ENERGYWATCHGROUP

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Renewable Energy Outlook 2030

Energy Watch Group Global Renewable Energy Scenarios

Executive Summary

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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

Zusammenfassung

Ziel dieser Studie ist es, eine alternative und – aus unserer Sicht – realistischere Perspektive der zukünftigen Rolle Erneuerbarer Energien in der globalen Energieversorgung zu präsentieren. Die dargestellten Szenarien basieren auf der in den letzten Jahrzehnten zu beobachtenden Entwicklung und Markteinführung Erneuerbarer Energien in den unterschiedlichen Weltregionen. Das Hauptaugenmerk der Szenarien liegt darauf, wie schnell eine Markteinführung Erneuerbarer Energien in den unterschiedlichen Regionen stattfinden könnte und welche finanziellen Belastungen sich durch diese Investitionen für die Gesellschaft ergeben würde. Um dieser Aufgabe gerecht zu werden, wurden viele Faktoren, wie Technologiekosten & Lernkurven für Herstellungskosten, Investitionen, die unterschiedliche wirtschaftliche Leistungsfähigkeit der Weltregionen, verfügbare Potenziale und der Verlauf des Wachstums, berücksichtigt.

Natürlich stellen die hier vorgestellten Szenarien lediglich zwei Möglichkeiten der zukünftigen Entwicklung dar – unter vielen anderen Möglichkeiten, aber sie repräsentieren realistische Möglichkeiten für die Zukunft der Erneuerbaren, die Anlass zu Optimismus geben. Die Ergebnisse der Szenarien zeigen, dass die Erzeugungskapazitäten– bis 2030 – in weit größerem Umfang ausgebaut werden können und das dies wesentlich kostengünstiger ist, als vielfach – auch von wissenschaftlicher Seite – gedacht und oftmals befürchtet.

Eine starke Unterstützung von politischer Seite her und ein hindernisfreier Zugang zum Markt vorausgesetzt, bestimmen letztlich die Investitionssummen über den weiteren Ausbau erneuerbarer Energietechnologien. Für die „REO 2030“ Szenarien wurde eine über die Zeit wachsende Bereitschaft für Investitionen eine saubere, sichere und nachhaltige Energieversorgung angenommen. Beginnend mit kleineren Summen, setzen die Szenarien voraus, dass bis zum Jahr 2030 ein bestimmter Investitionsbetrag pro Kopf der Bevölkerung erreicht werden kann. Dieses Investitionsziel unterscheidet sich für jede der zehn Regionen innerhalb der Szenarien (siehe Table 1). Die zwei Szenarien. „Low Variant“ (untere Variante) und „High Variant“ (obere Variante) genannt unterscheiden sich hinsichtlich der gesetzten Investitionsziele dergestalt, dass in der oberen Variante („High Variant) im Jahr 2030 im globalen Durchschnitt eine Investitionssumme von 124 € pro Kopf der Weltbevölkerung erreicht werden kann, in der unteren Variante („Low Variant“) jedoch nur die Hälfte dieses Betrags (62 € pro Kopf und Jahr).

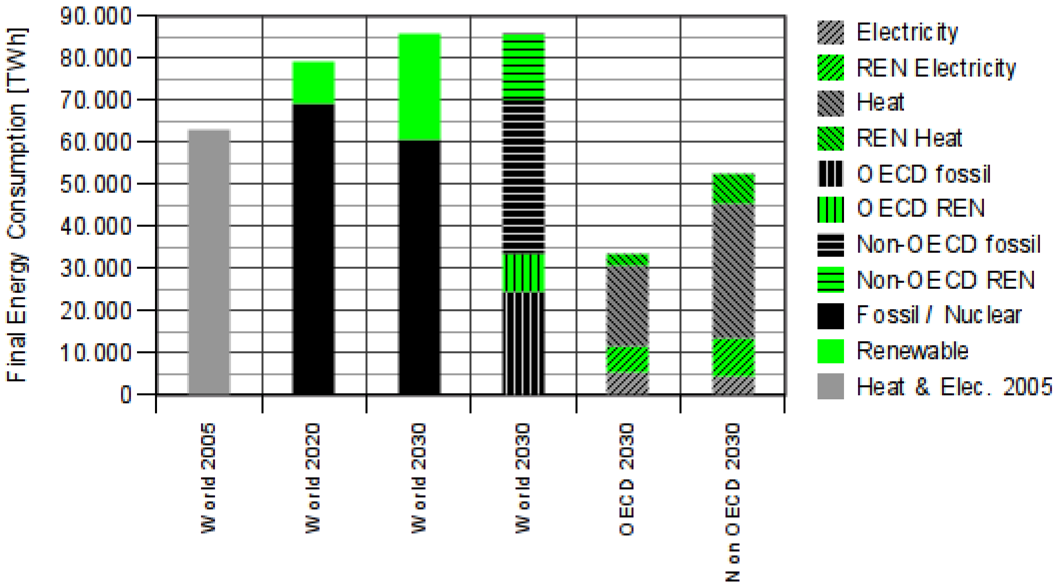
Dieser Szenarienansatz bedingt, dass auch die Verringerung der spezifischen Technologiekosten, welche mit der Ausweitung der Produktion einhergeht, berücksichtigt wird. Um diesem Umstand Rechnung zu tragen, wurde die Kostenverringerung jeder Technologie, berechnet auf Basis der Investitionen in die jeweilige Technologie und dem daraus resultierenden Anwachsen der Produktionsmengen, in den Szenarien berücksichtigt.

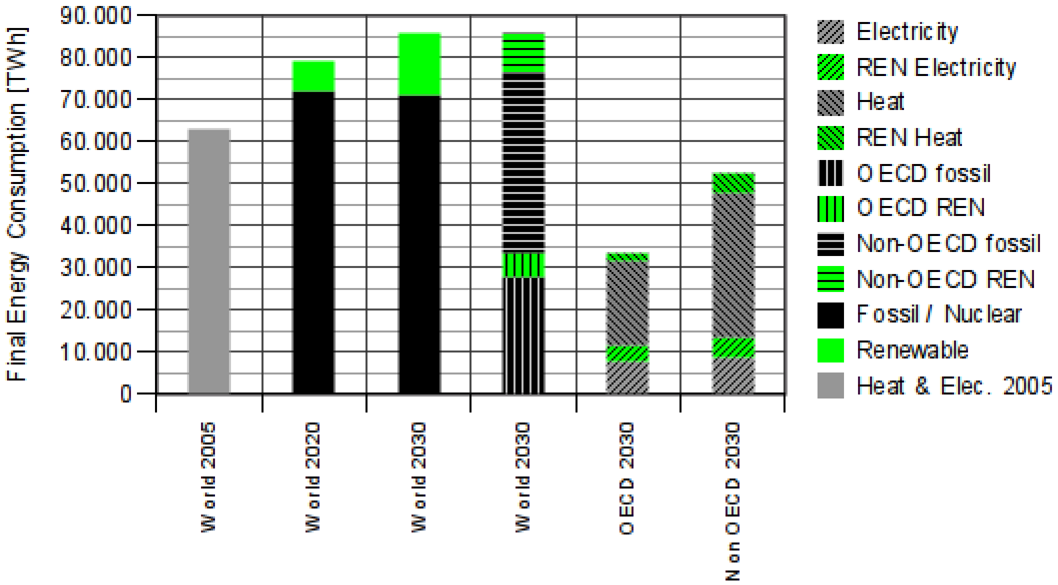
In der Hauptsache befassen sich die Szenarien mit dem Aspekt der Elektrizitätsversorgung, die Wärmeseite der Energieversorgung wird teilweise behandelt, Treibstoffe hingegen gar nicht betrachtet.

Die Entwicklung des globalen Endenergiebedarfs, auf welchen in den Szenarien Bezug genommen wird, wurde aus dem „World Energy Outlook 2006“ (WEO 2006) der Internationalen Energieagentur (IEA) übernommen.[1]

Bezogen auf den globalen Maßstab, zeigen die Ergebnisse des “High Variant”Szenarios eine Deckung von 29% des Endenergiebedarfs aus Erneuerbaren Energien in 2030. In der unteren Variante („Low Variant“), welche mit halb so großen Investitionen auskommt, kann eine 17%ige Deckung erreicht werden.

1 Obwohl zwischenzeitlich der neuere „World Energy Outlook 2007“ veröffentlicht wurde, ist die Referenz auf die Daten des WEO 2006 beibehalten worden. Dies liegt darin begründet, dass sich beide Publikationen hinsichtlich der angenommenen zukünftigen Entwicklung des Energieverbrauchs nur geringfügig unterscheiden. So unterscheidet sich beispielsweise der Primärenergiebedarf im „Alternative Policy Szenario“ beider Publikationen lediglich um 1,6%.





Der erste Balken (grau, ohne Schraffur) zeigt den globalen Endenergiebedarf (nur Strom und Wärme) für das Jahr 2005, ohne Unterscheidung zwischen erneuerbaren und nicht-erneuerbaren Energien. Die Balken 2 und 3 zeigen die weitere Entwicklung des Endenergiebedarfs bis 2030, den aus den Szenarien resultierenden Anteil Erneuerbarer Energien (grün) und den verbleibenden fossilen und nuklearen Anteil. Der vierte Balken zeigt die Werte für die OECD Länder (senkrecht schraffiert, grün für Erneuerbare, schwarz für fossil und nuklear) und entsprechend die nicht-OECD Länder (waagerecht schraffiert). Die Balken 5 und 6 zeigen jeweils detailliertere Ergebnisse für die OCED Länder (Balken 5) und die nicht_OECD Länder (Balken 6). Hierbei sind jeweils Strom nach Rechts ansteigend und Wärme nach Rechts abfallend schraffiert. Wieder sind die Erneuerbaren grün abgebildet, die fossilen und nuklearen diesmal jedoch grau)

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]

Die Ergebnisse der oberen Variante der Szenarien laufen darauf hinaus, dass im Jahr 2030 in der Gesamtheit der OECD Länder 54 % des Stroms und mehr als 13% der Wärme (jeweils Endverbrauch) aus erneuerbaren Quellen gedeckt werden kann. Insgesamt beläuft sich damit der

Anteil der Erneuerbaren auf 27% (17% in der unteren Variante, dabei etwa ein Drittel des Stroms und 8% der Wärme). Die Gesamtheit der nicht-OECD Länder steigt der Anteil erneuerbarer in der oberen Variante insgesamt auf 30% (18% in der unteren Variante) Dabei können die Erneuerbaren im Jahr 2030 beinahe 68% des Stroms und 17% der Wärme decken; in der unteren Variante sind die 36% beim Strom und 11% bei der Wärme.

Die Szenarien zeigen, dass die Erneuerbaren Energien das Potenzial besitzen einen bedeuten Beitrag im Kampf gegen den Klimawandel, zur Verringerung der Abhängigkeit von fossilen Energieträgern und zur Beendigung der Nutzung der Atomkraft zu leisten. Zwar steigt die Energieerzeugung aus fossilen und nuklearen Energieträgern in den Szenarien bis 2020 so weiter an, dass zu diesem Zeitpunkt mehr Energie aus ihnen gewonnen wird als der gesamte Strom und Wärmebedarf des Jahres 2005. Doch selbst in der unteren Variante der Szenarien fällt dieser Beitrag zum Jahr 2030 hin wieder leicht ab. In der oberen Variante findet zwischen 2020 und 2030 ein bemerkenswerter Rückgang der Energieerzeugung der Fossilen und Nuklearen statt, so dass deren Energieerzeugung wieder unter das Maß des des gesamten Strom- und Wärmebedarfs des Jahres 2005 fällt.

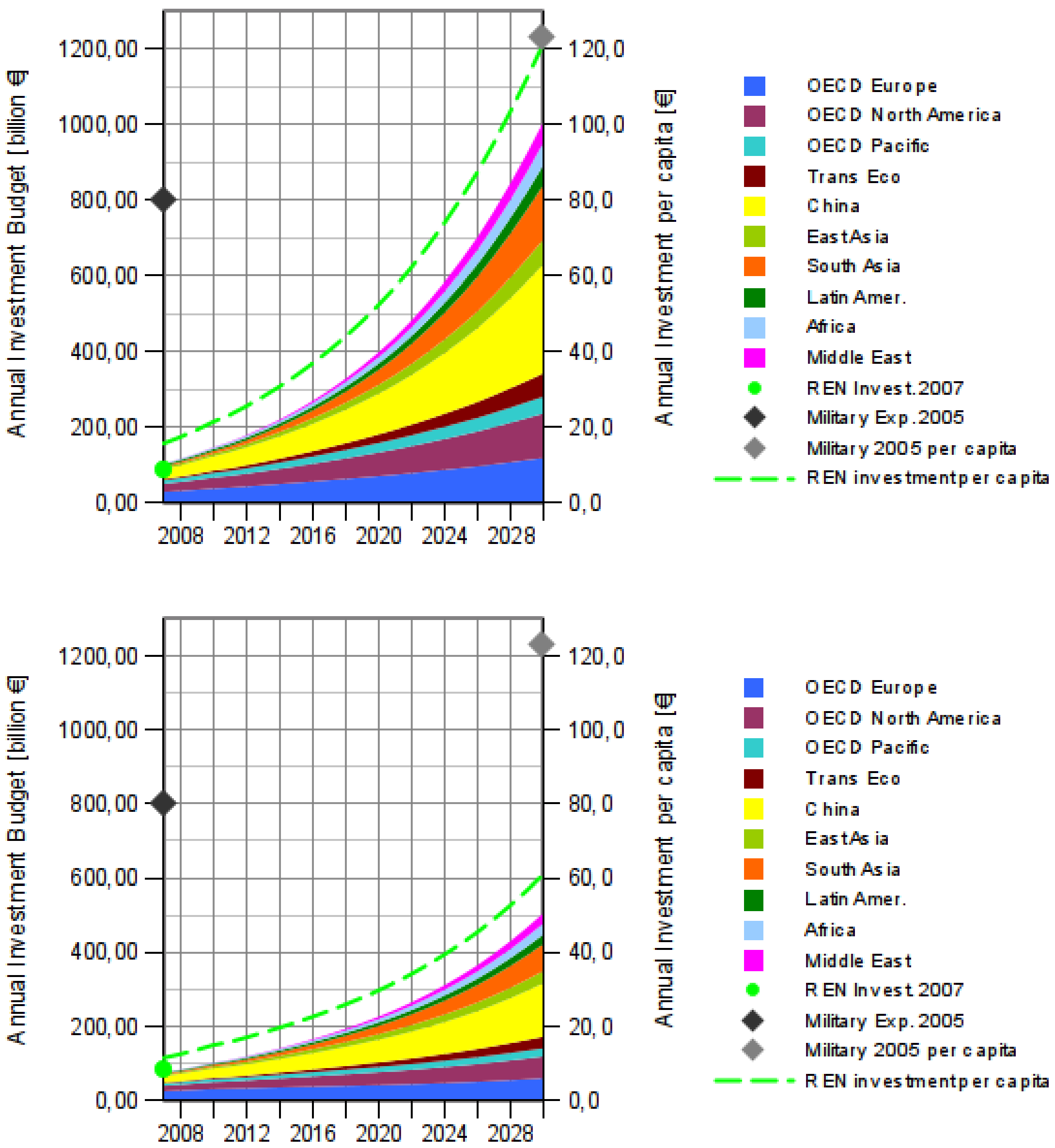
World Region	Investment per capita and year in 2030 [€2006/cap*a]		Total investment budgets in 2030 [billion €2006]	
	Low Variant	High Variant	Low Variant	High Variant
OECD Europe	111	223	60	121
OECD North America	110	220	59	118
OECD Pacific	112	224	22	44
Transition Economies	91	180	31	60
China	102	204	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
All regions	62	124	510	1021

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

In absoluten Zahlen ausgedrückt belaufen sich die Investitionen in erneuerbare Erzeugungskapazitäten im Jahr 2030 auf etwa 510 Milliarden € in der unteren Variante und auf etwa 1.021 Milliarden € in der oberen Variante der Szenarien. Der größte Einzelinvestor zu dieser Zeit ist China, gefolgt von Südasien – beide Regionen stellen beträchtliche Anteile der, bis dahin auf über acht Milliarden Menschen angestiegenen Weltbevölkerung – und OECD Europa das zwar über wesentlich weniger Einwohner verfügt, aber deutlich höhere pro Kopf Investitionen in 2030 erreicht. Die geringsten Investitionen werden in Lateinamerika (Latin America), dem Mittleren Osten (Middle East), Afrika (Africa) und schließlich den pazifischen OECD Ländern (OECD Pacific) erreicht.

Investitionen in der hier aufgezeigten Größenordnung sind oftmals etwas abstrakt oder erscheinen als unüberwindbares Hindernis. Um ein besseres Gefühl dafür zu vermitteln, was solche Summen in unserer heutigen Welt bedeuten, werden in der Darstellung 2 (Figure 2), neben den Investitionen in Erneuerbare Energien in den Szenarien, auch die globalen Militärausgaben des Jahres 2005 dargestellt [SIPRI; 2006]. Ausschließlich in der oberen Variante werden im Jahr 2030 Investitionen erreicht, die in ihrer Höhe mit den Militärausgaben des Jahres 2005 vergleichbar sind. Ein weiterer konkretisierender Vergleich ergibt sich aus den jährlichen Ausgaben für Kultur, die 2005 auf jeden Einwohner Deutschlands entfielen: diese beliefen sich auf etwa 100€ pro Kopf [DESTATIS; 2008].

Laut eines von United International Press im Februar 2008 veröffentlichten Artikels, beliefen sich die weltweiten Ausgaben für Erneuerbare Energien im Jahr 2007 auf etwa 117 Milliarden US Dollar oder etwa 84 Milliarden Euro (grüner Punkt in Figure 2), also zwischen den angenommen Investitionen beider „REO 2030“ Szenarien



Die farbigen Flächen und Markierungen auf der linken Y_Achse zeigen absolute Investitionssummen, während die gestrichelte Linie und Markierungen auf der rechten Y_Achse Investitionen pro Kopf in globalen Durchschnitt anzeigen.

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].

Bei der Entwicklung – und schließlich den erreichten – Erzeugungskapazitäten der Erneuerbaren ist der Unterschied zwischen der unteren und oberen Variante größer, als dies bei den Investitionsvolumina der Fall ist.Werden in der oberen Variante im Jahr 2030 insgesamt 4.450 GW Erzeugungskapazität der „neuen" Erneuerbaren (EE ohne Wasserkraft) erreicht, ist dies in der unteren Variante – mit 1.840 GW – weniger als die Hälfte.

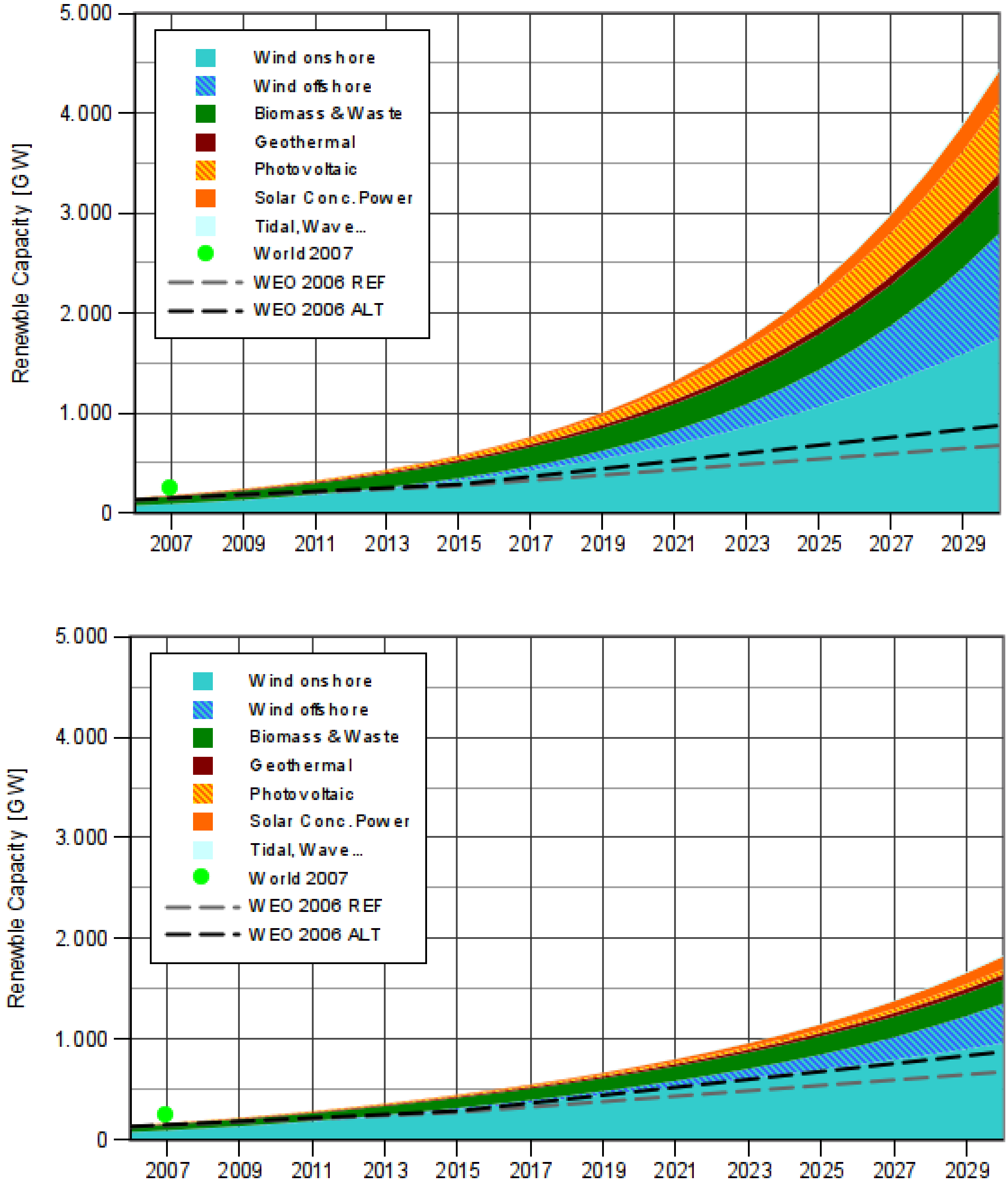


Figure 3: Development of "new" renewable electricity generating capacities in the world regions in the "High Variant" (upper figure) and "Low Variant Scenario" (lower figure) [EWG; 2008].Data on renewable capacity 2007: [REN 21; 2007].

Der bei weitem größte Teil der in 2030 erreichten Kapazität wird durch die onshore und offshore Windenergie gestellt. Generell zeigen alle Technologien in der oberen Variante ein deutlich höheres Wachstum, aber im Vergleich beider Szenarien kann die Photovoltaik als der große Gewinner gesehen werden. Stellt diese in der unteren Szenarienvariante in 2030 das viertgrößte Erzeugungskontingent, erreicht sie in der oberen Variante Platz zwei. Biomasse & Reststoffe (Biomass & Waste) folgen auf dem dritten Platz (zweiter Platz in der unteren Variante).

Geringere Beiträge zur gesamten Erzeugungskapazität entfallen auf die Geothermie und Gezeiten, Wellen & Meeresenergie (Tidal, Wave and other Maritimes; siehe Figure 3).

Die Szenarien beschäftigen sich mit dem Ausbau der sog. „neuen" Erneuerbaren, was Wasserkraft als Bestandteil der Ausbauszenarien und somit auch aus den aufgezeigten Investitionen ausschließt. Nichtsdestotrotz wurde der geplante Ausbau der Wasserkraft in den verschiedenen Regionen berücksichtigt (von heute etwa 762 GW auf etwa 856 GW in 2030), da Wasserkraft heute der bedeutendste erneuerbare Stromerzeuger ist und auch im Jahr 2030 noch eine wichtige – wenn auch geringere – Rolle für die regenerative Stromerzeugung spielen wird.

Die erneuerbare Stromerzeugung steigt mit den Ausbau der Kapazitäten an. Lag deren Erzeugung 2005 bei etwa 3.300 TWh (Terrawattstunden), steigt diese in den Szenarien bis 2030 auf etwa 8.600 TWh in der unteren und etwa 15.200 TWh in der oberen Variante (Balken in Figure 4).

Windenergie erreicht den größten Anteil an der erneuerbaren Stromerzeugung, aber der Anteil an der Erzeugung fällt geringer aus, als deren Anteil an den Erzeugungskapazitäten[2]. Trotzdem kommt die Windenergie in Bezug auf die Stromerzeugung in 2030 selbst in der unteren Szenarienvariante nahe an die Erzeugung aus Wasserkraft heran, in der oberen Variante übersteigt sie deren Erzeugung deutlich, um etwa 2.000 TWh. Biomasse & Reststoffe, Geothermie und solarthermische Stromerzeugung folgen auf den weiteren Plätzen.

Zum besseren Vergleich der hier dargestellten Szenarien mit dem „Alternative Policy Scenario" des WEO 2006 ist in der Grafik (Figure 4) auch die Entwicklung dieses Szenarios, durch marlierte Linien und transparente Flächen, dargestellt. Es ist leicht ersichtlich, dass im WEO 2006 Szenario von einem deutlich höheren Beitrag der Wasserkraft ausgegangen wird (Markierung und Fläche in Lila), der Beitrag der „neuen" Erneuerbaren hingegen (grüne Markierungen und Fläche, über der Wasserkraft aufgetragen), selbst hinter der unteren Variante der „REO 2030" Szenarien, deutlich zurückbleibt.

2 Dieses Ergebnis war so zu erwarten, da Windenergie (und auch die Photovoltaik) wetterabhängige Technologien sind, deren Produktivität nicht auf einem Niveau von z.B. Biomasse oder Geothermie erwartet werden kann.

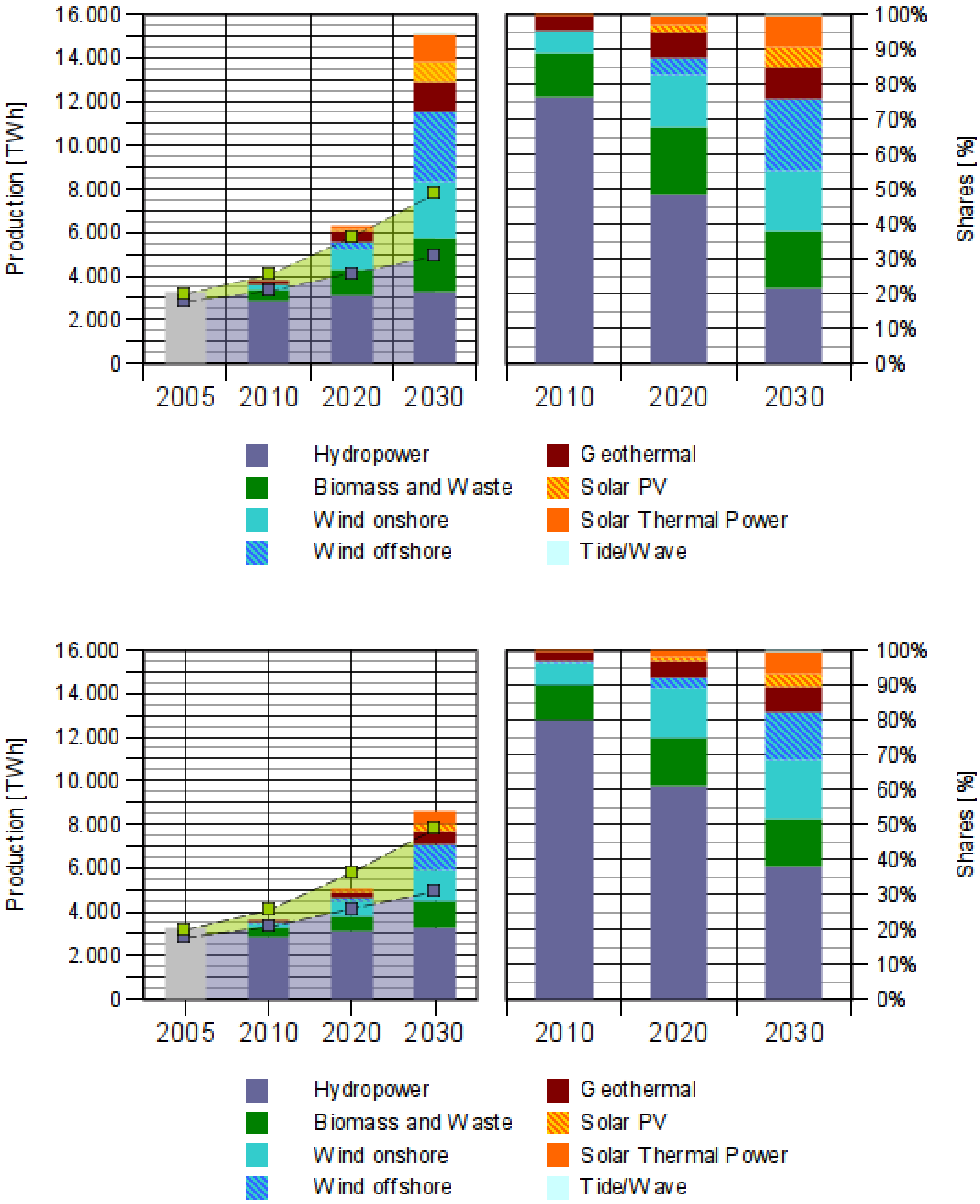


Figure 4: Development of electricity production from renewables in the "High Variant" (upper figure) and the "Low Variant Scenario" (lower figure), 2010 to 2030 [EWG; 2007]. Data 2005: [IEA; 2007b]

Bislagn wurde lediglich die elektrische Seite betrachtet, aber – wie Eingangs bereits erwähnt – wurde auch Wärmeerzeugung aus Erneuerbaren in den Szenarien betrachtet. Wärmeerzeugung findet sowohl in Kraft-Wärme-Kopplung (KWK) statt – die Hälfte der Biomasse E Reststoffe verwendenden Anlagen und die Hälfte der geothermischen Anlagen in den Szenarien werden als KWK-Anlagen angenommen – als auch durch solarthermische Kollektoren, denen beträchtliche Anteile der Investitionen zufallen. Insgesamt wird in der unteren Variante ein größerer

Schwerpunkt auf solarthermische Kollektoren gelegt, als in der oberen Szenarienvariante. Diese Entscheidung liegt darin begründet, dass solarthermische Kollektoren (Solarkollektoren) vergleichsweise billig sind und die untere Variante mit erheblich geringeren Investitionen auskommen muss als die obere Variante.

Die Kapazität der installierten Solarkollektoren steigt in der unteren Variante von 137 GW in 2006 auf beinahe 2.900 GW in 2030. Trotz der geringeren Gewichtung der Solarthermie in der oberen Variante, werden dort in 2030 etwa 3.800 GW thermische Leistung erreicht. Da die Entwicklung der Wärmeleistung aus KWK proportional zur Entwicklung der Stromerzeugung aus Biomasse & Reststoffen und der Geothermie verläuft, schlägt sich dies auch genau so in der Wärmeleistung beider Szenarien nieder: in der unteren Variante werden deutlich geringere Wärmeleistungen aus KWK erreicht, als dies in der oberen Variante der Fall ist.

Bezug nehmend auf den Endenergiebedarf, erreicht die obere Variante der Szenarien in 2030 eine erneuerbaren Deckungsgrad von knapp 30% und, aufgrund der deutlich geringeren Investitionen, etwas mehr als 17% in der unteren Variante.

Der erneuerbare Anteil im Stromsektor fällt in beiden Szenarien deutlich höher aus, als der Anteil der Erneuerbaren an der Deckung des Endenergiebedarf für Wärme. In der oberen Variante werden 2030 etwa 62% des Stroms und 16% der Wärme aus erneuerbaren Technologien gewonnen. In der unteren Variante sind dies 35% (Strom) bzw. 10% (Wärme).

In der abschließenden Bewertung zeigen beide Szenarien, dass die Möglichkeit zum Ausbau Erneuerbarer Energien bis 2030 wesentlich größer ausfällt, als im „Alternative Policy Scenario" des „World Energy Outlook 2006" dargestellt wird. Die dafür notwendigen Investitionen – oftmals als ein großes Problem für den Ausbau der Erneuerbaren angesehen – sind relativ gering, nicht nur in Bezug auf den laufenden und sich stetig beschleunigenden Klimawandel, sondern auch in Bezug auf heutige Investitionen in anderen Sektoren. Um eine Entwicklung zu erreichen, wie sie in der oberen Variante aufgezeigt wird, würde es ausreichen die Investitionen in erneuerbare Erzeugungstechnologien bis zum Jahr 2030 auf ein Niveau von durchschnittlich 124 € pro Kopf der Weltbevölkerung zu steigern; eine durchschnittliche pro Kopf Investition, wie sie im Bereich der Militärausgaben bereits im Jahr 2005 stattgefunden hat.

Es hat einen langen Zeitraum erfordert, die Erneuerbaren Energien in den Fokus wissenschaftlicher Forschung zu bringen und weitere Zeit war und ist für deren Markteinführung nötig. Die erfolgreiche Markteinführung, dies kann am Beispiel des Deutschen EEG gut gezeigt werden, erfordert effektive Förderkonzepte und kann zu einem dynamischen Wachstum führen. Das Wachstum der Windenergie in Deutschland, zum Beispiel, übertraf regelmäßig die gestellten Prognosen. Insgesamt betrachtet verlief der Ausbau der Erneuerbaren im globalen Kontext bislang zu zögerlich – und keineswegs in einem Ausmaß, dass geeignet wäre dem Klimawandel zu begegnen -, aber es muss auch als Erfolg betrachtet werden, dass die Erneuerbaren Energien heute zum normalen Bestandteil des Nachdenkens und Planens einer zukünftigen Energieversorgung gehören.

Trotz ermutigender Ansätze, wurde zu viel Zeit mit dem Streit über die Gründe der globalen Klimaveränderung sowie die Endlichkeit und Reichweite der fossilen Energieträger vergeudet, bevor man zu der Erkenntnis gelangte, dass Heute die Zeit dafür ist die Art und Weise, in der wir unseren Energiebedarf befriedigen – aber auch Art und Ausmaß der Energieverwendung – energisch und nachhaltig zu verändern. Dies ist eine Aufgabe, die dieser Generation zu leisten hat. Ein früheres Angehen dieser Aufgabe wäre sicherlich vorteilhafter gewesen. Aber die Aussicht, mit relativ geringen Investitionen, binnen zweier Jahrzehnte den Anteil Erneuerbarer Energien auf 62% des benötigten Stroms und insgesamt 30% des Bedarfs an Strom und Wärme steigern zu können, gibt Anlass zu Optimismus. Wir können die Probleme des Klimawandels und schwindender fossiler Energieträger bewältigen, wenn dies nur wirklich wollen und bereit sind diese Probleme energisch anzugehen.

Eine Entwicklung, wie in der oberen Variante dieser Szenarien dargestellt, birgt die Möglichkeit zur Reduzierung fossiler und nuklearer Erzeugungskapazitäten in der globalen Energieversorgung. Auch wenn die Energieversorgung, zumindest bis 2030, noch auf große Anteile fossiler Energieträger angewiesen sein wird, bietet ein massives Wachstum der Erneuerbaren einen, und unserem Kenntnisstand nach den einzigen, Weg aus der Abhängigkeit von Öl und anderen fossilen Energiequellen.

Es ist unsere feste Überzeugung, dass die Atomkraft nicht gebraucht wird, wenn wir jetzt eine Entwicklung in Gang setzen, wie sie hier vorgeschlagen wird. Es besteht keinerlei Notwendigkeit dafür, neue Atomkraftwerke zu bauen oder die Laufzeiten bereits bestehender über das geplante Maß hinaus zu verlängern. Die Nutzung der Atomkraft, mit allen damit verbundenen Problemen (z.B. Erzeugung und Verbreitung atomwaffenfähigen Materials, die ungelöste Frage der Endlagerung radioaktiver Abfälle oder die Gefahr schwerer Kraftwerksunfälle), kann beendet werden und muss so schnell wie möglich beendet werden. Statt Gelder für den Bau neuer Atomkraftwerke bereitzustellen, die definitiv keine nachhaltige Lösung unserer Energieprobleme erbringen können, sollte dieses Geld in die wirkliche Lösung der Probleme fließen, in die Erneuerbaren Energie.

Auch wenn die „REO 2030“ Szenarien eine Weg zur massiven Steigerung des Anteils regenerativer Energien in der Energieversorgung zeigen, sollten die Szenarien unser Augenmerk auch auf den Energieverbrauch und dessen zukünftiger Entwicklung lenken. In dieser Studie ist der Bezugsrahmen für die Entwicklung des Energiebedarfs aus dem „Alternative Energy Scenario“ des „World Energy Outlook 2006“ der Internationalen Energieagentur entnommen. Dies bedingt, dass, selbst in der oberen Variante der „REO 2030“ Szenarien, der Beitrag der nicht-erneuerbaren Energieerzeugung im Jahr 2030 beinahe so hoch ausfällt, wie der gesamte Endenergiebedarf an Strom und Wärme des Jahres 2005. Dies zeigt deutlich, dass wir uns der Frage des Energieverbrauchs mit derselben Anstrengung widmen müssen, wie der Frage der Energieerzeugung. Es sollte durchaus hinterfragt werden, ob die von der IEA in Aussicht gestellte Entwicklung des Energieverbrauchs ambitioniert und mutig genug ist, um darauf eine Lösungsansatz aufzubauen. Es ist unbestritten, dass enorme Potenziale zur Energieeinsparung vorhanden sind, insbesondere im Bereich der Wärme, und das wir diese Potenziale erschließen müssen. Aber dies ist eine Frage, die durch weitere Arbeit zu klären ist.

Introduction

The objective of developing the scenarios of this study is to present an alternative and more realistic view on the role renewable energies can play in a future global energy supply. Some of the latest global or regional scenarios are not really showing 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 showed in different regions within the last decades. The scenarios will show that renewable energy technologies have a huge potential to help to solve the climate change problem and to lower the dependence from fossil and nuclear energies.

At the latest since the currently released IPCC climate study there cannot be any legitimate doubt that the ongoing climate change is man-made. The possible magnitude of climate change is set to reach levels that threaten our economies, the stability of ecosystems and, hence, a sustainable development. Lately Nicholas Stern, former chief economist of the World Bank, draw the focus on the (previously unnoticed but already often published) economic aspects of climate change. According to Stern's analysis climate change could cause a decrease of the global GDP by at least 10%, and - in the worst case - even by 20%.

To avoid an increase in 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 the half by the middle of this century. As today's developed countries are the predominant contributors to global GHG emissions, it must be their commitment to make first moves towards a clean energy supply and to reduce their GHG emission by 80% within this time. 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 establishing 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[3] show us that the use of these technologies must be discontinued. With regard to nuclear fusion, this technology has so far not functioned and would also involve the production of radioactive waste if it did.

Over the medium- and long term 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 those renewable

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

sources should be kept on a minimum. This entails that energy has to be used as efficient as possible, i.e. renewable supply and energy efficient technologies must be combined.

One of the most common question regarding establishing a renewable energy supply is the time which is necessary to realise such a system. Some scenarios already addressed this question on a regional level[4]. The scenarios in this study deal with the question how fast renewable technologies might be implemented on a world wide scale and with the costs such a development would result in.

Addressing these questions cannot be separated from the question how, how fast and to which extend 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 time and costs makes the effort humanity has to take more apparent and more transparent. Last but no least the outcome of the scenarios will also help in defining goals for the reduction of greenhouse gas emissions.

4 e.g. [Enquete-Kommission; 2002], [SolCat; 2007] oder [Peter et al.; 2006], [Peter/Lehmann; 2005] (Kraftwerksersatz), [LTI; 1998], XXX Quellenhinweis auf DLR WI, UBA für D, , und ??? weitere ???

Methodology

We were asked to calculate the possible increase in renewable energy capacities assuming a hindrance free development. This means, 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 market penetration.

The REO scenarios consider ten world regions, which are the same as in IEA's "World Energy Outlook 2006" (WEO 2006). This is not done randomly, it helps to compare the results of this scenarios with the "World Energy Outlook" scenarios and other scenarios.

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 *willingness to pay* for clean, secure and sustainable energy supply. The assumed willingness to pay is expressed as a target level for annual payments per capita that - after a period of continuous growing investments into renewable energies - will be reached by the year 2030. As incorporating estimations regarding inflation are considered as uncertain, all amounts get expressed on a 2006 price basis.

Because all investments into energy supply will have to be paid by the energy consumers in the end, the extension of renewable energies will impose a financial burden to societies[5]. Although a growing acceptance of and support for clean energy supply by societies is assumed within this work, the Energy Watch Group respected that overstressing financial burdens might change society's attitude towards renewable energy support to the worse; with negative effects on the investors trust into the continuity of political support for renewable energy with unchanged conditions.

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", one (basic) to ensure the necessary technological diversification of renewable energy technologies and the other (advancement) to adapt development to existing potentials within the regions.

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

5 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.

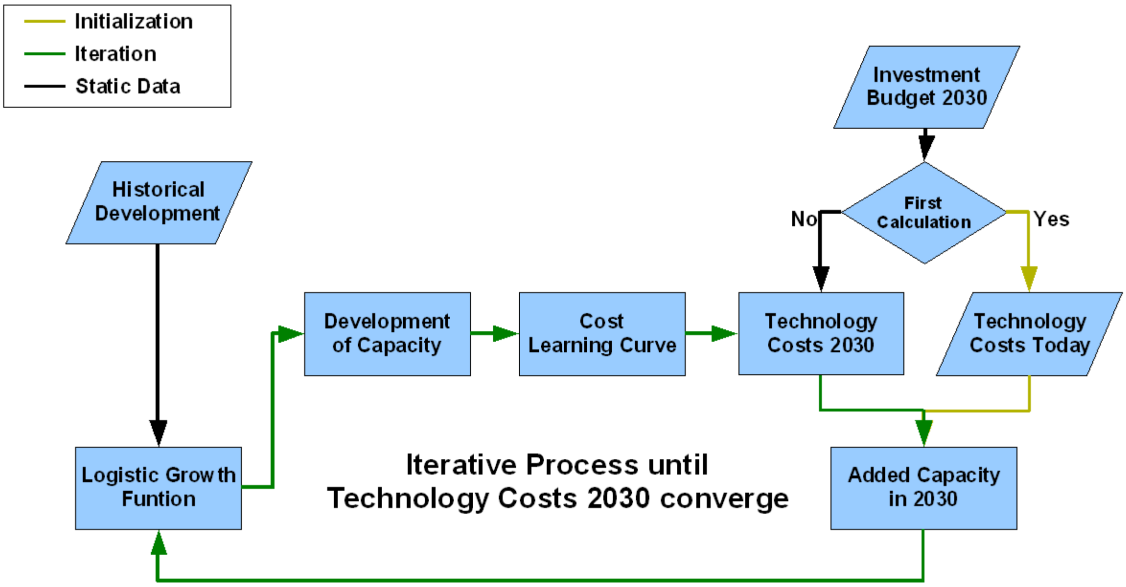


Figure 5: Flow chart of the scenario development process with iteration of technology costs and added capacities in 2030. [S. Peter, H. Lehmann; 2007]

Within the scenarios both, investment budgets and specific technology costs determine the generating capacities that can be added each year up to 2030, thus providing a target mark for the development of installed capacities until 2030. This is, in a first run, done using today's technology costs for the the whole period up to 2030. The resulting development of the total capacities installed world wide afterwards gets used to generate technology specific "learning-curves" for cost degression. The next run uses this decreased technology costs to recalculate installed generating capacities – with this corrected capacities technology costs get recalculated again 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.[6]

6 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, as the fixed investment budgets in 2030 determine the preceding development in terms of installed capacities and thus the decrease of specific technology costs.

Interaction of investment budget and technologies' cost decrease

The Renewable Energy Budget decides about 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 investment budget in 2030 and added capacity in 2030 are equivalent by the factor of specific technology costs in 2030. The decrease in specific technology cost is calculated using so called "learning curves". Learning curves consist of a progress ratio which determines by how much costs will decrease if production doubles. For example: With a progress 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 progress 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 considered period of time. 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 the 2030 investment target.

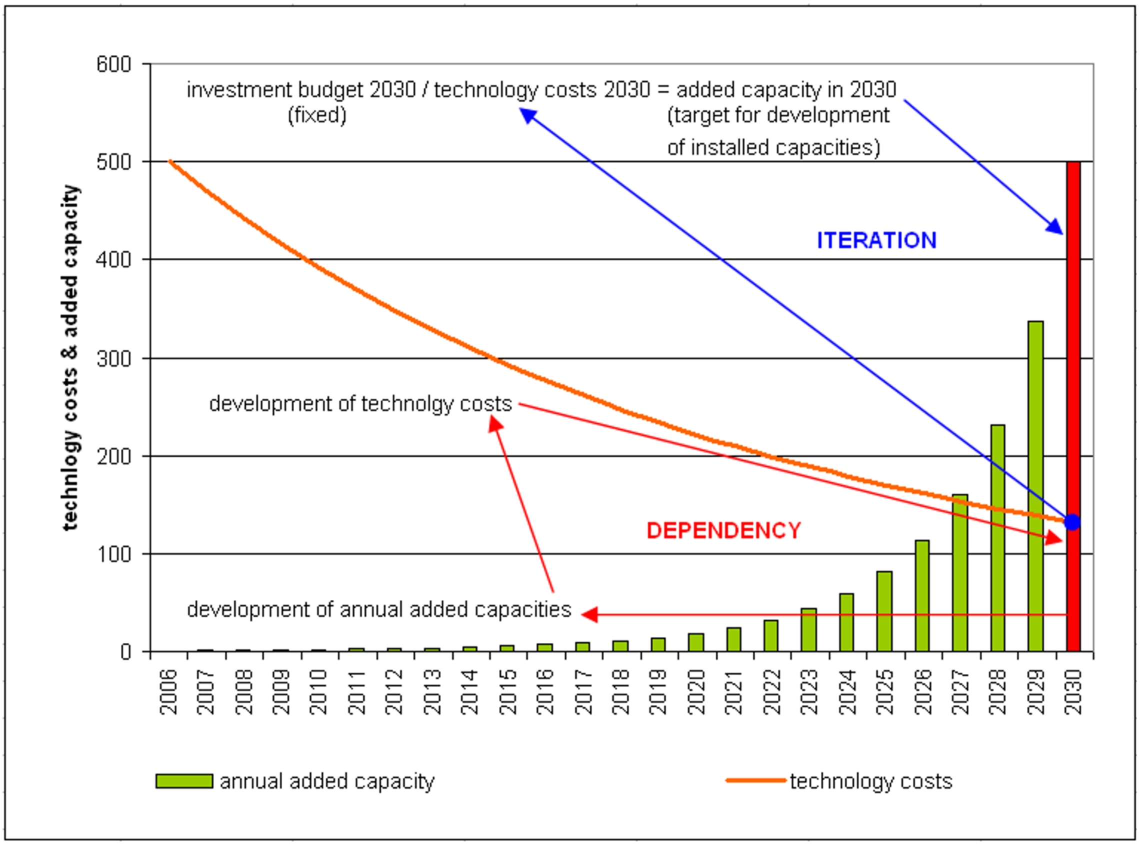


Figure 6: Example of translating the 2030 investment budget into new added capacities in 2030 with regard to degression of specific technology costs (see also Figure 5 on page 19 for more information on iterative technology cost calculation). [S. Peter, H. Lehmann; 2007]

General growth assumption

The general approach of mapping the development of single renewable technologies to the time line within the different regions uses so called "logistic growth functions", showing a typically s-curved shape 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 growth depends on is limited. In general the logistic growth starts with an exponential development that, in the course of time, gets more and more 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 it shows the development of stock (growth rates follow a bell-shaped curve).

Translated to e.g. growth of a technology logistic growth consists of a phase of market introduction, followed by a dynamic market growth which later declines due to market constraints, such as a high market penetration that makes it harder and harder 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 stock 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 case of renewable energies.

Another issue that can be well explained by means of a logistic growth function is the advantage of starting a development sooner. In the example below the strong red curve shows the development from the start, the lighter curves started 10 respectively 20 years earlier. After 20 years of development the curve called "logistic growth" shows a value of 10%, the curve starting 10 years earlier a value of almost 30% and the curve starting 20 years sooner a value of more than 50 %. This 20% per decade advantage in the example is still present one decade later for both 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 20 years earlier than for those that starts 10 years earlier (still almost 20% advantage for the "10 years sooner" curve but "only" 35% for the "20 years sooner" curve if compared to the "logistic growth" curve).

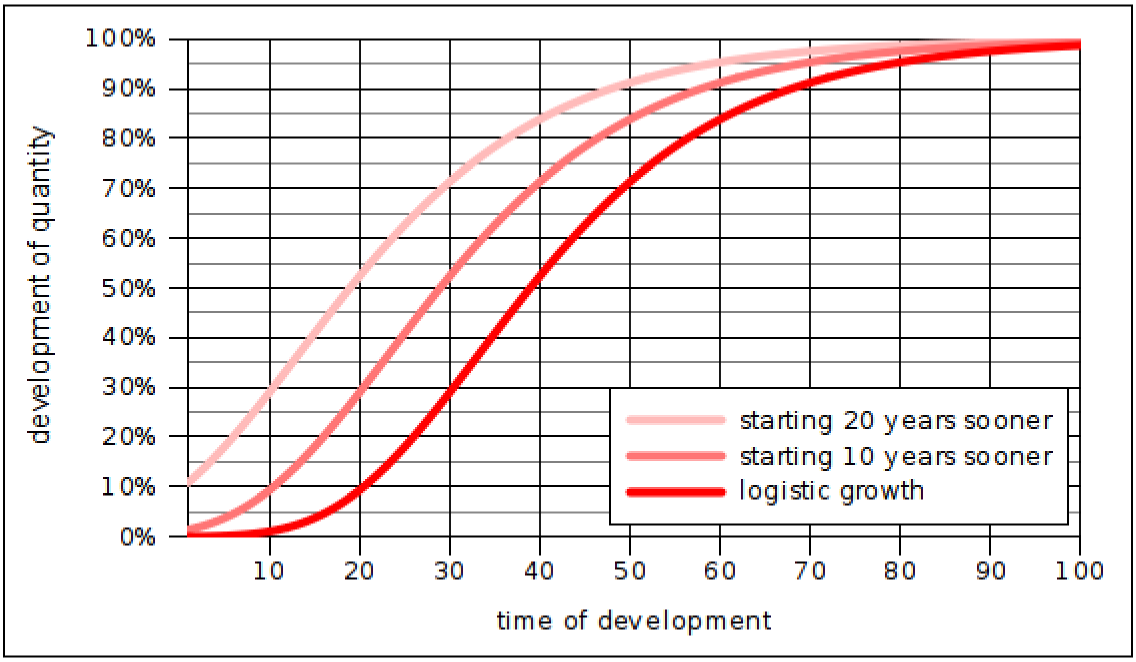


Figure 7: Example for logistic growth and the advantage of starting sooner [EWG; 2008].

One important question is, if a logistic growth function can reflect the growth characteristics of renewable energies in a way that can be seen as a valid approximation to 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 match each other sufficiently). Therefore the logistic growth function used in the "REO 2030" scenarios was 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 been a logistic growth so far.

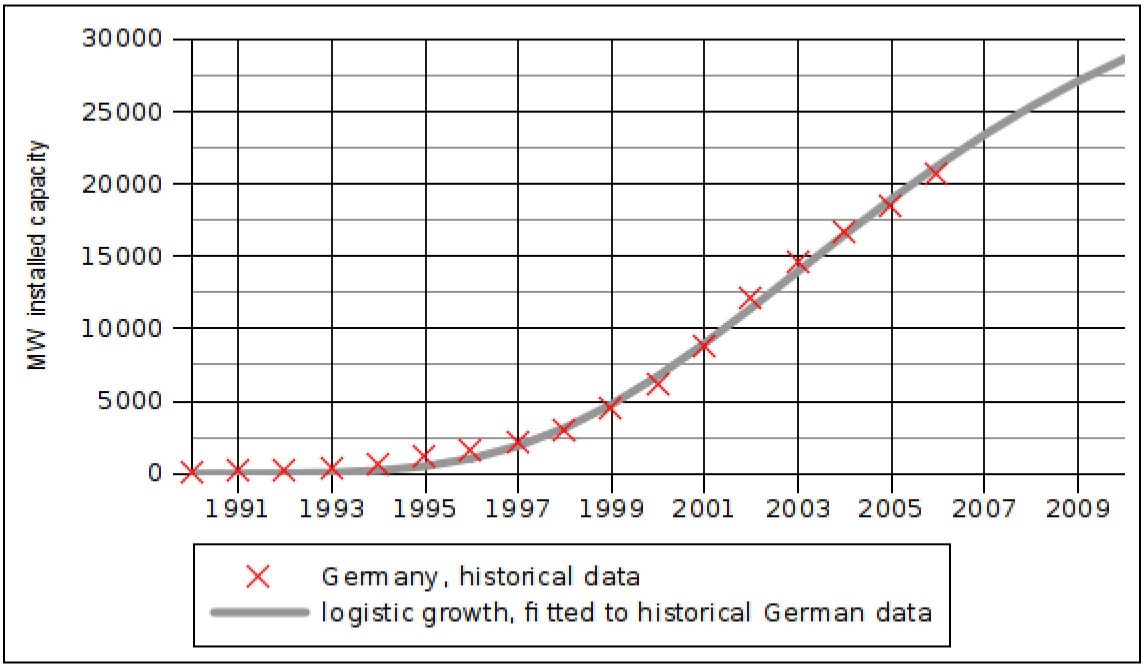


Figure 8: Example for fitting the logistic growth function used in the "REO 2030" scenarios to historical data of Wind Energy development in Germany.

Investment budgets for renewable Energy technologies

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 2030" scenarios we assume a growing *"willingness to pay"* for 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 (capita) that will be reached by the year 2030, after a period of continuous growing investments in to renewable energies. As incorporating estimations regarding inflation are considered as uncertain, all amounts are expressed on a 2006 price basis.

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[7] 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 into renewable generating capacities, respects expectations regarding the future economic development of the different regions. Therfore investment budgets are adapted to the economic situation of any of the regions. Thus stronger Economies have higher investment targets for 2030 than weaker economies, rapidly developing economies are assumed to spend more money, as they will have to improve energy supply anyway and so forth.

But this is not the only criterion for the set-up of the investment budgets. From beginning on there was some discussion about reasonable amounts per capita for the different regions. On the first try investment budgets have been decisively higher and with less differentiation between the regions. As this resulted in renewable electricity shares the working team judged as unreasonable high, investment targets were lowered region by region in order to get 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 nowadays less developed regions, will have to take stronger efforts in terms of the Gross Domestic Product's share they will have to spend to achieve the goals described in the scenarios. In the long term it must be considered that many of the non-OECD countries will foreseeable have a substantially higher economic growth than most OECD countries. Some of them will even be confronted with the task to develop a sufficient and reliable energy supply to keep up the pace of economic growth. This comprises that many of the less

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

developed non-OECD countries will have to take massive investments into infrastructure and energy supply as well, if they want to have the chance 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" per capita investments in 2030 grow to 220 € per capita and year (€/cap*a) 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). As the scenario is based on an iterative calculation, the achieved values does not exactly match these target values. The regions are very different in terms of population, 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.

The "Low Variant" of the "REO 2030" scenarios assumes half the investment budget of the "High Variant" but in both scenarios the relation of investments in the different regions is the same; with the highest per capita spendings in the OECD countries and lowest investment figures for Africa (see Table 3 on page 27 for details).

Looking at the figures for 2010, the OCED region starts with investments of about 60 € (OECD Pacific) to 70 € (OECD Europe) per inhabitant and year, while this figure is about 3½ € per capita in Africa. By 2020 the OECD countries already spend about 125 € to 131 € per capita for new renewable generating capacities. In China this is more than the half of this figure, while it is about the half in the Transition Economies and Middle East. The per capita investments in East Asia and Latin America are about the same (approx. 33 €). Smallest amounts are spent in South Asia (22 €/cap*a) and Africa, with 14 € per capita.

Due to the different number of inhabitants in the regions, China already is en 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 investments into renewable capacities (299 bill $€_{2006}$) is more the double the amount spent in South Asia (147 bill $€_{2006}$, second place). OECD Europe and OECD North America are on 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 that big difference between "High Variant" and "Low Variant" by 2010. In global average the 2010 budget in the "Low Variant" scenario is about 70% of the "High Variant's" budget. This difference grows during the further development, to 57 % of the "High Variant's" budget by 2020 and the half by 2030 (see Table 4 for details).

Distribution of investments to technologies

The distribution of investments is divided into a basic investment, which is equally distributed to all technologies considered (making up the half of the investment budget). The second fraction, named “advancement”, is generally oriented at the technologies' different potentials, 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 not “extra” investment into heat generation from Biomass & Waste or Geothermal Energy, which does not mean that these technologies aren't used for heat supply. The scenarios assume a certain fraction of Biomass & Waste and Geothermal plants to be cogeneration plant, 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 which 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 applied at every building possible (not only for heat, but also for cold). Photovoltaic holds the third place in investment ranking (15% on average), followed by biomass (11%) and geothermal energy (8%). Tidal & Wave and other maritime sources get least support, as those technologies are considered to evolve from prototype stage over field testing to mature technologies within the next years or the next decades for some of those technologies.

Compared to the “High Variant” scenario, there are differences in the distribution of investment budgets among the technologies in the “Low Variant”. 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 provide more support to the 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 that way, that the progress 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 for this relation (see also used progress ratios in Table 6 on page 32).

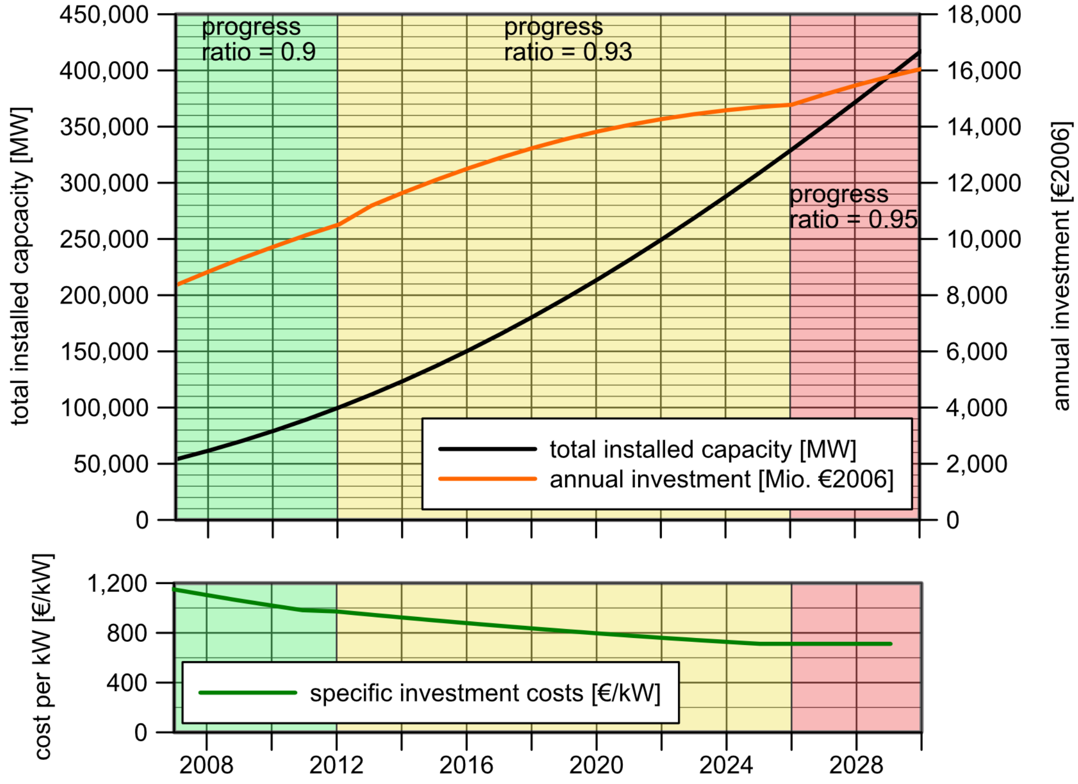


Figure 9: Example for calculating technology cost decrease by progress ratio. [EWG; 2008]

Starting point for technology costs is the same within both scenarios. Most expensive among the established technologies (which are all but Tidal, Wave & other Maritimes) in the beginning is Photovoltaic, followed by Geothermal, Biomass & Waste, Solar Concentrating Power and – with a substantial gap to those technologies – offshore and onshore Wind. Finally Solar Thermal Collectors are the cheapest technology (see Table 5 below for 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]

Also both scenarios use the same assumptions regarding cost progress ratios for the different technologies. To calculate the cost decrease for each of the technologies the following progress ratios are used[8]:

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

Due to the different 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, showing 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 during the year 2014. Finally PV is the fourth cheapest technology, with below 2,000 € per kW installed capacity.

8 The progress 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 by 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 2030 in the High and Low Variant Scenarios compared. [EWG; 2008]

There are substantial bigger decreases in costs in the "High Variant Scenario", but not to the same extend 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 stay above !,000 €/kW in the "Low Variant"). Photovoltaic costs (about 1,750 €/kW in the "Low Variant") reduce further to about 1,500 €/kW. Least 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.

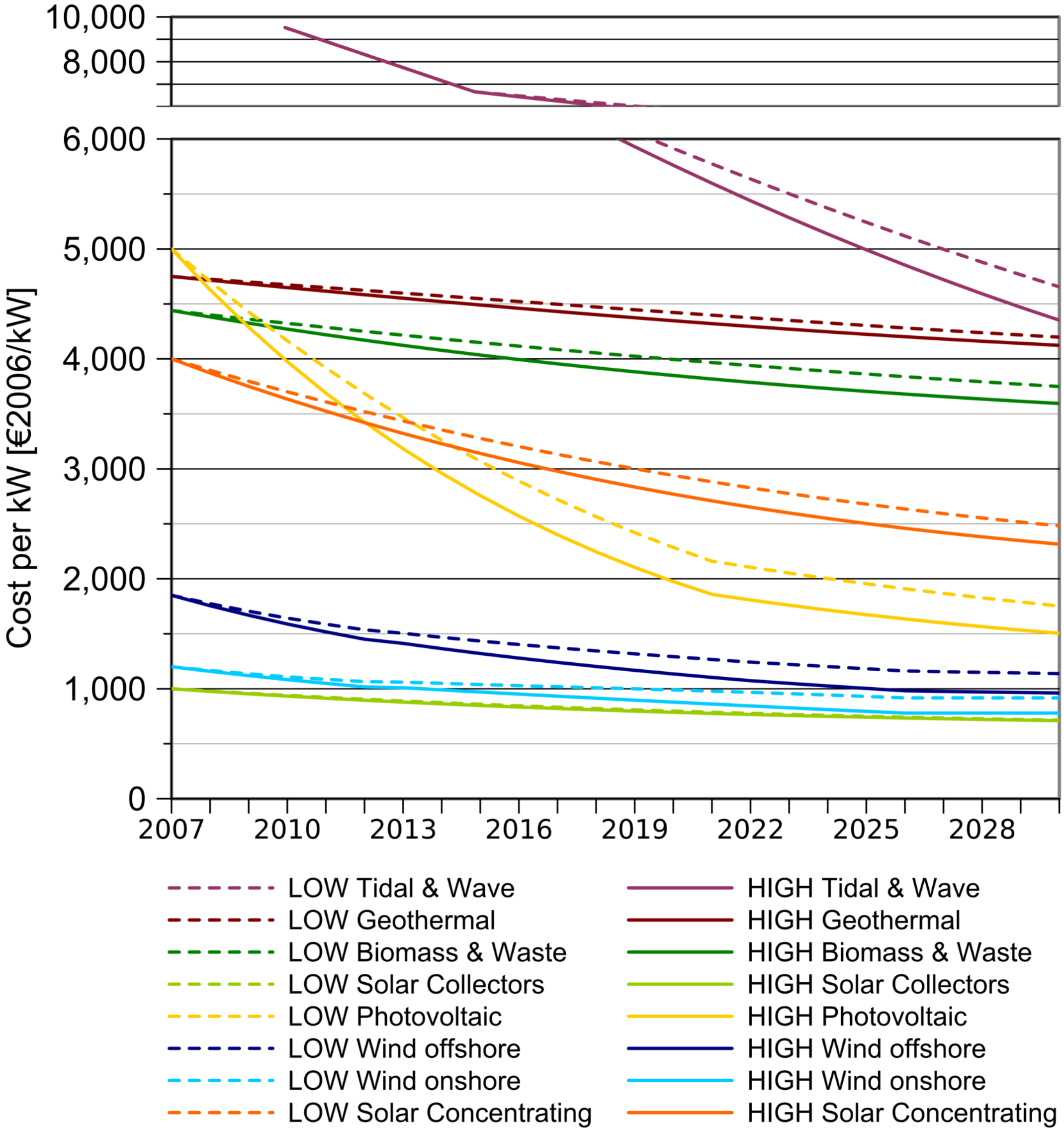


Figure 10: Development of technology costs in the scenarios. [EWG; 2008]

Development of investment budgets in the Scenarios

As the scenarios develop towards an investment target which 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).

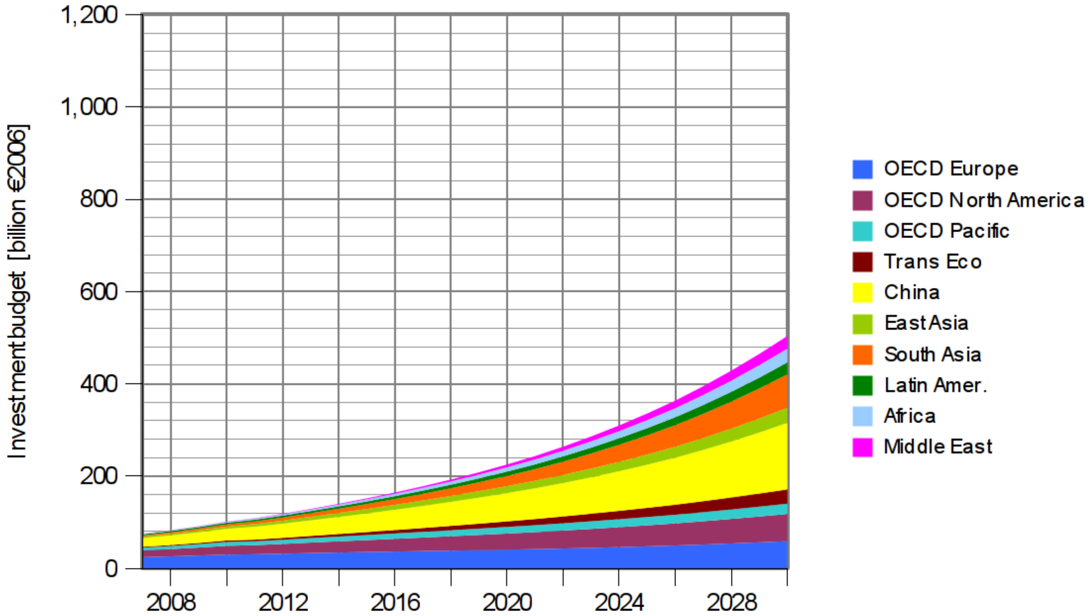


Figure 11: Development of investment budget in the ”Low Variant Scenario” [EWG; 2008]

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 ”Low Variant” and ”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 increase further to more than 170 billion €$_{2006}$ in 2020 (397 billion €$_{2006}$ total budget in the ”High Variant”).

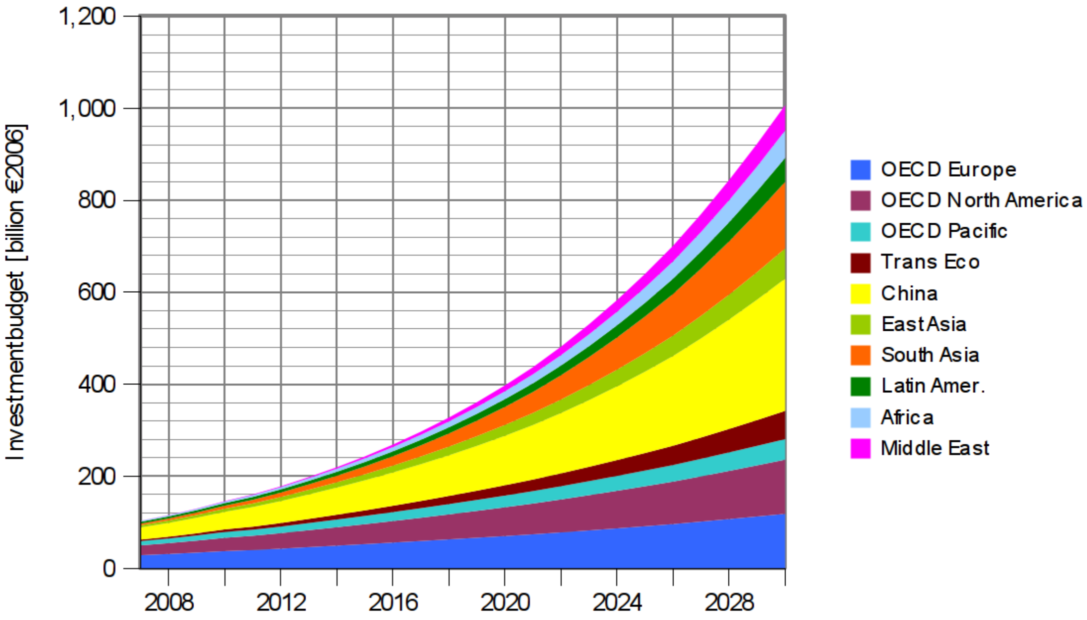


Figure 12: Development of investment budget in the "High Variant ScenarioV [EWG; 2008]

During the development there is a substantial change in the shares the different world regions contribute to the global renewable investment budget (Figure 12)[9]. While the majority of investments at the beginning stem from the OECD region (Europe, North America and Pacific), the distribution between OECD and non-OECD 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). Lowest contribution to the global renewable investments come 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.

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

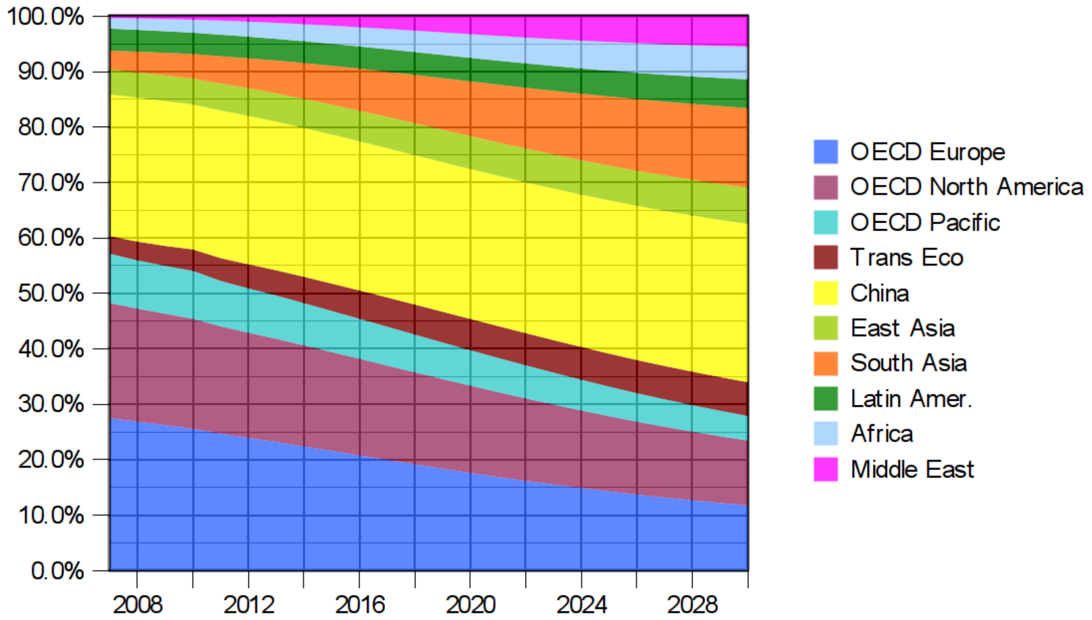


Figure 13: Development of shares at global investment budget in the "High Variant Scenario" [EWG; 2008]

To get a better feeling for what these investment figures mean in relation to our 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" the renewable investments per capita come close to what was globally spent for 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 cumulated amount – i.e. the costs of the whole renewable capacity extension under the assumption of stable military spendings – is much lower than the military expenditures that can be expected during that time.

Related to the actual 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 €)

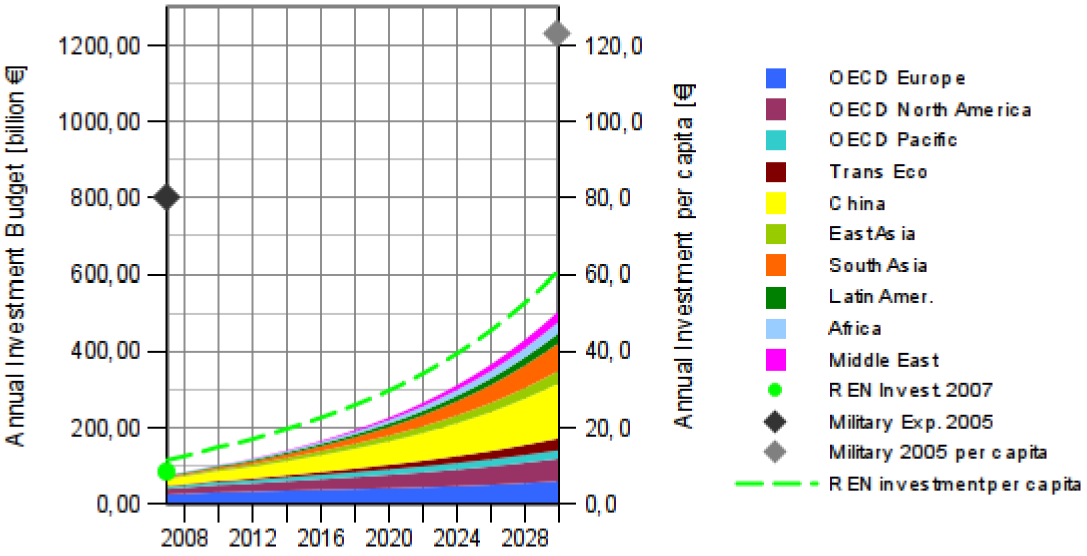


Figure 14: Development of investment budgets in the world regions in the "Low Variant Scenario" [EWG; 2008]. Data on military expenditures: [SIPRI; 2006]. Data on 2007 renewable energy investment: [UPI; 2008].

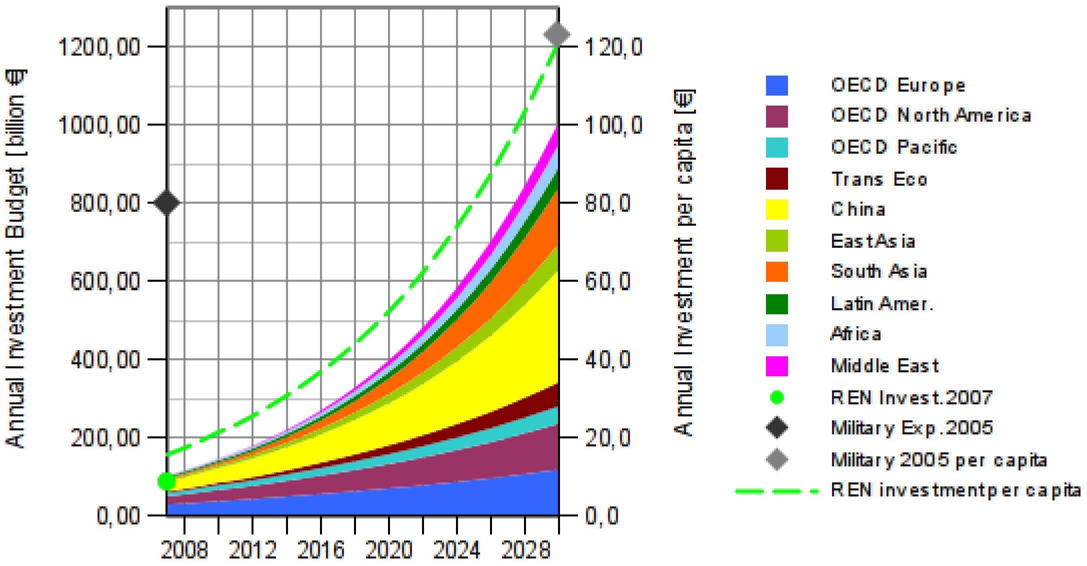


Figure 15: Development of investment budgets in the world regions in the "High Variant Scenario" [EWG; 2008]. Data on military expenditures: [SIPRI; 2006]. Data on 2007 renewable energy investment: [UPI; 2008].

Development of electricity generating capacities and electricity production

High Variant Scenario: General development in the global context

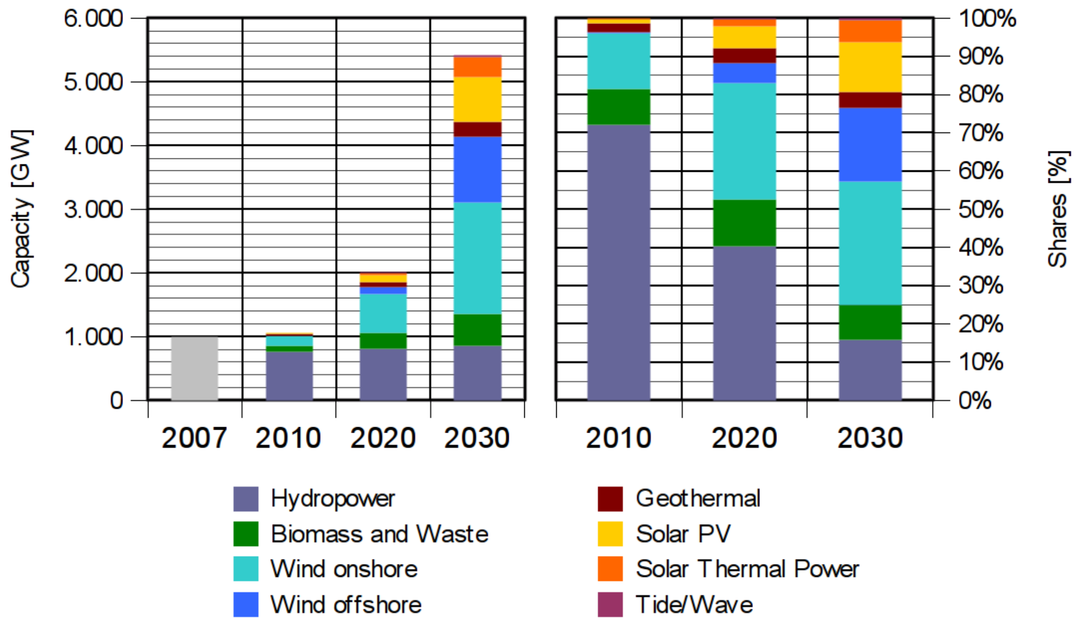


Figure 16: Development of renewable generating capacities in the "High Variant Scenario" on the global scale [EWG; 2007]. Data 2007: [REN 21; 2007]

Analysing the development of generating capacities in the "High Variant Scenario", hydropower will still be main contributor to renewable capacities by 2010[10]. Due to the massive extension of "new" renewable capacities (non-hydropower), this picture changes dramatically during the further development. Hydropower's share in generating capacities is more than 70 % on the global scale by 2010. Although hydropower capacities increases 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[11]. 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 extensions 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 2030.

10 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.

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

Offshore Wind Energy increases more dynamic than onshore Wind. Starting with an onshore/offshore ratio of about 97 % onshore and less than 3 % offshore, this picture changes substantially in the aftermath. 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 ten times from 2010 to 2020, the growth between 2020 and 2030 drops to a factor of somewhat more than six.

Biomass & Waste, contributing about 100 GW to the renewable capacities by 2010, looses it's third place to PV until 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' share in total renewable capacity is an exemption to other "new" renewables: While the share increase 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), virtually non visible by 2010 (2.4 GW or 0.2 % of renewable capacity), increases its capacity to about 40 GW by 2020, a factor of almost 29 against 2010, and to 313 GW by 2030, which is equivalent to a capacity increase by a factor of almost 8 between 2020 and 2030. In terms of the SCP share in total renewable generating capacity there is a growth from far less than one percent by 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 by 2010, the capacity increase to about 224 GW by 2030 results in about 90 GW capacity less than SCP. Nevertheless even the share of Geothermal Energy in total renewable capacities increases from slightly more than 2 % by 2010 to about 4 %. An exception to most other "new" renewables (except biomass) is, that 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 by and to about 33 GW until 2030, there is no time when this technology even gets close to contributing one percent to the total renewable generating capacities. This is not due to arbitrariness or the like, but reflects the working teams conviction, that those technologies will maintain in a prototype and/or testing phase for quiet 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 there is a Wind Energy contribution of 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.

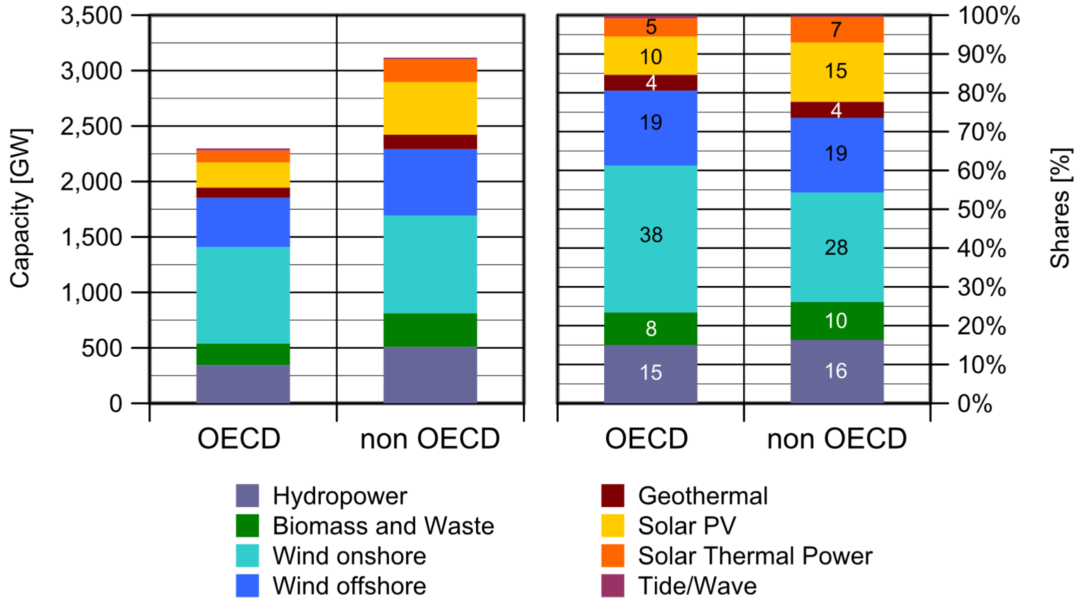


Figure 17: Structure of renewable capacities 2030 compared (OECD and non-OECD) [EWG; 2007].

Another considerable difference results from utilising solar energy, resulting from the fact, that many non-OECD countries are in geographical locations which favour the utilization of solar energy due to good solar irradiation. This comparably high share of countries with good solar irradiation in the non-OECD region results in Photovoltaic and Solar Concentrating Power having higher shares in total renewable generating capacity, if compared to the OCED regions. But differences of this magnitude had to be expected.

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, reaches from almost 50% (North America to more than 62% (Europe). In the non-OECD region this reaches from about one third (Latin America) to about two thirds (Middle East). The low Wind Energy share in Latin America does not result from low investments into Wind Energy, but from the extremely high share of hydropower, resulting from hydropower already being one of the top contributors to electricity supply and planned further additions. Actually Latin America is a special case in the scenario: Renewables contribution to the total generating capacity by far exceeds those in other regions, which also results from the massive hydropower capacities.

Photovoltaic and Solar Concentrating Power also show bigger 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 belong to the highest shares in the interregional comparison, it is South Asia having the lead with a massive 27 % of total renewable capacities consisting of PV. The reason for this extraordinary high share is the impressive population density by 2030 (more than 500 inhabitants per sqkm).

Low Variant Scenario: General development in the global context

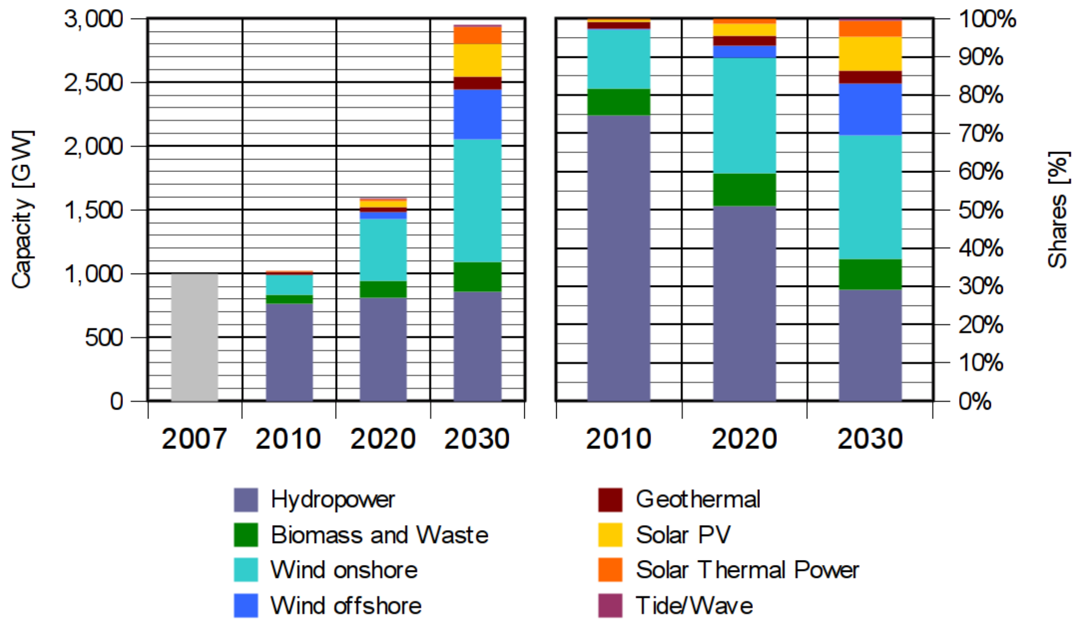


Figure 18: Development of renewable generating capacities in the "Low Variant Scenario" on the global scale [EWG; 2007]. Data 2007: [REN 21; 2007]

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 increasing hydropower capacities by more than 90 GW (from 762 GW by 2010 to 856 GW by 2030), the share drops to less than one third (29%) by 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, that the lower investments result in a 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 for about 30% of the total Wind Energy capacity finally (about 2% by 2010).

Photovoltaic (PV) shows the second biggest growth in generating capacities (plus 251 GW, from 7 GW in 2010 to 258 GW in 2030), and takes the second position in terms of generating capacity then, just in front of Biomass. Photovoltaic 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 (plus 166 GW), with shares of about 7 % in 2010, 8.6 % in 2020 and down to 8 % again in 2030.

Solar Concentrating Power (SCP), negligible in 2010 (2.4 GW or 0.2 % of renewable capacity), increases its capacity to about 20 GW by 2020 and to 128 GW by 2030. SCP share grows from far less than one percent by 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 by 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 % by 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 by 2010), always contribute far less than one percent to the renewable generating capacities. The biggest difference between the renewable capacities' structure in the OECD and non-OECD regions is the capacity contributed by Wind Energy, Hydropower and Photovoltaic. While in the OECD region there is 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 contribution to capacities in the non-OECD countries is about double the share as in the OECD countries (6 % OECD, 11% non-OECD).

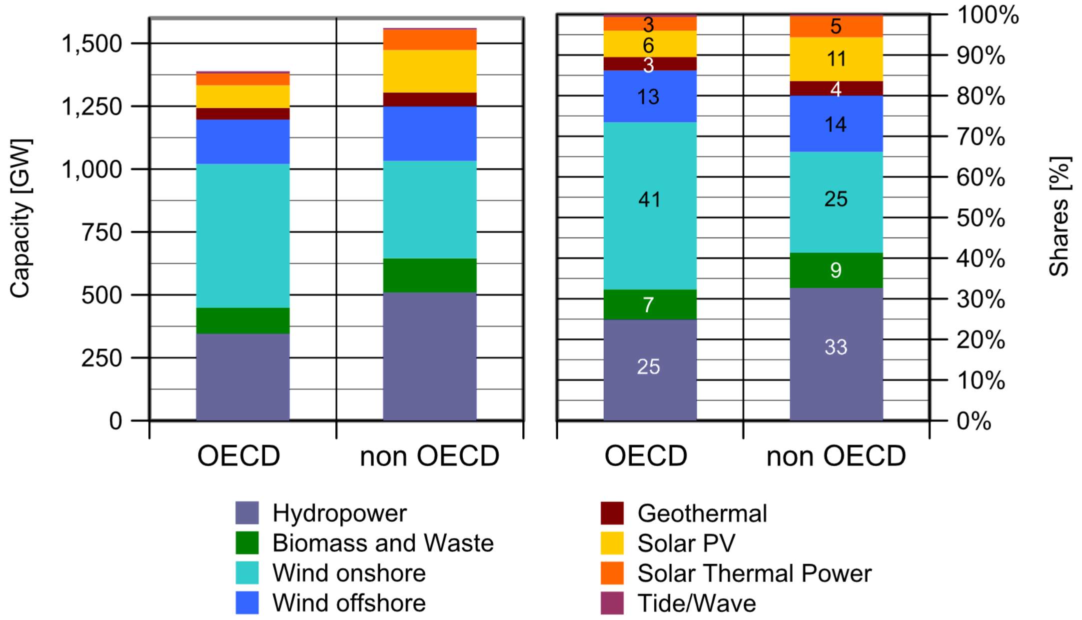


Figure 19: Structure of renewable capacities 2030 compared (OECD and non-OECD) [EWG; 2007].

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, on page 41 and the detailed description of the single regions in the annex).

Electricity production in the "High Variant" scenario

Naturally energy production from renewables increases with growing generating capacities. But 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 does not reflect the same way in the production figure.

Altogether renewables in the "High Variant Scenario" provide about 4,000 Terrawatthours (TWh) electricity by 2010. The production increase further to about 6,200 TWh by 2020 and to about 15,500 TWh by 2030

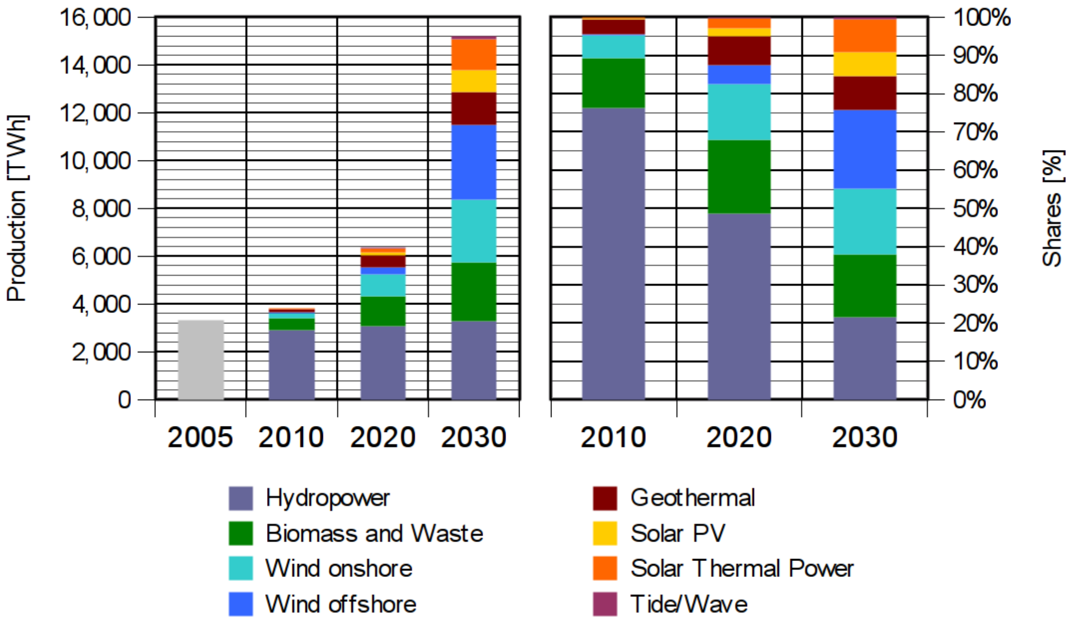


Figure 20: Development of electricity production from renewables in the "High Variant Scenario", 2010 to 2030 [EWG; 2007]. Data 2005: [IEA; 2007b]

Biggest producers by 2030 are Wind Energy, Hydropower and Biomass. Onshore Wind Energy production is slightly higher than electricity generation by Biomass (2,500 TWh from Biomass and more than 2,600 TWh from onshore Wind) but offshore Wind tops both of them by about 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 Terrawatthours (TWh) electricity by 2010. The production increase further to about 5,000 TWh by 2020 and to about 8,600 TWh by 2030 (Figure 21).

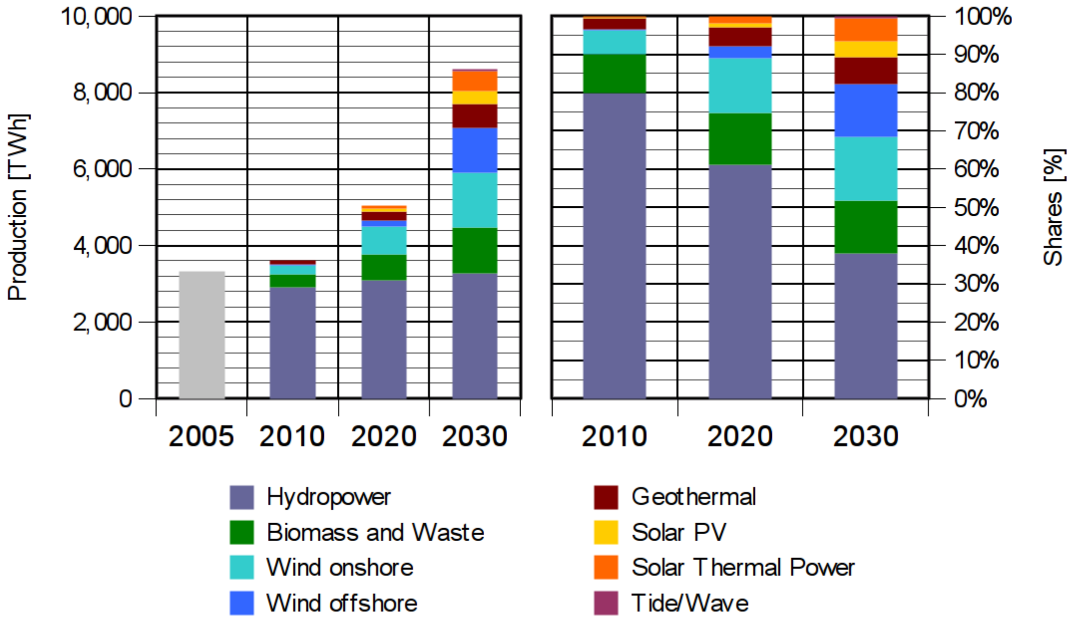


Figure 21: Development of electricity production from renewables in the "Low Variant Scenario", 2010 to 2030 [EWG; 2007]. Data 2005: [IEA; 2007b]

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

Development of Final Energy Supply

As we have been focused on electricity so far, this is the right place to write some words about heat, which is an essential part of the scenarios too. Heat production in the scenarios stems from Solar Thermal Collector systems on one side and from Biomass & Waste and Geothermal cogeneration plants on the other side. 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 for rating energy production by renewables is Final Energy. Please see also the text section on Primary Energy (page 53) to get a clue why those figures are not used within 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[12] (Terrawatthours) until 2030. OECD countries alone account for about 43% of that.

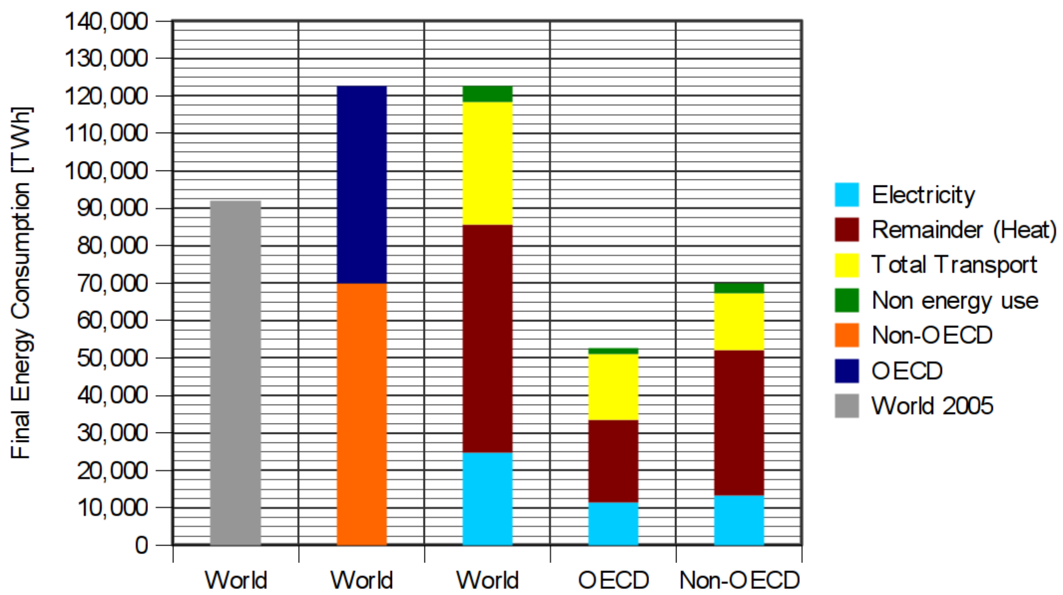


Figure 22: Global Final Energy consumption in OECD and in non-OECD countries. Data :[IEA; 2006]

Speaking of how final energy consumption is composed, heat demand is responsible for half of the final energy consumption, but this also contains traditional biomass use, especially in the non-OECD countries. Likely this is one good reason for the different shares of heat in the OECD

12 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 be well explained by the structural differences. While transport consumes one third of the final energy in the OECD this a bit more than one fifth in non-OECD. Electricity shares are about the same, with more or less one fifth (22 % OECD, 19 % non-OECD).

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

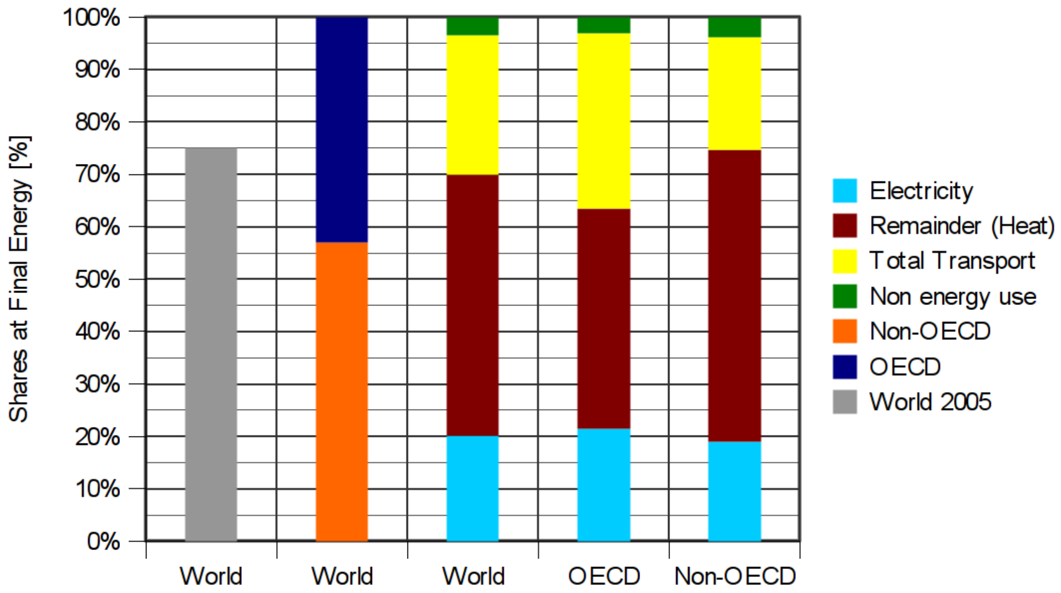


Figure 23: Distribution of final energy consumption between the OECD and non-OECD region and shares of electricity, heat, transport and non-energy use. Data converted from [IEA; 2006], [IEA; 2007a].

Although the development of energy demand provided by the IEA's World Energy Outlook is questionable from the perspective of the working team, it was taken as a reference to keep the "REO 2030" scenarios comparable to the ones published by the IEA.

Shares at Final Energy Supply in the "High Variant" scenario

The figures for electricity and heat result to a total of approx. 25,000 TWh 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 OECD (9,130 TWh) than in non-OECD (15,830 TWh). (Figure 24 and Figure 25)

According to the scenario results 54 % of electricity and 13 % of heat stem from renewable sources in the OECD countries in 2030. This is significantly different in the non-OECD countries: 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 almost 62 % of electricity but less than one fifth (16 %) of heat originate from renewable sources on the global scale in 2030.

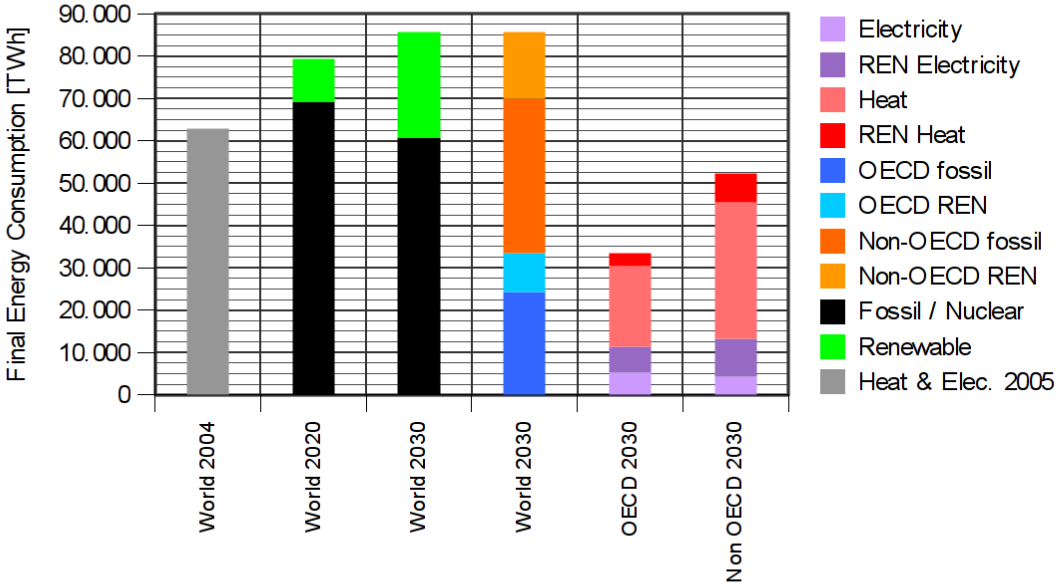


Figure 24: Renewable energy production in the ”High Variant Scenario” in 2030 [EWG; 2008]. Data on energy demand converted from [IEA; 2006], [IEA; 2007a].

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

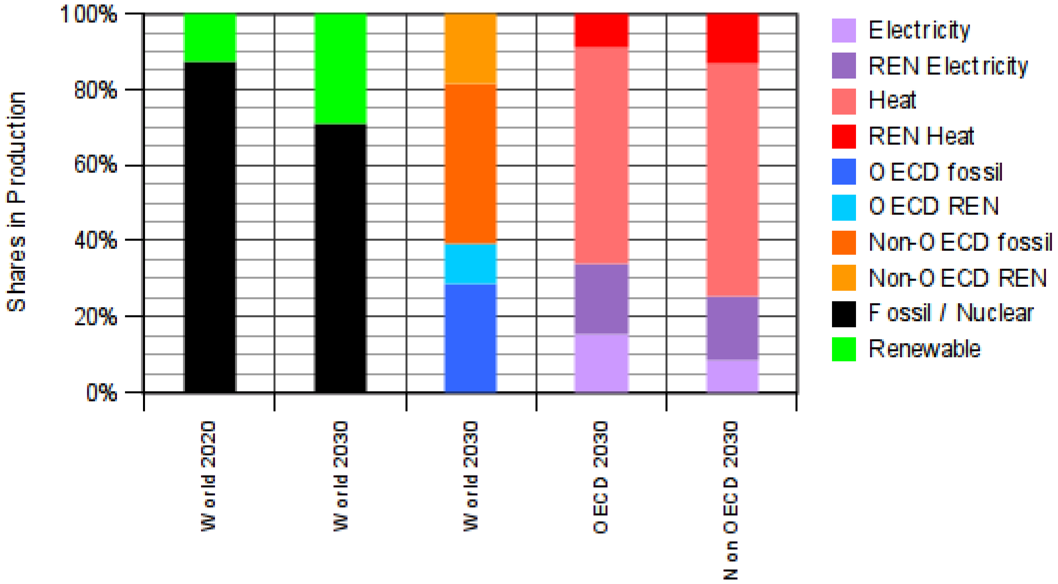


Figure 25: Renewable shares at final energy in the "High Variant Scenario" in 2030 [EWG; 2008]. Data on energy demand converted from [IEA; 2006], [IEA; 2007a].

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

The relation between the regions is quiet 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 more if compared to the "High Variant Scenario". Hence renewable shares in the heat sector does not reduce that much as with electricity.

The total 2030 energy production by renewables amounts to about 14,900 TWh in the "Low Variant Scenario" thereof about 8,600 TWh electricity and 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[13].

As already seen in the "High Variant", absolute energy production from renewables in the "Low Variant Scenario" also is different in the OECD and non-OECD regions, but the gap closed a little bit (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 both regions together can supply 17% of the global final energy demand from renewables.(Figure 26 and Figure 27)

13 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.

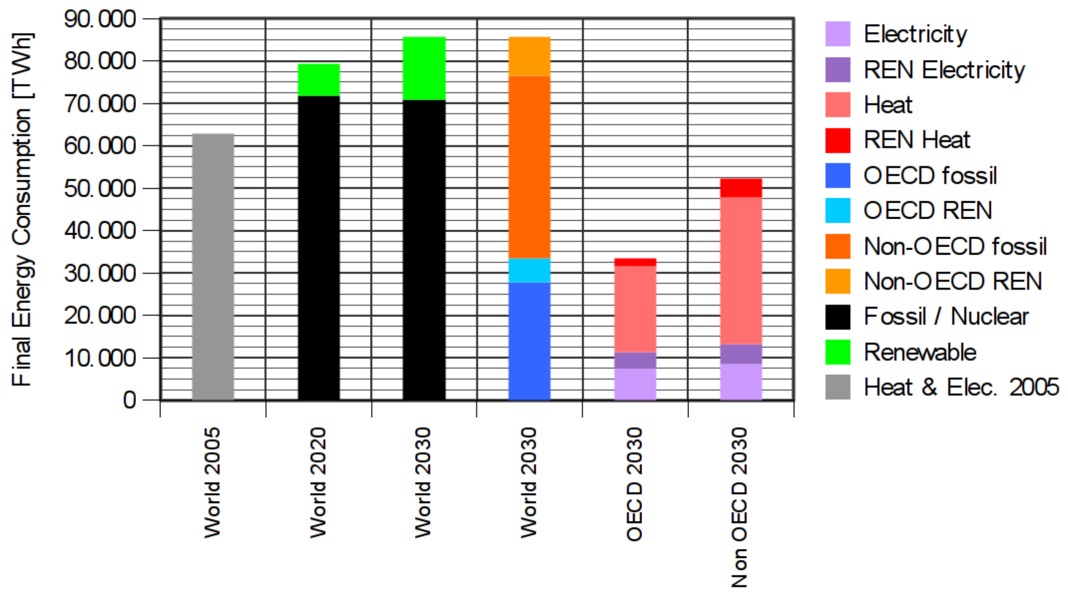


Figure 26: Renewable energy production in the "Low Variant Scenario" in 2030 [EWG; 2008]. Data on energy demand converted from [IEA; 2006], [IEA; 2007a].

There is a lower share of electricity and heat supplied by renewables in the OECD region than it is is the non-OECD. In the OECD one third of the final electricity and about 8 % of the final heat demand 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.

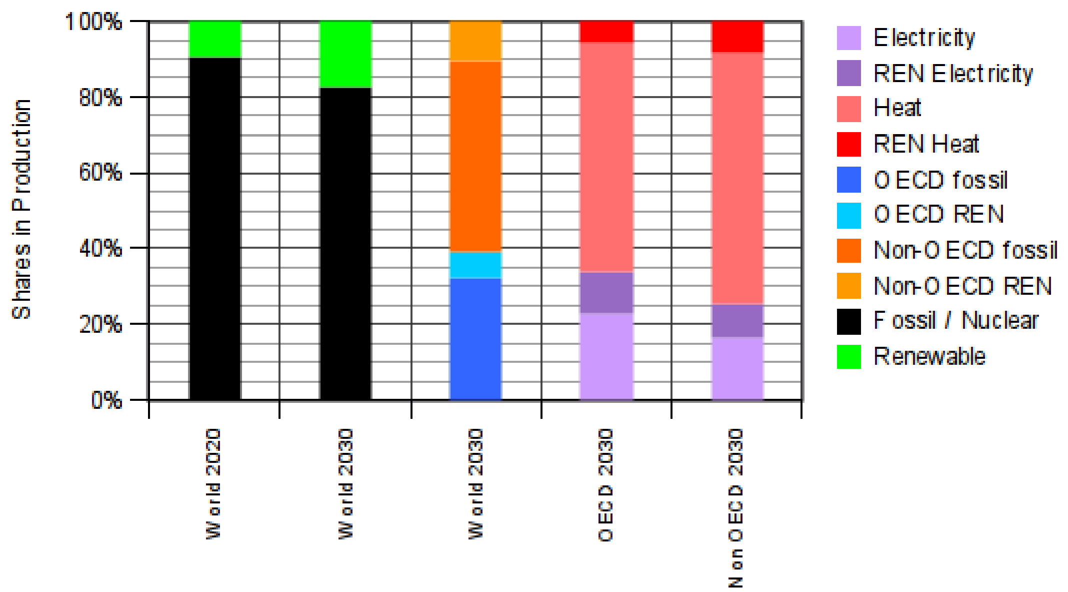


Figure 27: Renewable shares at final energy in the "Low Variant Scenario" in 2030 [EWG; 2008]. Data on energy demand converted from [IEA; 2006], [IEA; 2007a].

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 figures 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. Mostly primary energy balances use 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 inconsequent, but also unfair in judging the renewable contribution to energy supply. If renewables contribute to primary energy supply in official statistics, why only with their final energy production? Wouldn't it be better to express the renewables contribution as primary energy savings, as other, indeed primary energy consuming technologies, get substituted by renewables? The former 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. But this approach also has the downside that an average fossil plant efficiency has to be assumed to convert renewably produced electricity into its primary energy equivalent. How to handle this in scenarios with mid to long term projections? Isn't it much of guessing if we try to predict an average global plant efficiency for 2030? And if we can predict plant efficiency relatively precise, will it not be that renewables replace less effective plants first?

However, energy from renewable technologies will render a fraction of former used plants or maybe projected plants, might that be fossil or nuclear powered plants, needles and, thus, 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) could be judged 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 assuming the primary energy requirements for producing same amount of electricity using different technologies.

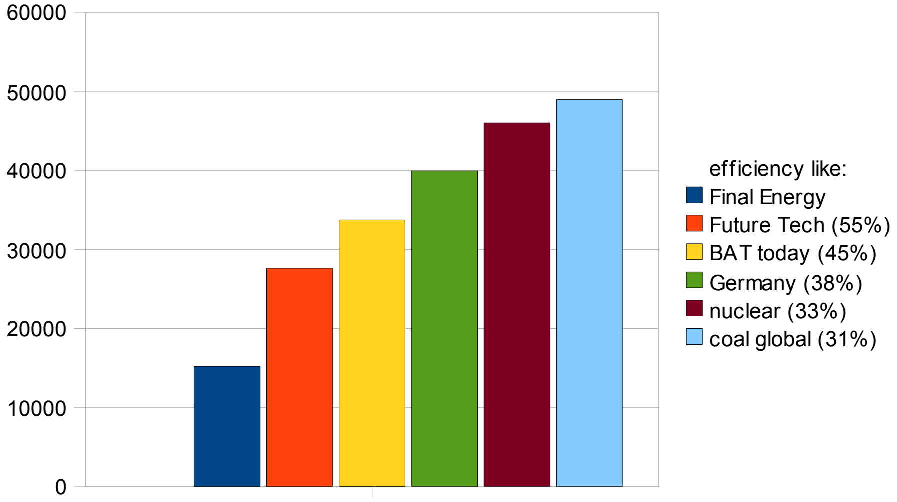


Figure 28: Converting electricity from renewable technologies into primary energy, different assumptions off plant efficiencies. [EWG; 2008]

Reality check

One might ask the question: Could all these investments into renewables be done at all? 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 other task than clean energy supply. Analysing military expenses in 2005 shows that about 799 billion € have been spent for military on the global scale. Assuming that this figure will remain stable from 2007 until 2030, the resulting cumulated expenditures can be well compared to the expenditures in the scenarios. If we take these military expenditures as 100%, 72 % of this would be sufficient to realise the development as described in the ”High Variant Scenario”. In relation to the ”Low Variant”, about the half of the military spendings would be sufficient. Regarding the fact that ongoing climate change,which is closely related to the way we satisfy our energy needs now, and it's severe consequences for earth's life support system is the greatest threat to mankind we are facing today, everybody can give his own answer if getting around this problems is not as worthy as military issues.

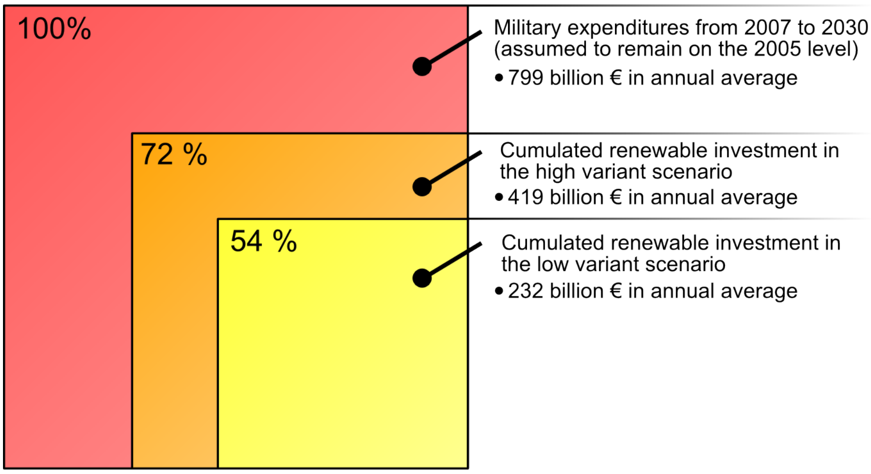


Figure 29: Comparison of Military expenses and the cumulated investments in the scenarios [EWG; 2008]. Data on military expenditures [SIPRI; 2007]

Another question that might arise is the question about production capacities. Is it possible to extend production capacities in order to allow an increase in generating capacities as described in the scenarios? Here again comparing the scenario figures to our today's world can deliver a base for everybody's own judgement.

The PV capacity added in the ”High Variant Scenario” in OECD Europe in 2030 is about 11,300 MW, which results to about 77,926,667 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 of the new installed PV area in 2030. Even considering the whole OECD Europe, the German insulating glass production in 2005 is about 30% of the PV area installed in OECD Europe in 2030.

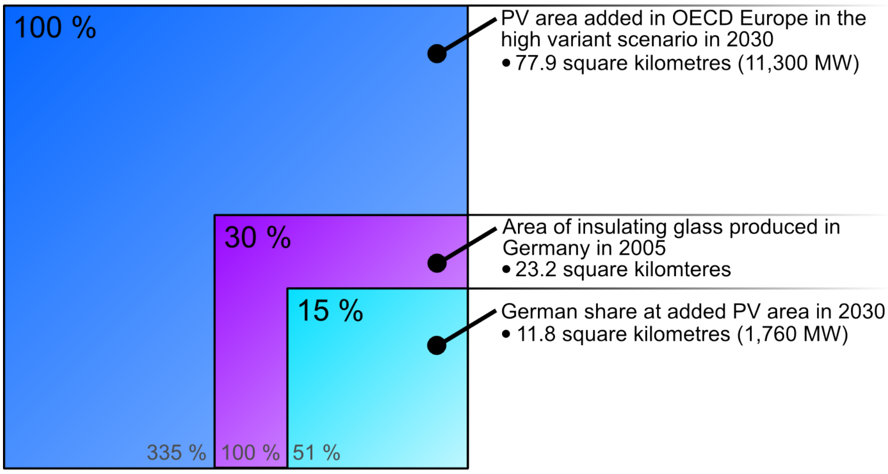


Figure 30: Added PV capacity in 2030 (High Variant) compared to insulation glass production in 2005 [EWG; 2008] Data on insulation glass production: [Destatis; 2005;]

Taking the German 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" is about 51 % of that. The PV area added in the whole OECD Europe region in 2030 ("High Variant Scenario") is 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% off 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 was about 3,247 MW or 2,328 plants [BWE; 2008], which is about the same amount of plants and about 2.2 times the capacity already installed in Germany within one year.

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

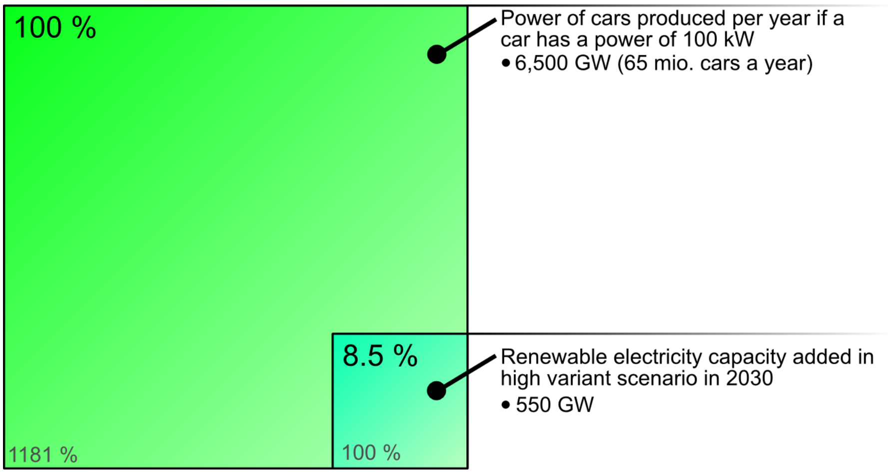


Figure 31: Power of cars produced pear year (today) compared to added renewable electricity generating capacity in the High Variant scenario in 2030 [EWG; 2008]. Car production: [PAWO; 2007].

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 which are produced in one year, or about the same power as all cars produced in Germany in one year.