €/kW
Biomass & Waste	4,400	
Geothermal	4,750	average value for ORC/KALINA and conventional plants, cost reduction only assumed for ORC/KALINA
Photovoltaic	5,000	
Solar Concentrating Power	4,000	
Tidal, Wave & other Maritimes	6,662	starting with prototype cost of 9,500 €/kW, which decreases down to 7,200 €/kW until 2015. Normal calculation with progress ratio (0.9) afterwards.
Solar Thermal Collectors	1,000	

Table 5: Initial technology costs used in the scenarios. [EWG; 2008]

Both scenarios also use the same assumptions regarding cost-progression ratios for the different technologies. To calculate the cost decrease for each of the technologies, the following progression ratios are used[10]:

Technology	Progress ratio
Wind Energy, onshore	0.85 up to 200 GW and 0.9 up to 2,000 GW
Wind Energy, offshore	Same as onshore, but calculated as different costs compared to onshore Wind Energy
Biomass & Waste	0.9 until 2010, 0.93 until 2020 and 0.95 until 2030
Geothermal	0.95
Photovoltaic	0.8 up to 200 GW and 0.9 up to 2,000 GW
Solar Concentrating Power	0.93 until 2020, and 0.95 until 2030
Tidal, Wave & other Maritimes	prototype phase until 2010, then 0.9
Solar Thermal Collectors	0.9

Table 6: Progress ratios for the technologies considered in the scenarios. [EWG; 2008]

Due to the varying development in the “High Variant” and “Low Variant” scenarios, the decrease of technology costs is different, too. Table 7 below gives an overview of the cost development per installed kW of capacity for the technologies used in the scenarios.

Although all technologies see a remarkable decrease in costs, the ranking does not change a lot. Only Photovoltaic, which shows the biggest decrease in costs, catches up some places in the ranking. Already by about 2010, PV is cheaper than Geothermal and Biomass & Waste and falls below the cost of Solar Concentrating Power in 2014. Finally, PV is the fourth-cheapest technology, with below 2,000 € per kW installed capacity.

10 The progression ratio represents a factor for cost decrease if production quantity doubles; e.g. with a progress ratio of 0.9 technology costs decrease by 10 % for any doubling of the produced quantity.

In the ”Low Variant Scenario”, technologies can be categorized into three cost classes in 2030: about 4,000 to 5,000 €/kW (Tidal and Wave, Geothermal and Biomass & Waste, about 2,000 to 2,500 €/kW (SCP and PV), and about 1,000 €/KW (Wind Energy and Solar Thermal Collectors).

Technology cost in the scenarios [€2006/kW]								
Scenario	Wind onshore	Wind offshore	Biomass & Waste	Geothermal	Photo-voltaic	Solar Con. Power	Tidal & Wave[1)]	Solar Collectors
Initial technology costs	1,200.0	1,850.0	4,400.0	4,750.0	5,000.0	4,000.0	6,662.0	1,000.0
Low variant scenario								
Low variant 2010	1,108.5	1,642.4	4,323.6	4,674.0	4,164.4	3,700.7	9,527.0	939.9
Low variant 2020	989.2	1,291.9	3,995.3	4,422.5	2,285.0	2,939.9	5,914.2	797.1
Low variant 2030	916.9	1,138.4	3,748.4	4,197.6	1,752.8	2,480.9	4,655.1	714.6
High variant scenario								
High variant 2010	1,082.8	1,588.9	4,270.9	4,648.6	3,975.5	3,634.2	9,527.0	933.1
High variant 2020	878.5	1,134.8	3,849.2	4,347.2	1,975.3	2,769.8	5,761.0	786.0
High variant 2030	778.9	961.7	3,594.6	4,123.5	1,504.3	2,314.8	4,351.9	710.1
Reduction high scenario against low scenario								
Cost reduction high 2010	**25.7**	**53.5**	**52.6**	**25.4**	**188.9**	**66.5**	**0.0**	**6.7**
as percentage	*2.3%*	*3.3%*	*1.2%*	*0.5%*	*4.5%*	*1.8%*	*0.0%*	*0.7%*
Cost reduction high 2020	**110.6**	**157.1**	**146.1**	**75.3**	**309.7**	**170.2**	**153.2**	**11.1**
as percentage	*11.2%*	*12.2%*	*3.7%*	*1.7%*	*13.6%*	*5.8%*	*2.6%*	*1.4%*
Cost reduction high 2030	**138.0**	**176.7**	**153.8**	**74.1**	**248.5**	**166.1**	**303.2**	**4.5**
as percentage	*15.1%*	*15.5%*	*4.1%*	*1.8%*	*14.2%*	*6.7%*	*6.5%*	*0.6%*
Reduction against initial technology costs in 2030								
Low variant scenario	**283.1**	**711.6**	**651.6**	**552.4**	**3,247.2**	**1,519.1**	**2,006.9**	**285.4**
as percentage	*23.6%*	*38.5%*	*14.8%*	*11.6%*	*64.9%*	*38.0%*	*30.1%*	*28.5%*
High variant scenario	**421.1**	**888.3**	**805.4**	**626.5**	**3,495.7**	**1,685.2**	**2,310.1**	**289.9**
as percentage	35.1%	48.0%	18.3%	13.2%	69.9%	42.1%	34.7%	29.0%

Table 7: Technology costs in 2030 in the High and Low Variant Scenarios compared. [EWG; 2008]

There are substantially greater decreases in costs in the ”High Variant Scenario”, but not to the same extent for all technologies. While Tidal & Wave, Geothermal, Biomass, Solar Concentrating Power and Solar Thermal Collectors only show a minor decrease in specific costs, Photovoltaic and Wind Energy benefit more from the higher investments in the ”High Variant Scenario”.

Both types of Wind Energy (onshore and offshore) fall below 1,000 €/kW until 2030 in the ”High Variant Scenario” (offshore Wind stays above 1,000 €/kW in the ”Low Variant”). Photovoltaic costs (about 1,750 €/kW in the ”Low Variant”) reduce further to about 1,500 €/kW. The lowest additional decrease in technology cost can be found for Geothermal Energy and Solar Thermal Collectors.

An overview of the development of technology costs in both scenarios is given in Figure 10 below.

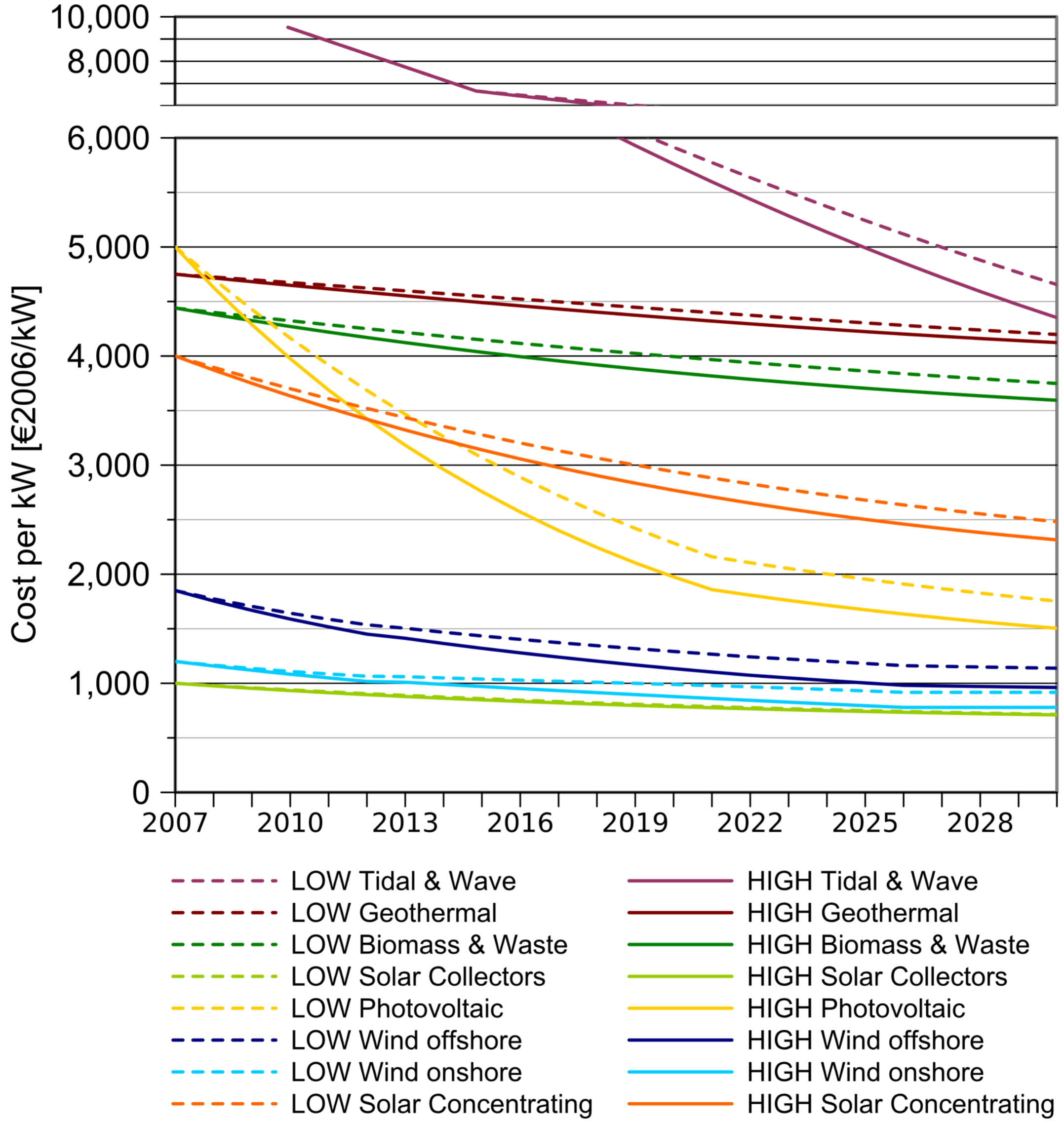


Figure 10: Development of technology costs in the scenarios. [EWG; 2008]

Development of Investment Budgets in the Scenarios

As the scenarios develop towards an investment target that was set for the year 2030, investments increase from year to year with increasing additions of renewable generating capacities.

The absolute global investment figure for 2010 in the ”Low Variant Scenario” is approx. 100 billion $€_{2006}$, about 225 billion $€_{2006}$ in 2020, and finally, slightly more than 500 billion $€_{2006}$ in 2030 (Figure 11).

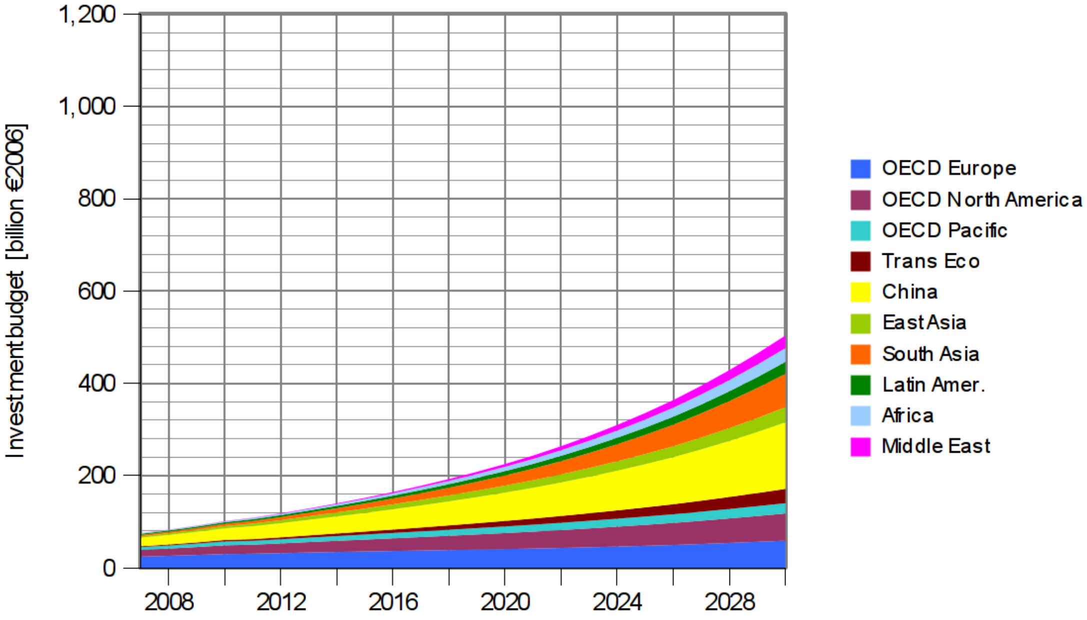


Figure 11: Development of investment budget in the ”Low Variant Scenario” [EWG; 2008]

The investment budget in the ”High Variant “reaches a level of double the amount than the ”Low Variant” in 2030 (1,000 billion $€_{2006}$). As both scenarios share the same starting point, the differences between the ”Low Variant” and the ”High Variant” grow considerably during the progress of capacity extension. In 2010, investments in the ”High Variant Scenario” are already about one-and-a-half times the investment figures in the ”Low Variant” (100 billion $€_{2006}$ in low and almost 146 billion $€_{2006}$ in the ”High Variant”). This gap increases further to more than 170 billion $€_{2006}$ in 2020 (397 billion $€_{2006}$ total budget in the ”High Variant”).

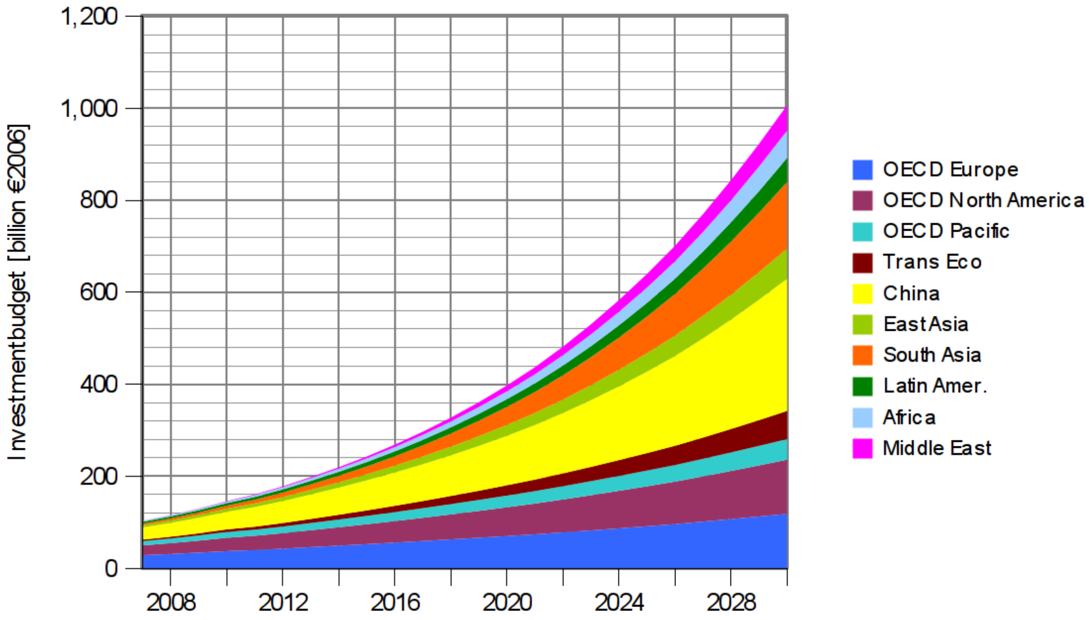


Figure 12: Development of investment budget in the "High Variant ScenarioV [EWG; 2008]

During the development there is a substantial change in the percentages the various world regions contribute to the global renewable investment budget (Figure 12)[11]. While the majority of the investment initially stems from the OECD region (Europe, North America, and the Pacific), the distribution between OECD and non-OECD countries is already well balanced before 2020. This trend in development lasts until 2030. As a result, the share of the non-OECD countries exceeds seventy percent by 2030, with the biggest contributions coming from the most populated regions, China and South Asia (29% China and 14% South Asia). The lowest contribution to the global renewable investments comes from OECD Pacific (4.4 %), Latin America (5.1 %), and the Middle East, with 5.4 %. OECD Europe and OECD North America show about the same shares (approx. 12 %), but investments are already lower than those in South Asia.

11 The figure shows the development in the High Variant scenario, but there are only minor differences between the two scenarios.

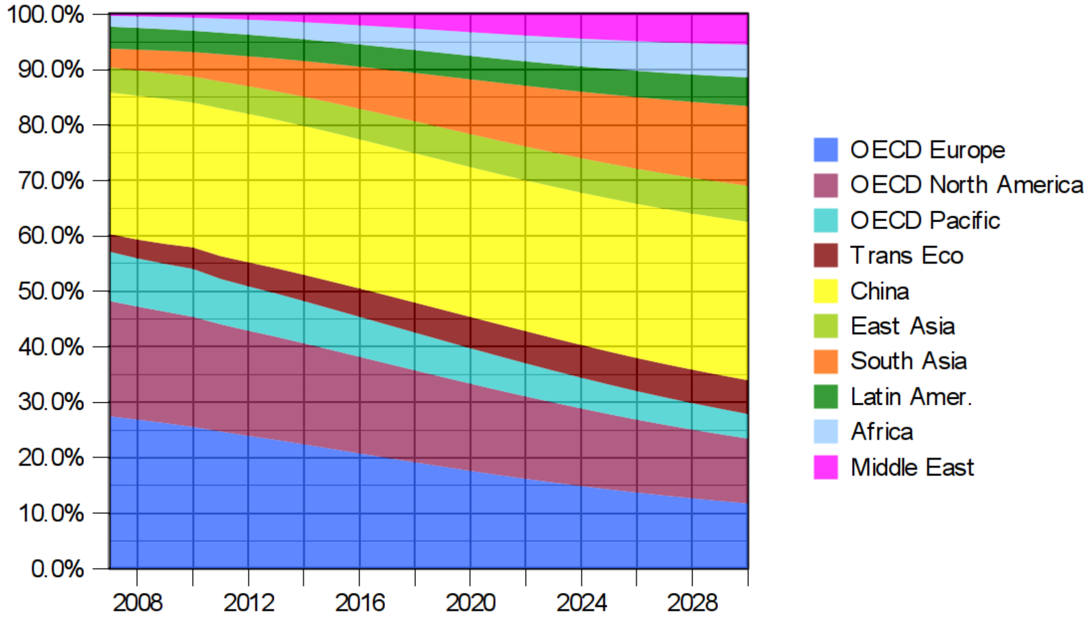


Figure 13: Development of shares at global investment budget in the "High Variant Scenario" [EWG; 2008]

To get a better feeling for what these investment figures mean in relation to today's real world, Figure 14 and Figure 13 show the development of the renewable investments as absolute values and per capita in comparison to the global military expenditures of 2005 [SIPRI; 2006]. Only in the "High Variant" does the renewable investments per capita come close to what was globally spent on the military in 2005 (black and grey markers). Although the absolute values, reached in the "High Variant Scenario" by 2030, are higher than the absolute military expenditures of 2005, the cumulative amount – i.e. the costs of the entire renewable capacity extension under the assumption of stable military spending – is much lower than the military expenditures that can be expected during that time.

Related to the current investments into the renewable energy sector (green dot), the 2007 investment budget in the "Low Variant" is somewhat lower than the real 2007 investments, while the budget is somewhat higher in the "High Variant Scenario". (Investments in 2007: about 84 billion €, "Low Variant": 76 billion €, "High Variant": 103 billion €)

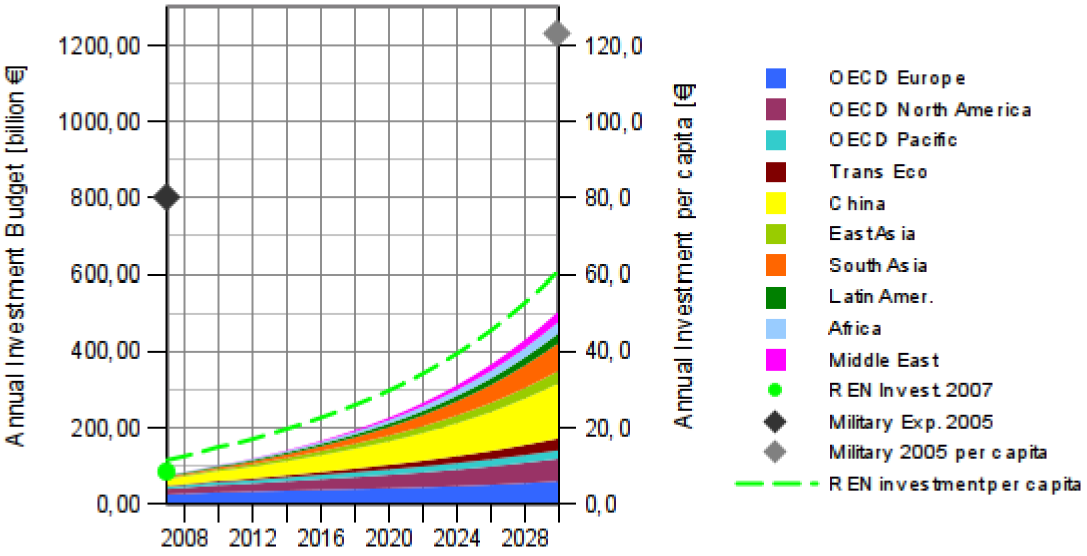


Figure 14: Development of investment budgets in the world regions in the "Low Variant Scenario" [EWG; 2008]. Data on military expenditures: [SIPRI; 2006]. Data on 2007 renewable energy investment: [UPI; 2008].

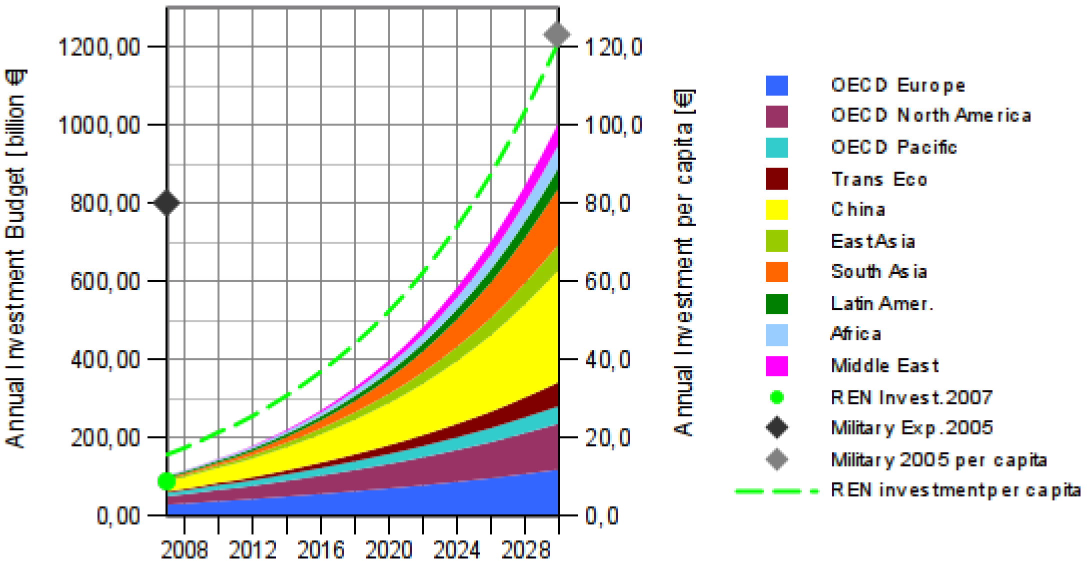


Figure 15: Development of investment budgets in the world regions in the "High Variant Scenario" [EWG; 2008]. Data on military expenditures: [SIPRI; 2006]. Data on 2007 renewable energy investment: [UPI; 2008].

Development of Electricity-Generating Capacities and Electricity Production

High Variant Scenario: General Development in the Global Context

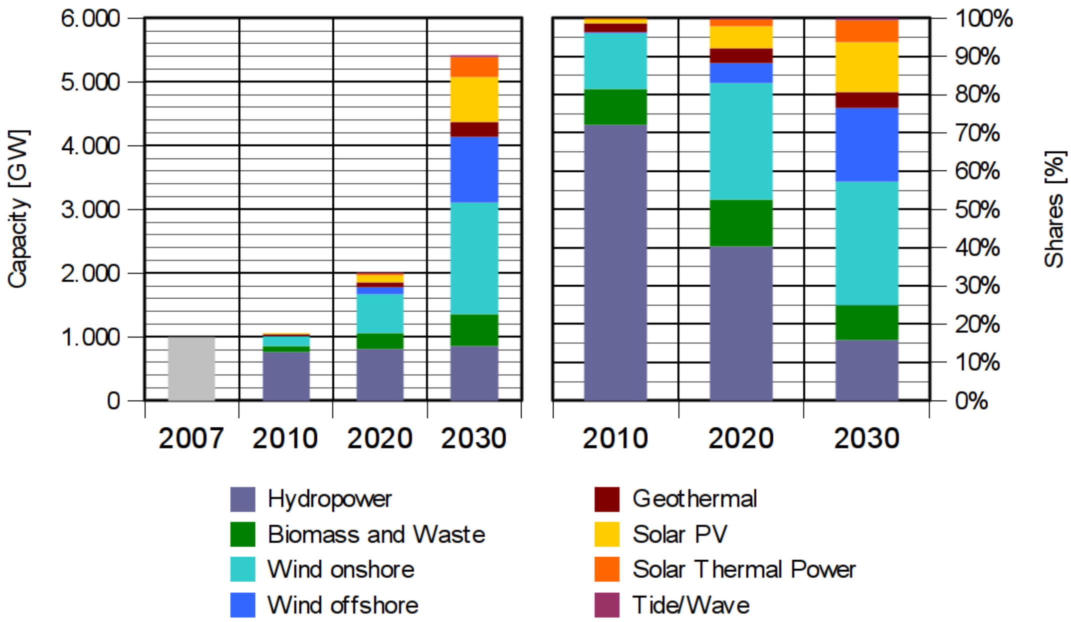


Figure 16: Development of renewable generating capacities in the "High Variant Scenario" on the global scale [EWG; 2007]. Data 2007: [REN 21; 2007]

Analysing the development of generating capacities in the "High Variant Scenario", Hydropower will still be the main contributor to renewable capacities by 2010[12]. Due to the massive extension of "new" renewable capacities (non-Hydropower), this picture changes dramatically during the further development stages. Hydropower's share in generating capacities is more than 70% on the global scale by 2010. Although Hydropower capacities increase by more than 90 GW (from 762 GW by 2010 to 856 GW by 2030), the share drops to 40% by 2020 and to only 16% by 2030. The biggest capacity additions result from the massive extension of Wind Energy[13]. While the total Wind Energy capacity is 156 GW by 2010, this figure grows to about 718 GW by 2020, a growth by a factor of more than 4.5. Until 2030, this capacity grows further to 2,792 GW, which is equivalent to an extension by a factor of almost 4 (2020 to 2030). The share of Wind Energy in total renewable capacities, about 15 % by 2010, increases to more than the half by

12 Although the further extension of hydropower capacities is not a part of the scenarios, planned capacity extensions – known to the working team - are considered in the renewable generating capacity figures. It has to be mentioned here that these planned hydropower extensions are considered as normal investments into energy supply in any of the regions, but they are not part of the investment budgets in the scenarios. In this sense investment budgets in the scenarios are for "new" renewables only.

13 This had to be expected due to the huge Wind Energy potential and the already good price competitiveness of Wind Energy.

2030. Offshore Wind Energy increases more dynamically than onshore Wind. Starting with an onshore/offshore ratio of about 97 % onshore and less than 3 % offshore, this picture subsequently changes substantially. By 2020, offshore Wind Energy already contributes 15 % to the total Wind Energy. After 2020, offshore Wind development even speeds up, so that – in the end – the onshore/offshore ratio is about two-thirds onshore and one third-offshore Wind.

Photovoltaic (PV) shows the second biggest growth in generating capacities, but – although capacity increases by about 690 GW from 2010 to 2030 (11 GW by 2010 and 701 GW by 2030) – this is not enough to reach hydropower's capacity by 2030. As with Wind energy, growth decreases in the second decade of development. While Photovoltaic capacity increases about tenfold from 2010 to 2020, the growth between 2020 and 2030 drops to a factor of just a bit higher than six.

Biomass & Waste, contributing about 100 GW to the renewable capacities by 2010, loses it's third place standing to PV by 2030. Capacity increases to about 245 GW by 2020 and further to 496 GW by 2030, a total capacity addition of almost 400 GW from 2010 to 2030. In terms of factored growth, capacity increases by about 2.5 times from 2010 to 2020, whereas capacity “only” doubles from 2020 to 2030. The development of Biomass's share in total renewable capacity is an exeption to other “new” renewables: While the share increases from about 9 % by 2010 to about 12 % by 2020, there is a decrease in the second decade of development, down to about 9 % again until 2030.

Solar Concentrating Power (SCP),generally insignificant in 2010 (2.4 GW or 0.2 % of renewable capacity), increases its capacity to about 40 GW by 2020, a factor of almost 29 compared with 2010, and to 313 GW by 2030, which is equivalent to a capacity increase by a factor of almost eight between 2020 and 2030. In terms of the SCP's share in of the total renewable generating capacity there is a growth from far less than one percent in 2010 to about six percent by 2030.

Geothermal Energy falls behind Solar Concentrating Power until 2030 on the global scale. Although Geothermal generating capacity is about ten times the capacity of SCP in 2010, the capacity increase to about 224 GW by 2030 results in about 90 GW capacity less than SCP's. Nevertheless, even Geothermal Energy's share of the total renewable capacities increases from slightly more than 2 % in 2010 to about 4 %, though in contrast to most other “new” renewables (except Biomass), there is virtually no further increase in share after 2020.

Tidal, Wave and other Maritimes (shortened as Tidal & Wave) are somehow like a poor cousin in the scenario. Although the capacity increases from almost zero to about 33 GW by 2030, at no point does this technology come close to contributing even one percent of the total renewable generating capacities. This assessment reflects the working team's conviction that these technologies will remain in the prototype and/or testing phase for quite a long while. One obvious difference between the renewable capacities' structure in the OECD and non-OECD regions is the capacity contributed by Wind Energy. While in the OECD region Wind Energy's contribution is almost 60%, this figure is less than 50% in the non-OECD region. As offshore

Wind Energy contributions are the same, the whole difference results from onshore Wind energy capacities.

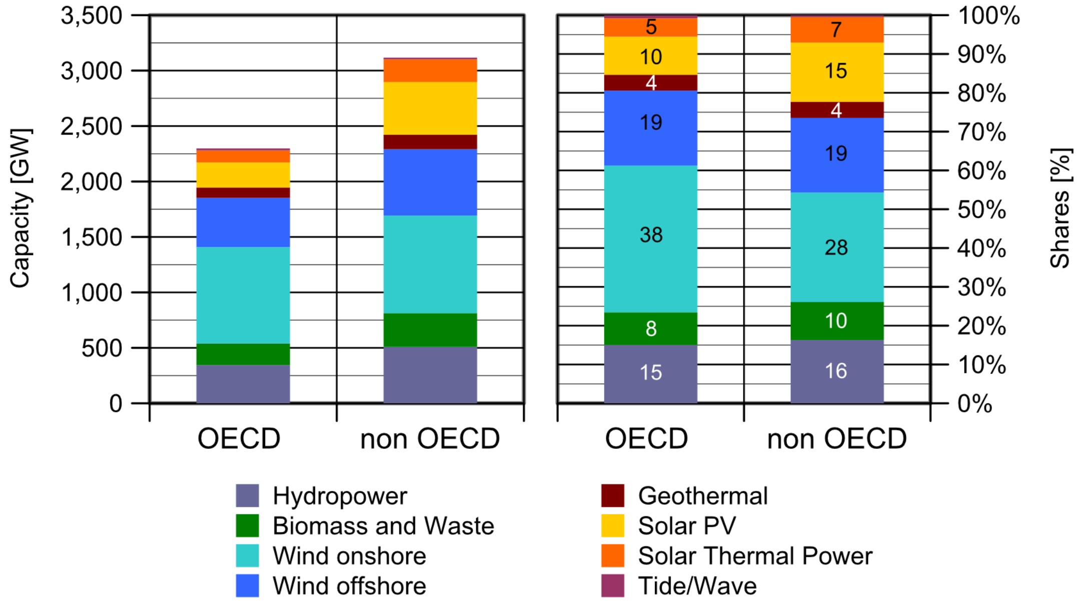


Figure 17: Structure of renewable capacities 2030 compared (OECD and non-OECD) [EWG; 2007].

Another considerable difference emerges from the use of solar energy, resulting from the fact, that many non-OECD countries are in geographical locations with high levels ofsolar irradiation. This comparably high percentage of countries with good solar irradiation in the non-OECD region results in Photovoltaic and Solar Concentrating Power having higher shares of the total renewable generating capacity when compared with the OCED regions. Of course, differences of this magnitude were anticipated.

There are also differences within the OECD regions as well as within the non-OCED regions. The share of Wind Energy in the OECD region (2030), for example, ranges from almost 50% in North America to more than 62% in Europe. In the non-OECD region, this ranges from about one third (Latin America) to about two thirds (Middle East). The low Wind Energy share in Latin America is not due to low investments in this technology, but rather to the extremely high share of Hydropower – this source already being one of the top contributors to the electricity supply and a technology whose expansion is already being planned. Actually, Latin America is a special case in the scenario: Renewables' contribution to the total generating capacity already exceeds that in other regions by far, which is also due to the massive hydropower capacities.

Photovoltaic and Solar Concentrating Power also manifest relatively large differences. The world leader in Solar Concentrating Power in the scenario is the Middle East, with more than 12% of the renewable capacity consisting of SCP (more than 13% for PV). Although the 13% PV in the Middle East has among the highest percentages in the interregional comparison, it is South Asia that has the lead, with PV constituting a massive 27 % of total renewable capacities . The reason for this extraordinary high share is the impressive population density by 2030 (more than 500 inhabitants per square kilometre).

Low Variant Scenario: General Development in the Global Context

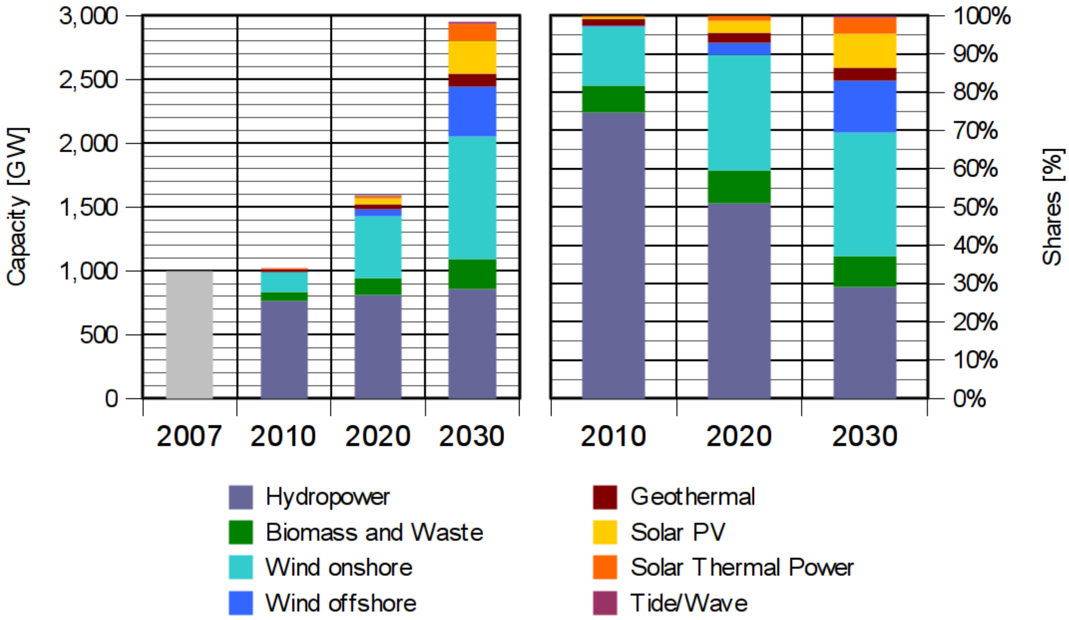


Figure 18: Development of renewable generating capacities in the "Low Variant Scenario" on the global scale [EWG; 2007]. Data 2007: [REN 21; 2007]

The development of generating capacities in the "Low Variant Scenario" shows Hydropower still having a share of more than half of the renewable capacities in 2020 (more than 70% by 2010). Although Hydropower capacities increase by more than 90 GW (from 762 GW in 2010 to 856 GW in 2030), the share drops to less than one third (29%) in 2030 due to the extension of "new" renewable capacities.

The general development of the "new" renewables is very similar to the "High variant Scenario", with the main difference being that the lower investments result in less dynamic development. Wind Energy shows the biggest increase in generating capacity, with 159 GW in 2010 and 1352 GW in 2030 (about 1,450 GW less than in the "High Variant"), Wind Energy contributes about 46% to the total renewable capacities by 2030 (about 15% in 2010). Offshore Wind Energy makes up about 30% of the total Wind Energy capacity (about 2% by 2010).

Photovoltaic (PV) shows the second-biggest growth in generating capacities (an increase of 251 GW, from 7 GW in 2010 to 258 GW in 2030), and takes the second position in terms of generating capacity then, just ahead of Biomass. Photovoltaic's share increases from less than one percent in 2010 to almost nine percent in 2030. Biomass itself grows from about 72 GW in

2010 to about 238 GW by 2030 (an increase of 166 GW), with shares of about 7% in 2010, 8.6% in 2020, and down again to 8 % in 2030.

Solar Concentrating Power (SCP), negligible in 2010 (2.4 GW or 0.2% of renewable capacity), increases to about 20 GW by 2020 and to 128 GW by 2030. SCP's share grows from far less than one percent in 2010 to slightly more than four percent by 2030.

Geothermal Energy falls behind Solar Concentrating Power until 2030 on the global scale. Although Geothermal generating capacity is about ten times the capacity of SCP in 2010, the capacity increase to about 102 GW by 2030 results in almost 30 GW less capacity than SCP. Nevertheless, the share of Geothermal Energy increases from slightly less than 2% in 2010 to three-and-a-half percent by 2030.

Tidal, Wave and other Maritimes (shortened as Tidal & Wave), which show a capacity increase to about 16 GW by 2030 (less than one GW in 2010), steadily contribute far less than one percent to the renewable generating capacities. The biggest difference among the structures of renewable capacities in the OECD and non-OECD regions is the capacity contributed by Wind Energy, Hydropower and Photovoltaic. While the OECD region sees a Wind Energy contribution of almost 55%, this figure is less than 40% in the non-OECD region. Hydropower makes up for one third of the renewable capacities in the non-OECD region, while this figure is one fourth in the OECD region. Photovoltaic's contribution to capacities in the non-OECD countries is about double its share in the OECD countries (6% OECD, 11% non-OECD).

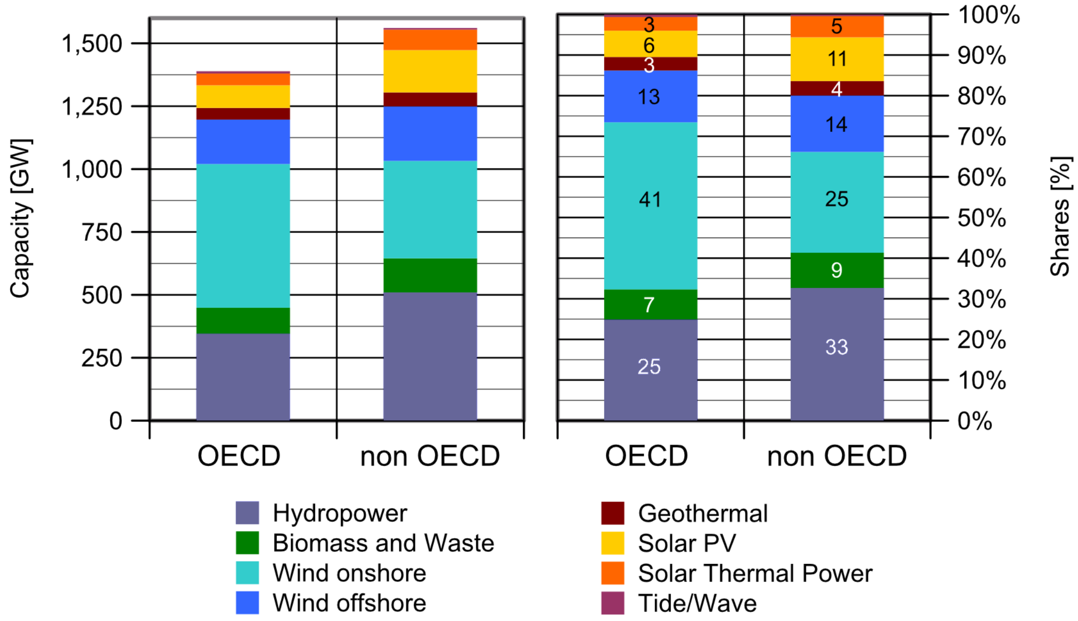


Figure 19: Structure of renewable capacities 2030 compared (OECD and non-OECD) [EWG; 2007].

Differences within the OECD and the non-OCED region are very similar to those described earlier in the "High Variant" section (see also "differences and specifics" in the "High Variant" section and the detailed description of the individual regions in the annex).

Electricity production in the "High Variant" Scenario

Naturally, energy production from renewables increases with growing generating capacities. However, the relation of generating capacities does not reflect the relation of energy production, as some technologies are more productive than others. Wind energy, for example, is less productive than Biomass or Geothermal energy. Relatively low productivity is more an attribute of fluctuation suppliers, i.e. wind energy and solar energy. Thus the predominance of wind energy in production capacities is not reflect the same way in the production figure.

Altogether, renewables in the "High Variant Scenario" provide about 4,000 Terrawatt-hours (TWh) of electricity by 2010. The production increases further to about 6,200 TWh by 2020 and to about 15,500 TWh by 2030[14].

The biggest producers by 2030 are Wind Energy, Hydropower and Biomass. Onshore Wind Energy production is slightly higher than electricity generation from Biomass (2,500 TWh from Biomass and more than 2,600 TWh from onshore Wind) but offshore Wind tops both by about

14 Although Hydropower is not part of the investment budgets, Hydropower's electricity production is considered as it is a renewable contribution to energy supply.

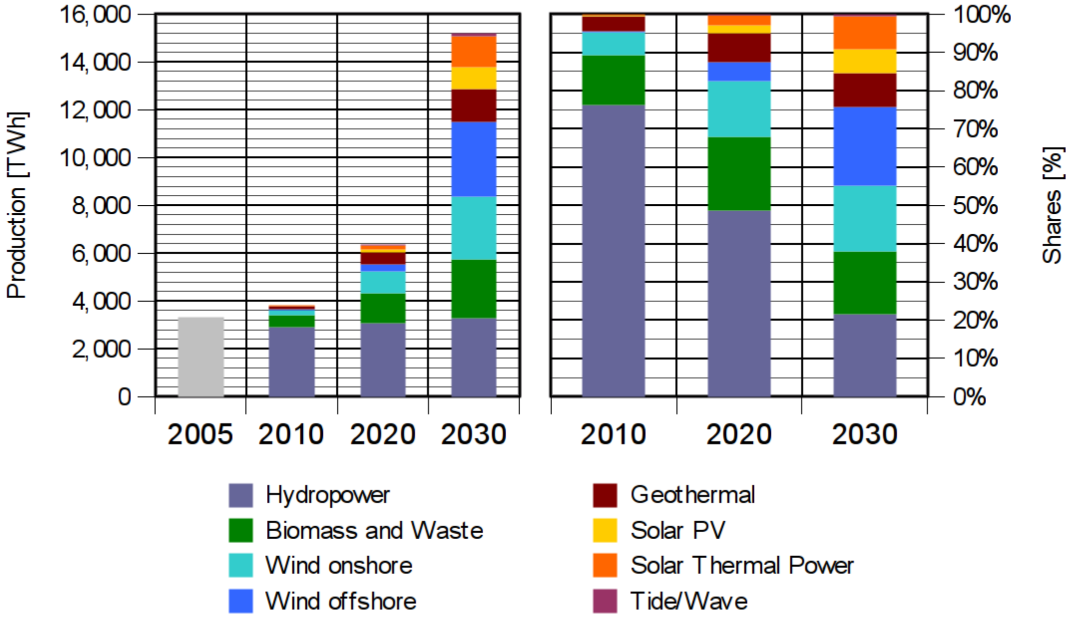


Figure 20: Development of electricity production from renewables in the "High Variant Scenario", 2010 to 2030 [EWG; 2007]. Data 2005: [IEA; 2007b]

500 TWh. Without Hydropower, the electricity generation from "new" renewables increases from about 900 TWh by 2010 to almost 12,000 TWh by 2030 (Figure 20).

The shares of Wind Energy and Photovoltaic in electricity generation do not reflect their shares in capacity, while the contributions of Hydropower, Biomass, Geothermal and Solar Concentrating Power are substantially higher than what could be expected if only looking at capacities.

Electricity Production in the "Low Variant" Scenario

Altogether renewables in the "Low Variant Scenario" provide about 3,600 terrawatt-hours (TWh) electricity in 2010. The production increases further to about 5,000 TWh by 2020 and to about 8,600 TWh by 2030 (Figure 21).

The biggest producers in 2030 are Wind Energy, Hydropower and Biomass. Offshore Wind Energy alone is on par with Biomass in terms of electricity generation. Without Hydropower, the electricity generation from "new" renewables increases from about 725 TWh in 2010 to more than 5,300 TWh by 2030.

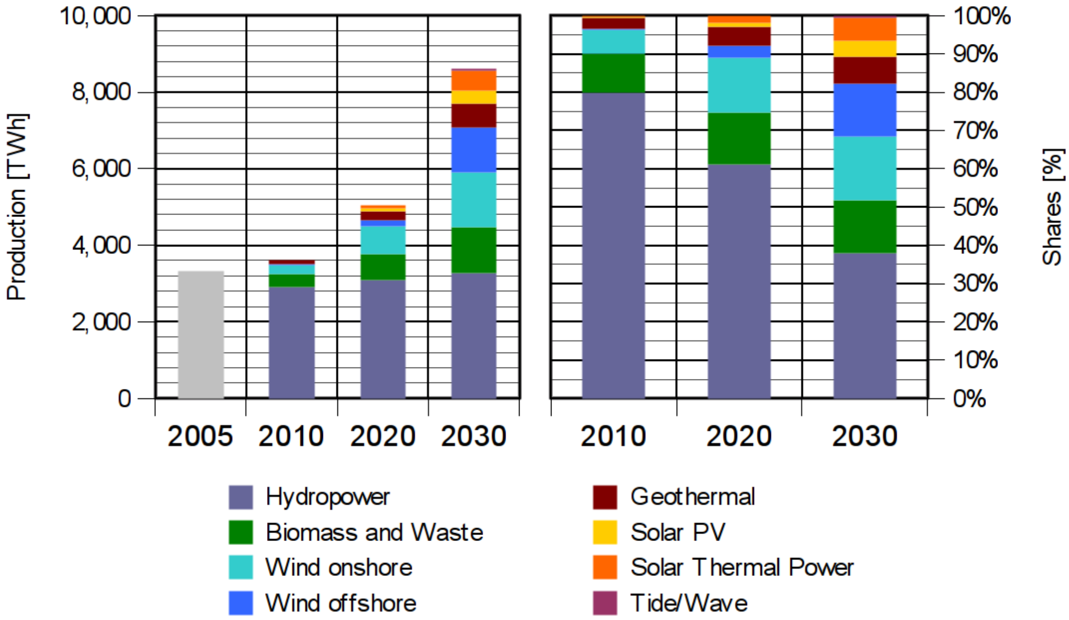


Figure 21: Development of electricity production from renewables in the "Low Variant Scenario", 2010 to 2030 [EWG; 2007]. Data 2005: [IEA; 2007b]

Development of Final Energy Supply

As the focus so far has been on electricity, it appears appropriate here to offer some information about heat, which is also an essential part of the scenarios. Heat production in the scenarios stems from Solar Thermal Collector systems on the one hand and from Biomass & Waste facilities and Geothermal cogeneration plants on the other. The related final energy figures, presented later in this chapter refer to this heat production as REN heat.

The "REO 2030" scenarios use the IEA's predictions of energy demand to calculate the shares in final energy supply in the scenarios. Reference tor rating energy production by renewables is final energy. Please also see the section on primary energy (page Fehler: Referenz nicht gefunden) for an explanation why these figures have not been used in this work.

Final Energy Demand in the WEO 2006, Alternative Scenario

According to the projection given by the "Alternative Policy Scenario" in the IEA's "World Energy Outlook 2006", the global final energy demand is set to rise to over 122,600 TWh[15] (Terrawatt-hours) until 2030. OECD countries alone account for about 43% of this number.

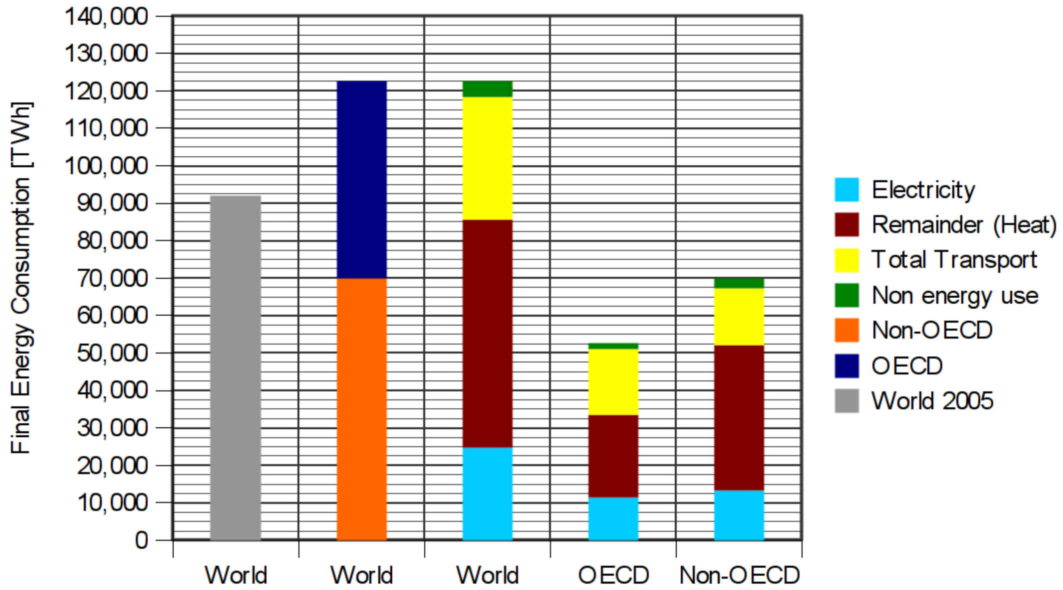


Figure 22: Global Final Energy consumption in OECD and in non-OECD countries. Data :[IEA; 2006]

In regard to the composition of final energy consumption, heat demand is responsible for half the final energy consumption, but this also comprises traditional biomass use, especially in the non-OECD countries. This is probably one good reason for the varying shares of heat in the OECD

15 This is more than 10,500 million tons of oil equivalent (Mtoe), with 1 Mtoe being 11.63 TWh

and non-OECD (42% OECD, 56% non-OECD). There are also significant differences in the transport sector's shares that might well be explained by the structural differences. While transport consumes one third of the final energy in the OECD, it is a bit more than one fifth in the non-OECD lands. Electricity shares are about the same: approximately one fifth (22% OECD; 19% non-OECD).

With regard to final energy demand development, the IEA projection suggests an increase by almost 40% from 2004 to 2030.

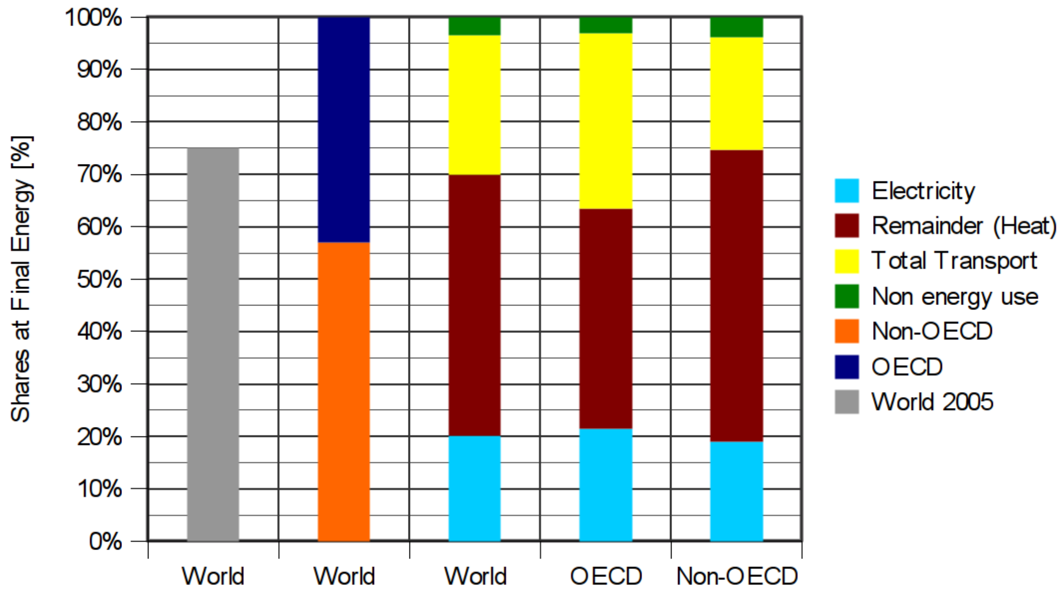


Figure 23: Distribution of final energy consumption between the OECD and non-OECD region and shares of electricity, heat, transport and non-energy use. Data converted from [IEA; 2006], [IEA; 2007a].

Although the working team has reservations regarding the IEA World Energy Outlook's view of the development of energy demand, it was taken as a reference to keep the "REO 2030" scenarios comparable to the ones published by the IEA.

Shares of Final Energy Supply in the "High Variant" Scenario

The figures for electricity and heat result in a total of approximately 25,000 TWh of energy production in the "High Variant Scenario"; about 15,200 TWh of that is electricity and about 9,800 TWh is heat (Figure 24). This is sufficient to boost renewables' share in final energy to somewhat less than one third (29%) until 2030. With regard to absolute energy production from renewables, this is significantly less in the OECD (9,130 TWh) than in non-OECD countries (15,830 TWh). (Figure 24 and Figure 25)

According to the scenario results, 54% of electricity and 13% of heat will stem from renewable sources in the OECD countries in 2030. This is significantly different in the non-OECD areas:

renewables contribute more than two thirds to final electricity demand (68 %) but only slightly less than one fifth to heat demand (17 %). Putting this together, the "High Variant Scenario" results point out that in 2030 almost 62 % of electricity will originate from renewable sources on the global scale but less than one fifth (16 %) of heat.

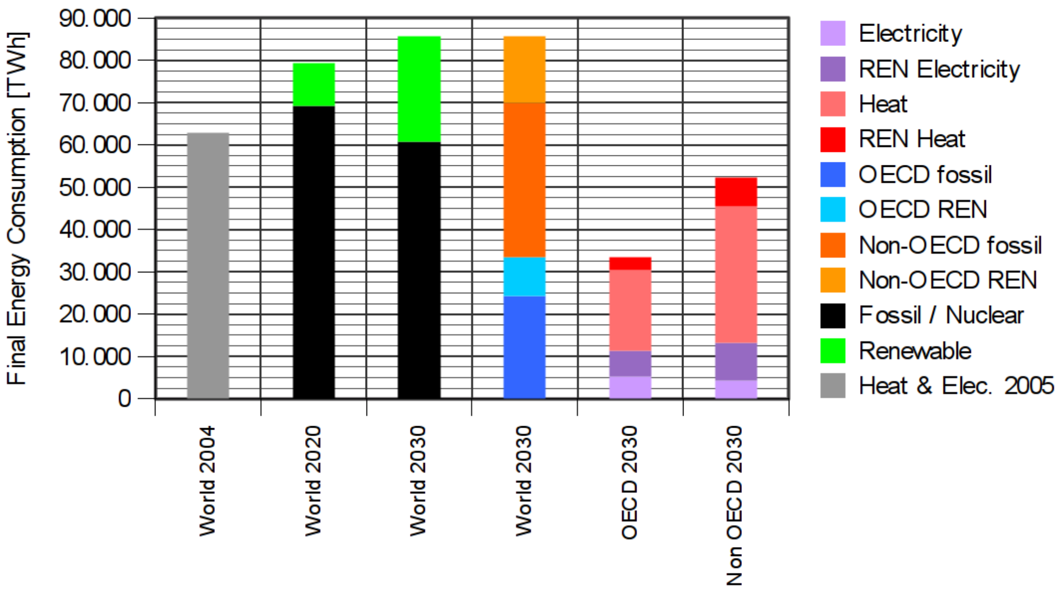


Figure 24: Renewable energy production in the "High Variant Scenario" in 2030 [EWG; 2008]. Data on energy demand converted from [IEA; 2006], [IEA; 2007a].

Although the absolute production from renewables differs in the OECD and non-OECD regions, the regional shares of renewables are comparable to a significant degree. In both regions renewables contribute about thirty percent to final energy demand (OECD 27%, non-OECD 30%)

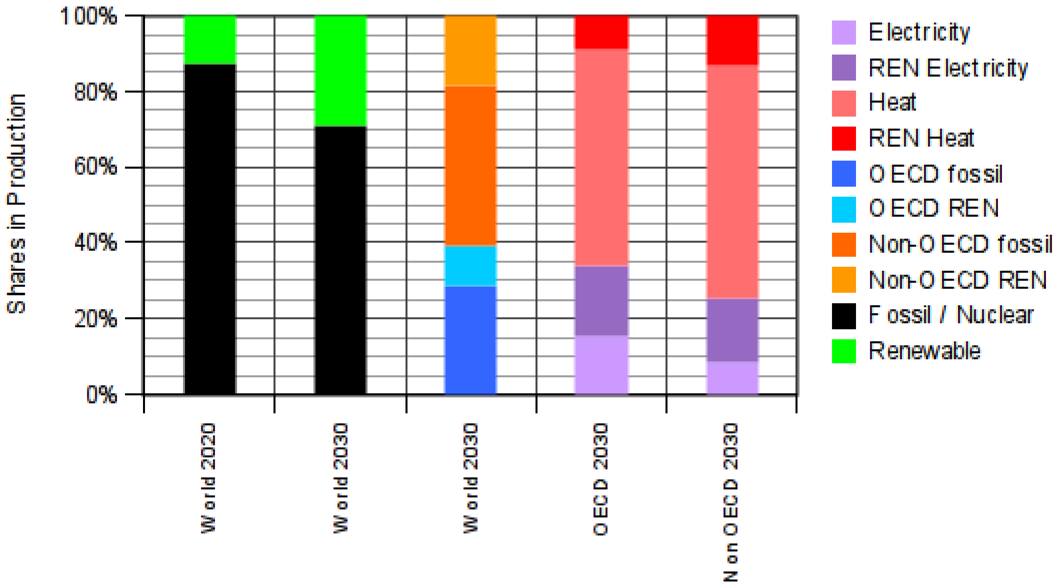


Figure 25: Renewable shares at final energy in the "High Variant Scenario" in 2030 [EWG; 2008]. Data on energy demand converted from [IEA; 2006], [IEA; 2007a].

Shares of Final Energy Supply in the "Low Variant" Scenario

The relation between the regions is quite similar to the "High Variant Scenario". An exception is the heat sector: the relatively low investments considered in the "Low Variant Scenario" led to the decision to favour the heat sector, in contrast to the "High Variant Scenario". Hence in this assessment, renewable shares in the heat sector do not decrease that much as in the case of electricity.

The total 2030 energy production from renewables amounts to about 14,900 TWh in the "Low Variant Scenario", of this electricity accounts for about 8,600 TWh and heat for 6,300 TWh heat (Figure 26). In relation to the "High Variant Scenario", this is a reduction of about 43 % in electricity generation and about 36 % in heat production[16].

As observed in the "High Variant", in the "Low Variant Scenario", too, the OECD and non-OECD regions differ in their absolute energy production from renewables, the gap, however, is somewhat less (5,600 TWh in OECD and 9,300 TWh in non-OECD). In both regions, renewables contribute about 17 (OECD) to 18 (non-OECD) percent to final energy supply, and the two regions together can supply 17% of the global final energy demand from renewables. (Figure 26 and Figure 27)

16 It has to be noted here, that electricity generation also includes hydropower, which is not a part of the investment budgets here. Not considering hydropower, the production from "new" renewables reduces by far more than the half.

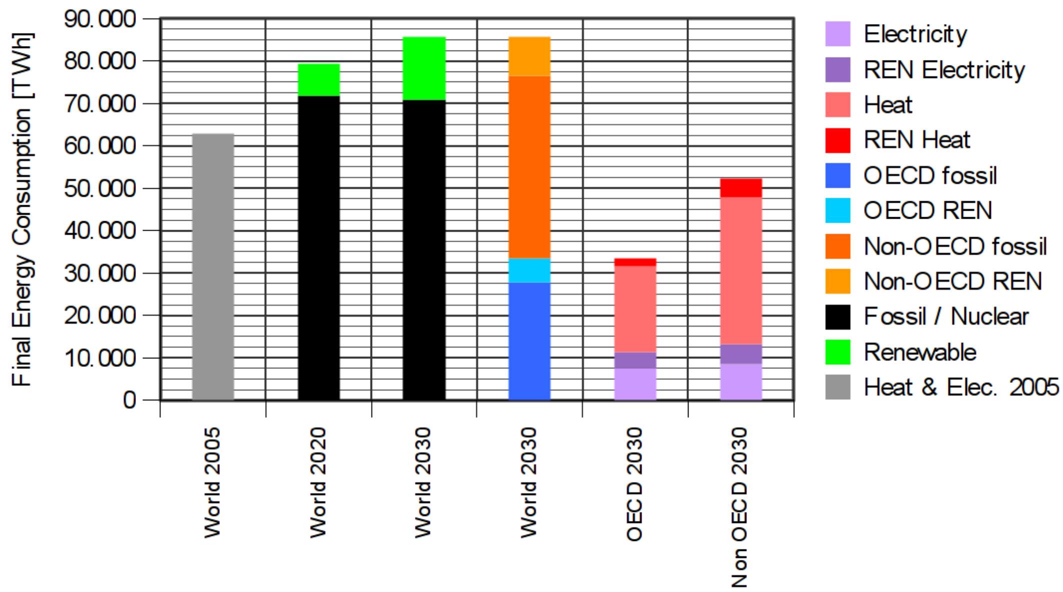


Figure 26: Renewable energy production in the "Low Variant Scenario" in 2030 [EWG; 2008]. Data on energy demand converted from [IEA; 2006], [IEA; 2007a].

A lower share of electricity and heat is supplied by renewables in the OECD region than in the non-OECD. In the former, one third of the final electricity and about 8% of the final heat demand will come from renewable technologies in 2030. The results for the non-OECD region show that almost 37% of electricity demand and about 11% of heat can be covered by renewable technologies.

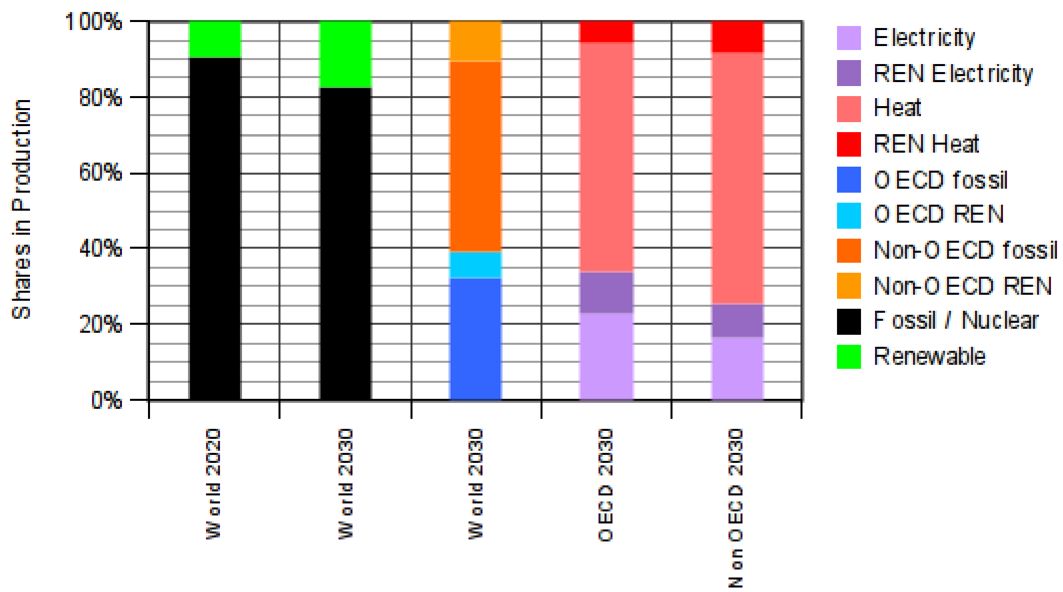


Figure 27: Renewable shares at final energy in the "Low Variant Scenario" in 2030 [EWG; 2008]. Data on energy demand converted from [IEA; 2006], [IEA; 2007a].

With regard to the global picture of electricity and heat supply in 2030, the ”Low Variant Scenario” achieves a 35% share in final electricity and about 10% in final heat.

Why This Study Does Not Show Primary Energy Figures

The working team decided not to show primary energy figures, as these statistics always contain conversions of final energy into an equivalent amount of primary energy, which themselves comprise assumptions of how to convert e.g. nuclear power or electricity from renewable sources. Primary energy balances usually adopt a factor of three to convert nuclear power into primary energy (i.e. a plant efficiency of 33%), and a factor of one for the conversion of renewable electricity.

In our opinion, this approach is not only inconsistent but also unfair in judging the renewable contribution to energy supply. If renewables contribute to primary energy supply in official statistics, why is only their final energy production considered? Wouldn't it be better to express the renewables' contribution as primary energy savings, since, in fact, it is primary energy consuming technologies that the renewables are replacing? The previous commonly used substitution approach tried to express the amount of primary energy that would have been necessary to produce an equivalent amount of electricity by conventional fossil plants. However, the accuracy of this approach can be questioned because an average fossil plant efficiency has to be assumed in order to convert renewably produced electricity into its primary energy equivalent. How can this problem be dealed with in scenarios involving middle to long-range projections? Isn't it a great deal of guessing brought into play if we try to predict an average global plant efficiency for 2030? Furthermore, if we are able to predict plant efficiency relatively precisely, will it not be the case that renewables replace less-effective plants first?

However, energy from renewable technologies will render a fraction of the previously used plants – or plants that might be projected – unnecessary, regardless of whether they use fossil fuel or nuclear-powered facilities., Thus, it will reduce the consumption of primary energy in comparison to a system without renewables.

The figure below (Figure 28) gives an overview of how the electricity production in the ”High Variant Scenario” (15,189 TWh) can be assessed under different assumptions: The dark blue bar (final energy) represents the conversion of green electricity into its primary energy equivalent as used today, even for such technologies as photovoltaic and wind energy. The other bars demonstrate assumptions of the primary energy requirements for producing identical amounts of electricity using various technologies.

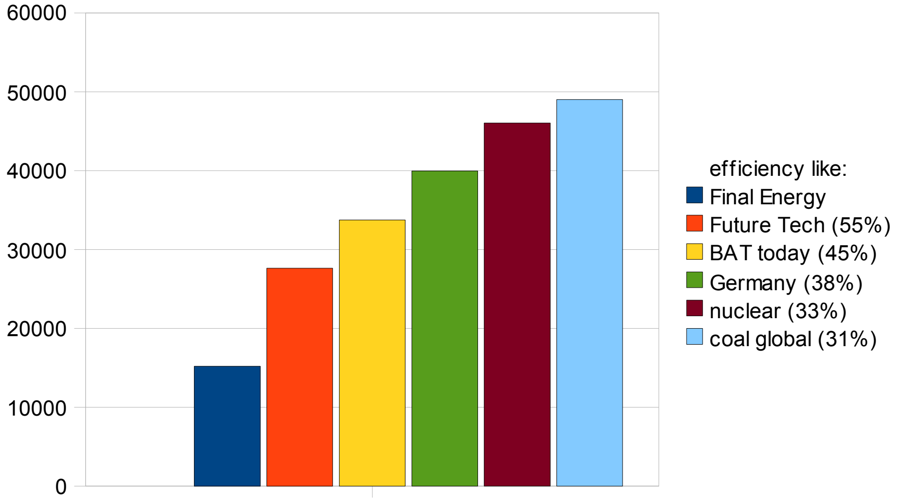


Figure 28: Converting electricity from renewable technologies into primary energy, different assumptions off plant efficiencies. [EWG; 2008]

Reality Check

One might ask the question: Could all these investments into renewables actually ever be made? To give an answer to this question it might be helpful to compare the total investments in the scenarios – i.e. summing up all investments from 2007 to 2030 – to actual expenditures in other sectors or for targets beside a clean energy supply. A simple illustration: Global military spending in 2005 totalled about 799 billion euros. Assuming that this figure will remain stable from 2007 until 2030, the resulting cumulative outlays can be compared meaningfully to the expenditures in the scenarios. If we take these military expenditures as 100%, 72% of this amount would be sufficient to realise the development described in the ”High Variant Scenario”. In relation to the ”Low Variant”, an amount equal to only about half of the military outlay would be adequate.

The Earth's life-support system is being affected by anthropogenic climate change. The severe consequences of this change, which is closely related to the way we satisfy our energy needs, is THE greatest threat facing humankind today. The authors of this report recommend that people the world over begin to ask themselves seriously whether the investments necessary to address these issues are not as worthwhile and productive as the money put into military matters.

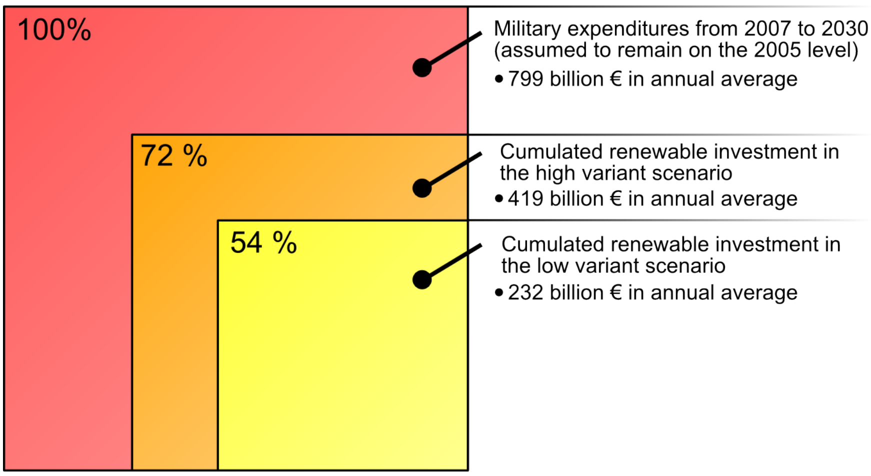


Figure 29: Comparison of Military expenses and the cumulated investments in the scenarios [EWG; 2008]. Data on military expenditures [SIPRI; 2007]

Another question that might arise relates to production capacities. Is it possible to extend production capacities in order to achieve an increase in generating capacities as described in the scenarios? Here again, comparing the scenario figures to our contemporary world can serve as a basis for people's own judgement.

The PV capacity added in the ”High Variant Scenario” in OECD Europe in 2030 is about 11,300 MW, which equals the output of about 78,000,000 m2 of solar cells at an efficiency of 15%. Assuming that all countries in OECD Europe install the same capacity per inhabitant, the

German share in capacity additions would be about 1,766 MW or about 11,773,333 square meters of solar cells. The production of insulating glass in Germany in 2005 was about 23,233,000 square meters, or about double the surface area seen as required for newly installed PV in 2030. Even considering the whole OECD Europe, the German insulating glass production in 2005 was already about 30% of the PV area to be installed in OECD Europe in 2030.

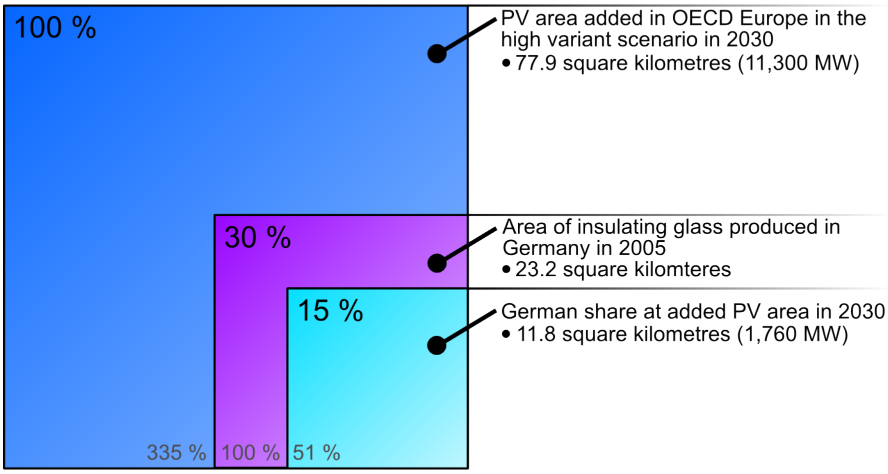


Figure 30: Added PV capacity in 2030 (High Variant) compared to insulation glass production in 2005 [EWG; 2008] Data on insulation glass production: [Destatis; 2005;]

Taking the German 2005 production of insulation glass as the 100% reference (grey, smaller numbers), the PV area added in Germany under the assumptions in the ”High Variant Scenario” equals about 51%. The PV area added in the whole of the OECD Europe region in 2030 (”High Variant Scenario”) is no more than about 3.3 times the German insulation glass production of 2005 (335%).

Only considering the installed capacities (1,766 MW in Germany in 2030), the new installed capacity in Germany in 2006 was 750 MW [BSW; 2007] and more than 1,100 MW in 2007 [Systeme Solaires; 2008], which is about 42% (2006) and 62% of the additions in the ”High Variant Scenario” in 2030.

The capacity of wind power plants added in OECD Europe in the ”High Variant Scenario” in 2030 is about 46,800 MW or 15,600 plants with 3 MW per plant (onshore and offshore). The German contribution would be about 7,070 MW or about 2,360 plants, if all countries in OECD Europe install the same amount per inhabitant. The highest annual added capacity in Germany has been about 3,247 MW or 2,328 plants [BWE; 2008], which is about the same number of plants and about 2.2 times the capacity already installed in Germany within one year.

Today's the global automobile production is about 65 million passenger cars per year and is set to rise to about 80 million by 2013 [PAWO; 2007]. Assuming an average power per car of 100 kW, the annual produced cars have a total output of 6,500 GW. This is about 1.2 times the capacity of the cumulative global generating capacity of all renewables including (predominantly already existing) Hydropower (5,415 GW) in the ”High Variant Scenario” by 2030.

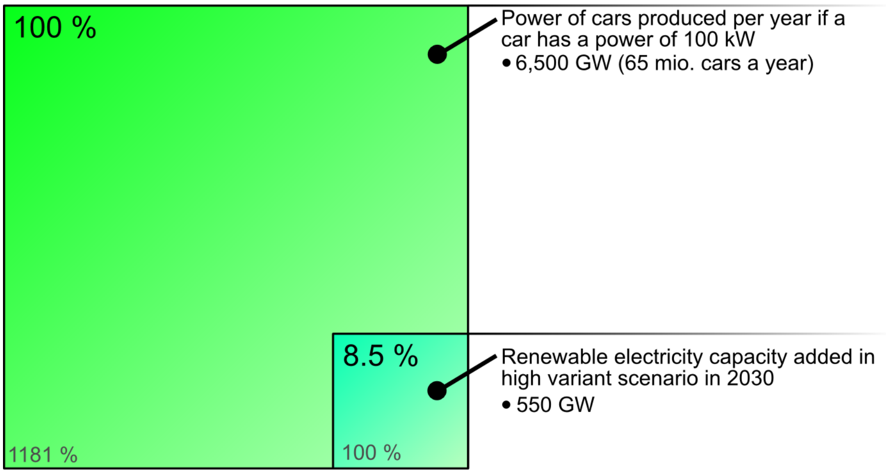


Figure 31: Power of cars produced pear year (today) compared to added renewable electricity generating capacity in the High Variant scenario in 2030 [EWG; 2008]. Car production: [PAWO; 2007].

The renewable electricity generating capacity added in 2030 in the “High Variant” scenario is 550.4 GW, which is less than one tenth of the actual power of car engines installed in cars produced in one year, or about the same power as Germany's annual automobile output.

Annex

Baseline data

Population and Population Development and land areas

For the scenarios data of the land area, the current population and population projections until 2030 is used. Data was taken from the U.S. Census Bureau International Data Base (http://www.census.gov/ipc/www/idb/idbsprd.html). Level of aggregation is countries. [U.S. Census; 2007]

Coastal lengths

The coastal length of the countries was taken from the "index mundi" country profiles (http://www.indexmundi.com). Level of aggregation is countries.

Gross Domestic Product

GDP data from the UN Statistic Division is used for scenario development (United Nations Statistic gation Division, GDP at current prices, http://unstats.un.org/unsd/snaama/dnllist.asp). Aggregation Level of data is countries. To get an impression of what the investment figures might mean by 2030, different GDP projections are used for comparing investment budgets to the regions GDP.

Current installed renewable capacities

The currently installed capacities of renewable energy technologies and the historical development was taken from different sources:

Wind Energy:

- British Petroleum Energy Statistics (http://www.bp.com/liveassets/bp_internet/globalbp/globalbp_uk_english/publications/energy_reviews_2006/STAGING/local_assets/downloads/pdf/table_of_cumulative_inst_wind_turbine_capacity_2006.pdf).
- EREC ("Renewable Energy Sources -the solution for the future", Prof. Arthouros Zervos, European Renewable Energy Council, Dinner debate, European Energy Forum, European Parliament, Brussels, Monday 24 January 2004),
- Bundesverband Windenergie, data for Germany (www.wind-energie.de)

Biomass & Waste

- Data of installed capacities in 2002 was taken from the IEA's World Energy Outlook 2004.

Geothermal Energy

- Data about geothermal energy use was taken from British Petroleum Energy Statistics (Geothermal Power by Country, 1990 – 2005), based on data by International Geothermal Association, papers presented at the World Geothermal Congress 2005.

Solar photovoltaic

- Data of photovoltaic use was taken from The International Energy Agency's Photovoltaic Power Systems Programme (PVPS, “TRENDS IN PHOTOVOLTAIC APPLICATIONS Survey report of selected IEA countries between 1992 and 2003”, International Energy Agency; 2004).

Solar thermal collectors

- Data on solar thermal collectors was taken from Renewable Energy Policy Network for the 21st Century, Renewables - Global Status Report 2005 and Update 2006)

Solar Concentrating Power

- Data on Solar Concentrating Power Plants was taken from the International Energy Agency's “Renewables Information”, 2003 Edition.

The Regions in detail

Generating capacities, production and investments in the "High Variant Scenario"

OECD Europe

Assumptions

The target for investments into new generating capacities in OECD Europe is 22 €$_{2006}$ per capita, which effectively – due to iterative calculation – result to 223 €$_{2006}$ per capita. Considering the projected changes in population this results to a total investment budget of about 121 billion €$_{2006}$ in 2030.

The distribution of investments among the different technologies is dominated by Wind Energy (about 35% in total, 10.5 % for onshore and 24.3 % for offshore). Second biggest share goes to Solar Thermal Collectors (16.2%), followed by Photovoltaics (14.5 %), Solar Concentrating Power (11 %), Biomass (10.6%), Geothermal Energy (9.2 %) and Tidal, Wave & other Maritim, with 3.7 %.

Although Wind Energy has the biggest investment shares in total, Photovoltaic, Solar Concentrating Power and Biomass – on the side of electricity producing technologies – all have higher investment shares than onshore Wind Energy alone.

OECD Europe, investment budgets and distribution of investments								
Population			**No. of inhabitants (Mio.)**			**Population density (cap/sqkm)**		
			542.8			111.5		
Investment 2030			**Target**			**Reached by iteration**		
Budget per capita			220 €$_{2006}$			223 €$_{2006}$		
Total investment budget						121 billion €$_{2006}$		
Wind onshore	**Wind offshore**	**Wind total**	**Biomass**	**Geothermal**	**PV**	**Solar Concentrating Power**	**Tide & Wave**	**Solar Collectors**
Shares of the different technologies (%)								
10.5%	24.3%	34.8%	10.6%	9.2%	14.5%	11.0%	3.7%	16.2%
Total investment into technologies (billion €$_{2006}$)								
12.69	29.35	42.05	12.81	11.15	17.58	13.32	4.44	19.58

Table 8: Scenario assumptions for OECD Europe in the high variant scenario [EWG; 2008].

Electricity

OECD Europe	Capacity (GW)		
Technology	**2010**	**2020**	**2030**
Total Renewables	**279.0**	**555.3**	**1098.3**
Hydropower	150.3	150.3	150.3
Biomass and Waste	20.8	42.8	74.5
Wind onshore	96.7	271.0	452.4
Wind offshore	3.0	41.6	232.5
Geothermal	3.7	14.1	35.7
Solar PV	4.1	29.9	112.5
Solar Thermal Power	0.1	3.6	32.0
Tide/Wave/Maritim	0.3	1.9	8.4

Table 9: Development of renewable electricity generating capacity in the OECD Europe region (“high variant”) [EWG; 2008].

The development of generating capacities in OECD Europe shows a massive extension until 2030. New renewables (non-hydro), making up less than the half of renewable capacities in 2010, overtake hydropower between 2010 and 2020 and – by 2030 – exceed hydropower's generating capacity by far. Although all new renewables show a massive growth in capacity, it is Wind Energy to outperform all other technologies. Especially offshore Wind Energy shows a massive increase after 2010. By 2030 more than 60% of the total renewable generating capacity is Wind Energy, another massive ten percent is made up by Photovoltaic. Although Geothermal Energy shows a significant stronger growth than Biomass & Waste, it still has only about the half generating capacity by 2030. Solar Concentrating Power reaches a capacity comparable to the one of Geothermal Energy. Tidal, Wave and other Maritimes do only show moderate growth and still contribute less than 1 % to the total renewable capacity by 2030.

Altogether renewable generating capacity in the "High Variant Scenario" increases to about 280 GW by 2010, further to 555 GW in 2020 and to about 1,100 GW in 2030. The capacity contributed by hydropower, assumed to be 150 GW over the whole period, drops from 54 % in 2010 to 27 % in 2020 and 14 % in 2030.

Wind Energy shows the biggest increase in generating capacities. Starting with almost 100 GW in 2010 (with 3 GW of that being offshore), the capacity reaches about 685 GW in 2030. The distribution between onshore Wind and offshore Wind is about two thirds to one third (452 GW onshore and 233 GW offshore). Solar Photovoltaic capacity in 2010 is about 4 GW, with an increase to about 30 GW by 2020 and 113 GW in 2030. This makes PV the second biggest contributor in terms of capacity by then. Another big contribution comes from Biomass, with 75 GW in 2030; increasing from 21 GW in 2010 and 43 GW in 2020. Geothermal Energy and Solar Concentrating Power (SCP) both contribute about the same capacity by 2030 (36 GW Geothermal and 32 GW SCP), with the difference that SCP is merely visible in 2010 (100 MW), while the Geothermal generating capacity is already about 4 GW by that time. Tidal, Wave and other Maritimes, considered being prototype technologies now, increase to slightly more than 8 GW by 2030.

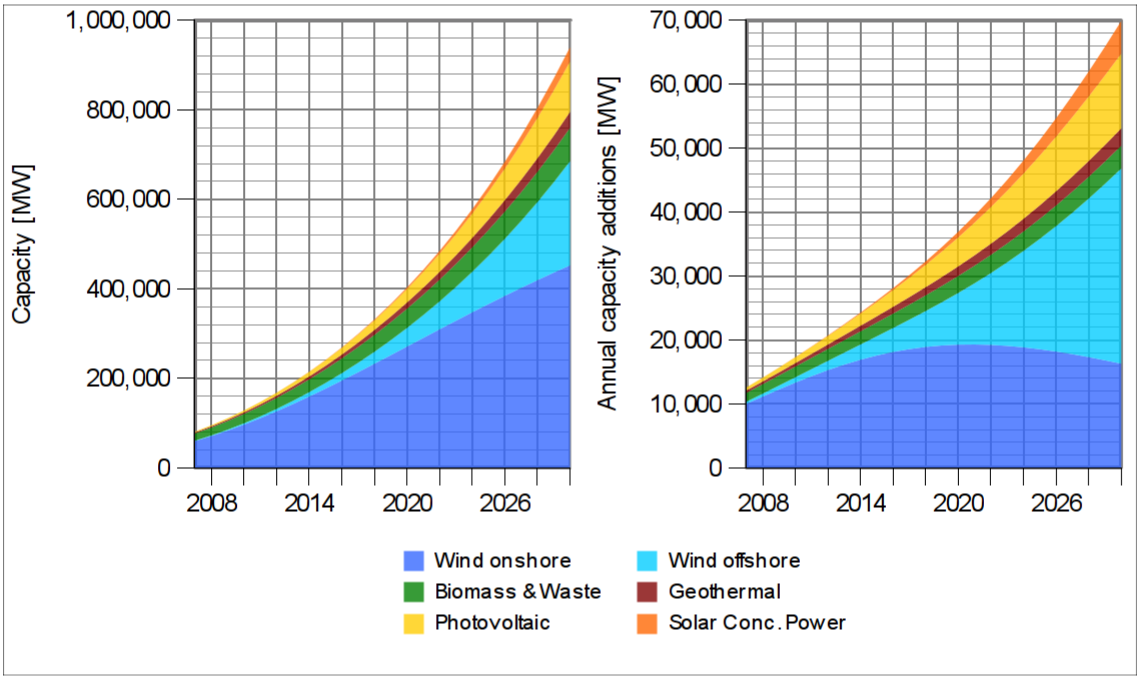


Figure 32: Development of renewable electricity generating capacity in OECD Europe ("High Variant") [EWG; 2007].

Heat

A considerable part of the heat generating capacities are connected to the electricity generating capacities, as they result from cogeneration plants using Biomass & Waste and Geothermal Energy as well.

OECD Europe	Capacity (GW)		
Technology	**2010**	**2020**	**2030**
Total Renewable Heat	**73.9**	**240.4**	**534.5**
Biomass Heat	17.3	35.7	62.0
Geothermal Heat	5.0	19.0	48.2
Solarthermal Collectors	51.6	185.8	424.2

Table 10: Development of renewable heat generating capacity in the OECD Europe region (“high variant”) [EWG; 2008].

While the Biomass heat generation capacity increases from 17 GW in 2010 to 62 GW in 2030, a smaller proportion results from Geothermal cogeneration (5 GW in 2010 to 48 GW in 2030).

Most heat generation capacity results from Solar Thermal Collector systems. In 2010 there already is a generation capacity of about 52 GW which increase to a massive 424 GW by 2030. Altogether there is a renewable heat generation capacity of 535 GW in 2030.

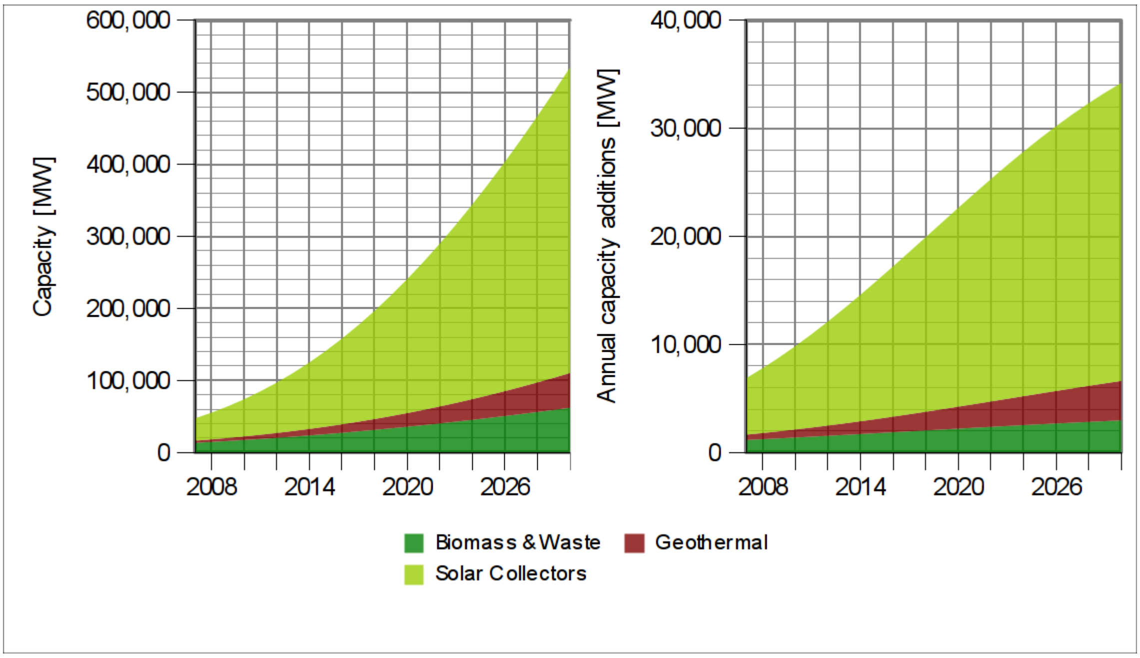


Figure 33: Development of renewable heat capacities in OECD Europe ("High Variant") [EWG; 2008].

Investment budget

The figure below shows the development of annual investments into renewable capacities (left hand side) and the development of shares the different technologies have at total investments (right hand side).

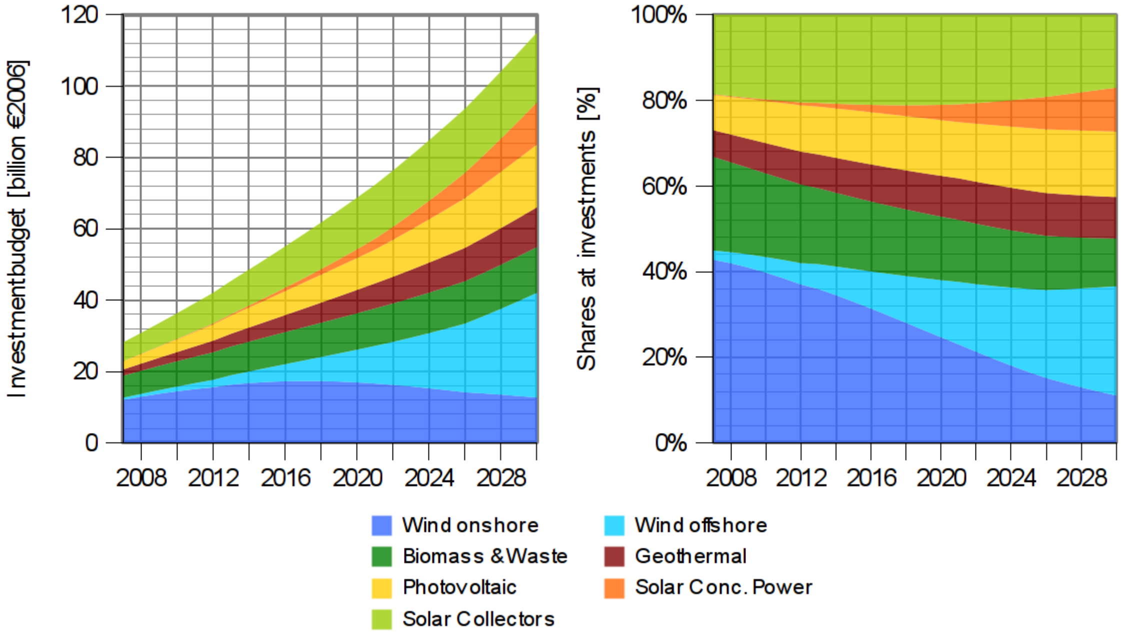


Figure 34: Development of the renewable energy investment budget in OECD Europe ("High Variant") [EWG; 2008].

<u>OECD North America</u>

Assumptions

The target for investments into new generating capacities in OECD North America is 220 $€_{2006}$ per capita, which was well met by iterative calculation. Considering the projected changes in population this results to a total investment budget of about 118 billion $€_{2006}$ in 2030.

The distribution of investments among the different technologies is dominated by Wind Energy (about 36% in total, 15.6 % for onshore and 20.1 % for offshore). Second biggest share goes to Solar Thermal Collectors (16.4%, higher than onshore Wind energy alone), followed by Biomass (13.3 %), Solar Concentrating Power (11.7 %), Photovoltaic (11%), Geothermal Energy (8.6 %) and Tidal, Wave & other Maritim, with 3.4 %.

The distribution is similar to that in OECD Europe, with of Wind Energy having the highest investments by far. Differences especially lie within the distribution between onshore Wind Energy and offshore installations, with onshore Wind showing a higher fraction than in the OECD Europe region. The investment share of onshore Wind Energy exceeds the shares off all other non-Wind electricity generating technologies. Investments into Biomass are higher than in OECD Europe too. Due to the huge potentials for Solar Concentrating Power, this technology is of higher significance than Photovoltaic.

OECD North America, investment budgets and distribution of investments								
Population			No. of inhabitants (Mio.)			Population density (cap/sqkm)		
			538.1			26.7		
Investment 2030			Target			Reached by iteration		
Budget per capita			220 $€_{2006}$			220 $€_{2006}$		
Total investment budget						118 billion $€_{2006}$		
Wind onshore	Wind offshore	Wind total	Biomass	Geothermal	PV	Solar Concentrating Power	Tide & Wave	Solar Collectors
Shares of the different technologies (%)								
15.6%	20.1%	35.7%	13.3%	8.6%	11.0%	11.7%	3.4%	16.4%
Total investment into technologies (billion $€_{2006}$)								
18.52	23.75	42.27	15.70	10.23	12.99	13.81	3.97	19.41

Table 11: Scenario assumptions for OECD North America in the high variant scenario [EWG; 2008].

Electricity

OECD North America	Capacity (GW)		
Technology	2010	2020	2030
Total Renewables	**220.9**	**387.0**	**871.0**
Hydropower	158.8	158.8	158.8
Biomass and Waste	23.7	50.2	88.9
Wind onshore	24.8	103.8	286.6
Wind offshore	0.5	15.9	148.5
Geothermal	8.6	21.2	42.1
Solar PV	2.5	20.5	81.0
Solar Thermal Power	1.8	14.9	57.5
Tide/Wave/Maritim	0.2	1.7	7.5

Table 12: Development of renewable electricity generating capacity in the OECD North America region ("High Variant") [EWG; 2008].

Renewable generating capacities in OECD North America massively increase until 2030. New renewables (non-hydro), making up less than one third of renewable capacities in 2010, overtake hydropower between 2010 and 2020 and – by 2030 – exceed hydropower's generating capacity by far. All new renewables show a strong growth until 2030, but Wind Energy performs best. Offshore Wind Energy does not show such massive growth as in Europe until 2010, but development speeds up a lot after 2020. By 2030 about half of the total renewable generating capacity is Wind Energy, with another proportion of more than nine percent coming from Photovoltaic. Although Biomass & Waste does not show the same strong growth as Wind energy or Photovoltaic, the generating capacity in 2030 is higher than Photovoltaic's capacity. Solar Concentrating Power, having a much lower capacity than Geothermal Energy in 2010, closes the gap to Geothermal Energy until 2020 and overtakes in the aftermath. Although Tidal, Wave and other Maritimes are secondary, they are not entirely insignificant.

Altogether renewable generating capacity in the "High Variant Scenario" increases to about 220 GW by 2010, to 390 GW in 2020 and further to about 870 GW in 2030 which is considerably less if compared to Europe. The capacity contributed by hydropower, assumed to be 160 GW over the whole period, drops from over 70 % in 2010 to 40 % in 2020 and less than 20 % in 2030.

Wind Energy shows the biggest increase in generating capacities. Starting with about 25 GW in 2010 (with offshore being negligible), the capacity reaches about 435 GW in 2030. The distribution between onshore Wind and offshore Wind is about two thirds to one third (287 GW onshore and 149 GW offshore), which is well comparable to the related figure for OECD Europe. Solar Photovoltaic capacity, about 2.5 GW in 2010, and increases to about 21 GW by 2020 and 81 GW in 2030. Although showing a stronger growth, this is not enough to take the second position from Biomass & Waste until 2030 (89 GW for Biomass & Waste in 2030). Another bigger proportion results from Solar Concentrating Power, with 58 GW in 2030; increasing from 2 GW in 2010 and 15 GW in 2020. Geothermal Energy, having a capacity of almost 9 GW by 2010, increases to about half the capacity of Biomass & Waste until 2030 (42 GW in 2030) . Tidal, Wave and other Maritimes, increase from about 0.2 GW in 2010 to slightly less than 8 GW by 2030.

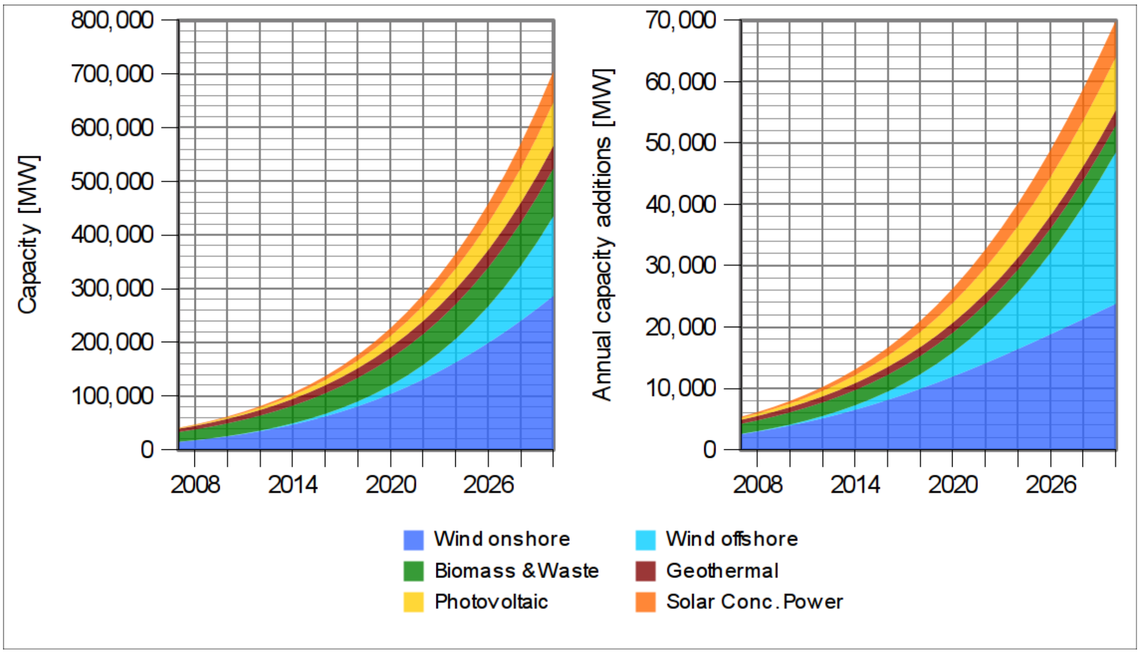


Figure 35: Development of renewable electricity generating capacity in OECD North America ("High Variant") [EWG; 2007].

Heat

OECD North America	Capacity (GW)		
Technology	**2010**	**2020**	**2030**
Total Renewable Heat	**87.6**	**257.5**	**551.1**
Biomass Heat	19.8	41.9	74.1
Geothermal Heat	11.5	28.6	56.9
Solarthermal Collectors	56.3	187.1	420.1

Table 13: Development of renewable heat generating capacity in the OECD North America region ("High Variant") [EWG; 2008].

Biomass heat generation capacity increases from 20 GW in 2010 to 74 GW in 2030 and – like in OECD Europe – is bigger than the capacity from Geothermal cogeneration, which itself increases from almost 12 GW in 2010 to 57 GW in 2030.

Most heat generation capacity results from Solar Thermal Collector systems. Starting with about 56 GW in 2010 the capacity increases to 420 GW by 2030. Altogether there is a renewable heat generation capacity of 551 GW in 2030.

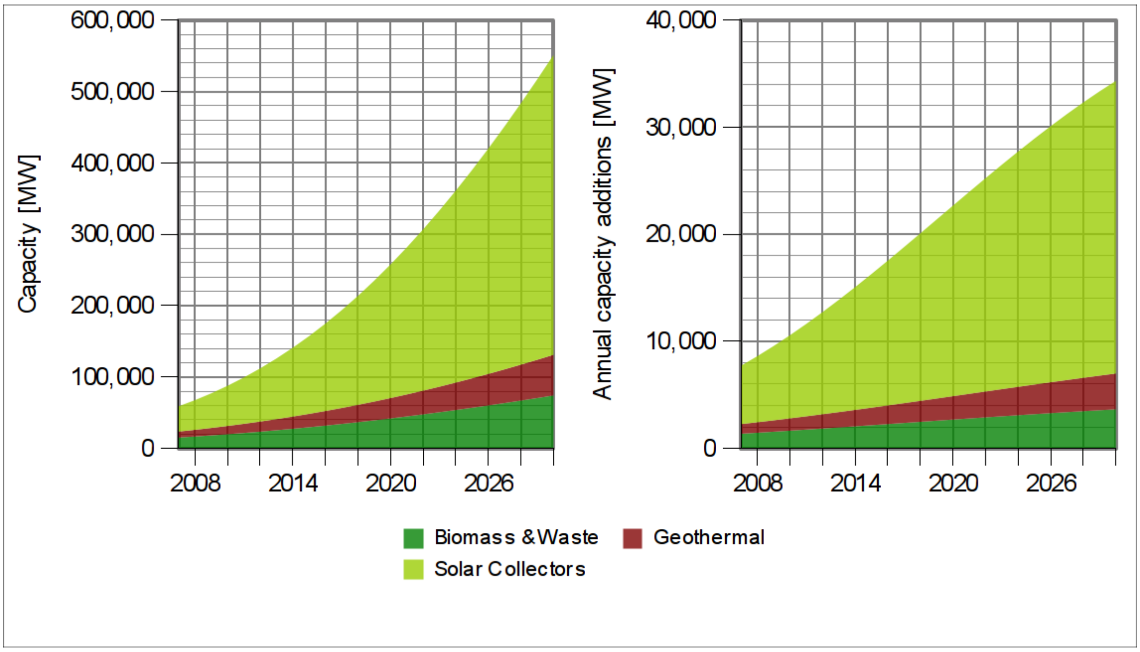


Figure 36: Development of renewable heat capacities in OECD North America ("High Variant") [EWG; 2008].

Investment budget

The figure below shows the development of annual investments into renewable capacities (left hand side) and the development of shares the different technologies have at total investments (right hand side).

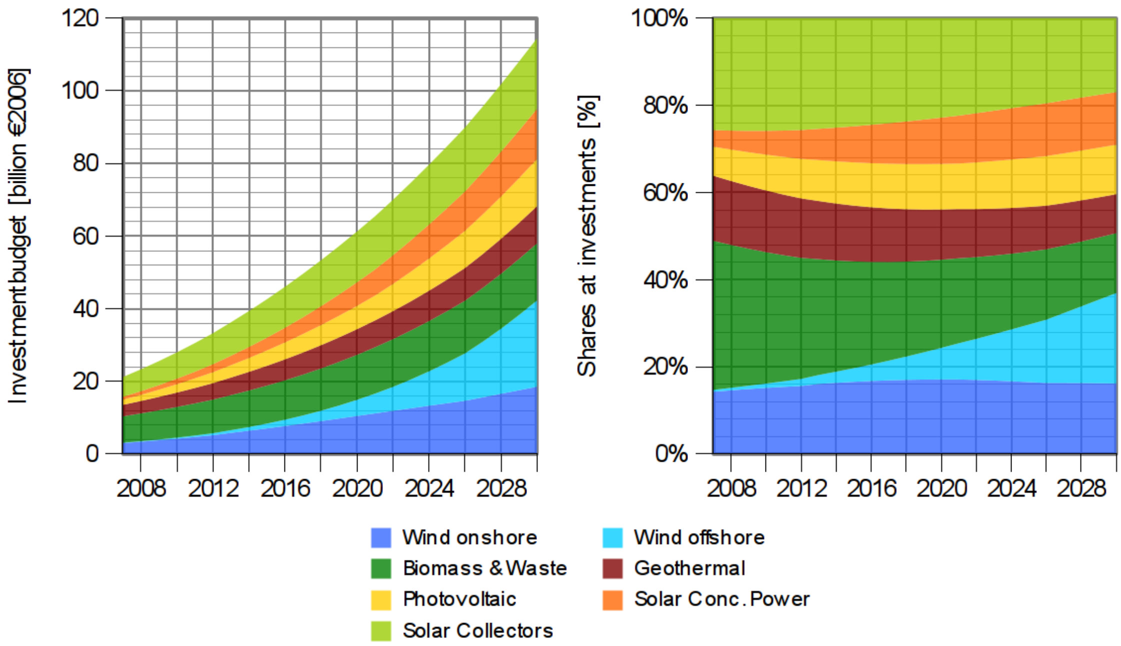


Figure 37: Development of the renewable energy investment budget in OECD North America ("High Variant") [EWG; 2008].

<u>OECD Pacific</u>

Assumptions

The target for investments into new generating capacities in OECD Pacific is 220 $€_{2006}$ per capita, which effectively resulted to 224 $€_{2006}$, due to the iterative calculation approach in scenario development. Considering the projected changes in population this results to a total investment budget of about 44 billion $€_{2006}$ in 2030.

The distribution of investments among the different technologies is dominated by Wind Energy (about 36% in total, 16.7 % for onshore and 19.8 % for offshore). Second biggest share goes to Solar Thermal Collectors (16.1%), followed by Solar Concentrating Power (16.5 %), Biomass (10.5 %), Photovoltaic and Geothermal Energy (8.6 % both) and Tidal, Wave & other Maritim, with 3.2 %.

As already seen for OECD Europe and North America, Wind Energy dominates the investment figure. The distribution between onshore and offshore Wind Energy is comparable to the distribution in OECD North America. Biggest difference to the OECD region is the role of Solar

Concentrating Power, which takes the third place in investment shares, mainly due the huge potentials in Australia. Solar Concentrating Power's share at investments is about the same as for onshore Wind Energy. Photovoltaic is of lower significance, as the population density in this region is by far lower if compared to OECD Europe or even to North America[17].

OECD Pacific, investment budgets and distribution of investments								
Population			**No. of inhabitants (Mio.)**			**Population density (cap/sqkm)**		
					194.8			12.0
Investment 2030			**Target**			**Reached by iteration**		
		Budget per capita	220 $€_{2006}$			224 $€_{2006}$		
		Total investment budget				44 billion $€_{2006}$		
Wind onshore	**Wind offshore**	**Wind total**	**Biomass**	**Geothermal**	**PV**	**Solar Concentrating Power**	**Tide & Wave**	**Solar Collectors**
Shares of the different technologies (%)								
16.7%	19.8%	36.4%	10.5%	8.6%	8.6%	16.5%	3.2%	16.1%
Total investment into technologies (billion $€_{2006}$)								
7.28	8.62	15.90	4.57	3.77	3.74	7.21	1.40	7.03

Table 14: Scenario assumptions for OECD Pacific in the high variant scenario [EWG; 2008].

Electricity

OECD Pacific	**Capacity (GW)**		
Technology	**2010**	**2020**	**2030**
Total Renewables	**61.0**	**136.2**	**329.1**
Hydropower	36.8	36.8	36.8
Biomass and Waste	9.4	17.7	29.1
Wind onshore	7.8	48.6	130.9
Wind offshore	0.5	9.4	62.6
Geothermal	3.1	8.1	16.0
Solar PV	3.3	12.6	32.4
Solar Thermal Power	0.1	2.5	18.7
Tide/Wave/Maritim	0.1	0.6	2.7

Table 15: Development of renewable electricity generating capacity in the OECD Pacific region ("High Variant") [EWG; 2008].

While hydropower, which has an unchanged capacity from now to 2030, contributes about 60% to all renewable capacities by 2010, the good performance of new renewables leads to a drop in hydropower's share to about one tenth by 2030. As a result of Wind Energy potentials and a comparably competitive price level, Wind energy again contributes most to increasing renewable generating capacities. While Wind Energy's capacity is about one fifth of hydropower's capacity in 2010, this figure increases to more than five times the capacity of hydropower by 2030. Here again the ratio of onshore to offshore Wind is about two thirds to one third. Photovoltaic does not reach the same capacity as hydropower by 2030, but it overtakes Biomass, although Photovoltaic

17 It has to be considered, that there are no "open land" installations of photovoltaic systems in the scenarios.

capacity is only about one third of the Biomass' capacity by 2010. Solar Concentrating Power and Geothermal Energy end up in about the same capacity.

Altogether renewable generating capacity in the "High Variant Scenario" increases to about 61 GW by 2010,further to 136 GW in 2020 and to about 329 GW in 2030. The share of new renewables increases to almost 90 % during that period.

Wind Energy capacities increase most, starting with about 8 GW in 2010 the capacity reaches about 194 GW in 2030, again with an onshore / offshore ratio of about two thirds to one third (131 GW onshore and 63 GW offshore). Solar Photovoltaic capacity, about 3 GW in 2010, increases to about 32 GW by 2030, which is slightly more than the contribution of Biomass (29 GW in 2030, about 9 GW in 2010). The 2030's contributions of Solar Concentrating Power and Geothermal Energy are definitely lower, with about 19 GW SCP and 16 GW Geothermal capacity both have more or less half the capacity of Biomass or Photovoltaic systems. Tidal, Wave and other Maritimes solely reach a capacity of less than 3 GW, or less than 1% of the total renewables by 2030.

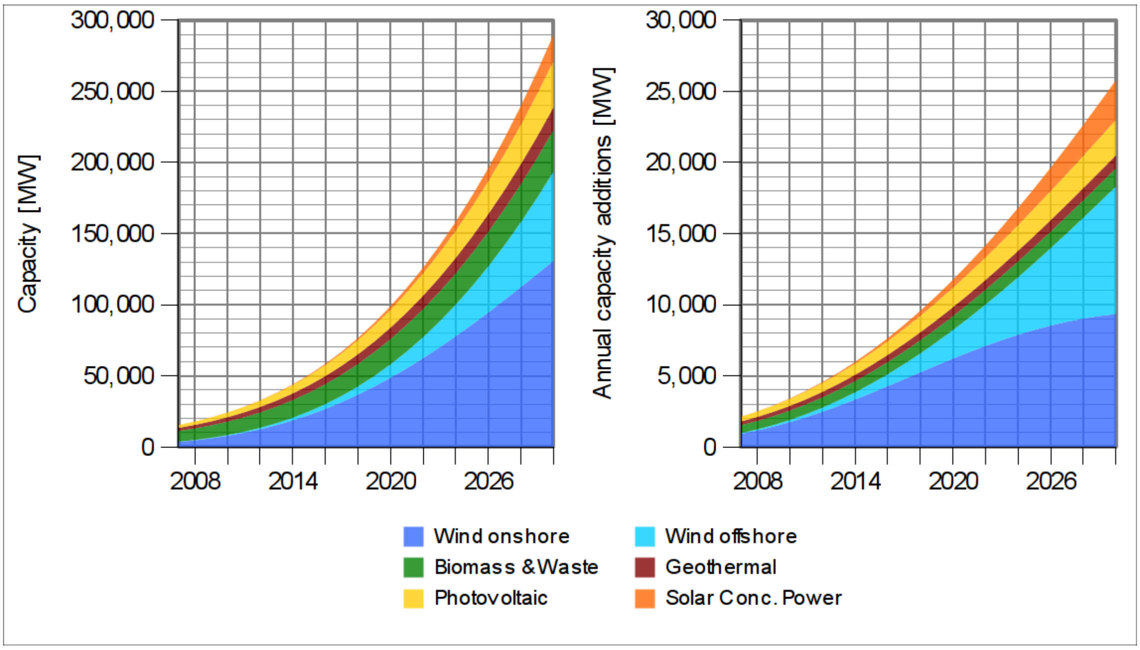


Figure 38: Development of renewable electricity generating capacity in OECD Pacific ("High Variant") [EWG; 2007].

Heat

OECD Pacific	Capacity (GW)		
Technology	**2010**	**2020**	**2030**
Total Renewable Heat	**36.1**	**104.0**	**212.5**
Biomass Heat	7.8	14.7	24.3
Geothermal Heat	4.2	10.9	21.6
Solarthermal Collectors	24.1	78.3	166.6

Table 16: Development of renewable heat generating capacity in the OECD Pacific region ("High Variant") [EWG; 2008].

Starting from different levels (8 GW Biomass and 4 GW Geothermal), Biomass and Geothermal reach comparable generation capacities by 2030 (24 GW Biomass, 22 GW Geothermal).

Biggest contribution in terms of capacity results from Solar Thermal Collector systems, with 21 GW in 2010 and 167 GW by 2030. Altogether there is a renewable heat generation capacity of 213 GW in 2030.

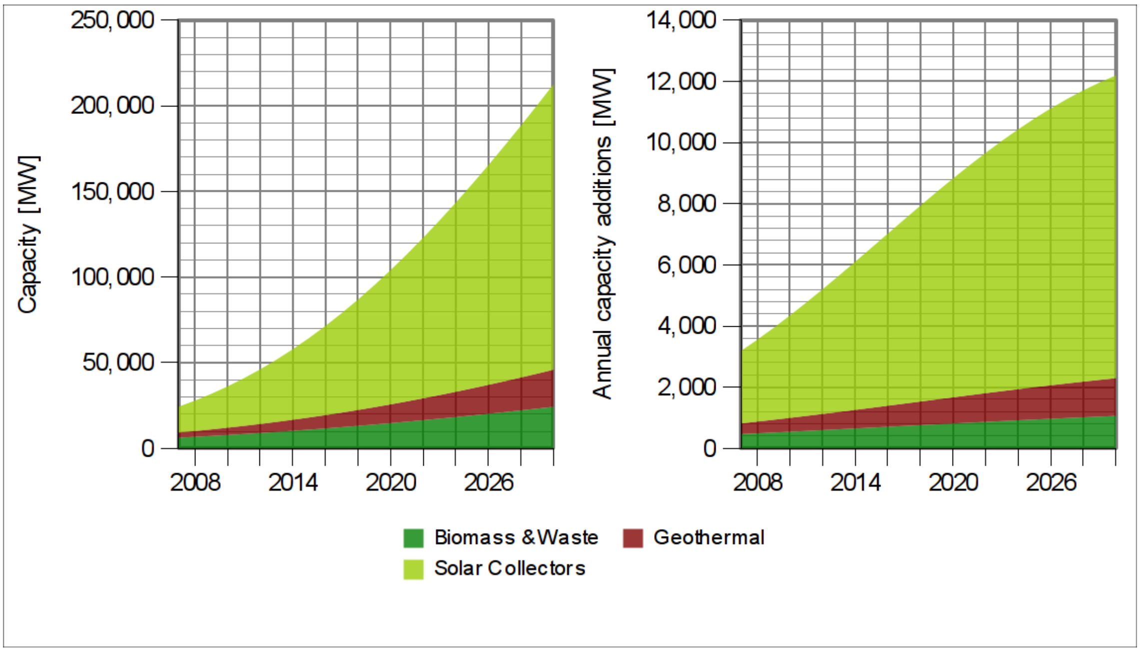


Figure 39: Development of renewable heat capacities in OECD Pacific ("High Variant") [EWG; 2008].

Investment budget

The figure below shows the development of annual investments into renewable capacities (left hand side) and the development of shares the different technologies have at total investments (right hand side).

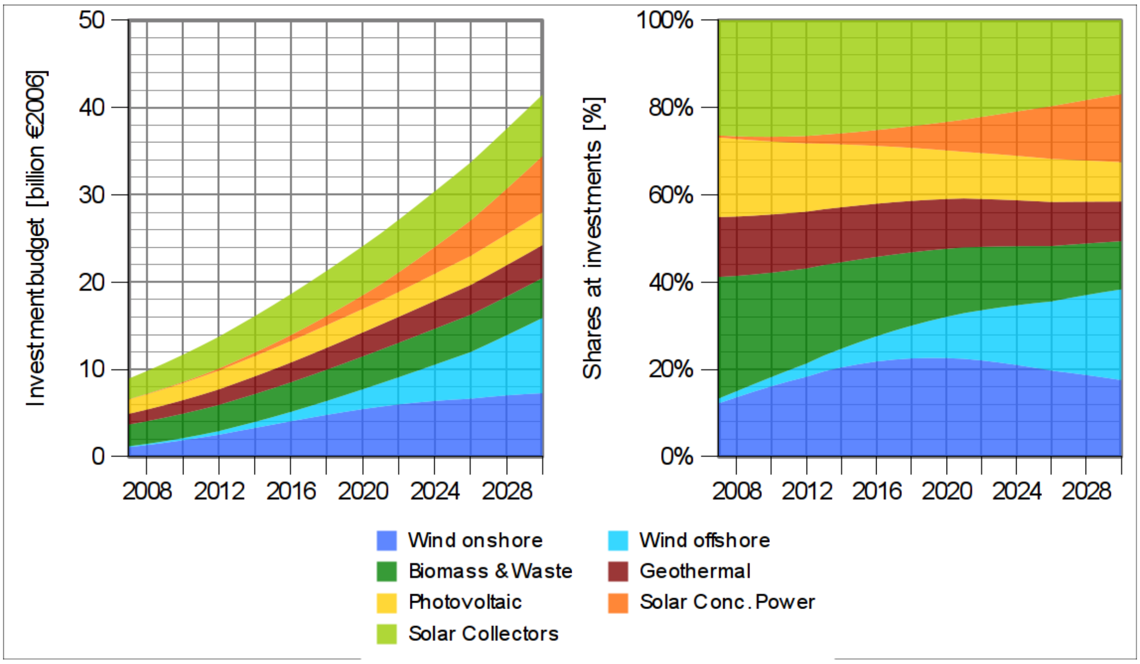


Figure 40: Development of the renewable energy investment budget in OECD Pacific ("High Variant") [EWG; 2008].

<u>Transition Economies</u>

Assumptions

The target for investments into new generating capacities in OECD Pacific is 180 $€_{2006}$ per capita, which well matched by iteration. Considering the projected changes in population this results to a total investment budget of about 60 billion $€_{2006}$ in 2030.

The distribution of investments among the different technologies is dominated by Wind Energy (about 35% in total, 21.3 % for onshore and 13.5 % for offshore). Second biggest share goes to Solar Thermal Collectors (23.9%, first place if Wind energy gets considered separately for onshore and offshore use), followed by Biomass (17.4 %), Geothermal Energy (11.4 %), Photovoltaic (10.7 %) and Tidal, Wave & other Maritimes, with 1.7 %.

As already seen in the OECD region, Wind Energy dominates the investment figure but there is a significant change in the distribution between onshore and offshore Wind Energy. In the Transition Economies onshore Wind Energy has a higher investment share than offshore Wind Energy because many countries in this region are landlocked. There are no investments into Solar Concentrating Power as no potentials were identified for this region. Instead of that there is a huge Biomass potential.

Transition Economies, investment budgets and distribution of investments								
Population			No. of inhabitants (Mio.)			Population density (cap/sqkm)		
			335.0			14.7		
Investment 2030			Target			Reached by iteration		
Budget per capita			180 €$_{2006}$			180 €$_{2006}$		
Total investment budget						60 billion €$_{2006}$		
Wind onshore	Wind offshore	Wind total	Biomass	Geothermal	PV	Solar Concentrating Power	Tide & Wave	Solar Collectors
Shares of the different technologies (%)								
21.3%	13.5%	34.8%	17.4%	11.4%	10.7%	0.0%	1.7%	23.9%
Total investment into technologies (billion €$_{2006}$)								
12.84	8.15	20.99	10.51	6.90	6.46	0.00	1.05	14.39

Table 17: Scenario assumptions for the Transition Economies in the high variant scenario [EWG; 2008].

Electricity

Transition Economies	Capacity (GW)		
Technology	2010	2020	2030
Total Renewables	**93.3**	**133.2**	**327.7**
Hydropower	87.6	97.9	108.2
Biomass and Waste	4.8	18.2	43.1
Wind onshore	0.1	7.0	90.2
Wind offshore	0.1	4.3	47.9
Geothermal	0.6	4.7	16.9
Solar PV	0.0	1.1	20.3
Solar Thermal Power	0.0	0.0	0.0
Tide/Wave/Maritim	0.0	0.1	1.1

Table 18: Development of renewable electricity generating capacity in the Transition Economies ("High Variant") [EWG; 2008].

Due to the planned capacity extensions, hydropower's capacity is assumed to increase by about twenty percent from 2010 to 2030. Nevertheless the share of hydropower drops from almost 100% of all renewables to about one third of the total renewable generating capacity by 2030. Major responsibility for this development lies within the extension of Wind Energy, which evolves from virtually nothing to a generating capacity which is about a quarter more than the hydropower capacity by 2030, with the already seen onshore/offshore ratio of about two thirds to one third. Biomass & Waste develops nearly as onshore Wind Energy, showing only slightly less capacity than onshore Wind by 2030. Photovoltaic, non existent by 2010, reaches about half of that capacity by 2030. Geothermal Energy, having more capacity than Wind energy in 2010, develops less dynamic and reaches a capacity somewhat below the capacity of Photovoltaic. Solar Concentrating Power does not play any role in the scenario for the Transition Economies, as no potentials have been identified that could be judged as reasonable for this technology.

Altogether renewable generating capacity in the "High Variant Scenario" increases to about 93 GW by 2010 , to 133 GW in 2020 and to about 328 GW in 2030, which is about the same as in OECD Pacific. The share of new renewables increases to almost two thirds during that period.

Wind Energy capacities increase most, starting with about 0.2 GW in 2010 the capacity reaches about 138 GW in 2030 (90 GW onshore and 48 GW offshore). Biomass & Waste capacity, about 5 GW in 2010, increases to about 43 GW by 2030, which is about double the contribution of Photovoltaic by that time (20 GW in 2030, none in 2010). Geothermal Energy, with almost 17 GW by 2030, contributes only slightly less than Photovoltaic. Tidal, Wave and other Maritimes can be rated as insignificant, with only about 1 GW by 2030.

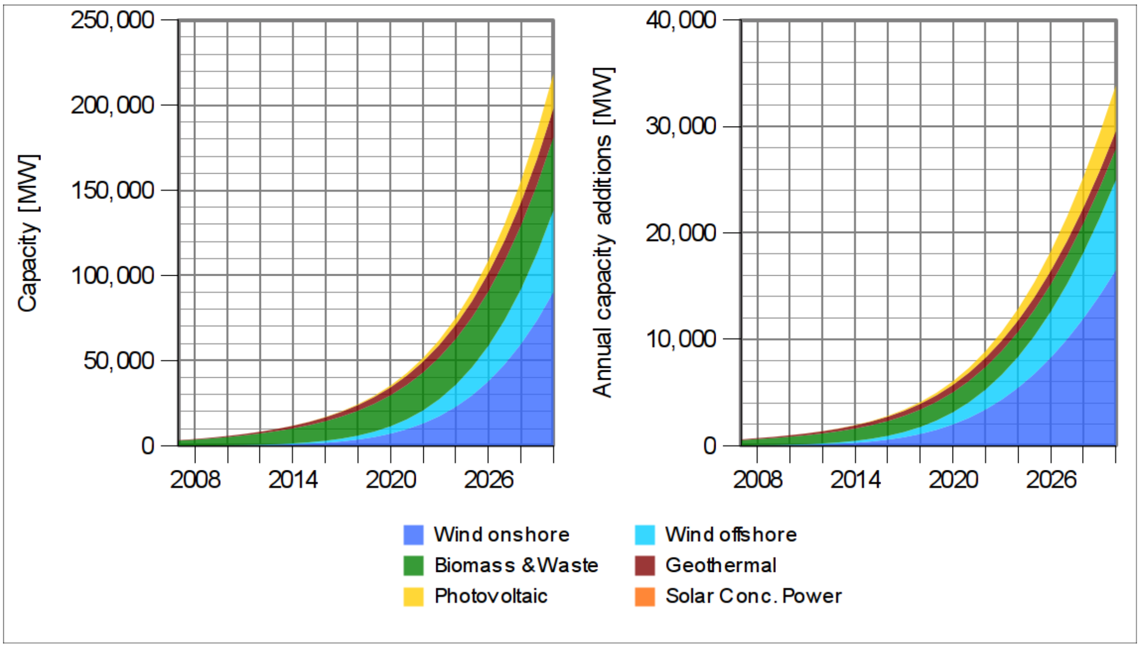


Figure 41: Development of renewable electricity generating capacity in the Transition Economies ("High Variant") [EWG; 2007].

Heat

Transition Economies	Capacity (GW)		
Technology	**2010**	**2020**	**2030**
Total Renewable Heat	**11.0**	**87.3**	**288.6**
Biomass Heat	4.0	15.2	35.9
Geothermal Heat	0.8	6.3	22.8
Solarthermal Collectors	6.2	65.8	229.8

Table 19: Development of renewable heat generating capacity in the Transition Economies ("High Variant") [EWG; 2008].

While the Biomass heat generation capacity increases from 4 GW in 2010 to 36 GW in 2030, there is a lower contribution from Geothermal cogeneration (1 GW in 2010 to 23 GW in 2030).

Solar Thermal Collector systems again contribute most to renewable heat capacities. Starting with about 6 GW in 2010 the capacity increases to 230 GW by 2030. Altogether there is a renewable heat generation capacity of 289 GW in 2030.

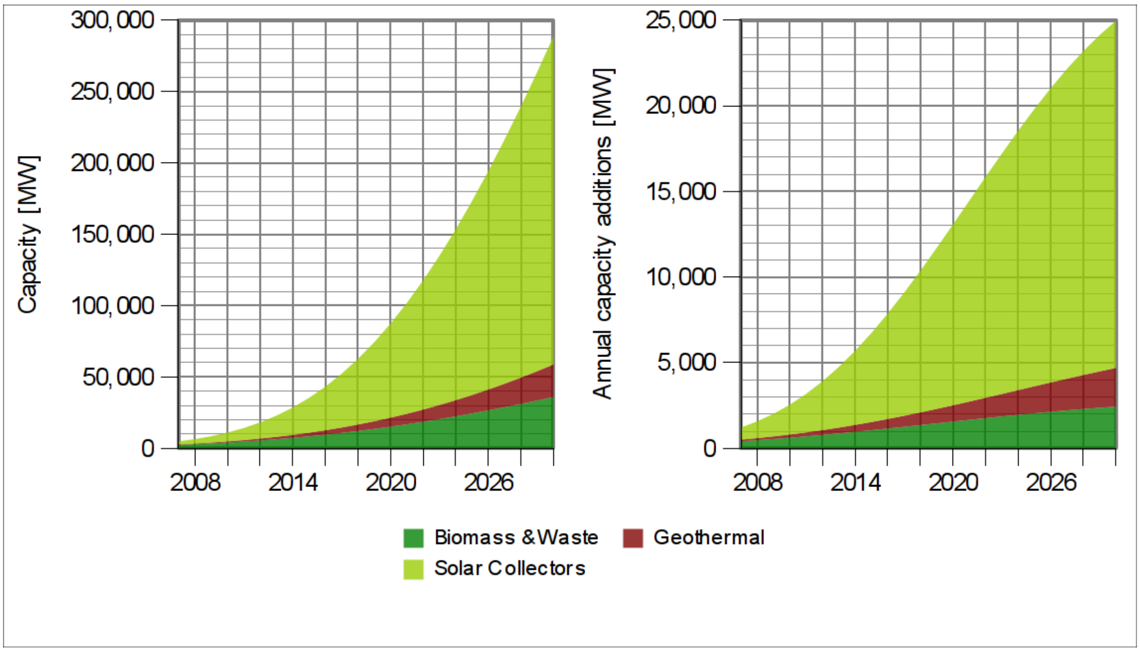


Figure 42: Development of renewable heat capacities in the Transition Economies ("High Variant") [EWG; 2008].

Investment budget

The figure below shows the development of annual investments into renewable capacities (left hand side) and the development of shares the different technologies have at total investments (right hand side).

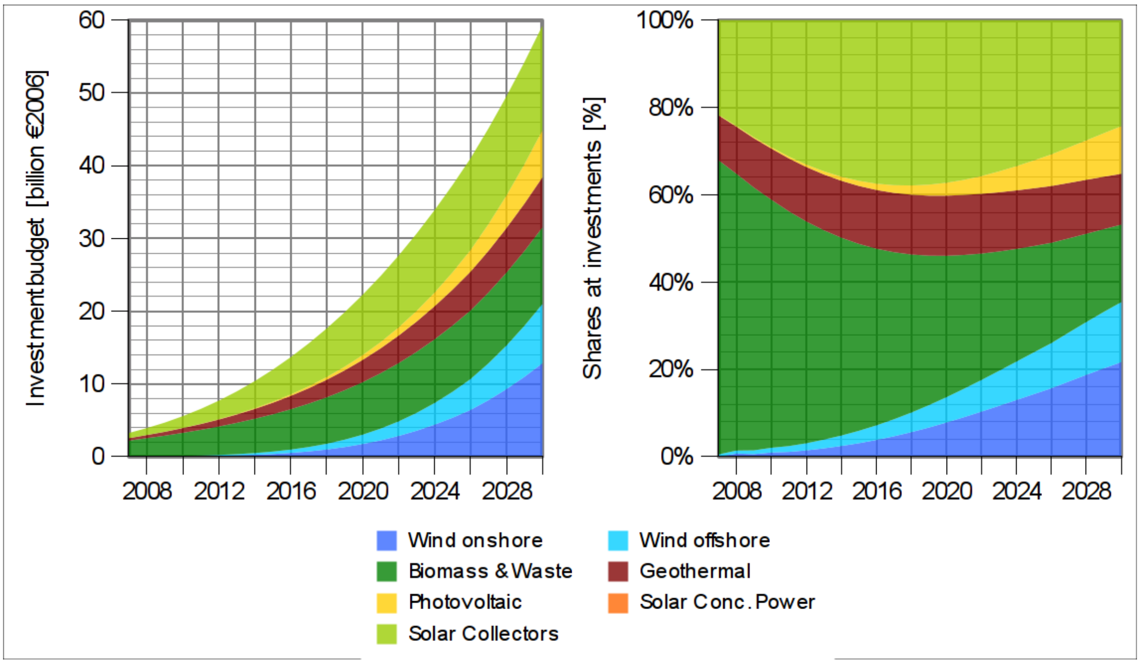


Figure 43: Development of the renewable energy investment budget in the Transition Economies ("High Variant") [EWG; 2008].

<u>China</u>

Assumptions

The target for investments into new generating capacities in China is 200 $€_{2006}$ per capita. Due to the iterative calculation in the scenario this value effectively resulted to 204 $€_{2006}$ per capita. Considering the projected changes in population this results to a total investment budget of about 299 billion $€_{2006}$ in 2030.

The distribution of investments among the different technologies is dominated by Wind Energy, although the share of wind Energy is considerably lower than in the OECD regions or the Transition Economies (about 28% in total, 11.8 % for onshore and 16.3 % for offshore). Second biggest share goes to Solar Thermal Collectors (23.9%, higher than onshore or offshore Wind Energy alone), followed by Photovoltaic (17.1 %), Solar Concentrating Power (13.9 %), Biomass (11 %), Geothermal Energy (7.9 %) and Tidal, Wave & other Maritimes, with 2.8 %.

Wind Energy dominates the investment figure but if Photovoltaic and Solar Concentrating Power are added, total solar electricity has a higher investment share than total Wind Energy. Photovoltaic alone has a higher share than both of the Wind Energy fractions, which is a result of the high population density. Biomass' share is about the same as onshore Wind Energy alone.

China, investment budgets and distribution of investments								
Population			No. of inhabitants (Mio.)			Population density (cap/sqkm)		
			1,468.8			157.5		
Investment 2030			Target			Reached by iteration		
Budget per capita			200 €2006			204 €2006		
Total investment budget						299 billion €2006		
Wind onshore	Wind offshore	Wind total	Biomass	Geothermal	PV	Solar Concentrating Power	Tide & Wave	Solar Collectors
Shares of the different technologies (%)								
11.8%	16.3%	28.1%	11.0%	7.9%	17.1%	13.9%	2.8%	19.2%
Total investment into technologies (billion €2006)								
35.22	48.88	84.10	32.87	23.62	51.20	41.68	8.45	57.38

Table 20: Scenario assumptions for China in the high variant scenario [EWG; 2008].

Electricity

China	Capacity (GW)		
Technology	2010	2020	2030
Total Renewables	**134.3**	**310.3**	**1232.1**
Hydropower	105.2	135.4	165.6
Biomass and Waste	22.2	65.2	141.7
Wind onshore	5.5	58.2	326.2
Wind offshore	0.1	13.3	247.8
Geothermal	0.5	7.8	44.0
Solar PV	0.6	23.1	211.5
Solar Thermal Power	0.1	6.9	86.7
Tide/Wave/Maritim	0.0	0.4	8.5

Table 21: Development of renewable electricity generating capacity in the China ("High Variant") [EWG; 2008].

Due to the planned capacity extensions, Hydropower's capacity is assumed to increase by more than the half from 2010 to 2030. Nevertheless the massive increase in new renewable generating capacities leads to a dropping share of Hydropower from almost eighty percent to less than fifteen percent. Biggest increase in capacity again results from Wind Energy, but the increase of Photovoltaic is not much less if compared to offshore Wind. The distribution between onshore and offshore Wind Energy differs from the regions described before: more than 40 % of the total Wind Energy capacity by 2030 is offshore. Biomass becomes the fourth largest generating capacity among all renewables, but there is a substantial gap to PV. Solar Concentrating Power also shows a strong growth, but the capacity reached by 2030 is less than half the Photovoltaic capacity. Geothermal energy grows even less and reaches about half the capacity of SCP by 2030.

Altogether renewable generating capacity in the "High Variant Scenario" increases to about 134 GW by 2010 and further to 310 GW in 2020 and about 1232 GW in 2030, which is about twenty percent more than actually in the OECD Europe region. The share of new renewables increases to more than 85 % during that period.

Wind Energy capacities increase most, starting with about 6 GW in 2010 the capacity increases to 72 GW in 2010 and – finally - reaches about 574 GW in 2030 (248 GW onshore and 326 GW offshore). Photovoltaic's capacity by 2030 is, with about 212 GW, not far behind the capacity of onshore Wind Energy. Third biggest contribution comes from Biomass & Waste, growing to about 22 GW by 2010 and to about 142 GW by 2030. While Solar Concentrating Power reaches about 87 GW by 2030 (from 0.1 GW in 2010), Geothermal Energy, starting with 0.5 GW in 2010, increases it's capacity to 44 GW in 2030. Tidal, Wave and other Maritimes manage to increase generating capacity to more than 8 GW, which is about the same capacity as in OECD Europe.

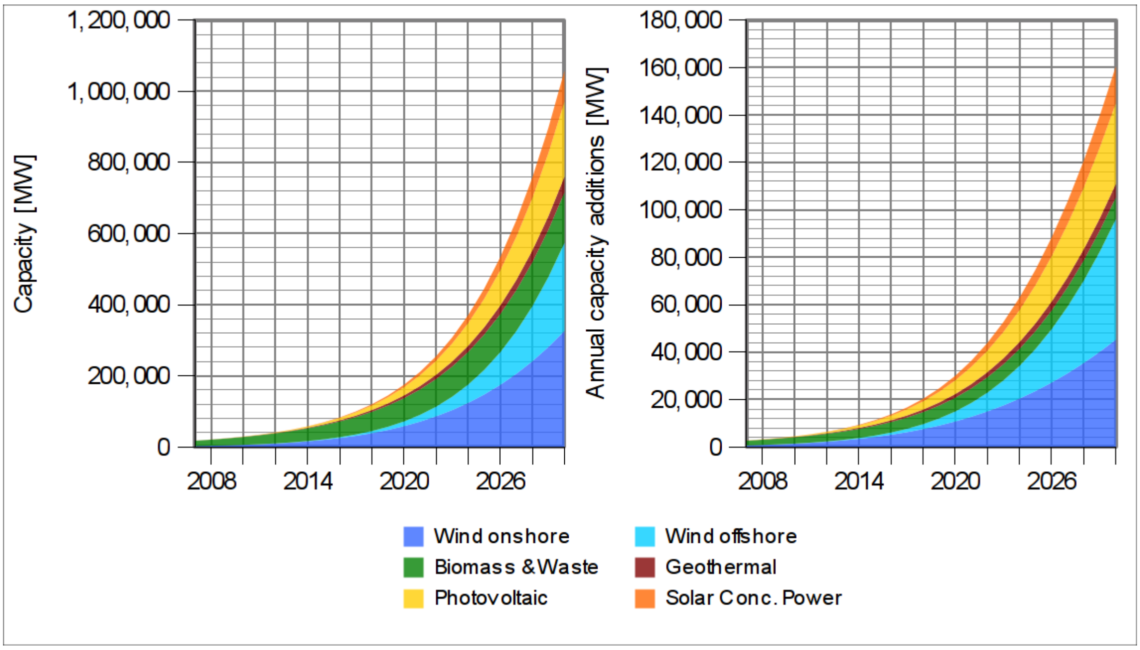


Figure 44: Development of renewable electricity generating capacity in China ("High Variant") [EWG; 2007].

Heat

China	Capacity (GW)		
Technology	**2010**	**2020**	**2030**
Total Renewable Heat	**170.5**	**660.6**	**1,509.5**
Biomass Heat	18.5	54.4	118.1
Geothermal Heat	0.7	10.5	59.5
Solarthermal Collectors	151.4	595.7	1,332.0

Table 22: Development of renewable heat generating capacity in China ("High Variant") [EWG; 2008].

Biomass, increasing from almost 19 GW (2010) to 118 GW (2030), reaches about double the heat capacity than Geothermal (almost 60 GW in 2030, coming from less than 1 GW in 2010).

Due to the high population density Solar Thermal Collector systems see a massive increase from already about 151 GW in 2010 to 1,332 GW by 2030. Altogether there is a renewable heat generation capacity of 1,510 GW in 2030.

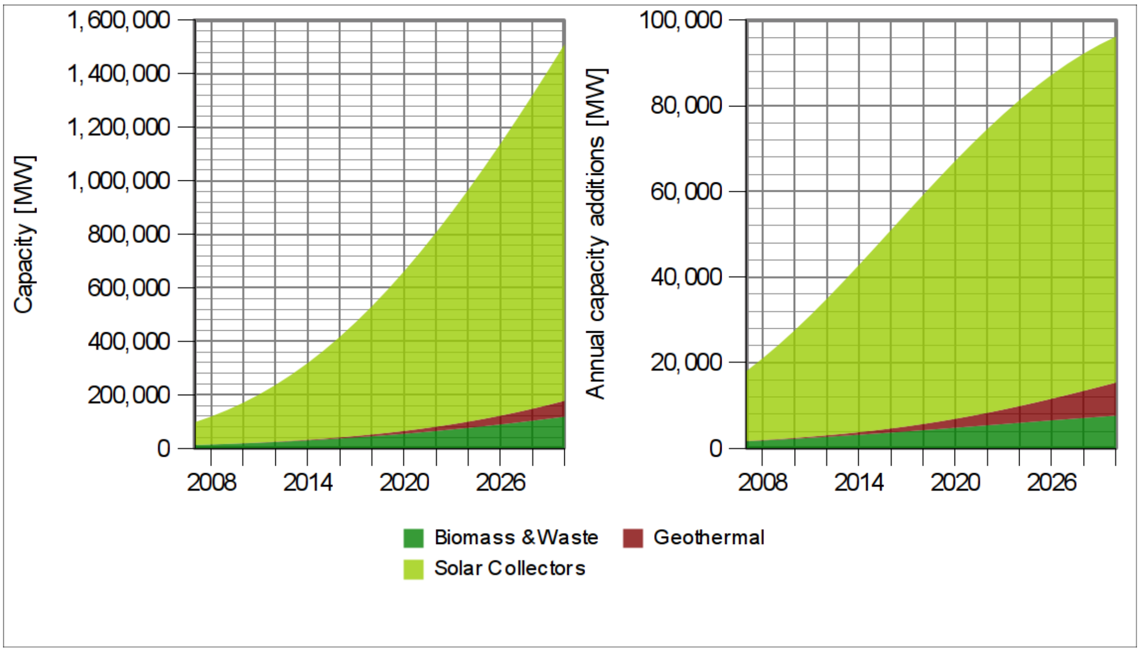


Figure 45: Development of renewable heat capacities in China ("High Variant") [EWG; 2008].

Investment budget

The figure below shows the development of annual investments into renewable capacities (left hand side) and the development of shares the different technologies have at total investments (right hand side).

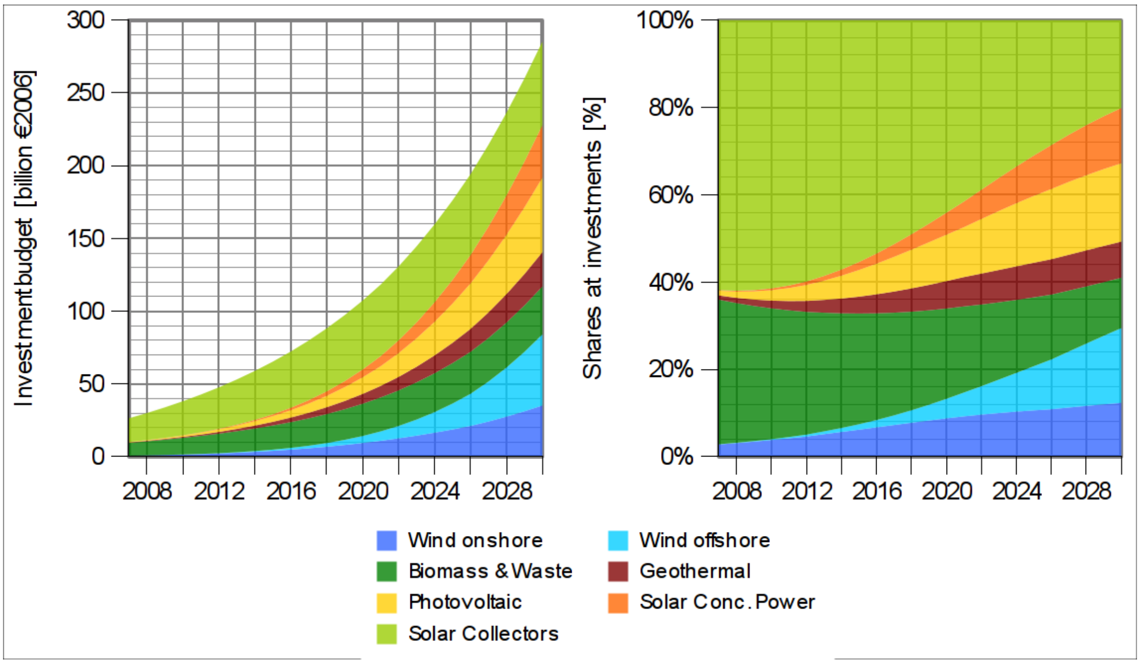


Figure 46: Development of the renewable energy investment budget in China ("High Variant") [EWG; 2008].

<u>East Asia</u>

Assumptions

The target for investments into new generating capacities in East Asia is 80 $€_{2006}$ per capita, effectively resulting to 81 $€_{2006}$ per capita, due to iterative calculation. Considering the projected changes in population this results to a total investment budget of about 66 billion $€_{2006}$ in 2030.

The distribution of investments among the different technologies is dominated by Wind Energy, comparable to the shares in the OECD regions. In total Wind Energy's share is 30 % (8.6 % for onshore and 21.4 % for offshore). Second biggest share goes to Solar Thermal Collectors (24.9%, but higher than any of the Wind Energy fractions alone), followed by Photovoltaic (13.6 %), Solar Concentrating Power (13.2 %), Biomass (9.8 %), Geothermal Energy (7.1 %) and Tidal, Wave & other Maritimes, with 1.4 %.

Altogether this distribution scheme is similar to the one for China, but onshore Wind Energy is of even lower significance (only on sixth place if onshore Wind energy is considered as standalone technology). Solar Concentrating Power and Photovoltaic are close together, making solar driven electricity generation almost as important as total Wind Energy (about 27% total solar).

East Asia, investment budgets and distribution of investments								
Population			No. of inhabitants (Mio.)			Population density (cap/sqkm)		
			806.5			151.1		
Investment 2030			Target			Reached by iteration		
Budget per capita			80 $€_{2006}$			81 $€_{2006}$		
Total investment budget						66 billion $€_{2006}$		
Wind onshore	Wind offshore	Wind total	Biomass	Geothermal	PV	Solar Concentrating Power	Tide & Wave	Solar Collectors
Shares of the different technologies (%)								
8.6%	21.4%	30.0%	9.8%	7.1%	13.6%	13.2%	1.4%	24.9%
Total investment into technologies (billion $€_{2006}$)								
5.63	14.05	19.68	6.45	4.63	8.93	8.63	0.94	16.31

Table 23: Scenario assumptions for East Asia in the high variant scenario [EWG; 2008].

Electricity

East Asia	Capacity (GW)		
Technology	2010	2020	2030
Total Renewables	**42.5**	**94.5**	**303.0**
Hydropower	29.6	29.6	29.6
Biomass and Waste	5.3	13.7	28.5
Wind onshore	2.1	29.6	95.4
Wind offshore	0.0	4.3	72.2
Geothermal	5.3	11.5	21.1
Solar PV	0.1	3.7	35.5
Solar Thermal Power	0.0	2.0	19.8
Tide/Wave/Maritim	0.0	0.0	0.9

Table 24: Development of renewable electricity generating capacity in East Asia ("High Variant") [EWG; 2008].

As there was no information on planned extensions of hydropower capacity, it is assumed to maintain on the same level over the whole period. While hydropower leads by far in 2010 (almost 70 % of all renewable capacities), this figure drops to about 31 % by 2020 and further down to somewhat below 10 % by 2030. Biggest capacity additions result from the dynamic extension of Wind Energy (from 2 GW in 2010 to 168 GW in 2030), with 43 % of the total Wind Energy capacity being installed offshore by then (95 GW onshore and 72 GW offshore). Offshore Wind exceeds the capacity of all other renewable capacities by far, the second biggest contributor – Photovoltaic, which benefits from the high population density, has a generating capacity of almost 36 GW. While Hydropower still holds the third place by 2030 (almost 30 GW), Biomass & Waste comes close to that figure (approx. 29 GW in 2030, coming from about 5 GW in 2010). Geothermal Energy also develops quiet well with a capacity increase from about

5 GW (2010) to more than 21 GW (2030), Geothermal electricity generating capacity is higher than the capacity reached by Solar Concentrating Power (close to 20 GW in 2030). Tidal, Wave & other Maritimes see a minor capacity increase which remains below 1 GW by 2030.

Altogether renewable generating capacity in the "High Variant Scenario" increases to about 43 GW by 2010,further to 95 GW in 2020 and to about 303 GW in 2030.

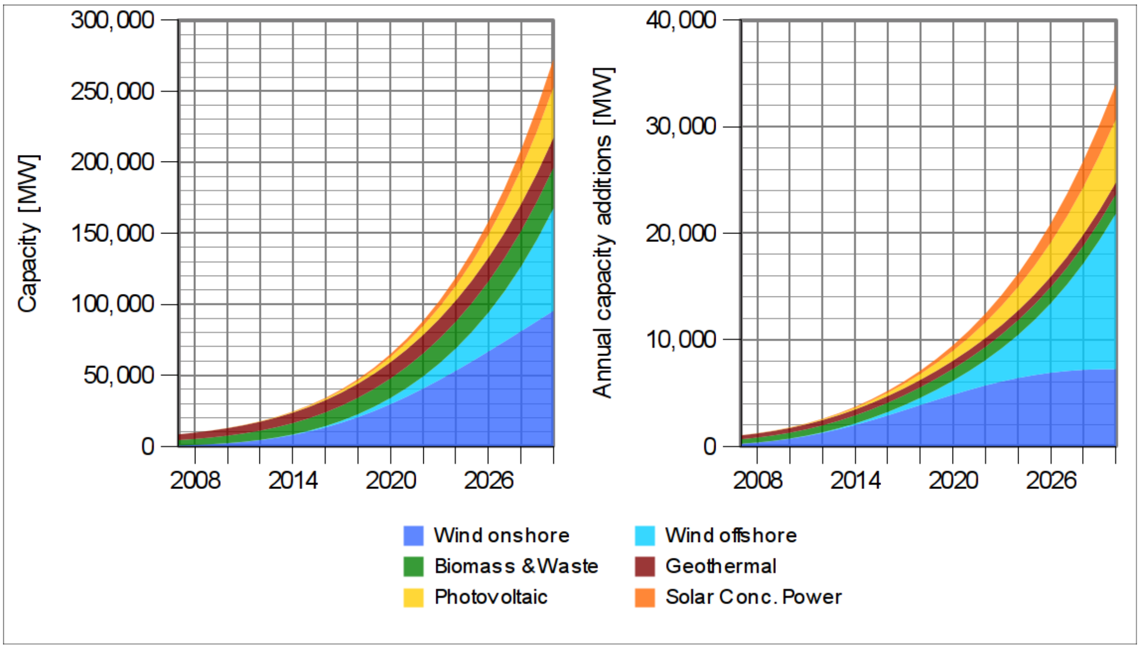


Figure 47: Development of renewable electricity generating capacity in East Asia ("High Variant") [EWG; 2007].

Heat

East Asia	Capacity (GW)		
Technology	**2010**	**2020**	**2030**
Total Renewable Heat	**17.8**	**80.8**	**267.8**
Biomass Heat	4.4	11.4	23.8
Geothermal Heat	7.2	15.5	28.5
Solarthermal Collectors	6.2	53.9	215.5

Table 25: Development of renewable heat generating capacity in East Asia ("High Variant") [EWG; 2008].

Biomass and Geothermal cogeneration perform relatively comparable. Biomass, starting with more than 4 GW in 2010, increase its heat capacity to about 24 GW by 2030. Geothermal cogeneration starts from a higher base level in 2010 (more than 7 GW) and reaches almost 29 GW by the end of development shown here.

Solar Thermal Collector systems make up for about 6 GW in 2010 – between Biomass and Geothermal – but perfoms much better in the aftermath. By 2030 the installed capacity of Solar Thermal Collectors is almost 216 GW. Altogether there is a renewable heat generation capacity of 268 GW in 2030.

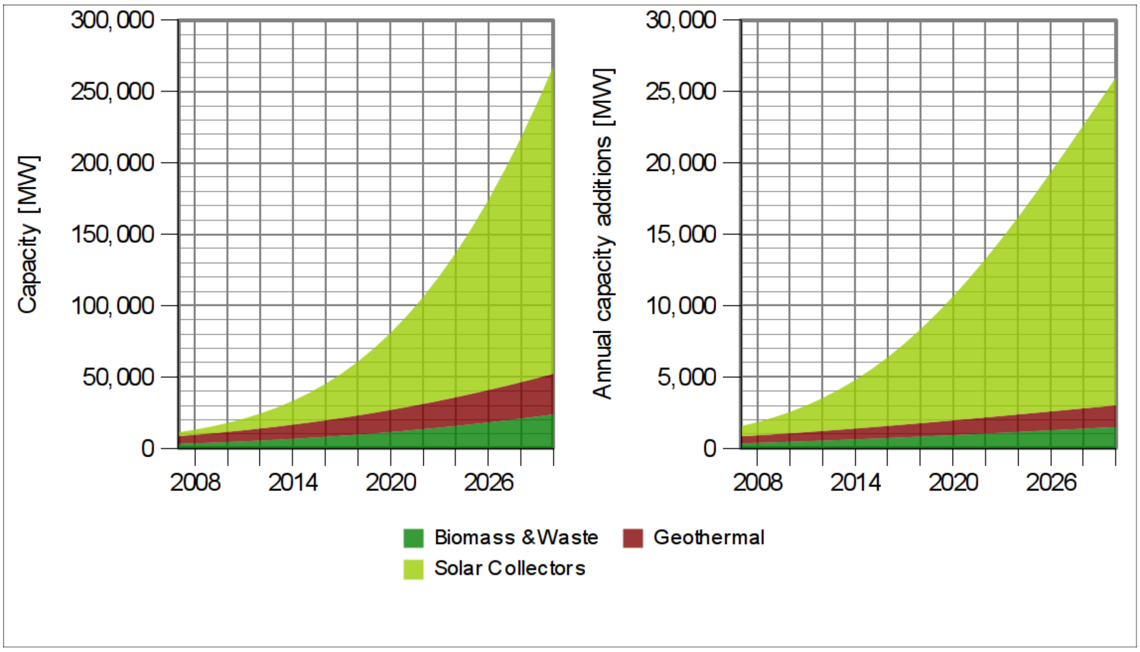


Figure 48: Development of renewable heat capacities in East Asia ("High Variant") [EWG; 2008].

Investment budget

The figure below shows the development of annual investments into renewable capacities (left hand side) and the development of shares the different technologies have at total investments (right hand side).

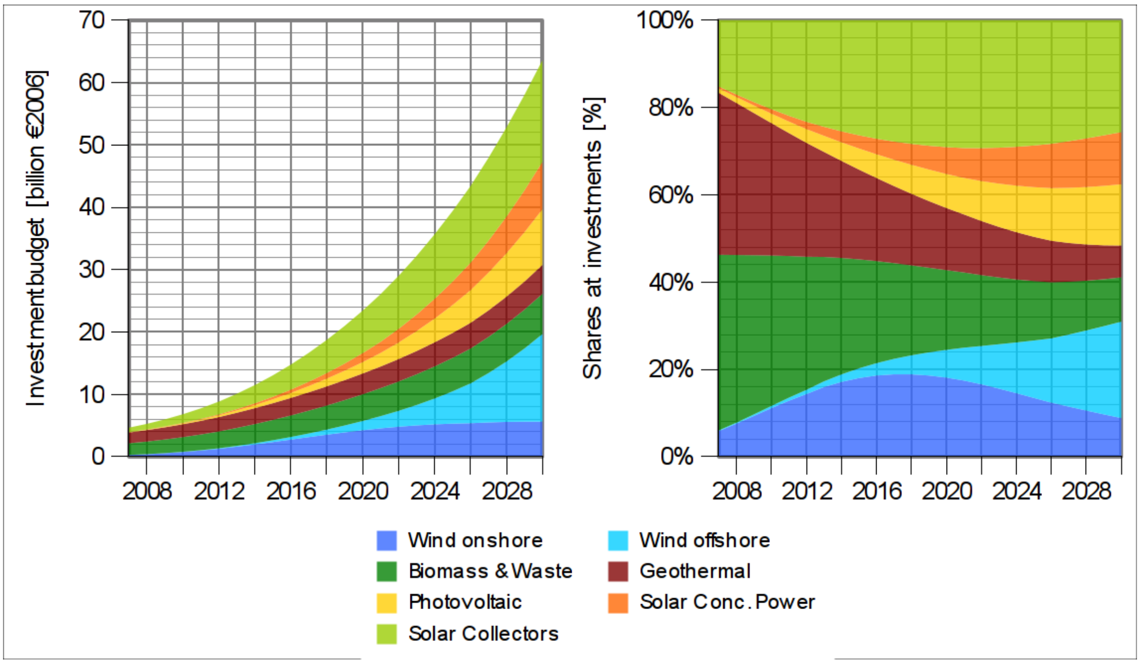


Figure 49: Development of the renewable energy investment budget in East Asia ("High Variant") [EWG; 2008].

South Asia

Assumptions

The target for investments into new generating capacities in East Asia is 70 $€_{2006}$ per capita, effectively resulting to 71 $€_{2006}$ per capita, due to iterative calculation. Considering the projected changes in population this results to a total investment budget of about 147 billion $€_{2006}$ in 2030.

Despite all other regions considered so far, it is not Wind Energy having the highest investment share, but Solar Thermal Collectors (almost 34%). Total Wind Energy even has a lower share than Photovoltaic, which – due to the extremely high population density – has an investment share of about a quarter of the total investments. Following Wind Energy is on third place (16.1 %, with 6.7 % onshore and 9.4 % offshore), followed by Solar Concentrating Power (10.6 %), Biomass (8 %) and Geothermal Energy, with 6.1 %. Tidal, Wave and other Maritimes are, as usual, last in terms of investment shares (1.4 %).

The investment scheme for South Asia differs quiet much from what has been described so far, as solar energy has by far the lead in this region. On the electrical side, Photovoltaic and Solar Concentrating Power together make up for more than one third, which is about the double of the investment share for onshore and offshore Wind Energy. Onshore Wind Energy alone has a lower share than Biomass and there is only a marginal gap to Geothermal Energy.

South Asia, investment budgets and distribution of investments								
Population			No. of inhabitants (Mio.)			Population density (cap/sqkm)		
			2,063.4			504.0		
Investment 2030			Target			Reached by iteration		
Budget per capita			70 €2006			71 €2006		
Total investment budget						147 billion €2006		
Wind onshore	Wind offshore	Wind total	Biomass	Geothermal	PV	Solar Concentrating Power	Tide & Wave	Solar Collectors
Shares of the different technologies (%)								
6.7%	9.4%	16.1%	8.0%	6.1%	24.1%	10.6%	1.3%	33.8%
Total investment into technologies (billion €2006)								
9.78	13.85	23.63	11.75	8.96	35.39	15.54	1.84	49.56

Table 26: Scenario assumptions for South Asia in the high variant scenario [EWG; 2008].

Electricity

South Asia	Capacity (GW)		
Technology	2010	2020	2030
Total Renewables	**53.7**	**123.3**	**471.9**
Hydropower	39.5	39.5	39.5
Biomass and Waste	2.1	10.8	34.5
Wind onshore	11.6	53.1	150.3
Wind offshore	0.0	4.0	69.3
Geothermal	0.1	2.1	14.6
Solar PV	0.2	11.3	130.8
Solar Thermal Power	0.0	2.5	31.0
Tide/Wave/Maritim	0.0	0.1	1.9

Table 27: Development of renewable electricity generating capacity in South Asia ("High Variant") [EWG; 2008].

Hydropower capacity is assumed to be stable over the whole development (almost 40 GW). Considering this, the share of Hydropower at the renewable capacities drops from nearly three quarters in 2010 to a little bit more than 8 % by 2030. Although biggest additions of generating capacity result from Wind Energy (from 12 GW in 2010 to 220 GW in 2030, thereof 150 GW onshore), Photovoltaic shows a massive increase in capacity and comes close the onshore Wind figure (almost 131 GW PV by 2030). This dynamic development is driven by the high population density in this region. Biomass & Waste remains below the capacity of Hydropower (approx. 35 GW Biomass in 2030, coming from about 2 GW in 2010), but Solar Concentrating Power follows with only a small gap (31 GW SCP in 2030). Geothermal Energy does not show that dynamic development and – finaly – increases to about half the capacity of SCP by 2030 (almost 15 GW Geothermal). Tidal, Wave & other Maritimes increase to almost 2 GW by 2030.

Altogether renewable generating capacity in the "High Variant Scenario" increases to about 54 GW by 2010, to 123 GW in 2020 and to about 472 GW in 2030.

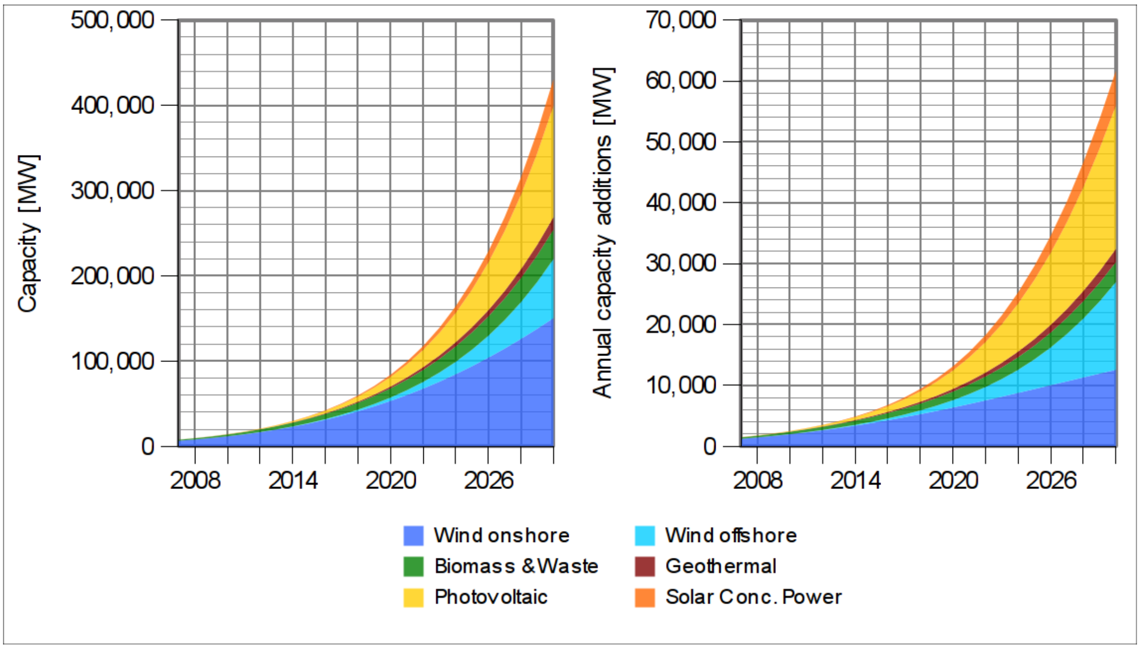


Figure 50: Development of renewable electricity generating capacity in South Asia ("High Variant") [EWG; 2007].

Heat

South Asia	Capacity (GW)		
Technology	**2010**	**2020**	**2030**
Total Renewable Heat	**9.5**	**124.2**	**624.4**
Biomass Heat	1.8	9.0	28.7
Geothermal Heat	0.2	2.8	19.7
Solarthermal Collectors	7.6	112.5	576.0

Table 28: Development of renewable heat generating capacity in South Asia ("High Variant") [EWG; 2008].

Altogether the renewable heat generation capacity increases to almost 10 GW in 2010 and to more than 624 GW in 2030. Most of the capacity results from Solar Thermal Collectors (about 8 GW in 2010 to 576 GW in 2030). Biomass performs better than Geothermal cogeneration. While there is an increase from about 2 GW (2010) to almost 29 GW (2030) for Biomass cogeneration, Geothermal heat capacity starts with far less than 1 GW in 2010 and increases to almost 20 GW in 2030.

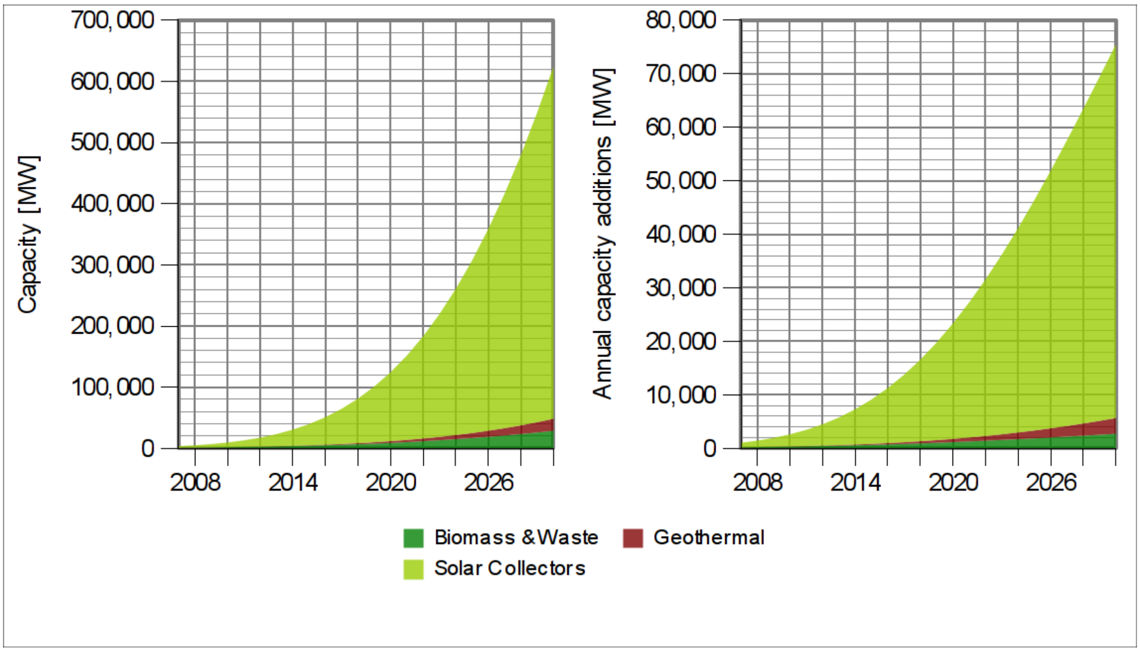


Figure 51: Development of renewable heat capacities in South Asia ("High Variant") [EWG; 2008].

Investment budget

The figure below shows the development of annual investments into renewable capacities (left hand side) and the development of shares the different technologies have at total investments (right hand side).

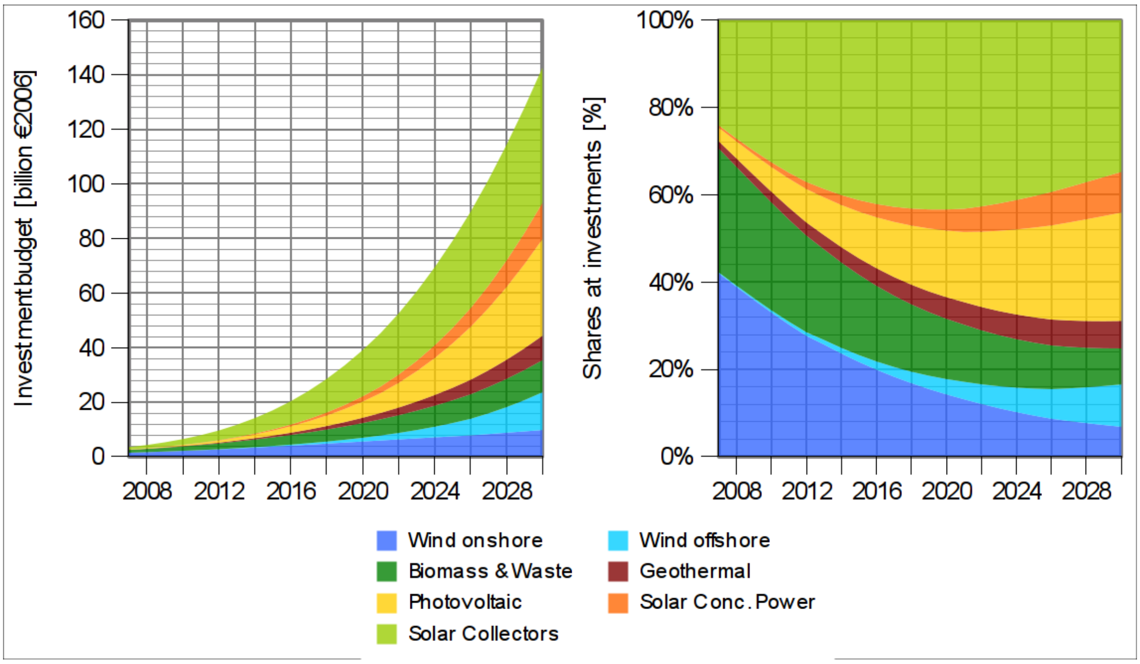


Figure 52: Development of the renewable energy investment budget in South Asia ("High Variant") [EWG; 2008].

<u>Latin America</u>

Assumptions

The target for investments into new generating capacities in Latin America is 90 $€_{2006}$ per capita, effectively resulting to 91 $€_{2006}$ per capita, due to iterative calculation. Considering the projected changes in population this results to a total investment budget of about 52 billion $€_{2006}$ in 2030.

As seen in most other regions, Wind Energy in total has the by far highest share at investments (35% in total, with 14.5 % onshore and 20.5 % offshore), with Solar Thermal collectors – again – being second (18 %). Third place goes to Solar Concentrating Power (13.2 %), directly followed by Geothermal Energy with 12.4 %. Photovoltaic and Geothermal Energy both contribute for about 10% of investments in 2030. Tidal, Wave and other Maritimes have a share of a merely 1.6 %.

Generally the investment scheme's structure for Latin America is similar to the one for OECD North America, but Solar Concentrating Power has a higher share than Biomass and Tidal, Wave and other Maritimes share is about the half if compared to North America. Solar electricity technologies together have a share of about 23 %, which is significantly lower than total for Wind Energy.

Latin America, investment budgets and distribution of investments								
Population			No. of inhabitants (Mio.)			Population density (cap/sqkm)		
					563.9			30.9
Investment 2030			Target			Reached by iteration		
Budget per capita			90 €2006			91 €2006		
Total investment budget						52 billion €2006		
Wind onshore	Wind offshore	Wind total	Biomass	Geothermal	PV	Solar Concentrating Power	Tide & Wave	Solar Collectors
Shares of the different technologies (%)								
14.5%	20.5%	35.0%	12.4%	9.9%	10.0%	13.2%	1.6%	18.0%
Total investment into technologies (billion €2006)								
7.49	10.54	18.03	6.41	5.08	5.14	6.79	0.81	9.26

Table 29: Scenario assumptions for Latin America in the high variant scenario [EWG; 2008].

Electricity

Latin America	Capacity (GW)		
Technology	2010	2020	2030
Total Renewables	**135.8**	**171.4**	**338.4**
Hydropower	125.0	131.4	137.8
Biomass and Waste	8.3	17.8	32.9
Wind onshore	0.7	7.9	57.5
Wind offshore	0.1	4.7	58.4
Geothermal	1.5	5.6	15.0
Solar PV	0.0	1.7	19.0
Solar Thermal Power	0.1	2.2	17.0
Tide/Wave/Maritim	0.0	0.0	0.8

Table 30: Development of renewable electricity generating capacity in Latin America ("High Variant") [EWG; 2008].

Planned extensions of Hydropower capacity will lead to a capacity increase of about 13 GW. Nevertheless the share of Hydropower at renewable capacities drops from 92 % in 2010 to below 41 percent by 2030.

Biggest capacity additions result from Wind Energy, which is well balanced between onshore and offshore installations. Starting with less than 1 GW capacity in 2010, the capacity grows to 116 GW by 2030, of which about the half is onshore (57.5 GW). This growth is not sufficient to take the first place from Hydropower, which has a capacity of about 138 GW by 2030. Biomass & Waste, with already more than 8 GW in 2010, increases its capacity to about 18 GW by 2020 and further to almost 33 GW by 2030, which is sufficient for becoming the third biggest contributor to renewable capacities. Solar Photovoltaic (19 GW in 2030), Solar Concentrating Power (17 GW) and Geothermal Energy (15 GW) take the next places with only smaller gaps in between these technologies. Tidal, Wave and other Maritims does evolve slow and remains below 1 GW until 2030.

Altogether renewable generating capacity in the "High Variant Scenario" increases to about 136 GW by 2010,further to 171 GW in 2020 and to about 338 GW in 2030.

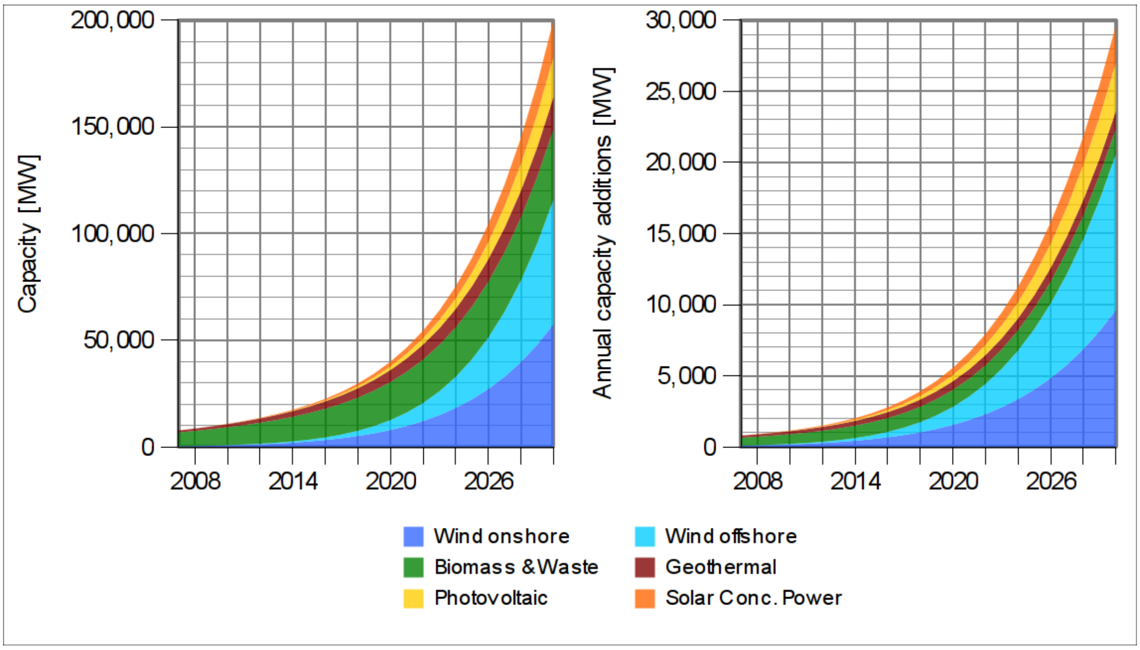


Figure 53: Development of renewable electricity generating capacity in Latin America ("High Variant") [EWG; 2007].

Heat

Latin America	Capacity (GW)		
Technology	2010	2020	2030
Total Renewable Heat	**15.9**	**63.1**	**183.7**
Biomass Heat	7.0	14.9	27.4
Geothermal Heat	2.0	7.6	20.3
Solarthermal Collectors	6.9	40.7	136.0

Table 31: Development of renewable heat generating capacity in Latin America ("High Variant") [EWG; 2008].

Biomass and Solar Thermal Collectors start from about the same level in 2010, but in the further development Solar Thermal Collector systems clearly outperform Biomass cogeneration in terms of heat capacity. While both technologies have a capacity of about 7 GW in 2010, Solar Collectors increase to 136 GW by 2030, which is significantly superior to the 27 GW Biomass cogeneration reaches by that time. Geothermal cogeneration does not perform much worse than

Biomass in terms of added capacity. Starting from 2 GW in 2010 the 2030 capacity reaches a level of more than 20 GW.

Altogether the a renewable heat generation capacity increase to almost 16 GW in 2010 and to more than 184 GW in 2030.

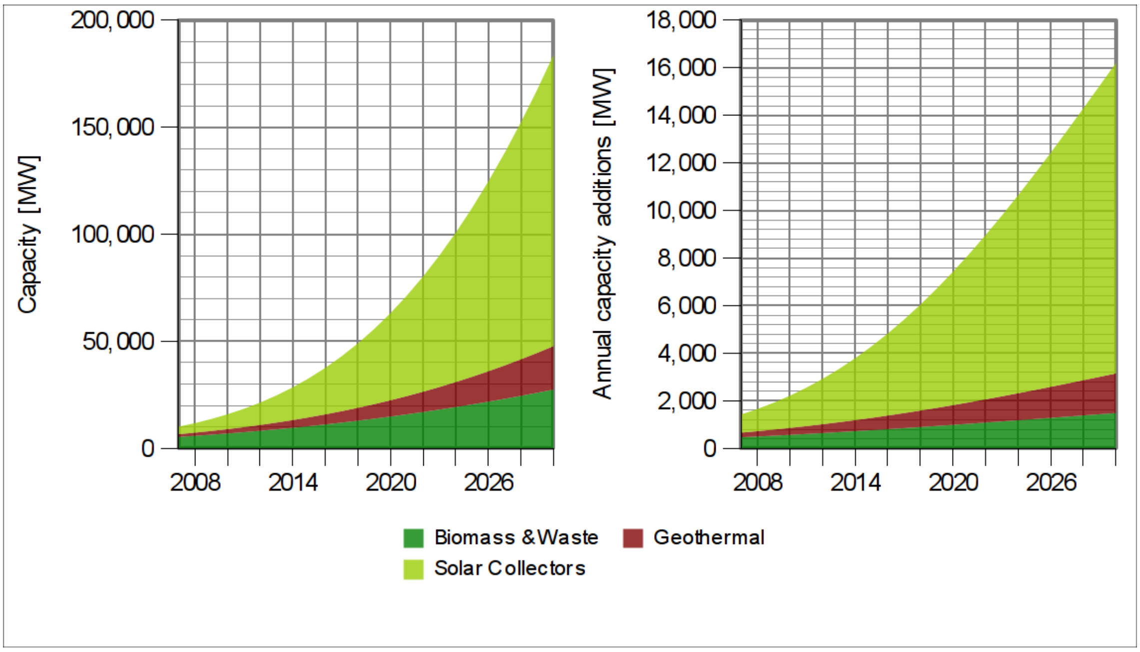


Figure 54: Development of renewable heat capacities in Latin America ("High Variant") [EWG; 2008].

Investment budget

The figure below shows the development of annual investments into renewable capacities (left hand side) and the development of shares the different technologies have at total investments (right hand side).

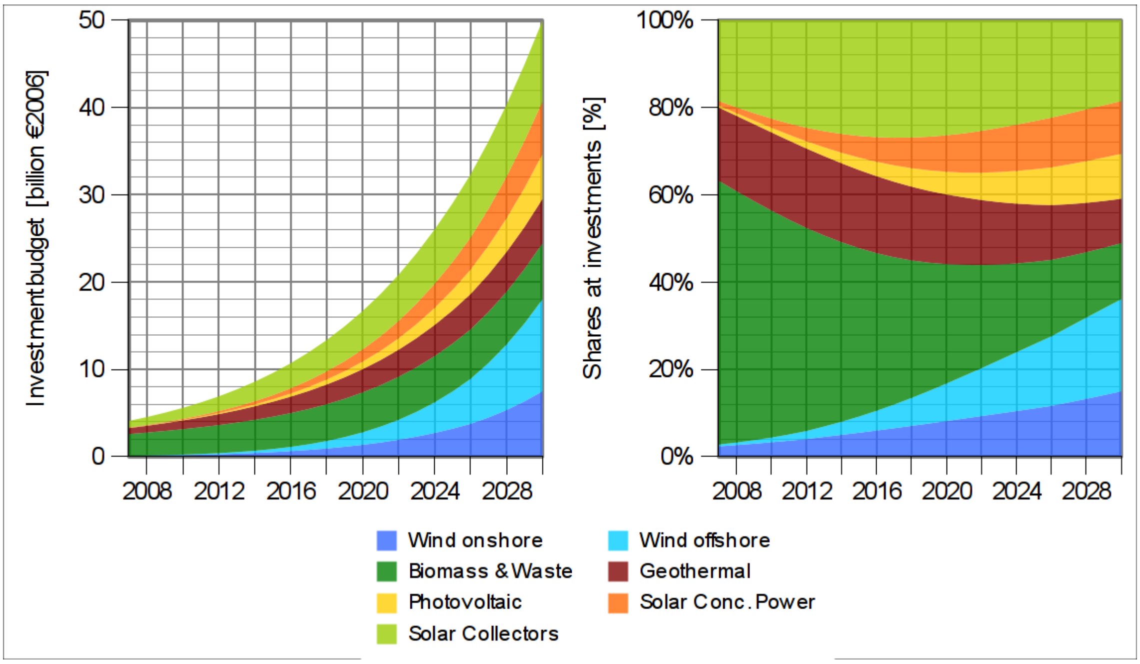


Figure 55: Development of the renewable energy investment budget in Latin America ("High Variant") [EWG; 2008].

Africa

Assumptions

The target for investments into new generating capacities in Africa is 40 $€_{2006}$ per capita, effectively resulting to 41 $€_{2006}$ per capita, due to iterative calculation. Considering the projected changes in population this results to a total investment budget of about 59 billion $€_{2006}$ in 2030.

The investment scheme's structure is dominated by Solar Thermal Collectors,which have a share at investments of slightly more then 30%[18]. Second placed is Wind Energy with 23.9 % (12.2 for onshore and 11.7 % for offshore), followed by Solar Concentrating Power (16 %), Biomass (11.2 %), Photovoltaic (10.6 %) ans Geothermal Energy, with 6.6 %. Tidal, Wave and other Maritimes have a negligible 1.3 %.

Due to the good solar potentials solar electricity , in terms of Photovoltaic and Solar Concentrating Power summed up (almost 27 %), has a higher share at the total investments as total Wind Energy (about 24 %). Nevertheless the share of Photovoltaic is lower than one might expect (lower than the one of Biomass), but this can be explained by the low population density and the lack of additional support, which is assumed for Solar Thermal Collectors.

18 It has to be noted here, that Solar Thermal Collectors cannot only be used for heating water or delivering process heat for production processes, but they can as well be used to produce cold or even for cooking, which will help to reduce the inefficient use of Biomass.

Africa, investment budgets and distribution of investments								
Population			No. of inhabitants (Mio.)			Population density (cap/sqkm)		
			1,455.2			50.7		
Investment 2030			Target			Reached by iteration		
Budget per capita			40 €$_{2006}$			11 €$_{2006}$		
Total investment budget						59 billion €$_{2006}$		
Wind onshore	Wind offshore	Wind total	Biomass	Geothermal	PV	Solar Concentrating Power	Tide & Wave	Solar Collectors
Shares of the different technologies (%)								
12.2%	11.7%	23.9%	11.2%	6.6%	10.6%	16.0%	1.3%	30.4%
Total investment into technologies (billion €$_{2006}$)								
7.27	6.95	14.22	6.64	3.92	6.30	9.48	0.78	18.06

Table 32: Scenario assumptions for Africa in the high variant scenario [EWG; 2008].

Electricity

Africa	Capacity (GW)		
Technology	2010	2020	2030
Total Renewables	**26.0**	**52.6**	**204.9**
Hydropower	21.6	21.6	21.6
Biomass and Waste	2.2	8.5	22.6
Wind onshore	1.1	10.9	64.0
Wind offshore	0.0	2.8	37.8
Geothermal	0.8	3.7	10.9
Solar PV	0.1	3.0	26.0
Solar Thermal Power	0.0	2.1	21.1
Tide/Wave/Maritim	0.0	0.0	0.8

Table 33: Development of renewable electricity generating capacity in Africa ("High Variant") [EWG; 2008].

While Hydropower remains on a capacity of almost 22 GW, other renewable technologies show a substantial increase in generating capacities. The share of Hydropower – more than 83 % in 2010 - drops to about one tenth by 2030.

Again Wind Energy shows the biggest increase in generating capacity (from about 1 GW in 2010 to about 102 GW in 2030), of which more than one third will be installed offshore by 2030 (64 GW onshore and 38 GW offshore). Hydropower looses its dominating position not only to both fractions of Wind Energy, but also to Photovoltaic (second place, 26 GW in 2030), Biomass & Waste (almost 23 GW in 2030) and Solar Concentrating Power, which takes the fourth place in the capacity ranking with more than 21 GW in 2030. Geothermal capacity increase to about the half of that (about 11 GW in 2030) and Tidal, Wave & other Maritimes only plays a minor role with less than 1 GW in 2030.

Altogether renewable generating capacity in the "High Variant Scenario" increases to about 26 GW by 2010, to 53 GW in 2020 and to about 205 GW in 2030.

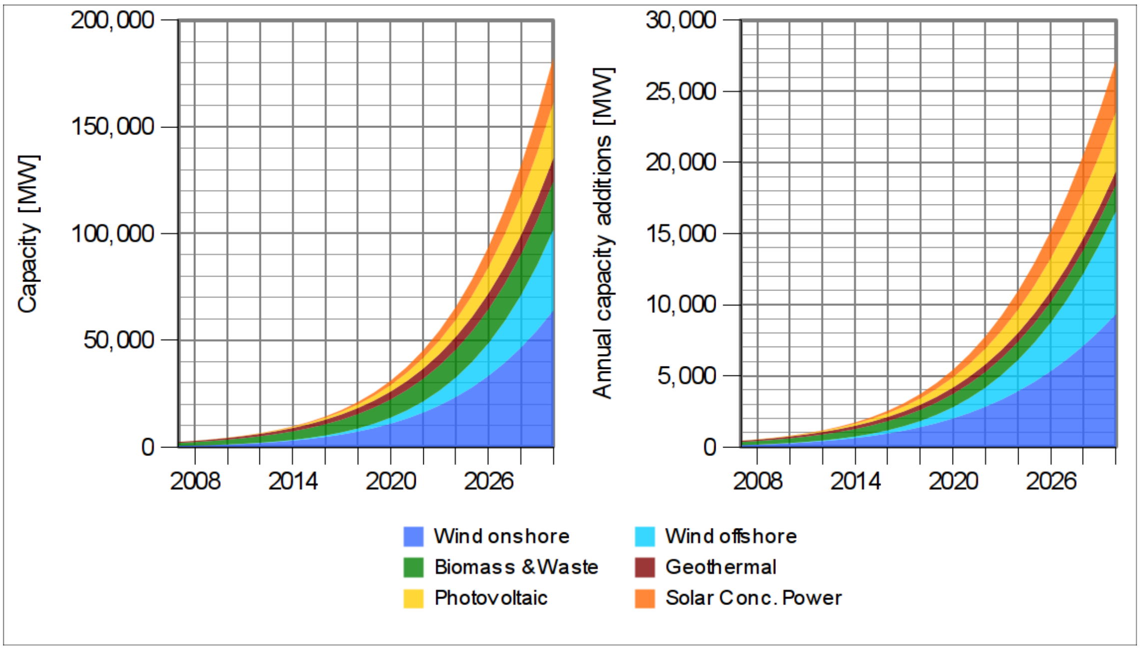


Figure 56: Development of renewable electricity generating capacity in Africa ("High Variant") [EWG; 2008].

Heat

Africa	Capacity (GW)		
Technology	**2010**	**2020**	**2030**
Total Renewable Heat	**6.7**	**52.5**	**236.1**
Biomass Heat	1.9	7.1	18.9
Geothermal Heat	1.1	5.0	14.7
Solarthermal Collectors	3.7	40.4	202.5

Table 34: Development of renewable heat generating capacity in Africa ("High Variant") [EWG; 2008].

Solar Thermal Collectors perform much better than both of the other technologies. While the installed capacity in 2010 is close to 4 GW, this figure increases to almost 203 GW by 2030. Biomass and Geothermal, both starting with lower figures in 2010 (2 GW Biomass and 1 GW Geothermal reach capacities of 19 GW (Biomass) and 15 GW (Geothermal) by the end of the period considered here.

Altogether the a renewable heat generation capacity increase to almost 7 GW in 2010 and to about 236 GW in 2030.

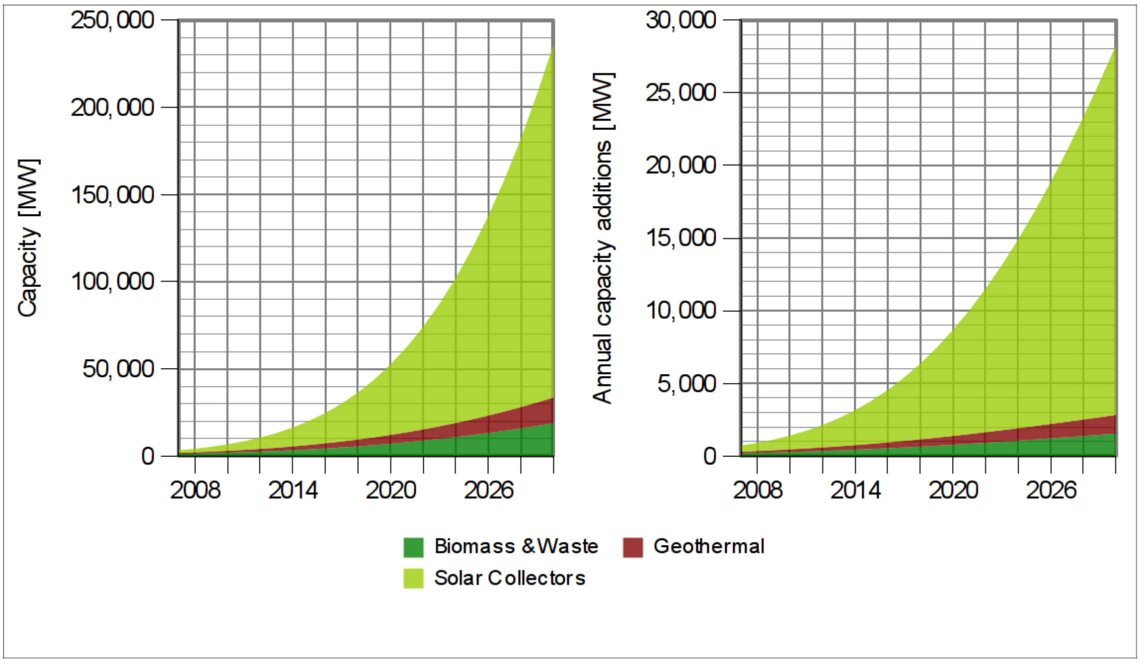


Figure 57: Development of renewable heat capacities in Africa ("High Variant") [EWG; 2008].

Investment budget

The figure below shows the development of annual investments into renewable capacities (left hand side) and the development of shares the different technologies have at total investments (right hand side).

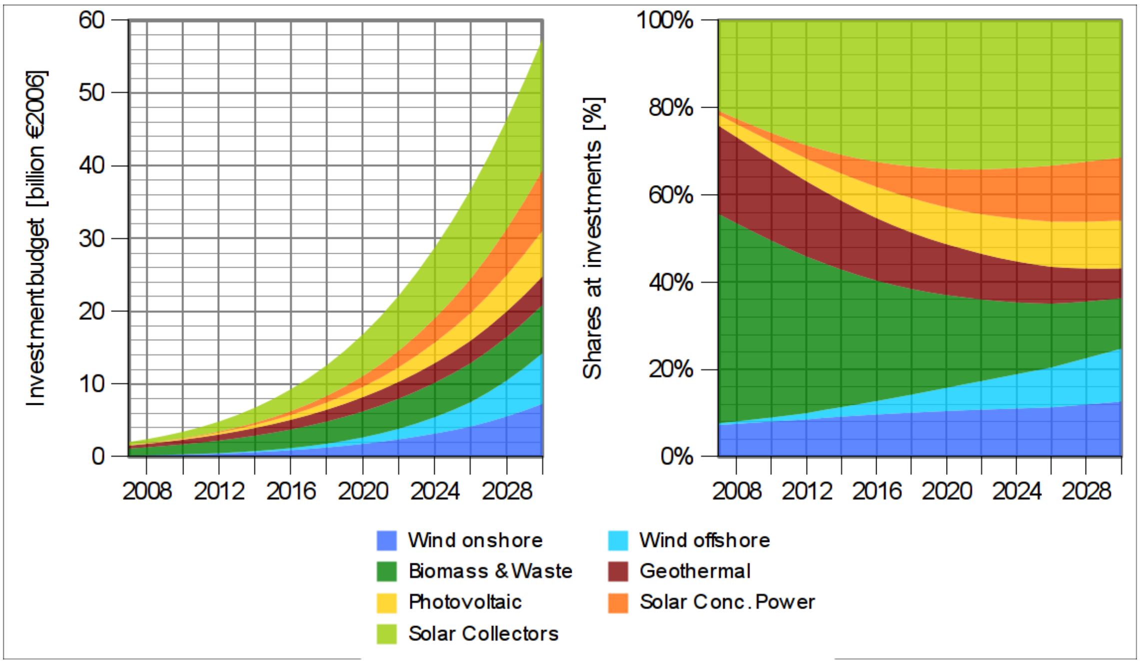


Figure 58: Development of the renewable energy investment budget in Africa ("High Variant") [EWG; 2008].

<u>Middle East</u>

Assumptions

The target for investments into new generating capacities in the Middle East is 200 $€_{2006}$ per capita, effectively resulting to 202 $€_{2006}$ per capita, due to iterative calculation. Considering the projected changes in population this results to a total investment budget of about 55 billion $€_{2006}$ in 2030.

Although the investment structure is dominated by the total of Wind Energy (34.4 %, with 14.3 % onshore and 20.1 % offshore), the structure is relatively well balanced between Wind energy and the total of solar electricity production. Both solar electricity technologies together (34.7 %) have almost the same as total Wind Energy. Other than in most of the regions, Solar Thermal Collectors take the third place, exceeded by Solar Concentrating Power (21 %) and Wind Energy. While there is no Biomass use assumed for this region (lack of potential), Geothermal Energy receives 9.5 % of the total investments by 2030. Another small fraction goes to Tidal, Wave and other Maritimes (1.3 %.)

Middle East, investment budgets and distribution of investments								
Population			No. of inhabitants (Mio.)			Population density (cap/sqkm)		
			272.3			52.5		
Investment 2030			Target			Reached by iteration		
Budget per capita			200 €2006			202 €2006		
Total investment budget						55 billion €2006		
Wind onshore	Wind offshore	Wind total	Biomass	Geothermal	PV	Solar Concentrating Power	Tide & Wave	Solar Collectors
Shares of the different technologies (%)								
14.3%	20.1%	34.4%	0.0%	9.5%	13.7%	21.0%	1.8%	19.6%
Total investment into technologies (billion €2006)								
7.86	11.07	18.93	0.00	5.26	7.52	11.56	0.99	10.81

Table 35: Scenario assumptions for the Middle East in the high variant scenario [EWG; 2008].

Electricity

Middle East	Capacity (GW)		
Technology	2010	2020	2030
Total Renewables	**9.0**	**42.6**	**238.8**
Hydropower	7.5	7.5	7.5
Biomass and Waste	0.0	0.0	0.0
Wind onshore	1.3	21.5	96.2
Wind offshore	0.1	5.5	64.7
Geothermal	0.0	0.9	7.9
Solar PV	0.1	3.7	32.0
Solar Thermal Power	0.1	3.6	29.5
Tide/Wave/Maritim	0.0	0.0	1.0

Table 36: Development of renewable electricity generating capacity in the Middle East ("High Variant") [EWG; 2008].

The unchanged capacity of Hydropower, together with a growth of other renewables, leads to a drop in the share of Hydropower from more than 82 % (2010) to only a little bit more than 3 % by 2030.

Wind Energy performs best, with an increase in generating capacity from slightly more than 1 GW in 2010 to about 161 GW in 2030. Offshore Wind energy plays an important role: more than 40 % of the total Wind Energy capacity isoffshore by then. As could have been expected for this region, Solar technologies also show a massive growth of generating capacities. While Photovoltaic becomes the second biggest contributor until 2030 (32 GW), Solar Concentrating Power, with almost 30 GW in 2030, gets close to this. Geothermal Energy (almost 8 GW in 2030) grows to a generating capacity somewhat above the capacity of Hydropower (7.5 GW). While Biomass is not a part of the supply system in the Middle East, Tidal, Wave & other Maritims grow to 1 GW generating capacity in 2030.

Altogether renewable generating capacity in the "High Variant Scenario" increases to about 9 GW by 2010, to 43 GW in 2020 and to about 239 GW in 2030.

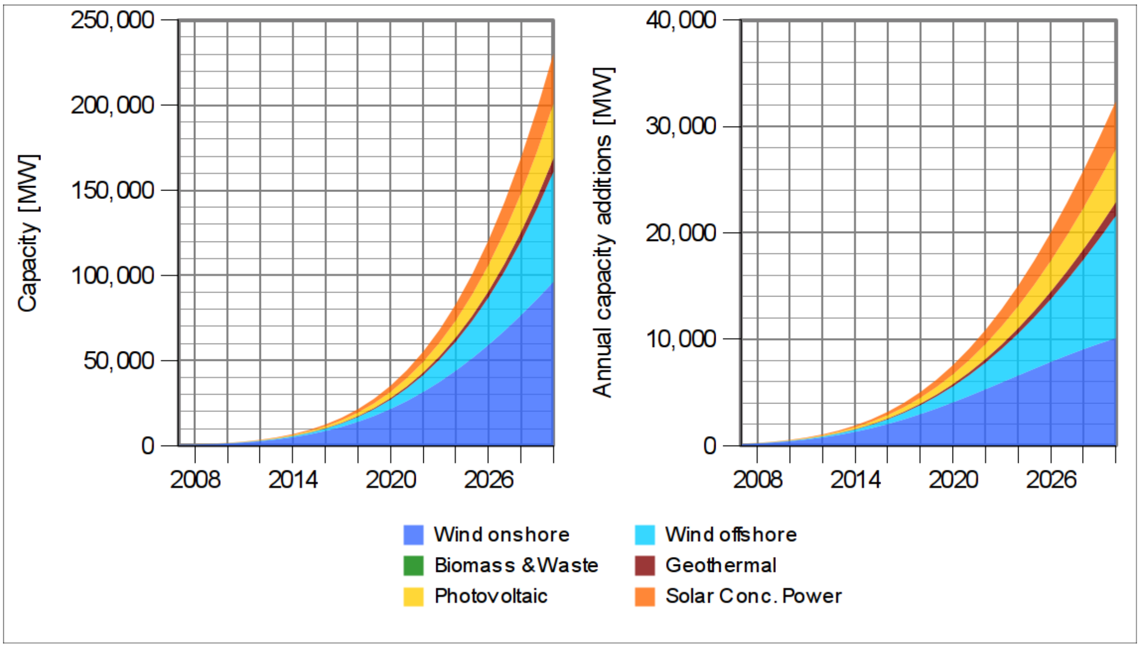


Figure 59: Development of renewable electricity generating capacity in the Middle East ("High Variant") [EWG; 2008].

Heat

Middle East	Capacity (GW)		
Technology	**2010**	**2020**	**2030**
Total Renewable Heat	**0.1**	**11.2**	**110.7**
Biomass Heat	0.0	0.0	0.0
Geothermal Heat	0.0	1.2	10.7
Solarthermal Collectors	0.1	10.0	100.1

Table 37: Development of renewable heat generating capacity in the Middle East ("High Variant") [EWG; 2008].

Biomass does not play any role in the Middle East. The main heat capacity results from the extension of Solar Thermal Collector systems. Starting from the scratch in 2010, the installed capacity in 2030 is about 100 GW. Geothermal cogeneration reaches about a tenth of that by 2030 (almost 11 GW).

Altogether the a renewable heat generation capacity is far less than 1 GW in 2010 and increase to about 111 GW in 2030.

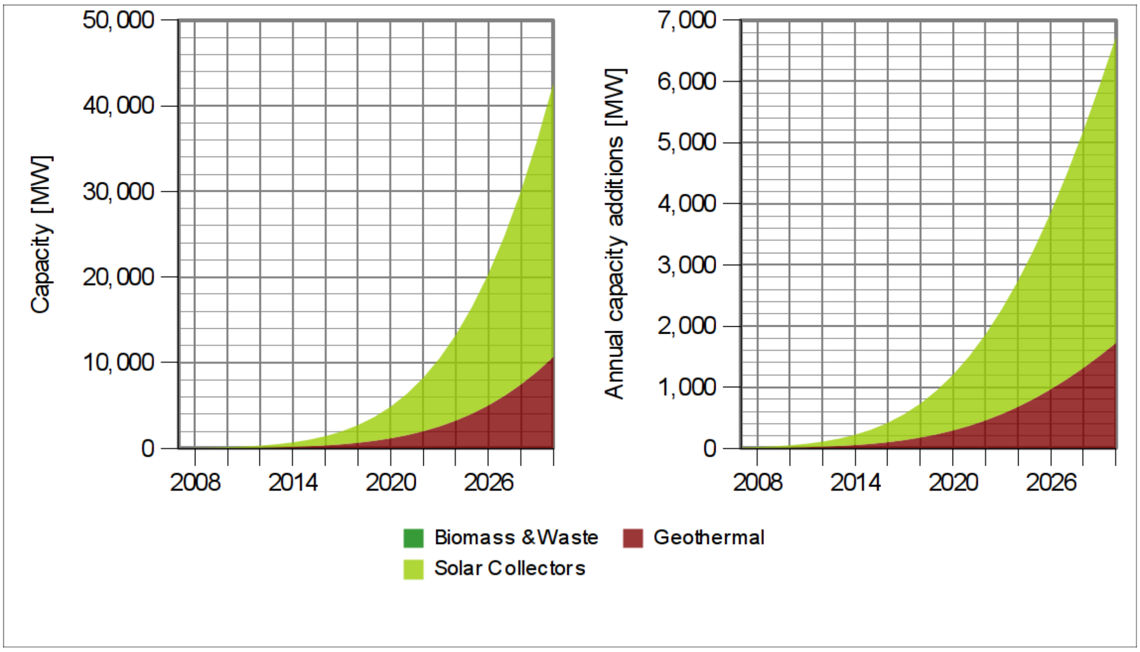


Figure 60: Development of renewable heat capacities in the Middle East ("High Variant") [EWG; 2008].

Investment budget

The figure below shows the development of annual investments into renewable capacities (left hand side) and the development of shares the different technologies have at total investments (right hand side).

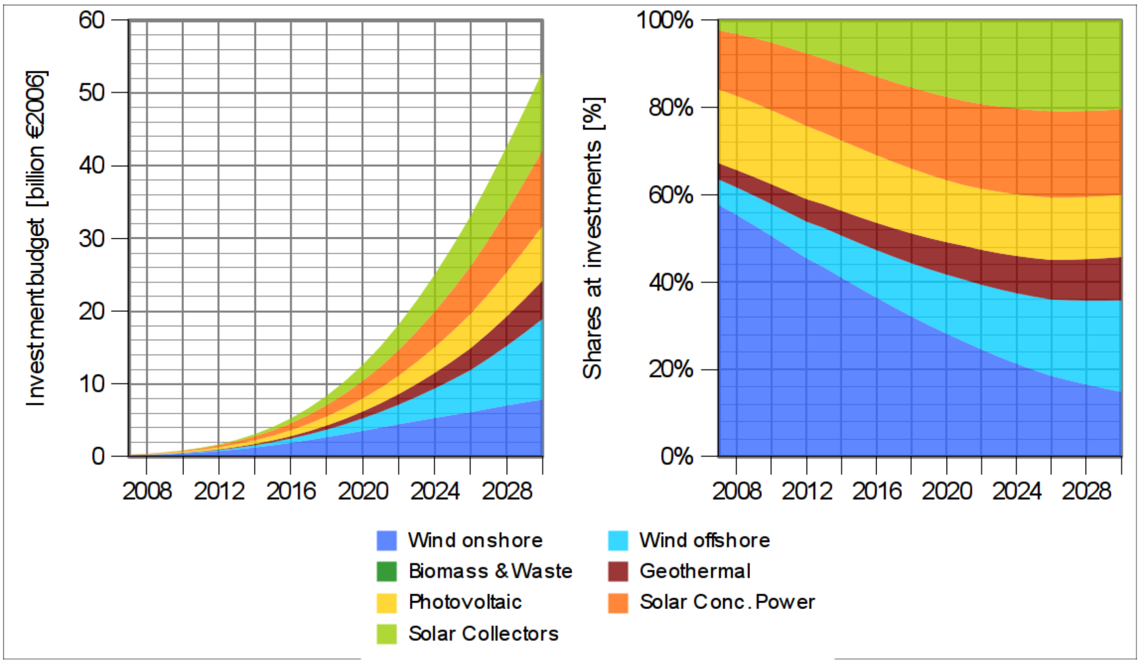


Figure 61: Development of the renewable energy investment budget in the Middle East ("High Variant") [EWG; 2008].

Generating capacities, production and investments in the "Low Variant" scenario

OECD Europe

Assumptions

The target for investments into new generating capacities in OECD Europe is 110 $€_{2006}$ per capita, which effectively – due to iterative calculation – result to 111 $€_{2006}$ per capita. Considering the projected changes in population this results to a total investment budget of about 60 billion $€_{2006}$ in 2030.

The distribution of investments among the different technologies is dominated by Wind Energy (about 31% in total, 9.5 % for onshore and 22 % for offshore). Second biggest share goes to Solar Thermal Collectors (24.5%), followed by Photovoltaic (13.1 %), Solar Concentrating Power (10 %), Biomass (9.5%), Geothermal Energy (8.3 %) and Tidal, Wave & other Maritimes, with 3.3 %.

Although Wind Energy has the biggest investment shares in total, Photovoltaic and Solar Concentrating Power – on the side of electricity producing technologies – have higher investment share than onshore Wind Energy alone.

OECD Europe, investment budgets and distribution of investments								
Population			**No. of inhabitants (Mio.)**			**Population density (cap/sqkm)**		
					542.8			111.5
Investment 2030			**Target**			**Reached by iteration**		
		Budget per capita	110 $€_{2006}$			111 $€_{2006}$		
		Total investment budget				60.4 billion $€_{2006}$		
Wind onshore	**Wind offshore**	**Wind total**	**Biomass**	**Geothermal**	**PV**	**Solar Concentrating Power**	**Tide & Wave**	**Solar Collectors**
Shares of the different technologies (%)								
9,5%	21,9%	31,3%	9,5%	8,3%	13,1%	10,0%	3,3%	24,5%
Total investment into technologies (billion $€_{2006}$)								
5,71	13,21	18,92	5,76	5,02	7,91	6,03	2,00	14,78

Table 38: Scenario assumptions for OECD Europe in the low variant scenario [EWG; 2008].

Electricity

OECD Europe	Capacity (GW)		
Technology	**2010**	**2020**	**2030**
Total Renewables	**277,4**	**467,8**	**700,2**
Hydropower	150,3	150,3	150,3
Biomass and Waste	15,8	26,0	39,8
Wind onshore	103,6	248,9	339,2
Wind offshore	2,1	18,9	91,3
Geothermal	2,6	7,4	16,9
Solar PV	2,6	13,2	44,6
Solar Thermal Power	0,1	1,9	13,9
Tide/Wave/Maritim	0,3	1,2	4,1

Table 39: Development of renewable electricity generating capacity in the OECD Europe region ("Low Variant") [EWG; 2008].

The development of generating capacities in OECD Europe shows a massive extension until 2030. New renewables (non-hydro), making up less than the half of renewable capacities in 2010, overtake hydropower between 2010 and 2020 and – by 2030 – exceed Hydropower's generating capacity by far. Although all new renewables show a massive growth in capacity, it is Wind Energy to outperform all other technologies. Especially onshore Wind Energy shows a massive increase after 2010. By 2030 more than 60% of the total renewable generating capacity is Wind Energy, followed by Photovoltaic with slightly more than 6 %. Although Geothermal Energy shows a growth almost comparable to Biomass & Waste, it still has far less than half the generating capacity by 2030. Solar Concentrating Power reaches a capacity close to the one of Geothermal Energy. Tidal, Wave and other Maritimes does not show that massive extension and still contribute less than 1 % to the total renewable capacity by 2030.

Altogether renewable generating capacity in the "Low Variant Scenario" increases to about 280 GW by 2010,further to 470 GW in 2020 and to about 700 GW in 2030. The capacity contributed by Hydropower, assumed to be 150 GW over the whole period, drops from 54 % in 2010 to 32 % in 2020 and to 21 % in 2030.

Wind Energy shows the biggest increase in generating capacities. Starting with more than 100 GW in 2010 (with 2 GW of that being offshore), the capacity reaches about 430 GW in 2030. The distribution between onshore Wind and offshore Wind is more than three fourths onshore and less than one fourth offshore (339 GW onshore and 91 GW offshore). Solar Photovoltaic capacity in 2010 is almost 3 GW, with an increase to about 13 GW by 2020 and 45 GW in 2030. This makes PV the second biggest contributor in terms of capacity by then. Another big contribution comes from Biomass; increasing from 16 GW in 2010 to 26 GW in 2020 and 40 GW in 2030. Geothermal Energy's capacity is only 3 GW more than Solar Concentrating Power (SCP), with 17 GW Geothermal and 14 GW SCP capacity. Tidal, Wave and other Maritimes, considered being prototype technologies now, increase to slightly more than 4 GW by 2030.

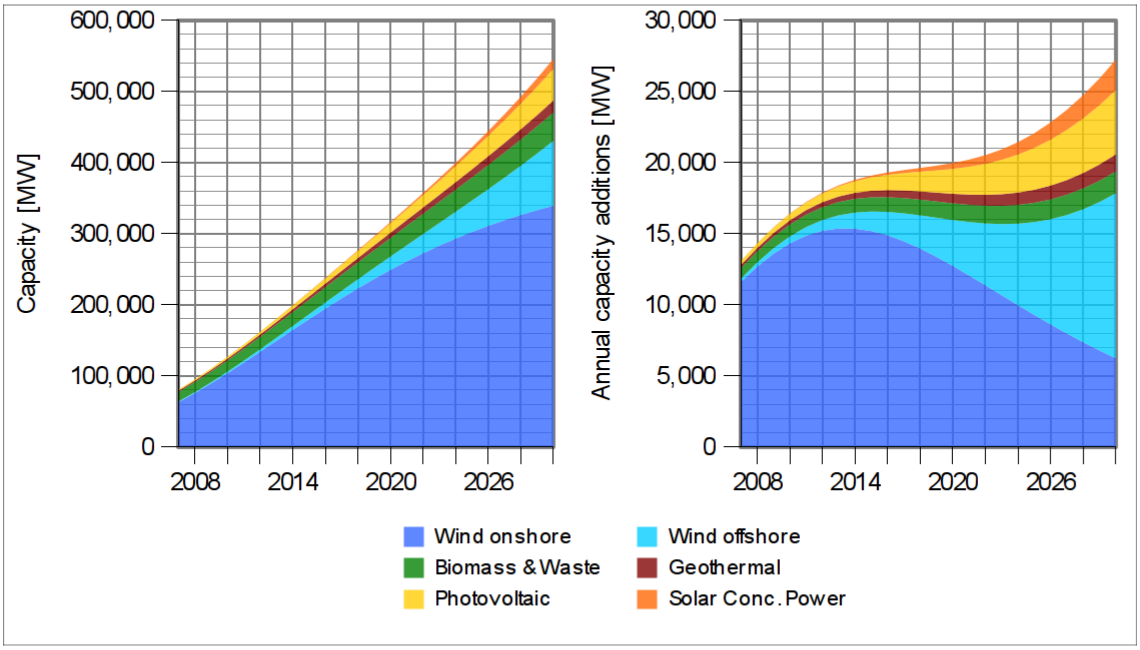


Figure 62: Development of renewable electricity generating capacity in OECD Europe ("Low Variant") [EWG; 2008].

Heat

OECD Europe	Capacity (GW)		
Technology	**2010**	**2020**	**2030**
Total Renewable Heat	**61.0**	**173.6**	**372.6**
Biomass Heat	13.2	21.7	33.1
Geothermal Heat	3.5	10.0	22.8
Solarthermal Collectors	44.3	141.8	316.6

Table 40: Development of renewable heat generating capacity in the OECD Europe region ("Low Variant") [EWG; 2008].

While the Biomass heat generation capacity increase from 13 GW in 2010 to 33 GW in 2030, a smaller proportion results from Geothermal cogeneration (almost 4 GW in 2010 to about 23 GW in 2030).

Most heat generation capacity results from Solar Thermal Collector systems. In 2010 there is already a generation capacity of about 44 GW which increases to approx. 317 GW by 2030. Altogether there is a renewable heat generation capacity of 373 GW in 2030 (61 GW in 2010).

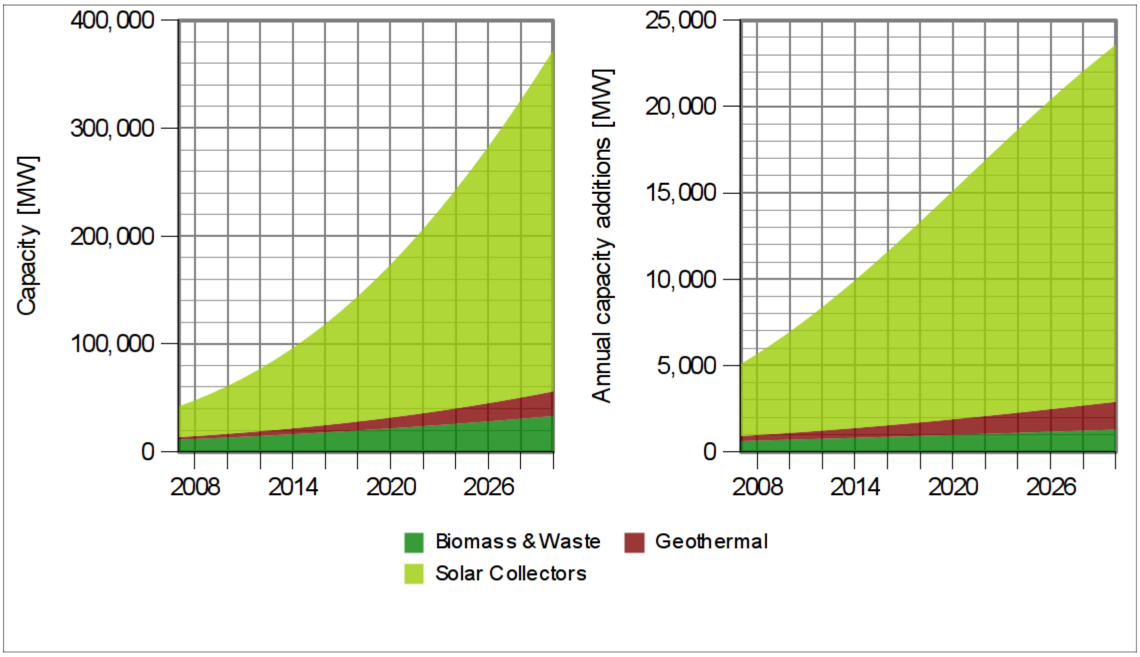


Figure 63: Development of renewable heat capacities in OECD Europe ("Low Variant") [EWG; 2008].

Investment budget

The figure below shows the development of annual investments into renewable capacities (left hand side) and the development of shares the different technologies have at total investments (right hand side).

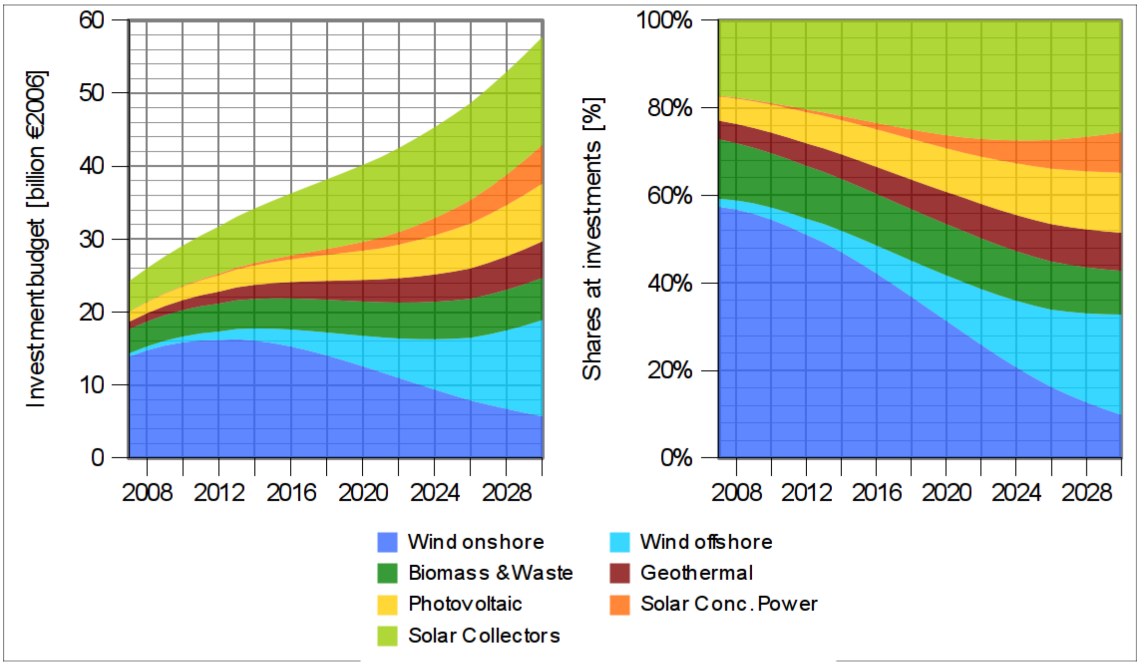


Figure 64: Development of the renewable energy investment budget in OECD Europe ("Low Variant") [EWG; 2008].

<u>OECD North America</u>

Assumptions

The target for investments into new generating capacities in OECD North America is 110 $€_{2006}$ per capita, which was well met by iterative calculation. Considering the projected changes in population this results to a total investment budget of about 59 billion $€_{2006}$ in 2030.

The distribution of investments among the different technologies is dominated by Wind Energy (about 32% in total, 14 % for onshore and 18 % for offshore). Second biggest share goes to Solar Thermal Collectors (25 %, higher than onshore or offshore Wind energy alone), followed by Biomass (12 %), Solar Concentrating Power (10.5 %), Photovoltaic (10%), Geothermal Energy (8 %) and Tidal, Wave & other Maritim, with 3 %.

The distribution is similar to that in OECD Europe in terms of Wind Energy having the highest investments by far. Differences especially lie within the distribution between onshore Wind Energy and offshore installations, with onshore Wind being closer to offshore Wind than in the OECD Europe region. Nevertheless even the investment share of onshore Wind Energy exceeds the shares off all other non-Wind electricity generating technologies. Investments into Biomass are higher too and, due to the huge potentials for Solar Concentrating Power, SCP is of higher significance than Photovoltaic.

OECD North America, investment budgets and distribution of investments								
Population			No. of inhabitants (Mio.)			Population density (cap/sqkm)		
			538.1			26.7		
Investment 2030			Target			Reached by iteration		
Budget per capita			110 €2006			110 €2006		
Total investment budget						59.2 billion €2006		
Wind onshore	Wind offshore	Wind total	Biomass	Geothermal	PV	Solar Concentrating Power	Tide & Wave	Solar Collectors
Shares of the different technologies (%)								
14,1%	18,1%	32,1%	11,9%	7,8%	9,9%	10,5%	3,0%	24,8%
Total investment into technologies (billion €2006)								
8.3	10.7	19.0	7.1	4.6	5.8	6.2	1.8	14.7

Table 41: Scenario assumptions for OECD North America in the low variant scenario [EWG; 2008].

Electricity

OECD North America	Capacity (GW)		
Technology	2010	2020	2030
Total Renewables	**209,6**	**303,4**	**507,8**
Hydropower	158,8	158,8	158,8
Biomass and Waste	17,9	30,1	46,9
Wind onshore	23,3	77,3	160,9
Wind offshore	0,5	8,2	59,9
Geothermal	6,2	12,2	21,5
Solar PV	1,5	8,7	31,6
Solar Thermal Power	1,2	7,0	24,5
Tide/Wave/Maritim	0,2	1,1	3,7

Table 42: Development of renewable electricity generating capacity in the OECD North America region ("Low Variant") [EWG; 2008].

Renewable generating capacities in OECD North America increase considerably until 2030. New renewables (non-hydro), making up about one fourth of renewable capacities in 2010, close the gap to hydropower between 2010 and 2020 and – by 2030 – exceed Hydropower's generating capacity by more than the double. All new renewables show a strong growth until 2030, but Wind Energy performs best. Offshore Wind Energy does only show marginal capacities until 2010, but development speeds up in the aftermath. By 2030 more than 40 % of the total renewable generating capacity is Wind Energy, followed by Biomass with about 9 % of all renewable capacities. Although Biomass & Waste does not show such strong growth as Wind energy or Photovoltaic, the generating capacity in 2030 is approx. 1.5 times the Photovoltaic capacity (third biggest capacity of the "new" renewables). Solar Concentrating Power, having a little bit less capacity than Photovoltaic in 2010, develops comparably weaker, but ends up with a higher generating capacity as Geothermal Energy in 2030. Although Tidal, Wave and other Maritimes are secondary, they are not entirely insignificant.

Altogether renewable generating capacity in the "Low Variant Scenario" increases to about 210 GW by 2010 and further to 300 GW in 2020 and about 510 GW in 2030 which is considerably less if compared to Europe. The capacity contributed by hydropower, assumed to be 160 GW over the whole period, drops from over 75 % in 2010 to 52 % in 2020 and less than one third in 2030.

Wind Energy shows the biggest increase in generating capacities. Starting with about 24 GW in 2010 (with offshore being negligible), the capacity reaches about 220 GW in 2030. The distribution between onshore Wind and offshore Wind is about three fourths to one fourth (161 GW onshore and 60 GW offshore), which is well comparable to the related figure for OECD Europe. Solar Photovoltaic capacity in 2010 is about 1.5 GW and increases to about 9 GW by 2020 and 32 GW in 2030. This is not enough to take the second position from Biomass & Waste until 2030 (47 GW for Biomass & Waste in 2030). Another bigger proportion results from Solar Concentrating Power, with almost 25 GW in 2030; increasing from about 1 GW in 2010 and 7 GW in 2020. Geothermal Energy, having a capacity of more than 6 GW by 2010, increases to somewhat less than half the capacity of Biomass & Waste until 2030 (almost 22 GW in 2030) . Tidal, Wave and other Maritimes, increase from about 0.2 GW in 2010 to slightly less than 4 GW by 2030.

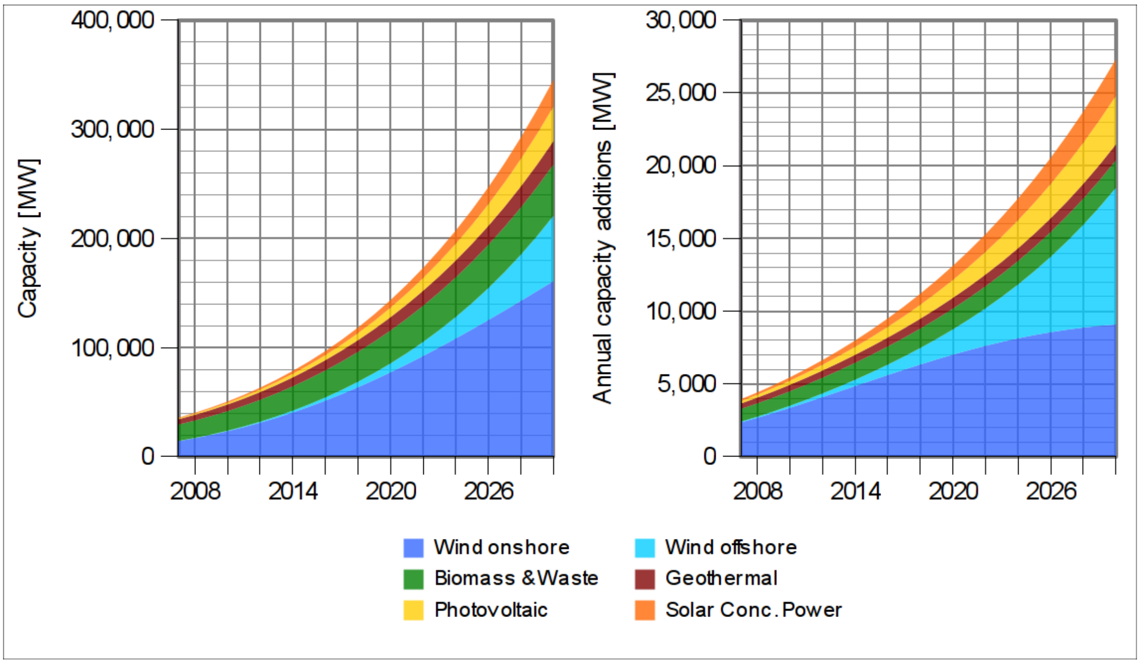


Figure 65: Development of renewable electricity generating capacity in OECD North America ("Low Variant") [EWG; 2008].

Heat

OECD North America	Capacity (GW)		
Technology	2010	2020	2030
Total Renewable Heat	**72.5**	**187.9**	**386.7**
Biomass Heat	14.9	25.1	39.1
Geothermal Heat	8.3	16.4	29.0
Solarthermal Collectors	49.3	146.4	318.6

Table 43: Development of renewable heat generating capacity in the OECD North America region ("Low Variant") [EWG; 2008].

The Biomass heat generation capacity increases from 15 GW in 2010 to 39 GW in 2030 and is bigger than the capacity from Geothermal cogeneration, which increase from about 8 GW in 2010 to 29 GW in 2030.

Most heat generation capacity results from Solar Thermal Collector systems. Starting with close to 50 GW in 2010 the capacity increases to about 319 GW by 2030. Altogether there is a renewable heat generation capacity of 387 GW in 2030 (73 GW in 2010).

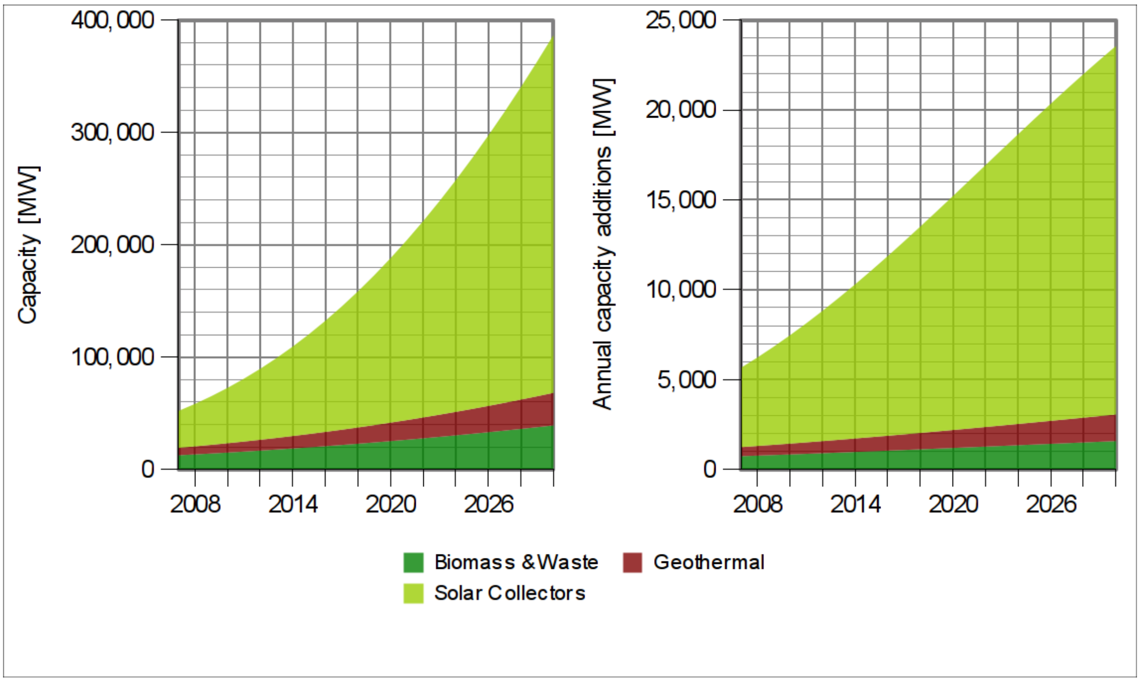


Figure 66: Development of renewable heat capacities in OECD North America ("Low Variant") [EWG; 2008].

Investment budget

The figure below shows the development of annual investments into renewable capacities (left hand side) and the development of shares the different technologies have at total investments (right hand side).

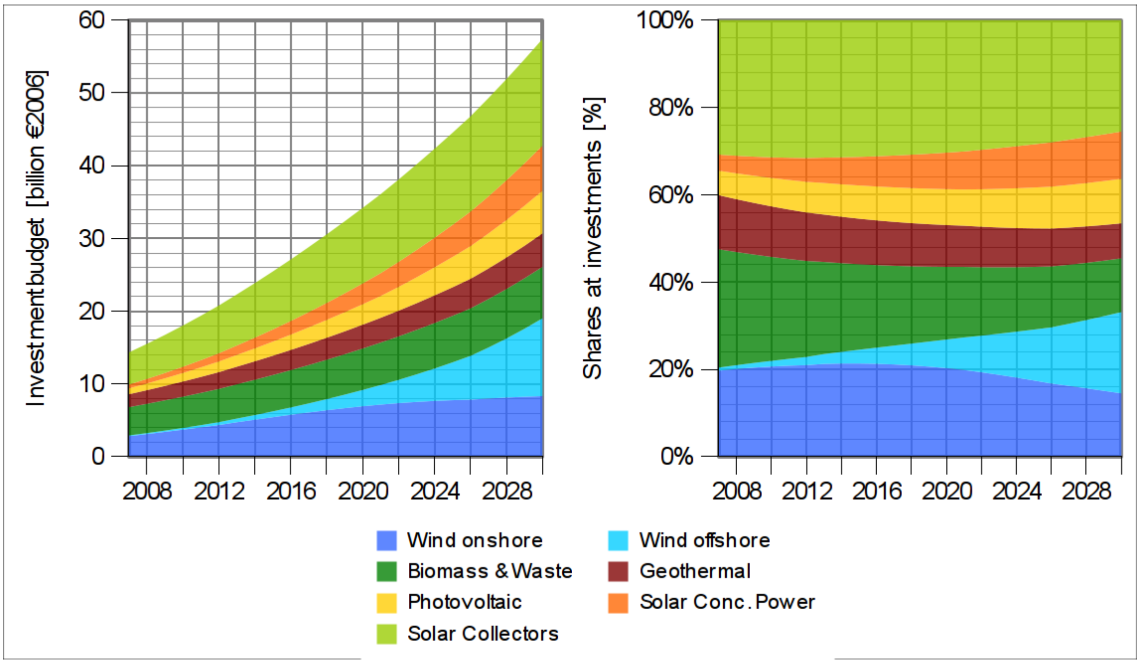


Figure 67: Development of the renewable energy investment budget in OECD North America ("Low Variant") [EWG; 2008].

<u>OECD Pacific</u>

Assumptions

The target for investments into new generating capacities in OECD Pacific is 110 $€_{2006}$ per capita, which effectively resulted to 112 $€_{2006}$, due to the iterative calculation approach in scenario development. Considering the projected changes in population this results to a total investment budget of about 22 billion $€_{2006}$ in 2030.

The distribution of investments among the different technologies is dominated by Wind Energy (about 33% in total, 15 % for onshore and 18 % for offshore). Second biggest share goes to Solar Thermal Collectors (24 %), followed by Solar Concentrating Power (15 %), Biomass (9 %), Photovoltaic and Geothermal Energy (almost 8 % both) and Tidal, Wave & other Maritimes, with 3 %.

As already seen for OECD Europe and North America, Wind Energy dominates the investment figure. The distribution between onshore and offshore Wind Energy is comparable to the distribution in OECD North America. Biggest difference to the other OECD regions is the role of Solar Concentrating Power, which takes the third place in investment shares (en par with onshore

Wind), which is mainly due to the huge potentials in Australia. Photovoltaic is of lower significance, as the population density in this region is by far lower if compared to OECD Europe or even to North America[19].

OECD Pacific, investment budgets and distribution of investments								
Population			No. of inhabitants (Mio.)			Population density (cap/sqkm)		
			194.8			12.0		
Investment 2030			Target			Reached by iteration		
Budget per capita			110 €$_{2006}$			112 €$_{2006}$		
Total investment budget						22 billion €$_{2006}$		
Wind onshore	Wind offshore	Wind total	Biomass	Geothermal	PV	Solar Concentrating Power	Tide & Wave	Solar Collectors
Shares of the different technologies (%)								
15.0%	17.8%	32.8%	9.4%	7.8%	7.7%	15.0%	2.9%	24.4%
Total investment into technologies (billion €$_{2006}$)								
3.3	3.9	7.2	2.1	1.7	1.7	3.3	0.6	5.3

Table 44: Scenario assumptions for OECD Pacific in the low variant scenario [EWG; 2008].

Electricity

OECD Pacific	Capacity (GW)		
Technology	2010	2020	2030
Total Renewables	**56,3**	**99,2**	**180,9**
Hydropower	36,8	36,8	36,8
Biomass and Waste	7,3	11,2	16,2
Wind onshore	7,2	34,1	71,2
Wind offshore	0,5	4,9	25,7
Geothermal	2,2	4,4	7,9
Solar PV	2,2	6,1	13,7
Solar Thermal Power	0,1	1,3	8,2
Tide/Wave/Maritim	0,1	0,4	1,3

Table 45: Development of renewable electricity generating capacity in the OECD Pacific region ("Low Variant") [EWG; 2008].

While hydropower, which has an unchanged capacity from now to 2030, contributes about 65 % to all renewable capacities by 2010, the good performance of new renewables leads to a drop in Hydropower's share to about one fifth by 2030. As a result of Wind Energy potentials and a comparably competitive price level, Wind energy again contributes most to increasing renewable generating capacities. While Wind Energy's capacity is about one fifth of Hydropower's capacity in 2010, this figure increases to more than 2.6 times the capacity of Hydropower by 2030. Here again the ratio of onshore to offshore Wind is about three fourths onshore to one fourth offshore. Photovoltaic does not reach the same capacity as any of the Wind Energy fractions by 2030, but it comes close to Biomass, although Photovoltaic capacity is only about one third of the Biomass'

19 It has to be considered, that there are no “open land” installations of photovoltaic systems in the scenarios.

capacity by 2010. Solar Concentrating Power and Geothermal Energy end up in about the same capacity.

Altogether renewable generating capacity in the "Low Variant Scenario" increases to about 56 GW by 2010,to almost 100 GW in 2020 and to about 180 GW in 2030. The share of new renewables increases to almost 80 % during that period.

Wind Energy capacities increase most, starting with about 8 GW in 2010 the capacity reaches about 97 GW in 2030 (71 GW onshore and 26 GW offshore). Solar Photovoltaic capacity, about 2 GW in 2010, increases to about 14 GW by 2030, which is somewhat less than the contribution of Biomass (16 GW in 2030, about 7 GW in 2010). The 2030's contributions of Solar Concentrating Power and Geothermal Energy are definitely lower, with about 8 GW capacity both have more or less half the capacity of Biomass. Tidal, Wave and other Maritimes solely reach a capacity of more than one GW, or less than 1% of the total renewables by 2030.

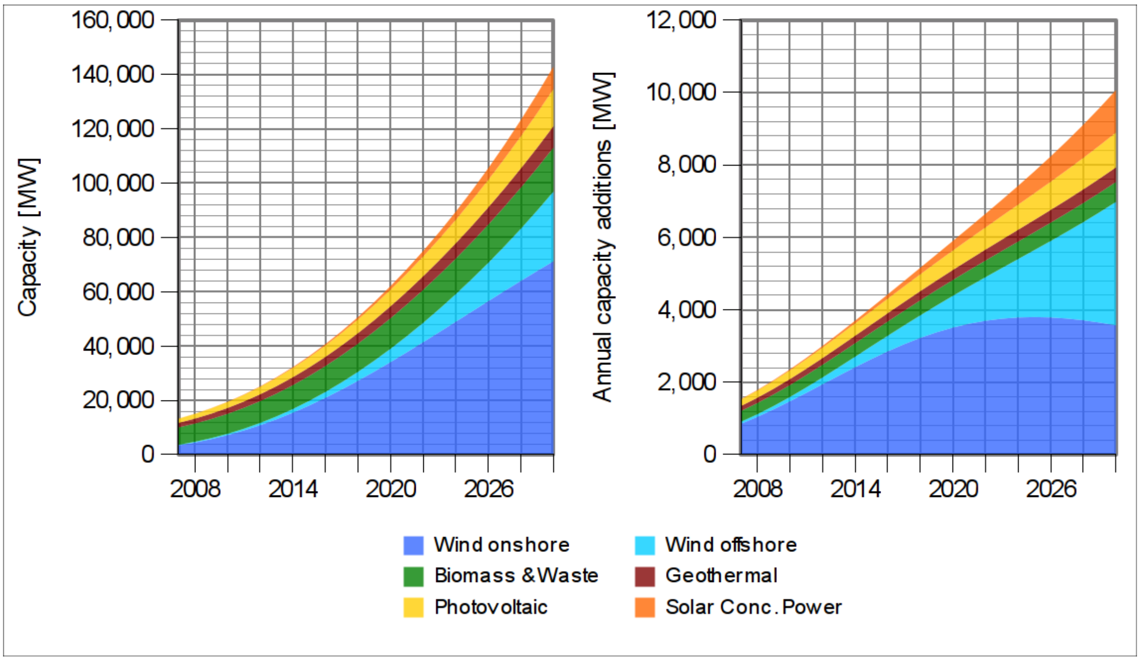


Figure 68: Development of renewable electricity generating capacity in OECD Pacific ("Low Variant") [EWG; 2007].

Heat

OECD Pacific	Capacity (GW)		
Technology	2010	2020	2030
Total Renewable Heat	**29.7**	**74.9**	**148.3**
Biomass Heat	6.1	9.3	13.5
Geothermal Heat	2.9	6.0	10.6
Solarthermal Collectors	20.6	59.6	124.1

Table 46: Development of renewable heat generating capacity in the OECD Pacific region ("Low Variant") [EWG; 2008].

The renewable heat generating capacities are dominated by Solar Thermal Collectors from the beginning. Starting with already almost 21 GW in 2010, the capacity increases further to more than 124 GW by 2030. Biomass already contributes second most in 2010 (6 GW) and this does not change until 2030 (almost 14 GW). Least contribution to renewable heat generating capacities results from Geothermal cogeneration. Starting with slightly less than 3 GW in 2010 the capacity increases to almost 11 GW until 2030.

Altogether there is a renewable heat generation capacity of 148 GW in 2030 (almost 30 in 2010).

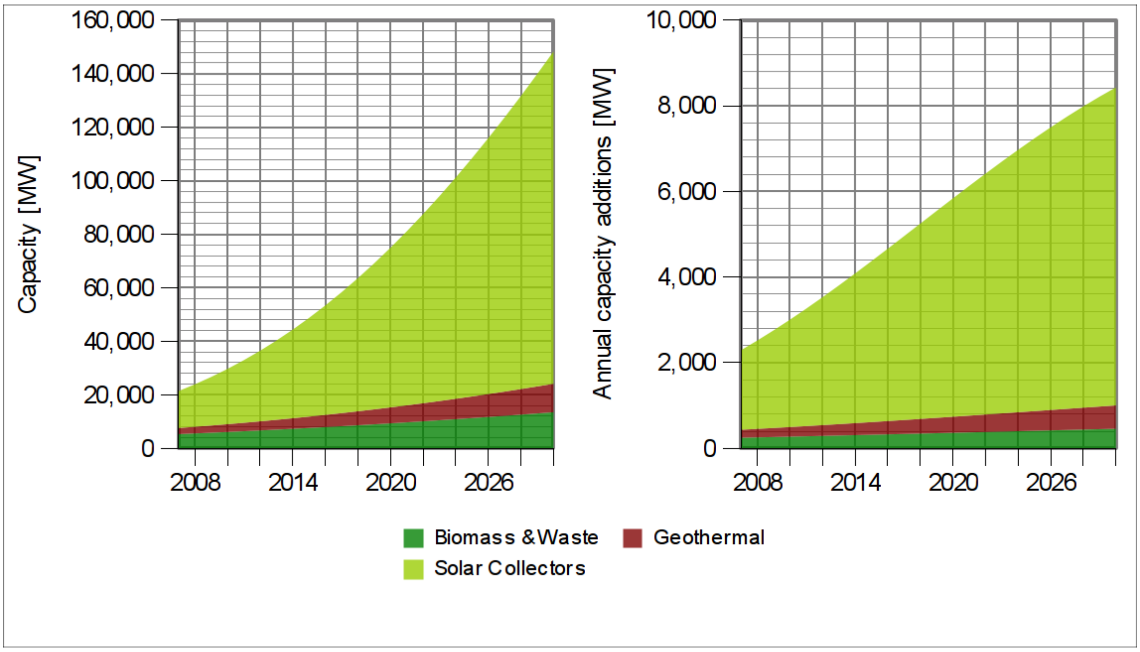


Figure 69: Development of renewable heat capacities in OECD Pacific ("Low Variant") [EWG; 2008].

Investment budget

The figure below shows the development of annual investments into renewable capacities (left hand side) and the development of shares the different technologies have at total investments (right hand side).

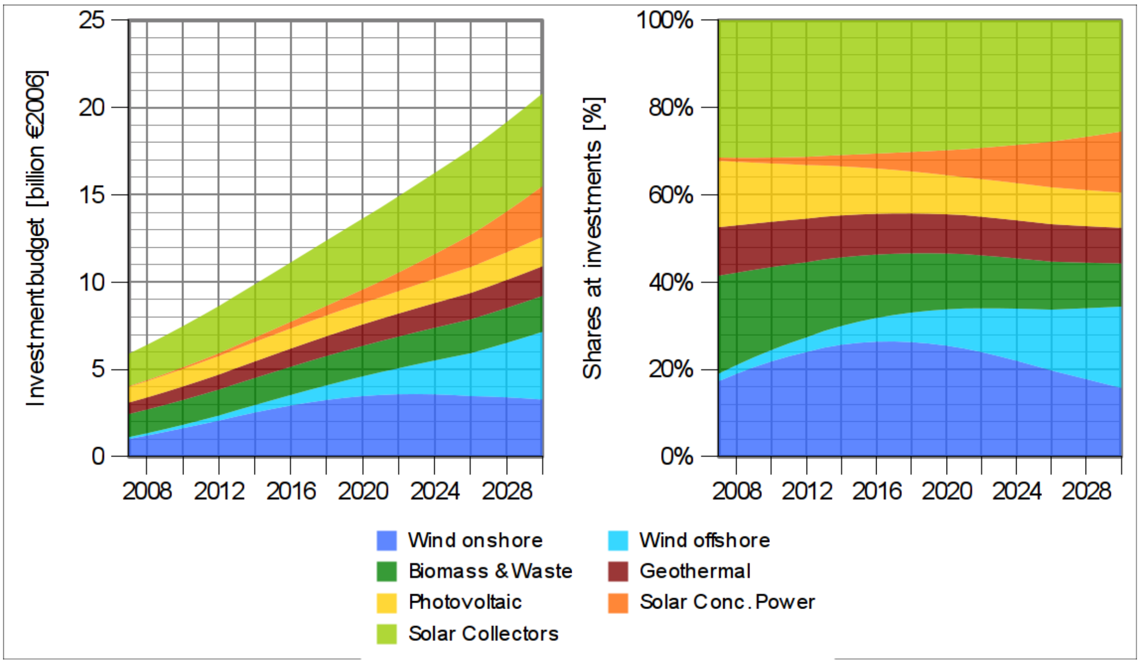


Figure 70: Development of the renewable energy investment budget in OECD Pacific ("Low Variant") [EWG; 2008].

<u>Transition Economies</u>

Assumptions

The target for investments into new generating capacities in OECD Pacific is 90 $€_{2006}$ per capita, which well matched by iteration. Considering the projected changes in population this results to a total investment budget of about 31 billion $€_{2006}$ in 2030.

The distribution of investments among the different technologies is dominated by Solar Thermal Collectors (39 %). Second biggest share goes to Wind Energy (about 28% in total, 17 % for onshore and 11 % for offshore), followed by Biomass (14 %), Geothermal Energy (9 %), Photovoltaic (almost 9 %) and Tidal, Wave & other Maritimes, with more than 1 %.

In contrast to the OECD regions, Solar Thermal Collectors dominate the investment figure. There is also a significant change in the distribution between onshore and offshore Wind Energy. In the Transition Economies onshore Wind Energy has a higher investment share than offshore Wind Energy because many of the countries in this region are landlocked. There are no investments into Solar Concentrating Power as no potentials were identified for this region. Instead of that there is a huge Biomass potential.

Transition Economies, investment budgets and distribution of investments								
Population			No. of inhabitants (Mio.)			Population density (cap/sqkm)		
			335.0			14.7		
Investment 2030			Target			Reached by iteration		
Budget per capita			90 €2006			91 €2006		
Total investment budget						31 billion €2006		
Wind onshore	Wind offshore	Wind total	Biomass	Geothermal	PV	Solar Concentrating Power	Tide & Wave	Solar Collectors
Shares of the different technologies (%)								
17.0%	10.8%	27.8%	14.0%	9.3%	8.7%	0.0%	1.4%	38.9%
Total investment into technologies (billion €2006)								
5.2	3.3	8.5	4.3	2.8	2.7	0.0	0.4	11.9

Table 47: Scenario assumptions for the Transition Economies in the low variant scenario [EWG; 2008].

Electricity

Transition Economies	Capacity (GW)		
Technology	2010	2020	2030
Total Renewables	**91,0**	**113,5**	**189,3**
Hydropower	87,6	97,9	108,2
Biomass and Waste	2,8	7,9	17,2
Wind onshore	0,1	3,1	31,9
Wind offshore	0,1	2,0	17,3
Geothermal	0,4	2,0	6,8
Solar PV	0,0	0,5	7,4
Solar Thermal Power	0,0	0,0	0,0
Tide/Wave/Maritim	0,0	0,0	0,4

Table 48: Development of renewable electricity generating capacity in the Transition Economies ("Low Variant") [EWG; 2008].

Due to the planned capacity extensions, Hydropower's capacity is assumed to increase by about twenty percent from 2010 to 2030. Nevertheless the share of Hydropower drops from almost 100% of all renewables to somewhat less than 60 % of the total renewable generating capacity by 2030. Major responsibility for this development lies within the extension of Wind Energy, which evolves from virtually nothing to a generating capacity which is close to the half of Hydropower's capacity by 2030 (49 GW in total, thereof 32 onshore and 17 offshore). More than one third of the Wind Energy capacity is offshore. Biomass & Waste develops nearly as offshore Wind Energy, showing about the same capacity than offshore Wind by 2030. Photovoltaic, non existent by 2010, reaches slightly more than 7 GW by 2030, which is about the same as Geothermal Energy (slightly less than 7 GW, 2030). Solar Concentrating Power does not play any role in the scenario for the Transition Economies, as no potentials have been identified that could be judged as reasonable for this technology. Tidal, Wave and other Maritimes can be rated as insignificant, with far less than 1 GW by 2030.

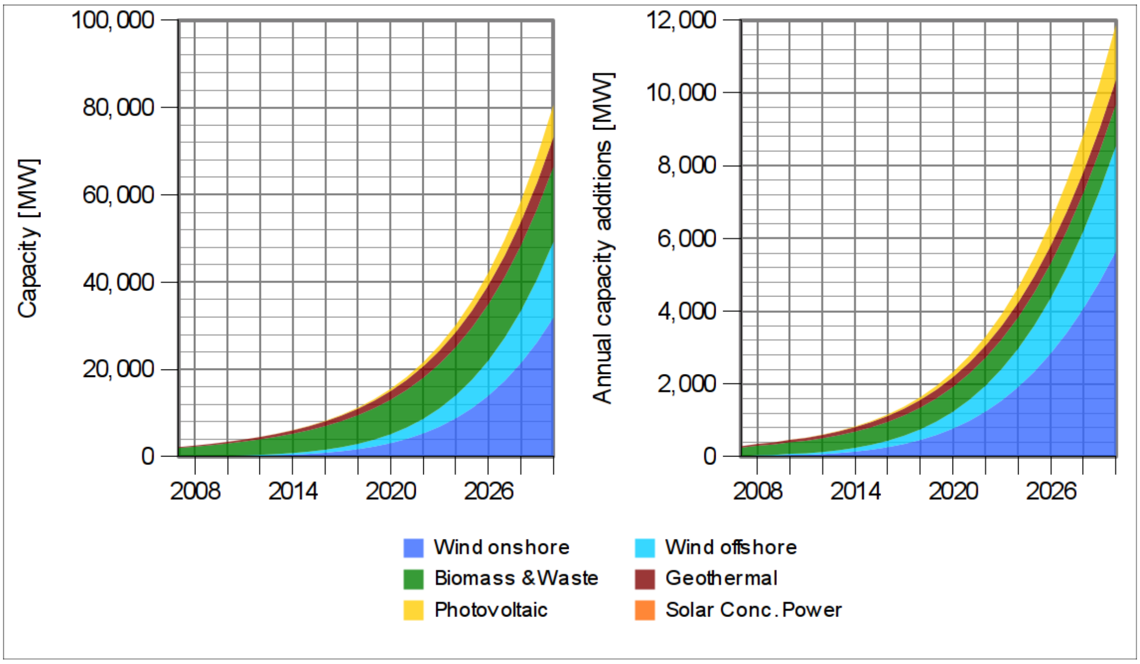


Figure 71: Development of renewable electricity generating capacity in the Transition Economies ("Low Variant") [EWG; 2008].

Altogether renewable generating capacity in the "Low Variant Scenario" increases to about 91 GW by 2010,further to 114 GW in 2020 and to about 190 GW in 2030, which is about 10 GW more than in OECD Pacific.

Heat

Transition Economies	Capacity (GW)		
Technology	**2010**	**2020**	**2030**
Total Renewable Heat	**8.0**	**58.7**	**201.6**
Biomass Heat	2.4	6.6	14.3
Geothermal Heat	0.5	2.7	9.2
Solarthermal Collectors	5.1	49.4	178.2

Table 49: Development of renewable heat generating capacity in the Transition Economies ("Low Variant") [EWG; 2008].

While the Biomass heat generation capacity increases from little more than 2 GW in 2010 to about 14 GW in 2030, there is a lower contribution from Geothermal cogeneration (less than 1 GW in 2010 to about 9 GW in 2030).

Solar Thermal Collector systems again contribute most to renewable heat capacities. Starting with about 5 GW in 2010 the capacity increases to 178 GW by 2030. Altogether there is a renewable heat generation capacity of 202 GW in 2030 (8 GW in 2010).

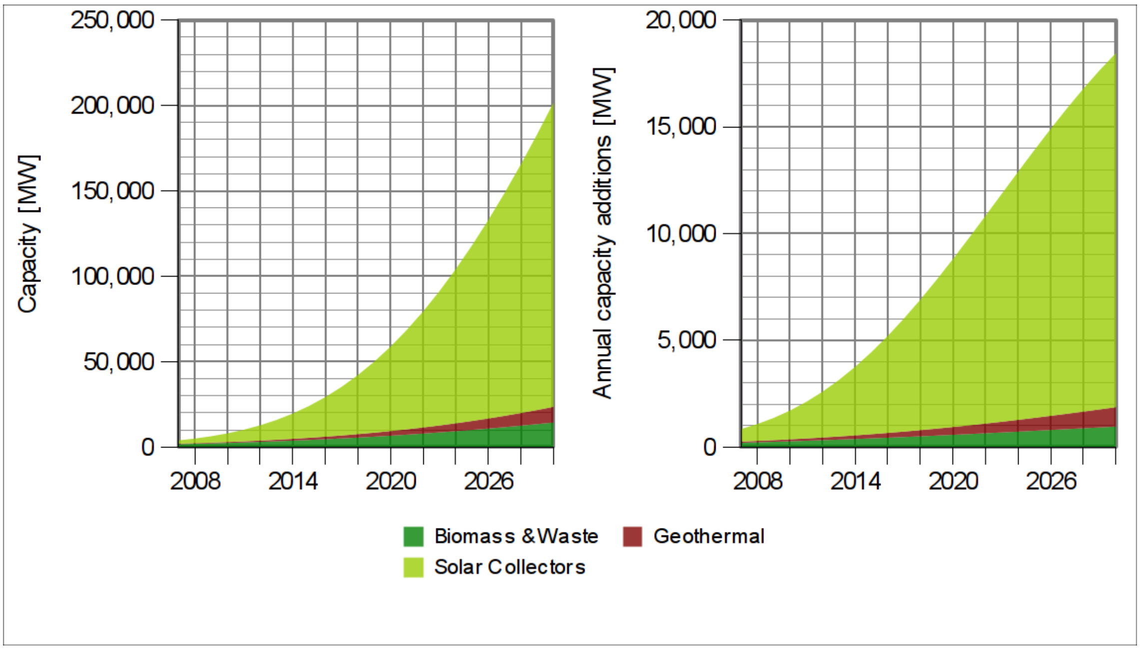


Figure 72: Development of renewable heat capacities in the Transition Economies ("Low Variant") [EWG; 2008].

Investment budget

The figure below shows the development of annual investments into renewable capacities (left hand side) and the development of shares the different technologies have at total investments (right hand side).

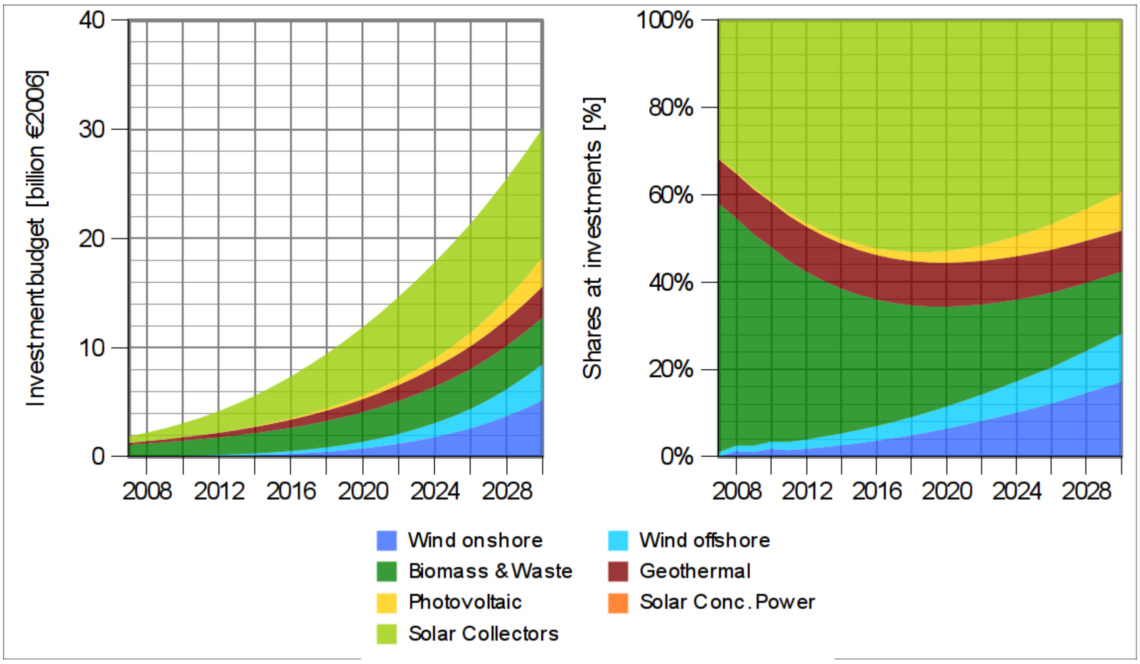


Figure 73: Development of the renewable energy investment budget in the Transition Economies ("Low Variant") [EWG; 2008].

<u>China</u>

Assumptions

The target for investments into new generating capacities in China is 100 $€_{2006}$ per capita. Due to the iterative calculation in the scenario this value effectively resulted to 102 $€_{2006}$ per capita. Considering the projected changes in population this results to a total investment budget of about 149 billion $€_{2006}$ in 2030.

The distribution of investments among the different technologies is dominated by Solar Thermal Collectors (about 31 % of investments). The share of wind Energy is considerably lower than in the OECD regions (about 24% in total, 10 % for onshore and 14 % for offshore). Third biggest share goes to Photovoltaic (15 %, more than onshore or offshore Wind alone)), Solar Concentrating Power (12 %), Biomass (9 %), Geothermal Energy (7 %). Last place in terms of investments goes to Tidal, Wave & other Maritimes, with about 2 %.

Both of the solar electric technologies have a higher investment share than offshore Wind Energy and SCP and Photovoltaic together have a higher investment share than total Wind Energy. Biomass' share is only a little less than onshore Wind Energy alone.

China, investment budgets and distribution of investments								
Population			No. of inhabitants (Mio.)			Population density (cap/sqkm)		
			1,468.8			157.5		
Investment 2030			Target			Reached by iteration		
Budget per capita			100 €$_{2006}$			102 €$_{2006}$		
Total investment budget						149 billion €$_{2006}$		
Wind onshore	Wind offshore	Wind total	Biomass	Geothermal	PV	Solar Concentrating Power	Tide & Wave	Solar Collectors
Shares of the different technologies (%)								
10.1%	14.0%	24.1%	9.4%	6.8%	14.7%	12.0%	2.4%	30.5%
Total investment into technologies (billion €$_{2006}$)								
15.1	20.9	36.0	14.1	10.1	21.9	18.0	3.6	45.6

Table 50: Scenario assumptions for China in the low variant scenario [EWG; 2008].

Electricity

China	Capacity (GW)		
Technology	2010	2020	2030
Total Renewables	**125,4**	**219,4**	**585,1**
Hydropower	105,2	135,4	165,6
Biomass and Waste	15,2	34,1	65,4
Wind onshore	4,0	28,0	128,7
Wind offshore	0,1	6,0	91,6
Geothermal	0,3	3,3	18,1
Solar PV	0,4	8,9	76,4
Solar Thermal Power	0,1	3,4	35,5
Tide/Wave/Maritim	0,0	0,3	3,8

Table 51: Development of renewable electricity generating capacity in China ("Low Variant") [EWG; 2008].

Due to the planned capacity extensions, Hydropower's capacity is assumed to increase by more than the half from 2010 to 2030. Nevertheless the massive increase in new renewable generating capacities leads to a dropping share of Hydropwer from over eighty percent to less than thirty percent. Biggest increase in capacity again results from Wind Energy, followed by Photovoltaic capacity, which is only about 15 GW less if compared to offshore Wind in 2030. The distribution between onshore and offshore Wind Energy differs from the regions described so far: more than 40 % of the total Wind Energy capacity by 2030 is offshore. Biomass becomes the fourth largest generating capacity among all renewables, but there is a substantial gap to PV. Solar Concentrating Power also shows a strong growth, but the capacity reached by 2030 is less than half the Photovoltaic capacity. Geothermal energy, besides Tidal, Wave and other Maritimes, shows the weakest growth and reaches about half the capacity of SCP by 2030.

Altogether renewable generating capacity in the "Low Variant Scenario" increases to about 125 GW by 2010, to 220 GW in 2020 and to about 585 GW in 2030. The share of new renewables increases from about 16 % in 2010 to almost 72 % during that period.

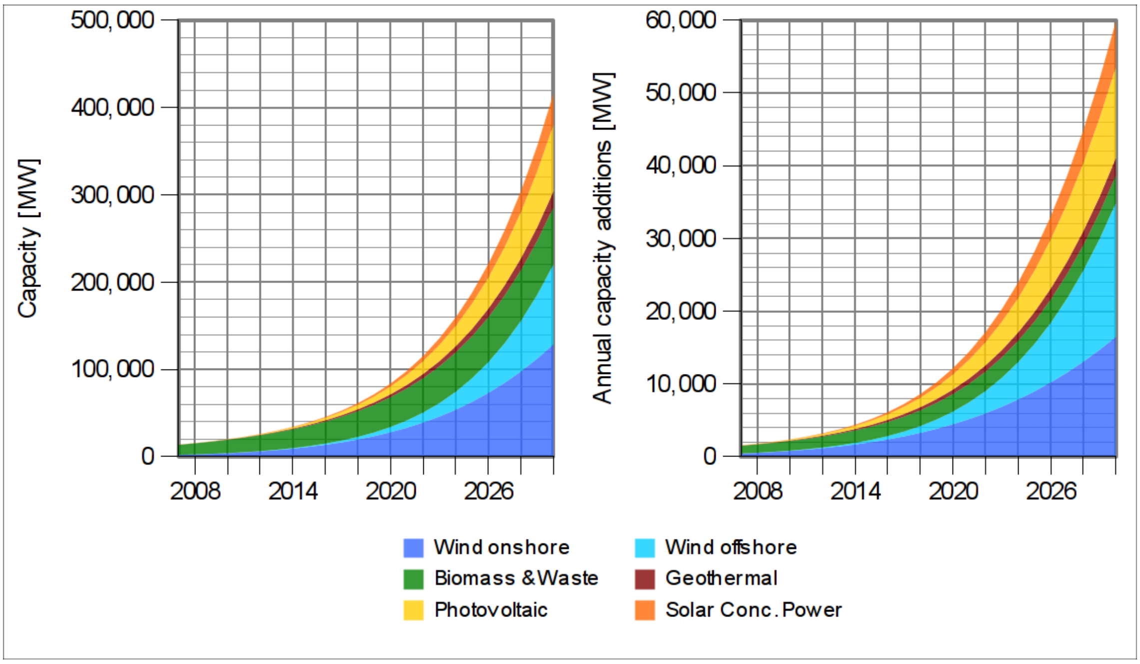


Figure 74: Development of renewable electricity generating capacity in China ("Low Variant") [EWG; 2008].

Wind Energy capacities increase most, starting with about 4 GW in 2010 the capacity increases to 34 GW in 2010 and – finally - reaches about 220 GW in 2030 (129 GW onshore and 92 GW offshore). Photovoltaic capacity by 2030 is about 76 GW, third biggest contribution comes from Biomass & Waste, growing to about 15GW by 2010 and to about 65 GW by 2030. While Solar Concentrating Power reaches about 36 GW by 2030 (from 0.1 GW in 2010), Geothermal Energy, starting with 0.3 GW in 2010, increases it's capacity to 18 GW in 2030. Tidal, Wave and other Maritimes manage to increase generating capacity to almost 4 GW, which is about the same capacity as in OECD North America.

Heat

China	Capacity (GW)		
Technology	**2010**	**2020**	**2030**
Total Renewable Heat	**140.7**	**483.7**	**1,088.0**
Biomass Heat	12.7	28.4	54.5
Geothermal Heat	0.4	4.5	24.5
Solarthermal Collectors	127.6	450.8	1,009.0

Table 52: Development of renewable heat generating capacity in China ("Low Variant") [EWG; 2008].

Biomass, increasing from almost 13 GW (2010) to closely 55 GW (2030), reaches more than double the heat capacity than Geothermal (almost 25 GW in 2030, coming from less than 1 GW in 2010).

The high population favours Solar Thermal Collector systems which see a massive increase from already almost 128 GW in 2010 to 1,009 GW by 2030. Altogether there is a renewable heat generation capacity of 1,088 GW in 2030 (141GW in 2010).

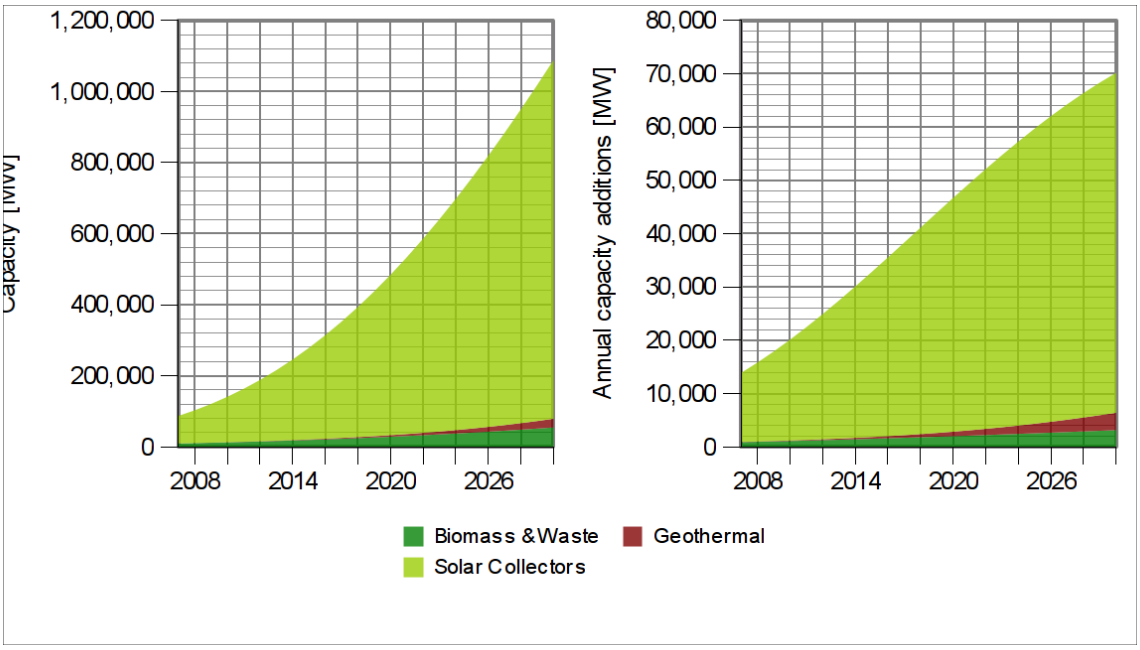


Figure 75: Development of renewable heat capacities in China ("Low Variant") [EWG; 2008].

Investment budget

The figure below shows the development of annual investments into renewable capacities (left hand side) and the development of shares the different technologies have at total investments (right hand side).

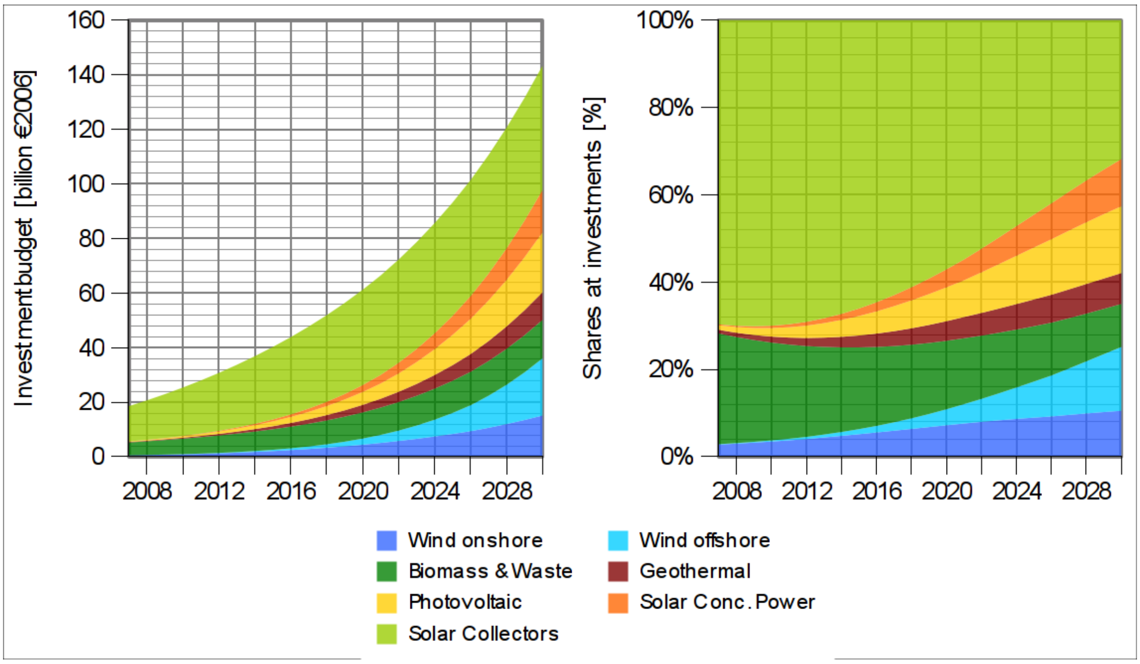


Figure 76: Development of the renewable energy investment budget in China ("Low Variant") [EWG; 2008].

<u>East Asia</u>

Assumptions

The target for investments into new generating capacities in East Asia is 40 $€_{2006}$ per capita, effectively resulting to 41 $€_{2006}$ per capita, due to iterative calculation. Considering the projected changes in population this results to a total investment budget of about 33 billion $€_{2006}$ in 2030.

The distribution of investments among the different technologies is dominated by Solar Thermal Collectors (42%), followed by the total of Wind Energy (23 %, 6.6 % for onshore and 16.5 % for offshore). Third biggest shares go to Photovoltaic (10.5 %) and Solar Concentrating Power (10.2 %), followed by Biomass (close to 8 %), Geothermal Energy (5.5 %) and Tidal, Wave & other Maritims, with about 1 %.

Altogether this distribution scheme is comparable to the one for China, but onshore Wind Energy is even lower significant (only on sixth place if onshore Wind energy is considered as standalone technology) and Solar Thermal Collectors receive even higher investment shares. Solar Concentrating Power and Photovoltaic are close together, making solar driven electricity generation almost as important as onshore and offshore Wind Energy together (about 21% total solar).

East Asia, investment budgets and distribution of investments								
Population			No. of inhabitants (Mio.)			Population density (cap/sqkm)		
			806.5			151.1		
Investment 2030			Target			Reached by iteration		
Budget per capita			40 $€_{2006}$			41 $€_{2006}$		
Total investment budget						33 billion $€_{2006}$		
Wind onshore	Wind offshore	Wind total	Biomass	Geothermal	PV	Solar Concentrating Power	Tide & Wave	Solar Collectors
Shares of the different technologies (%)								
6.6%	16.5%	23.2%	7.6%	5.5%	10.5%	10.2%	1.1%	42.0%
Total investment into technologies (billion $€_{2006}$)								
2.2	5.4	7.6	2.5	1.8	3.4	3.3	0.4	13.7

Table 53: Scenario assumptions for East Asia in the low variant scenario [EWG; 2008].

Electricity

East Asia	Capacity (GW)		
Technology	2010	2020	2030
Total Renewables	41,1	84,7	167,4
Hydropower	29,6	29,6	29,6
Biomass and Waste	3,7	7,3	12,8
Wind onshore	3,6	36,8	70,5
Wind offshore	0,0	1,9	24,5
Geothermal	4,1	6,8	10,5
Solar PV	0,1	1,3	11,7
Solar Thermal Power	0,0	1,0	7,4
Tide/Wave/Maritim	0,0	0,0	0,4

Table 54: Development of renewable electricity generating capacity in East Asia ("Low Variant") [EWG; 2008].

As there was no information on planned extensions of Hydropower capacity, it is assumed to maintain on the same level over the whole period. While Hydropower leads by far in 2010 (more than 72 % in 2010), this figure drops to about 18% by 2030.

Biggest increase in capacity results from Wind Energy, which overtakes Hydropower in terms of capacity until 2020. Both Wind energy fractions (onshore / offshore ratio is approx. three fourths to one fourth) have higher generating capacities than all other “new” renewables by 2030. Biomass becomes the third largest generating capacity, followed by Photovoltaic and – with only a small gap – Geothermal Energy. Solar Concentrating Power also shows a strong growth, but the capacity reached by 2030 is far less than Photovoltaic or Geothermal generating capacity.

Altogether renewable generating capacity in the "Low Variant Scenario" increases to about 41GW by 2010,r to 85 GW in 2020 and to about 167 GW in 2030.

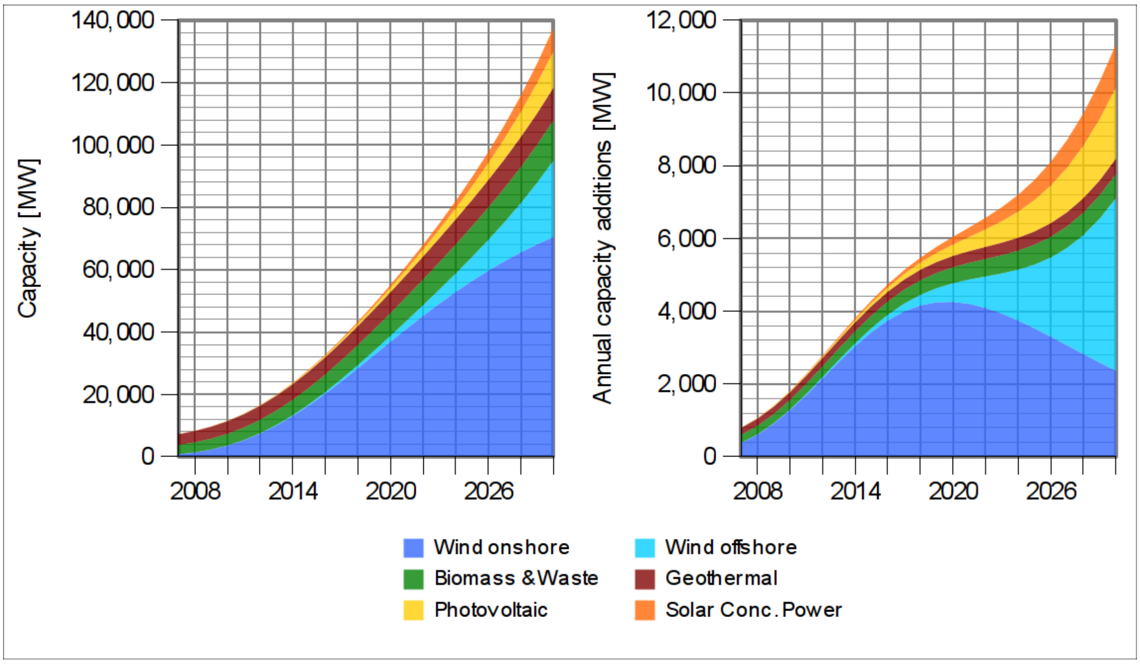


Figure 77: Development of renewable electricity generating capacity in East Asia ("Low Variant") [EWG; 2008].

Wind Energy, starting with about 4 GW in 2010, increases it's capacity to 39 GW in 2020 and reaches about 95 GW in 2030 (71 GW onshore and 25 GW offshore). The contributions reached by Biomass & Waste (13 GW, 2030), Photovoltaic (12 GW) and Geothermal Energy (almost 11 GW) are close together. Substantial smaller contributions result from SCP (more than 7 GW, 2030) and – with a big gap - Tidal, Wave and other Maritimes (0.4 GW, 2030).

Heat

East Asia	Capacity (GW)		
Technology	**2010**	**2020**	**2030**
Total Renewable Heat	**14.2**	**60.4**	**204.0**
Biomass Heat	3.1	6.1	10.7
Geothermal Heat	5.5	9.1	14.2
Solarthermal Collectors	5.6	45.3	179.1

Table 55: Development of renewable heat generating capacity in East Asia ("Low Variant") [EWG; 2008].

Considering the development in total, the renewable heat generating capacity increases to 14 GW by 2010 and further to 204 GW by 2030. Most of the capacity increase results from Solar

Thermal Collectors, which increase to a installed capacity of almost 6 GW until 2010 and to about 179 GW by 2030. Geothermal cogeneration takes the second place in terms of capacity. Starting with close to 6 GW in 2010 the capacity grows to more than 14 GW in 2030. Biomass capacity stays behind Geothermal cogeneration from the beginning on. While the 2010 capacity is 34 GW, this figure increases to almost 11 GW in 2030.

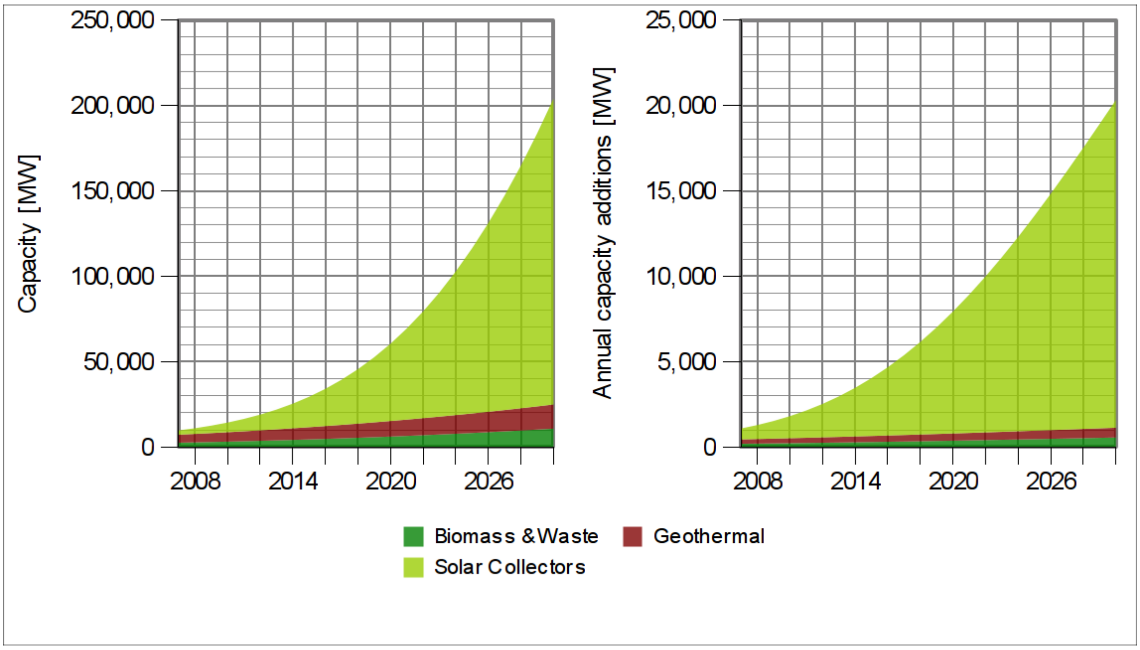


Figure 78: Development of renewable heat capacities in East Asia ("Low Variant") [EWG; 2008].

Investment budget

The figure below shows the development of annual investments into renewable capacities (left hand side) and the development of shares the different technologies have at total investments (right hand side).

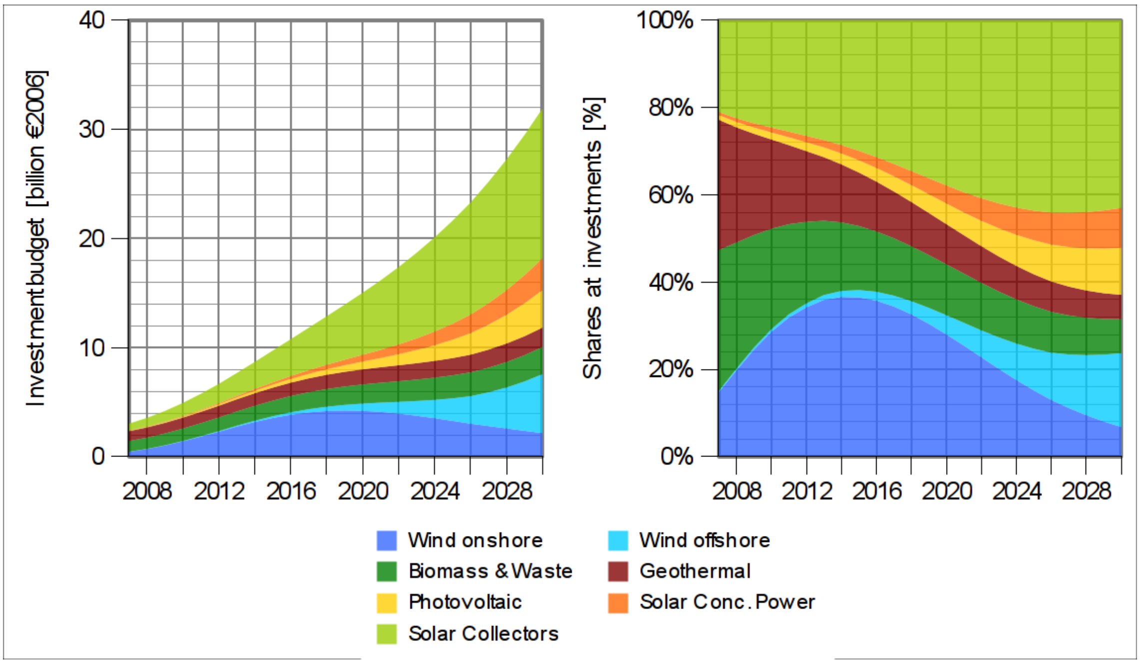


Figure 79: Development of the renewable energy investment budget in East Asia ("Low Variant") [EWG; 2008].

South Asia

Assumptions

The target for investments into new generating capacities in East Asia is 35 $€_{2006}$ per capita, which gets well matched by iterative calculation. Considering the projected changes in population this results to a total investment budget of about 73 billion $€_{2006}$ in 2030.

As seen for some of the previous described non-OECD regions, it is not Wind Energy having the highest investment share, but Solar Thermal Collectors (almost 47%). Total Wind Energy (13 %, with 5.4 % onshore and 7.6 % offshore) even has a lower share than Photovoltaic, which – due to the extremely high population density – has an investment share of about a fifth of the total investments. Fourth place in terms of investment shares goes to Solar Concentrating Power (8.5 %), followed by Biomass (6.4 %) and Geothermal Energy, with almost 5 %. Tidal, Wave and other Maritimes are, as usual, last in terms of investment shares (less than 1 %).

The investment scheme for South Asia differs quiet much from what has been described so far, as solar energy has the lead by far in this region. On the electrical side, Photovoltaic and Solar Concentrating Power together account for more than double the investment share for onshore and offshore Wind Energy. Onshore Wind Energy alone has a lower share than Biomass and there is only a marginal gap to Geothermal Energy.

South Asia, investment budgets and distribution of investments								
Population			No. of inhabitants (Mio.)			Population density (cap/sqkm)		
			2,063.4			504.0		
Investment 2030			Target			Reached by iteration		
Budget per capita			35 €2006			35 €2006		
Total investment budget						73 billion €2006		
Wind onshore	Wind offshore	Wind total	Biomass	Geothermal	PV	Solar Concentrating Power	Tide & Wave	Solar Collectors
Shares of the different technologies (%)								
5.4%	7.6%	12.9%	6.4%	4.9%	19.4%	8.5%	1.0%	46.9%
Total investment into technologies (billion €2006)								
3.9	5.5	9.5	4.7	3.6	14.2	6.2	0.7	34.3

Table 56: Scenario assumptions for South Asia in the low variant scenario [EWG; 2008].

Electricity

South Asia	Capacity (GW)		
Technology	2010	2020	2030
Total Renewables	**52,3**	**92,3**	**222,5**
Hydropower	39,5	39,5	39,5
Biomass and Waste	1,3	5,0	14,2
Wind onshore	11,1	39,4	80,4
Wind offshore	0,0	1,9	24,7
Geothermal	0,1	1,0	5,9
Solar PV	0,1	4,3	44,9
Solar Thermal Power	0,0	1,3	12,2
Tide/Wave/Maritim	0,0	0,1	0,8

Table 57: Development of renewable electricity generating capacity in South Asia ("Low Variant") [EWG; 2008].

Hydroppwer capacity is assumed as stable over the whole development, as there was no information about planned extension available. Consequently the share of Hydropower at renewable capacities drops from more than three thirds by 2010 to less than 18 percent by 2030.

Biggest capacity additions result from Wind Energy, which is predominated by onshore Wind. Starting with about 11 GW onshore Wind in 2010 (no offshore installations), the capacity grows to more than 105 GW by 2030, of which 80 GW are onshore then. The resulting onshore / offshore ratio is about three fourths onshore and one fourth offshore. Due to the high population density Photovoltaic is second with regard to generating capacities reached by 2030. By that time about 45 GW of Photovoltaic capacity is installed, which is considerably more than offshore Wind and even Hydropower. Biomass & Waste and Solar Concentrating Power are very close together, but Biomass reaches a little bit more generating capacity by 2030 (14 GW Biomass & Waste and 12 GW SCP). Geothermal Energy does not perform that well and ends up with almost 6 GW by 2030, only undercut by Tidal, Wave & other Maritimes (less than 1 GW by 2030).

Altogether renewable generating capacity in the "Low Variant Scenario" increases to about 52GW by 2010,further to 92 GW in 2020 and to about 223 GW in 2030.

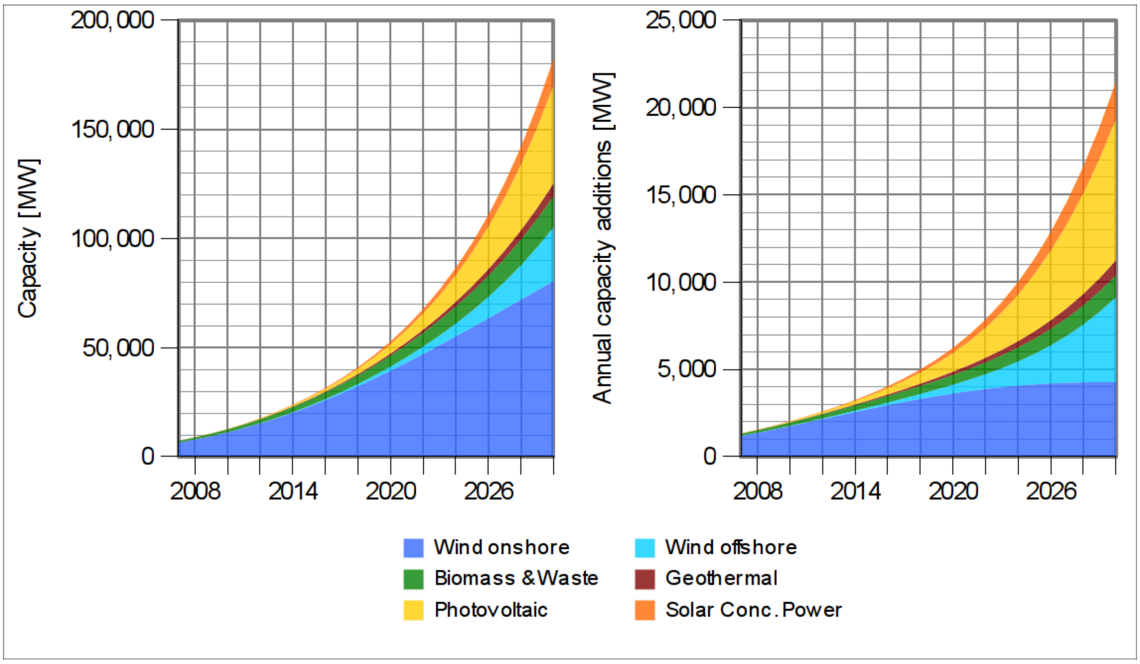


Figure 80: Development of renewable electricity generating capacity in South Asia ("Low Variant") [EWG; 2008].

Heat

South Asia	Capacity (GW)		
Technology	**2010**	**2020**	**2030**
Total Renewable Heat	**7.3**	**81.5**	**406.8**
Biomass Heat	1.1	4.2	11.8
Geothermal Heat	0.1	1.3	7.9
Solarthermal Collectors	6.0	76.0	387.0

Table 58: Development of renewable heat generating capacity in South Asia ("Low Variant") [EWG; 2008].

Altogether the renewable heat generation capacity increases to over 7 GW in 2010 and to almost 407 GW in 2030. Most of the capacity results from Solar Thermal Collectors (about 6 GW in 2010 to 387 GW in 2030). Biomass performs better than Geothermal cogeneration. While there is an increase from about 1 GW (2010) to almost 12 GW (2030) for Biomass cogeneration, Geothermal heat capacity stars with virtually nothing in 2010 and increases to almost 8 GW in 2030.

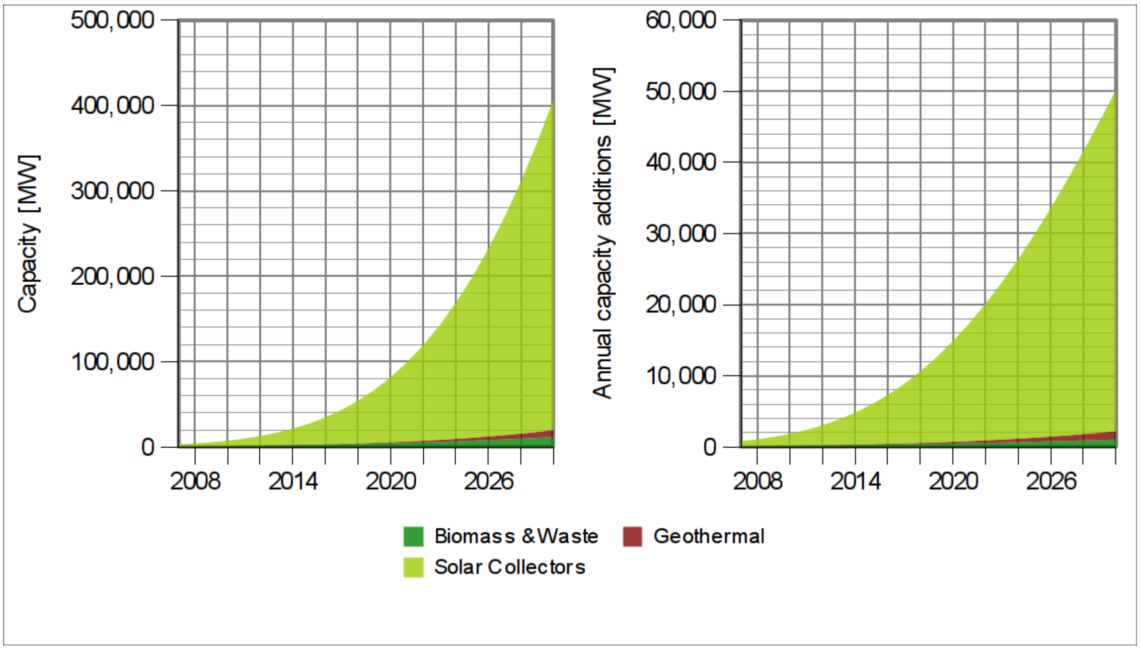


Figure 81: Development of renewable heat capacities in South Asia ("Low Variant") [EWG; 2008].

Investment budget

The figure below shows the development of annual investments into renewable capacities (left hand side) and the development of shares the different technologies have at total investments (right hand side).

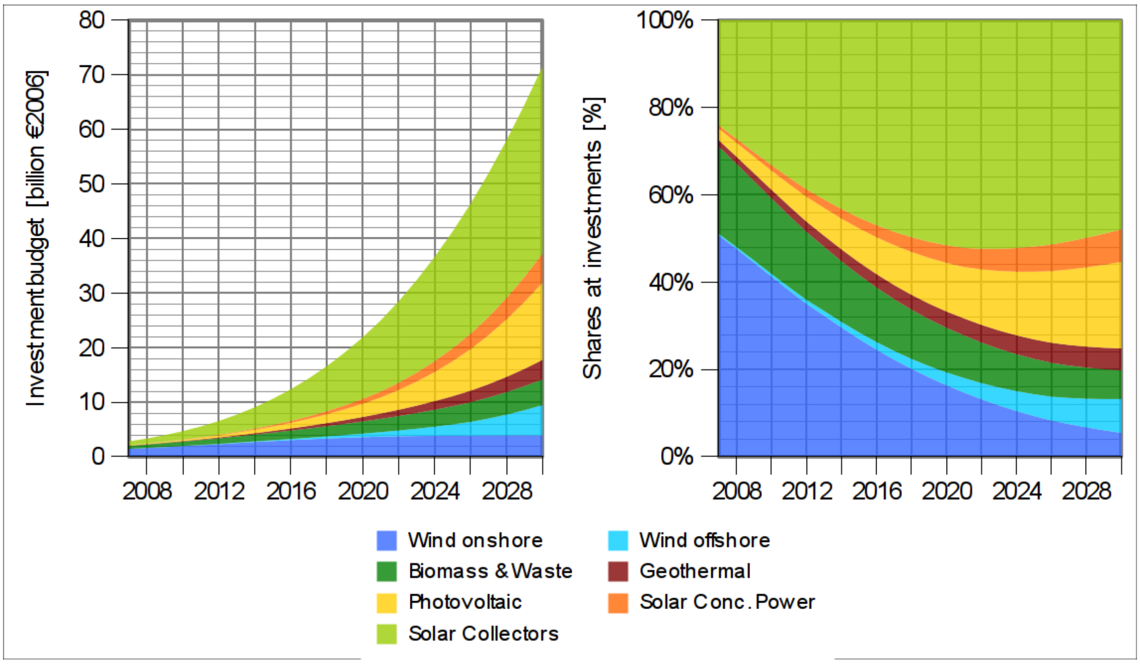


Figure 82: Development of the renewable energy investment budget in South Asia ("Low Variant") [EWG; 2008].

Latin America

Assumptions

The target for investments into new generating capacities in Latin America is 45 $€_{2006}$ per capita, effectively resulting to 46 $€_{2006}$ per capita, due to iterative calculation. Considering the projected changes in population this results to a total investment budget of about 26 billion $€_{2006}$ in 2030.

As seen in most other regions, Wind Energy in total has the highest share at investments (31% in total, with 13 % onshore and 18 % offshore), but only with a small gap to Solar Thermal collectors (second with 28 %). Third place goes to Solar Concentrating Power (11.6 %), directly followed by Biomass & Waste (almost 11 %). Photovoltaic and Geothermal Energy both contribute for about 9 % of investments in 2030. Tidal, Wave and other Maritimes have a share of a merely 1.4 %.

Generally the investment scheme's structure for Latin America is similar to the one for OECD North America. Solar electricity technologies together have a share of about 20 %, which is significantly lower than total for Wind Energy and Solar Thermal Collectors.

Latin America, investment budgets and distribution of investments								
Population			No. of inhabitants (Mio.)			Population density (cap/sqkm)		
			563.9			30.9		
Investment 2030			Target			Reached by iteration		
Budget per capita			45 €$_{2006}$			46 €$_{2006}$		
Total investment budget						26 billion €$_{2006}$		
Wind onshore	Wind offshore	Wind total	Biomass	Geothermal	PV	Solar Concentrating Power	Tide & Wave	Solar Collectors
Shares of the different technologies (%)								
12.7%	17.9%	30.7%	10.9%	8.6%	8.8%	11.6%	1.4%	28.1%
Total investment into technologies (billion €$_{2006}$)								
3.3	4.6	7.9	2.8	2.2	2.3	3.0	0.4	7.2

Table 59: Scenario assumptions for Latin America in the low variant scenario [EWG; 2008].

Electricity

Latin America	Capacity (GW)		
Technology	2010	2020	2030
Total Renewables	**133,4**	**154,1**	**224,3**
Hydropower	125,0	131,4	137,8
Biomass and Waste	6,5	11,0	17,5
Wind onshore	0,6	4,3	24,0
Wind offshore	0,1	2,4	22,9
Geothermal	1,1	3,1	7,2
Solar PV	0,0	0,7	7,2
Solar Thermal Power	0,1	1,2	7,4
Tide/Wave/Maritim	0,0	0,0	0,4

Table 60: Development of renewable electricity generating capacity in Latin America ("Low Variant") [EWG; 2008].

Planned extensions of Hydropower capacity will lead to a capacity increase of about 13 GW. Nevertheless the share of Hydropower at renewable capacities drops from almost 94 % by 2010 to about 61 percent by 2030.

Biggest capacity additions result from Wind Energy, which is well balanced between onshore and offshore installations. Starting with less than 1 GW capacity in 2010, the capacity grows to almost 47 GW by 2030, of which about the half is onshore (24 GW). Biomass & Waste, with already 6.5 GW in 2010, increases its capacity to 11 GW by 2020 and further to about 18 GW by 2030. The remaining technologies, except Tidal, Wave & other Maritimes, reach comparable levels by 2030 (7.2 GW for Geothermal and Photovoltaic and 7.4 GW for Solar Concentrating Power. Tidal. Wave and other Maritimes remain under a capacity of 1 GW until 2030.

Altogether renewable generating capacity in the "Low Variant Scenario" increases to about 133 GW by 2010, to 154 GW in 2020 and to about 224 GW in 2030, which is almost the same capacity as in South Asia.

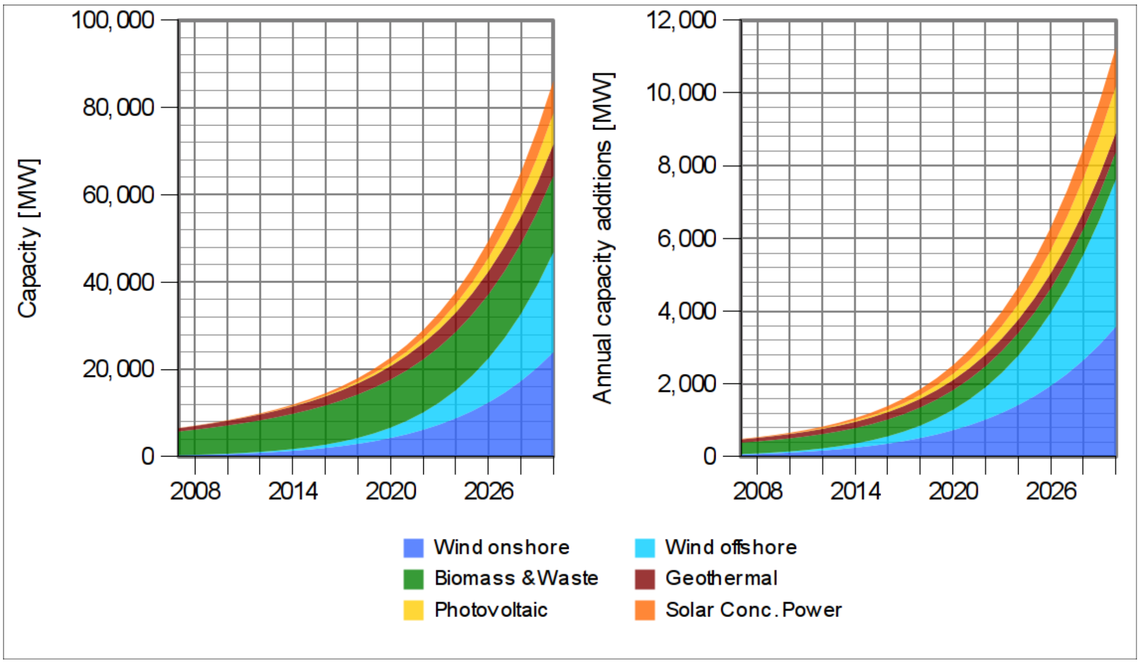


Figure 83: Development of renewable electricity generating capacity in Latin America ("Low Variant") [EWG; 2008].

Heat

Latin America	Capacity (GW)		
Technology	**2010**	**2020**	**2030**
Total Renewable Heat	**13.0**	**46.0**	**130.3**
Biomass Heat	5.4	9.2	14.6
Geothermal Heat	1.5	4.2	9.7
Solarthermal Collectors	6.1	32.6	106.0

Table 61: Development of renewable heat generating capacity in Latin America ("Low Variant") [EWG; 2008].

Biomass and Solar Thermal Collectors start from comparable levels in 2010, but in the further development Solar Thermal Collector systems (STC) clearly outperform Biomass cogeneration in terms of heat capacity. While these technologies have a capacity of about 6 GW (STC) and more than 5 GW (Biomass) in 2010, Solar Collectors increase to 106 GW by 2030, which is significantly superior to the almost 15 GW Biomass cogeneration reaches by that time. Geothermal cogeneration does not perform weaker. Starting from 1.5 GW in 2010 the 2030 capacity reaches a level of almost 10 GW.

Altogether the a renewable heat generation capacity increases to 13 GW in 2010 and to more than 130 GW in 2030.

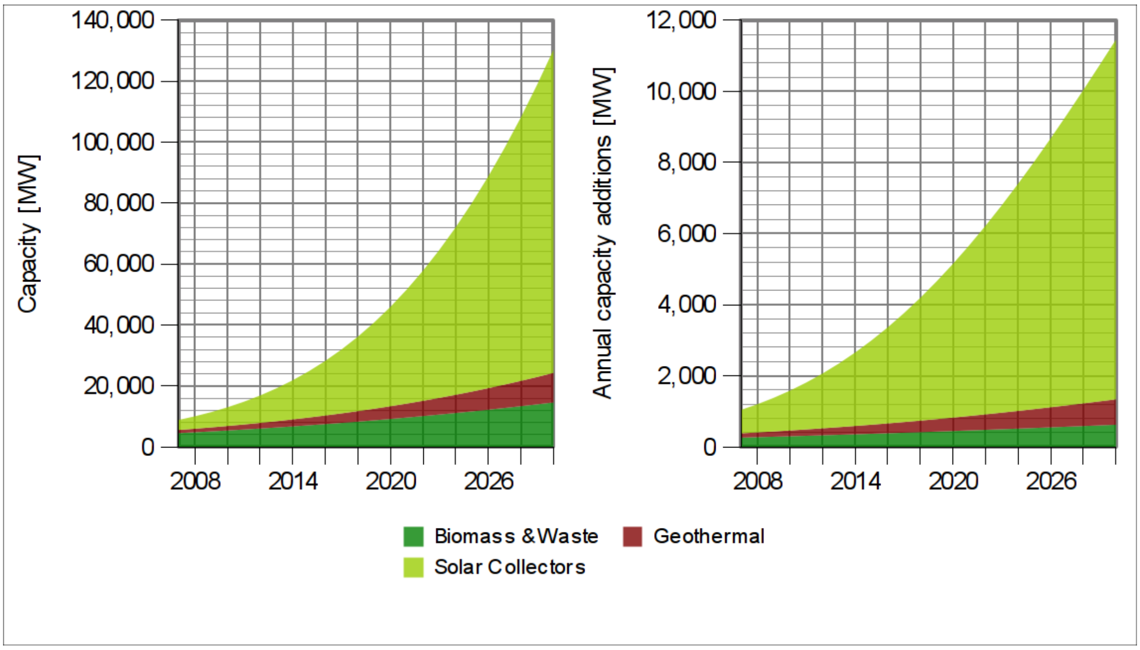


Figure 84: Development of renewable heat capacities in Latin America ("Low Variant") [EWG; 2008].

Investment budget

The figure below shows the development of annual investments into renewable capacities (left hand side) and the development of shares the different technologies have at total investments (right hand side).

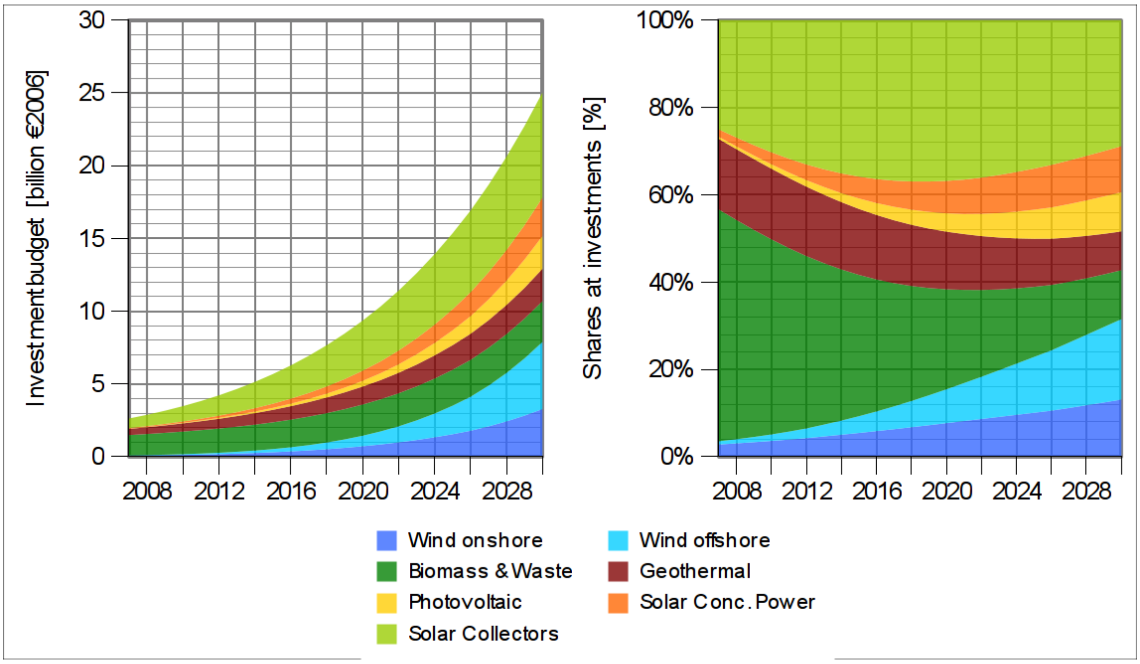


Figure 85: Development of the renewable energy investment budget in Latin America ("Low Variant") [EWG; 2008].

Africa

Assumptions

The target for investments into new generating capacities in Africa is 20 €$_{2006}$ per capita, which is well matched by iteration. Considering the projected changes in population this results to a total investment budget of about 30 billion €$_{2006}$ in 2030.

The investment scheme's structure is dominated by Solar Thermal Collectors,which have an investments share of slightly more then 53%[20]. Second placed is Wind Energy with 16 % (8.2 for onshore and 7,8 % for offshore), followed by Solar Concentrating Power (11 %), Biomass (7.5 %), Photovoltaic (7.1 %) and Geothermal Energy, with 4.4%. Tidal, Wave and other Maritimes have a negligible 0.3 %.

Due to the good solar potentials, solar electricity (Photovoltaic and Solar Concentrating Power together with about 18 %), has a higher share at investments as total Wind Energy. SCP alone reaches a higher investment share than both of the Wind Energy fractions. Nevertheless the share of Photovoltaic is lower than one might expect (e.g. lower than the one of Biomass), but this can be explained by the low population density and the lack of additional support, which is assumed for Solar Thermal Collectors.

Africa, investment budgets and distribution of investments								
Population			**No. of inhabitants (Mio.)**			**Population density (cap/sqkm)**		
			1,455.2			50.7		
Investment 2030			**Target**			**Reached by iteration**		
Budget per capita			20 €$_{2006}$			20 €$_{2006}$		
Total investment budget						30 billion €$_{2006}$		
Wind onshore	**Wind offshore**	**Wind total**	**Biomass**	**Geothermal**	**PV**	**Solar Concentrating Power**	**Tide & Wave**	**Solar Collectors**
Shares of the different technologies (%)								
8.2%	7.8%	16.1%	7.5%	4.4%	7.1%	10.7%	0.9%	53.3%
Total investment into technologies (billion €$_{2006}$)								
2.4	2.3	4.7	2.2	1.3	2.1	3.2	0.3	15.7

Table 62:

20 It has to be noted here, that Solar Thermal Collectors cannot only be used for heating water or delivering process heat for production processes, but they can as well be used to produce cold or even for cooking, which will help to reduce the inefficient use of Biomass.

Electricity

Africa	Capacity (GW)		
Technology	**2010**	**2020**	**2030**
Total Renewables	**24,5**	**34,9**	**81,3**
Hydropower	21,6	21,6	21,6
Biomass and Waste	1,4	3,7	8,3
Wind onshore	0,8	4,7	20,7
Wind offshore	0,0	1,2	11,4
Geothermal	0,5	1,5	3,9
Solar PV	0,1	1,3	8,1
Solar Thermal Power	0,0	0,9	7,0
Tide/Wave/Maritim	0,0	0,0	0,3

Table 63: Development of renewable electricity generating capacity in Africa ("Low Variant") [EWG; 2008].

As there are no known planned extensions of Hydropower capacity, this value is assumes as stable over the whole period considered here. As the “new” renewables capacity increases, the share of Hydropower at renewable capacities drops from close to 90 % by 2010 to only a little more than a quarter by 2030.

Biggest capacity additions result from Wind Energy, which has a distribution of about two thirds onshore and one third offshore installations by 2030. Starting with less than 1 GW capacity in 2010, the capacity grows to about 32 GW by 2030 (21 GW onshore and 11 GW offshore). By 2030 the onshore Wind capacity is on the same level with Hydropower (22 GW). Biomass & Waste, with only about 1 GW in 2010, increases its capacity to closely 4 GW by 2020 and further to slightly more than 8 GW by 2030, which is about the same capacity Photovoltaic reaches by that time. Solar Concentrating Power also gets close to this figure (7 GW in 2030). Geothermal Energy shows a weaker performance and approaches to 4 GW generating capacity by 2030. A minor contribution results from Tidal, Wave and other Maritimes, which remain below a capacity of 0.5 GW.

Altogether renewable generating capacity in the "Low Variant Scenario" increases to about 25 GW by 2010,further to 35 GW in 2020 and to about 81 GW in 2030.

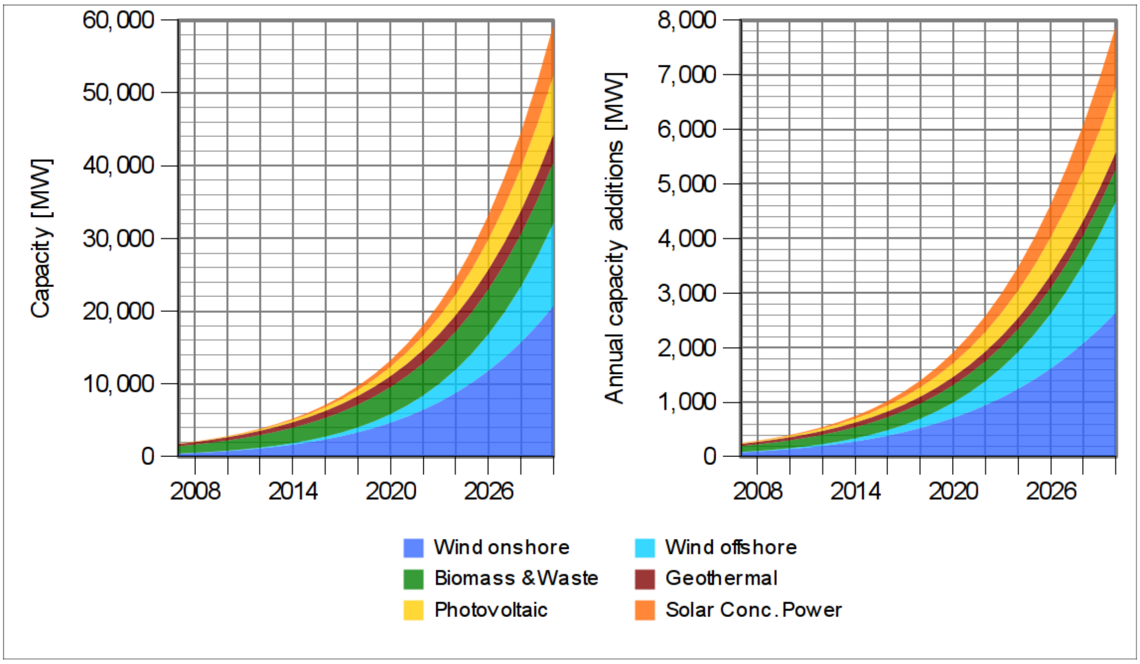


Figure 86: Development of renewable electricity generating capacity in Africa ("Low Variant") [EWG; 2008].

Heat

Africa	Capacity (GW)		
Technology	2010	2020	2030
Total Renewable Heat	**5.3**	**40.6**	**187.4**
Biomass Heat	1.2	3.1	6.9
Geothermal Heat	0.6	2.1	5.2
Solarthermal Collectors	3.5	35.5	175.3

Table 64: Development of renewable heat generating capacity in Africa ("Low Variant") [EWG; 2008].

Solar Thermal Collectors perform much better than both of the other heat producing technologies. While the installed capacity in 2010 is close to 4 GW, this figure increases to more than 175 GW by 2030. Biomass and Geothermal, both starting with low figures in 2010 (1 GW Biomass and less than 1 GW Geothermal) reach capacities of 7 GW (Biomass) and 5 GW (Geothermal) by the end of the period considered here.

Altogether the a renewable heat generation capacity increase to more than 5 GW in 2010 and to about 187 GW in 2030.

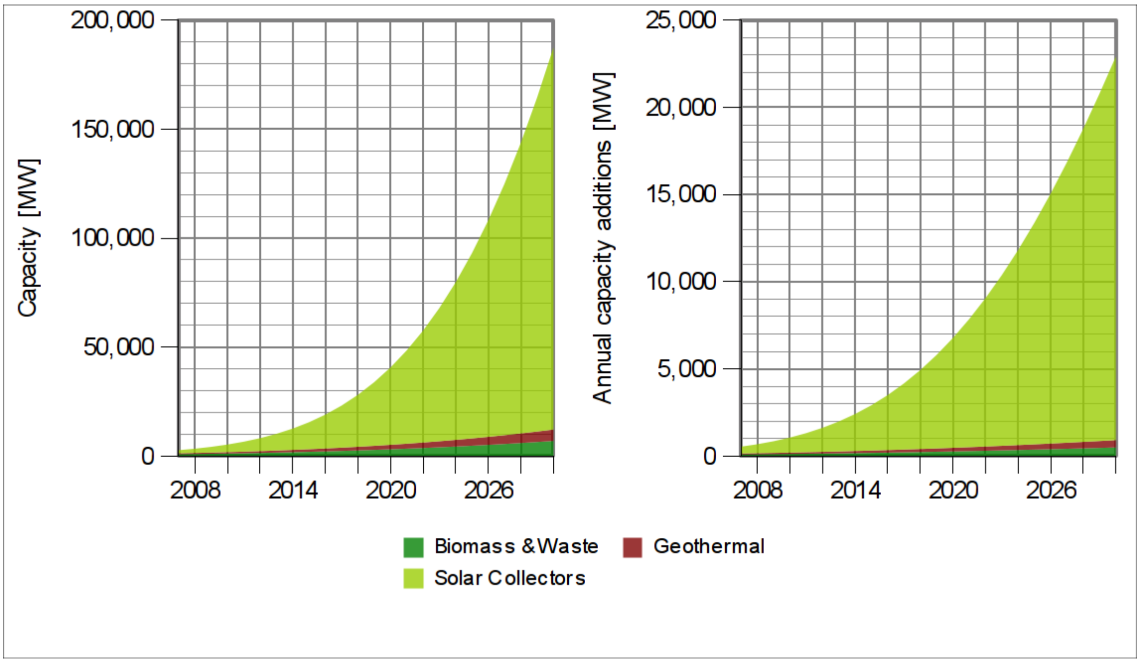


Figure 87: Development of renewable heat capacities in Africa ("Low Variant") [EWG; 2008].

Investment budget

The figure below shows the development of annual investments into renewable capacities (left hand side) and the development of shares the different technologies have at total investments (right hand side).

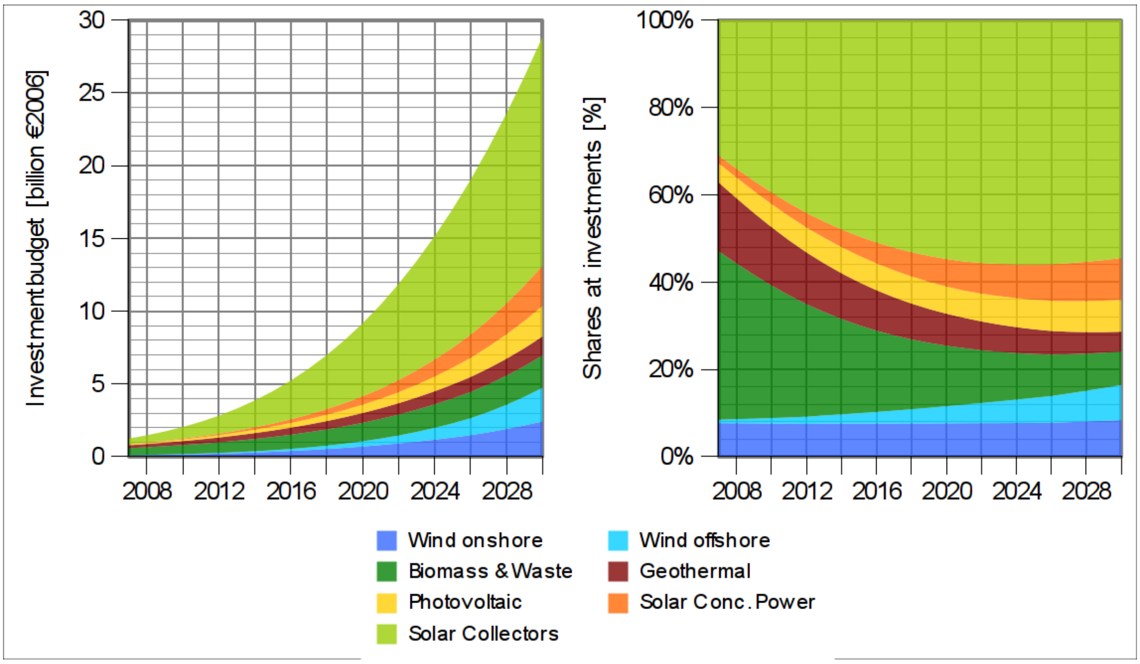


Figure 88: Development of the renewable energy investment budget in Africa ("Low Variant") [EWG; 2008].

Middle East

Assumptions

The target for investments into new generating capacities in the Middle East is 100 €$_{2006}$ per capita, effectively resulting to 101 €$_{2006}$ per capita, due to iterative calculation. Considering the projected changes in population this results to a total investment budget of about 28 billion €$_{2006}$ in 2030.

Although the investment structure is dominated by Wind Energy (30 %, with 12 % onshore and 17 % offshore), the structure is relatively well balanced between Wind energy, the total of solar electricity production (30 %) and Solar Thermal Collectors (31 %). Solar Concentrating Power alone (18 %) has a higher share than both Wind energy fractions and takes the lead over Photovoltaic (12 %) by far. While there is no Biomass use assumed for this region (lack of potential), Geothermal Energy receives 8 % of the total investments by 2030. Another small fraction goes to Tidal, Wave and other Maritimes (0.4 %.)

Middle East, investment budgets and distribution of investments								
Population			**No. of inhabitants (Mio.)**			**Population density (cap/sqkm)**		
			272.3			52.5		
Investment 2030			**Target**			**Reached by iteration**		
Budget per capita			100 €$_{2006}$			101 €$_{2006}$		
Total investment budget						28 billion €$_{2006}$		
Wind onshore	**Wind offshore**	**Wind total**	**Biomass**	**Geothermal**	**PV**	**Solar Concentrating Power**	**Tide & Wave**	**Solar Collectors**
Shares of the different technologies (%)								
12.2%	17.2%	29.5%	0.0%	8.2%	11.7%	18.2%	1.5%	30.9%
Total investment into technologies (billion €$_{2006}$)								
3.4	4.7	8.1	0.0	2.3	3.2	5.0	0.4	8.5

Table 65:

Electricity

Middle East	Capacity (GW)		
Technology	**2010**	**2020**	**2030**
Total Renewables	**8,4**	**20,7**	**91,0**
Hydropower	7,5	7,5	7,5
Biomass and Waste	0,0	0,0	0,0
Wind onshore	0,6	6,7	31,2
Wind offshore	0,1	2,6	24,3
Geothermal	0,0	0,4	3,2
Solar PV	0,1	1,7	12,2
Solar Thermal Power	0,1	1,8	12,1
Tide/Wave/Maritim	0,0	0,0	0,4

Table 66: Development of renewable electricity generating capacity in the Middle East ("Low Variant") [EWG; 2008].

As there are no known planned extensions of Hydropower capacity, this value is assumes as stable over the whole period considered here. The share of Hydropower at renewable capacities drops from close to 90 % by 2010 to only a little more than 8 % by 2030.

Biggest capacity additions result from Wind Energy, which already overtakes Biomass & Waste between 2010 and 2020. Onshore Wind Energy contributes about 56 % to the total generating capacity of Wind Energy by 2030. Starting with less than 1 GW capacity in 2010, the capacity grows to about 56 GW by 2030 (31.2 GW onshore and 24.3 GW offshore). Both solar electricity technologies end up with about the same generating capacity (about 12 GW) and show nearly the same development during the whole period the scenario covers. Geothermal Energy shows a much weaker performance and increases its generating capacity to a little bit more than 3 GW by 2030. A minor contribution results from Tidal, Wave and other Maritimes, which remain below a capacity of 0.5 GW.

Altogether renewable generating capacity in the "Low Variant Scenario" increases to about 8 GW by 2010, to 21 GW in 2020 and to about 91 GW in 2030.

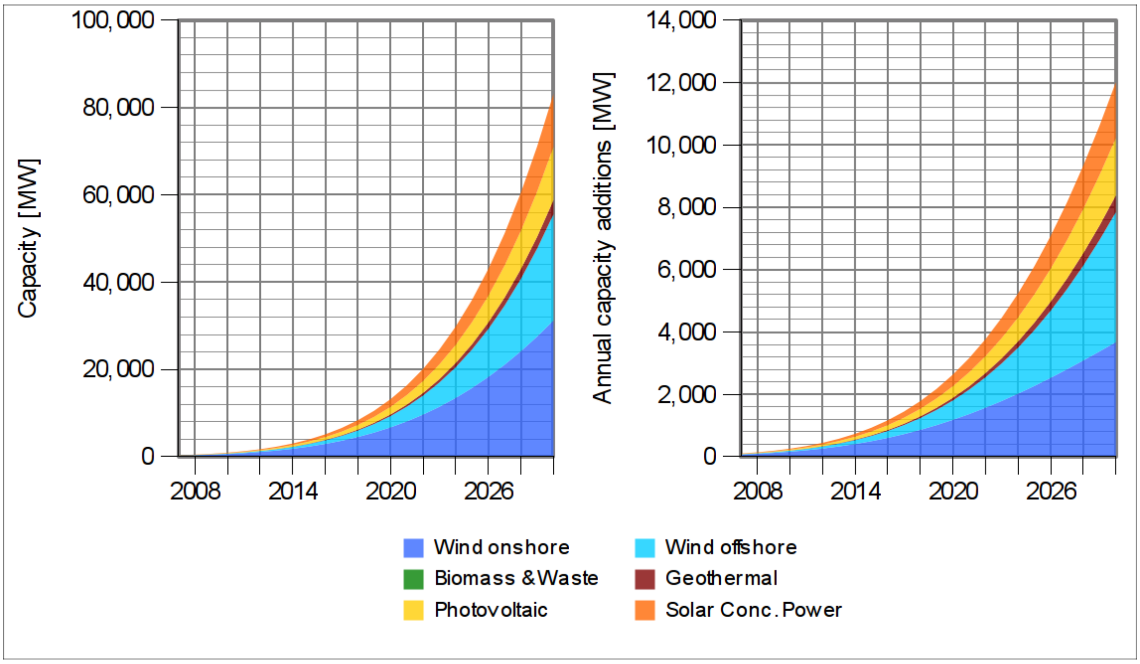


Figure 89: Development of renewable electricity generating capacity in the Middle East ("Low Variant") [EWG; 2008].

Heat

Middle East	Capacity (GW)		
Technology	**2010**	**2020**	**2030**
Total Renewable Heat	**0.1**	**8.2**	**81.0**
Biomass Heat	0.0	0.0	0.0
Geothermal Heat	0.0	0.5	4.4
Solarthermal Collectors	0.1	7.7	76.6

Table 67: Development of renewable heat generating capacity in the Middle East ("Low Variant") [EWG; 2008].

Biomass does not play any role in the Middle East. The main heat capacity results from the extension of Solar Thermal Collector systems. Starting from the scratch in 2010, the installed capacity in 2030 is about 77 GW. Geothermal cogeneration , with not much more than 4 GW, reaches by far less heat generating capacity by 2030.

Altogether the a renewable heat generation capacity is virtually non existent in 2010 and increases to 81 GW in 2030.

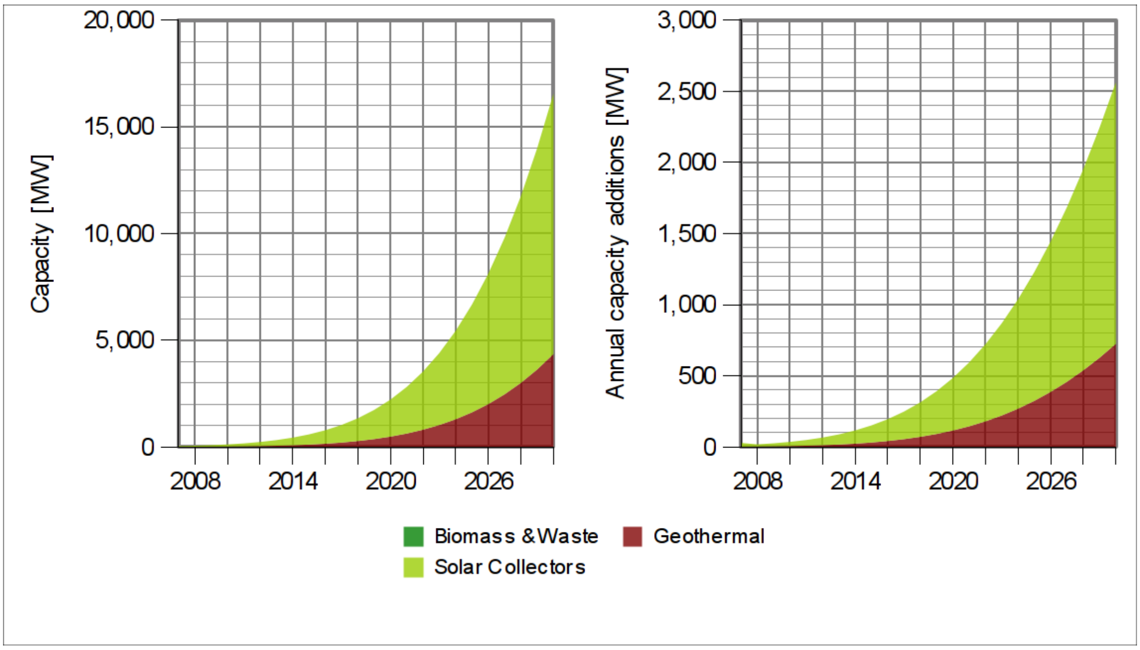


Figure 90: Development of renewable heat capacities in the Middle East ("Low Variant") [EWG; 2008].

Investment budget

The figure below shows the development of annual investments into renewable capacities (left hand side) and the development of shares the different technologies have at total investments (right hand side).

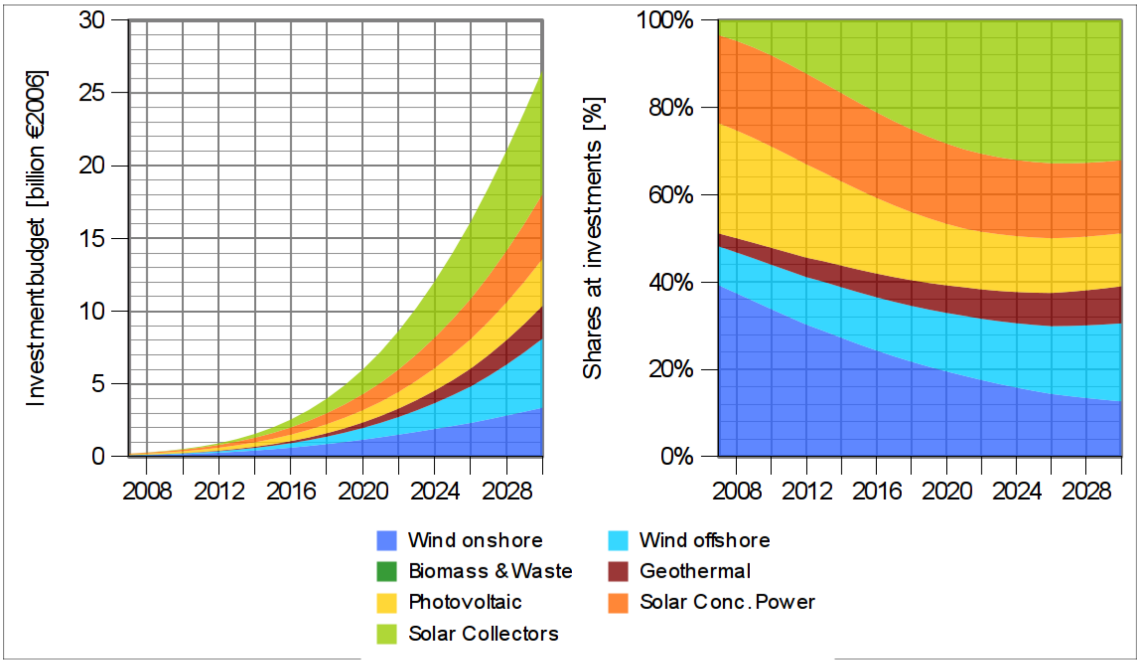


Figure 91: Development of the renewable energy investment budget in the Middle East ("Low Variant") [EWG; 2008].

Potentials used in the scenarios

A preliminary note on potentials

Estimating potentials for renewable energies is not an objective task. It might be somewhat disappointing to find such a statement in a study like this one, but this is true for several reasons.

The basis for any potential estimation must be a so called "theoretical potential" of renewable sources, which is the total amount of regenerating sources of energy the global ecosystem contains, with the restriction not to use more than gets regenerated within the same time. Most renewable sources - might that be biomass, wind or solar radiation - are driven by the sun. The distribution of sun power among these fractions is not fixed. Biomass potential, for example, gets reduced by sealing former arable areas or the degradation of soil by unsustainable agriculture and other factors. The fraction of sun power remaining in earth's atmosphere as air movement (i.e. wind, which is also a driving force for wave energy) varies with a changing earth climate. Thus the future amount of available biomass, wind and wave energy potentials are influenced by human activity and a changing climate. Geothermal energy, resulting from the earth's core and tidal energy are not exposed to common human activity.

The fraction mankind is able to convert into "useful" energy, called "technical potential", depends on several factors, such as technology, available areas for installation and lastly the will and/or the force to develop them. All these factors are not fixed as technology permanently develops, land and sea use patterns can be changed (as they permanently do) and the force to open up renewable sources of energy is set to increase with the ongoing depletion of fossil and nuclear fuels and the threats climate change imposes to the earth's life support system.

This study widely uses available data on the potentials of renewable sources. In some cases the data did not match the regional decomposition we like to present, or did only cover specific regions. In such cases we used the available data to derive potential assumptions for all the regions considered here, while strictly trying not to be too optimistic in terms of potentials available for use.

Wind energy

<u>Onshore</u>

The installable Wind Energy capacity was assumed to be 0.05 plants per square kilometre in average. Provided that plants will be installed in clusters (windparks), averaging to 9 plants with 2 MW each, the land use drops to 0.6% of the total land area.

Onshore Wind Energy		
Plants per sqkm	0.05	pcs.
Plant size	2	MW
clustering	18	max. MW power per sqkm
Avg. Windspeed1	6.9	m/s
Avg. Windspeed2	8.44	m/s

Table 68: General assumptions for estimating the onshore Wind Energy potential [EWG; 2007].

Considering the general set up, as shown in Table 68, the total global onshore Wind Energy potential amounts to about 13,500 GW of installable capacity. Due to the clustering of plants in windparks (nine plants per sqkm on average), the alteration of landscape is substantially lower than it would be with installing single plants on ample distributed locations. All in all utilizing the total potential would require less than 0.6 % of the total land area in each of the regions. As energy production depends on the quality of sites, this figure is calculated for two different average wind speeds. Considering the lower wind speed figure (6.9 m/s), about 23,600 TWh of electricity could be produced every year on average. The higher figure (8.4 m/s) would allow an electricity production of more than 43,600 TWh a year. The biggest Wind Energy potentials can be found in Africa, the Transition Economies and OECD North America, all offering a possible capacity of more than 2,000 GW.

Onshore Wind Energy						
Region	**Potential**	**Number of plants**	**Real area used**	**Fraction of total Area**	**Average productivity (TWh) at average m/s**	
					6.9	**8.4**
	(GW)	**(pieces)**	**(sqkm)**	**(%)**	**equivalent Full Load Hours**	
					1,749	**3,232**
OECD Europe	487	243,508	27,056	0.56%	852	1,574
OECD North America	2,018	1,008,923	112,103	0.56%	3,529	6,522
OECD Pacific	1,624	812,242	90,249	0.56%	2,841	5,251
Transition Economies	2,275	1,137,344	126,372	0.56%	3,978	7,352
China	933	466,373	51,819	0.56%	1,631	3,015
East Asia	534	266,915	29,657	0.56%	934	1,725
South Asia	409	204,687	22,743	0.56%	716	1,323
Latin America	1,825	912,653	101,406	0.56%	3,192	5,900
Africa	2,871	1,435,516	159,502	0.56%	5,021	9,280
Middle East	519	259,428	28,825	0.56%	907	1,677
WORLD	**13,495**	**6,747,588**	**749,732**	**0.56%**	**23,603**	**43,618**

Table 69: Onshore Wind Energy assumptions and potential used for scenario development [EWG; 2007].

The average wind speeds taken for example calculation are not pure estimation. Rather these figures rely on a detailed assessment of global wind conditions, performed by Cristina L. Archer and Mark Z. Jacobson. Their work describes an onshore wind energy potential of 72,000 GW, considering all locations with more than 6.9 m/s windspeed in 80m height and an installation density of six wind power plants per square kilometre, with 1.5 MW capacity each plant. The evaluation is based on measured data of 7,753 surface stations and 446 sounding stations. [Archer/Jacobson; 2005]

This is not the only figure which makes the potentials used in the EWG scenarios look like a low assessment of the capacity which could be installed by using all places that offer good wind conditions.

How low this estimation is gets obvious if the data presented above gets compared to the potentials shown by Johansson (see Table 70). According to the figures provided by Johannsson, about 30.200 square kilometres of land area offer sufficient wind conditions and the possible electricity generation amounts to 483.000 TWh.

Region	Land surface with sufficient wind conditions		Wind energy resources without land restriction	
	Percent	Thousands of km²	TWh	Exajoules
North America	41%	7,876	126,000	1,512
Latin America and Caribbean	18%	3,310	53,000	636
Western Europe	42%	1,968	31,000	372
Eastern Europe and former Soviet Union	29%	6,783	109,000	1,308
Middle East and North Africa	32%	2,566	41,000	492
Sub-Saharan Africa	30%	2,209	35,000	420
Pacific Asia	20%	4,188	67,000	804
China	11%	1,056	17,000	204
Central and South Asia	6%	243	4,000	48
TOTAL[a]	**27%**	**30,200**	**483,000**	**5,800**

* The energy equivalent is calculated based on the electricity generation potential of the referenced sources by dividing the electricity generation potential by a factor of 0.3 (a representative value for the efficiency of wind turbines, including transmission losses), resulting in a primary energy estimate. a. Excludes China.

Adapted from: Goldemberg, J. (ed) 2000. World Energy Assessment: Energy and the Challenge of Sustainability. New York: UNDP; World Energy Council. 1994. New Renewable Energy Resources: A Guide to the Future. London: Kogan Page Limited.

Table 70: Global onshore wind energy potential. [Johansson; 2004]

The comparably low assumption was taken for the scenario development in REO in order to reflect all possible restrictions and conflicts in land use and to show that there is no need for severe landscape alteration to install sufficient capacities of onshore wind energy.

Offshore

The offshore wind power potential used for the REO scenario development was calculated, by assuming an offshore installation density of 8 MW capacity per square kilometre of area.

As the considered area amounts to 2,635,500 square kilometres, or about 4.2 square kilometres per kilometre of coast line on average, the installable capacity amounts to 20,550 GW on the global scale. Considering an amount of 3,000 equivalent full load hours per year on average, this would result in an electricity production of about 61,660 TWh a year.

Biggest offshore potentials are located in OECD North America, Latin America, Africa and OECD Pacific, all having a potential of more than 2,000 GW. OECD North America leads by far – with 4,600 GW potential (second best – Latin America – has a potential of about 2,800 GW). Beside the assumptions described above, additional restrictions were made for OECD North America and the Transition Economies. In both cases the suitable area was lowered by a quarter, as both regions have many remote northern areas.

Offshore Wind Energy					
Region	**Potential**	**Number of plants**	**Available Area**	**Area considered (50% of total)**	**Electricity (at 3,000 FLH)**
	GW	**(pieces)**	**(sqkm)**	**(sqkm)**	**(TWh)**
OECD Europe	1,460.7	292,145	365,181	182,591	4,382
OECD North America	4,313.8	862,769	1,078,461	539,230	12,942
OECD Pacific	2,004.8	400,959	501,198	250,599	6,014
Transition Economies	1,870.4	374,075	623,458	311,729	5,611
China	1,444.5	288,892	361,115	180,557	4,333
East Asia	1,808.0	361,610	452,012	226,006	5,424
South Asia	705.4	141,079	176,348	88,174	2,116
Latin America	2,806.0	561,202	701,503	350,752	8,418
Africa	2,764.9	552,985	691,231	345,616	8,295
Middle East	828.2	165,649	207,061	103,530	2,485
WORLD	**20,552**	**4,110,420**	**5,271,030**	**2,635,515**	**61,656**

Table 71: Offshore Wind Energy assumptions and potential used for scenario development [EWG; 2007].

Compared to the “Seawind” study by Greenpeace, which assessed offshore wind energy areas for different European countries, this seems a reasonable assumption, even recognizing the differing situation at different coastal areas around the world. Looking at the Greenpeace figures (Table 72) it is obvious that these figures are much higher if compared to the assumptions made for the EWG scenario development.

Country	Offshore Area per kilometre of coastline		
	2010	2015	2020
Belgium	20.50	26.95	34.39
Denmark	3.35	4.48	11.96
Finland	20.96	30.68	50.55
France	4.66	8.67	19.10
Germany	4.05	7.01	11.05
Greece	0.19	0.43	1.58
Ireland	3.09	7.40	41.55
Italy	1.40	2.49	6.40
Netherlands	10.88	19.07	112.57
Portugal	0.38	1.55	5.80
Spain	1.42	2.55	6.72
Sweden	6.68	13.68	33.86
United Kingdom	2.68	5.68	23.80

Table 72: Available offhsore wind area per kilometre of coastline for different European countries, according to the Greenpeace "Seawind" study [Greenpeace; 2004]

As already seen for onshore Wind, existing offshore wind potential studies would have justified considering higher potentials than those used for the REO scenario development. Compared to the Wind Energy potential for Europe, given by the Greenpeace “Sea Wind Europe” study (7,000 GW if all areas are used by 100%, but even not considering Iceland, Norway, Poland and Turkey), the potential considered in this study is substantially lower (1,461 GW for whole OECD Europe).

This lower estimation was accepted for scenario development to reflect different, partially difficult coastal regions and possible restrictions due to non changeable other use of offshore regions.

Solar photovoltaic systems

The assumption for the utilization of solar energy was, that there are 12.5 square meters per inhabitant area (sqm/cap) on buildings available by 2050 in the OECD countries. For the non-OECD countries this figure is 10 square meters per inhabitant. In general it was not considered to install photovoltaic systems or solar thermal systems anywhere other than on buildings.

Half of the total resulting area is considered for photovoltaic systems, with the other half being set aside for solar thermal applications. Installable peak power of photovoltaic systems is calculated for a solar-cell efficiency of 16%, which results in an installable peak capacity of 7,731 GW on the global scale. The related energy production, calculated with the average solar irradiation for the different regions and/or countries, results to about 12,000 Terrwatthours per year (TWh/a)[21].

21 Wherever possible irradiation data for single countries is used to calculate the regions average.

The following table gives an overview of the assumptions and the potential for photovoltaic systems.

Solar Photovoltaic Potential at 2050 population							
Region	Potential	Area estimated	Area used (50% of total)	Average Insolation	Electricity	cell efficiency	Full Load Hours
	GW	sqm / cap	sqkm	wh/sqm*d	TWh/a	(%)	(FLH/a)
OECD Europe	518	12.5	3236.8	1,222	538	16.00%	1,039
OECD North America	609	12.5	3808.9	1,573	815	16.00%	1,337
OECD Pacific	174	12.5	1088.3	1,400	207	16.00%	1,190
Transition Economies	256	10.0	1597.5	1,211	263	16.00%	1,029
China	1,144	10.0	7151.7	1,211	1,178	16.00%	1,029
East Asia	714	10.0	4460.4	2,037	1,236	16.00%	1,731
South Asia	1,969	10.0	12305.2	2,111	3,533	16.00%	1,794
Latin America	488	10.0	3051.8	1,985	824	16.00%	1,687
Africa	1,587	10.0	9920.5	2,160	2,914	16.00%	1,836
Middle East	271	10.0	1694.8	2,160	498	16.00%	1,836
WORLD	**7,731**	**10.3**	**48315.9**		**12,005**		**1,553**

Table 73: Solar photovoltaic potential used for scenario development [EWG; 2007].

Solar-thermal systems

The general assumptions regarding available areas and the regional solar irradiation are identical to those used for photovoltaic systems, i.e. The half of the total available area is considered for installing solar thermal collectors. Differences lie within the collectors efficiency (65% gets used), which is substantially higher if compared to solar-cells. Additionally the area considered for capacity calculation was reduced by 10% to consider the inactive proportion of collector area due to the collectors framing.

The installable capacity of solar thermal collectors is almost 28,300 GW on the global scale. With an average productivity of slightly more than 1,800 equivalent full load hours per year, the potentially gross heat production results to more than 51,600 TWh per year.

The following table gives an overview of the assumptions and the potential for solar thermal systems.

Solar Thermal Potential at 2050 population							
Region	**Potential**	**Area estimated**	**Area used (50% of total area)**	**Average Insolation**	**Gross Heat**	**ccollector efficiency**	**Full Load Hours**
	GW	**sqm / cap**	**sqkm**	**wh/sqm*d**	**TWh/a**	**%**	**(FLH/a)**
OECD Europe	1,894	12.5	3,236.8	1,222	2,315	65.00%	1,222
OECD North America	2,228	12.5	3,808.9	1,573	3,505	65.00%	1,573
OECD Pacific	637	12.5	1,088.3	1,400	891	65.00%	1,400
Transition Economies	935	10.0	1,597.5	1,211	1,132	65.00%	1,211
China	4,184	10.0	7,151.7	1,211	5,066	65.00%	1,211
East Asia	2,609	10.0	4,460.4	2,037	5,315	65.00%	2,037
South Asia	7,199	10.0	12,305.2	2,111	15,196	65.00%	2,111
Latin America	1,785	10.0	3,051.8	1,985	3,544	65.00%	1,985
Africa	5,804	10.0	9,920.5	2,160	12,536	65.00%	2,160
Middle East	991	10.0	1,694.8	2,160	2,142	65.00%	2,160
WORLD	28,265	164.4	48,315.9		51,641		1,827

Table 74: Solar thermal collector potential used for scenario development [EWG; 2007].

Solar concentrating power

As detailed data on the regional potential of Solar Concentrating Power generation has not been available, a conservative assumption has been made, basically relying on a map of global direct normal solar irradiation, provided by Gregor Czisch. As this map was of a relatively low resolution, regional maps at higher resolution were used for additional potential estimation and to perform a crosscheck to ensure that there is no overestimation of global solar resources due to the low resolution.

Additionally the global map was vectorized for measurement and graphically adapted to the so called “Peters projection”, which is a map projection showing the real surface areas, without the increasing distortions towards the poles common maps usually show.

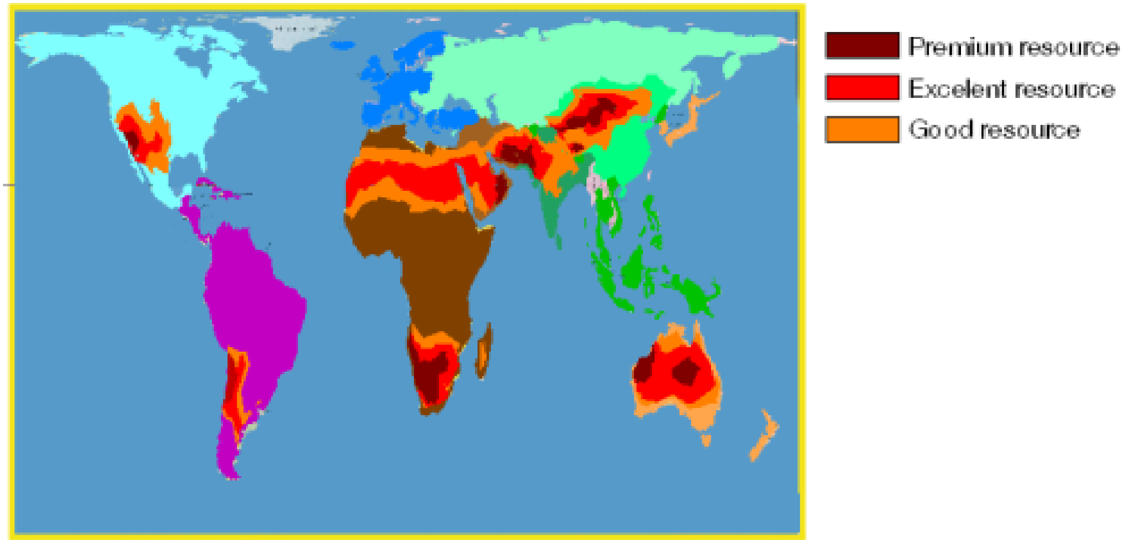


Figure 92: Solar thermal Power resources mapped to the "Peters projection" (showing true surface area), disaggregated into the regions used by the IEA [EWG; 2007].

The result of the process was a global map showing three different resource classes mapped to the regions as used by the IEA, using a projection that shows the true surface areas (picture below).

The three classes for direct solar irradiation are defined as follows:

Labelling	**Premium**	**Excellent**	**Good**
Class Indentifier	**Class 1**	**Class 2**	**Class 3**
kWh/sqm * a	2,750 to 3,000	2,500 to 2,750	2,250 to 2,500

Table 75: Solar irradiation classes for potential estimation of solar thermal power plants on the global scale [EWG; 2007].

Although there are no potentials for the northern Latin America and southern Europe marked within the global map, the cross-checking process showed, that additional potentials can be found using regional maps at higher resolution (e.g. DLR ISIS data provided by s@tellight; www.satel-light.com). This is namely for northern Latin America and southern Europe[22].

Considering the areas belonging to the three resources classes as listed in Table 75, with only taking small fractions of these areas into account for erecting plant (1% for class 1 sites, 0.5% for class 2 sites and 0.25% for class 3 sites), the installable capacity results to more than 3,500 GW on the global scale[23].

Special case for Europe: Although there are no resources, equal to the best resources in the world, Europe has done a lot of research & development on Solar Concentrating Power Plants and currently some projects are under development, resp. operational. The best resource within in Europe are in Spain and Portugal, reaching a yearly direct normal solar irradiation of about 2,230 to 2,555 kWh per square meter (about 6,100 to 7,000 Wh per square meter a day) in wider areas south to the 39^{th} degree of latitude. Altogether about 134,274 square kilometers of usable area have been identified, of which 1% is considered for installing Solar Concentrating Power plants. The average productivity for the European sites is 2,900 equivalent fill loaf hours a year, which is substantially lower if compared to other regions, with equivalent annual full load hours of more than 4,100 hours a year.
The amount of electricity, which potentially could be produced by that capacity is almost 15,300 TWh a year.

22 An additional information resource is the UNEP Solar and Wind Energy Resource Assessment (SWERA), which provides more detailed solar radiation maps for some of the Latin American countries, e.g. showing some class 3 resources within Brazil, Honduras and Guatemala.

23 The installable capacity was calculated with the assumption that one square kilometre is sufficient for a plant generating capacity of about 26 MW.

Solar Thermal Power							
Region	**Potential**	**Area used**	**used Area as % of resource classes total area**			**Electricity**	**Full Load Hours**
	(GW)	**(sqkm)**	**premium**	**excellent**	**good**	**(TWh/a)**	**(FLH/a)**
OECD Europe	34.4	1,342.7	1.00%			100	2,900
OECD North America	260.5	10,159.9	1.00%	0.50%	0.25%	1,090	4,185
OECD Pacific	744.9	29,051.0	1.00%	0.50%	0.25%	3,285	4,410
Transition Economies	0.0	0.0	1.00%	0.50%	0.25%	0	-
China	436.4	17,021.0	1.00%	0.50%	0.25%	1,884	4,317
East Asia	150.2	5,859.1	1.00%	0.50%	0.25%	646	4,299
South Asia	222.6	8,683.0	1.00%	0.50%	0.25%	957	4,298
Latin America 1)	210.5	8,209.8	1.00%	0.50%	0.25%	923	4,386
Africa	1,199.4	46,778.4	1.00%	0.50%	0.25%	5,179	4,318
Middle East	284.4	11,092.8	1.00%	0.50%	0.25%	1,220	4,288
WORLD	**3,543.4**	**138,197.7**				**15,283**	**4,313**

Table 76: Solar concentrating power plants assumptions and potential used for scenario development [EWG; 2007].

Biomass (electricity)

Biomass projections are somewhat difficult, as published potential data show a huge bandwidth and there is a substantial lack of information concerning today's real extend of biomass use. Some publications quote an overexploitation of biomass for different regions in Africa and China in general. Nevertheless there is no such thing as a natural law forcing people to use biomass in an inefficient way. Following it is assumed that inefficient use of biomass gets substituted by more sophisticated energy services, so that about the half of the available biomass potential, containing of residues (forest, crop, animal and solid municipal waste) and energy crops can be used for electricity generation by 2100.

As the given potentials have been on a global level, the potential was equally distributed among the regions in relation to the regions area. The Middle East was excluded as no biomass potential was assumed for that region. Table 76 and Table 74 give an overview of the underlying potential data and the remapping to the regions used in the EWG scenarios.

Source a)	Types of residues b)	Biomass residue potentially available (EJ y-1)			
		Year			
		1990	2020-2030	2050	2100
1	**FR, CR, AR**		31		
2c	**FR, CR, AR, MSW**		30	38	46
3	**FR, MSW**		90		
4					272
5	**FR, CR, AR, MSW**			217 - 245	
6		88			
7 c	**FR, CR, AR, MSW**		62	78	
8	**FR, CR, AR**		87		
A1 d	**Energy crops**			660	1118
A2 d	**Energy crops**			310	396
B1 d	**Energy crops**			449	703
B2 d	**Energy crops**			324	485

a 1: (Hall et al., 1993), 2: (Williams, 1995), 3: (Dessus et al., 1992), 4: (Yamamoto et al., 1999), 5: (Fischer and Schrattenholzer, 2001), 6: (Fujino et al., 1999), 7: (Johansson et al., 1993), 8: (Swisher and Wilson, 1993)

b FR = forest residues, CR = crop residues, AR = animal residues, MSW = municipal solid waste

c These studies rather estimated the potential contribution, instead of the potential available.

d Scenarios from the International Panel on Climate Change (IPCC) that depict the potential of energy crops combining the possible output from abandoned agricultural land, low-productive land, and rest land.
Adapted from: Hoogwijk, M., Faaij, A., Eickhout; B., de Vries, B. & Turkenburg, W. Submitted for publication. Potential of grown biomass for energy under four land-use scenarios.

Table 77: Global biomass potentials provided by Johansson at RENEWABLES 2004 in Bonn [Johansson; 2004].

The estimation of potentials used for the EWG scenarios is based on the lower assumption of the data given by Johansson. For biomass residues the upper value of the 2050 potential by Fischer and Schrattenholzer was used (245 EJ, Table 76, above), for energy crops it was the lowest IPCC data for 2100 (369 EJ).

The so given global potentials were equally distributed to the regions used in the scenarios by each region's land area. As there was no biomass potential considered for the Middle East, this fraction (resulting from distributing the global potential to the area) was mapped to the neighbouring regions (Africa, East Asia, South Asia). Table 74 (above) gives a more detailed overview of the figures that resulted from the redistribution of global biomass potentials to the scenarios regions.

Region	FR, CR, AR, MSW		Energy Crops IPCC		Totals	
	EJ/a, 2100	TWh/a, 2100	EJ/a, 2100	TWh/a, 2100	EJ/a, 2100	TWh/a, 2100
OECD Europe	9	2,608	15	4,216	25	6,824
OECD North America	39	10,807	63	17,468	102	28,276
OECD Pacific	16	4,477	26	7,236	42	11,713
Transition Economies	44	12,183	71	19,692	115	31,875
China	18	4,996	29	8,075	47	13,070
East Asia	10	2,859	17	4,621	27	9,662
South Asia	8	2,193	13	3,544	21	7,191
Latin America	35	9,776	57	15,802	92	25,578
Africa	55	15,377	89	24,854	145	43,867
Middle East	0	0	0	0	0	0
WORLD	**245**	**68,056**	**396**	**110,000**	**641**	**178,056**

Table 78: Result of the redistribution of global biomass potentials to the regions used in the EWG scenarios [EWG; 2007].

Calculating the installable generating capacity for biomass plants by the given potential (with assuming 5,000 equivalent full load hours per year) results in a capacity of more than 7,100 GW. The production figures are about 31,160 TWh a year, if 50% of the total biomass potential gets used for electricity generation in power plants with a conversion efficiency of 35% (For more details see Table 73, above).

Biomass Power Plants					
Region	Potential	Total biomass potential	Electricity (50% of potential considered)	Plant efficiency 1)	Full Load Hours
	(GW)	(TWh/a))	(TWh/a))	(%)	(FLH/a)
OECD Europe	273.0	6,824.5	1,194.3	35.0%	5,000.0
OECD North America	1,131.0	28,275.8	4,948.3	35.0%	5,000.0
OECD Pacific	468.5	11,713.2	2,049.8	35.0%	5,000.0
Transition Economies	1,275.0	31,874.9	5,578.1	35.0%	5,000.0
China	522.8	13,070.4	2,287.3	35.0%	5,000.0
East Asia	386.5	9,661.7	1,690.8	35.0%	5,000.0
South Asia	287.6	7,190.6	1,258.4	35.0%	5,000.0
Latin America 1)	1,023.1	25,577.7	4,476.1	35.0%	5,000.0
Africa	1,754.7	43,866.7	7,676.7	35.0%	5,000.0
Middle East	0.0	0.0	0.0	35.0%	5,000.0
WORLD	**7,122.2**	**178,055.6**	**31,159.7**	**40.0%**	**5,000.0**

1) Half of the plants are assumed to be cogeneration plant with an electrical efficiency of 30% and 50% heat efficiency. The other half consists of power plants with 40% electrical efficiency.

Table 79: Biomass power plants assumptions and potential used for scenario development [EWG; 2007].

Biomass (heat)

Heat from biomass was only considered in the form of biomass cogeneration plants, which produce electricity and useful heat in parallel. The major advantage of such plants is the very efficient use of resources, as there is no such waste of heat as in plants solely producing electricity[24]. The assumption for scenario development is, that half of the biomass plants are cogeneration plants, which requires them to be sited relatively close to heat costumers, whether this might be industrial, commercial or residential sites.

Cogeneration plants in the scenarios are assumed to have a heat to electricity ratio of 1.67 to 1 which is is equivalent to an electrical efficiency of 30% and a 50% efficiency for heat production.

Geothermal energy (electricity)

Based on the potentials given by the International Geothermal Association (IGA, http://iga.igg.cnr.it), some restrictions were made. It is assumed that the potential can be divided into resource that can easily be accessed and those, which are more complicated to develop, e.g for geographical or infrastructural reasons.

To get an appropriate regional distribution, the original IGA data had to be decomposes and redistributed to the regions used in this study[25]. Table 71 (above) gives an overview of the original data and the data redistributed to the regions used in the scenarios.

24 Most of the energy a conventional thermal power plant produces is heat. In a pure power plant (only delivering electricity to the grid) this heat is wasted as it gets released into the environment through cooling towers.

25 Original IGA data was distributed to the area of the regions contained and then proportionally redistributed to the regions used in this study. We are aware that this process potentially leads to some regions being over- or underestimated in terms of the region's geothermal potentials, but considered the systematic error to be neglectable for the purpose of the study.

Original data provided by IGA			
Region	**High-temperature resources suitable for electricity generation**		**Low-temperature resources suitable for direct use in million TJ/yr of heat (lower limit)**
	Conventional technology in TWh/yr of electricity	**Conventional and binary technology in TWh/yr of electricity**	
Europe	1,830	3,700	> 370
North America	1,330	2,700	> 120
Asia	2,970	5,900	> 320
Oceania	1,050	2,100	> 110
Latin America	2,800	5,600	> 240
Africa	1,220	2,400	> 240
World potential	**11,200**	**22,400**	**> 1,400**
Redistribution for the regions used in the EWG scenarios			
OECD Europe	851	1,721	172
OECD North America	1,330	2,700	120
OECD Pacific	1,084	2,167	114
Transition Economies	2,206	4,416	330
China	666	1,323	72
East Asia	381	757	41
South Asia	292	581	31
Latin America	2,800	5,600	240
Africa	1,220	2,400	240
Middle East	370	736	40
WORLD	**11,200**	**22,400**	**1,400**

Table 80: Global geothermal potential by International Geothermal Association and redistribution of potentials to the regions used in the scenarios [IGA; 2007], [EWG; 2007].

The installable capacities of geothermal power plants is calculated by the given potential electricity production and an assumed amount of 6,000 equivalent full load hours per year. This results in more than 3,700 GW of generating capacity, which could be installed on the global level. Only considering conventional use of geothermal resources, i.e. not using plants with Organic-Rankine-Cycle (ORC) or Kalina-cycle, this figure drops to about 1,900 GW. The related electricity production figures are about 22,400 TWh a year (including ORC and Kalina), respectively the half of this, if only using conventional plant technology. Table 69 (above) gives an overview of the distribution of installable capacities and electricity production within the different regions.

Geothermal Power Plants					
Region	Potential	Thereof conventional	Potential electricity if use is		Full Load Hours
	(GW)	(GW)	only conventional (TWh/a)	conventional & binary (TWh/a)	(FLH/a)
OECD Europe	286.8	141.8	851.0	1,720.7	6,000.0
OECD North America	450.0	221.7	1,330.0	2,700.0	6,000.0
OECD Pacific	361.2	180.6	1,083.8	2,167.1	6,000.0
Transition Economies	736.0	367.6	2,205.7	4,416.2	6,000.0
China	220.5	111.0	665.8	1,322.7	6,000.0
East Asia	126.2	63.5	381.1	757.0	6,000.0
South Asia	96.8	48.7	292.2	580.5	6,000.0
Latin America 1)	933.3	466.7	2,800.0	5,600.0	6,000.0
Africa	400.0	203.3	1,220.0	2,400.0	6,000.0
Middle East	122.6	61.7	370.4	735.8	6,000.0
WORLD	**3,733.3**	**1,866.7**	**11,200.0**	**22,400.0**	**6,000.0**

Table 81: Geothermal power plants assumptions and potential used for scenario development [EWG; 2007].

Geothermal Energy (heat)

As with the biomass plants, the scenarios assume half of the plants being cogeneration plants. The heat to electricity ratio for geothermal cogeneration is assumed as 2.7 to 1.

Initial technology costs

The table below gives an overview of the initial technology costs used a a base for calculating the decrease of costs per kW installed capacity for the different technologies.

Technology	Initial Costs [€2006/kW]	Remarks
Wind Energy, onshore	1,200	
Wind Energy, offshore	650	Additional costs compared to onshore Wind, resulting to initial cost of 1,850 €/kW
Biomass & Waste	4,400	
Geothermal	4,750	average value for ORC/KALINA and conventional plants, cost reduction only assumed for ORC/KALINA
Photovoltaic	5,000	
Solar Concentrating Power	4,000	
Tidal, Wave & other Maritimes	6,662	starting with prototype cost of 9,500 €/kW, which decreases down to 7,200 €/kW until 2015. Normal calculation with progress ratio (0.9) afterwards.
Solar Thermal Collectors	1,000	

Table 82: Initial technology costs used in the scenarios. [EWG; 2007]

Sources / Literature

[Archer/Jacobson; 2005]: Cristina L. Archer and Mark Z. Jacobson, „Evaluation of global wind power“, Department of Civil and Environmental Engineering, Stanford University, Stanford, California, USA, Received 20 September 2004; revised 14 March 2005; accepted 29 March 2005; published 30 June 2005, JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 110, D12110, doi:10.1029/2004JD005462; 2005.

[BP; 2006]: British Petroleum Energy Statistics, http://www.bp.com; 2006.

[BP; 2006a]: British Petroleum Energy Statistics, Geothermal Power by Country, 1990 – 2005, based on data by International Geothermal Association, papers presented at the World Geothermal Congress 2005; 2006.

[BSW; 2007]: Statistische Zahlen der deutschen Solarwirtschaft, Stand: Juni 2007

[BWE; 2006]; Bundesverband Windenergie, www.wind-energie.de; 2006.

[BWE; 2008]: Bundesverband Windenergie, online statistics, via internet: http://www.wind-energie.de.

[Destatis; 2005;]: Statistisches Bundesamt (Destatis); “Kulrutstatistiken – Kulturindikatoren auf einen Blick – Ein Ländervergleich”; 2008

[Destatis; 2005;]: Statistisches Bundesamt (Destatis); “Statistical Yearbook 2005 For the Federal Republic of Germany”; 2005

[DLR/WI; 2002]: Dr.-Ing. Manfred Fischedick (WI), Dr. Joachim Nitsch (DLR) et al., Wuppertal Institut für Klima Umwelt Energie (WI), DLR Institut für Thermophysik, “Langfristszenarien für eine nachhaltige Energienutzung in Deutschland” (“Long Term Scenarios for the Sustainable Use of Energy in Germany”), Forschungsvorhaben für das Umweltbundesamt, UFOPLAN FKZ 200 97 104; 2002

[Enquete-Kommission; 2002]: The German Parliament, “Enquete-Kommission Nachhaltige Energieversorgung unter den Bedingungen der Globalisierung und der Liberalisierung” (“Enquete-Commission Sustainable Energy Supply in the Face of Globalisation and Liberalisation”), DRs. 14/9400; 2002

[EREC; 2004]: European Renewable Energy Council, “Renewable Energy Sources -the solution for the future”, Prof. Arthouros Zervos, Dinner debate, European Energy Forum, European Parliament, Brussels; January 2004.

[Greenpeace; 2004]: Greenpeace, “Sea Wind Europe”; 2004.

[IEA; 2003]: International Energy Agency, “Renewables Information”, 2003 Edition; 2003.

[IEA; 2004]: International Energy Agency, “World Energy Outlook 2004”; 2004.

[IEA; 2004a]: International Energy Agency's Photovoltaic Power Systems Programme (PVPS), “TRENDS IN PHOTOVOLTAIC APPLICATIONS Survey report of selected IEA countries between 1992 and 2003”, International Energy Agency; 2004.

[IEA; 2006]: International Energy Agency (IEA), “World Energy Outlook 2006”; 2006

[IEA; 2007]: International Energy Agency (IEA), “World Energy Outlook 2007”; 2007

[IEA; 2007a]: International Energy Agency (IEA), “Key World Energy Statistics 2007”; 2007

[IEA; 2007b]: International Energy Agency (IEA), Paolo Frankl, "Renewable Energy - Global Scenarios and Policies"; 2007.

[IGA; 2001]: International Geothermal Association, via Internet: http://iga.igg.cnr.it/geo/geoenergy.php.

[index mundi; 2007]: index mundi, country profiles, http://www.indexmundi.com; 2007

[Johansson; 2004]: B. Johansson, Kes McCormick, Lena Neij, Wim Turkenburg, “The Potentials of Renewable Energy”, Thematic Background Paper, International Conference for Renewable Energies, Bonn 2004.

[LTI; 1998]: The LTI Research Group, “Long Term Integration of Renewable Energy Sources into the European Energy System”, publication series of the Centre for European Economic Research (ZEW), Physica.Verlag, ISBN-10: 3790811041; 1998

[PAWO; 2007]: PAWO Systems, The PAWO headlines'; May 2007.

[Peter et al.; 2006]: Stefan Peter (iSuSI), A. Doleschek (iSuSI), H. Lehmann (WCRE), J. Mirales (fundacio terra), J. Puig (Eurosolar), J. Corominas (Ecoserveis), M. Garcia (Ecoserveis), “Solar Catalonia - A Pathway to a 100% Renewable Energy System for Catalonia”; 2006

[Peter/Lehmann; 2005]: Stefan Peter, Harry Lehmann, “Das Deutsche Ausbaupotential Erneuerbarer Energien im Stromsektor” (“The Development Potential of Renewable Energies in the German Electrcity Sector”), EUROSOLAR Study; 2005

[REN 21; 2006]: Renewable Energy Policy Network for the 21st Century, Renewables - Global Status Report 2005 and Update 2006; 2006.

[REN 21; 2007]: Renewable Energy Policy Network for the 21st Century (REN21), "Renewables 2007 - Status Report", 2007.

[SIPRI; 2006]: Stockholm International Peace Research Institute (SIPRI), “SIPRI Yearbook 2006 – Armaments, Disarmament and International Security”; 2006

[Systeme Solaires; 2008]: SYSTÈMES SOLAIRES le journal des énergies renouvelables N° 184 – 2008, “BAROMÈTREPHOTOVOLTAÏQUE – AVRIL 2008”; 2008

[U.S. Census; 2007]: U.S. Census Bureau International Data Base (http://www.census.gov/ipc/www/idb/idbsprd.html)

[UN Stat; 2007]: United Nations Statistic Division, GDP at current prices, http://unstats.un.org/unsd/snaama/dnllist.asp; 2007.

[UPI; 2008]: United Press International, "Renewable investments increase in 2007", Feb. 07 2008, via internet: http://www.upi.com/International_Security/Energy/Briefing/2008/02/07/renewable_investments_increase_in_2007/2654/