INTERNATIONAL ENERGY AGENCY

In support of the G8 Plan of Action

DEPLOYING RENEWABLES

Principles for Effective Policies

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OECD

DEPLOYING RENEWABLES

Principles for Effective Policies

Renewable energy can play a fundamental role in tackling climate change, environmental degradation and energy security. As these challenges have become ever more pressing, governments and markets are seeking innovative solutions. Yet, what are the key factors that will determine the success of renewable energy policies? How can current policies be improved to encourage greater deployment of renewables? What impact can more effective policies have on renewables' share in the future global energy mix and how soon?

Deploying Renewables: Principles for Effective Policies addresses these questions. Responding to the Gleneagles G8 call for a clean and secure energy future, it highlights key policy tools to fast-track renewables into the mainstream. This analysis illustrates good practices by applying the combined metrics of effectiveness and efficiency to renewable energy policies in the electricity, heating and transport sectors. It highlights significant barriers to accelerating renewables penetration, and argues that the great potential of renewables can be exploited much more rapidly and to a much larger extent if good practices are adopted.

Carefully designed policy frameworks, customised to support technologies at differing stages of maturity, will deliver a strong portfolio of renewable energy technologies. *Deploying Renewables: Principles for Effective Policies* provides recommendations on key principles for policy design as a template for decision makers.

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INTERNATIONAL ENERGY AGENCY

The International Energy Agency (IEA) is an autonomous body which was established in November 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an international energy programme.

It carries out a comprehensive programme of energy co-operation among twenty-seven of the OECD thirty member countries. The basic aims of the IEA are:

- To maintain and improve systems for coping with oil supply disruptions.
- To promote rational energy policies in a global context through co-operative relations with non-member countries, industry and international organisations.
- To operate a permanent information system on the international oil market.
- To improve the world's energy supply and demand structure by developing alternative energy sources and increasing the efficiency of energy use.
- To promote international collaboration on energy technology.
- To assist in the integration of environmental and energy policies.

The IEA member countries are: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Republic of Korea, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom and United States. Poland is expected to become a member in 2008. The European Commission also participates in the work of the IEA.

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

The OECD is a unique forum where the governments of thirty democracies work together to address the economic, social and environmental challenges of globalisation. The OECD is also at the forefront of efforts to understand and to help governments respond to new developments and concerns, such as corporate governance, the information economy and the challenges of an ageing population. The Organisation provides a setting where governments can compare policy experiences, seek answers to common problems, identify good practice and work to co-ordinate domestic and international policies.

The OECD member countries are: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Republic of Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom and United States.
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International Energy Agency (IEA),
Head of Communication and Information Office,
9 rue de la Fédération, 75739 Paris Cedex 15, France.

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Foreword

The IEA emphasises that nothing less than an energy technology revolution is needed if we are to achieve a 50% reduction of global CO_2 emissions by 2050 – a target discussed by G8 leaders in Heiligendamm and endorsed at the recent Hokkaido Summit. Renewables will play a crucial role in this revolution. The IEA estimates that nearly 50% of global electricity supplies will have to come from renewable energy sources.

It is a huge challenge. Meeting these very ambitious objectives will require unprecedented political commitment and effective policy design and implementation. Governments are therefore now facing the question of how to stimulate the deployment of renewables in the most effective and cost-efficient way. But how do policies in place today measure up to these demands? Are they on the right track to underpin the necessary rates of technological change and market growth?

For the first time, the IEA has now carried out a comparative analysis of the performance of the various renewables promotion policies around the world. The study encompasses all OECD countries and the BRICS (Brazil, Russia, India, China and South Africa) and addresses all three sectors – electricity production, heating and transport fuels.

The analysis concludes that, to date, only a limited set of countries have implemented effective support policies for renewables and there is a large potential for improvement. Several countries have made important progress in recent years in fostering renewables with renewable energy markets expanding considerably as a result. However, much more can and should be done at the global level – in OECD countries, large emerging economies and other countries – to address the urgent need of transforming our unsustainable energy *present* into a clean and secure energy *future*.

Deploying Renewables: Principles for Effective Policies highlights success factors and key policy tools to fast-track renewables into the mainstream at the global level. It underscores significant barriers to accelerating renewables penetration, and argues that the great potential of renewables can be exploited much more rapidly and to a much larger extent if good practices are adopted.

In order to achieve a smooth transition towards the mass market integration of renewables, renewable energy policy design should reflect a set of fundamental principles in an integrated approach. *Deploying Renewables: Principles for Effective Policies* provides recommendations for policy design as a template for decision makers.

The results shown in this book are not always comfortable. But they are based on objective analysis and identify opportunities for improvement and change. We believe that policy makers who are charting the course of future national renewable strategies should give them serious consideration.

We look forward to working with governments and other relevant stakeholders in translating these principles into policy practice.

Nobuo Tanaka
Executive Director

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Questions and comments should be addressed to:

Samantha Ölz
International Energy Agency
9, rue de la Fédération
75739 Paris Cedex 15
FRANCE

Email: samantha.olz@iea.org

1. The workshop proceedings are publicly available on the IEA website at: http://www.iea.org/Textbase/work/workshopdetail.asp?WS_ID=318.

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Executive Summary

Introduction

Recent IEA and other scenarios have demonstrated that a large basket of sustainable energy technologies will be needed to address the challenges of moving towards clean, reliable, secure and competitive energy supply. Renewable energy sources (RES) and technologies (RETs) can play an important role in achieving this goal. Many countries have made progress in promoting renewables in their energy mix, but obstacles remain and greater efforts are needed. This report provides an assessment of the effectiveness and efficiency of renewable energy policies in OECD countries and Brazil, Russia, India, China and South Africa (BRICS). In 2005, these 35 countries accounted for 80% of total global commercial renewable electricity generation, 77% of commercial renewable heating/cooling (excluding the use of traditional biomass) and 98% of renewable transport fuel production.

In 2005, renewables (including hydropower) contributed 18% of global electricity generation, less than 3% of global heat consumption (excluding the use of traditional biomass[2]) and 1% of global transport fuel consumption. By 2030, renewables are projected to contribute 29% to power generation and 7% of transport fuels according to the IEA *World Energy Outlook* (*WEO*) Alternative Policy Scenario 2007 – in which policies currently under consideration are implemented. By 2050, the contribution of renewables could rise even further to almost 50% of electricity if the ambitious goal of a 50% global reduction in 2005 CO_2 emissions over that time horizon is met, represented by the BLUE scenarios in the IEA *Energy Technology Perspectives* (*ETP*) *2008*. While attainable, this objective will require very strong political and financial commitment as well as immediate action by all governments.

Some renewable energy technologies (RETs) are close to becoming commercial and should be the first to be deployed on a massive scale. Other RETs, which have a large potential, are less mature and require long-term visions. Reducing their costs will require a combined effort in research, development and demonstration (RD&D), and technology learning resulting from marketplace deployment. *ETP 2008* emphasises that a combination of both more and less mature RETs will play a major role in achieving deep CO_2 emission cuts in a competitive fashion. This finding highlights the urgency with which a framework of consistent, effective and long-term policies need to be implemented if a wide range of RETs is to be encouraged to move towards full market integration.

This report comprehensively examines data and information relating to renewable energy markets and policies over the period 2000-2005. It discusses wind, biomass, biogas, geothermal, solar PV, and hydro power in the electricity sector; biomass heat, geothermal and solar thermal in the heating sector; and ethanol and biodiesel in the transport sector.[3]

2. The use of traditional biomass is around 40 EJ or 9-10% of world primary energy supply.

3. In effect, this means that the study places emphasis on more mature RETs which have already progressed beyond the demonstration phase. Therefore, currently less mature technologies, such as offshore wind, enhanced geothermal systems (EGS), wave and tidal and marine currents, are not taken into account in this assessment.

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Methodology

- This assessment aims to measure the effectiveness of policies forpromoting renewables, over the period 2000 to 2005, by applying a quantitative *policy effectiveness indicator*. This indicator is calculated by dividing the additional renewable energy deployment achieved in a given year by the remaining mid-term assessed "realisable potential" to 2020 in the country concerned. The rationale for such an effectiveness indicator is that it minimises the risk of bias when comparing countries of different sizes, starting points in terms of renewable energy deployment and levels of ambition of renewable energy policies and targets, while taking into account the available renewable energy resource.
- The "realisable potential" is based on a long-term view of the technical potential adjusted to take account of unavoidable medium-term constraints on the rate of change, such as maximum market growth rates and planning constraints,. The mid-term realisable potentials for each RET are derived for the resources of each country, taking into account technology development.
- For most countries, the additional realisable potential to 2020 far outstrips the achieved deployment of renewables to date. The aggregate additional potential to 2020 for renewable electricity (RES-E) in OECD countries and BRICS amounts to 6 271 TWh. This is equivalent to 41% of 2005 total electricity generation and represents almost 2.5 times the current RES-E generation. In absolute terms, China has the largest additional potential, followed by the EU-27, the United States, India, Russia, Canada and Brazil. Overall, BRICS account for 47% of the additional realisable potential among those countries analysed.
- The ratio of additional potential to achieved generation in 2005 is even larger for renewable heat (RES-H). For solar thermal and geothermal heat the additional potential is almost thirty times the achieved heat production from these sources.
- In the case of renewable liquid transport fuels (RES-T), the estimated additional realisable potential of first-generation biofuels is more than five times the current production. This estimate is based on the conservative assumption that a maximum of 10% of current arable land would be used for energy crop cultivation in 2020, with a lower share (3.5-8.5%) assumed for the emerging economies (BRICS) due to potentially stronger competition with food production and environmental pressures.
- The assessment also addresses the cost of the incentives for each renewable energy technology in all OECD countries and BRICS. Different kinds of renewables incentives have different time patterns – depending, for instance, on whether they influence upfront investment costs or operating returns. The remuneration for each technology in every country was calculated by annualising the levels over a common period of 20 years. This report does not address the cost efficiency of renewable energy systems compared to other carbon abatement technology options.

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Main analytical findings

Renewable electricity (RES-E)

Onshore wind energy

Generally, the presence of non-economic barriers has a significant negative impact on the effectiveness of policies to develop wind power, irrespective of the type of incentive scheme. Such barriers include administrative hurdles (*e.g.* planning delays and restrictions, lack of co-ordination between different authorities, long lead times in obtaining authorisations), grid access, electricity market design, lack of information and training, and social acceptance.

A minimum level of remuneration[4] appears necessary to encourage wind power deployment. Until 2005, none of the countries that provide overall levels of remuneration below USD 0.07/kWh[5] witnessed significant deployment effectiveness.

The group of countries with the highest effectiveness (Germany, Spain,[6] Denmark and, more recently, Portugal) used feed-in tariffs (FITs) to encourage wind power deployment. Their success in deploying onshore wind stems from high investment stability guaranteed by the long term FITs, an appropriate framework with low administrative and regulatory barriers, and relatively favourable grid access conditions. In 2005, the average remuneration levels in these countries (USD 0.09-0.11/kWh) were lower than those in countries applying quota obligation systems with tradable green certificates (TGCs) (USD 0.13-0.17/kWh).

Beyond some minimum threshold level, higher remuneration levels do not necessarily lead to greater levels of policy effectiveness. The highest levels of remuneration on a per-unit-generated basis for wind among the countries studied are seen in Italy, Belgium, and the United Kingdom, which have all implemented quota obligation systems with TGCs. Yet none of these countries scored high levels of deployment effectiveness. This is likely related to the existence of high non-economic barriers as well as to intrinsic problems with the design of tradable green certificate systems in these countries, which cause higher investor risk premiums.

Wind development in the United States is supported by a mix of state and federal policies. At the federal level, wind power receives generous tax incentives in the form of a 10-year production tax credit – which, in effect, acts like a feed-in premium – and 5-year accelerated depreciation. The combination of federal tax incentives with state-level financial incentives and renewable energy quota obligation systems was a major driver in wind power capacity additions in the United States. To date, neither federal nor state support has been sufficient in isolation to foster growth in wind power. In addition, the lack of stability in the provision of the production tax credit on an ongoing basis has led to substantial boom-and-bust cycles in United States wind power installations in the 2000s.

4. Remuneration levels encompass the sum of the electricity price plus any premiums and/or incentives received for every unit of renewable electricity.
5. All figures are in USD 2005, evaluated at market exchange rates.
6. Since 2004, Spain offers renewable energy generators a choice between FITs and feed-in premiums (FIPs).

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Solid biomass electricity

The most successful countries in deploying biomass electricity over the 2000-2005 timeframe, relative to their respective realisable potential, are EU-OECD countries. The Netherlands, Sweden, Belgium, and Denmark have the highest levels of effectiveness.

As in the case of wind energy, a certain minimum level of remuneration, in this case about USD 0.08/kWh, is necessary to initiate deployment, and non-economic barriers impact negatively on policy effectiveness. Solid biomass generally shows that different types of incentive schemes can be effective. For example in Sweden quota obligation systems have been effective at moderate cost (USD 0.08/kWh), while in Belgium the quota obligation system has encouraged biomass deployment at high cost (USD 0.14/kWh). In the Netherlands (USD 0.12/kWh), Denmark (USD 0.09/kWh) and Hungary (USD 0.10/kWh), feed-in tariff and premium systems are in place.

The countries with high growth in deployment (Netherlands, Sweden, Belgium, and Denmark) succeeded due to the availability of abundant biomass combined with the opportunity for co-firing in coal-fired boilers. However, life-cycle assessment of bioenergy production is necessary to ensure the sustainability of this resource covering the full supply chain and possible land use changes. This might be a constraint for future exploitation, together with competition from other uses for access to the resource.

Biogas electricity

The amount of electricity generated from agricultural biogas, landfill gas and sewage gas between 2000 and 2005 was low relative to wind and solid biomass electricity. No generation of electricity from biogas was reported from any of the BRICS countries.

The level of remuneration necessary to create financially viable projects strongly depends on the specific fuel used as well as on the size of the project. Strong competition for feedstocks has recently developed from agricultural markets, and affects the viability of projects in many countries. Countries using FIT systems often implement very different remuneration levels for the promotion of different biogas technologies, and also differentiate by size of the installation.

The highest growth of biogas generation from 2000 to 2005 was in Germany, the United Kingdom and Luxembourg, with Germany and Luxembourg applying FITs and the United Kingdom a quota obligation system with TGCs. In Germany the FIT incentive scheme has shown relatively high costs compared with other countries due to the small-to-medium scale and type of feedstocks used in agricultural applications.

Besides the United Kingdom, Italy's quota obligation system with TGCs has shown some of the highest effectiveness levels, with the strong growth in both countries mainly based on an expansion of landfill gas capacity producing methane that is cheap relative to other biogas feedstocks.

Solar photovoltaics

The total mid-term realisable technical potential for photovoltaics (PV) in the OECD countries and BRICS is 394 TWh, equivalent to the United Kingdom's 2005 electricity production.

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However, the investment costs of PV systems, which represent the most important barrier to PV deployment, are still high. Since only 1% of the realisable potential had been exploited by 2005, the average 2000-2005 policy effectiveness levels for PV are lower by a factor of ten than for a more mature RET such as wind energy. The development of PV in terms of absolute installed capacity has been dominated by Germany and Japan, followed at some distance by the United States. These three countries were responsible for roughly 88% of the globally installed capacity at the end of 2005.

Feed-in tariffs (complemented by the easy availability of soft loans and fair grid access) have been very effective in Germany, albeit at a high cost (USD 0.65/kWh). In recent years, the level of the German FIT for solar PV has decreased to some extent, and an element of degression[7] has been introduced. The German parliament has approved proposals for acceleration of degression rates for stand-alone installations from 5% per year in 2008 to 10% per year in 2010 and 9% from 2011 onwards. This creates incentives to reduce costs, and hence move down the learning curve.

For many years, PV installations in the United States have benefited from federal tax incentives, but these have been insufficient to motivate PV installations. Therefore, more recently, California (which alone represents nearly 80% of the total national inventory), Arizona and New Jersey established aggressive incentive policies for PV, including tax rebates for residential and commercial installations and quota obligation systems with a solar-specific set-aside. Net metering, favourable retail rate structures and streamlined interconnection rules have also been enablers of sizable PV markets. These measures may become important triggers for PV market take-off in other countries as well.

Hydropower

In most OECD countries, with the exception of Canada and Turkey, the additional potential for hydropower deployment is small because the potential has either already been exploited or is affected by legal frameworks concerning integrated water management, such as the EU Water Framework Directive, and occasional public resistance. In many EU-OECD countries, growth is mostly takes the form of re-powering or upgrading existing large-scale plants or building new small-scale plants.

Nonetheless, in most BRICS, there has been remarkable progress in hydropower in recent years and there remains substantial additional potential to 2020. This growth is mainly driven by the drastically increased demand for electricity in BRICS countries. There is also a need for capacity expansion with regard to the hydrological aspects of water storage and management systems. Thus, with hydropower constituting an important element of integrated energy policy in these countries, renewable energy support schemes have – to a large extent – not been necessary to stimulate its development.

As large hydropower is often competitive with thermal and nuclear electricity generation, many countries have a strong interest in developing this technology. A main constraint can be the environmental impacts of large-scale development, which can severely delay the planning process and even derail the implementation of major projects.

7. Degression refers to a pre-determined (often annual) percentage decrease in the support level for a given renewable energy installation.

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Geothermal electricity

The main driver for the deployment of geothermal electricity is having suitable high temperature geothermal resources readily available without the need for deep drilling. This explains why only ten of the OECD countries and BRICS have any production of geothermal electricity. Iceland, Mexico and the United States showed the highest growth rate in recent years. Italy, the country with the highest policy effectiveness based upon a quota obligation system with TGCs, produces over 90% of all the geothermal electricity from EU-OECD countries.

Renewable heating (RES-H)

Policies to encourage the development and deployment of RES-H technologies have largely been neglected compared with those supporting renewable electricity or biofuels for transport. The relative absence of support policies, whether effective or not, and significant unexploited mid-term potentials, is why overall average policy effectiveness levels are lower by a factor of more than twenty relative to RES-E technologies. There is a lack of available data on RES-H markets and policies, especially in BRICS countries.

Geothermal heat

Despite the fact that the use of geothermal heat is well established in many countries, relative progress, as appraised by the effectiveness indicator, is slow, at least relative to the very large mid-term realisable potentials. A distinction also needs to be made between deep geothermal heat, often competitive with conventional heat where it is available, and heat from shallow ground source heat pumps. The main deployment barriers are cost, complex planning and permission procedures, and the distance between deep geothermal resources and centres of heat demand. Ground source heat pumps can be employed virtually anywhere in the world for both heating and cooling but have high investment costs, which necessitate policy support. This has been the reason for their limited deployment to date.

Switzerland and Turkey were by far the most effective countries in deployment of geothermal heat between 2000 and 2005. However, due to the lack of a significant high-temperature hydrothermal resource they do not belong to the leading group of countries for geothermal electricity production. Enhanced geothermal systems from deep drilling are at an early stage of maturity and costly but have widespread potential, if current cost barriers can be overcome.

Solar hot water

While solar thermal heat resources are abundant in many world regions, the impressive progress made in recent years – with production and installation having doubled over the period 2000-2005 – is concentrated in only a few countries. China is responsible for approximately half the global solar thermal heat generation and, together with Brazil and Austria, is currently progressing most quickly in utilising its realisable potential. In China, development can be attributed to the cost competitiveness of solar thermal heat in many regions of the country. The main drivers of burgeoning consumer demand in China are a poorly developed conventional heating infrastructure, a well-developed domestic manufacturing industry and changes in population demographics. Brazil does not provide

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policy support to solar thermal heat but has high solar radiation levels, whereas Austria has achieved an almost equally high effectiveness due to rather modest investments in grants, information dissemination and training programmes.

Main barriers to the deployment of solar thermal heat in most countries include inadequate planning guidelines, and lack of consistent economic incentives, awareness programmes and training opportunities. Some regulatory policies such as the solar heating obligation in Barcelona and other Spanish municipalities represent very interesting innovative policy measures to overcome these barriers, which could lead to significant growth.

Biomass heat and combined heat and power (CHP)

District heating and CHP plants are efficient uses of biomass resources if there is adequate heat demand sufficiently close to the production. Nonetheless, the overall achievement of CHP-based heat generation is rather moderate on a global level. The vast bulk of this technology is implemented in Europe, amounting to 80% of the overall generation of biomass CHP in all OECD countries and the BRICS. The BRICS countries represent 11% of biomass CHP heat while other OECD countries add the remaining 9%.

The effectiveness of this sector is higher than for other RES-H technologies but still significantly less than for RES-E technologies. By far the highest growth from 2000 to 2005 was reached in Scandinavian countries, in particular Denmark and Sweden. The critical success factors are cheap and abundant biomass potentials, which may be derived from a strong forest industry combined with effective incentives for the promotion of biomass electricity and biofuels for transport. As in the case of biomass-based electricity, the net life-cycle environmental benefits of biomass heat need to be carefully assessed in light of land-use change and feedstock transportation impacts arising from a large-scale expansion of bioenergy production. Also, funding of biomass CHP should be consistent with support for biomass electricity, based on the overall seasonal efficiency of the installation.

A further important success factor for biomass CHP-based heat generation is the existence of heating grids or the feasibility to construct new ones. This depends strongly on the density of heat demand and the tradition of grid-connected heat deployment which explains some of the success in Scandinavian countries. These basic conditions are also fulfilled in some of the BRICS countries such as China and Russia, where good potential exists.

Biofuels

From 2000 to 2005, OECD countries and the BRICS doubled their production of first-generation biofuels (ethanol and biodiesel). In 2005, they substituted 20 Mtoe of fossil fuels, representing 1% of 2005 worldwide transport energy. Ethanol production is clearly dominated by Brazil and the United States (where it benefits from considerable subsidies), with shares of 41% and 44% respectively of total 2005 ethanol production in OECD countries and the BRICS. Biodiesel production and consumption in turn have shown growth mostly in the EU region, supported by very high subsidies through tax exemptions. China and India also show relatively high effectiveness in their deployment of ethanol, the former having introduced a blending quota and the latter a tax exemption as well as a guaranteed price for ethanol producers.

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In contrast to most forms of renewable energy, which tend to be consumed and financed domestically, liquid biofuels can be traded and exported on a large scale. This means that a broader range of policies, such as import and export tariffs, can be used to influence the amount of biofuels consumed domestically, so that some countries produce biofuels in large quantities while consuming only a small part of the product.

The most widespread support measures are full or partial exemption from excise tax, eco-tax or value added tax as well as mandatory blending. Most countries promoting biofuels had tax measures in place or implemented them between 2000 and 2005, while blending quotas have been adopted only more recently.

Of all the countries examined, Brazil remains the front-runner in the production of sugarcane ethanol, which is driven by cost competitiveness and now relies on indirect tax relief. Germany, focusing primarily on biodiesel, enjoyed the highest policy effectiveness from 2000 to 2005 relative to its additional realisable potential to 2020. Nevertheless, Germany's progress came at a relatively high cost, mainly through a tax exemption which made biodiesel significantly cheaper than regular fossil-based diesel. It remains to be seen how the biodiesel market in Germany will develop now that the tax exemption has been removed. The United States had the second-highest effectiveness level, concentrating on the production of corn-based ethanol granting producer tax credits in addition to agricultural support mechanisms. Sweden was third-highest but at a relatively high cost, concentrating its efforts on ethanol in contrast to most other EU countries, which concentrated on biodiesel.

Most EU-OECD countries which were required to transpose the EU Biofuels Directive into national legislation showed accelerated growth in biofuel consumption over 2004-2005, in trying to achieve the indicative biofuel targets of a 2% transport fuel market share in 2005 and 5.75% in 2010, respectively.

This analysis focuses on the period 2000 to 2005 and, therefore, does not consider more recent policy developments and significant ramping up of biofuel targets. The higher targets have stimulated growing public concern surrounding the impacts from increasing biofuel production on land use change, agricultural product prices, deforestation and water use. Competition for the feedstock between energy and food production is increasingly being debated. Strong policy signals on the sustainable production and use of biofuels will need to accompany their large-scale market penetration, as is planned in the United States and the European Union.

Second-generation biofuel technologies under development are projected to play a vital part in achieving the objective of sustainable biofuel production sand consumption by widening the range of feedstocks and improving the environmental and cost efficiency of biofuels. Effective policies, including RD&D efforts, are needed to foster a rapid transition to second-generation technologies.

Key messages and conclusions

To date, only a limited set of countries have implemented effective support policies for renewables which have resulted in acceleration in renewables diffusion in recent years. There is a large potential for improvement of policy design in most countries and considerable realisable potential across all RETs in all the OECD countries and BRICS reviewed. If effective

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policies were adopted in many more countries, this potential could be exploited more rapidly and to a much larger extent.

The EU-OECD, other OECD countries and the BRICS showed substantial diversity in the effectiveness of policies implemented to support the individual RETs in the electricity, heating and transport sectors. The EU-OECD countries, which, overall, have a longer history of renewable energy support policies, feature among the countries with the highest policy effectiveness for all new renewable electricity generation technologies. The picture is more varied among the most mature renewable electricity technologies (*e.g.* hydro) and among renewable heating and transport technologies, with some other OECD countries and the BRICS also having implemented relatively effective policies.

A wide variety of incentive schemes in place can be effectively applied depending on the specific technology and country. However, to date non-economic barriers have significantly hampered the effectiveness of renewable support policies and driven up costs in many countries, irrespective of the type of incentive scheme.

It is therefore recommended to move beyond discussions over which specific incentive scheme functions best. The assessment must be of the entire policy framework into which incentive schemes are inserted. Overall, the effectiveness and efficiency of renewable energy policies are determined by the adherence to key policy design principles outlined below, as well as the consistency of measures.

Renewable policy design should reflect five fundamental principles:

- The removal of non-economic barriers, such as administrative hurdles, obstacles to grid access, poor electricity market design, lack of information and training, and the tackling of social acceptance issues – with a view to overcoming them – in order to improve market and policy functioning;
- The need for a predictable and transparent support framework to attract investments;
- The introduction of transitional incentives, decreasing over time, to foster and monitor technological innovation and move technologies quickly towards market competitiveness;
- The development and implementation of appropriate incentives guaranteeing a specific level of support to different technologies based on their degree of technology maturity, in order to exploit the significant potential of the large basket of renewable energy technologies over time; and
- The due consideration of the impact of large-scale penetration of renewable energy technologies on the overall energy system, especially in liberalised energy markets, with regard to overall cost efficiency and system reliability.

Reflecting these five principles in an integrated approach allows two concurrent goals to be achieved, namely to exploit the "low-hanging fruit" of abundant RETs which are closest to market competitiveness while preserving and implementing the long-term strategic vision of providing cost-effective options for a low-carbon future.

The main objective of an integrated approach is to achieve a smooth transition towards mass-market integration of renewables. This will also require a profound evolution of markets transforming today's situation - characterised by an inadequate price placed on carbon and

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other externalities, most renewables needing economic subsidies, and additional non-economic barriers preventing RET deployment – into a future energy system in which RETs compete with other energy technologies on a level playing field. The evolved market should place an appropriate price on carbon and other externalities and help to develop an infrastructure to accommodate large-scale RET integration. Once this is achieved, no or few additional economic incentives will be needed for RETs, and their deployment will be accelerated by consumer demand and general market forces.

Analysis suggests that policy frameworks which combine different technology-specific support schemes as a function of RET maturity would be best suited to successfully implement the key policy design principles and foster the transition of RETs towards mass-market integration.

Governments should develop a combination policy framework increasingly applying market principles as technology maturity and deployment increase. This is possible with a range of policy instruments, including price-based, quantity-based, research and development (R&D) support, and regulatory mechanisms.

As a general principle, less mature technologies further from economic competitiveness need, beyond continued R&D support, very stable low-risk incentives, such as capital cost incentives, feed-in-tariffs (FITs) or tenders (see Figure 1). For low-cost gap technologies such as on-shore wind or biomass combustion, other more market-oriented instruments like feed-in-premiums and TGC systems with technology banding[8] may be more appropriate. Depending on the specific market and resource conditions, and level of market integration across countries, technology banding may be necessary only in a transitional phase or may be bypassed in favour of a technology-neutral TGC system. Once the technology is competitive with other CO_2-saving alternatives and ready to be deployed on a large scale, and when appropriate carbon incentives are in place, these RET support systems can be phased out altogether. At that stage, renewable energy technologies will compete on a level playing field with other energy technologies.

National circumstances (RET potential, existing policy framework, existence of non-economic barriers, degree of market liberalisation, and energy system infrastructure) will influence the actual optimal mix of incentive schemes, and choosing when to complement R&D support with deployment support will be critical to the overall success of support policies.

All RET families are evolving rapidly and show significant potential for technology improvement. Renewable energy policy frameworks should be structured to enable the pursuit of technological RD&D and market development concurrently, within and across technology families, in order to address the various stages of development of different renewables and markets.

8. Technology banding refers to the technology differentiation of a quota obligation either by awarding technology-specific multiples of TGCs or by introducing technology-specific obligations.

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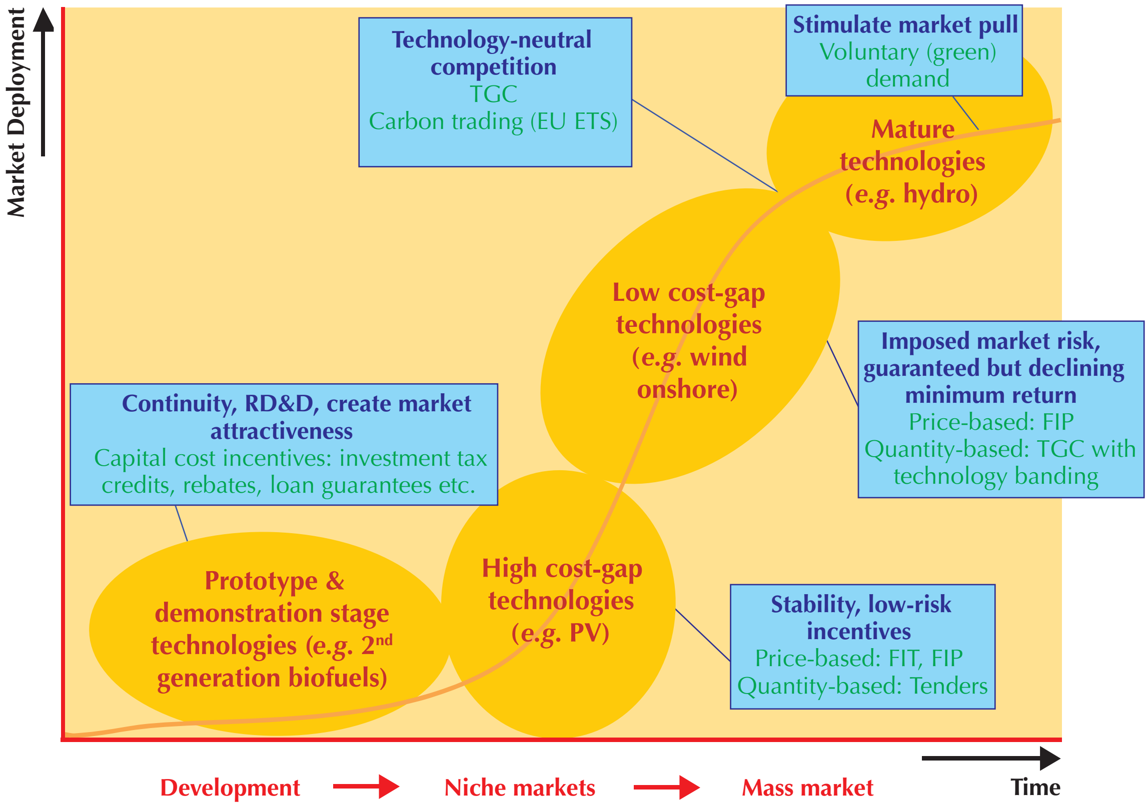
Figure 1. **Combination framework of policy incentives as a function of technology maturity**



NB: The positions of the various technologies and incentive schemes along the S-curve are an indicative example at a given moment. The actual optimal mix and timing of policy incentives will depend on specific national circumstances. The level of competitiveness will also change as a function of the evolving prices of competing technologies.

Recommendations

All governments are encouraged to note the following principles relating to policies supporting RET deployment:

- Realise the urgency of implementing effective support mechanisms in order to accelerate the exploitation of the major potential of renewable energy technologies to improve energy security and tackle climate change;
- Remove and overcome non-economic barriers as a first priority to improve policy and market functioning;
- Recognise the substantial potential for improvement of policy effectiveness and efficiency in most countries and learn from good practice;
- Focus on coherent and rigorous implementation of the five fundamental policy design principles, with the aim of maximising long-term cost efficiency while having regard to national circumstances;

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- Create a level playing field by pricing greenhouse gas emissions and other externalities appropriately in the market; and
- Move towards a combination framework of support schemes as a function of technology maturity level in order to foster smooth transition of renewable energy technologies towards mass-market integration, progressively employing market forces.

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Introduction

Context

Recent IEA and other scenarios have demonstrated that a large basket of sustainable energy technologies will be needed to address the challenges of moving towards clean, reliable, secure and competitive energy supply. Renewable energy technologies (RETs) can play an important role in achieving this goal. Nevertheless, it is important to stress that energy efficiency improvements have, in fact, the greatest potential for carbon savings at low or negative cost across all economic sectors, and with immediate results.

Box 1. **The case for renewables**

Renewables can help address the manifold challenges faced by today's energy system in the following respects:

- Contributing to climate change mitigation and general environmental protection.
- Fostering technological innovation, market creation and employment creation leading to economic growth.
- Enhancing energy supply security through diversification, prevention of conflicts over natural resources.
- Reducing poverty through better energy access and gender equality.
- Improving public health through reduced local air pollution and indoor air pollution.

These benefits are discussed at length in a wide range of sources while a concise treatment can be found in Goldemberg (2006).

Source: adapted from Goldemberg (2006).

By 2030, RETs are projected to contribute 29% to power generation and 7% to transport fuels according to the IEA *World Energy Outlook (WEO)* Alternative Policy Scenario 2007 (IEA, 2007b) – in which policies currently under consideration are implemented. By 2050, the contribution of renewables could rise even further to almost 50% of electricity if the ambitious goal of a 50% global reduction in 2005 CO_2 emissions over that time horizon is met, represented by the BLUE scenarios[9] in the IEA *Energy Technology Perspectives (ETP) 2008* (IEA, 2008). While attainable, this objective will require strong political and financial commitment as well as immediate action by all governments.

A gamut of RETs exists across the technology maturity spectrum from the research and development (R&D) stage, through the demonstration, deployment stages to market uptake (commercialisation).

9. In the BLUE Map scenario, which reflects relatively optimistic assumptions for all key technologies, end-use efficiency options (in electricity and fuel use) account for the largest 36% share of total emission reductions. Renewables are the technology area with the second-highest total emission reductions of 21% (IEA, 2008).

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Box 2. **Technology development stages**

R&D seeks to overcome technical barriers and to reduce costs. Commercial outcomes are highly uncertain, especially in the early stages.

In the **demonstration** stage, the technology is demonstrated in practice. Costs are high. External (including government) funding may be needed to finance part or all of the costs of the demonstration.

RETs at the **deployment stage** operate successfully technically, but may still be in need of support to overcome cost or non-cost barriers. With increasing deployment, technology learning will progressively decrease costs.

Diffusion/ Commercialisation: The technology is cost competitive in some or all markets, either on its own terms or, where necessary, supported by government intervention (*e.g.* to value externalities such as the costs of pollution).

Source: IEA, 2008.

Energy policy can influence technology development and market uptake (commercialisation) through the interplay of three main types of policies which target technology families or sub-sets of these at progressive stages of technology maturity:

- **Research, Development and Demonstration (RD&D) Policies;**
- **Market Deployment Policies** (also called support or promotion policies); and
- General **Energy Market Policies**.[10]

Aim of the publication

This book focuses primarily on the key principles behind the success of *market deployment policies* – measured in terms of their effectiveness and efficiency – to stimulate the diffusion of RETs in the electricity, heating and transport sectors. The regional scope of the analysis encompasses the OECD countries and the large emerging economies of Brazil, Russia, India, China and South Africa, also known as the BRICS.

10. (IEA, 2004).

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The quantitative assessment focuses on renewable energy markets and policies for those RETs which have had measurable deployment experience over the assessment period 2000 to 2005. It demonstrates deployment experiences over this period, as well as focusing on more recent trends over 2004-2005.

In effect, this means that the quantitative effectiveness and efficiency analysis discusses more mature RETs – *i.e.* onshore wind, biomass, biogas, geothermal, solar PV, and hydro power in the electricity sector; biomass heat, geothermal and solar thermal in the heating sector; and ethanol and biodiesel in the transport sector – which have already progressed beyond the demonstration phase and show significant deployment which can be put in relation to policies implemented. Therefore, currently less mature technologies, such as offshore wind, enhanced geothermal systems (EGS), wave and tidal and marine currents, are not taken into account in this chapter. The less mature technologies which are currently at the RD&D stages are addressed in the context of RD&D policies. For these technologies the report endeavours to distill the factors contributing to successful *RD&D policies*, with the aid of several recent examples.

It should be emphasised that an analysis of the cost efficiency of renewable energy systems relative to other carbon abatement technology options falls outside the scope of the publication. It also does not tackle the full economic and social value and costs of renewables. A planned follow-on study by the IEA will undertake estimations of external benefits – including greenhouse gas emission reduction, reduction of regional air pollution, local employment creation – as well as of the possible external costs. Moreover, the drivers of a successful progression from the RD&D to the market uptake stage and the possible impact of policy options to bridge this “valley of death” will be assessed in greater depth.

Publication structure

Part 1 of this publication contains the main analytical findings. Chapter 1 sets the scene by outlining the market trends for renewables in the electricity, heating and transport sectors since 1990. Chapter 2 derives the mid-term potentials for the technologies assessed and also appraises current RET production and investment costs on which the effectiveness and efficiency analysis rely. Chapter 3, the analytical heart of the publication, builds on the data evaluated in the previous background chapters to discuss the effectiveness and efficiency of policies implemented to support the relevant RETs. Chapter 4 examines the renewable energy R&D experiences in OECD countries and the BRICS countries, and identifies principles of good practice. Finally, Chapter 5 draws out conclusions and summary recommendations for designing effective policies for renewables deployment.

Part 2 which is available electronically in a companion CD-ROM – encompasses *i)* profiles on the renewable energy market and policy trends for each OECD member country and Brazil, Russia, India, China and South Africa as well as *ii)* additional statistical information and methodological background of interest to analysts.

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Chapter 1
Renewable Energy Technology Market Trends in OECD Countries and BRICS

Trends in renewable electricity (RES-E) markets

Between 1990 and 2005, the generation of electricity from renewable energy sources (RES-E) increased by 40% to 3 272 terawatt hours (TWh) globally, equivalent to 17.9% of electricity production (Table 1, page 35). The renewable energy share is lower than that of coal (40.3%) and only slightly behind natural gas (19.7%), but greater than that of nuclear (15.2%) and oil (6.6%). Hydro provides 16% of the world's electricity and 89.3% of total RES-E. Combustible renewables and waste, including solid biomass, play only a minor role today, supplying 1% of world electricity. Although growing rapidly, geothermal, solar and wind energy accounted for just 0.9% of world electricity production in 2005 (IEA, 2007a).[11]

Greater deployment of non-hydro renewable electricity is seen mainly in OECD countries within the European Union (OECD-EU), where strong national policies in support of renewables have encouraged growth.

Renewable electricity generation worldwide grew on average 2.4% per annum – slower than total electricity generation (2.9%). Consequently, the share of renewables in electricity production fell from 19.5% in 1990 to 17.9% in 2005. This decrease is due in particular to slow growth in OECD hydropower, which accounts for almost half of global renewable electricity (48%). Weak growth in RES-E generation in OECD (1.2%) was considerably lower than that of global electricity generation (2.1%). In contrast, in non-OECD regions, RES-E grew by 3.7%, only a slightly lower rate than for all electricity (4.2%).

Since 1995, growth in electricity production has been considerably higher in non-OECD regions, due to the developing economies of Asia and Africa in particular. Populations in these regions are growing faster than in OECD countries, and, as incomes increase, fuel switching occurs, from fuel-wood and charcoal to kerosene and liquefied petroleum gas for cooking, and populations attain better access to electricity. As a consequence, future electricity growth is expected to remain higher than in OECD countries (IEA, 2007a).

Hydropower dominates the renewable electricity mix in the four leading RES-E producing countries, namely China, Canada, the USA and Brazil. While the production of RES-E has for the most part followed an upward trend in all four countries, the variability of hydropower output due to meteorological conditions has led to temporary declines in RES-E during years of unusually low precipitation (Figure 1). The dramatic rise in absolute terms of RES-E generation in China – becoming the largest RES-E producer among OECD countries and Brazil, Russia, India, China and South Africa (BRICS) in 2005 – highlights the fact that hydro generation in non-OECD regions had exceeded that of OECD by 2001, reaching 56.5% of the world total in 2005. Indeed, most of the future increase of hydro is likely to occur in non-OECD regions, as this is where the resource is richest (IEA, 2007a) and electricity demand growth is much faster.

11. Due to lack of more recent data, this overview of trends in markets for renewable energy technologies (RETs) does not reflect the continued high growth rates exhibited by these markets since 2005, which are particularly dynamic for selected RETs, e.g. *wind energy and solar PV.*

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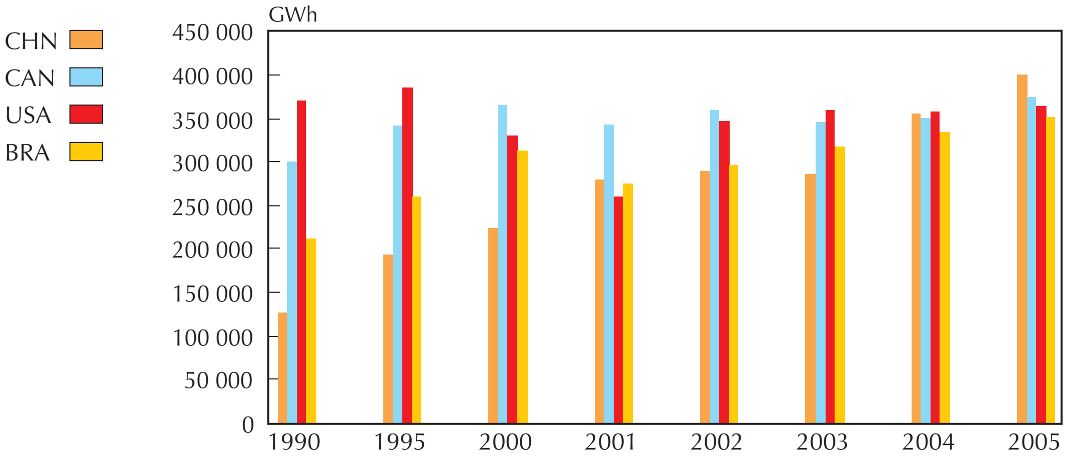
Figure 1. **Renewable electricity market trends for the four leading producers among OECD countries and BRICS, 1990-2005**



Source: IEA (2007a).

Key point

Over the 1990-2005 period, RES-E generation has increased in all four countries, with the variability of the dominant RES – hydropower – due to meteorological conditions leading to temporary fluctuations in RES-E output.

As a consequence of high growth in non-hydro ("new") renewables, OECD-EU countries supplied 40.7% of total renewables-based production in the OECD in 2005, up from 35% in 1990 (Table 1, page 35). The introduction in several OECD-EU countries of renewable energy support policies has stimulated this deployment of "new" renewables (Figure 2).

Germany generated the largest amount of non-hydro RES-E within this group of countries in 2005. The share of new renewables in total German RES-E jumped from 9% in 1990 to nearly 70% by 2005, with particularly accelerated growth since the introduction of the Renewable Energy Sources Act in 2000. The expansion has been most apparent in wind energy generation. Similarly, in Denmark, wind energy represented 65% of RES-E and 18% of total electricity generation in 2005. RES-E as a whole reached a share of 28% in that country.

Electricity from solid biomass is a significant contributor to increasing RES-E – between 20% and 84% of total renewable electricity - especially in those European Union (EU) countries with the potential for cheap and abundant biomass combined with the opportunity for co-firing with coal, such as Belgium, the Czech Republic, Finland, Hungary, Poland, Sweden, and the United Kingdom. Biogas electricity has grown little in EU countries – although more than in other OECD countries and BRICS countries. High growth in a few countries, as in the United Kingdom and Belgium – where biogas electricity had increased to 28% and 11% of RES-E respectively by 2005 – is due to an expansion of landfill gas capacity, producing methane at lower prices than from other biogas feedstock.

Measured against total RES-E production in 2005, solar photovoltaics (PV) contributed significantly only in Luxembourg (8.4% of RES-E), and Germany (2.1%), while most OECD-EU countries had a PV share of less than 1% of RES-E. Although still small in absolute amounts, installed PV capacity has been growing rapidly in recent years across many EU countries, led by Germany's dynamic market.

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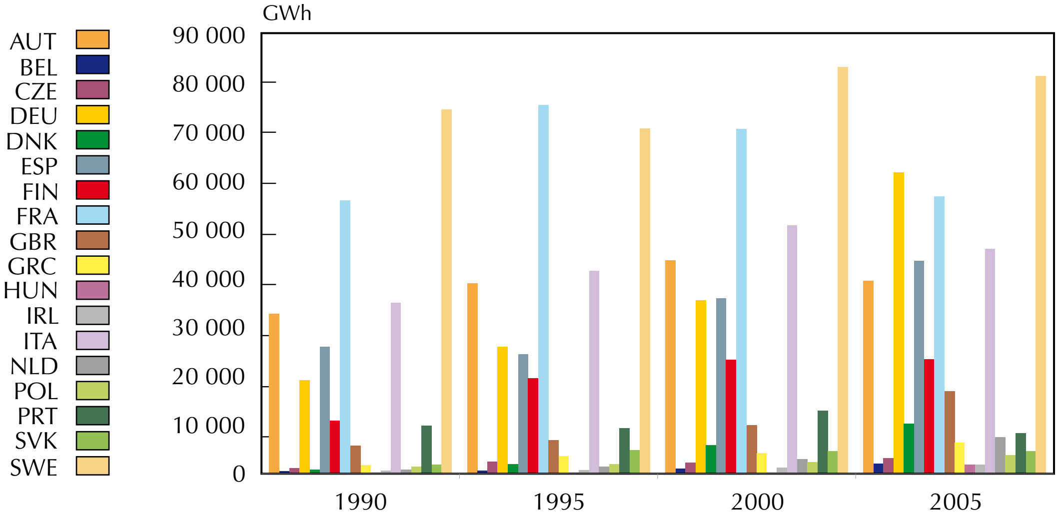
In 2005, hydropower continued to make up more than 60% of RES-E produced in Austria, the Czech Republic, Finland, France, Italy, the Slovak Republic, and Sweden. Most of these countries continue to focus their efforts on expanding small-scale[12] hydro power production. For example, the latter represented up to 30% of hydro electricity produced in Italy (EurObserv'ER, 2006).

Figure 2. **Renewable electricity generation trends in OECD-EU countries, 1990-2005**



Source: IEA (2007a).

Key point

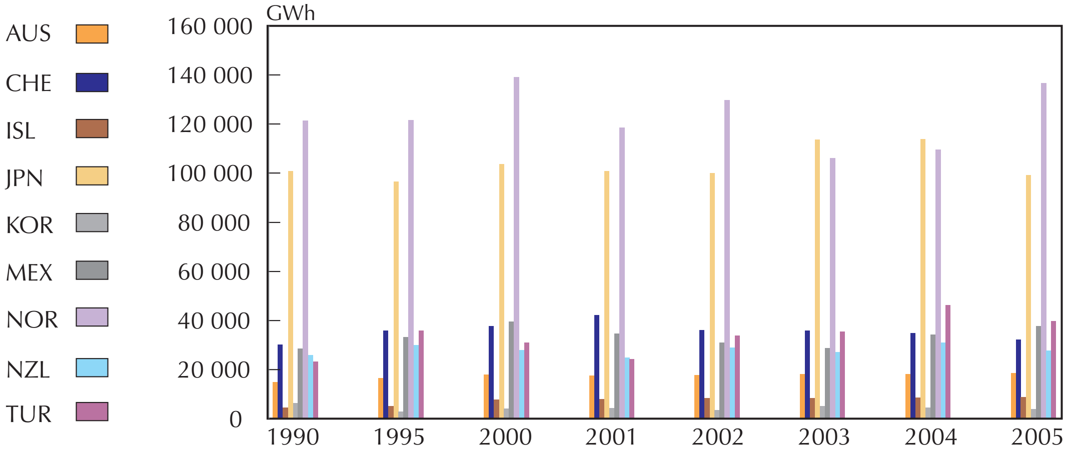
OECD-EU countries supply 41% of total RES-E among OECD countries due to a growing share of electricity from non-hydro renewables.

Overall, the share of RES-E has remained fairly stable in other OECD countries, with a few notable exceptions (Figure 3). A decline in the share of renewable electricity has been especially pronounced in emerging OECD economies, such as Korea, Mexico and Turkey (Table 1, page 35). These countries have experienced extreme consumption growth in the past decade, and generation has in some cases more than doubled since 1990. Due to high capacity installation costs or resource unavailability (*e.g.* hydropower generation which is contingent on meteorological conditions) rising demand is generally met by increasing electricity production from traditional fossil fuels rather than renewable sources.

As for BRICS, the RES-E production has increased significantly in China, India and Brazil, but has decreased in terms of total electricity generation shares (Figure 4). For instance, RES-E tripled in China over the period 1990-2005, but its share in total electricity generation decreased from 20% in 1990 to 16% in 2005. In Russia, RES-E has remained fairly constant, apart from the fluctuations due to the dominance of hydropower, while in South Africa it still at very low level compared to the other BRICS. In India, the share of non-hydro renewables, especially wind energy, jumped from 1.7% of total RES-E in 2000 to 7.5% in 2005.

12. Generally, small hydro power plants are defined as installations with capacities of less than 10 MW.

Figure 3. **Renewable electricity market trends in selected OECD countries, 1990-2005**

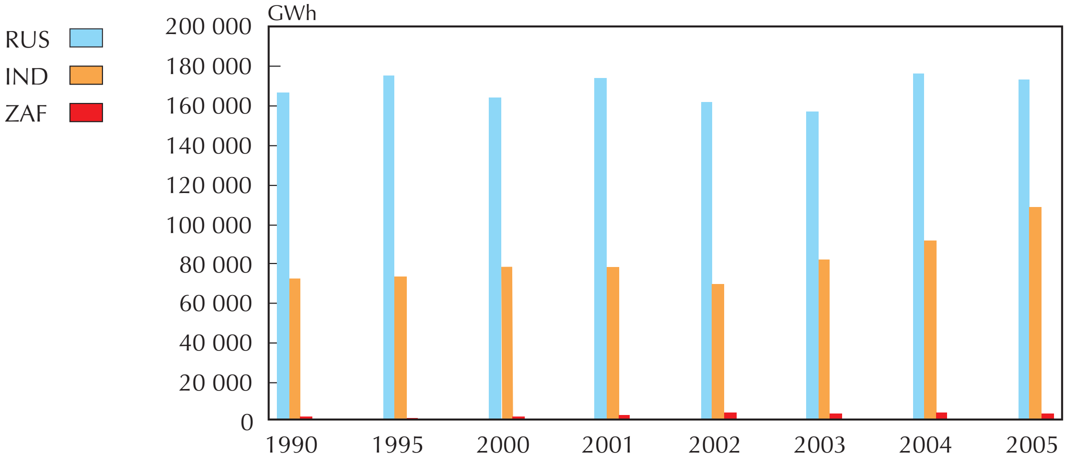


Source: IEA (2007a).

Key point

The share of renewable electricity has remained relatively stable in most non-EU OECD countries, but has declined in Korea, Mexico and Turkey.

Figure 4. **Renewable electricity market trends in selected BRICS countries, 1990-2005**



Source: IEA, 2007a

Key point

The share of renewable electricity generation in Russia, India and South Africa continues to fluctuate, while the share of new renewables has gradually increased in India.

Table 1 provides further statistical detail, summarising the RES-E trends since 1990 in absolute terms and as a share of total electricity generation.[13]

13. Annex 2 on the companion CD-ROM includes tables on the contribution of the individual renewable electricity (RES-E) technologies to aggregate RES-E production.

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Table 1. **Global RES-E trends in absolute terms and as a percentage of total electricity generation, 1990-2005**

	1990		1995	
Country	Renewable electricity generation (GWh)	Share of RE in total electricity generation (%)	Renewable electricity generation (GWh)	Share of RE in total electricity generation (%)
AUT	32 635	66.2%	38 904	70.5%
BEL	555	0.8%	668	0.9%
CZE	1 161	1.9%	2 407	4.0%
DEU	19 093	3.5%	25 932	4.9%
DNK	830	3.2%	1 978	5.4%
ESP	25 976	17.2%	24 408	14.7%
FIN	10 859	20.0%	19 545	30.5%
FRA	55 786	13.4%	75 321	15.3%
GBR	5 811	1.8%	6 871	2.1%
GRC	1 771	5.1%	3 564	8.6%
HUN	195	0.7%	219	0.6%
IRL	697	4.9%	729	4.1%
ITA	34 905	16.4%	41 458	17.5%
LUX	83	13.3%	107	22.0%
NLD	801	1.1%	1 400	1.7%
POL	1 472	1.1%	1 955	1.4%
PRT	9 852	34.7%	9 390	28.3%
SVK	1 880	7.4%	4 880	18.5%
SWE	74 452	51.0%	70 555	47.6%
AUS	14 748	9.6%	16 585	9.6%
CAN	300 625	62.4%	341 537	61.0%
CHE	30 234	55.0%	35 749	57.4%
ISL	4 504	99.9%	4 972	99.8%
JPN	100 806	12.0%	96 665	10.0%
KOR	6 362	6.0%	3 012	1.7%
MEX	28 602	23.0%	33 203	21.1%
NOR	121 358	99.8%	121 642	99.7%
NZL	25 966	80.5%	29 979	84.9%
TUR	23 228	40.4%	35 849	41.6%
USA	369 241	11.5%	384 343	10.8%
BRA	210 461	94.5%	259 418	94.1%
CHN	126 720	20.4%	193 474	19.2%
IND	71 688	24.8%	73 125	17.5%
RUS	165 982	15.3%	175 470	20.4%
ZAF	1 010	0.6%	529	0.3%
WORLD	**2 296 730**	**19.5%**	**2 639 273**	**20.0%**

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Table 1. *(continued)* **Global RES-E trends in absolute terms and as a percentage of total electricity generation, 1990-2005**

	2000		2001	
Country	**Renewable electricity generation (GWh)**	**Share of RE in total electricity generation (%)**	**Renewable electricity generation (GWh)**	**Share of RE in total electricity generation (%)**
AUT	43 590	72.5%	42 075	69.3%
BEL	1 044	1.3%	1 075	1.4%
CZE	2 277	3.1%	2 570	3.5%
DEU	35 475	6.3%	37 895	6.5%
DNK	5 851	16.2%	6 145	16.3%
ESP	35 808	16.1%	49 441	21.2%
FIN	23 273	33.3%	21 608	29.0%
FRA	70 506	13.2%	78 145	14.3%
GBR	9 970	2.7%	9 550	2.5%
GRC	4 144	7.8%	2 932	5.5%
HUN	243	0.7%	257	0.7%
IRL	1 185	5.0%	1 027	4.2%
ITA	50 681	18.8%	54 101	19.9%
LUX	170	39.3%	187	37.6%
NLD	2 994	3.3%	3 313	3.5%
POL	2 332	1.6%	2 783	1.9%
PRT	12 868	29.7%	15 741	34.1%
SVK	4 615	15.0%	5 081	15.9%
SWE	83 139	57.2%	83 319	51.6%
AUS	17 900	8.6%	17 622	8.1%
CAN	366 904	60.6%	342 176	58.0%
CHE	37 690	57.0%	42 203	59.4%
ISL	7 679	99.9%	8 029	100.0%
JPN	103 733	9.9%	100 736	9.8%
KOR	4 124	1.6%	4 258	1.5%
MEX	39 518	19.4%	34 619	16.6%
NOR	139 202	99.7%	118 581	99.5%
NZL	28 016	71.4%	24 825	63.0%
TUR	31 154	24.9%	24 346	19.8%
USA	330 184	8.2%	260 209	6.8%
BRA	312 395	89.5%	276 035	84.2%
CHN	224 835	16.6%	279 870	19.0%
IND	77 495	13.8%	77 762	13.4%
RUS	164 159	18.7%	174 016	19.6%
ZAF	1 408	0.7%	2 292	1.1%
WORLD	**2 841 144**	**18.5%**	**2 784 407**	**18.0%**

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Table 1. *(continued)* **Global RES-E trends in absolute terms and as a percentage of total electricity generation, 1990-2005**

	2002		2003	
Country	Renewable electricity generation (GWh)	Share of RE in total electricity generation (%)	Renewable electricity generation (GWh)	Share of RE in total electricity generation (%)
AUT	41 794	69.2%	35 027	60.7%
BEL	1 138	1.4%	1 192	1.4%
CZE	2 990	3.9%	1 876	2.3%
DEU	44 477	7.8%	46 438	7.8%
DNK	7 103	18.1%	8 414	18.2%
ESP	34 878	14.4%	56 354	21.9%
FIN	20 597	27.5%	19 270	22.9%
FRA	64 564	11.7%	63 423	11.3%
GBR	11 129	2.9%	10 627	2.7%
GRC	3 577	6.6%	5 892	10.2%
HUN	237	0.7%	336	1.0%
IRL	1 382	5.6%	1 138	4.6%
ITA	47 540	17.1%	42 894	15.1%
LUX	167	6.0%	139	5.0%
NLD	3 978	4.1%	3 969	4.1%
POL	2 767	1.9%	2 250	1.5%
PRT	9 733	21.3%	17 703	38.1%
SVK	5 420	16.8%	3 581	11.6%
SWE	71 143	48.5%	58 729	43.4%
AUS	17 804	7.9%	18 213	8.0%
CAN	359 923	59.9%	347 243	58.9%
CHE	36 151	55.2%	35 788	54.7%
ISL	8 410	99.9%	8 494	99.9%
JPN	99 995	9.5%	113 718	10.9%
KOR	3 434	1.0%	5 123	1.5%
MEX	30 867	14.4%	28 663	13.2%
NOR	129 740	99.6%	106 160	99.4%
NZL	28 810	70.1%	27 144	65.8%
TUR	33 966	26.2%	35 559	25.3%
USA	347 879	8.6%	360 135	8.9%
BRA	296 041	85.6%	317 886	87.1%
CHN	290 428	17.7%	286 152	15.0%
IND	68 637	11.5%	80 797	12.7%
RUS	162 396	18.3%	156 137	17.1%
ZAF	3 206	1.5%	2 578	1.1%
WORLD	**2 884 577**	**17.9%**	**2 921 235**	**17.5%**

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Table 1. *(continued)* **Global RES-E trends in absolute terms and as a percentage of total electricity generation, 1990-2005**

Country	2004 Renewable electricity generation (GWh)	2004 Share of RE in total electricity generation (%)	2005 Renewable electricity generation (GWh)	2005 Share of RE in total electricity generation (%)	1990-2005 growth
AUT	39 237	63.7%	39 357	62.5%	20.6%
BEL	1 497	1.8%	2 106	2.5%	279.5%
CZE	2 741	3.3%	3 133	3.8%	169.9%
DEU	56 500	9.3%	61 625	10.1%	222.8%
DNK	9 848	24.4%	10 216	28.2%	1 130.8%
ESP	50 684	18.3%	43 490	15.0%	67.4%
FIN	25 601	29.8%	23 448	33.2%	115.9%
FRA	64 344	11.3%	56 658	9.9%	1.6%
GBR	14 172	3.6%	16 919	4.3%	191.2%
GRC	5 918	10.1%	6 406	10.8%	261.7%
HUN	936	2.8%	1 870	5.2%	859.0%
IRL	1 394	5.5%	1 873	7.3%	168.7%
ITA	51 141	17.5%	45 979	15.6%	31.7%
LUX	195	5.8%	214	6.4%	157.8%
NLD	5 320	5.3%	7 465	7.4%	832.0%
POL	3 075	2.0%	3 846	2.5%	161.3%
PRT	12 314	27.5%	8 260	17.9%	–16.2%
SVK	4 126	13.5%	4 676	14.9%	148.7%
SWE	68 174	44.9%	81 230	51.3%	9.1%
AUS	18 214	7.6%	18 608	7.4%	26.2%
CAN	350 510	58.4%	374 080	59.6%	24.4%
CHE	34 754	54.4%	32 276	55.9%	6.8%
ISL	8 619	100.0%	8 681	99.9%	92.7%
JPN	113 919	10.6%	99 146	9.1%	–1.6%
KOR	4 631	1.3%	4 052	1.0%	–36.3%
MEX	34 348	15.3%	37 675	16.0%	31.7%
NOR	109 474	99.4%	136 638	99.5%	12.6%
NZL	30 866	72.1%	27 619	64.3%	6.4%
TUR	46 311	30.7%	39 748	24.5%	71.1%
USA	356 804	8.6%	364 678	8.5%	–1.2%
BRA	333 319	86.0%	351 911	87.3%	67.2%
CHN	356 031	16.2%	399 521	16.0%	215.3%
IND	91 102	13.6%	108 076	15.5%	50.8%
RUS	176 275	19.0%	173 135	18.2%	4.3%
ZAF	3 343	1.4%	3 026	1.2%	199.6%
WORLD	**3 121 357**	**17.9%**	**3 271 626**	**17.9%**	**42.4%**

Source: IEA (2007a).

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Trends in renewable heat (RES-H) markets

Market trends for commercial renewable heat

This section outlines the growth in renewable heat markets in OECD countries and the BRICS from 1990 to 2005. Data gaps are evident since heat tends to be widely distributed and poorly metered, especially where it is used on site by the producer. Commercial renewable heat data are mainly from biomass CHP and district heating plants. Market trends for solar thermal and geothermal systems are shown separately since, with the exception of Iceland, they make a relatively small contribution of around 400 petajoules (PJ) per year in total, in comparison with heat from bioenergy (excluding traditional biomass) that supplies around 10 times more (IEA and RETD, 2007). The majority of this heat from biomass combustion is for use directly onsite rather than for sale, so it does not appear in the commercial heat statistics.

When heat is sold off-site, the plants concerned are usually relatively large combined heat and power (CHP) or district heating plants, so sales data can be easily reported. In the millions of biomass combustion heat plants where the heat is used directly on site, the heat data are often not recorded, and so do not appear in national energy statistics. These plants range from 30 kW efficient domestic pellet burners to 20 MW boilers using wood process residues from sawmills to provide heat for the timber drying kilns. Even in countries where a database of the installed capacities of heating plants exists, if there is no meter installed then the number of hours that the plant operates each year cannot be assessed without undertaking a survey of plant operators.

Similarly, very widely distributed solar water heaters and small-scale ground source heat pumps make national heat data challenging to compile. Market trends for heating in the residential, commercial and industrial sectors from biomass, solar thermal or direct geothermal heat are therefore difficult to present with any degree of accuracy. In this section the available IEA data between 1990 and 2005 have been used to identify some of the market trends, but gaps are evident for some countries. Heating by electricity was excluded as was heat from traditional biomass used for cooking and comfort by one to two billion people mainly living in rural areas and developing countries.

Although there is growing interest in cooling applications for renewable energy sources, including district cooling using naturally cold water sources and solar absorption chillers, the current market is very small, and so is not discussed here. Passive solar heating and cooling of buildings are not included here, nor are ambient heat pumps.

Between 1990 and 2005, the demand for commercial heat from renewable energy sources worldwide almost doubled (Table 2, page 43), mainly supplied from the combustion of biomass. Also direct use of geothermal heat and solar thermal heating, mainly of water, almost doubled over this period.

More specifically, commercial heat sales from renewables in OECD countries and the BRICS, mainly from woody biomass combustion, have been highest in Sweden, Russia and China during the past two decades (Figure 5). Russian demand dropped significantly after 1990 and has remained below the level of Swedish demand since, due possibly both to the economic collapse of communism as well as to the increase in the availability of Russian natural gas. China's market is surprisingly small; this probably reflects the wide use of non-commercial distributed heat as well as data uncertainty.

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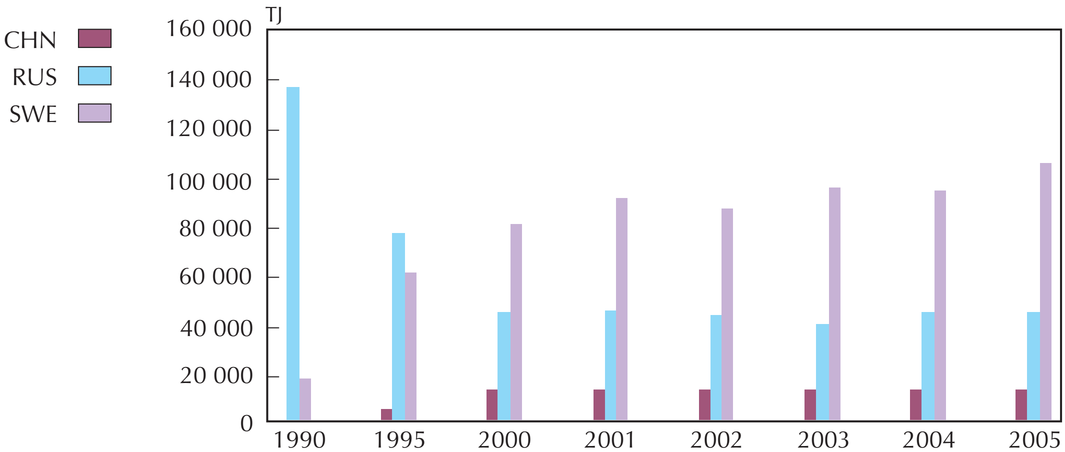
Figure 5. **Commercial renewable heat market trends for the three leading producers among OECD countries and BRICS, 1990-2005**



Source: IEA (2007a).

Key point

Commercial renewable heat production has significantly declined in Russia and has increased in Sweden.

In Sweden, the present primary energy supply from solid biomass, of around 400 PJ/yr, currently provides the major share of energy consumption in the industrial forest sector, and around half the primary fuel use in CHP and district heating plants, which provide over 100 PJ/yr of commercial heat. The 58% share of total heat supply in Sweden coming from renewable energy sources, largely for district heating, has increased significantly since the 1990s when oil was the main heating fuel (Figure 6). The average trend across 15 IEA countries (IEA-15)[14] in the residential sector over this period shows a slight reduction in the use of renewables for space heating from 11% in 1990 to 10% in 2004, with significant fuel switching from oil and coal to natural gas and small increases in electricity demand (IEA, 2007b). Austria, Denmark and Finland all showed increased district heat production – mainly from bioenergy – whereas France, Spain, New Zealand and the USA all experienced a decline in renewables over the period.

As elsewhere, accurate assessment of biomass use is not possible using current data collection systems and Sweden's methods to improve data collection, including the surveying of users, are being reviewed. Once refined, the method determined could be of interest for other countries.

Several OECD-EU member countries, other than Sweden, have had sucessful market increases in renewable energy heating, particularly countries with severe winter temperatures, including Austria (with renewables providing around 25% of total heat demand in 2005), Denmark (31%) and Finland (21%) (Figure 7). Germany has also seen an increasing trend since 2003, as a result of supportive policies, but the share of total heat demand from renewables remained below 3%.

14. The IEA-15 (Austria, Canada, Denmark, Finland, France, Germany, Italy, Japan, the Netherlands, New Zealand, Norway, Spain, Sweden, the United Kingdom and the United States) were selected for analysis because of the availability of detailed statistics.

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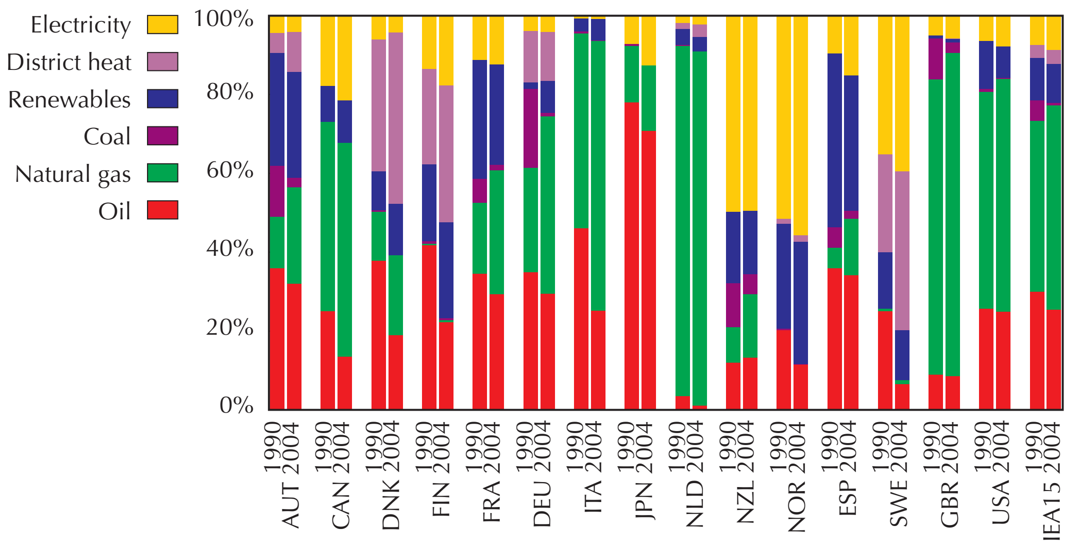
Figure 6. **Fuel shares for residential space heating in selected IEA countries, 1990 and 2004**

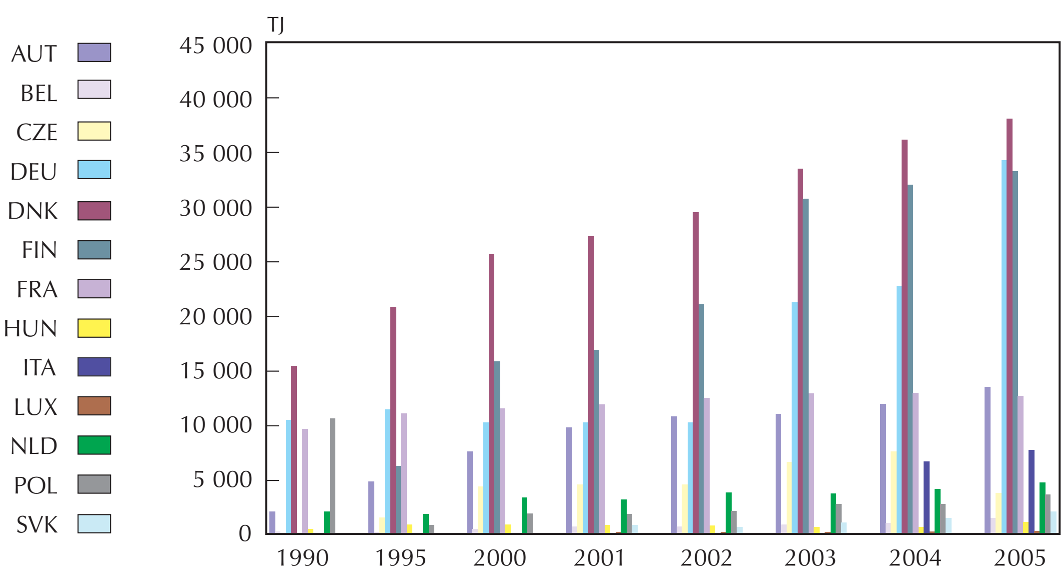


Source: IEA (2007b).

Key point

Across the IEA-15 countries as a whole, the share of renewables for space heating has declined slightly from 1990 to 2004.

Figure 7. **Renewable heat production trends in selected OECD-EU countries (excluding Sweden), 1990-2005**



Source: IEA (2007a).

Key point

Some OECD-EU countries, including Austria, Denmark and Finland, witnessed strong growth in commercial RES-H production. These countries also display significant renewables contributions to the total heat demand (more than 20%).

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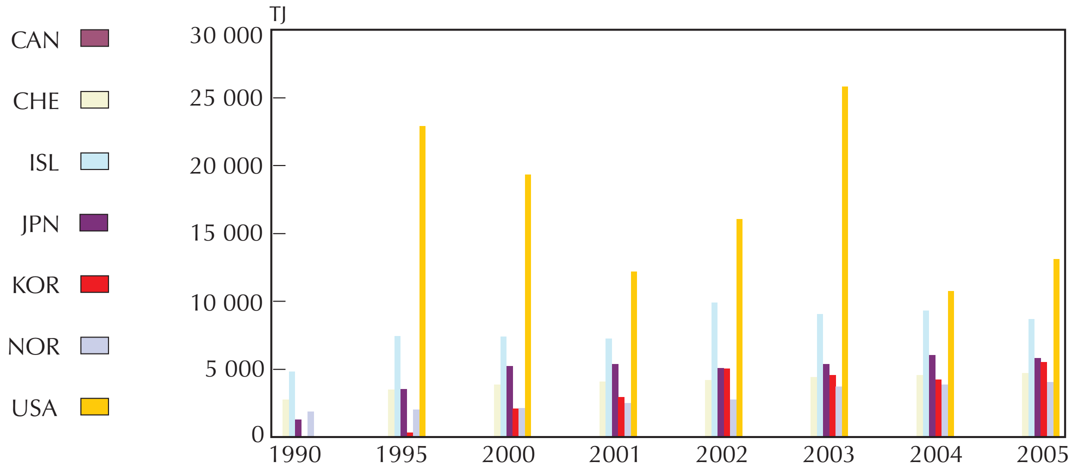
Poland, like Russia, experienced a sudden decline of renewable heat demand in the 1990s but the market has steadily increased in recent years, as it has in Slovakia, Hungary and the Czech Republic. With further support policies introduced, it can be imagined that these colder transition economies could expand their demand for renewable heat, as have the Scandinavian countries in the past. This would in part depend on the opportunities for investments to develop CHP and district heating schemes.

In some non-EU OECD countries, fairly stable commercial renewable heat markets have existed in recent years, such as Japan (22% of the total commercial heat market from renewables in 2005), Iceland (96%, mostly from geothermal), Korea (2.8%), Norway (31%), Switzerland (27%) and USA (5%) (Figure 8).

Figure 8. **Commercial renewable heat market trends in selected non-EU OECD countries, 1990-2005**



Source: IEA (2007a).
Note: Canada's 6 TJ/ year supply is too small to appear on the graph.

Key point

The share of commercial renewable heat markets has remained relatively stable in most non-EU OECD countries.

Warmer non-EU OECD countries such as Australia, Mexico, New Zealand and Turkey as well as Brazil, India and South Africa, have little if any commercial heat demand for buildings. Heat needed for industrial process purposes, if arising from renewable energy sources, is usually sourced and used directly on site. For example, one pulp and paper mill in New Zealand uses both locally sourced geothermal heat and its own biomass residues in a CHP plant. Hence no commercial heat market exists in these countries even though the renewable heat used is considerable.

Table 2 provides further statistical detail, summarising the RES-H trends since 1990 in absolute terms and share of RES-H in total heat production.[15]

15. Annex 2 on the CD-ROM attached to this publication includes tables on the contribution of the individual renewable heat (RES-H) technologies to aggregate RES-H production.

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Table 2. **Global trends in commercial RES-H in absolute terms and percent of commercial RES-H production in total heat generation, 1990-2005**

	1990		1995	
Country	Commercial renewable heat production (TJ)	Share of RE commercial heat production in total heat production (%)	Commercial renewable heat production (TJ)	Share of RE commercial heat production in total heat production (%)
AUT	2 056	7.2%	4 940	12.6%
BEL	120	1.2%	70	0.7%
CZE	0	0.0%	1 487	0.8%
DEU	10 874	2.4%	11 848	2.8%
DNK	16 095	17.4%	21 739	18.3%
ESP	42	15.8%	80	15.2%
FIN	0	0.0%	6 403	6.6%
FRA	9 999	50.0%	11 524	50.0%
GBR	0	x	0	x
GRC	0	x	0	x
HUN	399	0.5%	832	1.4%
IRL	0	x	0	x
ITA	0	x	0	x
LUX	0	x	0	0.0%
NLD	2 059	13.7%	1 762	2.5%
POL	11 014	1.5%	759	0.2%
PRT	0	0.0%	0	0.0%
SVK	0	0.0%	0	0.0%
SWE	16 965	21.7%	59 845	36.7%
AUS	0	0.0%	0	x
CAN	6	0.0%	6	0.0%
CHE	2 756	24.0%	3 483	26.5%
ISL	4 819	91.2%	7 439	92.6%
JPN	1 272	15.0%	3 530	21.5%
KOR	0	x	311	0.9%
MEX	0	x	0	x
NOR	1 871	28.9%	2 025	26.1%
NZL	0	x	0	x
TUR	0	x	0	x
USA	0	0.0%	22 911	5.6%
BRA	0	x	0	x
CHN	0	0.0%	4 126	0.4%
IND	0	x	0	x
RUS	135 720	1.4%	76 257	0.9%
ZAF	0	x	0	x
WORLD	**217 214**	**1.4%**	**250 195**	**1.9%**

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Table 2. *(continued)* **Global trends in commercial RES-H in absolute terms and percent of commercial RES-H production in total heat generation, 1990-2005**

	2000		2001	
Country	**Commercial renewable heat production (TJ)**	**Share of RE commercial heat production in total heat production (%)**	**Commercial Renewable heat production (TJ)**	**Share of RE commercial heat production in total heat production (%)**
AUT	7 850	16.5%	10 111	19.2%
BEL	388	1.7%	649	2.8%
CZE	4 435	3.2%	4 622	3.1%
DEU	10 652	3.4%	10 652	3.3%
DNK	26 804	22.5%	28 551	22.2%
ESP	0	x	0	x
FIN	16 479	13.2%	17 616	12.9%
FRA	11 996	8.9%	12 338	7.5%
GBR	0	0.0%	0	0.0%
GRC	0	0.0%	0	0.0%
HUN	773	1.1%	756	1.1%
IRL	0	x	0	x
ITA	0	x	0	x
LUX	6	0.5%	42	2.9%
NLD	3 423	3.0%	3 231	2.8%
POL	1 839	0.5%	1 815	0.5%
PRT	0	0.0%	0	0.0%
SVK	0	0.0%	727	1.2%
SWE	80 035	50.7%	90 748	52.1%
AUS	0	x	0	x
CAN	6	0.0%	6	0.0%
CHE	3 874	26.7%	4 088	26.4%
ISL	7 392	92.3%	7 254	92.3%
JPN	5 194	22.2%	5 369	23.0%
KOR	2 102	3.6%	2 937	3.0%
MEX	0	x	0	x
NOR	2 111	25.7%	2 480	24.0%
NZL	0	x	0	x
TUR	0	0.0%	0	0.0%
USA	19 306	6.0%	12 171	4.0%
BRA	0	0.0%	0	0.0%
CHN	12 224	0.8%	12 310	0.8%
IND	0	x	0	x
RUS	43 916	0.7%	44 485	0.7%
ZAF	0	x	0	x
WORLD	**275 040**	**2.3%**	**289 895**	**2.4%**

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Table 2. *(continued)* **Global trends in commercial RES-H in absolute terms and percent of commercial RES-H production in total heat generation, 1990-2005**

	2002		2003	
Country	Commercial renewable heat production (TJ)	Share of RE commercial heat production in total heat production (%)	Commercial renewable heat production (TJ)	Share of RE commercial heat production in total heat production (%)
AUT	11 206	22.5%	11 412	22.3%
BEL	642	2.8%	814	3.5%
CZE	4 610	3.2%	6 823	4.6%
DEU	10 652	3.4%	22 191	3.1%
DNK	30 865	24.2%	35 022	26.9%
ESP	0	x	0	x
FIN	21 993	15.2%	32 125	18.9%
FRA	12 986	7.6%	13 391	7.9%
GBR	0	0.0%	0	0.0%
GRC	0	0.0%	0	0.0%
HUN	707	1.1%	587	0.9%
IRL	0	x	0	x
ITA	0	x	0	x
LUX	48	3.1%	87	4.5%
NLD	3 906	3.4%	3 770	3.3%
POL	2 117	0.6%	2 766	0.8%
PRT	0	0.0%	0	0.0%
SVK	582	1.1%	961	1.7%
SWE	86 108	49.6%	94 753	53.5%
AUS	0	x	0	x
CAN	6	0.0%	6	0.0%
CHE	4 167	27.6%	4 420	27.6%
ISL	9 902	93.8%	9 043	93.2%
JPN	5 064	21.2%	5 360	22.7%
KOR	5 012	3.5%	4 550	3.2%
MEX	0	x	0	x
NOR	2 754	26.3%	3 702	31.6%
NZL	0	x	0	x
TUR	0	0.0%	0	0.0%
USA	16 033	4.3%	25 790	7.0%
BRA	0	0.0%	0	0.0%
CHN	12 393	0.8%	12 476	0.7%
IND	0	x	0	x
RUS	42 969	0.7%	39 224	0.6%
ZAF	0	x	0	x
WORLD	**303 955**	**2.5%**	**349 717**	**2.8%**

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Table 2. *(continued)* **Global trends in commercial RES-H in absolute terms and percent of commercial RES-H production in total heat generation, 1990-2005**

Country	2004 Commercial renewable heat production (TJ)	2004 Share of RE commercial heat production in total heat production (%)	2005 Commercial renewable heat production (TJ)	2005 Share of RE commercial heat production in total heat production (%)	
AUT	12 394	22.1%	14 009	24.4%	581.4%
BEL	930	4.0%	1 437	6.4%	1 097.5%
CZE	7 839	5.4%	3 851	2.8%	n/a
DEU	23 759	3.3%	35 835	2.8%	229.5%
DNK	37 844	29.1%	39 885	31.3%	147.8%
ESP	0	x	0	x	–100.0%
FIN	33 487	19.7%	34 779	21.3%	n/a
FRA	13 465	7.8%	13 187	7.0%	31.9%
GBR	0	0.0%	0	0.0%	n/a
GRC	0	0.0%	0	0.0%	n/a
HUN	576	0.9%	1 078	1.7%	170.2%
IRL	0	x	0	x	n/a
ITA	6 888	3.6%	7 974	4.1%	n/a
LUX	104	4.8%	156	6.1%	n/a
NLD	4 218	3.3%	4 818	2.8%	134.0%
POL	2 792	0.8%	3 704	1.1%	–66.4%
PRT	0	0.0%	0	0.0%	n/a
SVK	1 401	2.6%	2 056	3.9%	n/a
SWE	93 676	52.5%	104 869	57.9%	518.1%
AUS	0	x	0	x	n/a
CAN	6	0.0%	6	0.0%	0.0%
CHE	4 552	27.2%	4 716	27.3%	71.1%
ISL	9 319	93.5%	8 698	93.6%	80.5%
JPN	6 014	23.5%	5 788	22.3%	355.0%
KOR	4 198	2.3%	5 514	2.8%	n/a
MEX	0	x	0	x	n/a
NOR	3 869	31.5%	4 052	31.5%	116.6%
NZL	0	0.0%	0	0.0%	n/a
TUR	0	0.0%	0	0.0%	n/a
USA	10 753	4.6%	13 130	5.3%	n/a
BRA	0	0.0%	0	0.0%	n/a
CHN	12 560	0.7%	12 645	0.6%	n/a
IND	0	x	0	x	n/a
RUS	44 123	0.7%	43 767	0.7%	-67.8%
ZAF	0	x	0	x	n/a
WORLD	**358 863**	**2.8%**	**392 124**	**2.9%**	**80.5%**

NB: "n/a" means "not applicable"; "x" indicates that no commercial renewable heat was produced.
Source: IEA (2007a).

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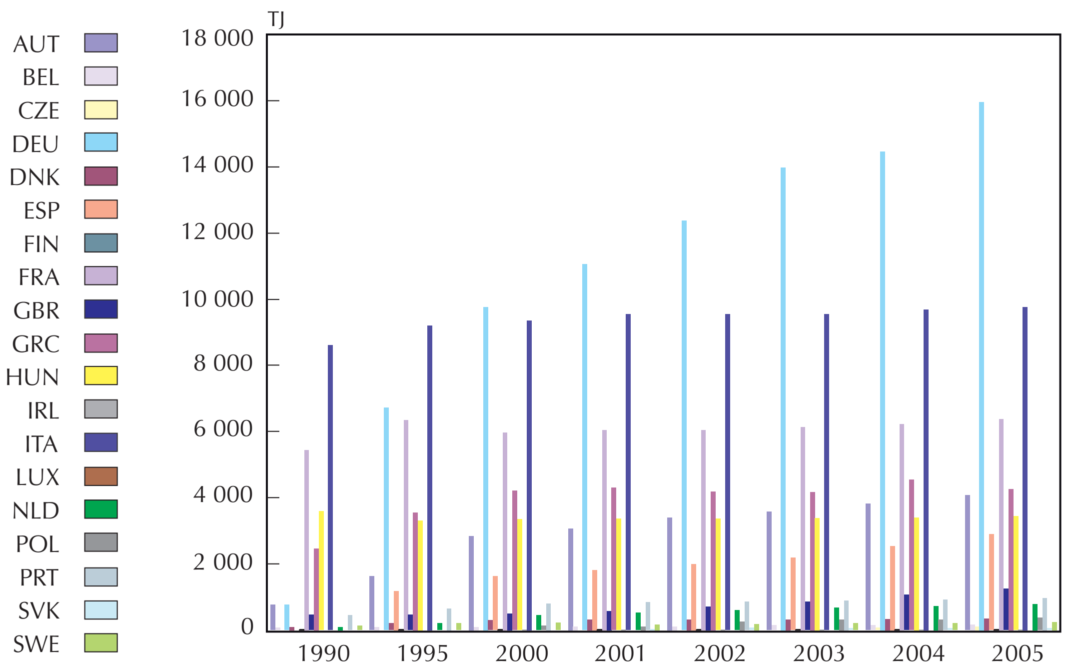
Market trends for solar and geothermal direct heating

Direct use of geothermal heat and solar heat, especially for water heating, is usually based on small-scale technologies for use in individual private dwellings and small businesses. Data are therefore difficult to assess, especially when grouped with commercial heat data, so here they are separated out to enable assessment of these sub-sector trends.

Overall, the trend in OECD-EU countries has been increased uptake of solar and geothermal systems since 1990 (Figure 9). Germany's exceptional growth, as in Austria, is once again due to its strong supportive policies for solar water heating, even though solar irradiation levels are less than in other European countries such as Greece. Here, early growth in solar water heating was evident in the 1990s, but this has since become stable. More recent significant growth in Spain is due to the strong ordinances introduced initially in Barcelona in 2000 and subsequently nationally (IEA and RETD, 2007).

Italy and Hungary have shown fairly stable contributions of direct geothermal heat since the 1990s. In spite of the doubling in Sweden since the 1990s, the total direct geothermal energy there remains small. However, its strongly supportive policy for the uptake of ground-source heat pumps has led to the highest deployment of this technology for any nation, providing around 15 PJ/yr of energy (IEA and RETD, 2007). Heat pump data are not included in this section.

Figure 9. **Trends in direct use of geothermal and solar thermal heat in OECD-EU countries, 1990-2005**



Source: IEA (2007a).

Key point

Certain OECD-EU countries – including Germany, Austria, Spain – have witnessed an increased uptake of solar and geothermal systems since 1990.

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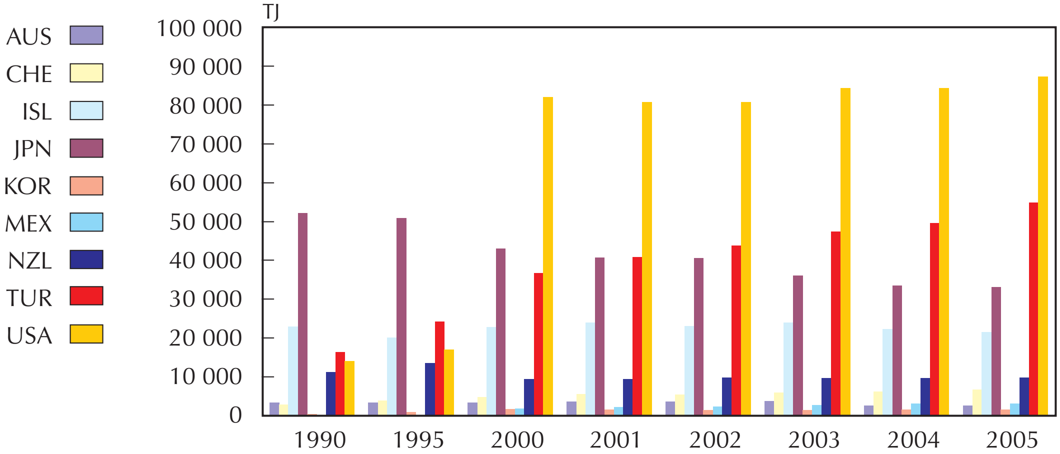
For non-EU OECD countries a similarly mixed pattern is evident (Figure 10). Policies in support of solar water heating were successful in the USA and Turkey in the 1990s, but more recently these markets appear to have stabilised. Iceland has had stable markets for direct use of geothermal heat since 1990, as has New Zealand.

Figure 10. **Trends in direct use of geothermal and solar thermal heat in non-EU OECD countries, 1990-2005**



Source: IEA (2007a).

Key point

A mixed pattern in direct use of renewable heat is evident in other OECD countries.

There are no data available for BRICS countries in this category.

Table 3 provides further statistical detail, outlining the trends in direct use of renewables for heat since 1990.

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Table 3. **Global trends in direct use of RETs for heat (in absolute terms), 1990-2005**

Country	Direct final use of geothermal and solar thermal energy				
	1990	1995	2000	2001	2002
AUT	772	1 635	2 851	3 074	3 405
BEL	78	92	96	116	115
CZE	0	0	0	0	0
DEU	758	6 713	9 760	11 061	12 375
DNK	93	205	307	313	320
ESP	0	1 174	1 624	1 814	1 994
FIN	16	17	16	17	17
FRA	5 437	6 342	5 967	6 040	6 045
GBR	461	461	502	587	706
GRC	2 471	3 556	4 204	4 301	4 195
HUN	3 599	3 305	3 357	3 364	3 365
IRL	4	6	12	12	13
ITA	8 598	9 214	9 364	9 539	9 539
LUX	0	0	2	2	3
NLD	89	198	456	527	604
POL	0	0	124	120	263
PRT	458	659	812	838	864
SVK	0	0	0	42	69
SWE	133	200	223	160	179
AUS	3 404	3 330	3 417	3 616	3 670
CAN	0	0	0	0	0
CHE	2 868	3 896	4 787	5 536	5 488
ISL	22 999	20 124	22 937	24 030	23 101
JPN	52 190	50 809	43 066	40 698	40 513
KOR	417	925	1 745	1 556	1 461
MEX	0	0	1 801	2 156	2 400
NOR	0	0	0	0	0
NZL	11 378	13 527	9 449	9 537	9 874
TUR	16 426	24 269	36 847	40 773	43 860
USA	14 066	16 997	82 021	80 808	80 725
BRA	0	0	0	0	0
CHN	0	0	0	0	0
IND	0	0	0	0	0
RUS	0	0	0	0	0
ZAF	0	0	0	0	0
WORLD	**164 158**	**191 481**	**278 562**	**285 083**	**291 087**

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Table 3 *(continued)* **Global trends in direct use of RETs for heat (in absolute terms), 1990-2005**

Country	Direct final use of geothermal and solar thermal energy			
	2003	2004	2005	1990-2005 growth
AUT	3 574	3 823	4 074	427.9%
BEL	152	154	164	110.2%
CZE	0	84	103	n/a
DEU	13 969	14 462	15 952	2 004.9%
DNK	325	337	359	286.0%
ESP	2 197	2 545	2 894	n/a
FIN	17	18	20	25.1%
FRA	6 129	6 224	6 382	17.4%
GBR	860	1 061	1 262	173.7%
GRC	4 177	4 547	4 270	72.8%
HUN	3 393	3 407	3 443	–4.3%
IRL	11	14	21	422.9%
ITA	9 539	9 688	9 764	13.6%
LUX	4	5	5	n/a
NLD	667	739	786	783.3%
POL	311	318	381	n/a
PRT	892	918	981	114.2%
SVK	53	51	57	n/a
SWE	199	200	247	85.7%
AUS	3 737	2 615	2 622	-23.0%
CAN	0	0	0	n/a
CHE	5 920	6 194	6 781	136.4%
ISL	24 095	22 396	21 596	-6.1%
JPN	36 202	33 524	33 189	-36.4%
KOR	1 394	1 569	1 561	274.3%
MEX	2 762	3 069	3 069	n/a
NOR	0	0	0	n/a
NZL	9 771	9 737	9 900	-13.0%
TUR	47 460	49 637	54 863	234.0%
USA	84 373	84 371	87 294	520.6%
BRA	0	0	0	n/a
CHN	0	0	0	n/a
IND	0	0	0	n/a
RUS	0	0	0	n/a
ZAF	0	0	0	n/a
WORLD	**299 673**	**303 388**	**315 231**	**92.0%**

NB: "n/a" means "not applicable".
Source: IEA (2007a).

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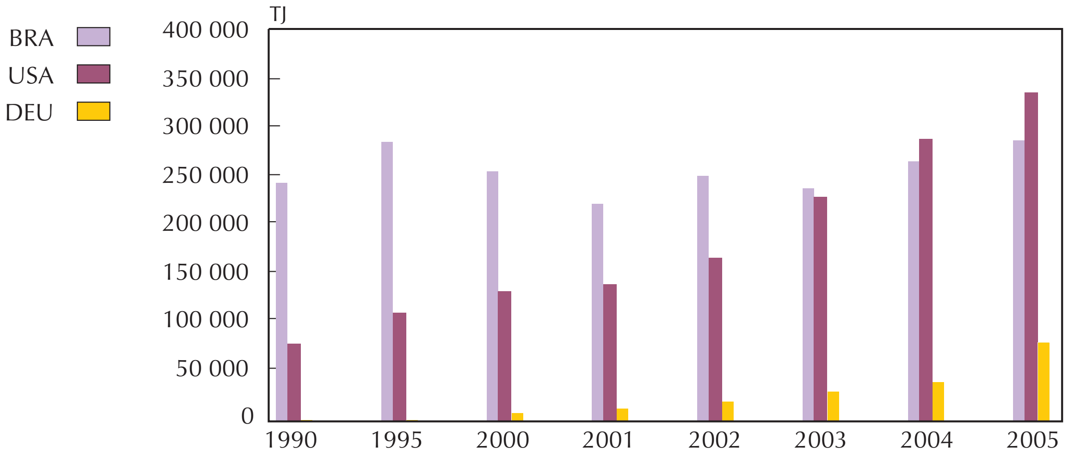
Trends in renewable transport fuel (RES-T) markets

The production of biofuels, including bioethanol and biodiesel, tripled between 1990 and 2005, when it provided 774 PJ (18.5 Mtoe) or just over 1% of road transport fuels (Table 4). It is estimated that by 2007 some 46 billion litres of ethanol (~1 100 PJ) and 8 billion litres (~300 PJ) of biodiesel had been produced worldwide for transport purposes (REN 21, 2007).

Brazil, the pioneer of ethanol production, based on its well established sugar cane industry, has recently been overtaken by the USA, which produces ethanol mainly from corn *(Zea mays)* (Figure 11). However, in Brazil, over 14% of total liquid transport fuel demand (on an energy basis) is met from biofuels, whereas in the USA this amount is 1.5%.

Figure 11. **Renewable transport fuel consumption trends for the three leading biofuel consumers, 1990-2005**



Source: IEA (2007a)

Key point

Ethanol consumption in the USA from (corn and imported sugarcane ethanol) has grown over fourfold since 1990, recently overtaking Brazilian ethanol consumption volumes, both ahead of Germany, the world's largest biodiesel producer.

Financial support mechanisms in Brazil have largely been phased out as the sugar and ethanol industries have matured, whereas US corn production remains heavily dependent on agricultural subsidies, as well as grants for biofuel processors. Energy input/output ratios, including indirect energy for manufacturing fertilisers, chemicals and agricultural machinery, are considerably higher for corn production than sugarcane, and ethanol yields per hectare are lower. Much of the energy inputs used to provide the necessary heat, power and transport into the system are fossil fuel-based, and this means that in terms of emissions over the full life-cycle, greenhouse gas (GHG) emissions from corn ethanol are usually not less than 80-90% of that of gasoline, per kilometre travelled. Sugarcane ethanol, in contrast, where

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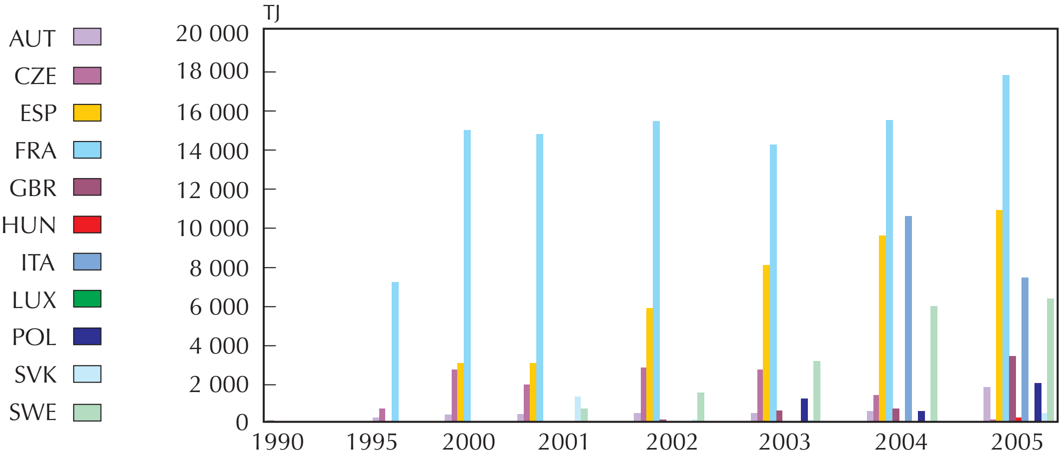
the bagasse by-product is used to provide process heat and power on site, produces only 10% of the GHG emissions of gasoline. GHG emissions from other feedstock used for ethanol and biodiesel production usually lie between those of corn and sugarcane.

Germany is the third highest biofuel producer, with significant growth in biodiesel production from oilseed rape again as a result of strongly supportive policies (Figure 11). In 2005, biodiesel provided around 3.4% of German road transport fuels, but supportive policies over the past decade have been estimated to have totalled several billion Euro leading to very high costs, of over EUR 1 000 per tonne of CO_2 emission avoided. Consequently, German policies have recently been revised and, as a result, the market for biodiesel is declining.

In addition, locally produced biodiesel can no longer compete with imported biodiesel based on soybean and palm oil feedstock, which are both cheap and high yield. Several German biodiesel production plants have closed down recently, and others are running well below capacity and likely to remain so in the near future (IEA, 2007a). This change in demand exemplifies the need for careful policy planning in order to be able to provide long-term commitments and greater investment confidence to industry, potential investors, financiers and other stakeholders, by reducing the risks.

In the EU, aside from the strong German leadership, other countries are also investing in biofuels. Relatively small volumes are being produced for use as an octane enhancer in low blends with gasoline, resulting in steady demand over the past decade. France has long produced ethanol from cereals; Austria's policies have resulted in steady growth since 1990; production in the Czech Republic has declined; and more countries including Spain, Slovakia, Sweden, UK, Poland and Italy have established policies since 2000; biofuels in Spain and Sweden in particular have experienced significant growth as a result (Figure 12). Overall, the total production of biofuels in the EU has grown steadily.

Figure 12. **Biofuel consumption trends in OECD-EU countries, 1990-2005**



Source: IEA (2007a).

Key point

Biofuel consumption in OECD-EU countries is showing steady growth with new countries entering the market annually and import volumes increasing.

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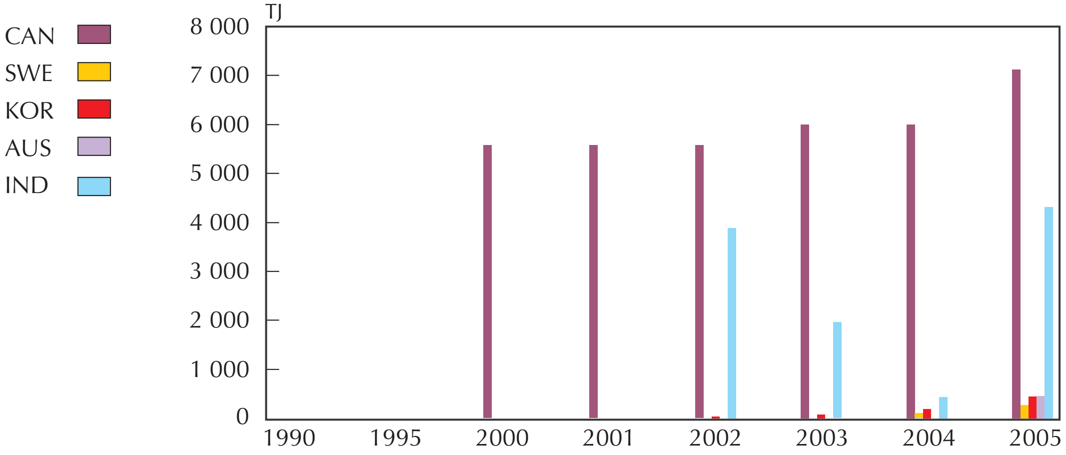
Biofuel imports have increased, but these are not discussed in detail. Recent concerns about the use of non-sustainable biomass feedstock and production methods for biofuels, and the concept of certification arising as a result, has caused some governments and oil companies to review their current policies relating to trade and tariffs. For example, the proposed 10% EU biofuels directive, announced in January 2008, is currently under debate, and supporting legislation will be sought through the European Parliament. This will attempt to ensure that biofuel suppliers, whether inside or outside EU, are able to certify that sustainability criteria have been met during energy crop production and growth, and biofuel processing.

Countries outside the EU producing significant amounts of biofuels each year (Figure 13) include India and South Korea.

Figure 13. **Biofuel consumption trends in other countries, 1990-2005**



Source: IEA (2007a).
Notes: Canadian data were unavailable for 1990 and 1995. The reason for large fluctuations in the Indian data from 2002 to 2005 is not known.

Key point

Canada, India and Australia have increased their production of bioethanol for internal consumption while Korea and Switzerland focused nearly exclusively on biodiesel production.

Table 4 provides further statistical detail, summarising the RES-T trends since 1990 in absolute terms and share of RES-T in total transport fuel consumption.[16]

16. *Annex 2 on the CD-ROM attached to this publication includes tables on the contribution of bioethanol and biodiesel respectively to aggregate RES-T production.*

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Table 4. **Global RES-T trends in absolute terms and percentage share of RES-T in total road transport fuel consumption, 1990-2005**

	1990		1995	
Country	Renewable road transport fuel consumption (TJ)	Share of RE road transport fuel in total road transport fuel consumption (%)	Renewable road transport fuel consumption (TJ)	Share of RE road transport fuel in total road transport fuel consumption (%)
AUT	73	0.0%	220	0.1%
BEL	0	0.0%	0	0.0%
CZE	0	0.0%	666	0.6%
DEU	0	0.0%	1 303	0.1%
DNK	0	0.0%	0	0.0%
ESP	0	0.0%	0	0.0%
FIN	0	0.0%	0	0.0%
FRA	0	0.0%	7 156	0.4%
GBR	0	0.0%	0	0.0%
GRC	0	0.0%	0	0.0%
HUN	0	0.0%	0	0.0%
IRL	0	0.0%	0	0.0%
ITA	0	0.0%	0	0.0%
LUX	0	0.0%	0	0.0%
NLD	0	0.0%	0	0.0%
POL	0	0.0%	0	0.0%
PRT	0	0.0%	0	0.0%
SVK	0	0.0%	0	0.0%
SWE	0	0.0%	0	0.0%
AUS	0	0.0%	0	0.0%
CAN	0	0.0%	0	0.0%
CHE	0	0.0%	0	0.0%
ISL	0	0.0%	0	0.0%
JPN	0	0.0%	0	0.0%
KOR	0	0.0%	0	0.0%
MEX	0	0.0%	0	0.0%
NOR	0	0.0%	0	0.0%
NZL	0	0.0%	0	0.0%
TUR	0	0.0%	0	0.0%
USA	0	0.0%	110 903	0.6%
BRA	245 258	20.2%	287 509	18.6%
CHN	0	0.0%	0	0.0%
IND	0	0.0%	0	0.0%
RUS	0	0.0%	0	0.0%
ZAF	0	0.0%	0	0.0%
WORLD	**251 400**	**0.5%**	**411 402**	**0.8%**

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Table 4 *(continued)* **Global RES-T trends in absolute terms and percentage share of RES-T in total road transport fuel consumption, 1990-2005**

	2000		2001	
Country	Renewable road transport fuel consumption (TJ)	Share of RE road transport fuel in total road transport fuel consumption (%)	Renewable road transport fuel consumption (TJ)	Share of RE road transport fuel in total road transport fuel consumption (%)
AUT	366	0.2%	403	0.2%
BEL	0	0.0%	0	0.0%
CZE	2 660	1.5%	1 924	1.0%
DEU	9 310	0.4%	13 035	0.6%
DNK	0	0.0%	0	0.0%
ESP	3 014	0.3%	3 014	0.3%
FIN	0	0.0%	0	0.0%
FRA	14 927	0.8%	14 715	0.8%
GBR	0	0.0%	0	0.0%
GRC	0	0.0%	0	0.0%
HUN	0	0.0%	0	0.0%
IRL	0	0.0%	0	0.0%
ITA	0	0.0%	0	0.0%
LUX	0	0.0%	0	0.0%
NLD	0	0.0%	0	0.0%
POL	0	0.0%	0	0.0%
PRT	0	0.0%	0	0.0%
SVK	0	0.0%	1 299	2.2%
SWE	0	0.0%	676	0.2%
AUS	0	0.0%	0	0.0%
CAN	5 573	0.3%	5 573	0.3%
CHE	0	0.0%	0	0.0%
ISL	0	0.0%	0	0.0%
JPN	0	0.0%	0	0.0%
KOR	0	0.0%	0	0.0%
MEX	0	0.0%	0	0.0%
NOR	0	0.0%	0	0.0%
NZL	0	0.0%	0	0.0%
TUR	0	0.0%	0	0.0%
USA	133 457	0.6%	140 492	0.7%
BRA	256 712	14.1%	223 048	12.2%
CHN	0	0.0%	0	0.0%
IND	0	0.0%	0	0.0%
RUS	0	0.0%	0	0.0%
ZAF	0	0.0%	0	0.0%
WORLD	**429 057**	**0.7%**	**407 154**	**0.7%**

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Table 4 *(continued)* **Global RES-T trends in absolute terms and percentage share of RES-T in total road transport fuel consumption, 1990-2005**

	2002		2003	
Country	Renewable road transport fuel consumption (TJ)	Share of RE road transport fuel in total road transport fuel consumption (%)	Renewable road transport fuel consumption (TJ)	Share of RE road transport fuel in total road transport fuel consumption (%)
AUT	439	0.2%	409	0.2%
BEL	0	0.0%	0	0.0%
CZE	2 774	1.4%	2 660	1.2%
DEU	20 483	0.9%	29 793	1.3%
DNK	0	0.0%	0	0.0%
ESP	5 827	0.5%	8 007	0.6%
FIN	28	0.0%	165	0.1%
FRA	15 387	0.8%	14 165	0.8%
GBR	111	0.0%	590	0.0%
GRC	0	0.0%	0	0.0%
HUN	0	0.0%	0	0.0%
IRL	0	0.0%	0	0.0%
ITA	0	0.0%	0	0.0%
LUX	0	0.0%	0	0.0%
NLD	0	0.0%	0	0.0%
POL	0	0.0%	1 179	0.3%
PRT	0	0.0%	0	0.0%
SVK	120	0.2%	81	0.1%
SWE	1 495	0.5%	3 105	1.1%
AUS	0	0.0%	0	0.0%
CAN	5 573	0.3%	6 002	0.3%
CHE	0	0.0%	0	0.0%
ISL	0	0.0%	0	0.0%
JPN	0	0.0%	0	0.0%
KOR	37	0.0%	74	0.0%
MEX	0	0.0%	0	0.0%
NOR	0	0.0%	0	0.0%
NZL	0	0.0%	0	0.0%
TUR	0	0.0%	0	0.0%
USA	168 389	0.8%	229 955	1.1%
BRA	251 704	13.4%	239 050	13.0%
CHN	0	0.0%	0	0.0%
IND	3 885	0.3%	1 956	0.2%
RUS	0	0.0%	0	0.0%
ZAF	0	0.0%	0	0.0%
WORLD	**479 262**	**0.8%**	**540 232**	**0.9%**

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Table 4 *(continued)* **Global RES-T trends in absolute terms and percentage share of RES-T in total road transport fuel consumption, 1990-2005**

	2004		2005		
Country	Renewable road transport fuel consumption (TJ)	Share of RE road transport fuel in total road transport fuel consumption (%)	Renewable road transport fuel consumption (TJ)	Share of RE road transport fuel in total road transport fuel consumption (%)	1990-2005 Growth
AUT	549	0.2%	1 793	0.6%	2 350.6%
BEL	0	0.0%	0	0.0%	n/a
CZE	1 368	0.6%	111	0.0%	n/a
DEU	40 846	1.8%	81 302	3.7%	n/a
DNK	0	0.0%	0	0.0%	n/a
ESP	9 533	0.7%	10 846	0.8%	n/a
FIN	193	0.1%	0	0.0%	n/a
FRA	15 441	0.9%	17 729	1.0%	n/a
GBR	663	0.0%	3 376	0.2%	n/a
GRC	0	0.0%	0	0.0%	n/a
HUN	0	0.0%	214	0.1%	n/a
IRL	0	0.0%	0	0.0%	n/a
ITA	10 537	0.6%	7 369	0.4%	n/a
LUX	37	0.0%	37	0.0%	n/a
NLD	0	0.0%	0	0.0%	n/a
POL	563	0.1%	1 973	0.4%	n/a
PRT	0	0.0%	0	0.0%	n/a
SVK	38	0.1%	439	0.6%	n/a
SWE	5 906	1.9%	6 300	2.0%	n/a
AUS	0	0.0%	456	0.0%	n/a
CAN	6 002	0.3%	7 128	0.4%	n/a
CHE	96	0.0%	262	0.1%	n/a
ISL	0	0.0%	0	0.0%	n/a
JPN	0	0.0%	0	0.0%	n/a
KOR	184	0.0%	442	0.0%	n/a
MEX	0	0.0%	0	0.0%	n/a
NOR	0	0.0%	0	0.0%	n/a
NZL	0	0.0%	0	0.0%	n/a
TUR	0	0.0%	0	0.0%	n/a
USA	289 394	1.3%	337 920	1.5%	n/a
BRA	266 862	13.3%	288 933	14.2%	17.8%
CHN	0	0.0%	0	0.0%	n/a
IND	429	0.0%	4 314	0.3%	n/a
RUS	0	0.0%	0	0.0%	n/a
ZAF	0	0.0%	0	0.0%	n/a
WORLD	**651 072**	**1.0%**	**774 100**	**1.2%**	**207.9%**

NB: “n/a” means “not applicable”.
Source: IEA (2007a).

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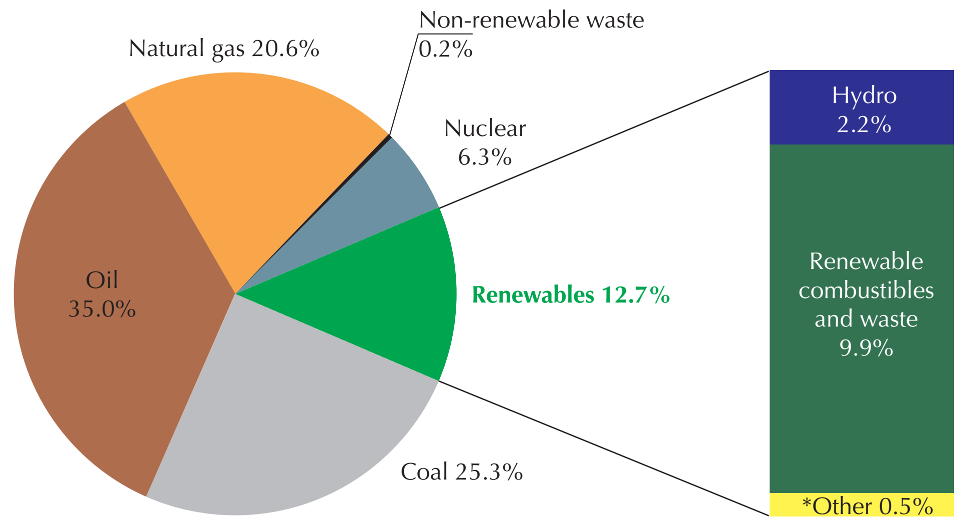
Renewables in primary energy supply

In 2005, world total primary energy supply (TPES) was 11 443 Mtoe, of which 12.7%, or 1 448 Mtoe, was produced from renewable energy sources. This compares to a share of 34% for oil, 25.3% for coal, 20.6% for natural gas and 6.3% for nuclear energy (IEA, 2007a).

Figure 14. **Share of renewables in world total primary energy supply, 2005**



** "Other" renewables comprise geothermal, wind, solar, tidal, and wave energy.*
Source: IEA (2007a).

Key point

Renewables contributed to TPES twice the amount of energy supplied by nuclear power, but had a smaller share than the different fossil energy sources.

Due to widespread non-commercial use in developing countries, solid biomass is by far the largest renewable energy source, representing 9.6% of world TPES, or 75.6% of global renewables supply. The second largest source is hydro power, which provides 2.2% of world TPES, or 17.4% of renewables. Geothermal is the third largest renewable source and is much smaller, representing 0.4% of world TPES, or 3.2% of renewables supply in the world. The contribution of "new" renewables (solar, wind and tide) to energy supply is still very marginal, representing less than 0.1% of world TPES, or 0.9% of renewables supply. However, the growth in supply of the "new" RETs wind and solar have outstripped that of the more mature technologies, hydropower and solid biomass, and of renewables in general. From 1990 to 2005, wind energy supply grew by 24.3% on average per year, while solar energy supply grew by 5.6% annually, compared to 2.1% for hydropower, 1.5% for solid biomass and 1.8% for overall renewables (IEA, 2007a).

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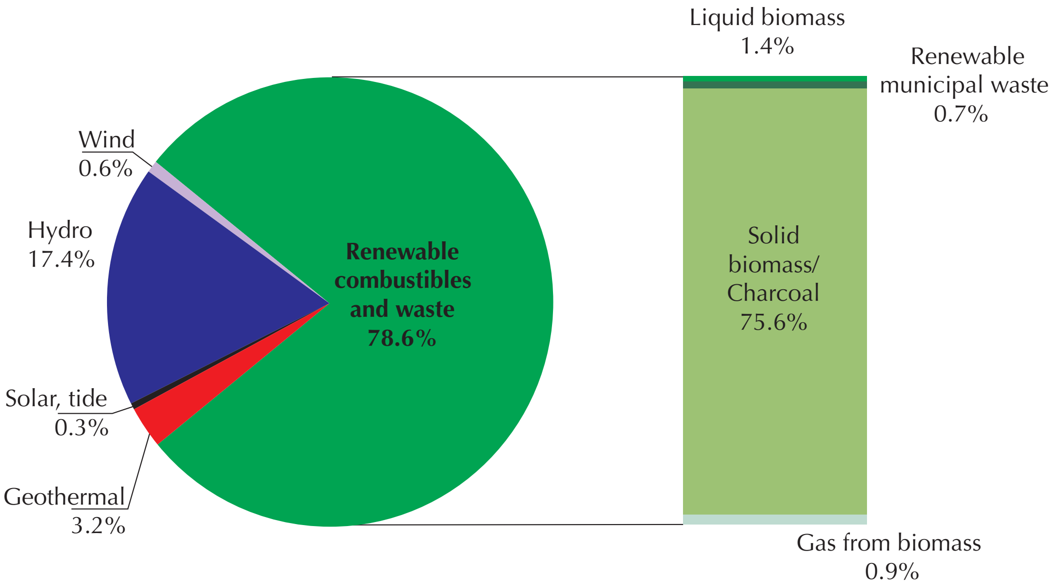
Figure 15. **Product shares in world renewable energy supply, 2005**



Source: IEA (2007a).

Key point

Solid biomass is by far the largest renewable energy source, with widespread consumption of non-commercial traditional biomass for residential cooking and heating in developing countries.

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Chapter 2
Potentials and Costs for Renewable Energy Technologies

A range of different renewable energy technologies (RETs) and resources exist for electricity, heat and biofuel production. A comprehensive investigation of the future RET development requires a detailed investigation of country-specific variables. For example, potentials for specific RETs vary with the available resource, and with technology development, but also depend on country-specific constraints.

In this chapter, the realisable mid-term potentials (to a time horizon of 2020) are discussed for the various RET options. Geographically, the assessment encompasses all OECD countries and the BRICS (Brazil, Russia, India, China and South Africa).

This assessment covers electricity generation from the following renewable energy sources (RES-E): biogas, biomass, renewable municipal waste, onshore wind, offshore wind, hydropower, solar thermal, solar photovoltaics (PV), tidal and wave energy, and geothermal energy. Assessed renewable heat technologies (RES-H) comprise heat from biomass-based combined heat and power production (CHP), geothermal heat, and solar thermal. In the transport sector, only the potential of first-generation biofuels is assessed, and no distinction is drawn among alternative technologies (ethanol, biodiesel, etc.).

Detailed descriptions and appraisals of the status of individual renewable energy technologies are available from the IEA publications *Renewable Energy RD&D Priorities: Insights from IEA Technology Programmes* (IEA, 2006) and *Energy Technology Perspectives 2008* (IEA, 2008).

Methodological approach

There is much discussion of the potentials of various energy resources in the literature. However, terminologies vary. Therefore, this report attempts first to establish clear definitions.

Theoretical potential: This represents the theoretical upper limit of the amount of energy that can be generated from a specific resource, over a defined area, based on current scientific knowledge. It depends on physical flows only (*e.g.* average solar irradiation on a certain region).

Technical potential: The technical potential can be derived on the basis of technical boundary conditions, *e.g.* efficiencies of conversion technologies, or overall technical limitations such as available land area for wind turbine installation. For most resources, the technical potential is dynamic: *e.g.* with improved research and development, conversion technologies may be improved, with resulting improvement in the technical potential.

Realisable potential: The realisable potential represents the maximum achievable potential, assuming that all existing barriers can be overcome and all development drivers are active. In this respect, general parameters such as market growth rates and planning constraints are taken into account. It is important to note that realisable potential is also time-dependent: it must relate to a certain year. In the long run, the realisable potential tends towards the technical potential.

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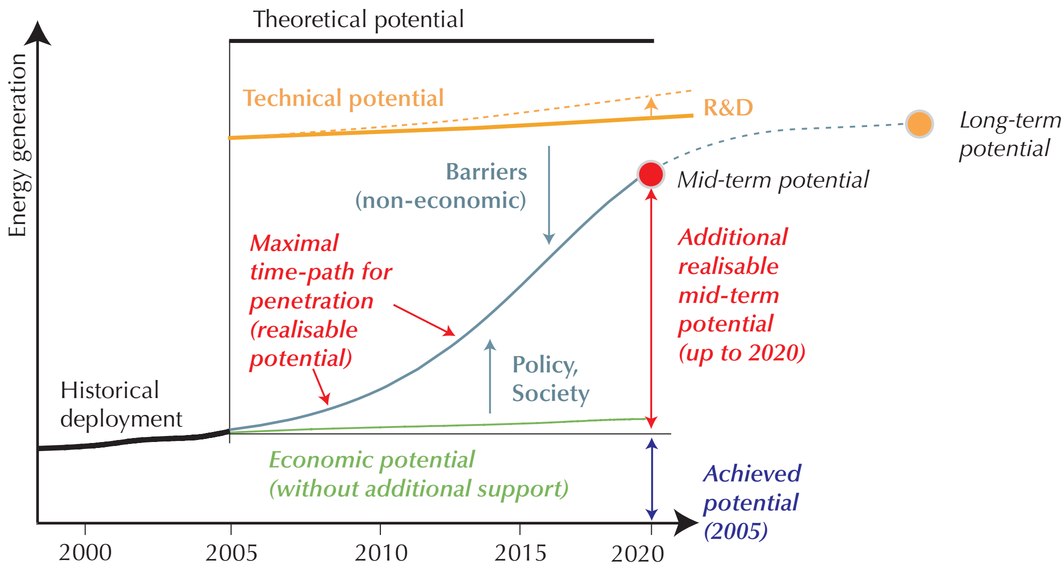
Mid-term potential: The mid-term potential is defined as the realisable potential in 2020.

Economic potential: The economic potential is defined as that potential which can be exploited without the need for additional support, *i.e.* whose exploitation is competitive compared with conventional incumbent technologies.

The **total realisable potential** is the sum of the achieved potential (cumulative installed capacity) by 2005 plus the **additional realisable potential** in the remaining timeframe (2005-2020).

The relationships among the different metrics of potential are depicted in Figure 1.

Figure 1. **Metrics relating to RET potentials**



Source: Based on IEA calculations & Resch et al., 2008.

Key point

In the long run, the realisable potential tends towards the technical potential.

The assessment of the realisable mid-term potential of RETs up to 2020 was carried out using the "Green-X" model for European countries and the "WorldRES" model for other OECD countries and the BRICS.[17]

17. The Green-X model, an independent computer programme, is the core product developed in the EU research project Green-X in the period 2002 to 2004 (Huber et al.*, 2004). It enables a comparative and quantitative analysis of the future deployment of RES in all energy sectors (i.e. electricity, grid-connected and non-grid, heat and transport) based on applied energy policy strategies in a dynamic context. The model was further expanded and updated in the EU projects FORRES 2020 (Ragwitz* et al.*, 2005) and OPTRES (Resch* et al.*, 2006) over the period 2004-2007. In its present version it covers all EU-27 countries plus Croatia. More detailed information is available at: www.green-x.at.*
The projections of renewable energy technologies (RETs) for the IEA World Energy Outlook 2007 *publication (IEA, 2007) were derived in the separate model "WorldRES", allowing an assessment of the future deployment. This model has been developed for this purpose by the Energy Economics Group (EEG) at Vienna University of Technology in cooperation with the Wiener Zentrum für Energie, Umwelt und Klima. This builds on previous work completed in a fruitful cooperation in the context of past years of the IEA's World Energy Outlook series.*

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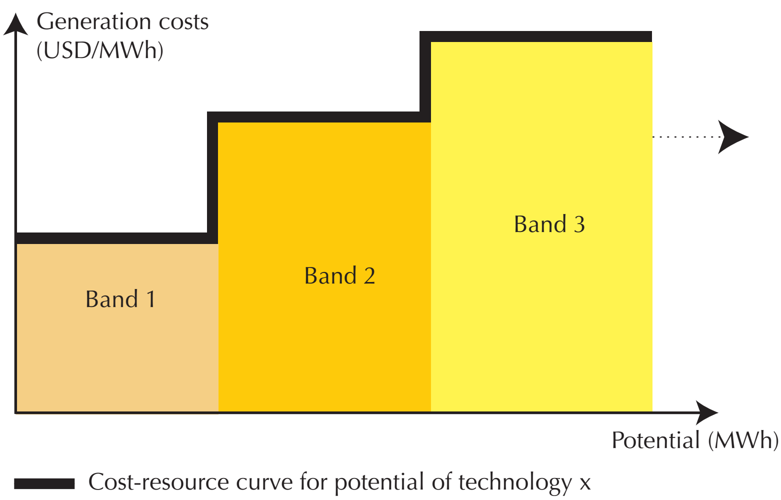
The applied models take three main aspects into account:

- country-specific static cost-resource curves for each renewable energy technology;
- experience curves related to technology learning; and
- country- and technology-specific diffusion S-curves.

First, the model calculates a static technical potential, based on the current state-of the art and costs of a given technology, using a static cost-resource curve (Figure 2). The latter describes the relationship between categories of technical available potentials and the corresponding cost of exploitation, which will depend on the specific local geographical resource. As for other energy technologies based on a limited resource, costs will rise with increasing utilisation. For example, in the case of wind energy, power plants with the best wind conditions, (*i.e.* wind density and average number of yearly full-load hours) will be exploited first, at a certain generation cost. Once this potential is used, another group of sites with lower wind density – and therefore higher costs per kWh – will be exploited; and so on. In reality, the cost-resource curve is a continuous function in function of the potential. For simplification purposes, the model uses a stepped discrete function, which subdivides the technology potential into different cost-resource bands (Figure 2).

Figure 2. **Cost-resource curve for potential of a specific RET**



Source: adapted from Ragwitz et al. *(2003).*
Note: The model assumes that renewable technologies are first applied in locations with best resource conditions and lower costs. After this potential band is exploited, other locations with less resource and higher costs are used.

However, a static cost-resource approach does not take into account technology learning and corresponding reduction of investment costs, which are of course crucial to calculate the potential over a longer period of time. In order to take this into account, the model uses technology experience / learning curves, which describe how costs decline with accumulated experience and corresponding cumulative production or installed capacity. In this way the cost-resource curve becomes dynamic, *i.e.* the costs of later potential band exploitation are actually lower, thanks to technology learning that occurred in the meantime.

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Empirical analysis on technology innovation has proven that costs decline by a constant percentage with each doubling of the produced/installed capacity. The key parameter here is the learning ratio (LR). For instance a LR of 15% means that the costs per unit are reduced by 15% for each doubling of cumulative installed capacity. As a benchmark, the learning rates indicated for wind on-shore, wind off-shore and solar photovoltaics (PV) in *Energy Technology Perspectives 2008* are respectively 7%, 9% and 18% (IEA, 2008).

The third aspect taken into account by the model is technology dynamics, *i.e.* the general patterns by which technologies diffuse through competitive markets.[18] In accordance with general diffusion theory, market penetration of any new technology typically follows an S-curve pattern. Applying such a curve to the potential reflects both technical and non-technical constraints. An example of the former is for instance the scaling up of component and technology manufacturing capacity, which needs time. Non-technical constraints include for instance market and administrative barriers.

The additional mid-term (2020) realisable potential calculated by the model is calibrated backwards from the long-term technical realisable potential, which represents the maximum achievable potential assuming that all existing barriers can be overcome and all driving forces are active. Applying such an S-curve also accounts for the starting point of deployment. For example, if a certain country has a significant long-term technical wind energy potential, but its achieved starting potential in 2005 is low, the exploitation of the whole technical potential will require significant time. As a consequence the realisable mid-term potential by 2020 will be significantly lower than the long-term technical potential.

The mid-term realisable potentials for every RET are derived for each country's resource and take into account technology development.

Overview of mid-term RET potentials

This section gives an overview of the outcomes of the assessment of realisable mid-term potentials (to 2020) for the range of considered RETs in OECD countries and the BRICS. Annex 2 provides greater detail on the assessment of the individual RET potentials and how they were derived.

Table 1 provides total future potentials[19] by technology and by country. All 27 EU Member States (EU-27) are grouped together. Corresponding data for the individual EU countries are given in Table 2.

At the global scale (comprising all OECD countries and the BRICS), the largest mid-term potentials exist in the electricity sector (8 918 TWh), followed by heat (5 667 TWh) and, finally, biofuels as reserved for the transport sector (1 556 TWh). However, the inclusion of decentralised biomass heat, comprising traditional as well as advanced biomass heat, would change this ranking, and raise renewable heat to first place[20].

18. *For a brief discussion of this topic see (Grübler* et al., *1998).*

19. *Please note that the assessed total realisable mid-term potentials comprise both the already exploited potential and the one to be realised in the near- to mid-term future to 2020.*

20. *Decentralised use of biomass for heat purposes is beyond the scope of the present report because of lack of statistical data on non-commercial use of bioenergy.*

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Table 1. **Total realisable mid-term potentials for RETs: OECD and BRICS**

Total realisable mid-term generation potentials for RETs (in TWh)	Biogas	Solid biomass	Renewable municipal waste	Geothermal electricity	Hydropower	Solar photovoltaics	Solar thermal electricity	Tidal and wave energy	Onshore wind	Offshore wind	**Total RES-E**	**Biofuels (domestic)**	Solar thermal heat	Geothermal heat	Biomass CHP heat	**Total RES-H**
USA	94.5	381.8	25.3	36.0	304.1	68.4	16.8	2.3	228.1	72.3	**1 229.6**	**427.4**	298.5	452.8	503.7	**1 255.0**
Canada	21.8	148.7	2.2	0.1	466.3	4.0	0.3	2.3	41.7	15.7	**703.2**	24.0	22.6	13.9	151.4	188.0
Mexico	12.0	71.2	5.5	12.2	52.0	7.3	2.7	0.1	5.1	1.2	**169.2**	**27.1**	13.0	7.3	55.2	75.5
Japan	14.6	28.4	16.8	6.6	115.8	26.0	0.0	1.0	17.7	17.2	**244.1**	3.2	47.6	53.0	50.0	150.6
Korea	4.3	5.8	5.3	0.0	10.7	10.4	0.1	0.4	1.5	9.0	**47.6**	**1.1**	4.9	10.1	11.6	26.6
Australia	19.9	57.5	10.9	1.4	26.4	12.6	4.2	0.9	29.8	9.6	**173.3**	17.4	37.8	26.3	51.5	115.6
New Zealand	1.4	3.7	0.4	4.3	35.2	0.4	0.1	0.3	9.7	1.1	**56.8**	**1.4**	1.3	43.9	9.7	54.8
Iceland	0.9	1.2	0.5	4.1	32.0	0.2	0.0	3.5	1.2	4.5	**48.1**	0.8	2.5	34.6	9.0	46.1
Norway	0.7	7.2	0.7	0.0	158.3	4.5	0.0	9.0	37.5	22.5	**240.3**	**2.8**	3.8	8.8	11.4	24.1
Switzerland	1.7	3.6	1.1	0.0	39.1	0.2	0.0	0.0	1.6	0.0	**47.4**	2.6	4.2	7.0	6.5	17.7
Turkey	15.9	18.8	2.8	4.2	120.0	15.0	17.5	10.0	24.8	14.3	**243.2**	**21.9**	74.3	60.1	27.9	162.3
Russia	27.3	155.4	5.0	5.4	387.8	0.7	0.8	0.2	23.6	2.1	**608.1**	43.7	25.9	60.4	232.4	318.7
China	182.4	420.0	76.2	3.0	1 048.4	111.0	10.2	0.5	142.0	5.7	**1 999.3**	**216.2**	517.4	343.7	437.8	1298.9
India	102.9	69.8	57.5	0.5	302.8	22.2	0.2	0.5	83.2	6.1	**645.8**	110.2	166.6	74.4	140.7	381.6
Brazil	14.4	87.9	4.6	0.0	500.1	15.3	2.7	0.2	7.9	1.4	**634.5**	**224.0**	17.1	10.8	60.6	88.5
South Africa	5.5	15.6	3.3	0.1	12.3	3.6	4.9	0.1	6.4	0.9	**52.8**	16.9	**13.7**	**10.6**	**14.1**	**38.4**
EU 27	123.6	364.9	39.9	9.5	430.2	92.2	29.9	124.6	300.0	259.8	**1 774.4**	**415.7**	454.3	406.7	563.3	1424.2
Global (OECD and BRICS)	**644**	**1 841**	**258**	**87**	**4 041**	**394**	**91**	**156**	**962**	**443**	**8 918**	**1 556**	**1 706**	**1 624**	**2 337**	**5667**

Source: Based on IEA calculations & Resch et al. *(2008).*

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Table 2 shows a similar ranking for the EU-27, with comparatively larger contributions of RETs in the heating sector.

As Tables 3 and 4 indicate, for most countries, the additional realisable potential to 2020 far outstrips the achieved deployment of renewables to date. The aggregate additional potential to 2020 for RES-E in OECD countries and the BRICS amounts to 6 271 TWh. This is equivalent to 41% of 2005 total electricity generation, and represents more than double the current RES-E generation. In absolute terms, China has the largest additional potential, followed by the EU-27, the USA, India, Russia, Canada and Brazil. Overall, BRICS account for 47% of the additional realisable potential among those countries analysed.

The ratio of additional potential to achieved generation in 2005 is even larger for RES-H.[21] For solar thermal and geothermal heat the additional potential is almost thirty times greater than the heat production from these sources in 2005.

In the case of renewable liquid transport fuels (RES-T), the estimated additional realisable potential of first-generation biofuels is more than five times the current production.

For the RES-E sector, Table 4 shows a similar picture for the EU-27 with regard to the ratio of additional potential to achieved generation. For RES-H, the additional potential in the EU-27 as a whole is more than 21 times achieved potential to date, which is lower than for the aggregated OECD countries and BRICS. For renewable transport fuels, the additional potential in the EU-27 is nearly ten times greater than the region's biofuel production in 2005.[22]

The following sections highlight individual sectors, also discussing technology specific prospects. All 27 EU countries are again grouped together.

21. For biomass CHP heat, the achieved potential is not taken into account, i.e. *total potential is equal to additional potential.*

22. A detailed discussion of the mid-term potentials for RETs in the European Union is presented in (Resch et al.*, 2006) and (Ragwitz* et al.*, 2005).*

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Table 2. **Total realisable mid-term RET potentials: EU-27**

Total realisable mid-term generation potentials for RETs (in TWh)	Biogas	Solid biomass	Renewable municipal waste	Geothermal electricity	Hydropower	Solar photovoltaics	Solar thermal electricity	Tidal and wave energy	Onshore wind	Offshore wind	**Total RES-E**	**Biofuels (domestic)**	Solar thermal heat	Geothermal heat	Biomass CHP heat	**Total RES-H**
Austria	1.9	7.5	0.9	0.0	44.7	2.7	0.0	0.0	0.5	0.0	**62.6**	**4.4**	7.7	9.5	10.5	**27.5**
Belgium	3.2	3.1	1.0	0.0	0.4	1.6	0.0	0.2	4.3	3.6	**17.4**	**3.6**	**9.6**	**13.1**	**8.7**	**31.5**
Denmark	1.9	5.3	1.0	0.0	0.0	1.4	0.0	2.6	8.7	10.8	**31.7**	**12.0**	5.4	9.4	9.9	**24.7**
Finland	1.3	20.5	0.7	0.0	15.6	1.7	0.0	1.5	7.9	4.1	**53.2**	**8.5**	**7.7**	**5.9**	**30.1**	**43.7**
France	22.8	68.4	6.0	0.2	73.6	16.3	0.0	13.2	56.4	29.9	**286.8**	**68.5**	68.7	49.4	97.8	**215.9**
Germany	16.4	49.4	4.8	0.0	25.1	15.0	0.0	7.7	53.3	76.8	**248.6**	**42.7**	**77.0**	**88.3**	**77.3**	**242.6**
Greece	1.6	6.2	0.4	0.2	5.0	2.9	2.6	4.0	8.8	2.6	**34.5**	**9.7**	10.4	5.7	6.8	**22.9**
Ireland	3.4	3.8	0.5	0.0	1.0	0.9	0.0	3.9	2.8	3.6	**19.8**	**4.7**	**3.6**	**3.5**	**9.3**	**16.4**
Italy	10.4	26.6	4.9	7.3	56.8	10.2	7.6	3.2	28.6	2.4	**158.0**	**28.4**	70.4	57.4	45.5	**173.3**
Luxembourg	0.2	0.3	0.0	0.0	0.1	0.1	0.0	0.0	0.2	0.0	**0.9**	**0.2**	**0.1**	**0.2**	**0.6**	**0.9**
Netherlands	4.3	3.9	2.4	0.0	0.1	3.3	0.0	1.0	5.6	19.8	**40.5**	**4.1**	14.9	14.1	12.8	**41.9**
Portugal	2.3	6.1	1.0	0.3	15.8	2.6	2.4	7.4	7.0	6.6	**51.5**	**5.4**	**10.0**	**3.3**	**6.8**	**20.2**
Spain	13.2	41.1	5.7	0.1	52.1	14.1	17.2	13.2	39.3	14.4	**210.5**	**51.2**	39.3	15.0	45.2	**99.5**
Sweden	1.9	15.7	1.5	0.0	75.1	3.5	0.0	3.0	9.8	13.6	**124.1**	**11.4**	**9.4**	**11.0**	**25.5**	**45.8**
United Kingdom	16.3	20.7	4.1	0.0	5.4	11.9	0.0	58.9	28.5	67.0	**212.8**	**25.4**	56.1	53.7	49.5	**159.3**
Cyprus	0.1	0.2	0.1	0.0	0.0	0.1	0.0	0.2	0.6	0.3	**1.6**	**0.3**	**6.9**	**7.1**	**0.3**	**14.4**

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Table 2. *(continued)* **Total realisable mid-term RET potentials: EU-27**

Total realisable mid-term generation potentials for RETs (in TWh)	Biogas	Solid biomass	Renewable municipal waste	Geothermal electricity	Hydropower	Solar photovoltaics	Solar thermal electricity	Tidal and wave energy	Onshore wind	Offshore wind	**Total RES-E**	**Biofuels (domestic)**	Solar thermal heat	Geothermal heat	Biomass CHP heat	**Total RES-H**
Czech Republic	2.2	6.9	0.4	0.0	2.5	0.6	0.0	0.0	4.5	0.0	**17.1**	**9.3**	5.0	5.3	10.3	**20.6**
Estonia	0.4	3.5	0.1	0.0	0.1	0.1	0.0	1.2	1.3	0.3	**6.9**	**3.3**	**0.7**	**0.7**	**4.7**	**6.2**
Hungary	2.2	11.5	0.8	0.0	1.4	0.3	0.0	0.0	1.2	0.0	**17.3**	**14.4**	5.0	7.6	14.5	**27.1**
Latvia	0.5	3.4	0.0	0.0	4.0	0.1	0.0	0.5	1.3	0.3	**10.1**	**6.9**	**1.1**	**1.1**	**4.8**	**7.0**
Lithuania	0.7	4.2	0.1	0.0	0.7	0.1	0.0	0.2	1.3	0.1	**7.5**	**11.5**	1.9	2.2	6.1	**10.3**
Malta	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	**0.5**	**0.0**	**0.2**	**0.0**	**0.1**	**0.3**
Poland	8.0	29.4	1.6	0.0	3.2	1.4	0.0	1.1	8.6	2.5	**55.8**	**49.8**	20.6	20.3	47.0	**88.0**
Slovakia	1.0	3.3	0.3	0.0	5.3	0.2	0.0	0.0	0.6	0.0	**10.7**	**4.3**	**2.5**	**4.2**	**5.0**	**11.8**
Slovenia	0.7	1.1	0.4	0.0	9.5	0.1	0.0	0.0	0.3	0.0	**12.1**	**0.6**	1.5	2.3	2.1	**5.9**
Bulgaria	1.4	7.5	0.3	1.3	10.8	0.4	0.0	0.8	7.3	0.4	**30.3**	**11.2**	**4.3**	**2.6**	**10.4**	**17.3**
Romania	5.2	15.4	0.9	0.1	21.7	0.8	0.0	0.5	6.7	0.2	**51.5**	**23.8**	14.2	13.5	21.7	**49.5**
EU 27	**124**	**365**	**40**	**9**	**430**	**92**	**30**	**125**	**300**	**260**	**1 774**	**416**	**454**	**407**	**563**	**1 424**

Source: Based on IEA calculations & Resch et al. *(2008).*

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Table 3. **Additional realisable mid-term RET potentials: OECD and BRICS**

Additional realisable mid-term generation potentials for RETs (in TWh)	Biogas	Solid biomass	Renewable municipal waste	Geothermal electricity	Hydropower	Solar photovoltaics	Solar thermal electricity	Tidal and wave energy	Onshore wind	Offshore wind	**Total RES-E**	**Biofuels (domestic)**	Solar thermal heat	Geothermal heat	Biomass CHP heat[1]	**Total RES-H**
USA	88.0	340.0	16.8	19.2	28.4	67.9	16.8	2.3	211.3	72.3	**871.6**	**330.8**	290.0	442.9	*n/a*	*n/a*
Canada	21.1	140.4	2.2	0.1	98.6	4.0	0.3	2.3	39.7	15.7	**324.4**	**22.5**	**22.6**	**13.9**	*n/a*	*n/a*
Mexico	12.0	68.3	5.5	4.9	22.9	7.2	2.7	0.1	5.1	1.2	**129.9**	**27.1**	12.8	7.3	*n/a*	*n/a*
Japan	14.6	15.9	13.4	3.3	26.5	24.2	0.0	1.0	15.1	17.2	**134.7**	**3.2**	**40.9**	**50.5**	*n/a*	*n/a*
Korea	4.2	5.8	5.3	0.0	6.7	10.4	0.1	0.4	1.3	9.0	**43.2**	**1.0**	4.5	10.1	*n/a*	*n/a*
Australia	19.0	56.4	10.9	1.4	10.1	12.5	4.2	0.9	27.8	9.6	**152.8**	**17.2**	**37.1**	**26.3**	*n/a*	*n/a*
New Zealand	1.3	3.1	0.4	1.5	10.0	0.4	0.1	0.3	9.2	1.1	**27.6**	**1.4**	1.3	39.5	*n/a*	*n/a*
Iceland	0.9	1.2	0.5	2.5	25.4	0.2	0.0	3.5	1.2	4.5	**39.8**	**0.8**	**2.5**	**25.4**	*n/a*	*n/a*
Norway	0.7	7.2	0.6	0.0	41.0	4.5	0.0	9.0	36.9	22.5	**122.1**	**2.8**	3.8	8.8	*n/a*	*n/a*
Switzerland	1.6	3.5	0.3	0.0	2.0	0.2	0.0	0.0	1.6	0.0	**9.2**	**2.5**	**4.0**	**5.4**	*n/a*	*n/a*
Turkey	15.8	18.8	2.8	4.2	77.7	15.0	17.5	10.0	24.7	14.3	**200.7**	**21.9**	69.8	49.4	*n/a*	*n/a*
Russia	27.3	150.2	5.0	5.0	215.3	0.7	0.8	0.2	23.5	2.1	**430.1**	**43.7**	**25.8**	**60.1**	*n/a*	*n/a*
China	182.4	411.7	76.2	2.9	665.6	110.9	10.2	0.5	139.4	5.7	**1 605.5**	**204.5**	485.4	343.7	*n/a*	*n/a*
India	102.9	69.7	57.5	0.5	204.1	22.0	0.2	0.5	73.9	6.1	**537.6**	**98.0**	**165.5**	**74.4**	*n/a*	*n/a*
Brazil	14.4	87.2	4.6	0.0	169.4	15.3	2.7	0.2	7.8	1.4	**303.1**	**142.3**	15.9	10.8	*n/a*	*n/a*
South Africa	5.5	15.2	3.3	0.1	11.1	3.6	4.9	0.1	6.4	0.9	**51.1**	**16.9**	**13.6**	**10.6**	*n/a*	*n/a*
EU 27	110.3	324.7	31.7	4.1	85.1	90.8	29.9	124.6	234.8	258.3	**1 294.2**	**377.8**	446.1	398.1	*n/a*	*n/a*
Global (OECD and BRICS)	**622**	**1719**	**249**	**50**	**1700**	**390**	**91**	**156**	**860**	**442**	**6 278**	**1 314**	**1 641**	**1 577**	*n/a*	*n/a*

1. Because of a lack of verifiable market data - especially in non-EU OECD countries - on the actual production (achieved potential) of biomass CHP heat to 2005, no assessment of the additional realisable potential was possible. Estimates of energy production and additional potentials were calculated on the basis of installed capacities for biomass CHP.

Source: Based on IEA calculations & Resch et al. *(2008).*

Table 4. **Additional realisable mid-term RET potentials: EU-27**

Additional realisable mid-term generation potentials for RETs (in TWh)	Biogas	Solid biomass	Renewable municipal waste	Geothermal electricity	Hydropower	Solar photovoltaics	Solar thermal electricity	Tidal and wave energy	Onshore wind	Offshore wind	**Total RES-E**	**Biofuels (domestic)**	Solar thermal heat	Geothermal heat	Biomass CHP heat[1]	**Total RES-H**
Austria	1.8	5.5	0.8	0.0	6.7	2.7	0.0	0.0	3.8	0.0	**21.3**	**3.8**	6.6	9.3	*n/a*	*n/a*
Belgium	3.0	2.1	0.7	0.0	0.1	1.6	0.0	0.2	4.1	3.6	**15.3**	**3.6**	**9.6**	**13.1**	*n/a*	*n/a*
Denmark	1.6	3.4	0.4	0.0	0.0	1.4	0.0	2.6	3.7	9.5	**21.8**	**12.0**	5.3	9.4	*n/a*	*n/a*
Finland	1.3	12.4	0.7	0.0	1.8	1.6	0.0	1.5	7.7	4.1	**31.1**	**8.5**	**7.7**	**5.9**	*n/a*	*n/a*
France	22.4	67.1	4.4	0.2	8.2	16.2	0.0	13.2	55.3	29.9	**216.8**	**62.8**	68.5	47.9	*n/a*	*n/a*
Germany	11.7	44.8	1.7	0.0	5.5	13.8	0.0	7.7	24.5	76.8	**186.5**	**20.1**	**74.1**	**86.7**	*n/a*	*n/a*
Greece	1.5	6.2	0.4	0.2	1.4	2.9	2.6	4.0	7.6	2.6	**29.5**	**9.7**	9.2	5.7	*n/a*	*n/a*
Ireland	3.3	3.8	0.5	0.0	0.3	0.9	0.0	3.9	1.6	3.6	**17.8**	**4.7**	**3.6**	**3.5**	*n/a*	*n/a*
Italy	9.2	24.4	3.5	1.9	5.6	10.2	7.6	3.2	26.9	2.4	**95.1**	**26.4**	70.1	55.0	*n/a*	*n/a*
Luxembourg	0.1	0.3	0.0	0.0	0.0	0.1	0.0	0.0	0.2	0.0	**0.7**	**0.2**	**0.1**	**0.2**	*n/a*	*n/a*
Netherlands	4.0	1.7	2.4	0.0	0.0	3.3	0.0	1.0	3.8	19.8	**35.9**	**4.1**	14.7	14.1	*n/a*	*n/a*
Portugal	2.3	4.7	0.7	0.2	3.6	2.6	2.4	7.4	5.1	6.6	**35.7**	**5.4**	**9.7**	**3.3**	*n/a*	*n/a*
Spain	12.6	39.5	5.7	0.1	22.1	14.1	17.2	13.2	22.7	14.4	**161.7**	**48.2**	38.5	14.9	*n/a*	*n/a*
Sweden	1.8	8.8	1.5	0.0	6.3	3.5	0.0	3.0	9.0	13.5	**47.5**	**9.7**	**9.3**	**11.0**	*n/a*	*n/a*
United Kingdom	11.6	17.3	4.1	0.0	0.5	11.9	0.0	58.9	25.5	67.0	**196.8**	**24.4**	55.8	53.7	*n/a*	*n/a*
Cyprus	0.1	0.2	0.1	0.0	0.0	0.1	0.0	0.2	0.6	0.3	**1.6**	**0.3**	**6.5**	**7.1**	*n/a*	*n/a*

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Table 4. *(continued)* **Additional realisable mid-term RET potentials: EU-27**

Additional realisable mid-term generation potentials for RETs (in TWh)	Biogas	Solid biomass	Renewable municipal waste	Geothermal electricity	Hydropower	Solar photovoltaics	Solar thermal electricity	Tidal and wave energy	Onshore wind	Offshore wind	**Total RES-E**	**Biofuels (domestic)**	Solar thermal heat	Geothermal heat	Biomass CHP heat[1]	**Total RES-H**
Czech Republic	2.1	6.3	0.4	0.0	0.8	0.6	0.0	0.0	4.5	0.0	**14.5**	**9.3**	5.0	5.3	*n/a*	*n/a*
Estonia	0.4	3.4	0.1	0.0	0.0	0.1	0.0	1.2	1.2	0.3	**6.8**	**3.2**	**0.7**	**0.7**	*n/a*	*n/a*
Hungary	2.2	9.9	0.7	0.0	1.2	0.3	0.0	0.0	1.2	0.0	**15.5**	**14.4**	5.0	6.6	*n/a*	*n/a*
Latvia	0.5	3.4	0.0	0.0	1.1	0.1	0.0	0.5	1.2	0.3	**7.1**	**6.9**	**1.1**	**1.1**	*n/a*	*n/a*
Lithuania	0.7	4.2	0.1	0.0	0.3	0.1	0.0	0.2	1.2	0.1	**7.1**	**11.4**	1.9	2.2	*n/a*	*n/a*
Malta	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	**0.5**	**0.0**	**0.2**	**0.0**	*n/a*	*n/a*
Poland	7.9	28.0	1.6	0.0	0.9	1.4	0.0	1.1	8.4	2.5	**51.7**	**49.3**	20.6	20.2	*n/a*	*n/a*
Slovakia	1.0	3.3	0.2	0.0	0.9	0.2	0.0	0.0	0.6	0.0	**6.2**	**4.2**	**2.5**	**4.2**	*n/a*	*n/a*
Slovenia	0.7	1.0	0.4	0.0	5.6	0.1	0.0	0.0	0.3	0.0	**8.1**	**0.5**	1.4	2.1	*n/a*	*n/a*
Bulgaria	1.4	7.5	0.3	1.3	7.7	0.4	0.0	0.8	7.3	0.4	**27.1**	**11.2**	**4.2**	**2.1**	*n/a*	*n/a*
Romania	5.2	15.4	0.9	0.1	4.5	0.8	0.0	0.5	6.7	0.2	**34.3**	**23.7**	14.2	12.7	*n/a*	*n/a*
EU 27	**110**	**325**	**32**	**4**	**85**	**91**	**30**	**125**	**235**	**258**	**1 294**	**378**	**446**	**398**	*n/a*	*n/a*

1. Because of a lack of verifiable market data - especially in non-EU OECD countries - on the actual production (achieved potential) of biomass CHP heat to 2005, no assessment of the additional realisable potential was possible. Estimates of energy production and additional potentials were calculated on the basis of installed capacities for biomass CHP.

Source: Based on IEA calculations & Resch et al. *(2008).*

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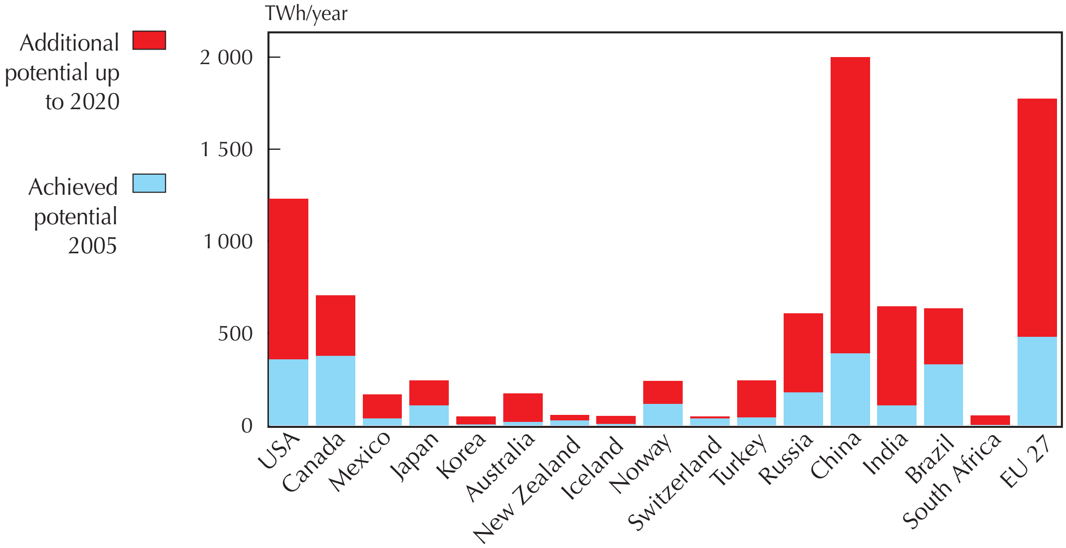
The renewable electricity sector (RES-E)

The following discussion illustrates the extent to which RETs may contribute to meeting demand for electricity up to 2020, by considering the specific resource conditions.

Figure 3 depicts the total realisable mid-term potentials for RES-E, by country, in absolute terms, relative to production in 2005. For most countries, the additional realisable potential to 2020 far outstrips the achieved deployment of renewables to date. In absolute terms this is particularly significant in China, EU-27, USA, India and Russia.

Figure 3. **Production (TWh) in 2005 and additional realisable mid-term potential (to 2020) for RES-E: OECD and BRICS**



Source: Based on IEA calculations & Resch et al. *(2008).*

Key point

For most countries, the additional realisable potential to 2020 far outstrips the achieved deployment of renewables to date.

Figure 4 shows the technology specific contributions to the additional realisable mid-term potentials for RES-E. This highlights the contributions of individual technologies.

Figure 5 illustrates the shares of individual RES-E technologies in the additional potential, by country. Shares vary among countries according to specific resource conditions.

In Figure 6, RES-E potentials are shown relative to national total electricity generation in 2005. This expresses the feasible contribution of RES-E to meeting overall demand for electricity, by country. The weighted average aggregate additional RES-E potential to 2020 in OECD countries and the BRICS is equivalent to 41% of 2005 total electricity generation.

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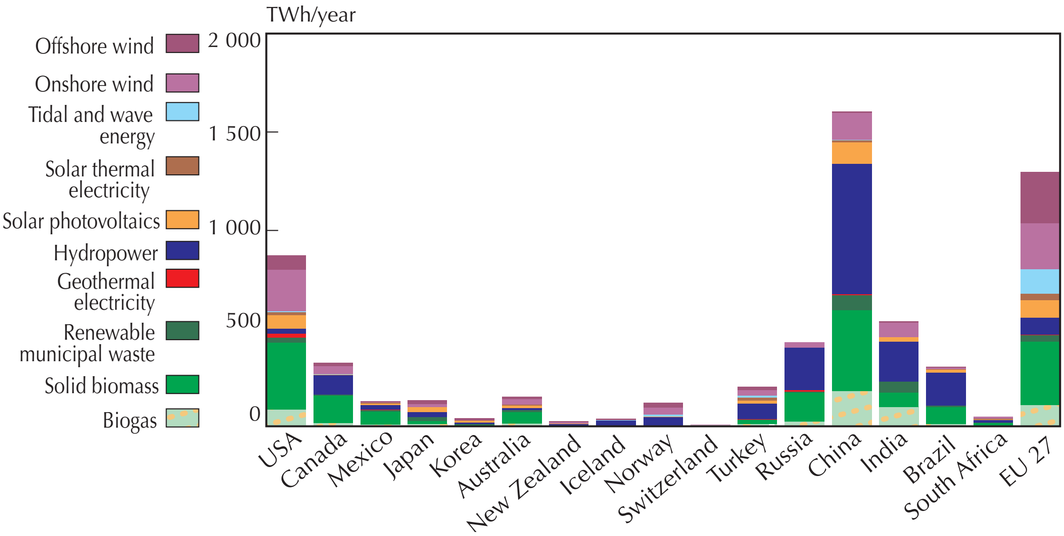
At the global scale, as well as in most countries, **hydropower** will remain the largest renewable contributor to electricity needs. As evident from Table 1, hydropower has a share of 45% of the total RES-E potential globally. However, 58% of this is already exploited. In absolute terms, the largest potentials are in China, followed by Brazil, Canada, and the EU-27. However, in relative terms, shares are low in the EU-27 and also in the USA, Korea and Australia, for example, where a large proportion of the total potential has already been exploited.

Figure 4. **Technology-specific additional realisable mid-term potentials (to 2020) for RES-E by country: OECD and BRICS**



Source: Based on IEA calculations & Resch et al. (2008).

Key point

The RES-E technologies with the potential to make major contributions in the medium-term (2020) are mainly those which have already reached, or are close to market competitiveness.

Biomass is another important renewable energy source. RES-E generation based on solid biomass, biogas and municipal renewable waste represents 31% of total RES-E potential in the OECD countries and BRICS, and a very high share of this (94%) remains to be exploited. All OECD countries and the BRICS have biomass in their resource portfolio. Large countries such as China and the USA possess the highest resources in absolute terms. Not only does a variety of biomass feedstocks exist, but also a variety of corresponding technology options, from co-firing in conventional power plants to small-scale combined heat and power (CHP) plant. Environmentally beneficial use as well as a consideration of possible social impacts is of key importance when striving for a massive market introduction. Electricity generation potentials, as indicated, refer largely to a combined use, *i.e.* where, besides electricity, heat production is also emphasised (CHP mode).

Delayed introduction of sustainability criteria may hinder the diffusion of promising technologies, and may consequently affect realisable mid-term potentials. Moreover, there is competition for feedstocks, *e.g.* with regard to energy crops required for biofuel production

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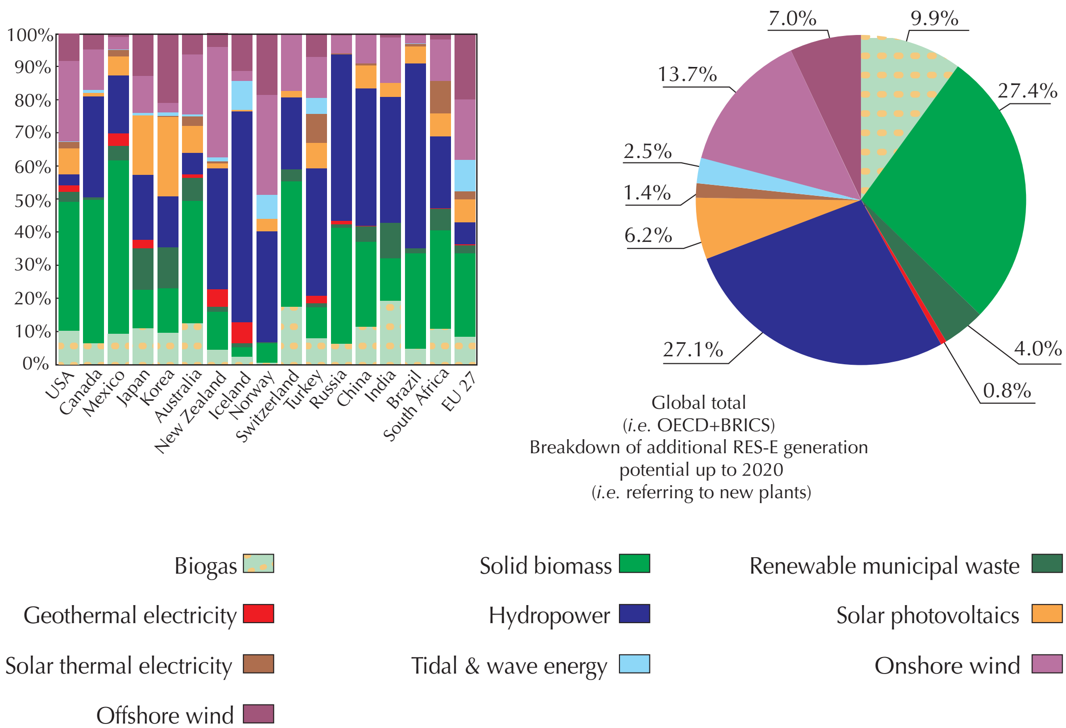
as well as electricity and heat generation. This may have an additional impact on the future uptake of renewables where ambitious targets are set for both options, *i.e.* biofuels and electricity generation.

Figure 5. **Technology shares of the additional realisable, mid-term potential for RES-E by country: OECD and BRICS**



Source: Based on IEA calculations & Resch et al. *(2008).*

Key point

Shares of specific RES-E technologies vary significantly among countries. The shares of less mature RES-E technologies (e.g. *wind off-shore and solar) are generally higher in OECD countries.*

Wind energy, like biomass, is characterised by a large future potential: 93% of the total realisable mid-term potential for onshore and offshore wind together remains to be exploited. The share of onshore wind energy in total RES-E potential for OECD countries and the BRICS is 11%, reflecting this technology's maturity. While in Europe offshore technology is also of key importance – partly due to limited suitable onshore sites – in most other parts of the world, onshore wind will likely dominate in the near to mid-term. In line with country size and resource availability, the largest mid-term potentials can be found in the European Union, the USA, China and India.

Solar energy is a promising future option that lags behind expectations. Recently, growing emphasis has been put on both photovoltaics (PV) and solar thermal electricity generation – especially in Europe, but also the USA and China, where a large PV manufacturing industry

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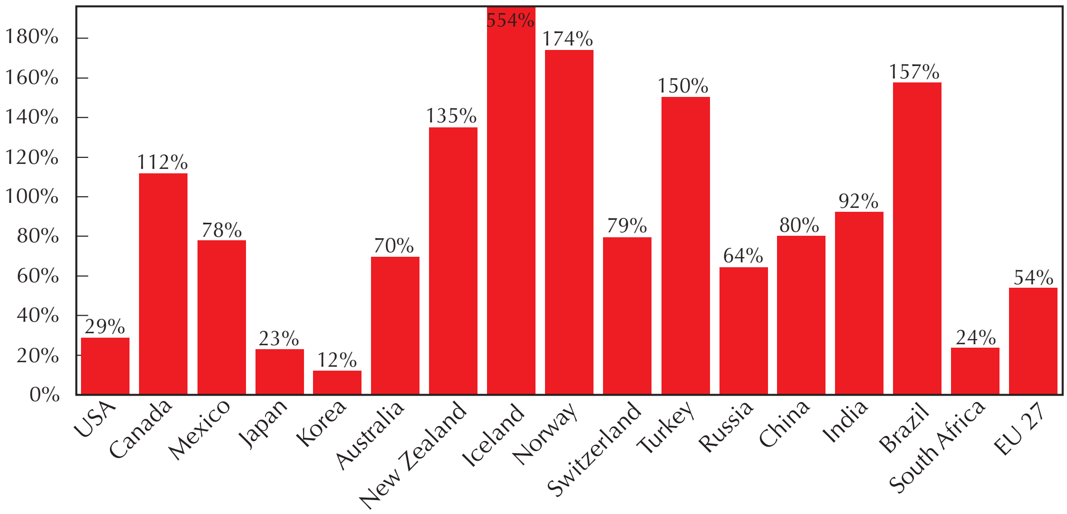
is being developed. A share of 4% of the total RES-E potential can be expected for PV in OECD countries and the BRICS if effective support within each country were to be implemented.

Figure 6. **Realisable mid-term (2020) potential contribution of RES-E to total electricity generation in 2005**



Source: Based on IEA calculations & Resch et al. *(2008).*

Key point

The additional RES-E potential to 2020 is equivalent to a significant share of current (2005) total electricity generation in most countries.

Geothermal electricity – in the form of conventional hydrothermal technology – is a proven RET option in some countries, *e.g.* Iceland, New Zealand, USA, Mexico and Italy. However, novel technology options such as enhanced geothermal systems (EGS, formerly known as hot dry rock) are likely to be developed and deployed more in the long run. This limits geothermal to approximately 1% of the total RES-E potentials to be exploited in the near- to medium -term.

Besides offshore wind energy, other marine technologies also show promise. However, for **tidal** and **wave energy**, a sizable mid-term deployment is assumed mainly in Europe.

Overall realisable mid-term potentials for RES-E illustrate for each technology what can be achieved if effective RET policies and measures are implemented in the near term. Summing up individual technologies at the country level may indicate the opportunity for substantial change relative to 2005 levels where cumulative technology potentials are greater than overall constraints, as illustrated in Figure 6, wherein certain countries are shown to have total electricity generation considerably lower than the potential for RES-E. However, even by implementing carefully designed energy policy, a specific country may not be able to exploit

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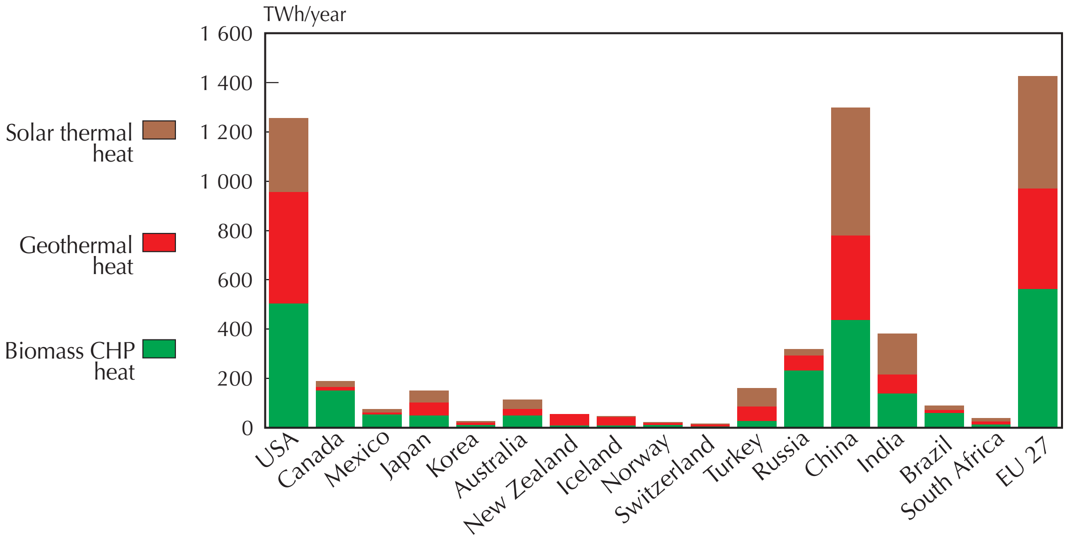
its cumulative potentials by 2020 due to cost constraints, or limitations arising from the integration of variable[23] renewables in electricity systems.

The heating sector

This section emphasises the potential of selected RETs to meet the demand for heat in the medium term, accounting for specific resource conditions. Figure 7 illustrates technology-specific, total realisable, mid-term potentials for RES-H by country.

Figure 7. **Technology-specific total potentials for RES-H in the mid-term (2020): OECD and BRICS**



Source: Based on IEA calculations & Resch et al. *(2008).*

Key point

The majority of OECD countries and the BRICS enjoy potentials for the three RES-H sources: biomass CHP, solar thermal and geothermal heat.

Further insights into country specific resource conditions are given in Figure 8, which shows the potential shares in RES-H production by source.

The combined production of electricity and **heat from biomass** offers huge potentials that are mostly still to be exploited. Among the assessed RES-H options, more than 40% of the cumulative total mid-term potential relates to biomass heat from CHP.[24] As stated in the previous section, all countries have some forms of biomass in their resource portfolio. Large countries such as China or the USA offer the largest resources in absolute terms. An

23. The output of variable renewable electricity technologies, such as wind, wave, tidal, solar and run-of-river hydro, varies according to the variability of the resource. This is a characteristic that distinguishes them from conventional fossil-fuelled power plants.

24. Because of a lack of verifiable market data – especially in the non-EU OECD countries – on the actual production (achieved potential) of biomass CHP heat to 2005, no assessment of the additional *realisable potential was possible. Estimates of energy production and additional potentials were calculated on the basis of installed capacities for biomass CHP.*

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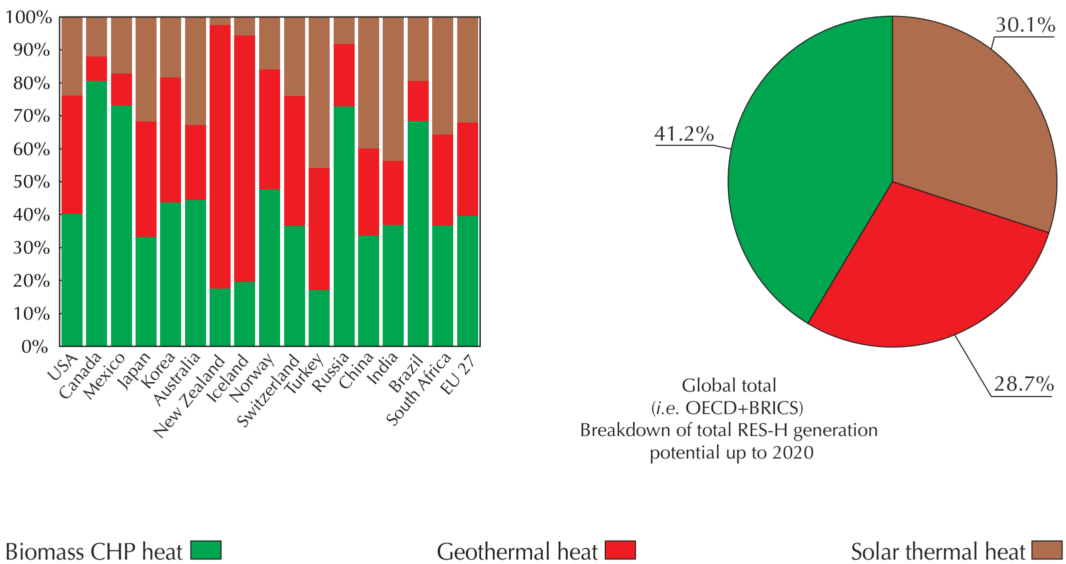
environmentally beneficial use as well as a consideration of possible social impacts is critical when aiming for mass market introduction.

Solar thermal and **geothermal heat** contribute in almost equal terms to the realisable mid-term potential for RES-H (each corresponding to around 30% of the total). The ratio of additional potential to achieved generation in 2005 is even larger for RES-H than for RES-E. For solar thermal and geothermal heat, the additional potential is almost thirty times greater than the achieved heat production from these sources. All countries include both RET options in their resource portfolio, where local conditions are favourable with regard to solar irradiation or geothermal resources, as well as corresponding overall heat demands. Accordingly, in absolute terms, large countries with high heat demands such as the USA or China (besides the European Union) have the highest potentials.

Figure 8. **Technology-specific shares of the total realisable mid-term potential for RES-H: OECD and BRICS**



Source: Based on IEA calculations & Resch et al. *(2008).*

Key point

With few exceptions, biomass CHP heat dominates total mid-term RES-H potential in most OECD and BRICS countries.

The transport sector

This section discusses the feasible contribution of biofuels to meeting demand for transport liquid fuels, as currently covered by diesel and gasoline, in the mid term.

Biofuels have a high future potential in almost all countries assessed, as, in general, they include some forms of biomass in their resource portfolio. In the short to medium term – *i.e.* for the production of first-generation biofuels – relevant feedstocks for large-scale biofuel production are mostly energy crops.

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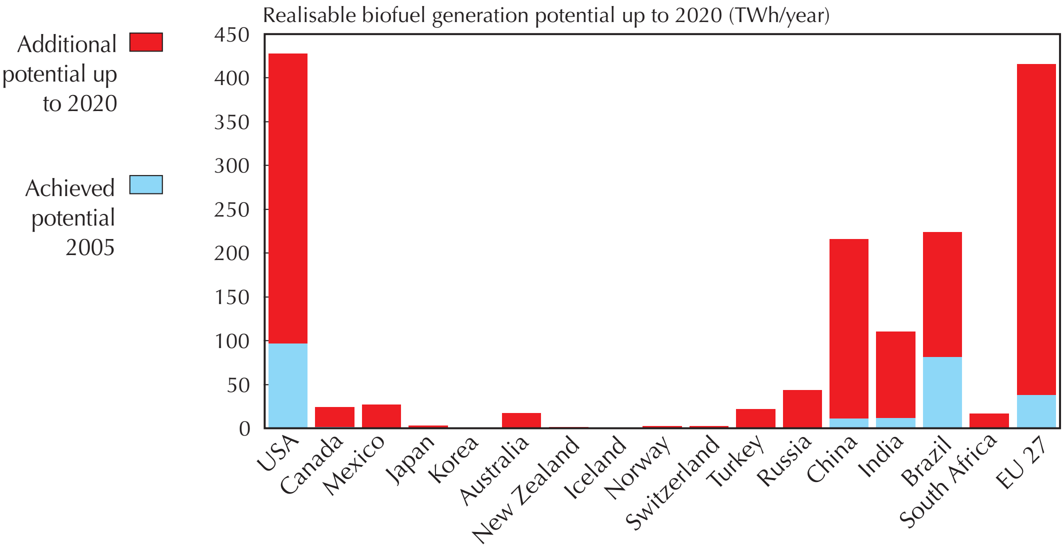
This analysis focuses on the period 2000 to 2005 and, therefore, does not consider more recent policy developments and significant ramping up of biofuel targets. The latter have stimulated growing public concern surrounding the impacts from increasing biofuel production on land use change, agricultural product prices, deforestation and water use. Competition for feedstocks between energy and food, fibre and chemicals production is increasingly being debated. Strong policy signals on the sustainable production and use of biofuels, and efforts to spur the competitiveness of second-generation technologies, will need to accompany their large-scale market penetration, as is presently planned in the USA and the EU.

However, environmentally beneficial use as well as a consideration of possible social impacts is of key importance. Delayed introduction of such sustainability criteria may hinder the diffusion of promising conversion technology options, and consequently affect the realisable mid-term potential tremendously. Additionally, competition with electricity and heat generation for feedstocks, which may further impact the future potential, occurs if ambitious targets are introduced for both options.

Figure 9 depicts the total realisable mid-term potentials for biofuels by country, distinguishing what has already been achieved by the end of 2005 (*i.e.* the achieved potential as of 2005) from the additional potential up to 2020.

Figure 9. **Achieved (2005) generation and additional realisable mid-term potential for biofuels: OECD and BRICS**



Source: Based on IEA calculations & Resch et al. *(2008).*

Key point

The estimated additional realisable potential of first-generation biofuels is more than five times current production. (This estimate is based on the conservative assumption that a maximum of 10% of current arable land would be used for energy crop cultivation in 2020, with a lower share (3.5 to 8.5%) assumed for the emerging economies (BRICS) due to potentially stronger competition with food production and environmental pressures.)

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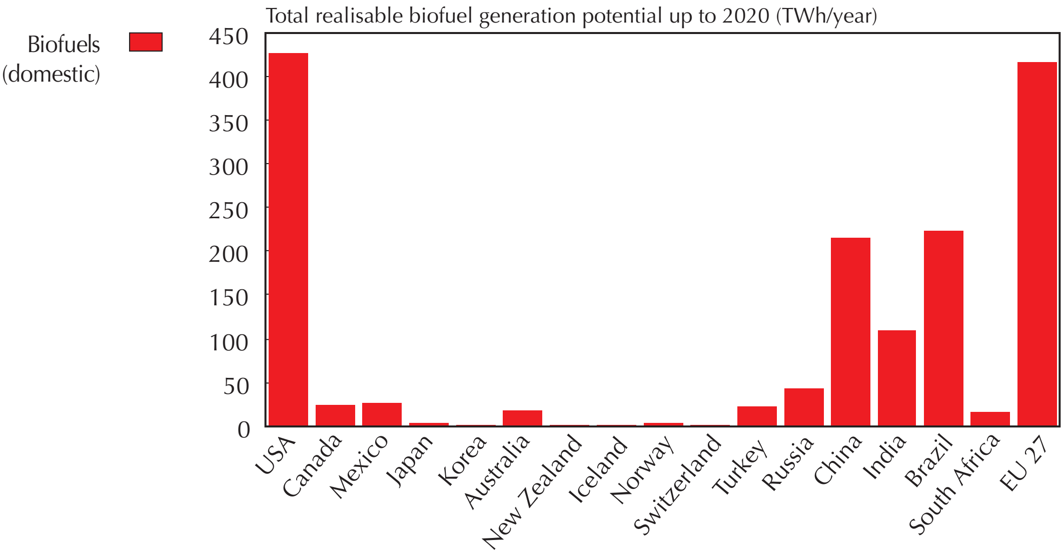
Figure 10 offers a country-specific breakdown of the total realisable mid-term potential for biofuels.

Figure 10. **Country-specific breakdown of realisable mid-term potential for biofuels: OECD and BRICS**



Source: Based on IEA calculations & Resch et al. *(2008)*

Key point

A small number of OECD as well as BRICS countries, which are also the current leading biofuel producers, show the largest total potentials for biofuels.

Overview of costs for RETs

Selected characteristics as well as costs of the most common renewable energy applications are shown in Table 5. Costs are in many cases still higher than for conventional energy technologies. Typical, wholesale power generation costs from conventional fuels are in the range USD 0.04-0.08/ kWh for new base-load power, but can be higher for peak load and higher still for off-grid diesel generators (IEA and NEA, 2005). Higher costs, and other market barriers, mean that most RETs continue to require policy support.

However, economic competitiveness is not static. The costs of many RETs are declining significantly with technology improvements and market maturity, although short-term market factors have temporarily halted this decline in some cases. At the same time, some conventional technology costs are also declining, *e.g.* with improvements in gas turbine technology, while others are increasing due to rising fuel costs and environmental requirements, among a range of factors. Future cost competitiveness also relates to uncertain future fossil fuel prices and future carbon-related policies (REN 21, 2008).

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Table 5. **Key characteristics and costs of renewable energy technologies**

Technology	**Typical characteristics**	**Typical current investment costs[1] (USD/kW)**	**Typical current energy production costs[2] (USD/MWh)**	**References**
POWER GENERATION				
Hydro				
Large hydro	Plant size: 10–18 000 MW	1 000–5 500	30–120	IEA, 2008
Small hydro	Plant size: 1–10 MW	2 500–7 000	60–140	IEA, 2008
Wind				
Onshore wind	Turbine size: 1–3 MW Blade diameter: 60–100 meters	1 200–1 700	70–140	IEA, 2008
Offshore wind	Turbine size: 1.5–5 MW Blade diameter: 70–125 meters	2 200–3 000	80–120	IEA, 2008
Bioenergy[3]				
Biomass combustion for power (solid fuels)	Plant size: 10–100 MW	2 000–3 000	60–190	IEA, 2008
Municipal solid waste (MSW) incineration	Plant size: 10–100 MW	6 500–8 500	n/a	IEA, 2007
Biomass CHP	Plant size: 0.1–1 MW (on–site), 1–50MW (district)	3 300–4 300 (on–site), 3 100–3 700 (district)	n/a	IEA, 2008
Biogas (including landfill gas) digestion	Plant size: <200 kW–10MW	2 300–3 900	n/a	IEA, 2008; IEA, 2007
Biomass co–firing	Plant size: 5–100 MW (existing), > 100 MW (new plant)	120–1 200 + power station costs	20–50	IEA, 2008
Biomass integrated gasifier combined cycle (BIGCC)	Plant size: 5–10 MW (demonstration), 30–200 MW (future)	4 300–6 200 (demonstration), 1 200–2 500 (future)	n/a	IEA, 2008

Table 5. *(continued)* **Key characteristics and costs of renewable energy technologies**

Technology	**Typical characteristics**	**Typical current investment costs[1] (USD/kW)**	**Typical current energy production costs[2] (USD/MWh)**	**References**
Geothermal power				
Hydrothermal	Plant size: 1–100 MW; Types: binary, single– and double–flash, natural steam	1 700–5 700	30–100	IEA, 2008
Enhanced geothermal system (EGS)	Plant size: 5–50 MW	5 000–15 000	150–300 (projected)	IEA, 2008
Solar energy				
Solar PV	Power plants: 1–10 MW; Rooftop systems: 1–5 kWp	5 000–6 500	200–800[4]	IEA, 2008; REN21, 2008
Concentrating solar power (CSP)	Plant size: 50–500 MW (trough), 10–20 MW (tower); 0.01–300 MW (future) (dish)	4 000–9 000 (trough)	130–230 (trough)[5]	IEA, 2008
Ocean energy				
Tidal and marine currents	Plant size: Several demonstration projects up to 300 kW capacity; some large–scale projects under development	7 000–10 000	150–200	IEA, 2008
HEATING/COOLING				
Biomass heat (excluding CHP)	Size: 5–50 kWth (residential)/ 1–5 MWth (industrial)	120/ kWth (stoves); 380–1 000/kWth (furnaces)	10–60	IEA, 2008; REN21, 2008
Biomass heat from CHP	Plant size: 0.1–50 MW	1 500–2 000/ kWth	n/a	IEA, 2008; IEA & RETD, 2007

Table 5. *(continued)* **Key characteristics and costs of renewable energy technologies**

Technology	**Typical characteristics**	**Typical current investment costs[1] (USD/kW)**	**Typical current energy production costs[2] (USD/MWh)**	**References**
Solar hot water/ heating	Size: 2–5 m^2 (household); 20–200 m^2 (medium/ multi–family); 0.5–2 MWth (large/ district heating); Types: evacuated tube, flat–plate	400–1 250/ m^2	20–200 (household); 10–150 (medium); 10–80 (large)	IEA & RETD, 2007; REN21, 2008
Geothermal heating/cooling	Plant capacity: 1–10 MW; Types: ground–source heat pumps, direct use, chillers	250–2 450/ kWth	5–20	IEA & RETD, 2007; REN21, 2008
BIOFUELS (1ST GENERATION)				
Ethanol	Feedstocks: sugar cane, sugar beets, corn, cassava, sorghum, wheat (and cellulose in the future)	0.3–0.6 billion per billion litres/ year of production capacity for ethanol	0.25–0.3/ litre gasoline equivalent (sugar); 0.4–0.5/ litre gasoline equivalent (corn)	REN21, 2008
Biodiesel	Feedstocks: soy, oilseed rape, mustard seed, palm, jatropha, tallow or waste vegetable oils	0.6–0.8 billion per billion litres/ year of production capacity	0.4–0.8/ litre diesel equivalent	REN21, 2008
RURAL (OFF-GRID) ENERGY[6]				
Micro-hydro	Plant capacity: 1–100 kW	1 000–2 000	70–200	REN21, 2008
Pico-hydro	Plant capacity: 0.1–1 kW	n/a	200–400	REN21, 2008
Biomass gasifier	Size: 20–5 000 kW	n/a	80–120	REN21, 2008
Small wind turbine	Turbine size: 3–100 kW	3 000–5 000	150–250	REN21, 2008

Table 5. *(continued)* **Key characteristics and costs of renewable energy technologies**

Technology	**Typical characteristics**	**Typical current investment costs[1] (USD/kW)**	**Typical current energy production costs[2] (USD/MWh)**	**References**
Household wind turbine	Turbine size: 0.1–3 kW	2 000–3 500	150–350	REN21, 2008
Village-scale mini-grid	System size: 10–1 000 kW	n/a	250–1 000	REN21, 2008
Solar home system	System size: 20–100 W	n/a	400–600	REN21, 2008

Source: IEA (2008), IEA (2007), IEA (2006), REN21 (2008).

Notes:

1. Using a 10% discount rate. The actual global range is wider as discount rates, investment cost, operation and maintenance costs, capacity factors and fuel prices vary. Wind and solar include grid connection cost.

2. Current costs relate to costs either in 2005 or 2006. Costs are exclusive of subsidies or policy incentives. Optimal conditions can yield lower costs, and less favorable conditions can yield substantially higher costs. Costs of off-grid hybrid power systems employing renewables depend strongly on system size, location, and associated items like diesel backup and battery storage.

3. Wide ranges due to plant scale, maturity of technology, detailed design variables, type and quality of biomass feedstocks, feedstock availability, regional variations, etc. Costs of delivered biomass feedstock vary by country and region due to factors such as variations in terrain, labour costs and crop yields.

4. Typical costs of 20–40 UScents/kWh for low latitudes with solar insolation of 2,500 kWh/m^2/year, 30–50 UScents/kWh for 1,500 kWh/m^2/year (typical of Southern Europe), and 50–80 UScents for 1,000 kWh/m2/year (higher latitudes).

5. Costs for (parabolic) trough[25] plants. Costs decrease as plant size increases. Plants with integrated energy storage have higher investment costs but also enjoy higher capacity factors. These factors balance each other, leading to comparable generation cost ranges for plants with and without energy storage.

6. No infrastructure required which allows for lower costs per unit installed.

25. Parabolic trough plant: Large cylindrical parabolic mirrors concentrate the sunlight on a line of focus. Several of these collectors in a row form a solar field. Molten salt is then used to transport the heat to a (conventional) gas or steam turbine.

Chapter 3
Effectiveness and Efficiency of Renewable Energy Market Deployment Policies

Key messages

- To date, only a limited set of countries has implemented effective support policies for renewable energy technologies (RETs) which have resulted in acceleration of renewables deployment in recent years. The "OECD-EU", "other OECD" member countries and "BRICS" show substantial diversity in the effectiveness of policies implemented to support the individual RETs in the electricity, heating and transport sectors.
- There is a large potential for improvement of policy design in most countries and considerable realisable potential across all RETs in all the OECD countries and BRICS reviewed. Experience gained in a wide variety of incentive schemes can be effectively applied depending on the specific technology and country.
- The OECD-EU member countries, which overall have a longer history of renewable energy support policies, feature among the countries with the highest policy effectiveness for all new renewable electricity generation technologies. The picture is more varied among the most mature renewable electricity technologies (*e.g.* hydro) and among renewable heating and transport technologies, with some other OECD countries and BRICS also having implemented relatively effective policies.
- In terms of quantitative assessment, the threshold of what is deemed to be successful depends on the specific technology's maturity. For the more mature RETs hydropower and wind, the most effective policies are linked to an effectiveness indicator of above 7%. Biogas electricity's status as a moderately mature RET is indicated by a lower effectiveness threshold of above 3%. The less mature technologies solar PV and solar hot water have low maximum effectiveness results of above 0.5% because they exhibit a substantial as yet untapped potential.
- To date, non-economic barriers – such as administrative hurdles (including planning delays and restrictions, lack of co-ordination between different authorities, long lead times in obtaining authorisations), grid access, electricity market design, lack of information and training, and social acceptance – have significantly hampered the effectiveness of renewable support policies and driven up costs in many countries, irrespective of the type of incentive scheme.
- Overall, the effectiveness and efficiency of renewable energy policies are determined by the adherence to key policy design principles outlined below, as well as by the consistency of measures. The assessment of the effectiveness of renewables deployment must consider the entire policy framework into which incentive schemes are inserted, rather than focusing on which specific incentive scheme functions best.

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- Renewable policy design should reflect five fundamental principles:
  - The removal of non-economic barriers, and the tackling of social acceptance issues – with a view to overcoming them – in order to improve market and policy functioning;
  - The need for a predictable and transparent support framework to attract investments;
  - The introduction of transitional incentives, decreasing over time, to foster and monitor technological innovation and move technologies quickly towards market competitiveness;
  - The development and implementation of appropriate incentives guaranteeing a specific level of support to different technologies based on their degree of technology maturity, in order to exploit the significant potential of the large basket of renewable energy technologies over time; and
  - The due consideration of the impact of large-scale penetration of renewable energy technologies on the overall energy system, especially in liberalised energy markets, with regard to overall cost efficiency and system reliability.

Overview

This chapter discusses the effectiveness and efficiency of deployment policies implemented to support the following renewable energy technologies (RETs): onshore wind, biomass, biogas, geothermal, solar PV, and hydro power in the electricity sector; biomass heat, geothermal and solar thermal in the heating sector; and ethanol and biodiesel in the transport sector. In effect, this means that the quantitative effectiveness and efficiency analysis discusses more mature RETs which have already progressed beyond the demonstration phase and show significant deployment which can be put in relation to policies implemented. Therefore, currently less mature technologies, such as offshore wind, enhanced geothermal systems (EGS), wave and tidal and marine currents, are not taken into account in this chapter.

The quantitative policy effectiveness and efficiency analysis focuses on renewable energy markets and policies over the period 2000 to 2005. It demonstrates deployment experiences over this period, as well as focusing on more recent trends over 2004/5. Because of the period for which verified market statistics were collected (2000-2005),[26] the effectiveness and efficiency of important renewable energy deployment policies which have been introduced since 2005, especially in the OECD-EU countries, have not been quantitatively assessed. Nevertheless, recently implemented policies are mentioned where relevant to indicate possible future market developments (*e.g.* see Table 2). For the purpose of this assessment, the 35 countries reviewed are classified into regions as follows: *i)* the OECD countries which are also European Union member states (OECD-EU), *ii)* other OECD countries (Other OECD), and *iii)* Brazil, Russia, India, China, South Africa (BRICS).

26. *See also Box 1.*

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Box 1. **Data collection strategy**

The analysis of effectiveness and efficiency relied on two main categories of data sources on renewable energy policies and markets.

OECD countries: The IEA used mainly verified policy data available in the IEA/JREC Global Renewable Energy Policies and Measures Database which is continuously updated and regularly reviewed by government experts (IEA, 2008b). Market data were obtained primarily from official IEA statistics (IEA, 2007c; IEA, 2007b). Where data inconsistencies were apparent in IEA statistics, expert information from the relevant renewable energy IEA Technology Agreements (the IEA's energy technology collaboration framework allow interested IEA member and non-member governments or other organisations to pool resources and to foster the research, development and deployment of particular technologies) helped reconcile the differences. Data sources other than official IEA statistics are explicitly referenced.

BRICS: To support the data collection on renewable energy markets and policies in Brazil, China, India, Russia and South Africa (BRICS), consultant experts in these countries collected policy and market data to feed in to the policy analysis. These statistics were complemented with market and policy data from the relevant IEA Implementing Agreements.

All additional verified information on policies and measures used for the purposes of the assessment was added to the IEA/JREC Global Renewable Energy Policies and Measures Database (IEA, 2006).

The trends in renewable energy markets and policies highlighted in this analysis are set out in greater detail in the profiles of the individual OECD countries and BRICS which are compiled in Annex 1 on the accompanying CD-ROM. Readers wishing to obtain a more detailed understanding of the technical characteristics of the RETs evaluated can refer to a wealth of literature, including IEA publications, (*e.g. Renewable Energy: RD&D Priorities*)[27] as well as the expert reports of the relevant IEA renewable energy Implementing Agreements.[28]

Measuring policy effectiveness and efficiency

The performance of a market deployment policy can be appraised by its impacts on a range of parameters, *i.e.* installed capacity, energy production, reduction in costs and prices, technological learning, industrial effects such as domestic manufacturing capacity and related employment effects, and public acceptance (Sawin, 2006). Nonetheless, the two fundamental factors often cited as a measure of policy success are the impact on market growth of the respective RET (or *policy effectiveness*) as well as the associated cost of the policy support (or *cost efficiency*). Quantitative indicators provide an appropriate tool to evaluate both criteria reliably.

27. IEA, 2006.

28. The wide-ranging research activities of the ten IEA Technology Agreements (also called Implementing Agreements) which focus on a specific RET and market deployment respectively are summarised on the following website: http://www.iea.org/Textbase/techno/technologies/renew.asp.

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This study attempts to measure the effectiveness of policies for promoting renewables, averaged over the period 2000 to 2005 and the years 2004/5 respectively, by applying a quantitative *policy effectiveness indicator*. This indicator is calculated by dividing the additional renewable energy deployment achieved in a given year by the remaining mid-term assessed "realisable potential" to 2020 in the country concerned. The rationale for such an effectiveness indicator is that it allows for unbiased comparisons across countries of different sizes, starting points in terms of renewable energy deployment and degrees of ambition of renewable energy policies and targets, while taking into account the available renewable energy resource.

The realisable potential is estimated based on a long-term view of the *technical* potential, adjusted to take account of unavoidable medium-term constraints, such as maximum market growth rates and planning constraints, on the rate of change. The mid-term realisable potentials for each RET are derived based on the resources of specific countries, and taking into account technology development.

The cost of the incentives for each renewable energy technology in all OECD countries and BRICS is also assessed. Different types of incentive have different characteristics over time – depending, for instance, on whether they relate to upfront investment costs, or operating returns. The remuneration for each technology in each country is expressed as a levelised return over a period of 20 years. This report does not address the cost efficiency of renewable energy systems relative to other carbon abatement technology options.

Policy effectiveness indicator

A number of indicators can be used to measure the effectiveness of policies supporting renewable energy. All of them show advantages and disadvantages (Table 1).

Table 1. **Overview of alternative indicators of policy effectiveness**

Indicator	Formula	Advantage	Disadvantage
Average annual growth rate	$g_n^i = \left(\frac{G_n^i}{G_{n-t}^i}\right)^{\frac{1}{t}} - 1$	Based on empirical values	No consideration of country-specific background
Absolute annual growth	$a_n^i = \frac{G_n^i - G_{n-1}^i}{n}$	Based on empirical values	No consideration of country-specific background
Effectiveness indicator	$E_n^i = \frac{G_n^i - G_{n-1}^i}{ADDPOT_n^i} = \frac{G_n^i - G_{n-1}^i}{POT_{2020}^i - G_{n-1}^i}$	Consideration of country specific background	Difficulties in the identification of additional mid-term potential

a_n^i : Absolute annual growth rate.
g_n^i : Average annual growth rate.
E_n^i : Effectiveness indicator for RES technology i for the year n.
G_n^i: Electricity generation by RES technology i in year n.
$ADDPOT_n^i$: Additional generation potential of RES technology i in year n until 2020.
POT_n^i: Total generation potential of RES technology i until 2020.

Source: IEA; Ragwitz & Held (2007b).

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A first possible approach[29] is to measure the degree to which a pre-defined goal set at the national level was achieved over a certain period. This has the advantage of assessing the consistency of targets and policies within each country. However, it makes a cross-country comparison difficult because the indicator is biased in favour of less ambitious countries – less ambitious targets can be achieved with less effort in terms of actual additional renewable energy generation.

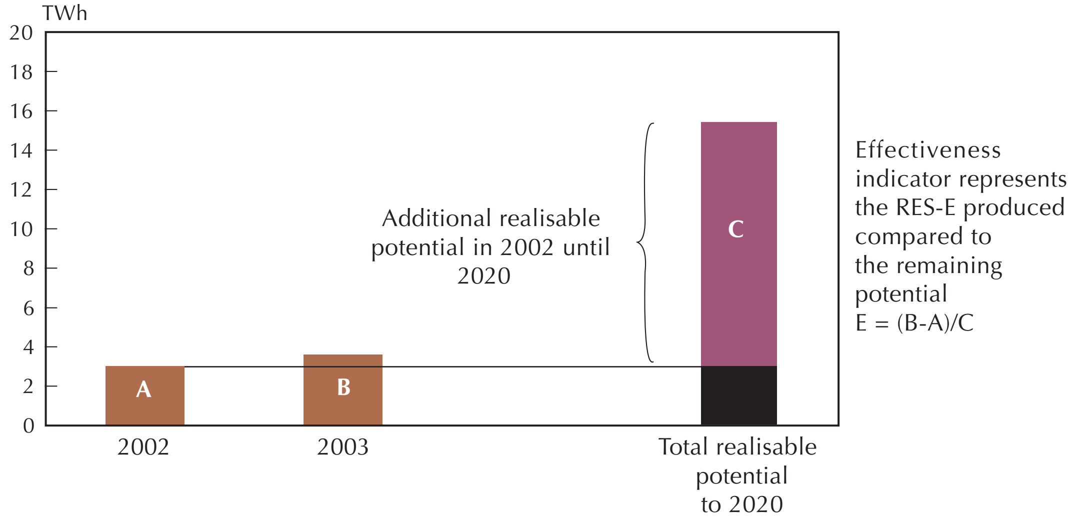
A second possibility is to look at the actual additional capacity or generation over a certain period, *i.e.* the absolute growth. This indicator is obviously a better measure for the absolute effort in favour of renewables. However, it does not account the size of the country and is biased in favour of larger countries.

In contrast, a third possible indicator, *i.e.* the annual growth rate, systematically favours small countries, and in general countries starting from a low level of deployed renewables.

A better solution seems to put in relation the annual additional growth with the actual renewable energy potential in a given country. This eponymous "effectiveness indicator" (Table 1) is expressed in percentage of remaining additional mid-term realisable potential for renewable energy production. It allows unbiased comparisons across countries of different sizes, starting levels of renewables deployment, and levels of ambition of renewables policies and targets.

As the effectiveness indicator reflects the absolute market growth relative to the country- and technology-specific opportunities, comparison of support instruments becomes possible.

Figure 1. **Example of the effectiveness indicator for a specific RET in a specific country in a specific year**



Source: IEA; Ragwitz & Held (2007b).

29. This approach is not listed in Table 1.

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A number of EU research projects have been using this indicator to assess the effectiveness of renewable energy policies in Europe (*e.g.* Ragwitz *et al.*, 2007c; Resch *et al.*, 2008) and results have been presented in the European Commission's 2005 Communication on the support of electricity from renewable energy sources (European Commission, 2005). The latest available results have been included in the impact assessment of the recent EC Renewables Directive proposal package (European Commission, 2008). They are based on the calculation of the national realisable renewable energy mid-term potentials calculated with the Green-X model (Huber *et al.*, 2004; Ragwitz *et al.*, 2005).

This report uses the same methodology, expanding the analysis to all OECD countries plus the BRICS.

Figure 1 shows as an example the calculation of the effectiveness indicator for a specific RET in a specific country in a specific year.

Remuneration level efficiency

The level of financial support paid to the renewable energy producer is a crucial characteristic of renewable energy policy support, significantly influencing policy effectiveness as well as the support costs.

Support levels need to be sufficient to stimulate capacity growth of RETs by offering a predictable profitability level to potential investors but should avoid windfall profits stemming from support levels exceeding real requirements of the RET. A comparison of support levels helps identify best policy practices that have shown greatest success in encouraging market growth at low costs.

However, this analysis does not compare actual support levels because of gaps in generation cost data at a disaggregated level for all countries assessed.[30] Therefore, the *remuneration level* over the whole lifetime of a renewable energy plant is used as an indicative proxy for support levels. Remuneration levels encompass the sum of the wholesale energy price plus any premiums and/or incentives received for every unit of renewable energy produced.

The analysis of remuneration level efficiency is restricted to the renewable electricity (RES-E) technologies reviewed as comprehensive data are lacking on prices for heat and transport fuels especially in non-OECD countries.

In order to make the remuneration level comparable, time series are generated of the expected support payments and electricity prices respectively and the net present value[31] calculated. The net present value is converted in to the annualised remuneration level as shown in Box 2.

30. This might affect the comparability as generation costs may differ significantly across countries.
31. The net present value represents the aggregate value of the support payments in each future year discounted to the present.

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Box 2. **Calculation of the annualised remuneration level for RES-E**

$$NPV = \sum_{t=l}^{n} \frac{\text{Remuneration level}_t}{(l + i)^t}$$

$$A = \frac{i}{(l - (l + i)-n)} * NPV$$

NPV → Net present value

A → Annualised remuneration level

I → interest rate

t → year

n → Payback time

Source: IEA; Ragwitz & Held (2007b).

The normalised remuneration levels are calculated by annualising the 2005 remuneration levels under the most relevant incentive scheme(s) for each technology in every country over a common period of 20 years, using a discount rate of 6.5%. This represents the net present value of the overall support payments discounted in each country for each technology.

In the case of a quota obligation system with tradable green certificates (TGCs), it is assumed that the remuneration level is composed of the conventional electricity price and the average value of the tradable green certificate. It is supposed that the elements of the time series remain constant during the time certificate trading is allowed. For feed-in tariff (FIT) systems, the total remuneration is equivalent to the fixed incentive paid to the RES-E producer (see also section below on Price-based market instruments). If the duration of FIT support differs from the reference period of 20 years, the total remuneration is annualised accordingly. Possible tariff degressions implemented in FIT designs are not considered.

The advantage of the presented indicator is that it allows a global picture of the financial remuneration offered by a specific incentive scheme throughout the lifetime of a RES-E plant. Nevertheless, the comparison of remuneration levels as it is calculated within this publication serves only as an indication of actual remuneration levels.[32]

32. For simplicity, the comparison is carried out on an aggregated level per technology category, while the tariffs within one technology category might differ significantly. In addition, the complexity of support scheme combinations in some countries complicates the exact calculation of the indicator.

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Overview of support schemes

Governments use a wide range of market-based instruments to subsidise renewable electricity. These can be divided into two categories: investment support (capital grants, tax exemptions or reductions on the purchase of goods) and operating support (price subsidies, green certificates, tender schemes and tax exemptions or reductions on the production of electricity).

In overall terms, operating support – support per unit of electricity produced – for renewable electricity is far more significant than investment support. Production incentives promote the desired outcome, *i.e.* the generation of energy, while fiscal incentives can play an important role during the initial stage of the market introduction when necessary funds are still limited.

Instruments providing operating support can be divided into instruments that fix a quantity of renewable electricity to be produced and in instruments that fix a price to be paid for renewable electricity. Economic theory has shown that under ideal conditions, quantity-based instruments and price-based instruments have the same economic efficiency.

Quantity-based market instruments

Under a **quota obligation**, governments set a particular target for renewables and put a corresponding obligation on producers, suppliers or consumers to source a certain percentage of their electricity from renewable energy. This obligation is usually facilitated by the use of tradable green certificates (TGCs). Under this scheme, an obligated party failing to meet its quota obligation has to pay a penalty. This provides the incentive to either directly invest in new renewable electricity plants or to buy green certificates from other producers or suppliers. The certificates are finally used to prove compliance with the obligation. The certificate price is determined on the market, but it strongly depends on several factors, including the level of quota target, the size and allocation of the penalty and the duration of the obligation. Quota obligation systems with TGCs are generally technology-neutral support mechanisms, aiming at promoting the most cost-efficient technology options. However, technology-specific support can be also provided through separate quotas (bands) per technology, different duration of support or value of certificate (more or less than one per MWh).

In **tendering systems**, a tender is announced for the provision of a certain amount of electricity from a certain technology source, and the bidding should ensure the cheapest offer is accepted. Denmark has recently decided to use tendering for the development of off-shore wind projects.

Price-based market instruments

FITs and feed-in premiums (FIPs) are granted to operators of eligible domestic renewable electricity plants for the electricity they feed into the grid. They are preferential, technology-specific and government regulated. FITs take the form of a total price per unit of electricity paid to the producers whereas the premiums (bonuses) are additional to the electricity market

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price. An important difference between the FIT and the premium payment is that the latter introduces competition between producers in the electricity market.

The cost for the grid operator is normally covered through the tariff structure. The usual duration of the tariff or premium is about 10 - 20 years. Guaranteed duration provides strong long-term certainty, which lowers the market risk to investors. Both feed-in tariffs and premiums can be structured to encourage specific technology promotion and cost reductions (the latter through stepped reductions in tariff/premiums).

Fiscal incentives

Fiscal incentives, such as tax exemptions or reductions, are generally used as supplementary support instruments. Producers of renewable electricity are exempted from certain taxes (*e.g.* carbon taxes) in order to compensate for the unfair competition they face due to external costs in the conventional energy sector. The effectiveness of such fiscal incentives depends on the applicable tax rate. In Nordic OECD countries, which apply high energy taxes, these tax exemptions can be sufficient to stimulate the use of renewable electricity; in countries with lower energy tax rates, they need to be accompanied by other measures.

Investment grants reduce capital costs and are also in the price-based mechanism category.

Evolution of support schemes in OECD countries and BRICS

Table 2 illustrates the progression of policy instruments to foster the deployment of renewable electricity (RES-E) introduced in OECD countries and Brazil, Russia, India, China and South Africa from the start of the analysis period to date.

At the end of 2005, 20 countries had FIT systems in place, 10 countries had implemented quota obligation systems with TGCs, six countries had introduced tender systems and 15 countries used other incentive systems in place. Some countries applied a variety of incentive schemes depending on technology, *i.e.* Australia, Brazil, Canada, China, France, India, Italy, Korea, the Netherlands, Norway, Poland, the Slovak Republic, Switzerland, and the United States. In the period since 2005, major changes in main incentive schemes occurred only in China, France, Ireland, Italy, the Netherlands, New Zealand and the Slovak Republic.

Current status and targets for renewables in OECD countries and BRICS

Table 3 summarises the policy targets and mandates set by OECD countries and Brazil, Russia, India, China and South Africa for renewable energy diffusion in the electricity (RES-E), heat (RES-H) and transport (RES-T) sectors. It contrasts the targets with the 2005 market penetration in the relevant sectors.

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Table 2. **Evolution of main RES-E policy support mechanisms from January 2000 to December 2007 (OECD and BRICS)**

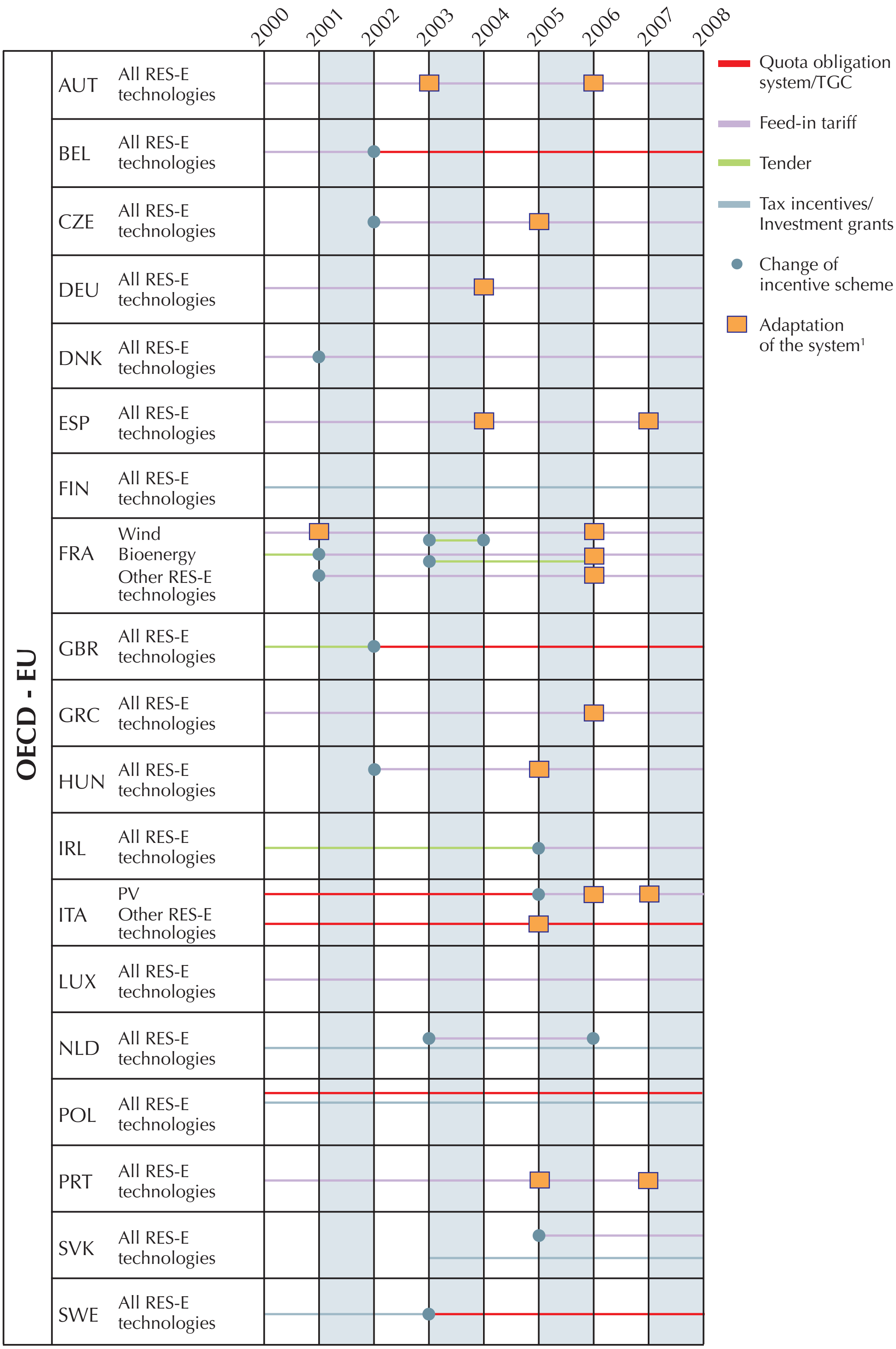

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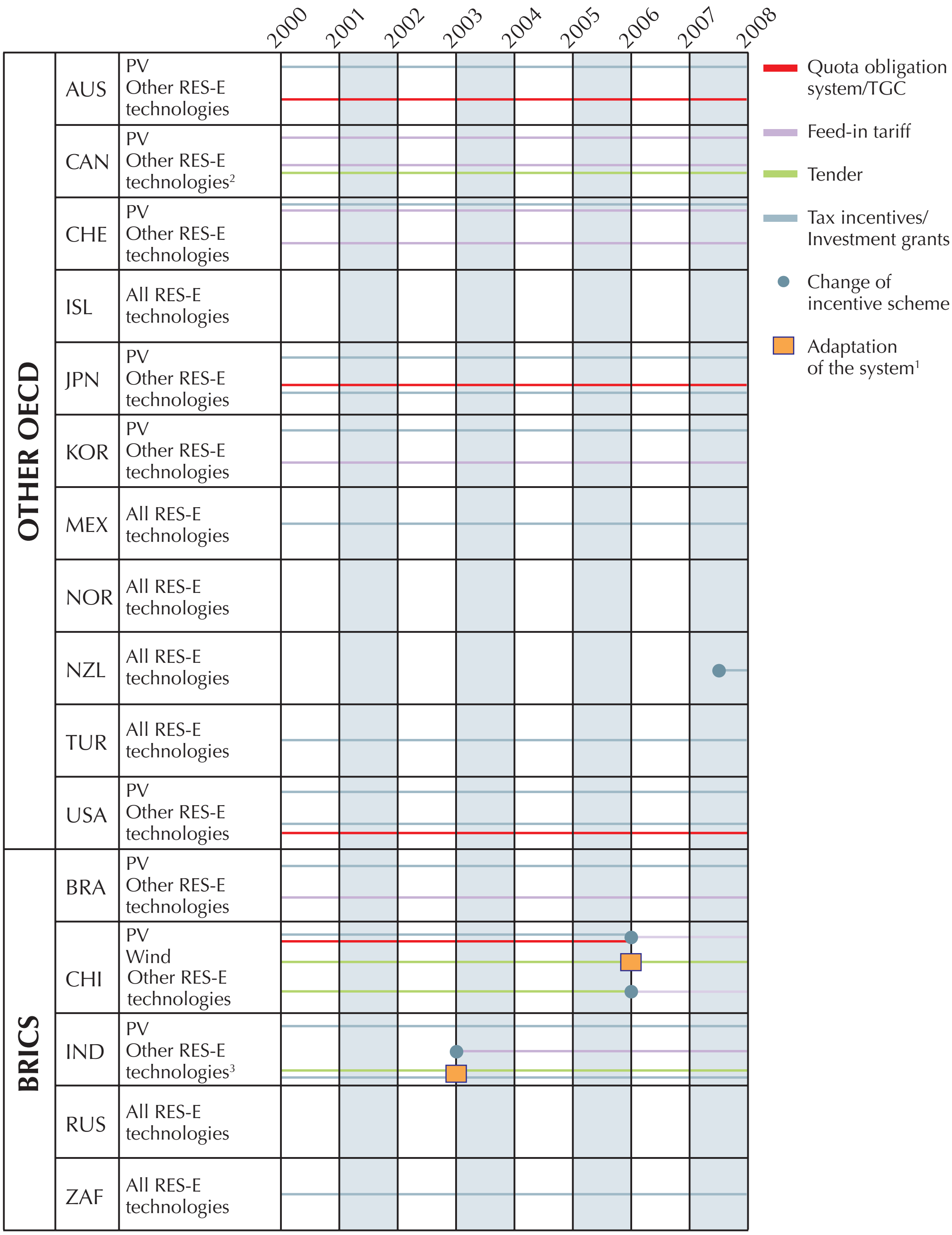
Table 2. **Evolution of main RES-E policy support mechanisms from 2000 to 2007 (OECD and BRICS)** *(continued)*



[1] The *implementation* date of the system adaptation is the relevant parameter. The position of the square indicates that the system adaptation was implemented sometime during the following year.
[2] Premium FIT for other RES-E technologies, FIT for PV.
[3] After the introduction of the Electricity Law in 2003, state governments began introducing FITs for some RES-E technologies and RES-E targets. The implementation date of new policies varied across states and it can be considered an ongoing process.
Source: IEA; Ragwitz et al. *(2008).*

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Table 3. **2005 renewable energy markets and mandatory and voluntary government policy targets (OECD and BRICS)**

Country	Renewable electricity generation (GWh) in 2005	Share of RE in total electricity generation in 2005 (%)	RES-E targets	Renewable heat production (TJ) [1]	Share of RE heat production in total heat production (%)	RES-H targets
AUT	39 357	62.5%	78% by 2010	18 083	29.4%	
BEL	2 106	2.5%	6.0% by 2010	1 601	7.1%	
CZE	3 133	3.8%	8.0% by 2010	3 954	2.8%	
DEU	61 625	10.1%	12.5% by 2010; 20% by 2020 (M)	51 787	4.0%	
DNK	10 216	28.2%	29% by 2010	40 244	31.5%	
ESP	43 490	15.0%	29.4% by 2010; 500 MW solar power by 2010	2 894	100.0%	
FIN	23 448	33.2%	31.5% by 2010	34 799	21.3%	
FRA	56 658	9.9%	21% by 2010	19 569	10.1%	50% increase from 2004 until 2010 in heat from RES
GBR	16 919	4.3%	10% by 2010; 15.4% by 2016 (M)	1 262	2.2%	> 10 000 MW_e of installed combined heat and power (CHP) capacity by 2010 w/ > 15% of government buildings using CHP
GRC	6 406	10.8%	20.1% by 2010	4 270	67.6%	
HUN	1 870	5.2%	3.6% by 2010	4 521	6.7%	
IRL	1 873	7.3%	13.2% by 2010	21	100.0%	
ITA	45 979	15.6%	25% by 2010; 3 GW of solar PV by 2016	17 738	8.7%	
LUX	214	6.4%	5.7% by 2010	161	6.3%	
NLD	7 465	7.4%	9.0% by 2010	5 604	3.3%	
POL	3 846	2.5%	7.5% by 2010	4 085	1.2%	
PRT	8 260	17.9%	45% by 2010	981	6.7%	
SVK	4 676	14.9%	31% by 2010	2 113	4.0%	
SWE	81 230	51.3%	60% by 2010	105 116	58.0%	
AUS	18 608	7.4%	9.5 TWh of electricity annually by 2010 (RPS)	2 622	100.0%	
CAN	374 080	59.6%	3.5% to 15% of electricity in 4 provinces (RPS); other types of targets in 6 provinces	6	0.0%	
CHE	32 276	55.9%		11 497	47.7%	
ISL	8 681	99.9%		30 294	98.1%	
JPN[2]	99 146	9.1%	1.63% by 2014; biomass power generation & waste power generation in the amount of 5 860 000 kl, as converted to crude oil, by 2010 (V)	38 977	65.9%	Biomass thermal utilization in the amount of 3 080 000 kl (this amount includes biomass-derived fuel – 500 000 kl – for transportation), as converted to crude oil, by 2010 (V)
KOR	4 052	1.0%	7% by 2010; 1.3 GW of grid-connected solar PV by 2011, including 100,000 solar homes	7 075	3.6%	

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Renewable road transport fuel consumption (TJ)	Share of RE road transport fuel in total road transport fuel consumption (%)	Existing biofuels policies and biofuel targets	Other renewable energy targets
1 793	0.6%		
0	0.0%		
111	0.0%		
81 302	3.7%	E2 and B4.4 by 2007; B5.75 by 2010; 6.75% of all transport fuels for 2010) 6.75% of all transport fuels for 2010 which is set to rise to 8% by 2015; 10% by 2020 (M = EU target)	
0	0.0%		
10 846	0,8%		
0	0.0%		
17 729	1.0%	5.75% by 2008, 7% by 2010,10% by 2015 (V); 10% by 2020 (M=EU target)	
3 376	0.2%	E2.5/B2.5 by 2008; E5/B5 by 2010; 10% of all transport fuels by 2020 (M =EU target)	
0	0.0%		
214	0.1%		
0	0.0%		
7 369	0.4%	E1 and B1; 5.75% of all transport fuels by 2010 (M); 10% by 2020 (M =EU target)	
37	0.0%		
0	0.0%		
1 973	0.4%		
0	0.0%		
439	0.6%		
6 300	2.0%		
456	0.0%	E2 in New South Wales, increasing to E10 by 2011; E5 in Queensland by 2010	
7 128	0.4%	E5 by 2010 and B2 by 2012; E7.5 in Saskatchewan and Manitoba; E5 by 2007 in Ontario	
262	0.1%		3.5 TWh from electricity and heat by 2010
0	0.0%		
0	0.0%	500 000 kl, as converted to crude oil, by 2010 (V)	
442	0.0%		

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Table 3. **2005 renewable energy markets and mandatory and voluntary government policy targets (OECD and BRICS)** *(continued)*

Country	Renewable electricity generation (GWh) in 2005	Share of RE in total electricity generation in 2005 (%)	RES-E targets	Renewable heat production (TJ)[1]	Share of RE heat production in total heat production (%)	RES-H targets
MEX	37 675	16.0%	> 1 GW added by 2006; 4 GW added by 2014	3 069	100.0%	Targets under consideration
NOR	136 638	99.5%		4 052	31.5%	
NZL	27 619	64.3%	90% by 2025	9 900	95.1%	
TUR	39 748	24.5%	2% of electricity from wind by 2010	54 863	60.6%	
USA	364 678	8.5%	5% to 30% (typical) on electricity in 25 states and DC (RPS)	100 424	29.8%	
BRA	351 911	87.3%	3.3 GW added by 2006 from wind, biomass, small hydro	0	0.0%	
CHN	399 521	16.0%	190 GW hydro, 5 GW wind, 5.5 GW biomass, 300 MW PV, 150 million m² SWH by 2010 300 GW hydro, 30 GW wind, 30 GW biomass, 1.8 GW PV, 300 million m² SWH by 2020	12 645	0.6%	
IND	108 076	15.5%	10% of added electric power capacity during 2003–2012 (expected 10 GW); 10.5 GW total wind power existing by 2012	0	0.0%	
RUS	173 135	18.2%	considering 7% by 2020	43 767	0.7%	
ZAF	3 026	1.2%	4% by 2013 (V)	0	0,0%	
WORLD	**3 271 626**	**17.9%**		**707 355**	**5 2%**	

NB: This table makes no claim to completeness.
M: mandatory ; V: voluntary; SWH: solar water heating.
[1]Renewable heat (RES-H) production encompasses i) commercially sold RES-H production and, for OECD countries, where applicable, ii) the direct use of Africa (BRICS). See Tables 2 and 3 in Chapter 1.
[2]Targets not including large hydro.

Source: REN21 (2008); GBEP (2007); IEA (2008b).

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Renewable road transport fuel consumption (TJ)	Share of RE road transport fuel in total road transport fuel consumption (%)	Existing biofuels policies and biofuel targets	Other renewable energy targets
0	0.0%	B20 by 2011/2012	
0	0.0%		7 TWh from heat and wind by 2010
0	0.0%		30 PJ of added capacity (inc. heat and transport fuels) by 2012
0	0.0%		
337 920	1.5%	Nationally, 130 billion liters/year by 2022 (36 billion gallons); E10 in Hawaii, Missouri, and Montana; E20 in Minnesota; B5 in New Mexico by 2012; B2 in Washington State; New York; California; Pennsylvania 3.8 billion liters/year (1 billion gallons) biofuels by 2017	
288 933	14.2%	E22 to E25 existing (slight variation over time); B2 by 2008 and B5 by 2013	
0	0.0%	E10 in 9 provinces, 15% of transport fuels by 2020	10% of TPES by 2010 16% of TPES by 2020
4 314	0.3%	E10 in 13 states/territories; a 5% blending mandate for ethanol will be established before end of 2007, and Planning Commission proposed to raise mandate to 10%. Regarding biodiesel, Committee for the Development of Biofuels has decided 20% of diesel consumption as blending target for 2011/2012	
0	0.0%		
0	0.0%	E8-E10 and B2-B2 (proposed)	10 TWh added final energy by 2013
774 100	**1.2%**		

renewables (solar thermal and geothermal) for heat. No data on the direct use of renewables for heat is available for Brazil, Russia, India, China and South

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Analysis of RE policy effectiveness and remuneration level efficiency: RES-E technologies

Before entering into the discussion of policy measures, their efficiency and their effectiveness, it is important to add the caveat that choice of support mechanism alone is not the only factor in the successful deployment of renewable energy technologies (RETs).

A number of non-economic barriers to renewables deployment persist in many locations. Administrative hurdles can lead to long project lead times. Planning delays and restrictions, lack of co-ordination between different authorities, authorisation delays can jeopardise the success of a development. Grid access and electricity market design can hinder the delivery of electricity and undermine the value of variable renewable technologies, such as wave, tidal, wind and solar. Inadequate information and training opportunities, and lack of social acceptance, can have significant negative impacts. A number of investigators have provided illustrative examples of non-economic barriers in the EU-25 by RET and by country, as perceived by stakeholders, (Coenraads *et al.*, 2006; Sawin, 2006; Edge, 2006).

The following sections discuss the effectiveness and efficiency of policy support with respect to individual technologies. The analysis focuses on OECD countries as well as Brazil, Russia, India, China, and South Africa. The most recent reliable data are from 2005. Note, however, that significant changes are likely to have occurred since this date.

Onshore wind

Key findings

- The presence of non-economic barriers, such as administrative hurdles (including planning delays and restrictions, lack of co-ordination between different authorities, long lead times in obtaining authorisations), grid access, electricity market design, lack of information and training, and social acceptance, has a significant negative impact on the effectiveness of policies to develop wind power, irrespective of the type of incentive scheme.
- A minimum level of remuneration[33] appears necessary to encourage wind power deployment. Until 2005, none of the countries that provide overall levels of remuneration below USD 0.07/kWh[34] witnessed significant deployment effectiveness.
- The group of countries with the highest effectiveness (Germany, Spain,[35] Denmark and, more recently, Portugal) used feed-in tariffs (FITs) to encourage wind power deployment. Their success in deploying onshore wind stems both from high investment stability guaranteed by the long term FITs and an appropriate framework with low administrative and regulatory barriers as well as relatively favourable grid

33. Remuneration levels equal the total tariff paid to a renewable electricity producer in the case of FITs. In all other cases, it encompass the sum of the electricity price plus any premiums and/or incentives received for every unit of renewable electricity.
34. All figures are in USD (2005), evaluated at market exchange rates.
35. Since 2004, Spain offers renewable energy generators a choice between FITs and feed-in premiums (FIPs).

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access conditions. In 2005, the average remuneration levels in these countries (USD 0.09-0.11/kWh) were lower than those in countries applying quota obligation systems with tradable green certificates (TGCs) (USD 0.13-0.17/kWh).

- Beyond some minimum threshold level, higher remuneration levels do not appear to yield greater levels of policy effectiveness. The highest levels of remuneration on a per-unit-generated basis for wind among the countries studied here are seen in Italy, Belgium, and the United Kingdom, which have all implemented quota obligation systems with TGCs. Yet none of these countries scored high levels of deployment effectiveness. This is likely related to the existence of high non-economic barriers as well as to intrinsic problems with the design of tradable green certificate systems in these countries, which lead to higher investor risk premiums.
- Wind development in the United States is supported by a mix of state and federal policies. At the federal level, wind power receives generous tax incentives in the form of a 10-year production tax credit – which, in effect, acts equivalently to a feed-in premium – and 5-year accelerated depreciation. The combination of federal tax incentives with state-level financial incentives and renewable energy quota obligation systems was a major driver in wind power capacity additions in the United States. To date, neither federal nor state support has been sufficient in isolation to foster growth in wind power. In addition, the lack of stability in the provision of the production tax credit on an ongoing basis has led to substantial boom-and-bust cycles in United States wind power installations in the 2000s.

Summary results

Onshore wind power development is accelerating at a rapid pace worldwide, but through 2005, 69% of the 56 GW of cumulative wind power capacity had been built in EU countries. Significant expansion of wind, in capacity terms, has also occurred in the United States (8.7 GW total installed capacity), India (4.4 GW), and China (1.3 GW).

The total mid-term realisable potential for onshore wind in the OECD countries and BRICS is 962 TWh, of which 89% remained to be exploited by the end of 2005.[36]

Table 4 clusters the results of the effectiveness and remuneration level analysis according to the examined countries' average 2000-2005 effectiveness levels. In addition, the table also shows the 2004/5 average effectiveness levels, the remuneration levels, 2005 market status and the most relevant policy instrument in place in 2005.

Main regional observations

Figure 2 displays the average effectiveness levels over the entire 2000-2005 period as well as the more recent average trend for 2004/5, whereby the countries are grouped by region.

36. For onshore and offshore wind energy together, 93% of the total realisable mid-term potential (1 405 TWh) remained to be exploited at the end of analysis period, which reflects the lower technology maturity and deployment of offshore wind.

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Table 4. **Onshore wind: Summary results of effectiveness and remuneration level (OECD and BRICS)**

Average yearly effectiveness level 2000-2005	Country	Range of average yearly effectiveness 2004/2005	Remuneration level	Cumulative capacity installed to end of 2005 (MW)	Main policy instrument(s) in 2005
> 7%	**DEU**	> 7%	medium	18 428	FIT
	ESP	> 7%	medium	8 317	FIT / premium FIT
	IRL	> 7%	medium	494	Tender[1]
	DNK	< 1%	medium	3 129	Premium FIT
3-7%	**PRT**	> 7%	medium	1 064	FIT
	NLD	> 7%	high	1 224	FIT / premium FIT
	AUT	> 7%	medium	827	FIT
	LUX	> 7%	medium	35	FIT
1-3%	**JPN**	3-7%	high	1 227	Quota obligation system with TGC / investment incentive
	KOR	3-7%	medium	99	FIT
	GRC	1-3%	medium	491	FIT
	ITA	1-3%	high	1 635	Quota obligation system with TGC
	GBR	3-7%	high	1 565	Quota obligation system with TGC
	IND	1-3%	medium	4 434	FIT / generation based Tender / tax measure
	BEL	1-3%	high	167	Quota obligation system with TGC
	USA	1-3%	low	8 706	Quota obligation system with TGC / tax measure
< 1%	**AUS**	1-3%	medium	740	Quota obligation system with TGC
	SWE	< 1%	medium	493	Quota obligation system with TGC
	NZL	1-3%	medium	168	n/a[2]
	POL	1-3%	medium	121	Quota obligation system with TGC
	CAN	< 1%	low	684	Tender / premium FIT

[1]Ireland switched to a FIT system in 2006, but through 2005 relied mainly on a tendering mechanism.
[2]New Zealand introduced a carbon levy on electricity generation, natural gas and gasoline consumption in 2007.

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Table 4. **Onshore wind: Summary results of effectiveness and remuneration level (OECD and BRICS)** *(continued)*

Average yearly effectiveness level 2000-2005	Country	Range of average yearly effectiveness 2004/2005	Remuneration level	Cumulative capacity installed to end of 2005 (MW)	Main policy instrument(s) in 2005
	FRA	1-3%	medium	723	FIT
	HUN	1-3%	medium	17	FIT
	SVK	< 1%	low	5	FIT
	NOR	< 1%	low	270	n/a
	CHN	< 1%	low	1 264	Generation based tender / other
	CZE	< 1%	medium	29	FIT / premium
	BRA	< 1%	medium	37	FIT
	CHE	< 1%	medium	12	FIT
	FIN	< 1%	medium	82	Tax measure
	TUR	< 1%	medium	21	FIT
	RUS	< 1%	low	12	n/a
	ZAF	< 1%	low	4	Investment incentive
	ISL	< 1%	medium	0	n/a
	MEX	< 1%	high	2	Tax measure

Effectiveness indicator	**Remuneration level**
>7 %	
3-7 %	< 7 US cent / kWh → low
1-3 %	7-12 US cent / kWh → medium
<1 %	> 12 US cent / kWh → high

Remuneration level results are actual figures, not normalised by capacity factors.

Source: Based on IEA calculations & Ragwitz et al. *(2008).*

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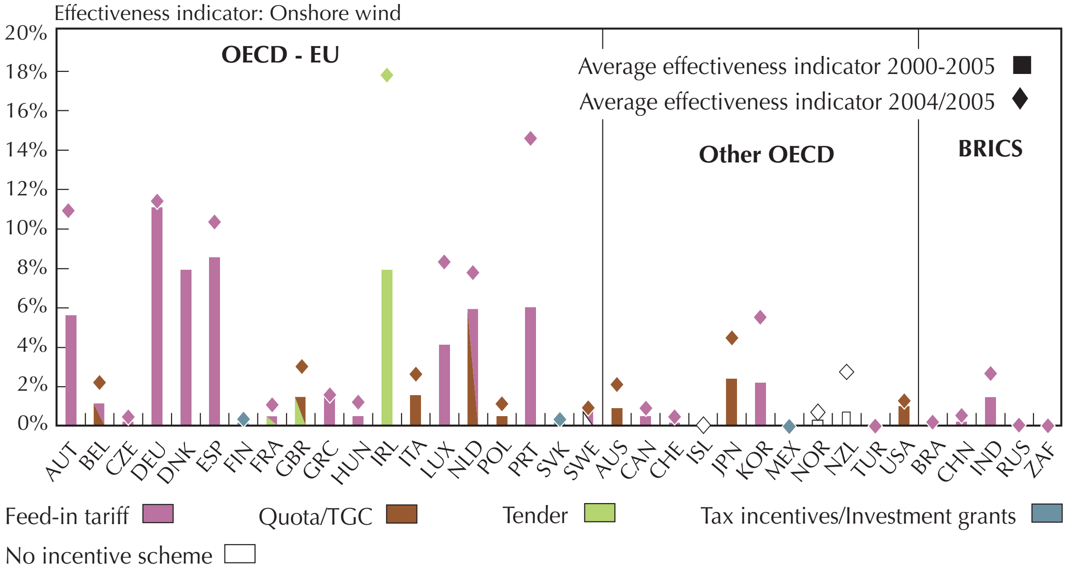
Figure 2. **Onshore wind: Average effectiveness 2000-2005 and average effectiveness 2004/2005 (by country)**



Source: Based on IEA calculations & Ragwitz et al. *(2008).*

Key point

Most countries with the highest average effectiveness over 2000-2005 and in 2004/5 used feed-in tariffs to foster wind power deployment.

From 2000 to 2005, the most successful countries in deploying wind power, relative to their realisable potential, were EU-15 countries. Germany, Spain, Ireland and Denmark have the highest effectiveness, with a second tier of countries including Portugal, Netherlands, Austria, Luxembourg, Japan, Korea, Greece, Italy, United Kingdom, India, Belgium and the United States (Table 4). Thus, 12 of the 16 countries with reasonable effectiveness levels from 2000-2005 are OECD-EU member countries.

Greater regional diversity of leading countries is discernable with regard to more recent wind power deployment from 2004 to 2005. The OECD-EU region still dominates, with 14 of the 20 leading countries, while Korea, Japan, Australia, New Zealand, the United States and India also show relatively high effectiveness levels. The United States has led the world in wind additions in 2005 but, as evidenced by the 2000-2005 and more recent 2004/5 effectiveness levels, can still tap a substantial portion of its vast realisable onshore wind potential. Nevertheless, wind power deployment is clearly expanding rapidly beyond the borders of the early EU-15 market leaders.

The effectiveness of some countries in supporting onshore wind has changed dramatically in recent years. In Portugal, the introduction of a new FIT led to a significant increase in effectiveness in 2004-2005. In contrast, in Denmark, policy effectiveness has significantly decreased due to a policy interruption in 2001, the elimination of the country's ambitious FIT, and a stronger focus on the development of offshore wind (Swisher & Porter, 2006).

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Beyond the OECD-EU member countries, the other OECD countries have implemented the most effective policy mechanisms over the period. Leading countries in this respect include Japan and Korea followed by the United States, Australia and New Zealand. In some cases the difference in effectiveness in 2004/05 compared to 2000-2005 mark a breakthrough or at least a new step in the deployment of wind energy in the country. This is the case for example in Korea, where the implemented FIT showed substantially improved effectiveness in 2004/2005.

In contrast, the incentive schemes in the new EU member states (Czech Republic, Hungary, Poland, Slovak Republic) have had relatively low levels of effectiveness over the 2000-2005 period, a trend which continued to 2004/2005.

Among BRICS, only India moderately tapped its significant realisable onshore wind potential from 2000 to 2005, with the introduction of feed-in tariff systems across many Indian states from 2003 onwards, due to more favourable national framework policies.[37] Through 2005, Brazil, Russia, and South Africa had installed limited quantities of wind power. China, on the other hand, had started to expand its wind generation by 2005. While the effectiveness of its policies towards wind had not been very effective through 2005; 2006 data indicates a significant expansion of wind power generating capacity after implementation of that country's renewable energy law in 2006.

Policy effectiveness and remuneration level

Figure 3 plots the indicator of average effectiveness levels in 2004/5 against the 2005 annualised remuneration level for each country.

Four of the five countries with the highest levels of policy effectiveness in deploying wind power from 2000 to 2005 as well as in 2004/5, namely Germany, Spain, Denmark and Portugal, primarily used feed-in tariff systems to encourage that deployment.[38] Interestingly, the policy support being provided by these countries is not among the highest in remuneration terms.

Beyond the OECD-EU region, feed-in tariffs also serve as a primary policy mechanism in Korea, India, and Brazil, with some early albeit limited success. Nonetheless, it is clear that the implementation of a feed-in tariff alone does not guarantee success. A number of other countries, including the Slovak Republic and Switzerland, have used feed-in tariff systems but, because the level of remuneration has not been attractive, have seen limited wind power deployment.

Quota obligation systems with TGCs in the OECD-EU, including those in the United Kingdom, Italy, and Belgium, have to date offered high levels of remuneration to onshore wind projects, but have only just begun to see an increase in policy effectiveness. The empirical evidence available to date from these countries suggests that the short-term investment horizon offered by their respective support systems either may be insufficient to stimulate sufficient investor interest or lead to investors requiring high risk premiums. The low effectiveness indicator for onshore wind in these countries is also caused by significant non-economic barriers, leading to large authorisation and project development times and higher total costs.

37. India's Electricity Act of 2003, for example, requires all state-level energy regulatory commissions to encourage electricity distributors to procure a specified minimum percentage of power generation from renewable energy sources (Lewis, 2007).

38. Ireland switched to a FIT system in 2006, but through 2005 relied on a tender mechanism.

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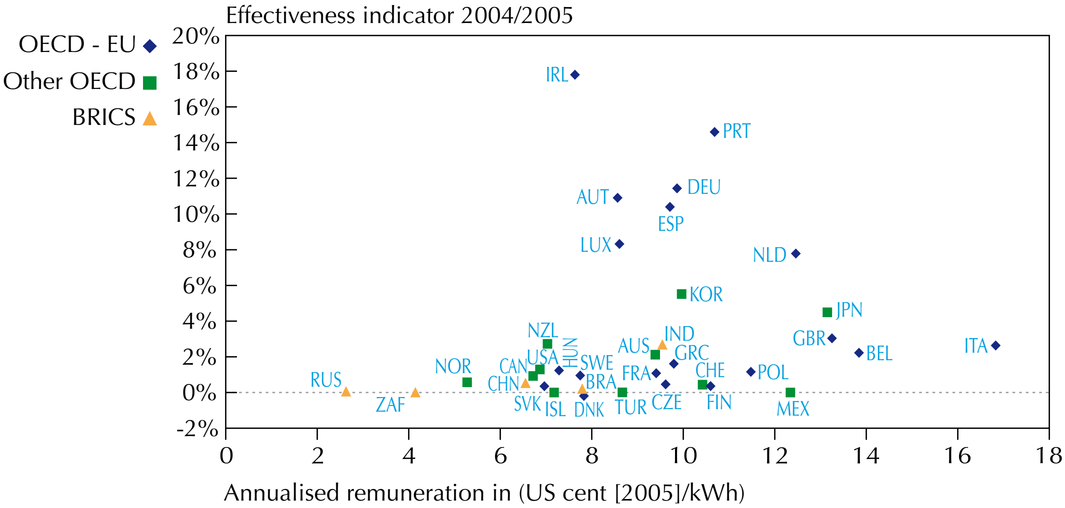
Figure 3. **Onshore wind – Policy effectiveness versus annualised remuneration levels**



Source: Based on IEA calculations & Ragwitz et al. *(2008).*

Key point

Beyond a minimum remuneration level of about USD 0.07/kWh, higher remuneration levels do not necessarily correlate with greater policy effectiveness.

Other countries which introduced quota obligation systems with TGCs, including Australia and the United States, have also witnessed increasing effectiveness of these policies over time, with lower overall average remuneration levels for onshore wind than those OECD-EU countries using similar deployment policies.

In the United States, onshore wind has benefited from a minimum level of national support, through a production tax incentive and accelerated depreciation. In addition, by the end of 2005, 20 US States plus the District of Columbia[39] had implemented mandatory quota obligation systems, the so-called Renewable Portfolio Standards (RPS) which add to this minimum level of federal support. Many – but not all – of these RPS include the trading of green certificates. In addition, *non-binding* renewable energy targets have been introduced in some states.[40]

Significant differences in market growth are evident among US States (see Box 3). For example in Texas, a relatively high level of effectiveness has been achieved at low levels of overall remuneration, while in others (*e.g.* New England) low levels of effectiveness have been achieved despite high overall remuneration. An important factor driving these differences may be the relative stability of different TGC quota obligation systems. Electricity market systems that encourage longer-term contracting are often better able to support new wind power additions effectively and efficiently than those markets in which short-term trade in TGCs predominate (Wiser and Langniss, 2001; Swisher and Porter, 2006).

39. As of April 2008, this had increased to 25 states plus the District of Columbia (Wiser and Barbose, 2008).

*40. As of the end of 2007, four states without a mandatory RPS had instead created voluntary targets through legislation: Missouri, North Dakota, and Virginia created their targets in 2007, while Vermont established its target in 2005 (*ibid.*).*

Box 3. **Onshore wind power additions in the United States**

The United States led the world in annual onshore wind power capacity additions in 2005, yet still has vast remaining resource potential. Wind development in the United States is supported by a mix of state and federal policies. At the federal level, wind power receives generous tax incentives in the form of a USD 20/MWh, 10-year production tax credit, and 5-year accelerated depreciation. These federal incentives have made wind power competitive with conventional (coal-fired) sources of generation in some regions of the country, though the lack of stability in the provision of the production tax credit on an ongoing basis has led to substantial boom-and-bust cycles in U.S. wind power installations in the 2000s.

The combination of federal tax incentives with state-level financial incentives and renewable energy quota obligation systems was a major driver in wind power capacity additions in the United States (Table 5).

Table 5. **Wind power growth in the United States**

State	Installed wind capacity, 2000-2005	Proportion of total wind installations in the US, 2000-2005	Major policy motivators
Texas	1666 MW	26.4%	Federal tax policy, and state quota obligation
Iowa	584 MW	9.3%	Federal tax policy, state goal and tax incentives, quota obligations in nearby states
California	503 MW	8.0%	Federal tax policy, and state quota obligation
Oklahoma	474 MW	7.5%	Federal tax policy, and state tax incentives
Minnesota	420 MW	6.6%	Federal tax policy, and state quota obligation
New Mexico	404 MW	6.4%	Federal tax policy, and state quota obligation
Washington	394 MW	6.2%	Federal tax policy, state tax incentives, quota obligations in nearby states
Oregon	274 MW	4.3%	Federal tax policy, state tax incentives, quota obligations in nearby states
Kansas	262 MW	4.1%	Federal tax policy, and state tax incentives
Wyoming	215 MW	3.4%	Federal tax policy and quota obligations in nearby states
Rest of US	1112 MW	17.7%	multiple

Source: Wind capacity data from EIA (2007).

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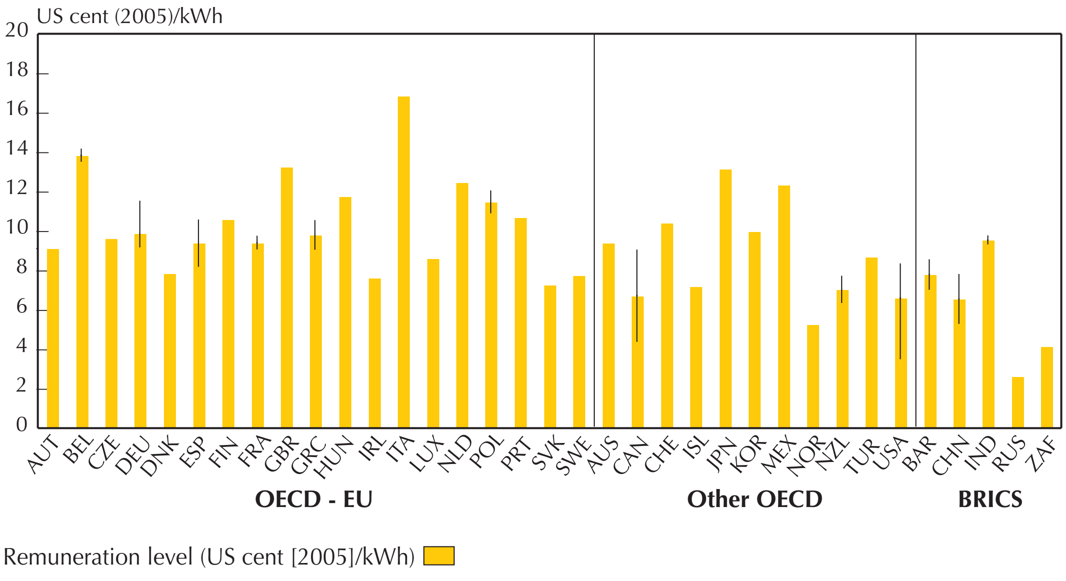
Box 3. **Onshore wind power additions in the United States** *(continued)*

The combination of federal tax incentives with state-level financial incentives and renewable energy quota obligation systems was a major driver in wind power capacity additions in the United States. To date, neither federal nor state support has been sufficient in isolation to foster growth in wind power. In addition, the lack of stability in the provision of the production tax credit on an ongoing basis has led to substantial boom-and-bust cycles in United States wind power installations in the 2000s. In New England, for example, aggressive quota obligation systems exist, but TGCs are primarily purchased in short-term markets, and as a result wind power projects have sometimes not been able to obtain the level of long-term revenue security needed to achieve financing; this despite the fact that the combination of wholesale power prices and short term TGC prices offer very high overall levels of remuneration. Costly and time-consuming siting and permitting procedures have also dramatically slowed wind development in that region.

Figure 4. **Onshore wind: 2005 annualised remuneration levels of the countries reviewed**



NB: "|" indicates minimum and maximum remuneration values.
Source: Based on IEA calculations & Ragwitz et al. *(2008).*

Key point

To 2005, high levels of remuneration were evident in quota obligation systems with TGCs in the OECD-EU region, including those in the United Kingdom, Italy, and Belgium.

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Electricity from solid biomass

Key findings

- The countries most successful in deploying biomass electricity over the 2000-2005 timeframe, relative to their respective realisable potential, are OECD-EU member countries. The Netherlands, Sweden, Belgium, and Denmark are found to have the highest levels of effectiveness.
- As in the case of wind energy, a certain minimum level of remuneration, in this case about USD 0.08/kWh, is necessary to initiate deployment. Non-economic barriers impact negatively on policy effectiveness.
- Solid biomass generally shows that different types of incentive schemes can be effective. For example in Sweden quota obligation systems have been effective at moderate cost (USD 0.08/kWh), while in Belgium the quota obligation system has encouraged biomass deployment at high cost (USD 0.14/kWh). In the Netherlands (USD 0.12/kWh), Denmark (USD 0.09/kWh) and Hungary (USD 0.10/kWh) feed-in tariff and premium systems are in place.
- The countries with high growth in deployment (Netherlands, Sweden, Belgium, and Denmark) succeeded due to the availability of abundant biomass combined with the opportunity for co-firing in coal-fired boilers. However, life-cycle assessment of bioenergy production is necessary to ensure the sustainability of this resource covering the full supply chain and possible land use changes. This might be a constraint for future exploitation, together with competition for access to the resource for other uses.

Summary results

The total mid-term realisable potential for solid biomass electricity in the OECD countries and BRICS is 1841 TWh, of which 93% remained to be exploited by the end of 2005.

Total electricity generation from solid biomass – from electricity-only and CHP plants – in 2005 is quite evenly distributed across the OECD and BRICS, although recent developments have occurred mainly in OECD-EU member countries (Table 6). OECD-EU member countries represented roughly one-third of the total biomass electricity generation in 2005 from those countries included in the analysis.

Non-EU OECD countries showed the largest contribution, with about 55% of total biomass generation of the considered countries. The United States, Japan, Canada, China and Finland feature among the leading countries for total biomass generation which is based mainly on capacity installed prior to 2000.

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Table 6. **Solid biomass electricity: Summary results of effectiveness and remuneration level (OECD and BRICS)**

Average yearly effectiveness level 2000-2005	Country	Range of average yearly effectiveness 2004/2005	Remuneration level	Generation in 2005 (GWh)	Main policy instrument(s) in 2005
> 10%	NLD	> 10%	medium	2 246	FIT / premium FIT
5-10%	SWE	> 10%	medium	6 848	Quota obligation system with TGC
	DNK	5-10%	medium	1 898	Premium FIT
0.5-5%	BEL	> 10%	high	960	Quota obligation system with TGC
	GBR	0.5-5%	high	3 388	Quota obligation system with TGC
	HUN	5-10%	medium	1 574	FIT[1]
	JPN	0.5-5%	high	12 507	Quota obligation system with TGC / investment incentive
	DEU	0.5-5%	medium	4 647	FIT
	ITA	0.5-5%	high	2 166	Quota obligation system with TGC
	NZL	0.5-5%	medium	565	n/a[2]
	PRT	0.5-5%	medium	1 351	FIT
	POL	0.5-5%	medium	1 399	Quota obligation system with TGC
	BRA	0.5-5%	low	8 279	FIT
	AUT	0.5-5%	high	1 930	FIT
	RUS	< 0.5%	low	5 184	n/a
< 0.5%	ESP	< 0.5%	medium	1 595	FIT / premium FIT
	IND	< 0.5%	medium	1 104	FIT / generation based tender / tax measure
	CHN	< 0.5%	low	8 251	Generation based tender / other
	AUS	< 0.5%	medium	1 100	Quota obligation system with TGC
	MEX	< 0.5%	high	2 958	Tax measure
	USA	< 0.5%	low	41 791	Quota obligation system with TGC / tax measure

1. The Hungarian FIT system for biomass electricity was introduced in 2005.
2. New Zealand introduced a carbon levy on electricity generation, natural gas and gasoline consumption in 2007.

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Table 6. **Solid biomass electricity: Summary results of effectiveness and remuneration level (OECD and BRICS)** *(continued)*

Average yearly effectiveness level 2000-2005	Country	Range of average yearly effectiveness 2004/2005	Remuneration level	Generation in 2005 (GWh)	Main policy instrument(s) in 2005
	CAN	< 0.5%	low	8 305	Tender / premium FIT
	CHE	< 0.5%	medium	77	FIT
	CZE	0.5-5%	medium	560	FIT / premium FIT
	IRL	< 0.5%	medium	8	Tender[3]
	GRC	< 0.5%	medium	0	FIT
	ISL	< 0.5%	medium	0	n/a
	LUX	< 0.5%	medium	0	FIT
	NOR	< 0.5%	low	0	n/a
	SVK	< 0.5%	low	4	FIT
	FRA	< 0.5%	medium	1359	FIT
	ZAF	< 0.5%	low	460	Investment incentive
	KOR	< 0.5%	low	33	FIT
	TUR	< 0.5%	medium	5	FIT
	FIN	< 0.5%	low	8136	Tax measure

3. Ireland switched to a FIT system in 2006, but through 2005 relied mainly on a tendering mechanism.

Effectiveness indicator	Remuneration level
> 10 %	
5-10 %	< 7 US cent / kWh → low
0.5-5 %	7-12 US cent / kWh → medium
< 0.5 %	> 12 US cent / kWh → high

Source: Based on IEA calculations & Ragwitz et al. *(2008).*

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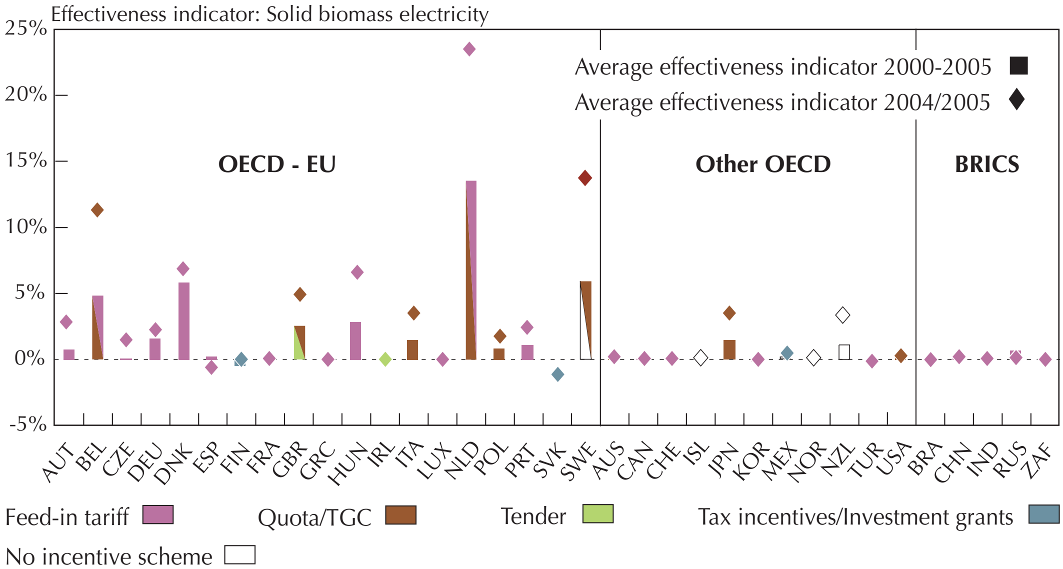
Main regional observations

Figure 5. **Solid biomass electricity: Average effectiveness 2000-2005 and average effectiveness 2004/2005 (by country)**



Source: Based on IEA calculations & Ragwitz et al. *(2008).*

Key point

To 2005, OECD-EU member countries – having implemented a diverse range of effective support instruments – have exhibited much higher policy effectiveness levels than countries in the other regions.

From 2000-2005, OECD-EU countries, led by Netherlands, Sweden, and Denmark, witnessed the most dynamic biomass-for-electricity markets in recent years, as defined by the effectiveness indicator (Figure 5). A large number of other countries showed good deployment effectiveness, including Belgium, the United Kingdom, Japan, Germany, Italy, New Zealand, Portugal, Poland, Brazil and Austria and Russia.

Interestingly, four of the five leading countries in terms of total biomass generation (United States, Canada, China and Finland, but excluding Japan) had low levels of deployment effectiveness from 2000-2005, in part because biomass electricity deployment in these countries preceded the year 2000, the analysis start date.

From 2004-2005, most of the leading countries significantly increased their effectiveness, on average by more than a factor of two. This shows that the biomass electricity sector is rapidly gaining attention, especially in OECD-EU member countries. The Czech Republic entered the group of more effective countries in this more recent period. Other countries have concentrated their efforts on combined heat and power (CHP) technologies, *e.g.* Belgium, which exhibited strong growth in this. A number of other OECD countries also advanced their pace in developing biomass electricity, in particular Japan, Australia, Mexico and the United States (Figure 6).

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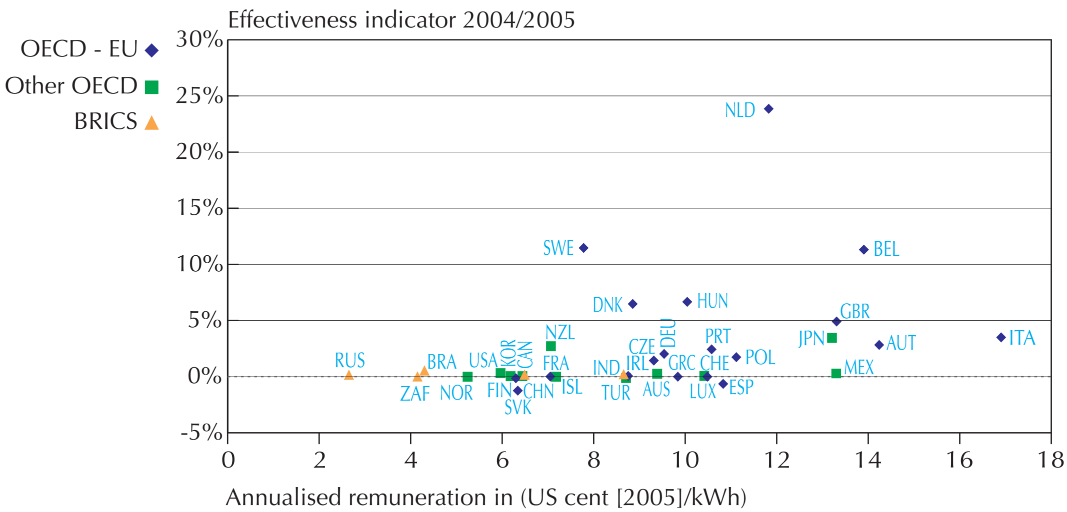
Among the BRICS, only Russia (5 TWh total deployment in 2005) and China (8 TWh total deployment in 2005) have seen moderate growth of biomass projects in the electricity sector, although the level of development compared to available potential is still small. In Brazil, India, and South Africa, the growth of this sector was almost negligible. Some of these countries have historically used biomass for traditional heating purposes, therefore making biomass electricity generation with more modern technology less popular. As these trends continue in many of the BRICS countries, it may be somewhat inappropriate to compare the effectiveness of biomass electricity deployment in the BRICS with that in the OECD countries.

Policy effectiveness and remuneration level

Figure 6. **Solid biomass electricity: Policy effectiveness versus annualised remuneration levels**



Source: Based on IEA calculations & Ragwitz et al. *(2008).*

Key point

Different types of incentive schemes, such as quota obligation systems, feed-in tariff and premium systems can be effective.

Biomass electricity generation involves a wide variety of feed-stocks and generation technologies which makes a comparison of policy effectiveness across countries more complex. Feed-stock prices may vary significantly between agricultural and forestry residues and products. Conversion technologies may include large biomass co-firing plants as well as small-scale decentralised applications.

A significant fraction of the recent growth observed in the Netherlands, United Kingdom, Hungary, Sweden, Italy and Belgium has been based on co-firing technologies. Austria and Germany, meanwhile, have concentrated on small-scale (below 20 MW) decentralised applications.

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Despite these complexities, a certain minimum level of remuneration of about USD 0.08/kWh is necessary to initiate deployment. Beyond some minimum threshold level, however, higher levels of remuneration do not appear necessarily to lead to greater levels of policy effectiveness. In particular, some countries are found to have reasonably high remuneration levels, but only moderate effectiveness indicators.

Nonetheless, to date, only a limited set of countries have been successful in combining a reasonable growth of solid biomass electricity generation with moderate levels of remuneration. The most successful countries in this respect are Sweden, the Netherlands and Denmark. In Sweden, the focus on medium- to large-scale applications using CHP technologies, combined with a long tradition in forestry industries, are the most relevant factors explaining the recent growth in biomass generation at moderate remuneration levels. In Denmark, a reasonably designed FIT, strong CHP traditions, and the use of agricultural residues at moderate costs are important elements of success. In the Netherlands, the combination of co-firing policies and cheap imported biomass resources (*e.g.* palm oil) are important aspects. In the OECD-EU region, FIT systems dominate, with 13 of 19 countries primarily using this mechanism, and with five other countries using a quota obligation model (Table 6). Beyond the OECD-EU, a greater diversity of support mechanisms is in use. In particular, the United States uses a combination of a federal production tax incentive and state-based quota obligation systems with TGCs, Australia uses a quota obligation system, and Korea uses feed-in tariffs. The United States witnessed significant growth in biomass electricity generation, especially in co-generation plant, in the 1980s as a result of attractive FITs. More recently, federal and state policy support has favoured wind generation, and biomass electricity generation has only very recently begun to increase again in some states as a result of quota obligations.

The BRICS show limited success in developing biomass electricity. Brazil, Russia and South Africa currently show low remuneration levels. While Russia historically developed biomass electricity generation, growth has come to halt more recently. China also shows a rather low remuneration level and limited recent deployment. India shows a somewhat higher remuneration level but deployment is rather moderate.

A key reason for the achievements of the most successful countries like the Netherlands, Sweden, Hungary, Belgium, and Denmark is the availability of cheap abundant biomass, *e.g.* wood residues and industrial wood wastes in Sweden combined with the option of co-firing. Relatively high remuneration levels in Italy and the United Kingdom are primarily caused by high certificate prices of short-term TGCs. Generally, it can be observed that quota obligation systems, *e.g.* in Sweden, can be much more effective than in the case of wind energy, which can be attributed to the fact that biomass deployment is typically less investment intensive and therefore less affected by high risk perception.

Nevertheless, life-cycle assessment of bioenergy production is necessary to ensure the sustainability of this resource covering the full supply chain and possible land use changes. This might be a constraint for future exploitation, together with competition for access to the resource from other uses.

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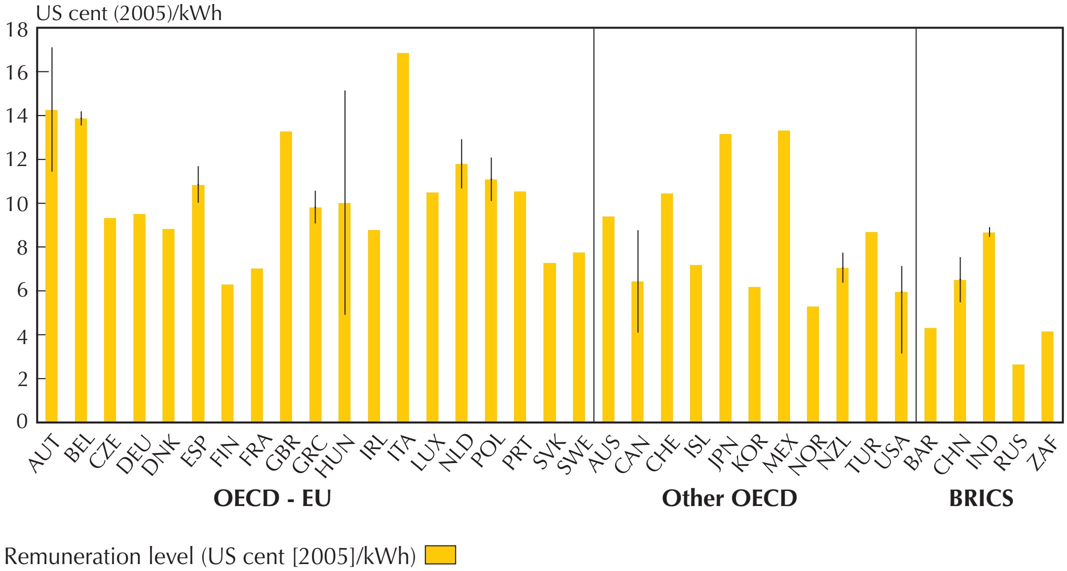
Figure 7. **Solid biomass electricity: 2005 annualised remuneration levels of the countries reviewed**



NB: "I" indicates minimum and maximum remuneration values
Source: Based on IEA calculations & Ragwitz et al. *(2008).*

Key point

Remuneration levels are quite evenly distributed between regions as well as among countries with different incentive schemes.

Biogas Electricity

Key findings

- Electricity generated from agricultural biogas, landfill gas and sewage gas between 2000 and 2005 was low relative to wind and solid biomass electricity. No generation of electricity from biogas was reported from any of the BRICS.
- The level of remuneration necessary to create financially viable projects strongly depends on the specific fuel used as well as on the size of the project. Strong competition for feedstocks has recently developed from agricultural markets, and affects the viability of projects in many countries. Countries using FIT systems often implement very different remuneration levels for the promotion of different biogas technologies, and also differentiate by size of the installation.

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- The highest growth of biogas generation from 2000-2005 was in Germany, the United Kingdom, and Luxembourg, with Germany and Luxembourg applying FITs and the United Kingdom a quota obligation system with TGCs. In Germany the FIT incentive scheme has shown relatively high costs compared with other countries due to the small-to-medium scale and type of feedstocks used in agricultural applications.
- Besides the United Kingdom, Italy's quota obligation system with TGCs has shown some of the highest effectiveness levels, with the strong growth in both countries mainly based on an expansion of landfill gas capacity producing methane which is cheap relative to other biogas feedstocks.

Summary results

Technologies treated in this section include anaerobic digestion of organic materials producing biogas (agricultural biogas), sewage gas and landfill gas. Similar to the case of solid biomass electricity, biogas technology development in recent years has been based almost entirely in a limited number of EU countries. Compared to wind energy, total existing biogas capacity is more evenly distributed, with roughly 60% of the generation in 2005 in EU countries, and 40% generated in non-EU OECD countries (Table 7). Leading countries in terms of total biogas generation include the United States, Germany, and the United Kingdom. No relevant generation of biogas electricity was reported from any of the BRICS countries.

Main regional observations

From 2000-2005, the overall progress in exploiting the mid-term realisable potential of biogas electricity, as represented by the effectiveness indicator, was relatively low compared to the case of onshore wind energy and biomass electricity (Figure 8). The total mid-term realisable potential for biogas electricity in the OECD countries and BRICS is 644 TWh, of which 96% remained to be exploited at the end of the analysis period.

The highest growth in biogas deployment was witnessed in OECD-EU countries, *i.e.* Germany, Greece and Luxembourg, all applying fixed feed-in tariffs, Belgium with a quota obligation system based on TGCs combined with a minimum FIT, Italy with a quota obligation system based on TGCs, and the United Kingdom with a tendering system, replaced in 2002 by a quota obligation system. The Finnish tax rebates have been unable to trigger relevant investments in biogas plants. The high growth in Italy and the United Kingdom was mainly based on expansion of landfill gas capacity, whereas in Denmark and Germany agricultural biogas had a significant share in the observed growth.

In 2004/5, policy effectiveness significantly increased in some countries, *i.e.* Sweden, Portugal, and the Czech Republic, compared to the 2000-2005 average. More specifically in the latter two countries the accelerated deployment was mainly due to the introduction of a new FIT in the Czech Republic and to a change of the FIT in Portugal. As in the case of wind energy, Denmark's policy change, lowering the feed-in premium remuneration on electricity from biogas, led to growth stagnating.

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Table 7. **Biogas electricity: Summary results of effectiveness and remuneration level (OECD and BRICS)**

Average yearly effectiveness level 2000-2005	Country	Range of average yearly effectiveness 2004/2005	Remuneration level	Generation in 2005 (GWh)	Main policy instrument(s) in 2005
> 3%	DEU	> 3%	high	4 708	FIT
	GBR	> 3%	high	4 690	Quota obligation system with TGC
	LUX	> 3%	medium	27	FIT
0.5-2%	GRC	0.5-2%	medium	122	FIT
	ITA	0.5-2%	high	1 197	Quota obligation system with TGC
	BEL	0.5-2%	high	223	Quota obligation system with TGC
	DNK	< 0.5%	medium	274	Premium FIT
	SWE	0.5-2%	medium	65	Quota obligation system with TGC
	KOR	< 0.5%	low	130	FIT
< 0.5%	ESP	< 0.5%	medium	582	FIT / premium FIT
	AUS	0.5-2%	medium	930	Quota obligation system with TGC
	USA	< 0.5%	low	6 449	Quota obligation system with TGC / tax measure
	FRA	< 0.5%	medium	462	FIT
	PRT	0.5-2%	high	35	FIT
	AUT	0.5-2%	high	72	FIT
	POL	< 0.5%	medium	111	Quota system with TGC
	IRL	0.5-2%	medium	122	Tender[1]
	CZE	0.5-2%	medium	160	FIT / premium FIT
	SVK	< 0.5%	low	5	FIT
	ISL	< 0.5%	medium	4	n/a
	NLD	< 0.5%	medium	294	FIT / premium FIT
	CHE	< 0.5%	medium	149	FIT

1. Ireland switched to a FIT system in 2006, but through 2005 relied mainly on a tendering mechanism.

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Table 7. **Biogas electricity: Summary results of effectiveness and remuneration level (OECD and BRICS)**

Average yearly effectiveness level 2000-2005	Country	Range of average yearly effectiveness 2004/2005	Remuneration level	Generation in 2005 (GWh)	Main policy instrument(s) in 2005
	TUR	< 0.5%	medium	29	FIT
	CAN	< 0.5%	low	731	Tender / premium FIT
	BRA	< 0.5%	low	0	FIT
	CHN	< 0.5%	low	0	Generation based tender / other
	FIN	< 0.5%	low	0	Tax measure
	HUN	< 0.5%	medium	0	FIT
	IND	< 0.5%	medium	0	FIT / generation based tender / tax measure
	JPN	< 0.5%	high	0	Quota obligation system with TGC / investment incentive
	MEX	< 0.5%	high	0	Tax measure
	NOR	< 0.5%	low	0	n/a
	RUS	< 0.5%	low	0	n/a
	ZAF	< 0.5%	low	0	Investment incentive
	NZL	< 0.5%	low	116	n/a[2]

2. New Zealand introduced a carbon levy on electricity generation, natural gas and gasoline consumption in 2007.

Effectiveness indicator	Remuneration level
>3 %	
2-3 %	< 7 US cent / kWh → low
0.5-2 %	7-12 US cent / kWh → medium
<0.5 %	> 12 US cent / kWh → high

Source: Based on IEA calculations & Ragwitz et al. *(2008).*

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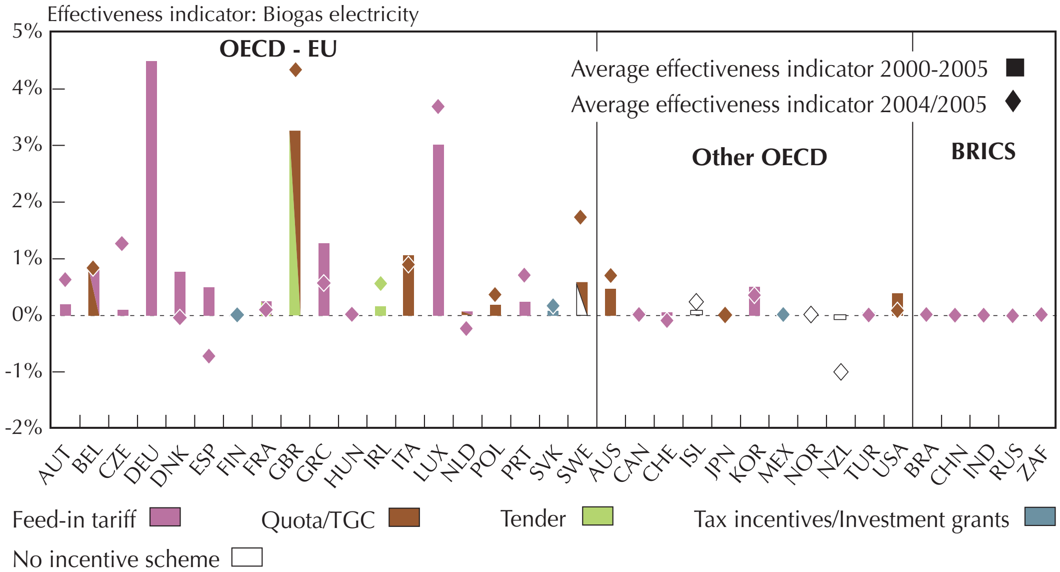
Figure 8. **Biogas electricity: Average effectiveness 2000-2005 and average effectiveness 2004/2005 (by country)**



Source: Based on IEA calculations & Ragwitz et al. *(2008).*

Key point

Over the six-year period, OECD-EU countries saw the highest growth in biogas production relative to their respective potentials. More recently in 2004/5, policy effectiveness increased in other OECD countries.

Beyond the OECD-EU region, only the Australian quota obligation system and the FIT in Korea were able to stimulate some growth, albeit at a rather moderate. The United States is the world's largest supplier of biogas electricity, but has seen slow growth in recent years. This is, in part, a result of the fact that some of the biogas development in the United States preceded the year 2000, and focused on landfill and sewage gas. As the potential for landfill and sewage gas has become exploited, growth in the sector has declined. More recently, quota obligations and state grant programs have begun to spur some additional growth in landfill and sewage gas usage as well as agricultural biogas, though this growth remains slow.

In the BRICS, the average effectiveness was low from 2000-2005. One reason for this may be the fact that biogas is frequently used for heating and cooking in developing countries, especially in China and India.

Policy effectiveness and remuneration level

The level of remuneration necessary to create financially viable projects in biogas electricity strongly depends on the specific fuel used, *e.g.* landfill gas, sewage gas, agricultural biogas, as well as on the size of the project. Countries using feed-in systems often implement very different remuneration levels for the promotion of different biogas technologies. Thereby, differentiation in support levels occurs between small and large-scale plants as well as between plants using different types of fuel. While Germany focuses on the promotion of small- to medium-scale agricultural plants, Denmark and Spain focus more on medium- to large-scale applications.

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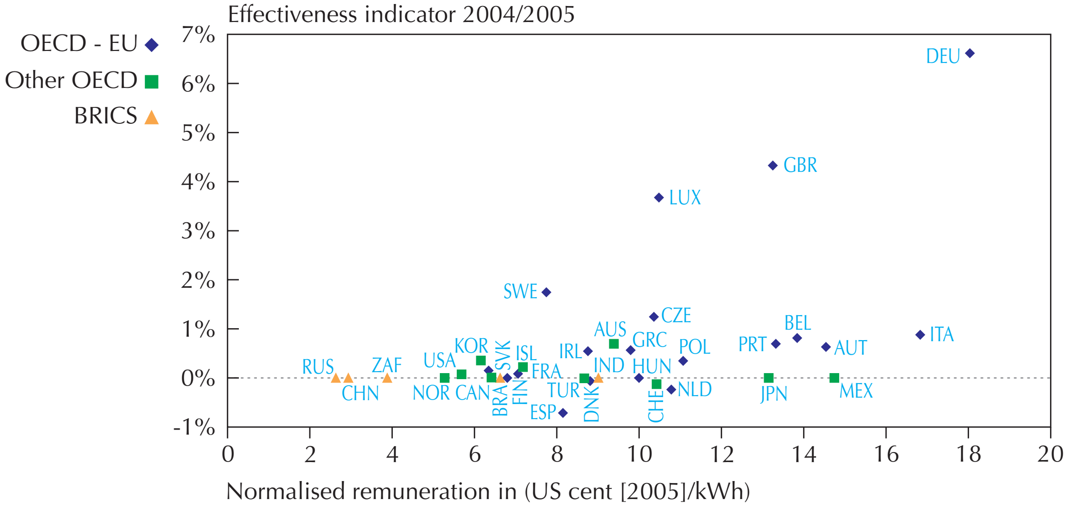
Figure 9. **Biogas electricity: Policy effectiveness versus annualised remuneration levels**



Source: Based on IEA calculations & Ragwitz et al. *(2008).*

Key point

The highest effectiveness in 2004/5 was in Germany, the United Kingdom, and Luxembourg, with Germany and Luxembourg applying FITs and the United Kingdom a quota obligation system with TGCs.

In general, the relationship between remuneration level and effectiveness is more pronounced for biogas electricity than for onshore wind and biomass electricity (Figure 9). Furthermore, it can be observed that there are fewer countries with very high remuneration levels and very low effectiveness. In many instances, a high remuneration level appears to be necessary to attain reasonable effectiveness. This is particularly caused by the fact that a high effectiveness can only be reached for a longer period if many biogas technology options, including more expensive feedstocks, such as agricultural biogas, are exploited.

Depending on the specific type of plant type and size and of feedstock used, a minimum remuneration level of about USD 0.08/kWh appears to be necessary. However, this minimum remuneration can increase significantly once low-cost biogas options like landfill gas are exploited.

Countries using quota obligation systems seem to perform better in the case of biogas than for wind energy but show again rather high remuneration levels, due to the high level of TGC prices in recent years. In the United States, low remuneration levels in general, combined with the fact that many low cost landfill gas options have already been exploited, have led to a slowing of biogas growth.

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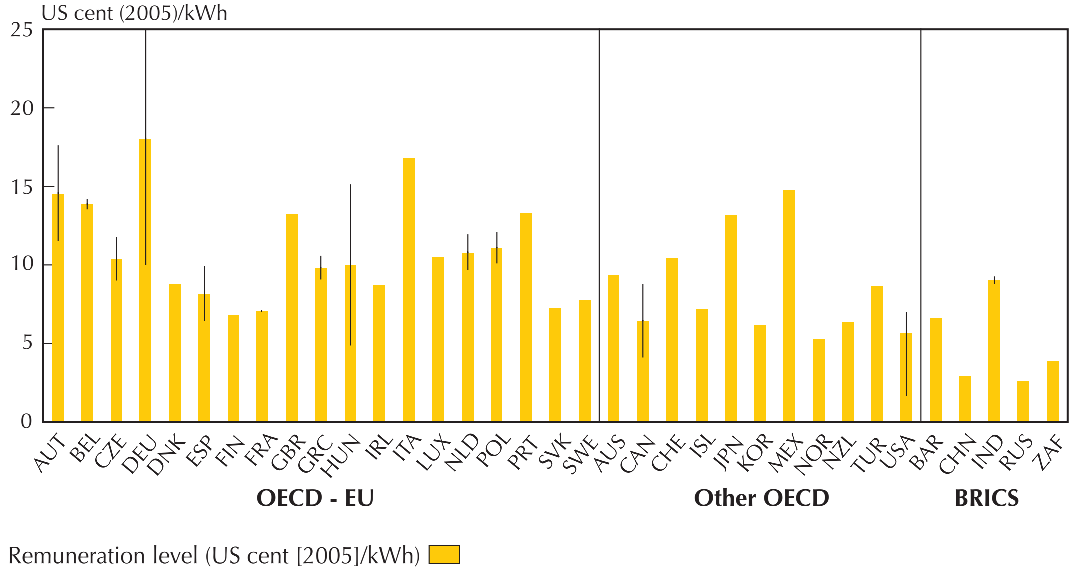
Figure 10. **Biogas electricity: 2005 annualised remuneration levels of the countries reviewed**



NB: "|" indicates minimum and maximum remuneration values.

Source: Based on IEA calculations & Ragwitz et al. *(2008).*

Key point

Differences in average remuneration levels reviewed also relate to the specific type of biogas conversion plant and feedstock used.

Solar photovoltaics (PV)

Key findings

- The investment costs of solar PV systems are still high, representing the most important barrier to PV deployment. Since only 1% of the realisable potential had been exploited by 2005, the average 2000-2005 policy effectiveness levels for PV are lower by a factor of ten than for a more mature RET such as wind energy.
- The development of PV in terms of absolute installed capacity has been dominated by Germany and Japan followed at some distance by the United States. These three countries were responsible for roughly 88% of the globally installed capacity at the end of 2005.
- Feed-in tariffs, complemented by the availability of soft loans and non-discriminatory grid access have been effective in Germany, albeit at a high cost. Japan and the United States have applied investment subsidies as main incentive scheme, possibly complemented by other support measures.
- Net metering, favourable retail rate structures and streamlined interconnection rules have also been enablers to sizable PV markets. These measures may become important triggers for PV market take-off in other countries as well.

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Summary results

The total mid-term realisable potential for solar PV in the OECD countries and BRICS is 394 TWh, equivalent to the United Kingdom's 2005 electricity production. Since only 1% of the realisable potential had been exploited by 2005, the average 2000-2005 policy effectiveness levels for PV are lower by a factor of ten than for a more mature RET such as wind energy.

The development of solar PV in terms of total installed capacity has been dominated by Germany and Japan, followed by the United States (Table 8). These three countries were responsible for roughly 88% of global installed capacity as of the end of 2005. Two countries of the BRICS region, namely India and China, as well as Australia belong to a second tier of market leaders.

More recently, and relative to their respective realisable potentials, other countries have gained momentum in developing solar PV. They include Luxembourg, Switzerland, the Netherlands, Austria and Spain.

Main regional observations

Relative to available realisable potential, the strongest growth of PV generation from 2000-2005 is observed in Luxembourg and Germany, followed by Japan, Switzerland, the Netherlands, Australia, Austria and the United States (Table 8). In all of these countries, except in Japan, Australia and the United States, this development was achieved by fixed FITs. In Japan, Australia and the United States, investment incentive programs have been mainly responsible for this development. The level of effectiveness in Luxembourg and Germany was significantly above the level in any other country. Luxembourg has experienced a very high market growth during 2004 and 2005 due to an exceptionally high feed-in tariff level (Figure 11). Among OECD-EU countries reasonable progress was also achieved in Austria, the Netherlands and Spain, whereas in Austria the overall effectiveness of the policy was limited due to a cap applied to the total installed capacity.

In other OECD countries, the highest effectiveness was observed in Japan, Switzerland and Canada. In Japan, the main driver was a 50% investment incentive programme, whereas in Switzerland a feed-in tariff with relatively low remuneration level has been applied.

The United States, with the third-largest PV market, scores poorly in terms of policy effectiveness. For many years, PV installations in the United States have benefited from federal tax incentives but these have been insufficient to significantly motivate PV installations. This is because the country has only begun to tap its enormous solar potential, with significant additions coming from only a couple of states, California and New Jersey (see Box 4). More recently, California (which alone represents nearly 80% of the total market), Arizona, and New Jersey established aggressive incentive policies for PV, including tax rebates for residential and commercial installations and quota obligation systems with a solar-specific set-aside. Australia's PV capacity mostly consists of a limited number of large-scale installations.

The progress of the BRICS is again rather limited, caused by lack of deployment activities in the case of Brazil, Russia and South Africa. In China and India, in turn, the effectiveness indicator is biased due to the huge potential of these countries. Both countries have shown

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Table 8. **Solar PV: Summary results of effectiveness and remuneration level (OECD and BRICS)**

Average yearly effectiveness level 2000-2005	Country	Range of average yearly effectiveness 2004/2005	Remuneration level	Cumulative capacity installed to end of 2005 (MW)	Main policy instrument(s) in 2005
> 0.5%	**LUX**	> 0.5%	high	25	FIT
	DEU	> 0.5%	high	1 508	FIT
	JPN	> 0.5%	high	1 421	Investment incentive / quota obligation system with TGC
	CHE	> 0.5%	medium	26	FIT / investment incentive
0.05-0.2%	**NLD**	0.05-0.2%	medium	51	FIT / investment incentive
	AUS	0.2-0.5%	medium	72	Investment incentive
	AUT	0.05-0.2%	high	22	FIT
	USA	0.05-0.2%	high	479	Investment incentive
	IND	< 0.05%	medium	86	Tax measure
< 0.05%	**ESP**	< 0.05%	high	37	FIT (net metering)
	CAN	0.05-0.2%	medium	17	Investment incentive
	ZAF	< 0.05%	medium	14	Tax measure
	ITA	< 0.05%	high	34	Premium FIT[1]
	MEX	< 0.05%	medium	19	Tax measure
	KOR	< 0.05%	high	14	Investment incentive
	DNK	< 0.05%	medium	3	FIT
	BEL	< 0.05%	medium	2	Investment incentive
	FIN	< 0.05%	medium	4	Investment incentive
	CHN	< 0.05%	low	70	Investment incentive / tax measure[2]
	GBR	< 0.05%	medium	11	Investment incentive

1. Italy introduced a feed-in premium support scheme for solar PV in July 2005.
2. In 2006, China introduced implementation rules for a PV feed-in tariff, within the regulations linked to its Renewable Energy Law.

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Table 8. **Solar PV: Summary results of effectiveness and remuneration level (OECD and BRICS)**

Average yearly effectiveness level 2000-2005	Country	Range of average yearly effectiveness 2004/2005	Remuneration level	Cumulative capacity installed to end of 2005 (MW)	Main policy instrument(s) in 2005
	FRA	< 0.05%	high	16	FIT
	PRT	< 0.05%	high	2	FIT
	GRC	< 0.05%	high	1	FIT / investment incentive
	SWE	< 0.05%	low	4	Quota obligation system with TGC
	RUS	< 0.05%	low	0	n/a
	NOR	< 0.05%	low	7	n/a
	BRA	< 0.05%	low	0	Investment incentive
	CZE	< 0.05%	medium	0	FIT
	HUN	< 0.05%	medium	0	FIT
	IRL	< 0.05%	low	0	n/a
	ISL	< 0.05%	low	0	n/a
	NZL	< 0.05%	low	0	n/a[3]
	POL	< 0.05%	medium	0	Quota obligation system with TGC
	SVK	< 0.05%	low	0	n/a
	TUR	< 0.05%	low	0	FIT

3. New Zealand introduced a carbon levy on electricity generation, natural gas and gasoline consumption in 2007.

Effectiveness indicator	Remuneration level
> 0.5 %	
0.2-0.5 %	< 10 US cent / kWh → low
0.05-0.2 %	10-30 US cent / kWh → medium
< 0.05 %	> 30 US cent / kWh → high

Source: Based on IEA calculations & Ragwitz et al. (2008).

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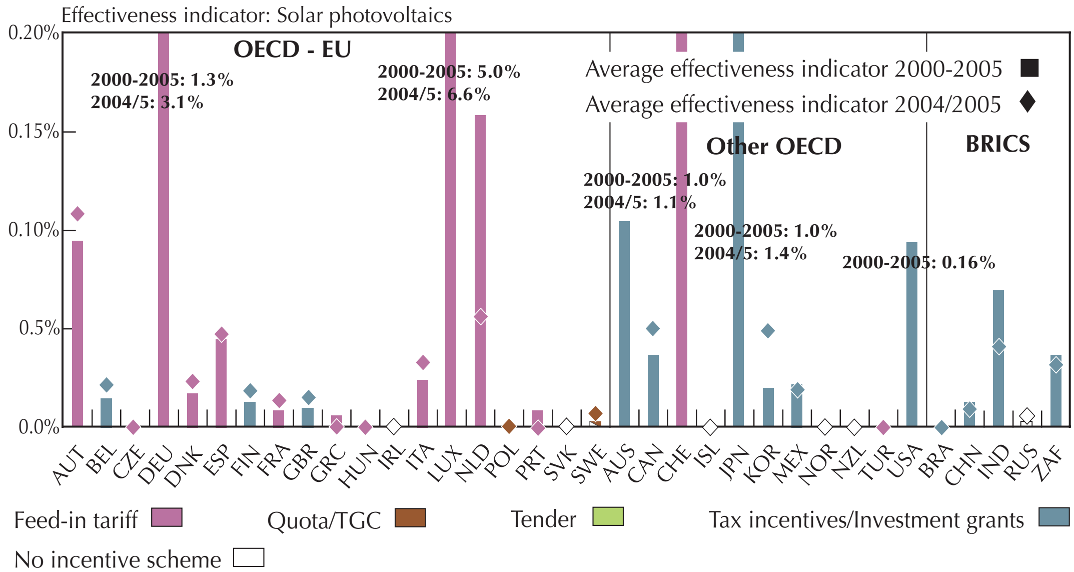
Figure 11. **Solar PV: Average effectiveness 2000-2005 and average effectiveness 2004/2005 (by country)**



Source: Based on IEA calculations & Ragwitz et al. *(2008).*

Key point

The highest effectiveness levels by far were seen in Luxembourg, Germany, Japan and Switzerland, both from 2000 to 2005 as well as more recently.

accelerated growth in recent years, India's installed capacity tripled from 2000 to 2005, China's even increased 3.5-fold, but both countries are still in the initial stage of development. China's domestic market consists mainly of demonstration projects and Chinese PV producers aim primarily at exporting to foreign markets, especially Japan or Germany.

Policy effectiveness and remuneration level

As Figure 12 is dominated by Germany and Japan, which are by far the market leaders, and Luxembourg, Figure 13 presents the same graph in larger scale to provide a closer look at the effectiveness of the other countries.

For the solar PV sector, the remuneration offered has reached a sufficient level mostly in OECD-EU countries, *i.e.* Austria, Germany, Spain, France, Greece, Italy, Luxembourg, Portugal, as well as in Japan, Korea and the United States. The exceptional high effectiveness in Luxembourg can be explained by a very high remuneration level in 2004 and 2005.

Feed-in tariffs, complemented by the availability of soft loans and non-discriminatory grid access have been effective in Germany, albeit at a high cost (USD 0.65/kWh). In recent years, the level of the German FIT for solar PV has decreased to some extent, and an element of degression has been introduced. The The German parliament has approved proposals for

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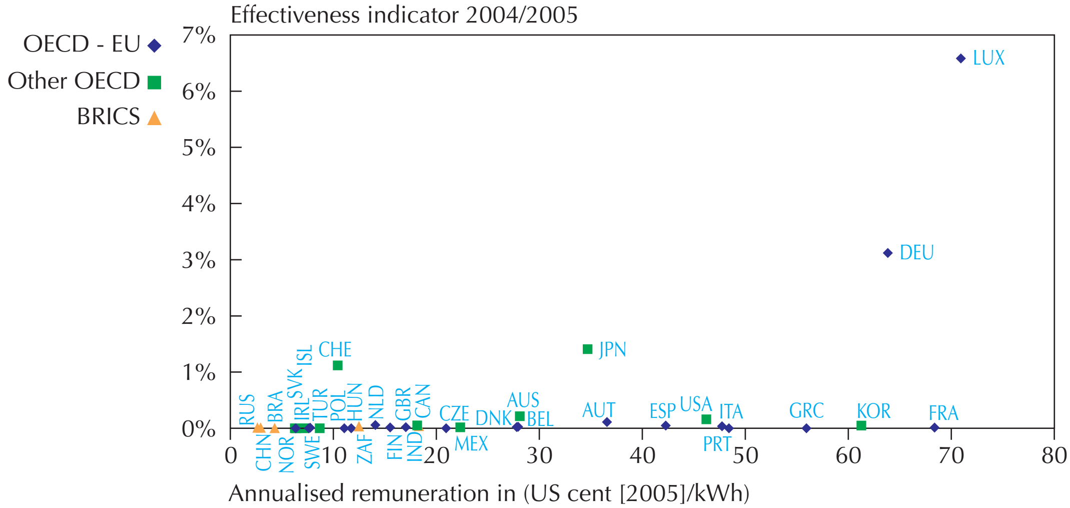
Figure 12. **Solar PV: Policy effectiveness versus annualised remuneration levels (normal scale)**

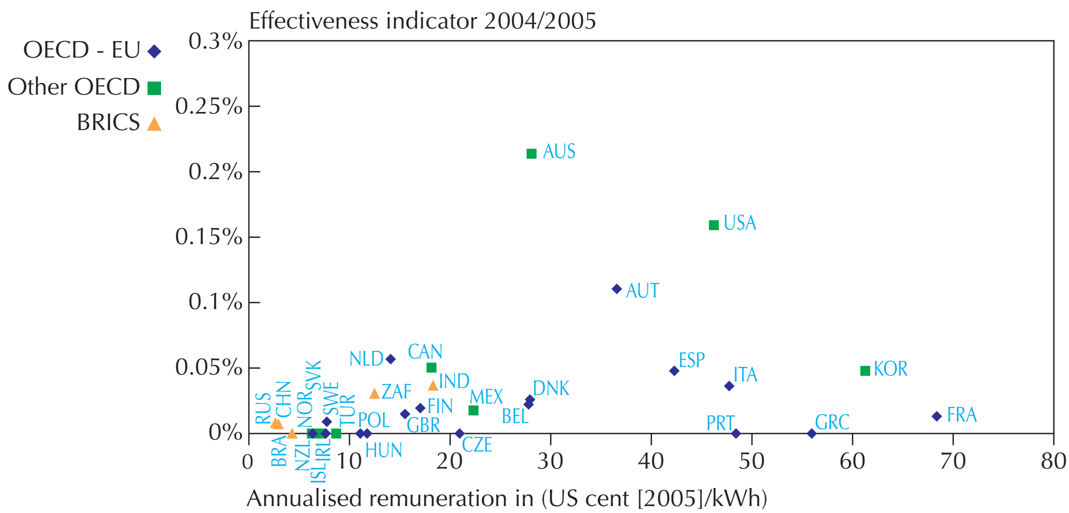


Source: Based on IEA calculations & Ragwitz et al. *(2008).*

Key point

The high effectiveness levels of Luxembourg and Germany were accompanied by high remuneration.

Figure 13. **Solar PV: Policy effectiveness versus annualised remuneration levels (large scale)**



Source: Based on IEA calculations & Ragwitz et al. *(2008).*

Key point

At lower levels of exploited realisable potential, investment incentives are relatively effective, as in Australia and the USA.

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acceleration of degression rates for stand-alone installations from 5% per year in 2008 to 10% per year in 2010 and 9% from 2011 onwards. This creates incentives to reduce costs and, hence, move down the learning curve.

France, on the other hand, shows even higher remuneration levels at very limited effectiveness, indicating that a similar willingness to pay does not exist, most likely influenced by non-economic barriers, such as high administrative hurdles for project developers to surmount (Coenraads *et al.*, 2006).

Among the countries with high effectiveness, Japan offered the lowest average remuneration, which is probably linked to the unit cost reductions induced by Japan's world leading long-established domestic PV industry.

Interestingly, some countries such as Greece and Italy showed relatively high remuneration with rather limited success from 2000-2005, which indicates the importance of additional non-economic barriers for PV deployment, such as lack of information and acceptance among authorising bodies and the wider community. However, recent policy developments in these two countries, involving the introduction of FITs for grid-connected PV installations in Italy in 2007 and in Greece in 2004, are fostering faster market growth.

In the United States, PV support comes both from federal tax incentives and state-level programs. Noteworthy state-level programs include both investment incentives and quota obligation systems with solar set-asides (see Box 4).

In China and India, support mechanisms were revised in 2005, as previous support policies had not generated growth at desired level. Both countries aim for PV to play a greater role in rural electrification, although remuneration in 2005 and incentives are not suited to foster a breakthrough.

Box 4. **Solar PV market developments in the United States**

The United States is currently the world's third-largest market for solar PV installations, though it has only begun to tap its enormous solar potential.

What distinguishes the United States from some other countries is that energy policy decisions are made at both the federal and state levels. For many years, PV installations have benefited from federal tax incentives, in the form of both an investment-based tax credit and 5-year accelerated depreciation. Those incentives, however, have not been sufficient to singularly motivate PV installations. As a result, only in those states that have developed aggressive incentive programs in addition to the federal incentives have solar markets begun to flourish.

Table 9, for example, shows the top three state PV markets in the US, in terms of installed grid-connected PV capacity over the 2000-2005 timeframe. California is clearly the leading state (with nearly 80% of the total U.S. market); with somewhat sizable markets in Arizona (6%) and New Jersey (5%) as well. The remainder of the United States represented just 9.5% of total grid-connected PV installations over this timeframe. As also shown in the table, growth in these three primary state markets is out of proportion to those states' population. Just as interestingly, the third largest market – New Jersey – is not among the states with the highest levels of insolation.

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Box 4. **Solar PV market developments in the United States** *(continued)*

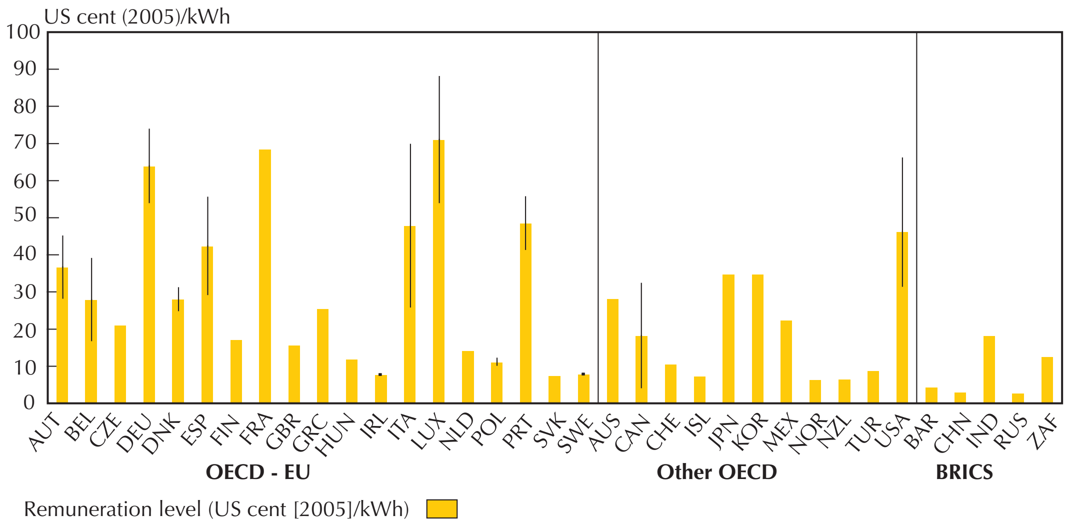
Table 9. **Grid-connected PV capacity growth in the United States**

State	Installed PV capacity, 2000-2005	Proportion of total PV installations in the US, 2000-2005	Proportion of US population, 2005
California	156.7 MW	79.5%	12.2%
Arizona	12.4 MW	6.3%	2.0%
New Jersey	9.2 MW	4.7%	2.9%
Rest of US	18.6 MW	9.5%	82.9%

Source: PV capacity data from (IREC, 2006).

Clearly, factors other than population levels and the solar resource are affecting the location of PV installation in the United States. Of most importance, California, Arizona, and New Jersey have established aggressive incentive policies for solar. In California, over the 2000-2005 timeframe, favourable rebates were offered to residential and commercial PV installations. In Arizona, a quota obligation system with a solar-specific set-aside was in place over this period, encouraging utilities to develop larger, utility-scale PV installations. And finally, in New Jersey, an up-front rebate was combined with a quota obligation system to offer aggressive support for PV. Net metering, favourable retail rate structures, and streamlined interconnection rules have also been enablers to sizable PV markets. Those U.S. states without sizable PV installations typically lack a specific economic incentive policy (whether a rebate, production incentive, or quota obligation), or else lack enabling and favourable net metering or interconnection rules.

Figure 14. **Solar PV: 2005 annualised remuneration levels of the countries reviewed**



NB: "|" indicates minimum and maximum remuneration values.

Source: Based on IEA calculations & Ragwitz et al. *(2008).*

Key point

Average remuneration levels in those countries that have stimulated market growth are higher for solar PV than for other more mature RETs due to existing high investment costs.

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Hydropower[41]

Key findings

- In most OECD countries, with the exception of Canada and Turkey, the additional potential for hydropower deployment is small because the potential has either already been exploited or is affected by legal frameworks regarding integrated water management, such as the EU Water Framework Directive, and occasional public resistance. In many OECD-EU countries, growth is taking place mostly in re-powering or upgrading of large scale plants or in form of new small scale plants.
- Nonetheless, in most BRICS, there has been remarkable progress in recent years and there remains significant additional potential to 2020. This growth is driven mainly by their drastically increased demand for electricity. There is also a need for capacity expansion in the hydrological aspects of water storage and management systems. Thus, with hydropower constituting an important element of integrated energy policy in these countries, renewable energy support schemes have – to a large extent – not been necessary to stimulate its development.
- As large hydropower is often competitive with thermal and nuclear electricity generation, many countries have a strong interest in developing this technology. A main constraint can be the environmental impacts of large-scale development which can severely delay the planning process and even derail the implementation of large-scale projects.

Summary results

The total mid-term realisable technical potential for hydropower in the OECD countries and BRICS is very large, 4041 TWh, of which 58% had already been exploited by the end of 2005, reflecting this RET's advanced level of technological maturity.

For some countries, the effectiveness indicator results may be less meaningful because their remaining additional realisable hydropower potentials may be small due either to large exploitation in the past or regulatory constraints on exploitation.[42]

41. For hydropower, the annual electricity generation has been calculated on the basis of installed capacity and an average capacity factor to exclude from the analysis the yearly variation in available resource due to climatic conditions. Pumped storage is excluded from the analysis.

42. In mature markets, the remaining potential, which is the denominator in the definition of the effectiveness indicator, approaches zero, amplifying some smaller changes in the numerator, i.e. *the additional generation capacity over a specific time frame. The effect of this is that some countries show a very high effectiveness level because of the small remaining potential rather than a large increase in capacity.*

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Nevertheless, there has been remarkable progress in some countries with significant remaining potentials. Table 10 shows the hydropower added between 2000 and 2005 by the countries adding capacity most rapidly.

The BRICS especially – with the exception of South Africa – showed accelerated growth in recent years, mainly as a consequence of these economies' dramatically increased demand for electricity over the analysis period, with sizable remaining mid-term potentials. There is also a need for capacity expansion for the hydrological aspects of water storage and management systems. Thus, with hydropower constituting an important element of integrated energy policy in these countries, renewable energy support schemes have – to a large extent – not been necessary to stimulate its development.

The decision-making processes for large hydropower projects differ from other RET plant scales since the former are often based on long term strategic motivations of the incumbent electricity market stakeholders rather than on short term economic motives of new agents in the electricity sector. It should be noted that this analysis does not distinguish between small and large hydropower, as differentiated data are not available and the definitions of large and small hydropower vary between countries and stakeholder groups.

Table 10. **The seven leading countries in terms of additional installed hydropower capacity from 2000 to 2005**

Country	Additional capacity installed, 2000-2005 (GW)	Cumulative capacity installed to end of 2005 (GW)
CHN	37.17	116.52
BRA	9.79	70.86
IND	6.63	30.45
CAN	4.57	71.80
ITA	3.59	16.98
TUR	1.73	12.91
RUS	1.60	45.90

Source: Based on IEA calculations & Ragwitz et al. *(2008).*

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Table 11. **Hydropower: Summary results of effectiveness (OECD and BRICS)**

Average yearly effectiveness level 2000-2005	Country	Range of average yearly effectiveness 2004/2005	Cumulative capacity installed to end of 2005 (MW)	Main policy instrument(s) in 2005
> 7%	ITA	> 7%	16 976	Quota obligation system with TGC
5-7%	PRT	> 7%	4 497	FIT
	FIN	> 7%	3 035	Tax measure
1-5%	BRA	1-5%	70 858	FIT
	POL	5-7%	915	Quota obligation system with TGC
	CAN	1-5%	71 801	Tender / premium FIT
	CHN	5-7%	116 520	Generation based tender / Other
	CHE	1-5%	13 355	FIT
	IND	1-5%	30 446	FIT / generation based tender / tax measure
	AUT	1-5%	8 231	FIT
	TUR	< 1%	12 906	FIT
	JPN	< 1%	22 133	Quota obligation system with TGC / investment incentive
	MEX	1-5%	10 285	Tax measure
	GRC	1-5%	2407	FIT
< 1%	FRA	1-5%	20 984	FIT
	RUS	< 1%	45 900	n/a
	ISL	< 1%	1 163	n/a
	AUS	< 1%	7 795	Quota obligation system with TGC
	CZE	1-5%	1 020	FIT / premium FIT
	KOR	< 1%	1 583	FIT
	HUN	< 1%	49	FIT
	LUX	< 1%	38	FIT
	NLD	< 1%	37	FIT / premium FIT

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Table 11. **Hydropower: Summary results of effectiveness (OECD and BRICS)** *(continued)*

Average yearly effectiveness level 2000-2005	Country	Range of average yearly effectiveness 2004/2005	Cumulative capacity installed to end of 2005 (MW)	Main policy instrument(s) in 2005
	ZAF	< 1%	668	Investment incentive
	ESP	< 1%	12 872	FIT / premium FIT
	NZL	< 1%	5345	n/a[1]
	IRL	< 1%	234	Tender[2]
	BEL	< 1%	105	Quota obligation system with TGC
	SWE	5-7%	16 302	Quota obligation system with TGC
	NOR	< 1%	26 410	n/a
	SVK	1-5%	1596	FIT
	USA	< 1%	77 540	Quota obligation system with TGC / tax measure
	DNK	< 1%	11	Premium FIT
	DEU	1-5%	4143	FIT
	GBR	> 7%	1513	Quota obligation system with TGC

1. New Zealand introduced a carbon levy on electricity generation, natural gas and gasoline consumption in 2007.
2. Ireland switched to a FIT system in 2006, but through 2005 relied mainly on a tendering mechanism.

Effectiveness indicator	Remuneration level
>7 %	
5-7 %	< 6 US cent / kWh → low
1-5 %	6-10 US cent / kWh → medium
<1 %	> 10 US cent / kWh → high

Source: Based on IEA calculations & Ragwitz et al. *(2008).*

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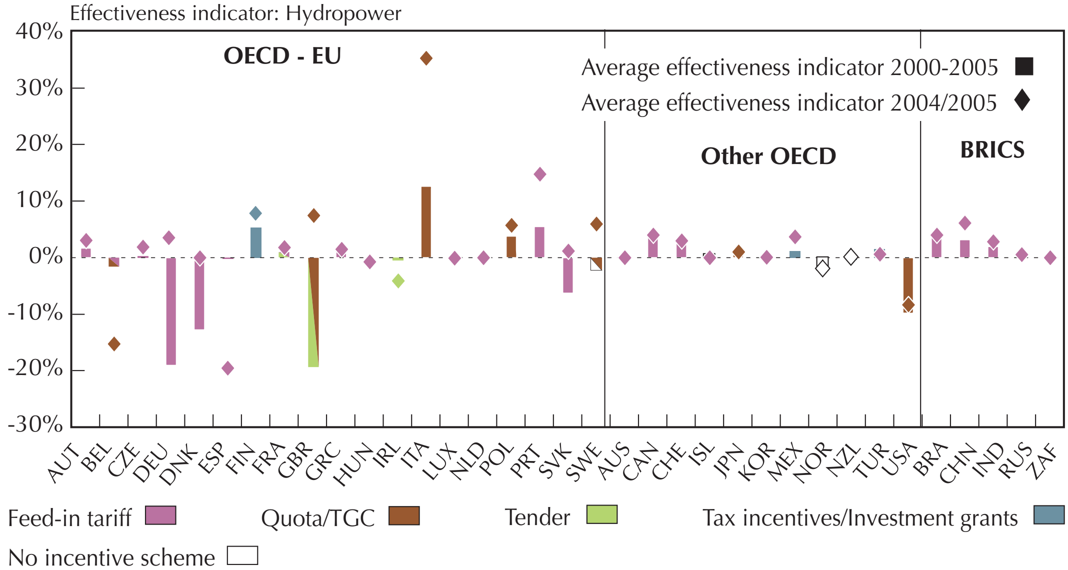
Policy effectiveness: main regional observations

Figure 15. **Hydropower: Average effectiveness 2000-2005 and average effectiveness 2004/2005 (by country)**



Source: Based on IEA calculations & Ragwitz et al. *(2008).*

Key point

The BRICS show sizable progress in developing this technology in recent years, but substantial potential remains to be exploited. The high effectiveness levels especially in the EU-OECD countries reflect the low additional realisable potential.

From 2000-2005, the highest effectiveness levels were achieved in Italy, Portugal and Finland (Figure 15). In particular Portugal significantly increased its installed capacity especially during 2004 and 2005. In Finland, the additional remaining potential is very small, so a small amount of additional capacity has a rather significant effect on the effectiveness indicator.

A second tier of countries includes Brazil, Poland, Canada, China, Switzerland, India, Austria, Turkey, Japan, Mexico and Greece. Thus, the spectrum of highly to moderately effective countries is significantly broader than for biogas and PV, also including three large emerging economies and six EU countries. This also stems from the need for hydropower capacity expansion and hydrological aspects, *e.g.* the need for water storage and management systems. As large hydropower is often competitive with thermal and nuclear electricity generation, many countries have a strong interest in developing this technology. A main constraint can be the environmental impacts of large-scale development which can severely delay the planning process and even derail the implementation of large projects.

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Some countries, namely China, India, Portugal, Brazil, Poland and Turkey increased their installed capacity by 10% or more from 2000 to 2005 (Table 10). The fact that three of these six most dynamic countries in terms of market growth are BRICS highlights their dynamic hydro development in recent years.

China's support policy is not homogeneous, being mainly based on case-to-case investment incentives. The growth in recent years resulted primarily from large-scale projects above 50 MW. Small-scale hydropower accounted for only 23% of capacity installed in 2005, representing only about 30% of the country's potential.

While India's market has been open to private investors since 1991, private sector investments in hydropower are still insignificant, mostly due to lack of both financial and administrative support. New policies introduced in 2003 (namely the 50 000 MW Hydro Initiative and Electricity Act) aim at creating an investment friendly environment, which is needed to exploit the country's hydropower potential. By 2005, only 20% of the realisable potential had been achieved.

Brazil is already highly reliant on hydropower, which represents about 80% of its generation capacity. Until 2005, the country had not built any further large-scale hydropower plants since the 1984 commissioning of Itaipu, the world's largest hydroelectric plant in terns of power output with an installed capacity of 14 GW. It has since focused mainly on supporting small-scale projects, with good results especially since a new feed-in law was introduced in 2002.

Turkey's hydropower system differs from that of other countries since it operates on a Build-Operate-Transfer principle, meaning that most plants are state-owned and the market not easily accessible for private developers. Turkey has made encouraging steps towards energy sector liberalisation since 2001, which may explain its recent high growth.

In OECD-EU countries, recent market expansion has been mostly through re-powering or upgrading of large-scale plants or the commissioning of new small-scale plants, both of which options generally require deployment support. Poland exemplifies this trend well, having steadily increased its small-scale capacity in recent years, with an average growth rate of 3% per annum.

Geothermal electricity

Key findings

- The main driver for the deployment of geothermal electricity is having suitable high temperature geothermal resources readily available without the need for deep drilling. This explains why only ten of the OECD countries and BRICS have shown any production of geothermal electricity.
- Iceland, Mexico and United States showed the highest growth rate in recent years, and Italy, the country with the highest policy effectiveness based upon a quota obligation system with TGCs, produces over 90% of all the geothermal electricity from OECD-EU member countries.

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Summary results

The total mid-term realisable potential for geothermal electricity in the OECD countries and BRICS is 87 TWh, of which 43% had already been realised at the end of the analysis period. This relatively high exploitation indicates the high level of technological maturity of conventional hydrothermal technology.[43]

To date, geothermal power is typically exploited with conventional hydrothermal technology, while the technology for enhanced geothermal systems (EGS) is still at the RD&D stage. The main driver for the production of geothermal electricity is the accessibility of high temperature (above 100°C) geothermal resources without the need for deep drilling.

While the long-term technical potential of geothermal power is sizable – also reflecting RD&D efforts to make EGS competitive – historical development as well as medium-term future deployment is based on relatively limited potentials utilising hydrothermal technology in a small number of countries with tectonically active regions (IEA, 2008a). Moreover, geothermal power is used most efficiently in co-generation, but the potential is often located in regions with low population density and, thus, low heat demand. This explains why only ten OECD and BRICS countries produce geothermal electricity, with only three of those countries being OECD-EU countries.

Table 12. **Geothermal electricity: Summary results of effectiveness (OECD and BRICS)**

Average yearly effectiveness level 2000-2005	Country	Range of average yearly effectiveness 2004/2005	Generation in 2005 (GWh)	Main policy instrument(s) in 2005
> 2%	ITA	< 0.1%	5 324	Tax credit/ Quota obligation system with TGC
	MEX	> 2%	7 299	n/a
	ISL	> 2%	1 658	n/a
0.2-2%	AUT	< 0.1%	2	FIT (CHP plants)
	RUS	0.2-2%	396	n/a
	USA	> 2%	16 778	Quota obligation system with TGC
	NZL	> 2%	2 852	n/a
< 0.1%	TUR	< 0.1%	94	n/a
	BRA	> 2%	n/a	n/a
	CHN	< 0.1%	79	n/a[1]
	PRT	< 0.1%	71	n/a
	JPN	< 0.1%	3 226	Quota obligation system with TGC

1. China introduced a feed-in tariff for geothermal electricity in 2006 within the regulations linked to its Renewable Energy Law.

Effectiveness indicator	> 2 %	0.2-2 %	0.1-0.2 %	< 0.1 %

Source: Based on IEA calculations & Ragwitz et al. *(2008).*

43. Enhanced geothermal systems, in contrast, are still at the demonstration stage and therefore represent only a minor contribution to the mid-term realisable potential to 2020 for geothermal electricity.

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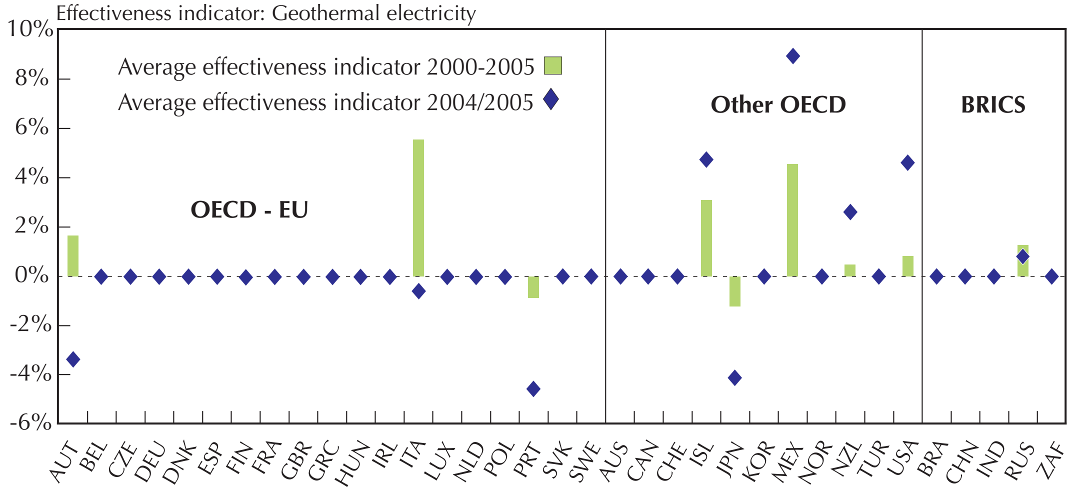
Policy effectiveness: main regional observations

Figure 16. **Geothermal electricity: Average effectiveness 2000-2005 and average effectiveness 2004/2005 (by country)**



Source: Based on IEA calculations & Ragwitz et al. *(2008).*

Key point

The non-EU OECD countries producing geothermal electricity have witnessed a greater increase in achieved potential in 2004/5 than OECD-EU countries and the BRICS.

Italy, the country with the highest effectiveness from 2000-2005, is by far Europe's leading producer of geothermal electricity, producing over 90% of Europe's geothermal electricity (Figure 16). The country increased its annual geothermal power generation by 13% over the period, although growth slowed more recently in 2004/5 due to operational difficulties at large plants and construction at several others. It should be pointed out that the long construction periods of three to five years for new plants cause delays between the implementation of policy measures and their effects. As a result, there are phases in which no growth can be observed in deployment, although new capacities are being built.

Mexico, which has generated geothermal electricity for 30 years, is the country with the second-largest market in the recent years. It added 100 MW of capacity between 2000 and 2005 and expects continuous near-term growth.

Iceland is the most intensive user of geothermal power, meeting almost one-fifth of its electricity needs from geothermal power. Geothermal energy plays an important role in the energy mix only in Iceland and to a smaller degree New Zealand (Figure 17). The United States remains the largest producer of geothermal energy with an installed capacity of over 2 100 MW and significant potentials remaining in western regions. Nevertheless, the growth indicated for 2004/2005 is primarily from a re-injection development at one of the major plants, with little additional capacity having been added over the analysis period.

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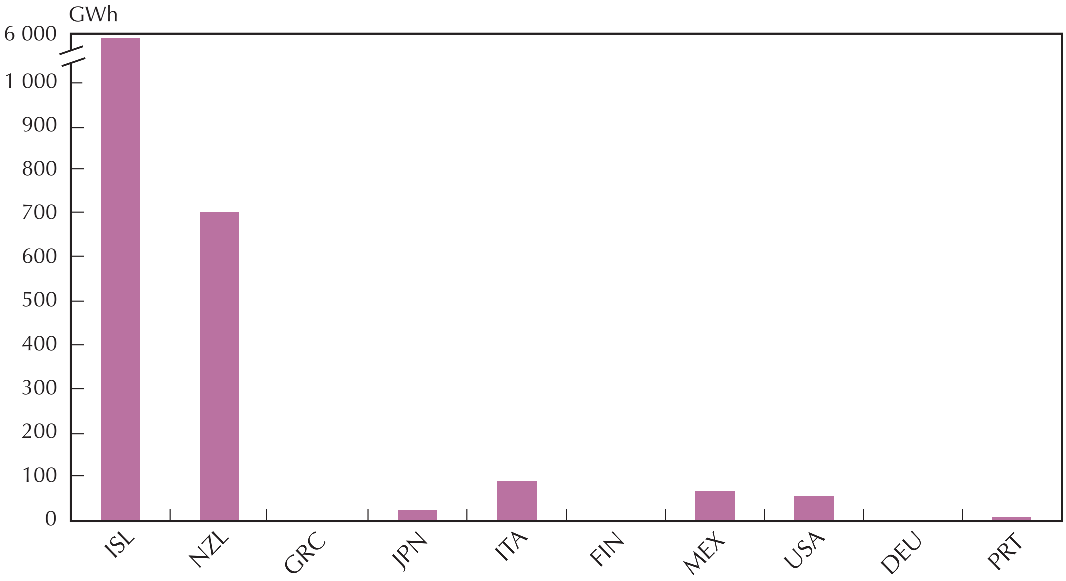
Almost all countries with any progress from 2000 to 2005 already had significant generation capacities in the previous decades, except Austria, which in the past had used geothermal resources predominantly for heating.

Reducing drilling risks to enable development of the resources is important in ensuring effective policy for stimulating geothermal deployment, as this can constitute up to 33-50% of geothermal project costs (IEA, 2008a).

Figure 17. **Geothermal electricity: Average consumption per capita in 2005**



Source: Based on IEA calculations & Ragwitz et al. *(2008).*

Key point

Geothermal energy plays an important role in the electricity mix of Iceland and, to a lesser extent, in New Zealand.

Analysis of RE policy effectiveness and remuneration level efficiency: RES-H technologies

Box 5. **Data availability on markets and policies for renewable heat (RES-H)**

Data gaps are apparent with regard to diffusion trends and relevant policies for RES-H, especially in non-IEA member countries. Compared to electricity and transport fuels markets, the heat market has been less closely scrutinised when policy makers have considered the design of the majority of renewable energy policies.

Available data are scant on policies and measures to stimulate the market uptake of RES-H (IEA and RETD, 2007).

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Box 5. **Data availability on markets and policies for renewable heat (RES-H)** *(continued)*

With regard to RES-H diffusion, official government statistics only capture the commercially traded fuel inputs to heat production as well as the commercial sale of heat by contract to a third party use (e.g. residential, commercial or industrial consumers).

Thus, while the data on grid-connected and centralised systems, such as district heating, CHP plants and industrial process heating, will be more reliable, heat production in non-grid connected and decentralised systems, such as ground-source heat pumps and domestic solar thermal for hot water and swimming pool heating, is not included in official statistics. Therefore, the actual contribution of renewables to heating is understated in official statistics (IEA, 2007a).

Geothermal heat

Key findings

- Despite the fact that the use of geothermal heat is well established in many countries, relative progress, as appraised by the effectiveness indicator, is slow, at least relative to the very large mid-term realisable potentials. A distinction also needs to be made between deep geothermal heat, often competitive with conventional heat where it is available, and heat from shallow ground source heat pumps.
- The main deployment barriers are cost, complex planning and permitting procedures and the distance between deep geothermal resources and centres of heat demand. Ground source heat pumps can be employed virtually anywhere in the world for both heating and cooling but have high investment costs, which necessitate policy support. This has been the reason for their limited deployment to date.
- Switzerland and Turkey were by far the most effective countries between 2000 and 2005. This is a substantial achievement, since the two countries lack significant high-temperature hydrothermal resources and, therefore, do not belong to the leading group of countries for geothermal electricity production.
- Enhanced geothermal systems from deep drilling are at an early stage of maturity and costly but have widespread potential, if current cost barriers can be overcome.

Summary results

Between 2000 and 2005, Spain, Switzerland, Austria and Turkey boosted their geothermal heat output by 50-60%, while the United States raised its production by over 15 petajoules (PJ) per year, which represents an increase of over 75% (Table 13). Over the same period, Iceland's deployment of geothermal heat did not grow much as geothermal heat already covers about 90% of demand for housing, which demonstrates this renewable heating technology's significant possibilities.

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However, despite the fact that geothermal heating, including heat from geothermal or ground source heat pumps, is well established in many countries, the relative progress, as appraised by the effectiveness indicator, is slow. A distinction also needs to be made between deep geothermal heat, often competitive with conventional heat where it is available, and heat from shallow ground source heat pumps.

The total mid-term realisable potential for geothermal heat in the OECD countries and BRICS is 1624 TWh (5846 PJ), of which only 3% had been realised by the end of 2005.

Table 13. **Geothermal heat: Summary results of effectiveness (OECD and BRICS)**

Average yearly effectiveness level 2000-2005	Country	Range of average yearly effectiveness 2004/2005	Generation in 2005 (TJ)	Main policy instrument(s) in 2005
> 1%	CHE	> 1%	5 743	Investment incentive
	TUR	> 1%	38 763	n/a
0.1-0.2%	USA	0.1-0.2%	35 661	n/a
	AUT	< 0.1%	821	n/a
	ISL	< 0.1%	33 200	n/a
< 0.1%	RUS	< 0.1%	1 200	n/a
	POL	< 0.1%	381	n/a
	KOR	0.1-0.2%	107	n/a
	ESP	< 0.1%	321	n/a
	DEU	< 0.1%	5 750	Investment incentive (capital grants, preferential loans)[1]
	FRA	< 0.1%	5 442	Risk coverage fund / tax credit
	HUN	< 0.1%	3 598	n/a
	DNK	< 0.1%	132	Building standards
	GBR	< 0.1%	33	Investment incentive (capital grants)
	PRT	< 0.1%	42	n/a
	BEL	< 0.1%	79	n/a
	ITA	< 0.1%	8 916	Investment incentive (tax credits)
	IRL	< 0.1%	2	Investment incentive (capital grants)
	SVK	< 0.1%	197	n/a
	GRC	< 0.1%	47	n/a
	JPN	< 0.1%	8 958	Investment incentive (subsidies)
	NZL	< 0.1%	15 672	n/a

1. Germany promulgated its federal Renewable Energy Heating Law in 2008, which requires all new residential buildings, starting in 2009, to obtain at least 14 percent of household heating and hot water energy from renewables, including solar, biomass and geothermal. The German federal government has allocated EUR350 million per year for capital grants to help homeowners meet their requirements (REN21, 2008).

Effectiveness indicator	> 1 %	0.2-1 %	0.1-0.2 %	< 0.1 %

Source: Based on IEA calculations & Ragwitz et al. *(2008).*

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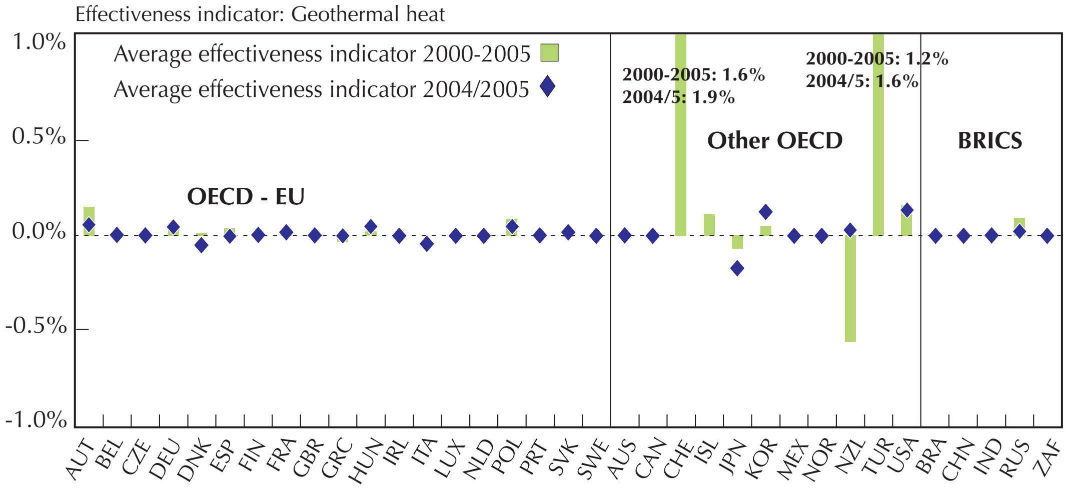
Policy effectiveness: main regional observations

Figure 18. **Geothermal heat: Average effectiveness 2000-2005 and average effectiveness 2004/2005 (by country)**



Source: Based on IEA calculations & Ragwitz et al. *(2008).*

Key point

The only countries which from 2000 to 2005 have significantly tapped their geothermal heat potential are Switzerland and Turkey.

As shown in Table 13 and Figure 18, only five countries showed a policy effectiveness indicator above 0.1%. All others had negligible results.

Switzerland and Turkey were by far the most effective countries between 2000 and 2005 – a substantial achievement since these countries do not have the highest potentials for geothermal electricity production due to the lack of a significant high-temperature hydrothermal resource.

The next most effective include the United States, Austria and Iceland, all of which already made substantial use of geothermal heat prior to 2000. However, the diffusion growth rates in these countries had declined considerably in 2004-2005.

Other countries with sizable geothermal heat production in the past include Germany, France, Italy, Hungary, Japan and New Zealand. However, none of these countries have seen significant growth over the analysis period.

From 2000-2005, the only country – among those for which policy information was available – which implemented policy support for geothermal heat is Korea, which focuses on energy utilisation for baths and on geothermal heat pumps for public and industrial buildings.

In many cases, the exploitation of geothermal heat potential is competitive given conventional heat prices, indicating that the development of successful projects mainly requires assistance in planning and permission procedures.

Enhanced geothermal systems (EGS) from deep drilling are at an early stage of maturity and costly but have widespread potential, if current cost barriers can be overcome.

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Solar hot water

Key findings

- While solar thermal heat resources are abundant in many world regions, the impressive progress made in recent years, with production and installation having doubled over the period 2000-2005, is concentrated in only a few countries.
- China is responsible for approximately half of global solar thermal heat generation and, together with Brazil and Austria, is currently progressing most quickly in utilising its realisable potential. In China, development can be more attributed to the cost competitiveness of solar thermal heat in many regions of the country. The main drivers of burgeoning consumer demand in China are a poorly developed conventional heating infrastructure, a well-developed domestic manufacturing industry, and changes in population demographics.
- Brazil does not provide policy support to solar thermal heat but has high solar radiation levels whereas Austria has achieved an almost equally high effectiveness due to rather modest investments in grants, information dissemination and training programmes.
- Main barriers to the deployment of solar thermal heat in most countries include inadequate planning guidelines, lack of consistent economic incentives, awareness programmes and training opportunities.
- Some regulatory policies such as the solar heating obligation in Barcelona and other Spanish municipalities represent very interesting innovative policy measures to overcome these barriers, leading to significant growth.

Summary results

In contrast to some other renewable energy technologies (RETs) analysed, such as geothermal heating, the contribution of solar thermal heat is more widespread among countries. Due to its full or partial competitiveness (depending on the location) and the distributed nature of the potential, the use of solar thermal heat is widespread over the world.

Active solar heating of water covers a wide range of heat generation processes, flat glazed collectors, non-glazed collectors and vacuum collectors typically with heat storage facilities. The sector has advanced substantially over the analysis period. Relative to 2000, the cumulative generation in 2005 of the countries reviewed had doubled with an increase of over 100 PJ (Table 14). China, the benchmark both in terms of total generation and relative market progress, was responsible for about 50% of global solar hot water production in 2005. The United States contributed about 20% of 2005 global hot water production from solar energy. Significant other countries exploiting solar hot water potential were Japan, Turkey, Germany, Brazil, Greece, India and Austria.

Yet the potential of solar thermal heat is very high and substantially untapped. The total mid-term realisable technical potential for solar thermal heat in the OECD countries and BRICS is 1 706 TWh (6 142 PJ), of which only 3% was exploited as of the end of 2005. As a consequence, all policy effectiveness indicators over the period 2000-2005, including the ones of the most active countries, are below 1% (Figure 19).

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Table 14. **Solar hot water: Summary results of effectiveness (OECD and BRICS)**

Average yearly effectiveness level 2000-2005	Country	Range of average yearly effectiveness 2004/2005	Generation in 2005 (TJ)	Main policy instrument(s) in 2005
> 0.5%	**BRA**	> 0.5%	4 270	n/a[1]
	AUT	> 0.5%	3816	Investment incentive (capital grants) (federal, regional) information dissemination training programmes
	CHN	> 0.5%	11 5358	n/a[2]
	NZL	0.2-0.5%	230	n/a
0.2-0.5%	**DEU**	0.2-0.5%	10 655	Investment incentive (capital grants, preferential loans)[3]
	TUR	0.2-0.5%	16 111	n/a
0.05-0.2%	**ESP**	0.2-0.5%	2 577	Building regulations (federal, local)
	LUX	0.05-0.2%	5	n/a
	MEX	0.05-0.2%	730	n/a
	CHE	0.2-0.5%	1 039	n/a
	NLD	0.05-0.2%	786	n/a
	CZE	0.2-0.5%	103	n/a
	IND	0.05-0.2%	4 037	n/a[4]
	PRT	0.05-0.2%	939	n/a
	GRC	0.05-0.2%	4 224	n/a
	DNK	0.05-0.2%	411	n/a
	HUN	< 0.05%	81	n/a

1. In 2007, Brazil's largest city Sao Paulo promulgated a law requiring solar hot water in all new buildings larger than 800 square metres (REN21, 2008).
2. Several Chinese municipalities have introduced solar hot water mandates since 2005, e.g. Shenzhen in 2006.
3. Germany promulgated its federal Renewable Energy Heating Law in 2008, which requires all new residential buildings, starting in 2009, to obtain at least 14 percent of household heating and hot water energy from renewables, including solar, biomass and geothermal. The German federal government has allocated EUR350 million per year for capital grants to help homeowners meet their requirements (REN21, 2008).
4. In 2006, the National Capital Territory of Delhi introduced a solar water heating obligation on certain building types, including hospitals, schools and large residential buildings.

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Table 14. **Solar hot water: Summary results of effectiveness (OECD and BRICS)** *(continued)*

Average yearly effectiveness level 2000-2005	Country	Range of average yearly effectiveness 2004/2005	Generation in 2005 (TJ)	Main policy instrument(s) in 2005
	ZAF	0.05-0.2%	378	n/a
	GBR	0.05-0.2%	1 229	n/a
< 0.05%	**BEL**	< 0.05%	113	n/a
	ITA	0.05-0.2%	850	Investment incentive (installation subsidies)
	RUS	< 0.05%	151	n/a
	SWE	0.05-0.2%	247	n/a
	IRL	< 0.05%	19	n/a
	FRA	< 0.05%	941	Risk coverage fund / investment incentive (grants) / tax credits
	FIN	< 0.05%	20	n/a
	SVK	< 0.05%	1	n/a
	CAN	< 0.05%	0	n/a
	ISL	< 0.05%	0	n/a
	NOR	< 0.05%	0	n/a
	POL	< 0.05%	0	n/a
	USA	0.05-0.2%	30 629	State, local: investment incentives (grants, buy-downs) / tax credits / soft loans
	AUS	< 0.05%	2 623	Quota obligation system with TGC[5]
	KOR	0.2-0.5%	1 454	n/a
	JPN	< 0.05%	24 237	n/a

5. In July 2007, the Australian federal government introduced a tax rebate system for the installation of solar and heat pump hot water systems in existing homes.

Effectiveness indicator	> 0.5 %	0.2-0.5 %	0.05-0.2 %	< 0.05 %

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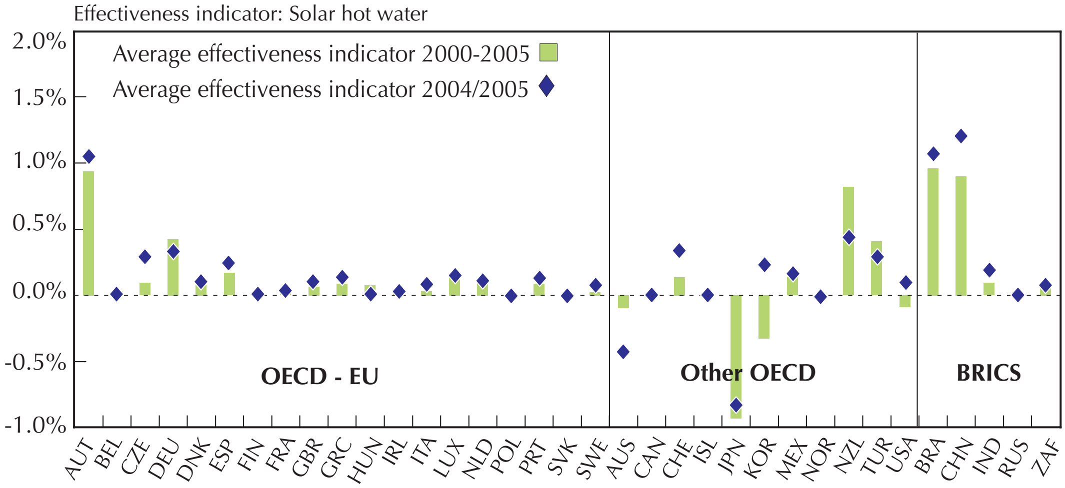
Policy effectiveness: main regional observations

Figure 19. **Solar hot water: Average effectiveness 2000-2005 and average effectiveness 2004/2005 (by country)**



Source: Based on IEA calculations & Ragwitz et al. *(2008).*

Key point

China and Brazil show significant relative progress in exploiting their potential as do selected OECD-EU countries. The strong growth in the emerging economies was mainly market-led in contrast to the importance of policy drivers in the European countries.

The six countries with the highest effectiveness over the period 2000-2005 are Brazil, Austria, China, New Zealand, Germany and Turkey.

The six countries with the highest effectiveness over the period 2000-2005 are Brazil, Austria, China, New Zealand, Germany and Turkey.

Among these countries, growth in China was the most impressive with an average annual growth rate of 33% over this period. While market growth in China since the 1980s was stimulated at the outset by modest investment incentives, there has been no relevant policy support during the analysis period. The drivers for solar water heater market penetration include an abundant solar resource in many regions, a lack of reliable conventional heating options, a well-developed domestic manufacturing industry, and changes in population demographics increasing the demand for hot water (IEA & RETD, 2007).

Brazil's development has also been impressive with average growth rates of almost 30% between 2000 and 2005.

Only two OECD-EU countries (Austria and Germany) feature among the most dynamic users of solar hot water technologies over the period 2000-2005. Both countries achieved their market leadership in Europe with rather modest investment incentives, showing that major drivers for the development of solar thermal heating systems are investment incentives such as grants, coupled with targeted awareness-raising and training initiatives.

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Countries which have significantly increased their effectiveness in 2004/5 are Spain, Switzerland, the Czech Republic and Korea. Some sub-national policies such as the solar heating obligation in Barcelona represent innovative policy measures which lead to significant market uptake.[44]

Generally, average 2000-2005 market growth of about 10% per year across all OECD countries and BRICS was significantly lower than that of the most successful countries like China and Brazil.

Biomass CHP heat

Key findings

- District heating and CHP plants are efficient uses of biomass resources if there is sufficient heat demand close to the production. Nonetheless, the overall achievement of CHP-based heat generation is rather moderate on a global level. This technology is implemented predominantly in Europe, with 80% of the overall generation of biomass CHP in OECD countries and BRICS. Of the remaining 20%, the BRICS represent 11% and other OECD countries add the remaining 9%.
- The effectiveness of this sector is higher than for other RES-H technologies but still significantly less than for RES-E technologies. By far the highest growth from 2000 to 2005 was reached in Scandinavian countries, in particular Denmark and Sweden.
- The critical success factors are cheap and abundant biomass potentials which may be derived from a strong forest industry combined with effective incentives for the promotion of biomass electricity and biofuels for transport.
- As in the case of biomass-based electricity, the net life-cycle environmental benefits of biomass heat need to be carefully assessed in light of land-use change and feedstock transportation impacts arising from a large-scale expansion of bioenergy production. Also, funding of biomass CHP should be consistent with support for biomass electricity, based on the overall seasonal efficiency of the installation.
- A further important success factor for biomass CHP-based heat generation is the existence of heating grids or the feasibility to construct new ones. This depends strongly on the density of heat demand and the tradition of grid-connected heat deployment which explains some of the success in Scandinavian countries. These basic conditions are also fulfilled in some of the BRICS, such as China and Russia, where good potential exists.

Summary results

Grid connected heat from district heating and combined heat and power (CHP)[45] plants is generally a highly efficient use of biomass feedstocks. This technology is implemented predominantly in Europe, with 80% of the overall generation of biomass CHP in OECD countries and BRICS (Table 15). Of the remaining 20%, the BRICS represent 11% and other OECD countries the remaining 9%.

44. In 2006, Spain introduced an obligation at the national level.
45. CHP is also known as co-generation (of heat and power).

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Table 15. **Biomass CHP heat: Summary results of effectiveness (OECD and BRICS)**

Average yearly effectiveness level 2000-2005	Country	Range of average yearly effectiveness 2004/2005	Level of support	Generation in 2005 (TJ)	Main policy instrument(s) in 2005
> 2%	**DNK**	> 2%	low	26 762	n/a
	SWE	> 2%	low	67 570	n/a
0.2-2%	**FIN**	0.2-2%	low	27 223	n/a
	AUT	> 2%	low	4 831	n/a
	LUX	0.2-2%	low	156	Investment incentive (capital grants, preferential loans)
	DEU	> 2%	low	30 568	n/a[1]
	CHE	0.2-2%	low	4 546	Building regulations (federal, regional, local)
	BEL	0.2-2%	low	1 385	n/a
	KOR	< 0.1%	low	1 517	n/a
	NLD	0.2-2%	low	2 424	n/a
	NOR	< 0.1%	low	1 564	n/a
	SVK	< 0.1%	low	232	n/a
0.1-0.2%	**ITA**	0.2-2%	low	7 974	n/a
< 0.1%	**POL**	0.1-0.2%	low	2 361	n/a
	FRA	< 0.1%	low	10 139	Risk coverage fund / tax credit
	IND	< 0.1%	low	2 708	n/a
	HUN	0.2-2%	low	619	n/a
	CHN	< 0.1%	low	12 645	n/a
	AUS	< 0.1%	low	0	n/a
	CAN	< 0.1%	low	6	n/a
	GBR	< 0.1%	low	0	n/a
	GRC	< 0.1%	low	0	n/a
	IRL	< 0.1%	low	0	n/a

1. Germany promulgated its federal Renewable Energy Heating Law in 2008, which requires all new residential buildings, starting in 2009, to obtain at least 14 percent of household heating and hot water energy from renewables, including solar, biomass and geothermal. The German federal government has allocated EUR350 million per year for capital grants to help homeowners meet their requirements (REN21, 2008).

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Table 15. **Biomass CHP heat: Summary results of effectiveness (OECD and BRICS)** *(continued)*

Average yearly effectiveness level 2000-2005	Country	Range of average yearly effectiveness 2004/2005	Level of support	Generation in 2005 (TJ)	Main policy instrument(s) in 2005
	ISL	< 0.1%	low	0	n/a
	JPN	< 0.1%	low	0	n/a
	MEX	< 0.1%	low	0	n/a
	NZL	< 0.1%	low	0	n/a
	PRT	< 0.1%	low	0	n/a
	RUS	< 0.1%	low	0	n/a
	TUR	< 0.1%	low	0	n/a
	ZAF	< 0.1%	low	0	n/a
	ESP	< 0.1%	low	0	n/a
	BRA	< 0.1%	low	2 965	n/a
	USA	< 0.1%	low	13 130	n/a
	CZE	< 0.1%	low	3 851	n/a

Effectiveness indicator	> 2.0 %	0.2-2.0 %	0.1-0.2 %	< 0.1 %

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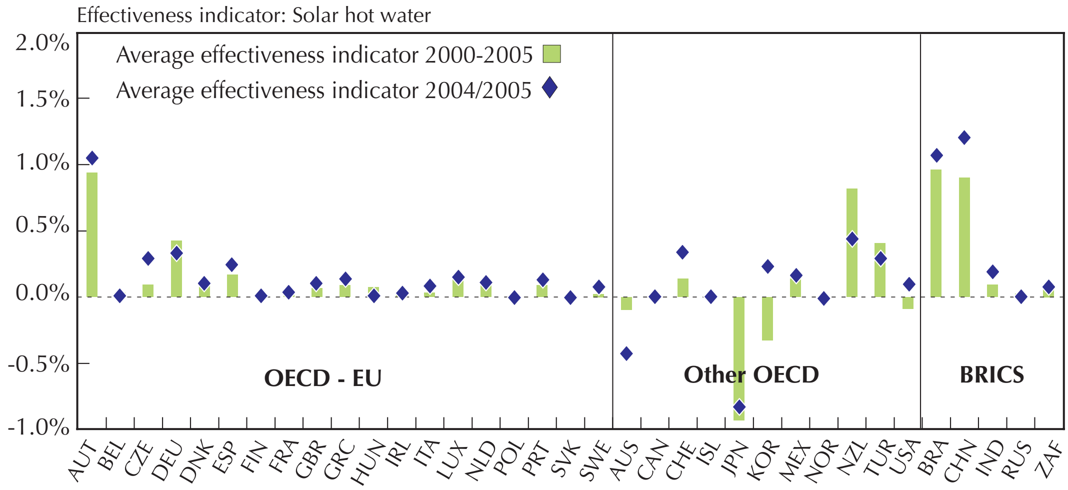
The overall achievement of biomass CHP-based heat generation is rather moderate on a global level. The effectiveness of this sector is higher than for other RES-H technologies but still significantly less than for RES-E technologies. The total mid-term realisable technical potential for biomass CHP heat in the OECD countries and BRICS is 2 337 TWh (8413 PJ).[46]

Policy effectiveness: main regional observations

Figure 20. **Biomass CHP heat: Average effectiveness 2000-2005 and average effectiveness 2004/2005 (by country)**



Source: Based on IEA calculations & Ragwitz et al. *(2008).*

Key point

By far the highest growth from 2000 to 2005 was achieved in Scandinavian countries, in particular Denmark and Sweden.

By far the highest growth from 2000 to 2005 was achieved in Scandinavian countries, in particular Denmark and Sweden (Figure 20). In terms of cumulative deployment, Denmark, Finland and Sweden contributed more than 50% of 2005 generation across all OECD countries and the BRICS.

Only two non-EU OECD countries, Switzerland and Korea, are among the 13 most effective countries during the period 2000-2005, with the former being the only non-EU country witnessing market growth in 2004/5, as indicated by a positive effectiveness level.

The critical success factors are cheap and abundant biomass potentials which may be derived from a strong forest industry combined with effective incentives for the promotion of biomass electricity and biofuels for transport (see sections on Electricity from Solid Biomass and Biofuels respectively).

46. Because of a lack of verifiable market data – especially in the non-EU OECD countries – on the actual production (achieved potential) of biomass CHP heat to 2005, no assessment of the additional *realisable potential was possible. Estimates of energy production and additional potentials were calculated on the basis of installed capacities for biomass CHP.*

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Sweden provided investment incentives for biomass-fired CHP plants during the periods 1991-1996 and 1998-2003. In addition, Sweden offered energy tax exemptions for biomass as well as investment incentives for district heating. In Denmark, investment incentives for biomass CHP systems as well as a quota for biomass use imposed on utilities were the main drivers. In Finland, a key policy driver was the energy tax exemption for biomass fuels as well as direct investment incentives for biomass plants. In Austria and Luxembourg, investment incentives for biomass plants combined with exemptions from energy taxes can also be viewed as the main support measures. In 2005, Germany introduced a CHP bonus for heat generation from biomass CHP plants within the framework of its renewable energy law.

In some OECD-EU countries, the substitution out of coal in industrial power-only and CHP plants is also driven by high coal prices combined with greenhouse gas emission caps under the European Union Greenhouse Gas Emissions Trading Scheme (EU ETS). In Poland, for example, the industrial use of biomass CHP increased substantially in 2005, the EU ETS' first year of operation.[47]

A further important success factor for biomass CHP-based heat generation is the existence of heating grids or the feasibility of constructing new ones. This depends strongly on the density of heat demand and the tradition of grid-connected heat deployment which explains some of the success in Scandinavian countries. These basic conditions are also fulfilled in some of the BRICS, *e.g.* China and Russia, where good potential exists.

Among the BRICS, only Brazil and China showed any deployment. However, the relevant installed capacity predates 2000 with neither country experiencing any market growth during the analysis period.

As in the case of biomass-based electricity, the net life-cycle environmental benefits of biomass heat need to be carefully assessed in light of land-use change and feedstock transportation impacts arising from a large-scale expansion of bioenergy production. Also, funding of biomass CHP should be consistent with support for biomass electricity, based on the overall seasonal efficiency of the installation.

Analysis of RE policy effectiveness and support level: RES-T technologies

Biofuels

Key findings

- From 2000 to 2005, OECD countries and the BRICS doubled their production of first-generation biofuels (ethanol and biodiesel). In 2005, they substituted for 20 Mtoe, representing 1% of 2005 worldwide transportation energy.
- Ethanol production is clearly dominated by Brazil and the United States -where it benefits from considerable subsidies – with shares of 41% and 44% respectively in total 2005 ethanol production among OECD countries and the BRICS.

47. *Specific support measures were only implemented in 2006.*

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- Biodiesel production and consumption in turn has shown growth mostly in the OECD-EU region, supported by very high subsidies through tax exemptions. China and India also show relatively high effectiveness in their deployment of ethanol, the former having introduced a blending quota and the latter a tax exemption as well as a guaranteed price for ethanol producers.
- In contrast to most forms of renewable energy which tend to be consumed and financed domestically, liquid biofuels can be traded and exported on a large scale. This means a broader range of policies, such as import and export tariffs, can be used to influence the amount of biofuels consumed domestically so that some countries produce biofuels in large quantities while consuming only a small part of the product.
- The most widespread support measures are full or partial exemption from excise tax, eco-tax or value—added tax as well as mandatory blending. Most countries promoting biofuels had tax measures in place or implemented them between 2000 and 2005, while blending quotas have been adopted only more recently.
- Of all the countries examined, Brazil remains a front-runner in the production of sugarcane ethanol which is driven by cost competitiveness and now relies on very low indirect tax relief. Germany, focusing primarily on biodiesel, enjoyed the highest policy effectiveness from 2000 to 2005 relative to its additional realisable potential to 2020. Nevertheless, Germany's progress came at a relatively high cost, mainly through a tax exemption which made biodiesel significantly cheaper than regular fossil-based diesel. It remains to be seen how the biodiesel market in Germany will develop now that the tax exemption has been removed. The United States had the second-highest effectiveness level, concentrating on the production of corn-based ethanol granting producer tax credits besides agricultural support mechanisms. Sweden was third-highest but at a relatively high cost, concentrating its efforts on ethanol in contrast to most other EU countries.
- Most OECD-EU member countries which were required to transpose the EU Biofuels Directive into national legislation showed accelerated growth in biofuel consumption over 2004/2005, in trying to achieve the indicative biofuel targets of a 2% transport fuel market share in 2005 and 5.75% in 2010, respectively.
- This analysis focuses on the period 2000 to 2005 and, therefore, does not consider more recent policy developments and significant ramping up of biofuel targets. The latter have stimulated growing public concern surrounding the impacts from increasing biofuel production on land use change, agricultural product prices, deforestation and water use. Competition for feedstocks between energy versus food production is increasingly being debated. Strong policy signals on the sustainable production and use of biofuels will need to accompany their large-scale market penetration, as is planned in the United States and the EU.
- Second-generation biofuel technologies under development are projected to play a vital part in achieving this objective by widening the range of feedstocks and improving the environmental and cost efficiency of biofuels. Effective policies, including RD&D efforts, are needed to foster a rapid transition to second-generation technologies.

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Summary results

This quantitative analysis only considers first-generation liquid biofuels for transportation which mainly encompass biodiesel, made from vegetable oils, and ethanol made from sugar or cereals. From 2000 to 2005, OECD countries and the BRICS doubled their production of these two first-generation biofuels. In 2005, they substituted for 20 Mtoe of fossil fuels, representing 1% of 2005 worldwide transport energy.

Ethanol production is clearly dominated by Brazil and the United States, benefiting from considerable subsidies, with shares of 41% and 44% respectively of total 2005 ethanol production of the OECD countries and BRICS.

Biodiesel production and consumption in turn showed growth mostly in OECD-EU countries, supported by high subsidies through tax exemptions.

In contrast to the other RETs analysed, which are consumed mostly domestically, liquid biofuels can be traded internationally on a large scale. This fact impacts the analysis. First, some countries produce biofuels in large quantities with low domestic consumption.[48] While most of the relevant biofuel production is traded between neighbouring countries, export distances have increased in recent years.[49] Therefore, biofuel *consumption* was chosen as the appropriate parameter for the analysis rather than *production*. Secondly, a wider range of policies, including import and export tariffs, influence the level of domestic biofuel consumption than in the case of non-traded energy products, such as electricity and heat.

Most countries with biofuel targets foster both production and consumption. The most relevant consumption-related measures are full or partial exemption from taxation, *e.g.* excise tax, eco tax, value-added tax (VAT) and mandatory blending quotas (Table 16). Almost all relevant countries have lengthy experience with fiscal measures, whereas blending quotas were only recently adopted in most countries, probably because of the lack of technical long-term experience.[50]

Box 6. **Caveats to discussion of policy effectiveness for biofuels**

This quantitative analysis focuses on the period 2000 to 2005, and therefore does not consider more recent policy developments and significant ramping up of biofuel targets. The latter have stimulated growing public concern surrounding the impacts from increasing biofuel production on land use change, agricultural product prices, deforestation and water use. Competition for feedstocks between energy and food production is being increasingly debated. Strong policy signals on the sustainability of production and use of biofuels will need to accompany their large-scale market penetration, as is planned in the USA and the EU.

Second-generation biofuel technologies under development are projected to play a vital role in achieving this objective by widening the range of feedstocks and improving the environmental and cost efficiency of biofuels. Effective policies, including RD&D efforts, are needed to foster a rapid transition to second-generation technologies.

48. For example, Denmark produced 80 million litres of biodiesel in 2005 which were mostly exported to Germany.

49. Brazilian ethanol, for example, is sold to the EU and Japan.

50. The United States allows blends up to 20% biodiesel (B20) while the EU allows a maximum blend of 5% (B5). Pure biodiesel (B100) requires some adjustments to the engine. Ethanol can be blended up to 10% (E10) without technical problems.

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Table 16. **Biofuels: Summary results of effectiveness and support level (OECD and BRICS)**

Average yearly effectiveness level 2000-2005	Country	Range of average yearly effectiveness 2004/2005	Support (tax exemption) for biodiesel	Support (tax exemption) for biogasoline	Consumption in 2005 (TJ)	Main policy instrument(s) in 2005
> 5%	**DEU**	> 5%	high	high	81 302	Tax exemption
1.5-5%	**USA**	1.5-5%	low	low	347 546	Tax exemption
	SWE	1.5-5%	high	medium	6 300	Tax exemption
	KOR	1.5-5%	low	low	442	n/a[1]
	AUT	1.5-5%	medium	medium	2 306	Blending quota[2] / tax exemption
0.05-1.5%	**ITA**	1.5-5%	high	medium	7 369	Tax exemption / blending quota
	ESP	0.05-1.5%	medium	medium	10 846	Tax exemption
	LUX	1.5-5%	low	medium	37	Blending quota / tax exemption
	CHN	0.05-1.5%	low	low	41 927	Blending quota (provincial level)
	IND	0.05-1.5%	low	low	43 782	Tax exemption / guaranteed price[3]
	GBR	1.5-5%	medium	low	3 376	Tax exemption
	FRA	0.05-1.5%	high	medium	20 441	Tax exemption / blending quota
	CHE	0.05-1.5%	high	low	262	Tax exemption
	CAN	0.05-1.5%	medium	low	5 386	Tax exemption[4]
	POL	0.05-1.5%	medium	medium	1 973	Tax exemption
	FIN	< 0.05%	low	low	0	n/a
	AUS	0.05-1.5%	low	low	456	Blending quota / tax exemption
	HUN	0.05-1.5%	low	medium	214	Tax exemption
< 0.05%	**BEL**	0.05-1.5%	high	medium	37	Tax exemption
	IRL	0.05-1.5%	high	medium	37	Tax exemption
	DNK	< 0.05%	low	low	0	n/a

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Table 16. **Biofuels: Summary results of effectiveness and support level (OECD and BRICS)** *(continued)*

Average yearly effectiveness level 2000-2005	Country	Range of average yearly effectiveness 2004/2005	Support (tax exemption) for biodiesel	Support (tax exemption) for biogasoline	Consumption in 2005 (TJ)	Main policy instrument(s) in 2005
	GRC	< 0.05%	medium	low	0	n/a
	ISL	< 0.05%	low	low	0	n/a
	JPN	< 0.05%	low	low	0	Voluntary target
	MEX	< 0.05%	low	low	0	n/a
	NLD	< 0.05%	medium	high	0	n/a
	NOR	< 0.05%	low	low	0	n/a
	NZL	< 0.05%	low	low	0	Tax exemption
	PRT	< 0.05%	high	medium	0	n/a
	RUS	< 0.05%	low	low	0	n/a
	TUR	< 0.05%	low	low	0	n/a
	ZAF	< 0.05%	low	low	0	n/a[4]
	BRA	1.5-5%	low	low	293 793	Tax exemption / blending quota
	CZE	< 0.05%	high	low	111	Tax exemption
	SVK	0.05-1.5%	low	low	440	n/a

4. In 2006, South Africa introduced a voluntary blending target up to 9 percent and a 10 percent blending target has been proposed.

Effectiveness indicator	Support (tax exemption) for biodiesel (USD / litre)	Support (tax exemption) for biogasoline (USD / litre)
0.2 - 2 %	< 0.20 USD → low	< 0.50 USD → low
0.1 - 0.2 %	0.20-0.50USD → medium	0.50-1.00 USD → medium
< 0.1 %	> 0.50 USD → high	> 1.00 USD → high

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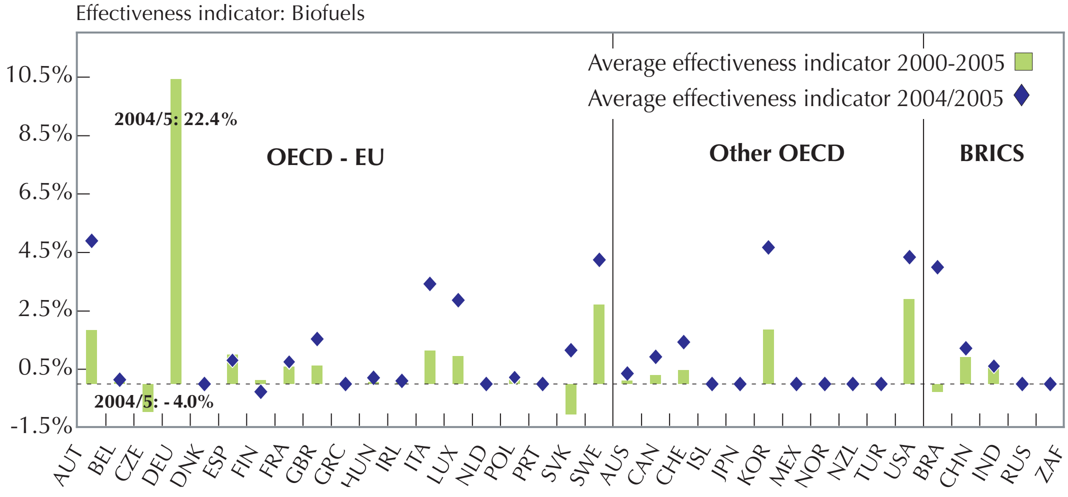
Policy effectiveness: main regional observations

Figure 21. **Biofuels: Average effectiveness 2000-2005 and average effectiveness 2004/2005 (by country)**



Source: Based on IEA calculations & Ragwitz et al. *(2008).*

Key point

From 2000-5, OECD-EU countries showed strong growth mostly in biodiesel consumption, with Germany leading by a wide margin, while the USA, Sweden, and Korea dominated increases in ethanol consumption. In 2004/5, Brazil's effectiveness level increased significantly.

The significant differences in support levels for first-generation biofuels across OECD countries and the BRICS can be attributed mostly to varying tax (exemption) levels as well as to differences in production costs.

Germany showed the highest growth rate by far among OECD countries and the BRICS, during both 2000-2005 (10.5%) and over 2004-2005 (22.4%), relative to its mid-term biofuel potential to 2020 (Figure 21). While the country's ethanol market has shown incipient growth, the primary focus remains on biodiesel. Germany has promoted biofuels at a high cost mainly through a tax exemption, which made biodiesel significantly cheaper than regular fossil diesel. Until 2003, only pure biodiesel (B100) was permitted, but starting in January 2004, blends up to five percent (B5) were allowed, leading to a continuously increasing share of biodiesel in conventional diesel fuels.[51] It remains to be seen how the biodiesel market in Germany will develop now after a gradual removal of the tax exemption over the period until 2012 was introduced in mid-2006. In contrast, ethanol is allowed in blends up to five percent (E5) although the average blend is about 2%. An infrastructure for an 85% ethanol blend (E85) is being considered but is not yet in place to generate significant demand.

51. The main customers are transport companies, which represent 45% of the biodiesel sold; 15% is used for blends while only 15% is sold directly as B100 to private consumers.

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In the next tier of countries, the United States, Sweden, Korea and Austria have shown an average effectiveness of 1-3% from 2000-2005, which accelerated to 4-5% in 2004- 2005.

From 2000 to 2005, the United States policy measures fostered a doubling of ethanol consumption to 347 546 TJ. The USA supported biofuels mainly through a tax break, which was abandoned in 2004. The replacement Volumetric Ethanol Excise Tax Credit (VEETC) was available to blenders/ retailers from January 2005 onwards. Until 2010, the incentive provides ethanol blenders with USD 0.135 per litre (l) of pure ethanol, meaning that E10 (*i.e.* a 10% ethanol blend), which is the biofuel blend favoured by the federal measures, is supported with USD 0.013/l, while E85 is eligible for USD 0.114/l. The Energy Policy Act of 2005 set the overall biofuel target in a so-called Renewable Fuel Standard (RFS) at 28.4 billion litres by 2012, mostly by promoting E10. In December 2007, the Energy Independence and Security Act of 2007 entered into force, increasing the RFS to 36 billion gallons of biofuel in 2022, with a cap on corn-based ethanol at 15 billion gallons and a requirement that "advanced biofuels" – including ethanol from cellulosic biomass, biodiesel and butanol – account for 21 billion of the total.

In addition, individual US states provide further support for ethanol and/or biodiesel through producer subsidies.

Sweden, unlike most other European countries, concentrated its efforts on high-blend ethanol (E85) and had relatively low biodiesel consumption. 80% of ethanol was imported, mostly from Brazil, until certain tax loopholes were abolished in 2006 to support Swedish producers.[52] While E85, like biodiesel, is exempt from both carbon dioxide tax and energy tax, it requires a special infrastructure and cannot be sold at regular gas filling stations without technical modifications. To promote flex-fuel vehicles (FFV) running on E85 these cars are exempt from congestion charges and receive other benefits, *e.g.* access to free parking.

Korea's main objective in increasing its blending of biodiesel is to decrease its dependence on foreign fuel imports, thus most of its consumption is produced domestically.

China and India also show relatively high effectiveness in their deployment of ethanol, with the former having introduced a blending quota and the latter a tax exemption as well as a guaranteed price for ethanol producers. China, with no significant production or consumption in 2000, increased its grain-based ethanol consumption to 37 028 TJ in 2005, and also consumed a small amount (4 899 TJ) of biodiesel.[53] Specific quota regulations remain within provinces' remit in the 2002 National Fuel Ethanol Programme, of which nine provinces had implemented E10 blending mandates by the end of 2007 (REN21, 2008). Concerned that ethanol fuel production using food crops, especially corn, could affect the food supply problem, the Chinese government began to restrict production of corn ethanol from at the end of 2006 and announced further subsidies and tax breaks for both biofuel producers and farmers who raise feedstocks other than grains. In 2007, the central government formally announced a 2020 target of satisfying 15% of its transport demand through biofuels and in March 2008 short-term 2010 targets were set: 43.5 kilobarrels per day (kb/d) for non-grain bioethanol fuel and a much lower biodiesel target of 4 kb/d by 2010 (GBEP, 2007).

52. In September 2007, the Sweden announced that it intends to abolish the protective duty introduced in 2006, most likely by 1st January 2009, if it receives regulatory approval by the European Commission.

53. While increased development of biodiesel is expected since the diesel market in China is twice the size of gasoline, present production is limited. The main challenge facing large-scale biodiesel production is the lack of feedstock, resulting from the short supply of edible vegetable oils. China is the largest importer of soybeans and imports significant quantities of other oil-based products. Coupled with the lack of fatty organic matter, the lack of arable land exacerbates the difficulty of biodiesel production (GBEP, 2007).

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India introduced a blending quota for ethanol, mainly derived from molasses (a by-product of sugar production), through its 2002 Ethanol Blended Petrol Programme (EBPP), which mandated the sale of E5 in nine states and four union territories. However, the mandatory blending was abandoned in late 2004 due to low sugar production, rising feedstock costs and inconsistent ethanol supply. Since October 2007, five percent blending of ethanol with petrol has been mandatory across India and states have been given the option to increase this to 10%. As of mid-2008, at least 14 Indian states and territories had actually implemented the E5 mandate (FACTS Global Energy, 2008). An E10 blend is to become mandatory from October 2008. Other important support measures include a uniform ethanol producer price of INR 21.50 (USD 0.54) per litre, permitting sugarcane juice as an ethanol feedstock, and extending a freight subsidy to sugar mills for exports by one year to early 2009.

Most OECD-EU member countries which were required to transpose the EU Biofuels Directive into national legislation showed accelerated growth in biofuel consumption over 2004-2005, in trying to achieve the indicative biofuel targets of a 2% transport fuel market share in 2005 and 5.75% in 2010, respectively.

Of the countries examined, Brazil, the world's second-largest ethanol producer and largest ethanol exporter, remains the front-runner in the production of sugarcane ethanol, which is driven by cost competitiveness and now relies on indirect tax relief. The country has fostered industrial-scale ethanol production since the 1970s in its National Alcohol Programme (PRÓ-ÁLCOOL), initially to reduce its import dependence as a reaction to the oil crises. From its inception in 1975, PRÓ-ÁLCOOL encompassed a growing range of measures, primarily price guarantees and subsidised loans for farmers, an ethanol blending quota of 20-25%, import tariffs on foreign ethanol, a ban on diesel-powered vehicles and the mandatory use of alcohol-powered vehicles for all governmental institutions. The programme was accompanied by trade policies that successfully aim at giving Brazilian ethanol a competitive advantage on international markets. At the moment, this is still hindered by protectionist policies, especially on the part of the EU and the United States. This deep policy-driven experience gives Brazil several competitive advantages – besides a favourable climate for sugarcane – including long-established production facilities and capacities for ethanol fuel and suitable vehicles.

Ethanol production, mostly destined for export, increased significantly over the analysis period. Domestic consumption began increasing from 2004 onwards, with the large-scale market penetration of FFV, which benefit from a product tax reduction. Ethanol, which benefits from reduced VAT rates compared to gasoline[54], especially in populous and economically dominant states such as São Paulo, supplied 40% of Brazil's transport fuel demand in 2005.

Brazilian domestic demand growth is expected to stay robust, with an increase in the mandated level of ethanol in gasoline[55], sales predominance of flex fuel vehicles – which by early 2008 represented 90% of new vehicle sales in the country – and attractive ethanol prices relative to gasoline.

54. On average, the price of E85 in 2003 and 2004 was 45% lower than that of regular gasoline.
55. 25% as of July 2007.

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Chapter 4
Research, Development and Demonstration (RD&D) Trends for Renewables

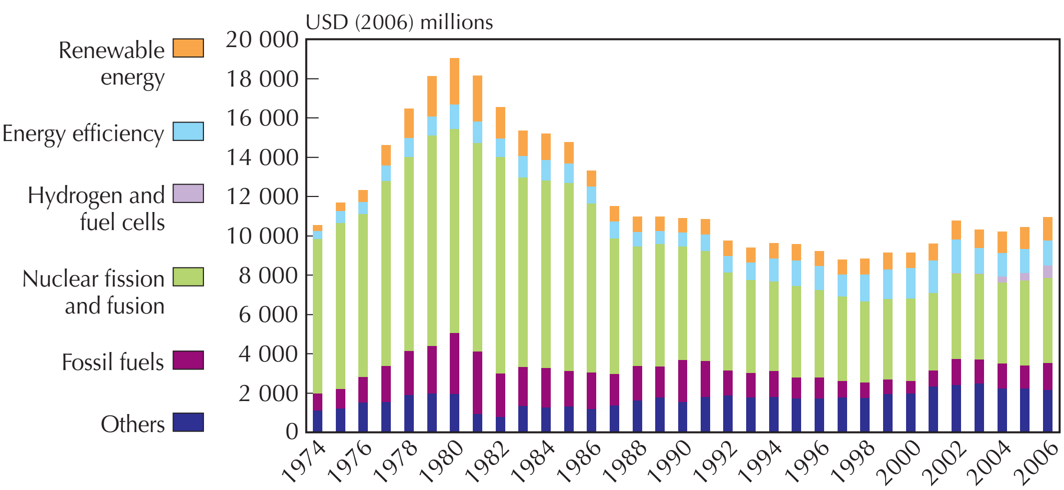
National renewable energy RD&D spending in IEA countries

In the absence of internalisation of external costs, such as those resulting from GHG emissions, pollution remediation and damage to health, some renewable energy technologies (RETs) remain non cost-competitive with conventional energy sources. Further cost reduction is therefore essential, and research and development financing, alongside market development, is a crucial driver towards such reductions.

Overall energy RD&D spending[56]

Energy research and development (RD&D) spending nearly doubled between 1974 and 1980 in response to oil price shocks, peaking in 1980 at around USD (2006) 19 billion. However, as oil market related fears diminished, energy RD&D spending dropped almost as quickly as it had risen, to around two-thirds, then half of peak spending, at which level it remained until the end of the 1990s (Figure 1).

Figure 1. **All IEA member country energy RD&D spending, 1974-2006**



Source: IEA (2007a).

In recent years, energy-related spending has shown some signs of increase, mainly due to new spending on hydrogen and fuel cell research, renewables, and fossil fuels. Nonetheless, spending in real terms in 2006 was only just in excess of 1974 levels.

56. All conversions to USD are at 2006 market exchange rates, except where specified otherwise. The data on IEA countries' RD&D budgets are taken from the IEA Energy Technology R&D Statistics. These can be accessed on the IEA website at: http://www.iea.org/Textbase/stats/rd.asp.

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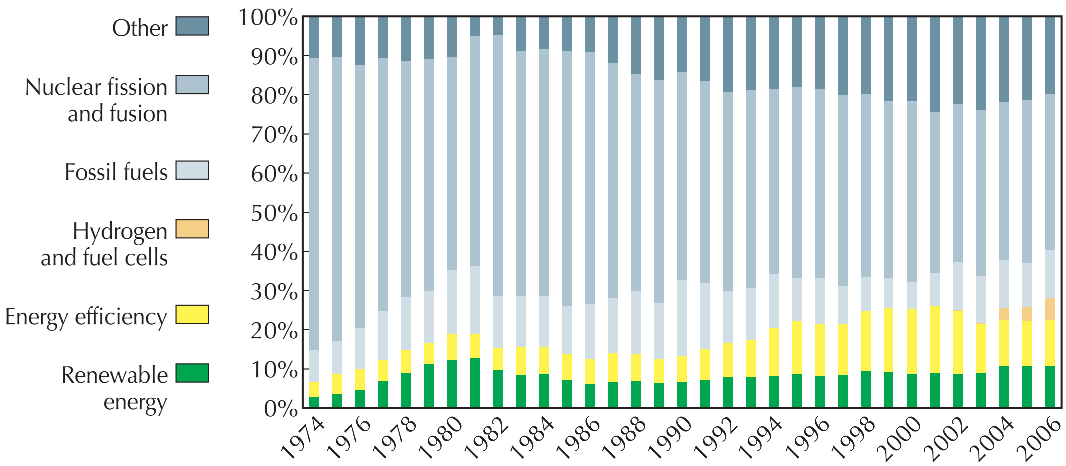
Renewable energy share of RD&D spending

In 1974, renewable energy (RE) RD&D spending accounted for 2.7% of energy RD&D spending, rising quickly to 12.9% in 1981 (Figure 2). The renewable energy share never fell to 1974 levels after the 1980 spike, as was the case with energy RD&D spending overall, but nonetheless it fell steadily, to 6.2% by 1986. Since then it has increased with only occasional drops, to the present 10.8% of all energy RD&D spending. This increase may reflect the impact of climate change drivers.

Figure 2. **Renewable energy share of all IEA country energy RD&D, 1974-2006**



Source: IEA (2007a).

Technology shares of RE RD&D spending

Box 1. **RET groupings in IEA statistics on RD&D spending**

There are some differences in terminology and in the RET groupings between the assessment of RET potentials in Chapter 2 and the research, development and demonstration trends for the individual RETs detailed in this chapter.

These differences are due to the IEA definitions of technology groupings for the statistics on IEA country RD&D budgets. Explanations of the technology groupings mentioned in Chapters 2 and 4 are available in Annex A. More detailed information on the RD&D technology categories used can be obtained by consulting the documentation on the IEA energy technology RD&D budget statistics: *http://wds.iea.org/WDS/tableviewer/document.aspx?FileId=1092.*

All IEA country expenditure on RD&D relating to RE peaked in 1980 at more than USD (2006) 2.1 billion (Figure 3). By 1990, spending had fallen to less than a third of this amount. Since the low of 1988, spending has increased slightly to around USD 750 million annually.

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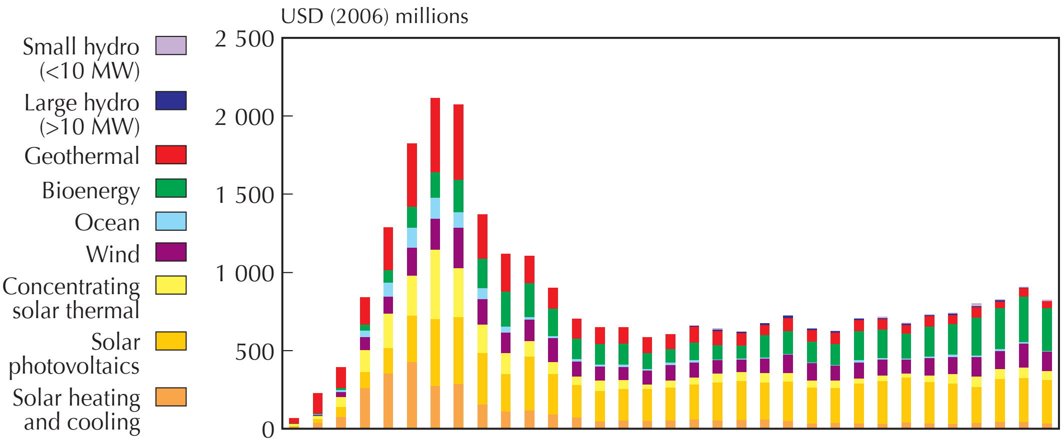
Figure 3. **All IEA country RD&D budgets by technology, 1974-2006**

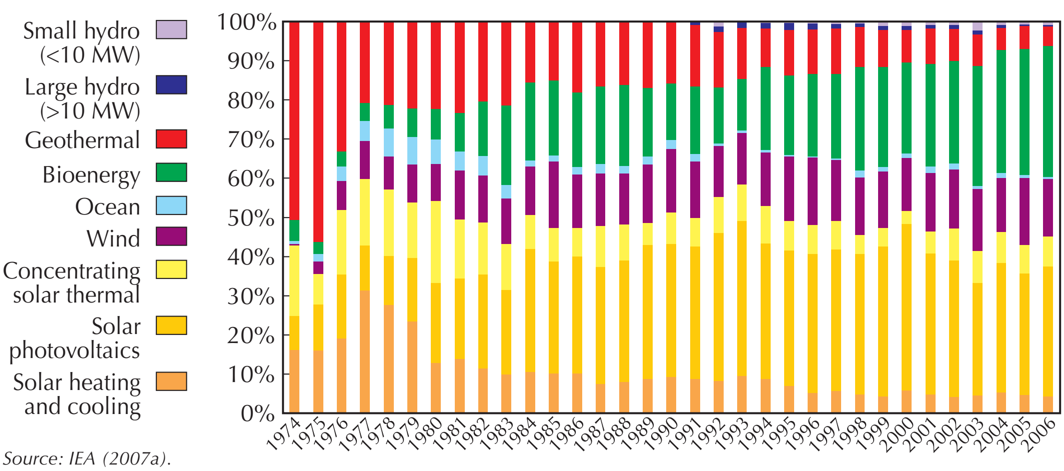


Source: IEA (2007a).

Charting public spending by technology share reveals distinct changes in priority over the period. From the beginning of the peak until 1984, spending reflected increased interest in almost all of the major RET areas, with the exception of hydro power. In particular, geothermal, concentrating solar thermal, photovoltaic and solar heating and cooling technologies received attention. Since 1986, photovoltaic technology continued to receive a significant share, while others had reduced shares.

From 1974 to 2006, some USD 28 billion were spent on RE RD&D, equivalent to around 7% of total energy RD&D spending. Over the period, solar PV has received the lion's share of funding – over 25%. Bioenergy and geothermal have received 17% and 16% respectively. Solar heating and cooling (11%), concentrating solar thermal (11%) and wind power (13%) have received similar amounts. In marked contrast, ocean energy has received less than 3% of total funding, while in total hydropower has received less than 1%. These shares are illustrated in Figure 4.

Figure 4. **Technology shares of all IEA country renewables RD&D budgets, 1974-2006**



Source: IEA (2007a).

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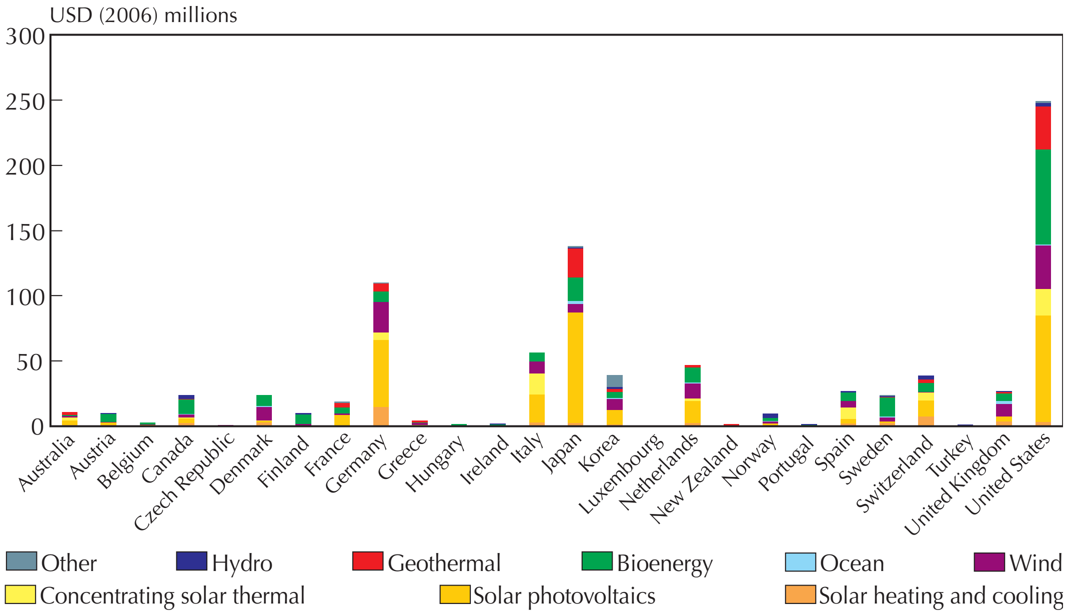
In 2006, the picture is very different from both before and during the peak, with photovoltaic and bioenergy each capturing a third of total spending, wind energy 15%, concentrating solar thermal 8%, geothermal 5%, and solar heating and cooling 4%. In 2006, hydro received a little over 1%, in line with its average over the period, while ocean energy received just 0.5%.

Country-specific spending and their priorities

Renewable energy RD&D funding priorities typically reflect resource endowments. For example, New Zealand and Turkey have major geothermal resources; not surprisingly, over 55% of RD&D funding in New Zealand and 38% in Turkey was for geothermal over the period. Norway allocated nearly 35% of its renewable energy RD&D to hydropower. On average, biomass accounts for between 48% and 88% of the renewable energy RD&D budgets in Austria, Canada, Finland, Hungary and Sweden. About 43% of renewable energy RD&D in Denmark and 35% in the United Kingdom went to wind energy; both countries have significant wind energy potential. Natural resource endowments do not, however, always dictate RE RD&D priorities. Potential industrial opportunities often play a role in resource allocation. Germany has limited solar resources, but its budget for solar PV represented more than 47% of its RE RD&D budget from 1990-2006.

Figure 5 shows average annual renewable energy RD&D public spending for a shorter period – 1990 to 2006. The United States, Germany and Japan together accounted for nearly 57% of annual spending, and the greatest focus is on solar PV. Unsurprisingly, it is in these countries that solar PV developed most quickly. Wind energy technology in Denmark benefited from earlier efforts and therefore reached a rather mature stage in advance of the others. Italy, the Netherlands and Switzerland accounted for an additional 15% of total renewables RD&D funding for the same period. Over the same period, the United States had the highest average renewables RD&D budget of USD 249 million per year; Japan's average annual budget was USD 140 million and Germany's was USD 110 million (IEA, 2007a).

Figure 5. **Average annual renewables RD&D budgets, 1990-2006**



Source: IEA (2007a).

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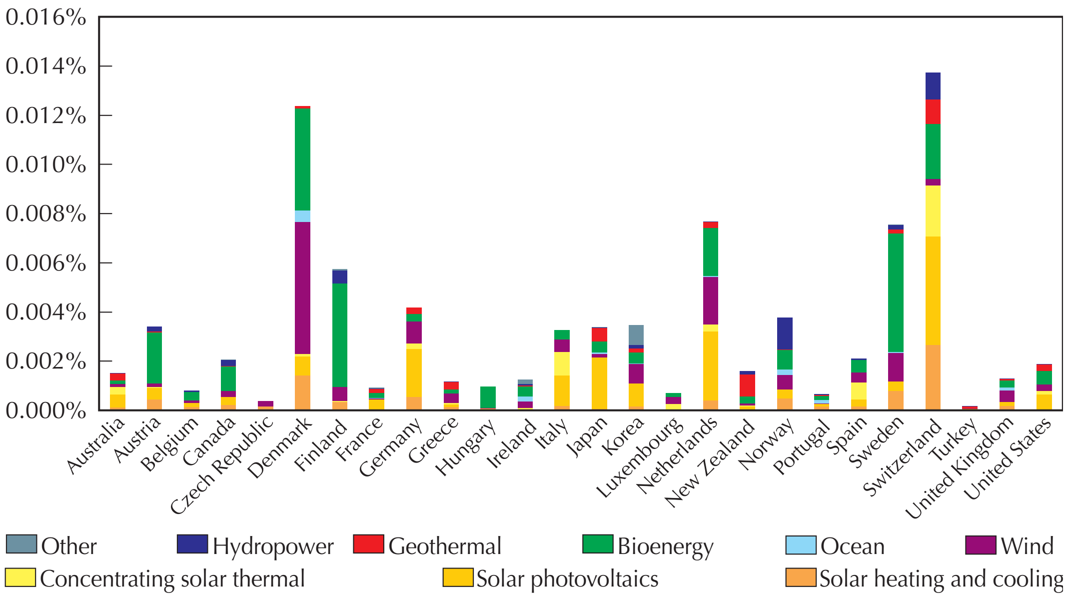
Examining average renewables RD&D budgets on a share of GDP basis (Figure 6) offers another perspective. On this basis, Switzerland, with the highest spending of IEA countries on RE at nearly 0.014% of GDP, and Denmark, at just over 0.012%, are in the first rank. The Netherlands, Sweden and Finland follow at between 0.006% and 0.008%. Japan and Germany are in the next rank with Austria, Italy, Japan, Korea and Norway, at around 0.003%. Weighting spending on a GDP basis also reveals a broader set of priorities, reinforcing the link between local resources and public funding. All technologies are present, with marked emphasis on bioenergy. Also the Danish influence on wind energy maturity becomes clear.

Figure 6. **Average annual renewables RD&D budgets, as a percentage of GDP, 1990-2006**



Source: IEA (2007a).

Recent public RD&D spending on renewables

In recent years, spending in real terms on RE RD&D has shown renewed vigour, partly in response to increasing concerns over climate change, environmental degradation, security of supply and rising oil prices, and the consequent need to find alternatives to conventional technologies. Over the period 2000 to 2005, spending in the United Kingdom increased by over 600%, in France by 200%, in Canada by 40%, in Hungary by 600%, in Italy by 90%, in Japan by 50%, and in New Zealand by 90%. The increasing trend does not apply to all countries however; for example in Norway and Portugal spending declined over the period by 30% and 40% respectively.

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National RD&D spending in selected non-OECD countries

India

The Ministry of New and Renewable Energy (MNRE) has supported related RD&D since 1982, and more recently has encouraged participation by industry in publicly funded research.

In its 11th Five-Year Plan (2007–2012), MNRE budget proposals include USD 370 million on RE research and development (Table 1), divided amongst bioenergy, solar, wind and small hydropower, and national research institutes. Solar energy will receive the largest share (27%), then wind (16%), bioenergy (10%), and small hydropower (3.4%). A large amount (27%) is dedicated to technology innovation.

The total figure represents about 14% of total government funding related to RE, and is a significant increase on previous years.

Table 1. **Proposed outlay on renewable energy RD&D in India's 11th Five-Year Plan (2007-2012)**

	INR millions	USD (2007) millions
Bioenergy	1500	36.2
Solar energy	3600	86.3
Wind energy	2000	48.3
Small hydropower	500	12.1
New technology	4000	96.6
Solar Energy Centre	400	9.7
Centre for Wind Energy Technology (C-WET)	400	9.7
National Institute of Renewable Energy (NIRE)	400	9.7
Other	1820	44.0
Total	14 620	353.1

Source: MNRE (2008).

China

From 2001 to 2006 the Chinese government spent a total of USD 126 million on RD&D in the renewables sector. Solar PV and wind received the lion's share with 39% and 36% respectively. Both solar heating and cooling technologies and bioenergy received 9% of total government RD&D expenditures. Concentrating solar thermal received 4%, and ocean energy 3%. Figure 7 reveals a marked acceleration in renewables RD&D spending, increasing by about 500% over the period. Chinese and Indian technology priorities are roughly in line with those of OECD countries, which is to say that geothermal, ocean and hydropower, and concentrating solar thermal technologies receive less attention. In 2006, ocean energy and concentrating solar thermal received additional public funding.

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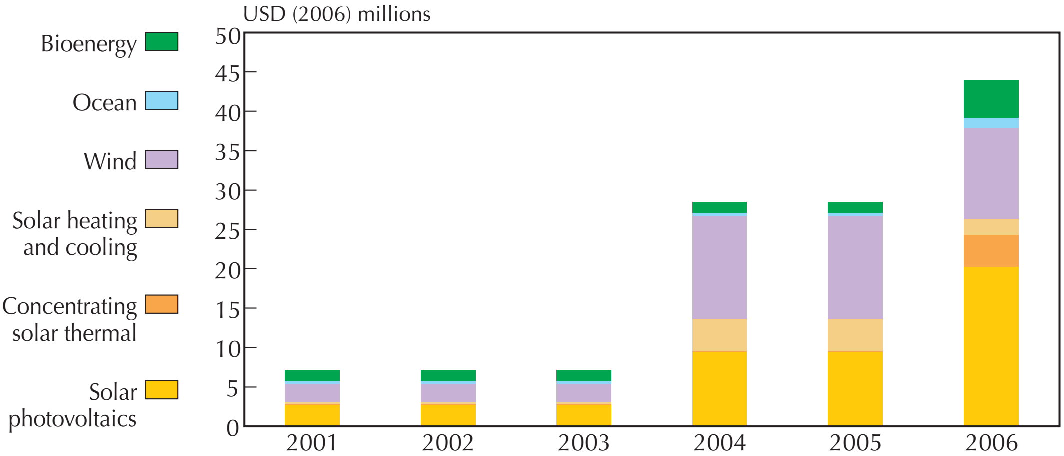
Figure 7. **Chinese public spending on renewables RD&D**



Source: Li et al. *(2007).*

Renewable energy RD&D spending is channelled through the Ministry of Science and Technology (MoST) and the National Development and Reform Commission (NDRC). Funds are also available through the Ministry of Finance, following a provision of the Renewable Energy Law. RD&D funds on RE offered by MoST during the Ninth Five-Year Plan period will be CNY 60 million. In addition, there are some subsidies for demonstration projects and training courses by NDRC, and the Ministry of Finance (MoF).

A new measure, the Interim Measures of Special Fund Management for Developing Renewable Energies, was announced by the Ministry of Finance in May, 2006. Under this measure, special funds shall be allotted to the multi-sectoral development of renewable energies, with the objective of reducing reliance on fossil fuels. Transport sector foci include bioethanol from sugar cane and cassava; and biodiesel from palm oil, algae, and other crops. Renewable electricity foci include wind energy, solar energy and ocean energy; and geothermal and solar in the building heating and cooling sector. Uses of the special funds include research, demonstration projects, preparation of standards, rural, island and stand-alone electrification resource and technology evaluation, education, and the promotion of local industry and services. These funds are intended to supplement private funds.

South Africa

The South African Energy Research Institute (SANERI) was established in 2006 to co-ordinate and fund energy RD&D. For the financial year April 2006 to March 2007 (2006/7), SANERI funded a total of ZAR 15 million (USD 2 million) for research chairs at universities, a teaching and research hub for renewable and sustainable energy, and other short-term projects on renewables. This represents 26% of the overall research budget of ZAR 58 million.

The research budget for SANERI for 2007/2008 was expected to stand at ZAR 40 million (USD 5.5 million) and the share of RE research spending will remain at about a quarter. From 2008 onwards the budget is expected to significantly increase with a quarter of funding set aside for renewables.

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Notably, a significant investment (USD 1.9 million) in RD&D by the Department of Science and Technology (DST) has led to the development and commercialization of new, cheaper solar PV technology (Morris, 2007).

Russia

The Russian government allocates funds to RE RD&D through various ministries and agencies, including the Ministry of Science and Education, the Ministry of Industry and Energy, the Academy of Science, the Ministry of Economy, the Ministry of Agriculture, and the Ministry of Natural Resources.

According to estimates, from 1998 to 2003, the Ministry of Industry and Energy invested approximately RUB 70-80 million (approximately USD 3 million) per annum in RE RD&D; and the Ministry of Science and Technology, another RUB 100-120 million (USD 4-5 million) per annum.

The government reportedly plans to spend RUB 4.6 billion (USD 188 million) over 2008-2012 to enhance the production of biodiesel from rape seed. In 2007, the Russian Ministry of Industry and Energy, in collaboration with UNESCO, proposed the establishment of a Sustainable Energy Development Centre, which will include activities related to RE research and development.

RD&D programmes

The benefits of RD&D do not only include technology development to respond to the needs of secure, clean efficient energy supply; high RD&D spending in Germany has also yielded employment, industry leadership and progress towards renewables targets. Germany spent over USD 5 billion on all energy RD&D from 1991 to 2006, a quarter of which was on RE (IEA, 2007a).

More renewables RD&D funding is necessary if renewable energy sources are to make the major contributions desired and expected. In several countries, recent funding cuts to geothermal have created a situation in which RD&D has been cut back to basic levels. Consequently, expertise may be lost due to job cuts. More funding could help stem both trends, while facilitating acquisition of the manpower needed to realise more rapid achievement of the identified priorities.

RD&D programmes in policy frameworks

In the broadest sense, policies to support the uptake of any technology can be divided into those which support "technology push" (research and development) and those which help develop a "market pull" (deployment policies). National policy relating to RE has tended to begin with RD&D policies. This is a practical starting point as first of all technology must be developed to the demonstration level.

Figure 8 shows the year in which selected countries implemented RD&D funding in the field of RE. Most of the leading countries in renewables terms implemented programmes relatively early on.

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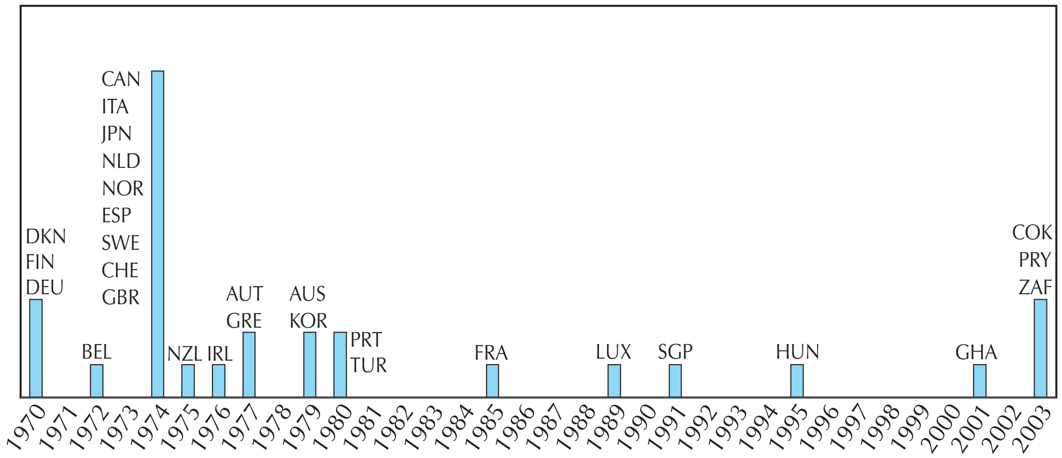
Figure 8. **Implementation date of national renewables RD&D programmes**



Source: IEA (2007a).

In recent years, members of the research community have begun to refer to the existence of a "valley of death" existing between the demonstration of a technology and its uptake by the market, even with proven cost-benefit balance. If countries are to benefit fully from resulting innovations, and if these are to be enabled to make the leap from "novel" technology status to the mainstream, then coherent policy frameworks should be designed to seamlessly join RD&D policies pushing technologies towards the market with "market pull" policies.

Leaving it to market forces alone, or private research efforts, may lead to harvesting the low hanging fruit, at the expense of valuable fruit higher up the tree. Government RD&D investment is usually targeted at areas with high risk and long-term perspectives, whereas private sector involvement tends usually to be in pre-competitive, short-term demonstration and commercialisation of technologies.

International collaboration

The OECD Science, Technology and Industry Scoreboard 2007 Report suggests that an increasing proportion of research and development – in all technology areas – is taking place in the international sphere. Increased international collaboration is also occurring in the renewable energy sector (OECD, 2007). For example, the United States and the People's Republic of China signed a Memorandum of Understanding (MoU) in December 2007 to promote further research into and greater use of biomass. The MoU covers the exchange of scientific, technical, and policy information on biomass production and its conversion into biofuels and other products, and focuses in particular on long-term RD&D.

International collaboration, on both multilateral and bilateral bases, can maximise the benefit of RD&D. Within the context of increasing globalisation and shift in emphasis away from national RD&D, such international collaborations promise good returns on RD&D investment through the sharing among participants of financial outlay, workload and results. With national RD&D spending still considerably below what is needed, international collaboration to increase synergies becomes even more important.

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There are at least three general benefits of international collaboration:

- reduce redundant spending of national funds on RD&D that is underway in other countries;
- make use of specialised expertise and resources that reside in one country to the benefit of all collaborators; and
- enable technology exchange with developing countries, and the opportunity to benefit from comparative advantages.

For example, funds for wind energy research are provided by the European Union (EU). During 2006, more than 20 RD&D projects related to wind energy were running with the support of the 5^{th} and 6^{th} Framework Programmes – the main EU tool supporting research.

The IEA Renewable Energy Working Party (REWP) and its related technology-specific, collaborative programmes – Implementing Agreements – are committed to working together to define mid- to long-term RD&D priorities for RETs. The objective is to develop targeted approaches to key development areas and concerns, with maximum shared benefit, including across-the-board cost reductions and increased market share.

There are numerous benefits to the IEA approach:

- reduced cost and duplication of work;
- greater project scale;
- information sharing and networking;
- linking IEA countries and non-member countries;
- linking research, industry and policy;
- accelerated development and deployment;
- harmonised technical standards;
- strengthened national RD&D capability; and
- protection of intellectual property rights.

Structuring RD&D

In November 2007, the European Commission proposed a Strategic Energy Technology Plan whose objective is to enable the bloc to achieve its 2020 and 2050 objectives for greenhouse gas emission reductions, and uptake of renewable energy and energy efficiency. The European Commission found that research in these areas is often under-funded, poorly coordinated and dispersed, and efficient actions to develop new energy technologies, lower their costs and bring them to the market are required.

The following elements and procedures have been found to contribute to good and effective policy making in technology research:

- Policy should be integral to a defined RE strategy, itself part of an overall energy strategy.
- Policy should be structurally linked to measures for commercialisation and deployment as part of a coherent framework.

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- Priorities must be clearly defined, but flexible enough to alter as breakthroughs are made, or as needs shift. The involvement of all stakeholders - private sector, academic and other stakeholders is paramount here.
- Evaluation and monitoring mechanisms should be in place from the start with clear guidance on what is expected.
- Clear definition and boundaries of the roles of government and all stakeholders.
- Adequate funding is essential, to match the range and potential benefits of technologies.
- Funding must be stable. RD&D can be a lengthy business; a degree of predictability with regard to funding availability is essential.
- Public-private partnerships should encourage both elements to provide significant funding.
- International collaboration can provide significant benefits (see above).

Setting objectives

The existence of a clear national RE policy is the most important precondition to formulate an effective, efficient RE RD&D strategy. Priorities for energy RD&D are generally based around policy making. In the United Kingdom, such landmarks include the 2003 Energy White Paper and the May 2007 White Paper "Meeting the Energy Challenge." An earlier identification of RD&D priorities was carried out by the Chief Scientific Adviser's Energy Research Review Group in 2001/2002. This study identified six key technology areas for research, including CO_2 sequestration, energy efficiency, hydrogen production and storage, nuclear power (waste), solar PV, and wave and tidal power. Transparency – and the involvement of all major stakeholders in defining a national energy RD&D strategy – are of key importance.

Consistent research programmes with well-defined periods and funds are essential to provide clear signals to researchers as well as to private investment. In Germany, for example, the Fifth Energy Research Programme was launched in 2005, wherein energy RD&D expenditures will increase annually to a total annual budget of EUR 144 million by 2008 (IEA, 2007b). In Japan, another world leader in solar PV technology, PV has consistently received the largest amount of annual investment.

A balanced portfolio of objectives is particularly important since individual RD&D projects may well fail to achieve their goals. Rather than viewing the failure of individual projects as symptoms of overall programme failure, policy makers should recognise that project failures may generate considerable knowledge, and that a RD&D programme with no failures in individual research projects is probably pursuing an overly conservative portfolio.

It is often difficult to get a coherent overview of public RD&D programmes as these may be fragmented or uncoordinated. In most IEA countries, no single organisation has overall responsibility for energy research. A multiplicity of bodies means that overall coordination is essential if duplication of research themes and effort is to be avoided. Standard approval procedures, advisory boards, and research associations can assist here.

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In the United Kingdom, for example, priorities are set by a number of organisations, with limited apparent coherency. The most important entities are the Department for Innovation, Universities and Skills; the Department for Business, Enterprise and Regulatory Reform (DBERR), including the Technology Strategy Board and the Energy Technologies Institute; the Department for Environment, Food and Rural Affairs (Defra), a number of Research Councils, the Energy Research Partnership, the UK Energy Research Centre, and the Carbon Trust (IEA, 2007c).

In contrast, in Spain, most public research planning originates from the Ministry of Education and Science, and is primarily executed by CIEMAT, an institution working with the ministry (IEA, 2005a).

An integrated approach to priority setting is important, involving linked sectors, technologies, infrastructure, and supply chains. Particularly in the electricity sector, renewable energy priorities should be correlated with system wide RD&D.

Changing needs in the short- to long-term

The right strategy is not necessarily based on choice of technology 'champions' – no one technology can provide the entire energy needs of a country in an economically optimal, environmental sound and secure manner. A portfolio of technologies will be needed in the long run, according to available national resources and technology strengths.

Of course, a country may choose technology foci and these may change over time. Such apparent changes in priority may reflect changing fashions, belief that a certain technology is mature enough to receive less focus or, conversely, that a technology which has hitherto received support is no longer considered to be a desirable course of action. Good policy practice suggests that a degree of flexibility here is valuable.

For example, in Australia, 34% of the reported cumulative budget on RE RD&D for the period from 1990 to 2005 was spent on solar PV technology, and only 8% on solar thermal energy, while in 1993 almost 80% of renewables RD&D was allocated to the latter. Spending on bioenergy, which accounted for the second largest share in terms of public RE RD&D in the mid-90s (39% in 1997), was stopped completely in the subsequent years, while funds were diverted to geothermal technology, which was the second largest beneficiary from 1999 onwards (IEA, 2007a).

Clear national RE RD&D priorities should be established, and communicated to energy and research sector stakeholders. Development targets should be clear, quantified to whatever degree possible, and preferably categorised into objectives arising in the short, medium and long-term. Focusing uniquely on those RETs that are closest to market, while bringing about quick gains in sustainable supply, will lead to a hiatus in deployment once the "low hanging fruit" have been plucked. The long-term view must be maintained so that development proceeds smoothly.

For example, German government promotion of renewables RD&D consists of two levels. First, clear priority is given to selected technologies that have been identified as able to contribute to short- to medium-term gains in sustainable supply. Concurrently, a second, relatively broad approach covers other technologies that are still in the fundamental (long-term) research phase. This dual approach ensures flexibility: when a technology leaves the

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fundamental research phase and demonstrates the capability to contribute meaningfully to energy supply, focus can easily be shifted to it. Ongoing monitoring of results and technology status is crucial in this approach, and should involve both public and private research experts.

Efficient use of funds

Government leadership in the development of new energy technologies is possible even with relatively low investments. Given a supportive policy framework, relatively small government investments in RD&D can achieve much by:

- providing early attention to and leadership to new technology frontiers;
- signalling government interest in new areas, thereby encouraging private investment to respond; and
- attracting attention from potential collaborators, including national governments.

Although government energy RD&D budgets have increased recently in the United States and to a lesser extent in Europe, concerns remain that insufficient funding is made available to meet longer-term energy policy objectives. RD&D policies can include direct and indirect financing of RD&D institutions, programmes and projects, and are important instruments to help meet national energy policy objectives. With this in mind, and given the very limited available financing in most IEA countries, a coherent energy RD&D strategy, with clear prioritisation in line with national RE policy goals, is essential.

Monitoring and evaluation

In addition to proper prioritisation, effective monitoring and evaluation of the performance of government-funded RD&D are also crucial to maximise the cost-effectiveness of the RD&D programme. New programmes should be justified by demonstrating their significance, consistency with national priorities, and likelihood of success (risk). Existing programmes need regular evaluation, and possibly modification, redirection or termination.

The role of the private sector

Direct government spending on renewables RD&D represents only a percentage of total spending in IEA countries. The other major source of financing for RD&D is private companies. This may differ considerably in terms of scope from its public counterpart. Private RD&D activities tend to focus on the near term, and on applied RD&D, aimed at bringing a particular product to market. In contrast, public efforts tend to focus on longer-term, fundamental research, often bringing together a large number of partners to work in a collaborative manner. Long-term research, often based in the academic sector, is less likely to be constrained by concerns of intellectual property, than is the case in private sector research.

Figure 9 illustrates public and private roles in the succession of phases commonly seen in the development of a new technology. During the basic research phase, the technology is far from market and therefore less likely to be of interest to the private sector which must necessarily focus on the nearer term. However, as the technology develops and applications become defined, private sector research will tend to increase and public collaborative RD&D decrease as intellectual property issues become more sensitive.

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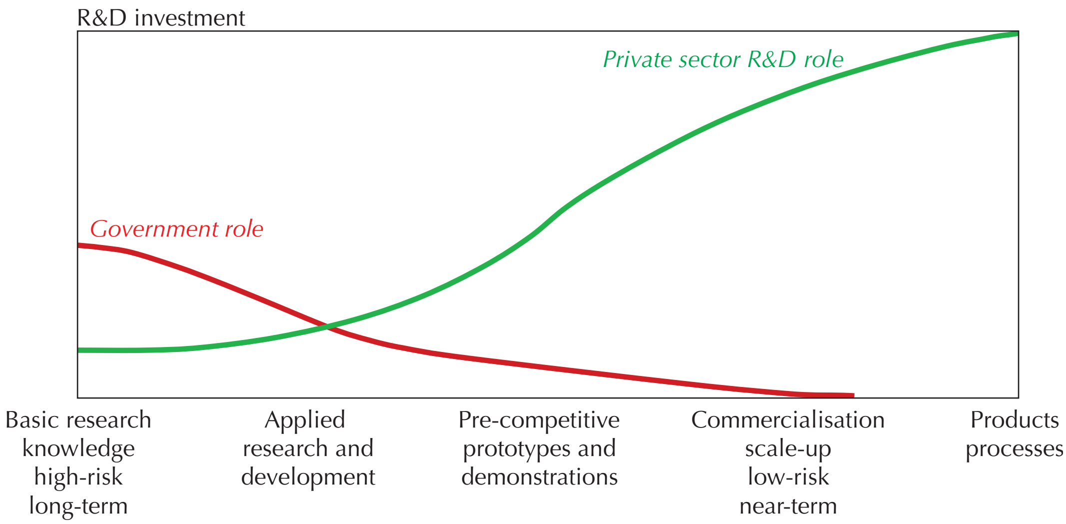
Often the leading edge of a technology type may be close to market. This does not mean that no fundamental research work remains to be done. For example, onshore wind power is competitive at good sites, but, emphatically, there is still much to be done in the field of wind energy as a whole, as highlighted in (IEA Wind, 2007). The same applies to other RETs.

Figure 9. **Illustration of respective government and private sector RD&D roles in phases of research over time**



Source: IEA (2007d).

Often, collaborative RD&D needs public support. The EU, through its Sixth and Seventh Framework Programmes for research and development, has introduced the concept of Technology Platforms. These provide an opportunity for collaboration among a very wide range of stakeholders, including industry, academia, policy makers, the public, etc. At present technology platforms in the renewable energy sector exist for solar PV, wind power, solar water heating and biofuels.

Private sector involvement in research financing is significant, but accurate figures are hard to come by. Many companies may invest in the region of 3-5% of their turnover in research activities. In some cases the RD&D intensity is higher still. In Europe, following the initiation of Technology Platforms for individual and groups of technologies, the private sector is being encouraged to engage with the public sector, mainly on longer-term research, the intention being that private companies match public (EU) spending.

The recently published OECD Science, Technology and Industry Scoreboard 2007 suggests that OECD member country policy to foster overall RD&D – *i.e.* not just energy – is shifting from a direct subsidy approach, through public procurement, towards tax relief. In 2005, direct government funds financed an average of 7% of business RD&D, down from 11% in 1995. In contrast, 20 OECD countries offered tax relief for business RD&D in 2006, up from only 12 countries in 1995 (OECD, 2007).

The Australian Low Emissions Technology Demonstration Fund, for example, targets private financial investment. This is over and above Government investment, and an order of

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magnitude higher: AUD 500 million (EUR 306 million) of the total AUD 700 million (EUR 429 million) were allocated to RETs, and other low emission technologies. 2004 measures, for example, include programmes aimed at RD&D of storage technologies and improving wind forecasting capabilities (IEA, 2005b).

A shift in policy towards supporting private research – as opposed to collaborative research in the public domain – would likely increase the influence of market forces on the choice of project – and therefore choice of technology. While this may be beneficial in terms of short-term deployment of RETs per se, it might mean that less opportunity would exist to regulate the support given to specific technologies. If the trend appears in the renewable energy field, it is likely to bring with it a shorter-term view, possibly reducing the support given to RD&D in technologies which are considered to have great long-term potential, but which are still relatively distant from the market place, as compared with more mature alternatives.

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Chapter 5
Conclusions and Recommendations

Policy effectiveness in OECD countries and BRICS

The "EU-OECD", "other OECD" member countries and "BRICS" show substantial diversity in the effectiveness of policies implemented to support the individual RETs in the electricity, heating and transport sectors.

Those EU-OECD countries which, overall, have a longer history of renewable energy support policies, feature among the countries with the highest policy effectiveness for all new renewable electricity generation technologies. The cases of electricity from wind and solid biomass provide a good example: they represent together 75% of total non-hydro renewable electricity generation in the OECD countries and the BRICS. Among the 35 countries analysed in the study, the top eight showing the highest average yearly policy effectiveness levels over the period 2000-2005 for wind energy are European countries (all above 3%, the maximum being Germany with 11%). In the case of solid biomass electricity, six EU-OECD countries show an average yearly policy effectiveness level above 2% (Netherlands has the maximum with 11.5%). The non-EU OECD country with the highest indicator levels is Japan, with 2.4% for wind and 1.4% for solid biomass.

The analysis highlights that the effectiveness of policies is generally improving with time over the period, *i.e.* the average effectiveness indicators level in the years 2004-2005 are generally higher than the average values over the period 2000-2005. Again, this tendency is stronger in Europe than in other countries.

The average 2000-2005 effectiveness indicators levels in BRICS countries are negligible for all non-hydro renewable electricity technologies, the only exceptions being India for wind (1.5%) and Russia for geothermal electricity (1.3%).

The picture is more varied among the most mature renewable electricity technologies (*e.g.* hydropower) and among renewable heating and transport technologies, with some other OECD and BRICS countries also having implemented relatively effective policies.

For example, China and Brazil are the leading countries for solar thermal heat, and Switzerland and Turkey for geothermal heat. However, with the exception of biomass CHP in Denmark and Sweden, even the highest average policy effectiveness indicators for renewable heat are low (around 1%), *i.e.* significantly lower than those for renewable electricity. This reflects the fact that the total realisable mid-term renewable heat potential has still largely been unexploited so far. For example, the remaining additional potential to 2020 for solar thermal and geothermal heat is almost thirty times the achieved heat production from these sources until 2005. The main reason is that policies to encourage the development and deployment of renewable heat have largely been neglected compared with those supporting renewable electricity or biofuels. This is clearly a policy area with a significant potential for improvement.

As for biofuels, seven OECD countries plus Brazil show significantly increasing average effectiveness indicators (between 2.5% and 4.5%, except for Germany which has

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witnessed 22.4%) in 2004-2005 with respect to 2000-2005. However, this analysis does not consider more recent policy developments and significant ramping up of biofuel targets. The latter have stimulated growing public concern surrounding the impacts from increasing biofuel production on land use change, agricultural product prices, deforestation and water use. The actual future potential and effectiveness of policies on biofuels will largely depend on sustainability criteria, which are likely to be adopted soon in the legislation of several countries. They will also depend on the ability of effective policies, including research, development and demonstration (RD&D) efforts, to foster a rapid transition to second biofuel generation technologies. This is beyond the scope of the present analysis and will need further research.

Overall, a general conclusion from the analysis is that to date only a limited set of countries has implemented effective support policies for renewables which have resulted in acceleration of renewables diffusion in recent years: the best case is wind with 8 countries over the total 35 analysed. There is a large potential for improvement of policy design in most countries and there is considerable realisable potential across all renewable energy technologies (RETs) in all the OECD countries and BRICS reviewed.

It can be therefore argued that if effective policies were adopted in many more countries, this potential could be exploited more rapidly and to a much greater extent.

Solid biomass in Russia can provide an example of quantification of the potential. The country has a significant untapped potential, due to a lack of deployment policies. The average policy effectiveness for solid biomass over the period 2000-2005 in Russia was only 0.6%. Assuming the country were to progressively improve its policy effectiveness, reaching by 2010 the average policy effectiveness indicator of the three most successful countries over the period 2000-2005 (*i.e.* 5.4%)[57] and maintaining a constant level of annual capacity additions until 2020, Russia would produce a cumulative total of almost 100 TWh of electricity from solid biomass by 2020. This is close to the total 2005 electricity generation from solid biomass in all OECD countries, namely 108 TWh (IEA, 2007).

Main lessons learnt and principles for effective policies

The previous sections show that there are effective policies in place, but only in a limited set of countries. Sometimes policies are effective for one specific technology but not for others. What are the lessons learnt from the analysis and what kind of conclusions can be drawn for improving future policies?

Again, it is useful to look at the example of the two most deployedRETs, *i.e.* wind energy and electricity from solid biomass. In the case of on-shore wind, a combination of long term feed-in tariffs (FITs), guaranteeing high investment stability and an appropriate framework with low administrative and regulatory barriers as well as relatively favourable grid access conditions, has driven successful deployment in several European countries. The specific remuneration levels (in USD/kWh) are moderate and lower than the ones in countries applying quota obligation systems with tradable green certificates (TGCs). However, the case of solid biomass

57. Excluding co-combustion of biomass in coal plants.

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shows that different types of incentive schemes (quota obligation systems with TGCs, FITs, feed-in-premiums) were effective in different countries.

The policy effectiveness indicator, linking the incremental generation over a given period with the mid-term realisable potential of a certain RET, is actually a combined measure of three determinant success factors:

- the country's level of policy ambition, *e.g.* in terms of established renewable energy targets;
- the presence of a well-designed incentive scheme; and
- the capability of overcoming non-economic barriers, which can prevent the proper functioning of the market and ultimately limit the effects of the policies in place.

High policy effectiveness indicators are observed in those countries where all three factors co-exist at the same time. However, if just one of the three key factors is missing, this is likely to cause failure of the policy, regardless of the specific incentive scheme in place and, to some extent, of the level of economic support provided.

In particular, non-economic barriers can significantly hamper the effectiveness of policies and drive up costs, irrespective of the type of incentive scheme. They include administrative hurdles, obstacles to grid access, poor electricity market design, lack of information and training, and social acceptance issues. For instance, long and bureaucratic authorisation and permit procedures can lead to a significant increase of investment risk and eventually to project failure. Insufficient grid capacity planning and reinforcement, or long and not transparent procedures for grid connection can also be very significant limiting factors, in particular in the case of wind energy. Last but not least, opposition of local stakeholders based on the "Not-In-My-Backyard (NIMBY)" syndrome can have similar effects of increasing project realisation times, driving up costs or even eventually terminating the project.

This also partly explains why high financial incentives alone are not enough to guarantee the deployment of renewable energy. Investors look for ways to reduce and share investment risks. In fact the potential and perceived risk, more than the high level of support remuneration and profit, is key to the capability of policy to attract investments in effective and efficient manner.

As mentioned, non-economic barriers are major risk factors. However, risk can also depend on specific incentive characteristics. A major positive characteristic of feed-in-tariffs is their ability to guarantee a return over a long period of time (usually from 15 to 20 years). The long-term predictability of support is actually more important than the economic level of the incentive itself. On the contrary, quota obligation systems (as designed and applied so far) intrinsically lead to higher risk premiums, due to higher remuneration uncertainty and usually shorter support periods. Moreover, policy risk itself is another key determinant factor. Stop-and-go situations, *e.g.* due to government and sudden policy changes, are extremely detrimental to the deployment of renewables. This has occurred in several countries in the past, independent of the specific incentive scheme applied.

The above factors explain why effective policy systems have, in practice, frequently also been the most cost-efficient ones. So far, technology-specific support schemes such as well-designed feed-in tariffs correctly tuning incentives, providing a long-term predictability of

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support and being applied in an appropriate policy framework properly addressing non-economic barriers, have proven to be both effective and cost-efficient.

Being a more market-oriented incentive mechanism, quota obligation systems with tradable green certificates should theoretically be more cost-efficient than other schemes, in the sense that markets should lead to the best allocation of resources and the exploitation of the most cost-efficient technology options. However, the analysis carried out in the 35 countries has shown that so far – with the single notable exception of support for solid biomass electricity in Sweden – the quota obligation systems applied showed higher transaction costs and turned out to be much less effective and more costly than expected (in terms of specific level of remuneration per kWh).

Yet, it would be a wrong conclusion to exclude these incentive schemes from a portfolio of possible effective and efficient policies for renewables in the future. Firstly, the observed low policy effectiveness indicators for quota obligation systems are the combined effect of country-specific problems related to the specific incentive scheme design, and of the presence of important non-economic barriers in those countries. Secondly, these schemes have still a major potential for improvement and optimisation, and could play a major role, in particular as a support mechanism for the most mature RETs.

A more general look at future policy schemes reveals a number of important aspects that need to be taken into account, irrespectively of the specific chosen incentive scheme.

First of all, it is important to remember that incentives for renewable energy are justified in order to compensate for present market failures, such as the lack of internalisation of externalities related to climate change emissions and other environmental impacts. However, such incentives are not meant to be permanent. On the contrary, their objective is to drive the transition towards the large-scale market integration of renewables in an effective and cost-efficient manner. Therefore, renewable energy incentive schemes must be transitional and decreasing over time, in order to foster and monitor technological innovation, and move towards market competitiveness. To date, this is accomplished by some well-designed feed-in tariffs schemes in some countries, but not by all of them. Feed-in tariffs which do not foresee a clear incentive reduction over time may be effective for the kick-off deployment stage of renewables, but are clearly not economically sustainable in the medium- to long-term. Progressive incentive reduction can be easily integrated into tendering schemes. In quota obligation systems, it can be obtained by introducing price caps, which can be progressively reduced over time as technology improves.

Some RETs are close to becoming commercial and should obviously be the first to be deployed on a massive scale. Other renewables, which have a large potential, are less mature and require long-term visions. Only through a combined effort in RD&D and technology learning resulting from marketplace deployment will their costs be reduced. The recently published IEA scenario analysis published in *Energy Technology Perspectives 2008* (IEA, 2008) emphasises that a combination of both mature and less mature RETs will play a major role in achieving deep CO_2 emission cuts in a competitive fashion. This finding highlights the need for a framework of consistent, effective and long-term policies to be developed and implemented if a wide range of RETs is to be encouraged to move towards full market integration. More specifically, this requires the establishment of technology-specific support systems, based on the varying degree of technology maturity of different RETs. If well

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implemented and monitored, such a system is can exploit the significant potential of the large basket of RETs over time, while minimising costs in the long run.

Feed-in tariffs and tender schemes are technology-specific support schemes by nature. However, quota obligation systems can also address the varying levels of technology maturity including some kind of "technology banding" measures. The latter can include different durations of support or different values of certificates for the specific technologies. Such technology banding was recently introduced both in Italy and the United Kingdom.

As market deployment increases over time towards large-scale diffusion of renewables in the energy market, other important aspects related to the entire energy system need to be taken into account, in particular with regard to overall cost efficiency and system reliability. A key enabler is for the incentive schemes to allow the progressive integration of renewables in liberalised energy markets. For instance, it is important for renewable energy producers to be progressively exposed to competition and market risks. The more market-oriented mechanisms like quota obligation and green certificate systems are naturally more suited to this purpose. On the contrary, rigid feed-in tariff schemes creating very large renewable energy market sectors, isolated and protected from the risks and competition in the remaining part of liberalised energy systems, do not seem sustainable as a support scheme in the long-term, when renewable energy reaches very large-scale deployment. However, feed-in premiums, *i.e.* feed-in systems providing only an additional support on top of the market electricity price, are a move in the right direction towards market integration of renewables.

The past debate on renewable energy policies has been mostly focusing on the dichotomy between feed-in tariffs and quota obligation systems with renewable green certificates. This debate is out of date and slightly misleading. Both systems show success and failures depending on country- and technology-specific factors. Precise design criteria and fine-tuning of the incentive scheme are key factors. Moreover, to date, non-economic barriers have significantly hampered the effectiveness of renewable support policies and driven up costs in many countries, irrespective of the type of incentive scheme. Furthermore, there are clear recent signs of convergence of the two incentive systems. For instance, feed-in premium tariff options are introducing a more market-oriented element into this category of incentive schemes. And in quota obligation systems, technology banding allows adjustment of the level of support for RETs as a function of the different levels of technological maturity.

In conclusion, there exists a wide variety of incentive schemes that can be effectively applied depending on the specific technology and country. It makes sense therefore to move beyond discussions over which specific incentive scheme functions best. The assessment needs to focus on the entire policy framework into which incentive schemes are inserted. Overall, the effectiveness and efficiency of renewable energy policies are determined by the adherence to the key policy design principles outlined below, as well as the consistency of measures and the overall policy framework. Renewable policy design should reflect five fundamental principles:

- The removal of non-economic barriers, such as administrative hurdles, obstacles to grid access, poor electricity market design, lack of information and training, and the tackling of social acceptance issues – with a view to dealing with the issues raised – in order to improve market and policy functioning;
- The need for a predictable and transparent support framework to attract investments;

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- The introduction of transitional incentives that decrease over time, to foster and monitor technological innovation and move technologies quickly towards market competitiveness;
- The development and implementation of appropriate incentives guaranteeing a specific level of support to different technologies based on their degree of technology maturity, in order to exploit the significant potential of the large basket of RETs over time; and
- The due consideration of the impact of large-scale penetration of RETs on the overall energy system, especially in liberalised energy markets, with regard to overall cost efficiency and system reliability.

Towards an integrated policy approach

Reflecting these five principles in an integrated approach permits two concurrent goals to be achieved, namely to exploit the "low-hanging fruit" of abundant RETs which are closest to market competitiveness while not losing sight of the long-term strategic vision of providing cost-effective options for a low-carbon future.

The main objective of an integrated approach is to achieve a smooth transition towards mass market integration of renewables. This will also require a profound evolution of markets from today's situation – characterised by an inadequate price on carbon and other externalities, most renewables needing economic subsidies, and additional non-economic barriers preventing RET deployment – to a future energy system in which RETs compete with other energy technologies on a level playing field. The evolved market should place an appropriate price on carbon and other externalities and help to develop an infrastructure to accommodate large-scale RET integration. Once this is achieved, no or few additional economic incentives will be needed for RETs and their deployment will also pulled by consumer demand and general market forces.

Analysis suggests that policy frameworks which combine different technology-specific support schemes as a function of RET maturity would be best suited to successfully implement the key policy design principles and foster the transition of RETs towards mass market integration.

Governments should develop a combination policy framework increasingly applying market principles as technology maturity and deployment increase. This is possible with a range of policy instruments, including price- and quantity-based ones, R&D support, and regulatory mechanisms.

As a general principle, less mature high cost technologies further from economic competitiveness, such as solar PV, need, beyond continued R&D support, very stable low-risk incentives such as capital cost incentives, FITs or tenders (Figure 1). For low cost-gap technologies such as on-shore wind or biomass combustion, other more market-oriented instruments like feed-in-premiums and TGC systems with technology banding may be more appropriate. Depending on the specific market and resource conditions, and level of market integration across countries, technology banding may be necessary only in a transitional phase or may be bypassed in favour of a technology-neutral TGC system. Once the technology is competitive with other CO_2-saving alternatives and ready to be deployed on a large scale, and when appropriate carbon incentives are in place, these RET support systems can be

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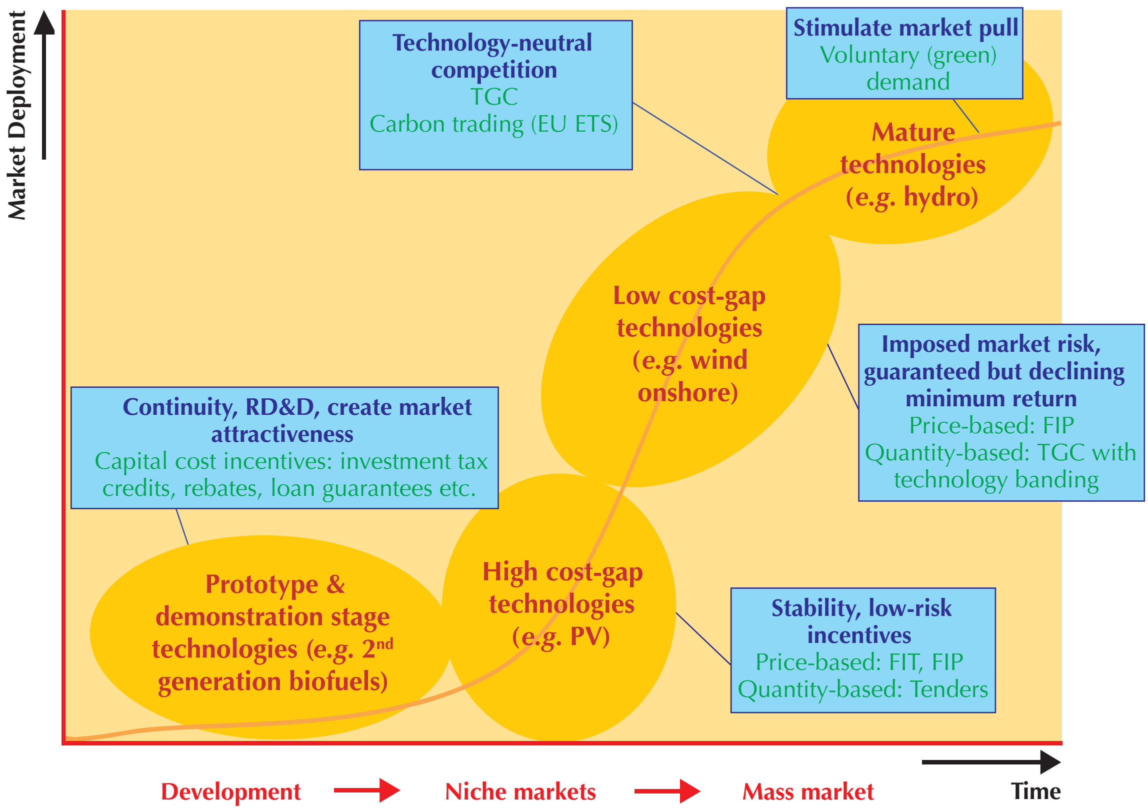
phased out altogether. At that stage, RETs will compete on a level playing field with other energy technologies.

National circumstances – RET potential, existing policy framework, existence of non-economic barriers, degree of market liberalisation, and energy system infrastructure – will influence the actual optimal mix of incentive schemes, and choosing when to complement R&D support with deployment support will be critical to the overall success of support policies.

All RET families are evolving rapidly and show significant potential for technology improvement. Renewable energy policy frameworks should be structured to enable the pursuit of technological RD&D and market development concurrently, within and across technology families, in order to address the various stages of development of different renewables and markets.

Figure 1. **Combination framework of policy incentives in function of technology maturity**



NB: The positions of the various technologies and incentive schemes along the S-curve are an indicative example at a given moment. The actual optimal mix and timing of policy incentives will depend on specific national circumstances. The level of competitiveness will also change in function of the evolving prices of competing technologies.

Key point

An integrated approach combining different policy incentives depending on technology maturity is the most effective way to achieve a smooth transition towards mass market integration of renewables.

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Recommendations

A number of recommendations to policy-makers can be proposed on the basis of the analysis and main conclusions.

The removal of non-economic barriers to the diffusion of renewable energy should be a high-priority focus of policy design and implementation. Non-economic barriers, such as administrative complexities or hurdles, grid access issues with regards to connection, social acceptance of new technologies or lack of information and training, still act as "showstoppers" in many cases, even in cases where RETs are close to economic competitiveness with conventional energy technologies. The removal of these barriers thus remains a key first-priority area for future policy work, irrespective of the specific incentive scheme in place.

The predictability and overall consistency of the designed policies are prerequisites to successful policy making. In order to reach an acceptable level of risk for potential investors in renewable energy, policies proposed or in place must be able to provide the confidence that they ensure as much stability and certainty as possible in the incentives they contain. This also helps to reduce overall cost.

Policy support mechanisms for RETs should be designed to be transitional as they are for other technologies, with decreasing support levels over time, and be able to evolve to account for continuously changing conditions. Regular reviews of the mechanisms in place and of the progress achieved are crucial to ensure that renewable energy penetration and deployment occurs smoothly and effectively.

An integrated and long-term approach providing technology-specific support is recommended. While exploiting the cheapest renewable energy resources is an obvious priority, there is also the need for urgent action to provide a stable long-term policy framework in order to allow industry to improve the performance and reduce costs of less mature technologies. Combined with the monitoring of technology improvement and consequent adaptation of technology-specific incentives, this will lead to the minimisation of total costs in the long run.

The main objective of policies is to contribute to a more secure and cleaner energy supply. This implies that – in the medium-term – a portfolio of RETs needs to be brought into the mainstream in an evolved market, to lead the transition from the current system in which many renewables need subsidies to a future fully competitive, level playing field integrating carbon prices and other external costs of conventional energy technologies.

To achieve such a smooth transition towards full market integration of renewable energy, governments are encouraged to note the following principles relating to policies supporting RET deployment:

- Realise the urgency to implement effective support mechanisms in order to exploit the major potential of RETs to improve energy security and tackle climate change;
- Remove and overcome non-economic barriers as a first priority to improve policy and market functioning;
- Recognise the substantial potential for improvement of policy effectiveness and efficiency in most countries and learn from good practice;

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- Focus on coherent and rigorous implementation of the five fundamental policy design principles, with the aim of maximising long-term cost efficiency while having regard to national circumstances;
- Create a level playing field by pricing greenhouse gas emissions and other externalities appropriately in the market; and
- Move towards a combination framework of support schemes as a function of technology maturity level in order to foster smooth transition of RETs towards mass-market integration, progressively employing market forces.

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Annex A
Definitions, Abbreviations, Acronyms and Units

Technology definitions[58]

Biofuels/Liquid biomass

Biofuels/liquid biomass includes the following fuels and bioadditives: such as biogasoline (bioethanol, biomethanol, bioETBE, bioMTBE, etc.), biodiesel and other liquid biofuels.

- *Bioethanol:* ethanol produced from biomass and/or biodegradable fraction of organic waste.
- *Biodiesel:* diesel quality liquid fuel produced from biomass.
- *Biomethanol:* methanol produced from biomass and/or the biodegradable fraction of organic waste.

Biogas

Biogas is a gas composed principally of methane and carbon dioxide, derived principally from the anaerobic fermentation of biomass and solid waste and is combusted to produce heat and/or power. It comprises:

- *Landfill gas,* formed by the digestion of organic landfilled wastes;
- *Sewage sludge gas,* produced from the anaerobic fermentation of sewage sludge;
- *Other biogas,* such as biogas produced from the anaerobic fermentation of animal slurries and of wastes in abattoirs, breweries and other agro-food industries.

Biomass co-firing

Combustion of small shares of biomass in coal-fired power plants.

Combined heat and power (CHP)

Co-generation of usable heat and power.

Geothermal energy

Energy available as heat emitted from the earth's crust, usually in the form of hot water or steam. It is exploited at suitable sites:

58. *More detailed information can be obtained by consulting the annual IEA publications* Renewables Information, Electricity Information, Energy Balances of OECD Countries *and* Energy Balances of Non-OECD Countries. *Detailed descriptions and appraisals of the status of individual renewable energy technologies are available from the IEA publications* Renewable Energy RD&D Priorities: Insights from IEA Technology Programmes and Energy Technology Perspectives 2008.

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- for *electricity generation* using dry steam or high enthalpy brine after flashing;
- *directly as heat* for district heating, agriculture, etc.

Hydropower

Kinetic energy of falling water converted into electricity in hydroelectric plants.

However, *only hydro generation net of pumped storage* is included in "Total Renewable Energy Supply". For the purposes of the effectiveness and efficiency analysis and in the country profiles, hydropower is net of pumped storage.

Ocean energy

Mechanical energy derived from ocean currents, tidal movement or wave motion and exploited for electricity generation.

Renewable municipal waste

Renewable municipal waste consists of the biodegradable part of municipal waste products that are combusted directly to produce heat and/or power. It comprises waste produced by the residential, commercial and public services sectors that is collected by local authorities for disposal in a central location, including biodegradable hospital waste.

Solid biomass

Included are:

- *Charcoal:* the solid residue of the distillation and pyrolysis of wood and other vegetal material;
- *Wood, wood wastes, other solid wastes:* purpose-grown energy crops (poplar, willow etc.), a multitude of woody materials generated by an industrial process (wood/paper industry in particular) or provided directly by forestry and agriculture (firewood, wood chips, bark, sawdust, shavings, chips, black liquor, etc.) as well as wastes such as straw, rice husks, nut shells, poultry litter, crushed grape dregs, etc. Combustion is the preferred technology for these solid wastes. The quantity of fuel used is reported on a *net* calorific value basis.

Solar energy

Solar radiation exploited for hot water production, space heating and/or electricity generation[59], separately defined as:

- *Solar photovoltaics (PV)*: This is solar radiation exploited for electricity generation by photovoltaic cells.
- *Solar thermal:* This is solar radiation exploited for :

59. Passive solar energy for direct heating, cooling or lighting of dwellings or other buildings is not included.

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i) hot water production or the seasonal heating of swimming pools by flat plate collectors; and/or
ii) electricity generation by solar thermal-electric plants.

There are three main *solar thermal-electric* technologies:

- *Parabolic trough plant:* Large cylindrical parabolic mirrors concentrate the sunlight on a line of focus. Several of these collectors in a row form a solar field. Molten salt is then used to transport the heat to a (conventional) gas or steam turbine.
- *Solar power tower plant:* The solar field of a central receiver system, *i.e.* the power tower, is made up of several hundred mirrors which concentrate the sun light to the central receiver. Similar to above, air or molten salt is used to transport the heat to a conventional gas or steam turbine.
- *Dish/Stirling Technology:* Parabolic dish concentrators are rather small units – in the range of kilowatts – in contrast to the above technology concepts.

Trough and power tower plant are usually equipped either with a thermal storage block or a hybrid fossil burner in order to guarantee a non-fluctuating power supply.

Total final consumption

Total final consumption is the sum of consumption by the different end use-sectors. TFC is broken down into energy demand in the following sectors: industry, transport, other (includes agriculture, residential, commercial and public services) and non-energy uses. Industry includes manufacturing, construction and mining industries. In final consumption, petrochemical feedstocks appear under industry use. Other non-energy uses are shown under non-energy use.

Total primary energy supply

Total primary energy supply is equivalent to total primary energy demand. This represents inland demand only and, except for world energy demand, excludes international marine bunkers.

Traditional biomass

Traditional biomass refers mainly to non-commercial biomass use.

Transformation sector

The transformation sector comprises the conversion of primary forms of energy to secondary forms as well as further transformation processes.

Wind energy

Kinetic energy of wind exploited for electricity generation in wind turbines.

NB: The kinetic wind energy that is harvested as mechanical force for such applications as water pumps is not included.

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Definitions used for IEA energy technology research, development and demonstration (RD&D) statistics [60]

Renewable energy sources

Renewable energy sources encompasses bioenergy, geothermal energy, hydropower, ocean energy, solar energy, wind energy, and other renewables.

Bioenergy

Bioenergy encompasses:

- *Production from transport biofuels including from wastes:* conventional biofuels; cellulosic conversion to alcohol; and biomass gas-to-liquids.
- *Production of other biomass-derived fuels including wastes:* bio-solids, bio-liquids; biogas thermal; and biogas biological.
- *Applications for heat and electricity:* bio-heat excluding multi-firing with fossil fuels; –bio-electricity excluding multi-firing with fossil fuels; CHP (combined heat and power) excluding multi-firing with fossil fuels; and – recycling and uses of urban, industrial and agricultural wastes not covered elsewhere.
- *Other bio-energy:* improvements of energy crops; and research on bio-energy production potential and associated land-use effects; and other.

Geothermal energy

Geothermal energy includes *hydro-thermal, enhanced geothermal systems (EGS or hot dry rock), geothermal heat applications, including agriculture*.

Hydropower

Hydropower encompasses:

- *Large hydropower:* hydropower plants with capacity of 10MW and above.
- *Small hydropower:* hydropower plants with capacity of below 10MW.

Ocean energy

Ocean energy includes: *tidal power; wave energy; ocean current power*; and *ocean thermal power*.

Solar energy

Solar energy encompasses:

60. The IEA RD&D statistics data can be accessed at: http://www.iea.org/Textbase/stats/rd.asp. More detailed information on the RD&D technology categories used can be obtained by consulting the documentation on the IEA energy technology RD&D budget statistics: http://wds.iea.org/WDS/tableviewer/document.aspx?FileId=1092 .

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Solar heating and cooling (including daylighting): collector development; hot water preparation; combined-space heating; active solar heating and cooling; passive solar heating and cooling; daylighting; solar architecture; solar drying; solar-assisted ventilation; swimming pool heating; and low-temperature process heating.

Solar photovoltaics (PV): solar cell development; PV module development; PV inverter development; building-integrated PV-modules; and PV system development.

Concentrating solar thermal[61] and high temperature applications: concentrating collector development; solar thermal power plants (design, construction and testing); solar high-temperature applications for process heat; and solar chemistry.

Wind energy

Wind energy encompasses: *converter development; system integration; on-shore applications; and off-shore applications*.

Other renewables

The technology category encompasses: studies of renewable energy potentials not covered elsewhere; and other.

Regional definitions

BRICS

BRICS refers to: Brazil, Russia, India, China and South Africa.

China

China refers to the People's Republic of China and Hong Kong.

EU-25

EU-25 refers to: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden and the United Kingdom.

EU-27

EU-27 refers to: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden and the United Kingdom.

61. Concentrating solar thermal is an alternative denotation for concentrated solar power (CSP) or solar thermal electricity (see entry for solar energy).

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EU-OECD

EU-OECD refers to: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, Netherlands, Poland, Portugal, Slovak Republic, Spain, Sweden and the United Kingdom.

Group of Eight (G8)

Canada, France, Germany, Italy, Japan, Russia, the United Kingdom and the United States.

G8+5 countries

The G8 countries (Canada, France, Germany, Italy, Japan, Russia, the United Kingdom and the United States), plus the five leading emerging economies – Brazil, China, India, Mexico and South Africa.

IEA member countries

Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Republic of Korea, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States.

IEA-15

IEA-15 refers to: Austria, Canada, Denmark, Finland, France, Germany, Italy, Japan, the Netherlands, New Zealand, Norway, Spain, Sweden, the United Kingdom and the United States.

OECD countries

Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Republic of Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States.

Other OECD

Other OECD refers to the non-EU OECD countries: Australia, Canada, Iceland, Japan, Republic of Korea, Mexico, New Zealand, Norway, Switzerland, Turkey and the United States

Abbreviations and acronyms

BRICS	Brazil, Russia, India, China, South Africa
CHP	combined heat and power
CSP	concentrating solar power
EU	European Union

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EU ETS	European Union Greenhouse Gas Emission Trading Scheme
EU-25	the European Union between 1st May 2004 and 31st December 2006, comprising 25 member states
EU-27	the European Union as of 1st January 2007, comprising 27 member states
EU-OECD	OECD countries which are also European Union member states
IEA	International Energy Agency
LR	learning rate
MoU	Memorandum of Understanding
n/a	not applicable
NB	*Nota Bene* (note well)
NIMBY	Not-In-My-Backyard
OECD	Organisation for Economic Co-operation and Development
PV	photovoltaics
R&D	research and development
RD&D	research, development and demonstration
RE	renewable energy
RES	renewable energy sources
RES-E	electricity generated from renewable energy sources
RES-H	heat produced from renewable energy sources
RES-T	transport fuels produced from renewable energy sources
RET	renewable energy technology
TFC	total final consumption
TPES	total primary energy supply
VAT	value-added tax

Country three-letter ISO codes

AUS	Australia
AUT	Austria
BEL	Belgium
BRA	Brazil
CAN	Canada
CHE	Switzerland
CHN	China (People's Republic of, and Hong Kong)
COK	Cook Islands
CZE	Czech Republic
DEU	Germany

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DNK	Denmark
ESP	Spain
FIN	Finland
FRA	France
GHA	Ghana
GBR	United Kingdom
GRC	Greece
HUN	Hungary
IND	India
ISL	Iceland
IRL	Ireland
ITA	Italy
JPN	Japan
KOR	Korea
LUX	Luxembourg
MEX	Mexico
NLD	The Netherlands
NOR	Norway
NZL	New Zealand
POL	Poland
PRT	Portugal
PRY	Paraguay
RUS	Russia
SGP	Singapore
SVK	Slovak Republic
SWE	Sweden
TUR	Turkey
USA	United States
ZAF	South Africa

Currency codes

AUD	Australian dollar
CNY	(Chinese) Yuan renminbi
EUR	Euro, which is the legal tender since 1 January 1999 (with the cash changeover occurring on 1 January 2002) in 12 OECD-EU countries: Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal and Spain.
INR	Indian rupee

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RUB	new Russian ruble
USD	United States dollar
ZAR	South African rand

Units

CO_2	carbon dioxide
GWh	gigawatt-hour, 1 kilowatt-hour equals 10^9 watt-hours
ha	hectare
J	joule
kb	kilobarrel
kWh	kilowatt-hour, 1 kilowatt-hour equals 10^3 watt-hours
kWp	kilowatt peak
kWth	kilowatt thermal
l	litre
m^3	cubic metre
Mtoe	million tonnes of oil equivalent
MWh	megawatt hour, 1 megawatt-hour equals 10^6 watt-hours
PJ	petajoule, 1 petajoule equals 10^{15} joules
TJ	terajoule, 1 terajoule equals 10^{12} joules
toe	tonne of oil equivalent
TWh	terawatt-hour, 1 terawatt-hour equals 10^{12} watt-hours

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Annex B
References

Introduction

Goldemberg, J. (2006), "The Case for Renewable Energies" in Aßmann, D., U. Laumanns, D. Uh (eds.), *Renewable Energy: A Global Review of Technologies, Policies and Markets*, Earthscan, London.

IEA (2004), *Renewable Energy: Market and Policy Trends in IEA Countries*, OECD/IEA, Paris.

IEA (2008), *Energy Technology Perspectives 2008: Scenarios & Strategies to 2050*, OECD/IEA, Paris.

Chapter 1. Global Renewable Energy Technology Markets

EurObserv'ER (2006), *Small Hydropower Barometer*, Systèmes Solaires No. 174, Prepared in the scope of "EurObserv'ER" project, Observatoire des Énergies Renouvelables (Observ'ER), Paris.

IEA (2007a), *Renewables Information 2007*, OECD/IEA, Paris.

IEA (2007b), *Energy Use in the New Millennium: Trends in IEA Countries*, OECD/IEA, Paris.

IEA and RETD (2007), *Renewables for Heating and Cooling: Untapped Potential*, OECD/IEA and IEA Renewable Energy Technology Deployment Implementing Agreement (RETD), Paris.

REN21 (2008), *Renewables 2007 Global Status Report*, REN21 Secretariat, Paris and Worldwatch Institute, Washington, D.C.

Chapter 2. Potentials and Costs for Renewable Energy Technologies

Grübler, A., N. Nakićenović and D.G. Victor (1998). "Dynamics of Energy Technologies and Global Change", *Energy Policy*, Vol. 27 (1999), pp. 247-280.

Huber, C., T. Faber, R. Haas, G. Resch, J. Green, S. White, S. Ölz, H. Cleijne, W. Ruijgrok, P.E. Morthorst, K. Skytte, M. Gual, P. del Rio, F. Hernández, A. Tacsir, M. Ragwitz, J. Schleich, W. Orasch, M. Bokemann and C. Lins (2004), *GREEN-X – Deriving optimal promotion strategies for increasing the share of RES-E in a dynamic European electricity market*, Final report of the research project GREEN-X (Contract No. ENG2-CT-2002-00607) within the 5th Framework Programme of the European Commission, DG Research, coordinated by Energy Economics Group (EEG) with contributions from IT Power, KEMA, RISØ, CSIC, FhG-ISI, WIENSTROM, EGL, EREC; Energy Economics Group, Institute for Power Systems and Energy Economics, Vienna University of Technology, Vienna.

© OECD/IEA, 2008

IEA (2006), *Renewable Energy: RD&D Priorities – Insights from IEA Technology Programmes*, OECD/IEA, Paris.

IEA (2007), *World Energy Outlook 2007*, OECD/IEA, Paris.

IEA (2008), *Energy Technology Perspectives 2008: Scenarios & Strategies to 2050*, OECD/IEA, Paris.

IEA and NEA (2005), *Projected costs of generating electricity*, OECD/IEA and Nuclear Energy Agency, Paris.

Ragwitz M., J. Schleich, C. Huber, G. Resch, T. Faber, M. Voogt, W. Ruijgrok, and P. Bodo (2005), *FORRES 2020 - Analysis of the renewable energy's evolution up to 2020*, Final report of the project FORRES 2020 - on behalf of the European Commission, DG TREN, coordinated by FhG-ISI with contributions from EEG, ECOFYS, KEMA and REC, Karlsruhe.

REN21 (2008), *Renewables 2007 Global Status Report*, REN21 Secretariat, Paris and Worldwatch Institute, Washington, D.C.

Resch, G., R. Haas and T. Faber (2008), *The future potential for renewable energies – Assessment of their mid-term realisable potential up to 2020 at global scale*, Report prepared for the International Energy Agency, Energy Economics Group, Institute for Power Systems and Energy Economics, Vienna University of Technology, Vienna.

Resch G., T., Faber, R. Haas, M. Ragwitz, A. Held and I. Konstantinaviciute (2006), *Potentials and cost for renewable electricity in Europe: The Green-X database on dynamic cost-resource curves*, Report of the project OPTRES (Assessment and optimisation of renewable energy support measures in the European electricity market) as conducted by a consortium led by Fraunhofer ISI for the European Commission, DGTREN, Intelligent Energy for Europe – Programme (Contract No. EIE/04/073/S07.38567), Energy Economics Group at Vienna University of Technology, Vienna.

Chapter 3. Effectiveness and Efficiency of Market Deployment Policies

Coenraads, R., M. Voogt and A. Morotz (2006), *Analysis of barriers for the development of electricity generation from renewable energy sources in the EU-25*, Report of the project OPTRES (Assessment and optimisation of renewable energy support measures in the European electricity market) as conducted by a consortium led by Fraunhofer ISI for the European Commission, DGTREN, Intelligent Energy for Europe – Programme (Contract No. EIE/04/073/S07.38567), ECOFYS, Utrecht.

Edge, G. (2006), "A Harsh Environment: The Non-Fossil Fuel Obligation and the UK Renewables Industry", in K. Mallon (ed.), *Renewable Energy Policy and Politics – A Handbook for Decision-Making*, Earthscan, London.

EIA (2007), *State Renewable Electricity Profiles 2005*, Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, U.S. Department of Energy, Washington, DC.

© OECD/IEA, 2008

European Commission (2008), *The support of electricity from renewable energy sources*, SEC(2008) 57, Commission Staff Working Document, published on 23 January 2008, Accompanying document to the Proposal for a Directive of The European Parliament and of The Council on the promotion of the use of energy from renewable sources (COM(2008)19), Commission of the European Communities, Brussels.

European Commission (2005), *The support of electricity from renewable energy sources*, COM(2005) 627, Communication from the Commission, published on 7 December 2005, Commission of the European Communities, Brussels.

FACTS Global Energy (2008), *India's Ethanol Mandate: Key Aspects and Implications*, Energy Advisory Report, Issue no. 338, June 2008, FACTS Global Energy, Singapore.

GBEP (2007), *A Review of the Current State of Bioenergy Development in G8+5 Countries*, Global Bioenergy Partnership (GBEP) Secretariat, Food and Agricultural Organisation, FAO/GBEP, Rome.

Huber, C., T. Faber, R. Haas, G. Resch, J. Green, S. White, S. Ölz, H. Cleijne, W. Ruijgrok, P.E. Morthorst, K. Skytte, M. Gual, P. del Rio, F. Hernández, A. Tacsir, M. Ragwitz, J. Schleich, W. Orasch, M. Bokemann and C. Lins (2004), *GREEN-X – Deriving optimal promotion strategies for increasing the share of RES-E in a dynamic European electricity market*, Final report of the research project GREEN-X (Contract No. ENG2-CT-2002-00607) within the 5th Framework Programme of the European Commission, DG Research, coordinated by Energy Economics Group (EEG) with contributions from IT Power, KEMA, RISØ, CSIC, FhG-ISI, WIENSTROM, EGL, EREC; Energy Economics Group, Institute for Power Systems and Energy Economics, Vienna University of Technology, Vienna.

IEA (2006), *Renewable Energy: RD&D Priorities – Insights from IEA Technology Programmes*, OECD/IEA, Paris.

IEA (2007a), *Contribution of Renewables to Energy Security*, IEA Information Paper, OECD/IEA, Paris.

IEA (2007b), *Energy Balances of OECD Countries 2004-5*, OECD/IEA, Paris.

IEA (2007c), *Renewables Information 2007*, OECD/IEA, Paris.

IEA (2008a), *Energy Technology Perspectives 2008: Scenarios & Strategies to 2050*, OECD/IEA, Paris.

IEA (2008b), "IEA/JREC Global Renewable Energy Policies and Measures Database", http://www.iea.org/textbase/pm/grindex.aspx, accessed 15 March 2008.

IEA and RETD (2007), *Renewables for Heating and Cooling: Untapped Potential*, OECD/IEA and IEA Renewable Energy Technology Deployment Implementing Agreement (RETD), Paris.

IREC (2006), "U.S. Solar Market Trends", presentation held by Larry Sherwood on behalf of the Interstate Renewable Energy Council at Solar 2006 Conference, 7-13 July 2006, Denver Colorado, http://www.solar2006.org/presentations/tech_sessions/t25-m207.pdf .

© OECD/IEA, 2008

Lewis, J. I. (2007), A Comparison of Wind Power Industry Development Strategies in Spain, India and China, Report prepared for the Center for Resource Solutions, Supported by the Energy Foundation, China Sustainable Energy Program, Center for Resource Solutions, San Francisco.

Ragwitz M., J. Schleich, C. Huber, G. Resch, T. Faber, M. Voogt, W. Ruijgrok and P. Bodo (2005), *FORRES 2020 - Analysis of the renewable energy's evolution up to 2020*, Final report of the project FORRES 2020 (Tender No. TREN/D2/10-2002) for the European Commission, DG TREN, coordinated by Fraunhofer Institute Systems and Innovation Research (Fhg-ISI) with contributions from EEG, ECOFYS, KEMA and REC, Fraunhofer Institute Systems and Innovation Research, Karlsruhe.

Ragwitz, M. and A. Held (2007a), *Effectiveness and efficiency of present RES-E support policies in EU Member States*, Presentation made by the Fraunhofer Institute Systems and Innovation Research at Global Best Practice in Renewable Energy Policy Making Workshop, 29 June 2007, IEA Secretariat, Paris, http://www.iea.org/Textbase/work/2007/bestpractice/Ragwitz.pdf, accessed 23 January 2008.

Ragwitz, M. and A. Held (2007b), *Policy effectiveness and support level efficiency of market deployment policies for RET – Methodological introduction*, Report prepared for the International Energy Agency, Fraunhofer Institute Systems and Innovation Research, Karlsruhe.

Ragwitz, M., A. Held, G. Resch, T., Faber, R. Haas, C. Huber, R. Coenraads, M. Voogt, G. Reece, P.E. Morthorst, S. Grenaa Jensen, I. Konstantinaviciute and B. Heyder (2007c), *OPTRES – Assessment and optimisation of renewable energy support measures in the European electricity market*, Final Report of the project as conducted by a consortium led by Fraunhofer Institute Systems and Innovation Research for the European Commission, DGTREN, Intelligent Energy for Europe - Programme (Contract No. EIE/04/073/S07.38567), Fraunhofer Institute Systems and Innovation Research, Karlsruhe.

Ragwitz, M., A. Held, B. Pfluger, K. Nuemann, G. Resch, T. Faber and R. Wiser (2008), *Assessment of the effectiveness of renewable energy support schemes in the OECD and BRICS countries*, Report to the International Energy Agency, Fraunhofer Institute Systems and Innovation Research, Karlsruhe/ Energy Economics Group, Vienna University of Technology, Vienna/ Lawrence Berkeley National Laboratory, Berkeley.

Resch, G. (2008), *Summary of the project FUTURES-E - Deriving a Future European Policy for Renewable Electricity*, as conducted by a consortium led by Energy Economics Group (EEG) with contributions from Agencija za prestrukturiranje energetike d.o.o. (ApE), Ambiente Italia srl Istituto di Ricerche (AMBIT), Centralne Laboratorium Naftowe (EC BREC/CLN), Ecofys UK (ECOFYS), Elektrizitäts-Gesellschaft Laufenburg Austria GmbH (EGL), Fraunhofer Institute for Systems and Innovation Research (Fh-ISI), Lithuanian Energy Institute (LEI), Risø National Laboratory (RISØ) for the European Commission, DGTREN, Intelligent Energy for Europe - Programme (Contract No. EIE/06/143/SI2.444285), http://www.futures-e.org/, accessed 22 February 2008.

Sawin, J.L. (2006), "National Policy Instruments: Policy Lessons for the Advancement and Diffusion of Renewable Energy Technologies Around the World", in Aßmann, D., U.

© OECD/IEA, 2008

Laumanns, D. Uh (eds.), *Renewable Energy: A Global Review of Technologies, Policies and Markets*, Earthscan, London.

Swisher, R. and K. Porter (2006), "Renewable Policy Lessons from the US: The Need for Consistent and Stable Policies", in K. Mallon (ed.), *Renewable Energy Policy and Politics – A Handbook for Decision-Making*, Earthscan, London.

REN21 (2008), *Renewables 2007 Global Status Report*, REN21 Secretariat, Paris and Worldwatch Institute, Washington, D.C.

Wiser, R. and G. Barbose (2008), *Renewables Portfolio Standards in the United States: A Status Report with Data through 2007*, Lawrence Berkeley National Laboratory, Berkeley.

Wiser, R. and O. Langniss (2001), *The Renewables Portfolio Standard in Texas: An Early Assessment*, Lawrence Berkeley National Laboratory, Berkeley.

Chapter 4. Research, Development and Demonstration Trends for Renewables

Morris, G. (2007), *Renewable Energy Markets and Policies – Country Profile: South Africa*, Report prepared for the International Energy Agency, AGAMA Energy, Cape Town.

IEA (2005a), *Energy Policies of IEA Countries: Spain 2005 Review*, OECD/IEA, Paris.

IEA (2005b), *Energy Policies of IEA Countries: Australia 2005 Review*, OECD/IEA, Paris.

IEA (2006), *Renewable Energy: RD&D Priorities – Insights from IEA Technology Programmes*, OECD/IEA, Paris.

IEA (2007a), *IEA Energy Technology R&D Statistics*, IEA, Paris, http://www.iea.org/Textbase/stats/rd.asp, accessed 21 November 2007.

IEA (2007b), *Energy Policies of IEA Countries: Germany 2006 Review*, OECD/IEA, Paris.

IEA (2007c), *Energy Policies of IEA Countries: The United Kingdom 2006 Review*, OECD/IEA, Paris.

IEA (2007d), *Reviewing R&D Policies: Guidance for IEA Review Teams*, OECD/IEA, Paris.

IEA Wind (IEA Implementing Agreement for Co-operation in the Research, Development, and Deployment of Wind Energy Systems) (2007), *2006 IEA Wind Energy Annual Report of the Executive Committee for the Implementing Agreement for Cooperation in the Research, Development and Deployment of Wind Energy Systems of the International Energy Agency*, IEA Wind, Paris.

Li, J. *et al.* (2007), *Renewable Energy Markets and Policies – China*, Report prepared for the International Energy Agency, Chinese Renewable Energy Industries Association (CREIA), Beijing.

MNRE (2008), Indian Ministry for New and Renewable Energy, *MNRE Eleventh Plan 2007-12, Summary of Proposals*, http://mnes.nic.in/, accessed 30 January 2008.

OECD (2007), *OECD Science, Technology and Industry Scoreboard 2007*, OECD, Paris.

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Chapter 5. Conclusions and Recommendations

IEA (2007), *Renewables Information 2007*, OECD/IEA, Paris.

IEA (2008), *Energy Technology Perspectives 2008: Scenarios & Strategies to 2050*, OECD/IEA, Paris.

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