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Wind Energy in Latin America

Gabriel Blanco

International Council fo Science
Regional Committee for Latin America and the Caribbean
Scientific Planning Group on Sustainable Energy
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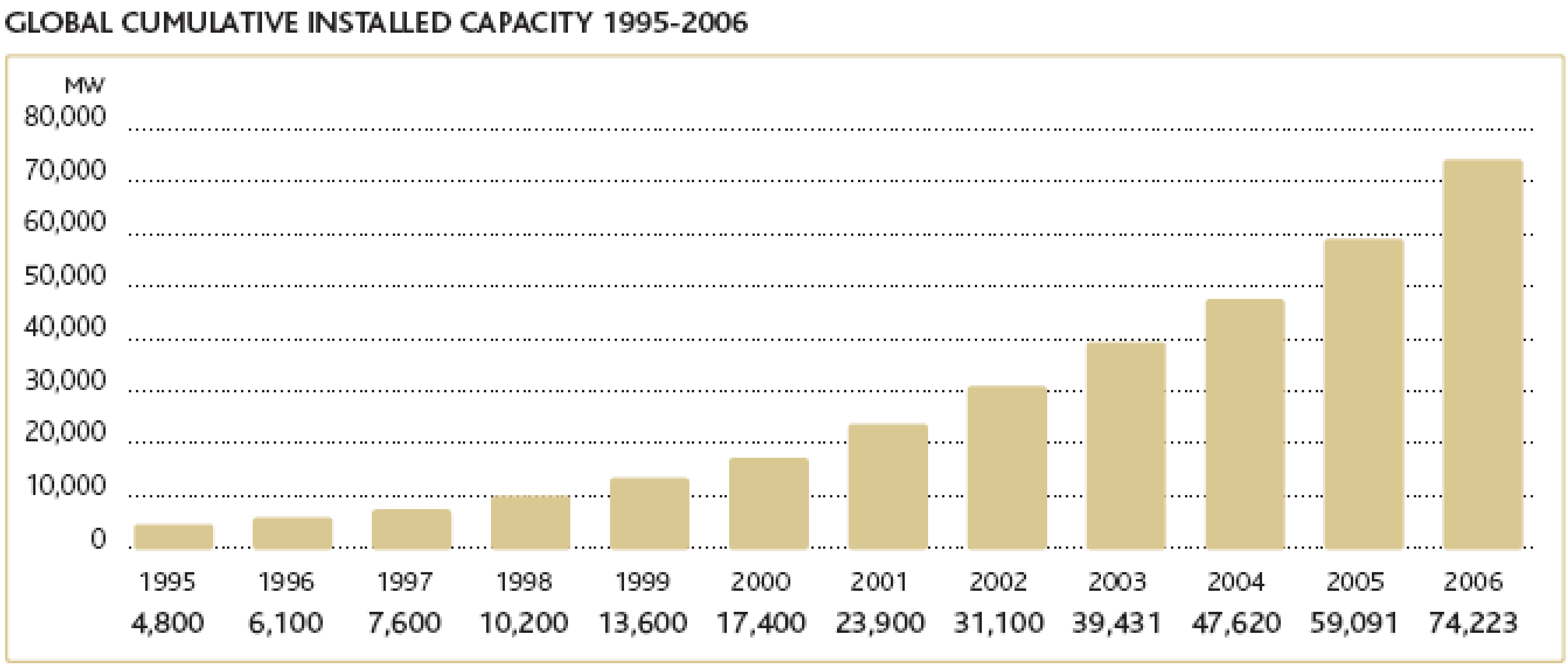
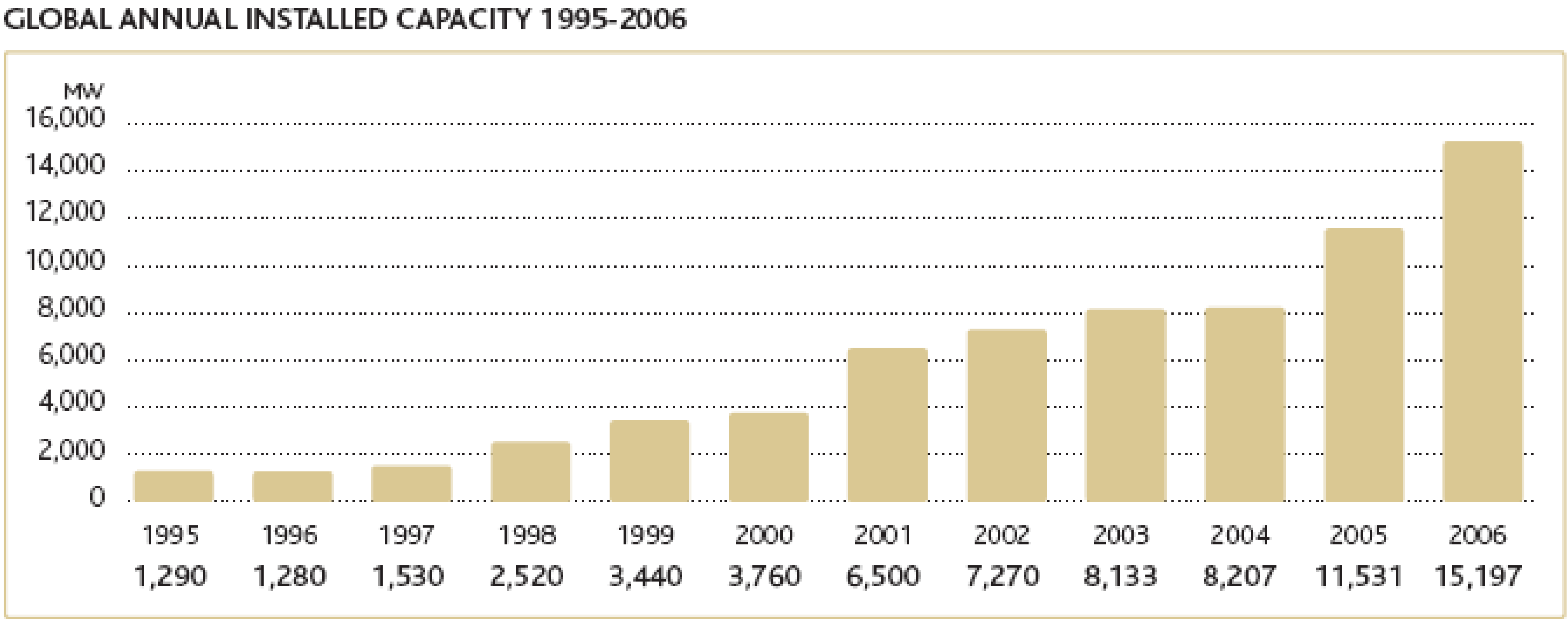
Global cumulative wind power installed capacity 1995-2006



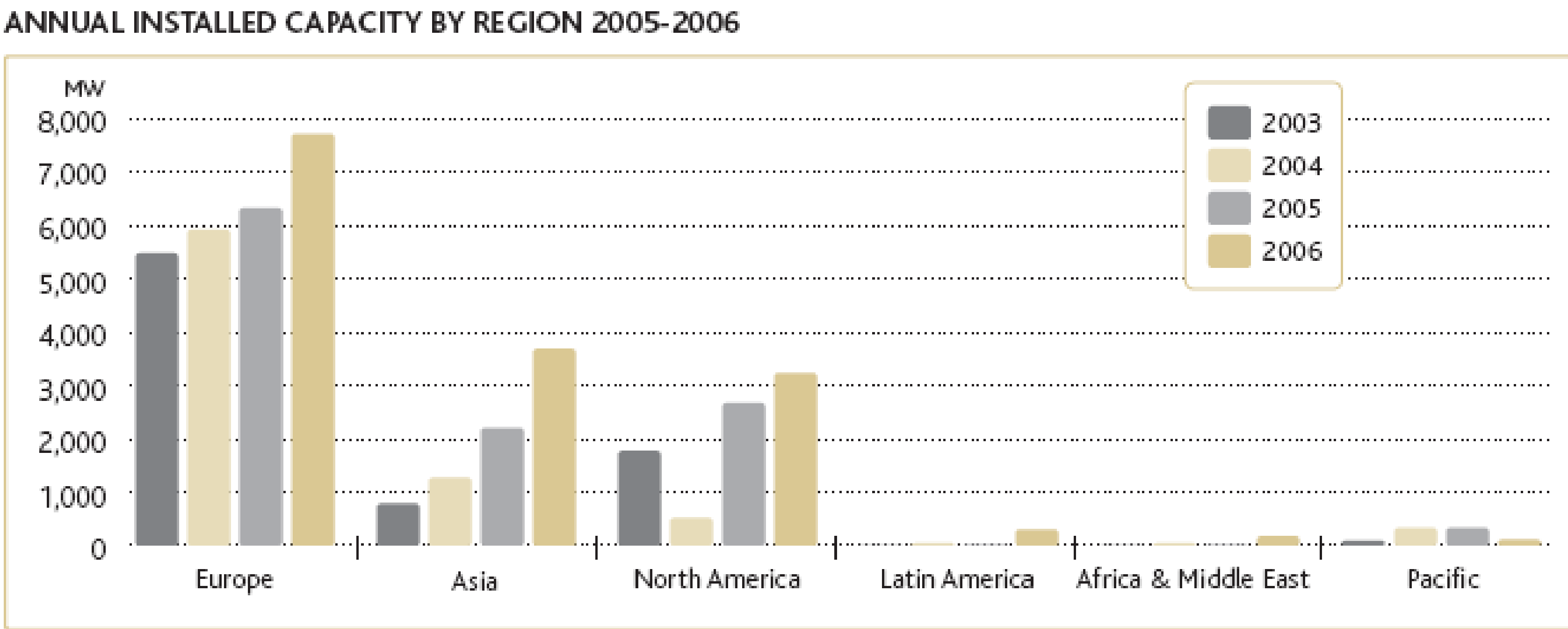
Source: GWEC, 2007

Global annual wind power installed capacity 1995-2006



Source: GWEC, 2007

Annual wind power installed capacity by region 2003-2006



Source: GWEC, 2007

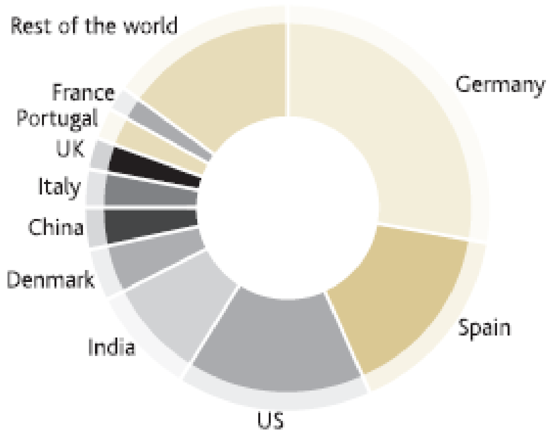
Latin America & Caribbean: wind power installed capacity by country

	Total end 2005	New 2006	Total end 2006
Brazil	29	208	237
Mexico	3	85	88
Costa Rica	71	3	74
Caribbean (w/o Jamaica)	35	-	35
Argentina	27	-	27
Colombia	20	-	20
Jamaica	20	-	20
Others[5]	7	-	7
Total	**212**	**296**	**508**

Source: GWEC, 2007

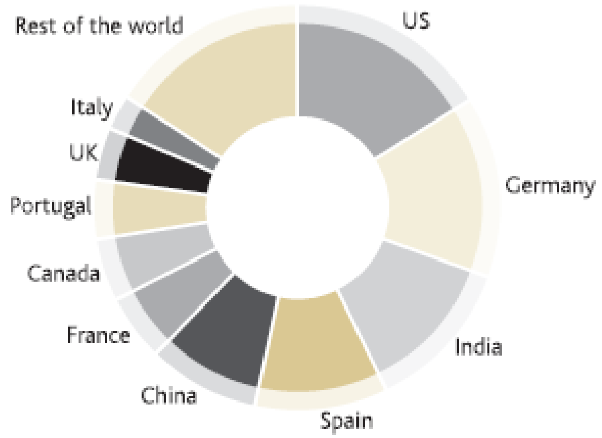
Global wind power installed capacity

TOP 10 TOTAL INSTALLED CAPACITY



	MW	%
Germany	20,622	27.8
Spain	11,615	15.6
US	11,603	15.6
India	6,270	8.4
Denmark	3,136	4.2
China	2,604	3.5
Italy	2,123	2.9
UK	1,963	2.6
Portugal	1,716	2.3
France	1,567	2.1
Rest of the world	11,005	14.8
Total top 10	**63,218**	**85.2**
Total	**74,223**	

TOP 10 NEW CAPACITY



	MW	%
US	2,454	16.1
Germany	2,233	14.7
India	1,840	12.1
Spain	1,587	10.4
China	1,347	8.9
France	810	5.3
Canada	776	5.1
Portugal	694	4.6
UK	634	4.2
Italy	417	2.7
Rest of the world	2,405	15.8
Total top 10	**12,792**	**84.2**
Total	**15,197**	

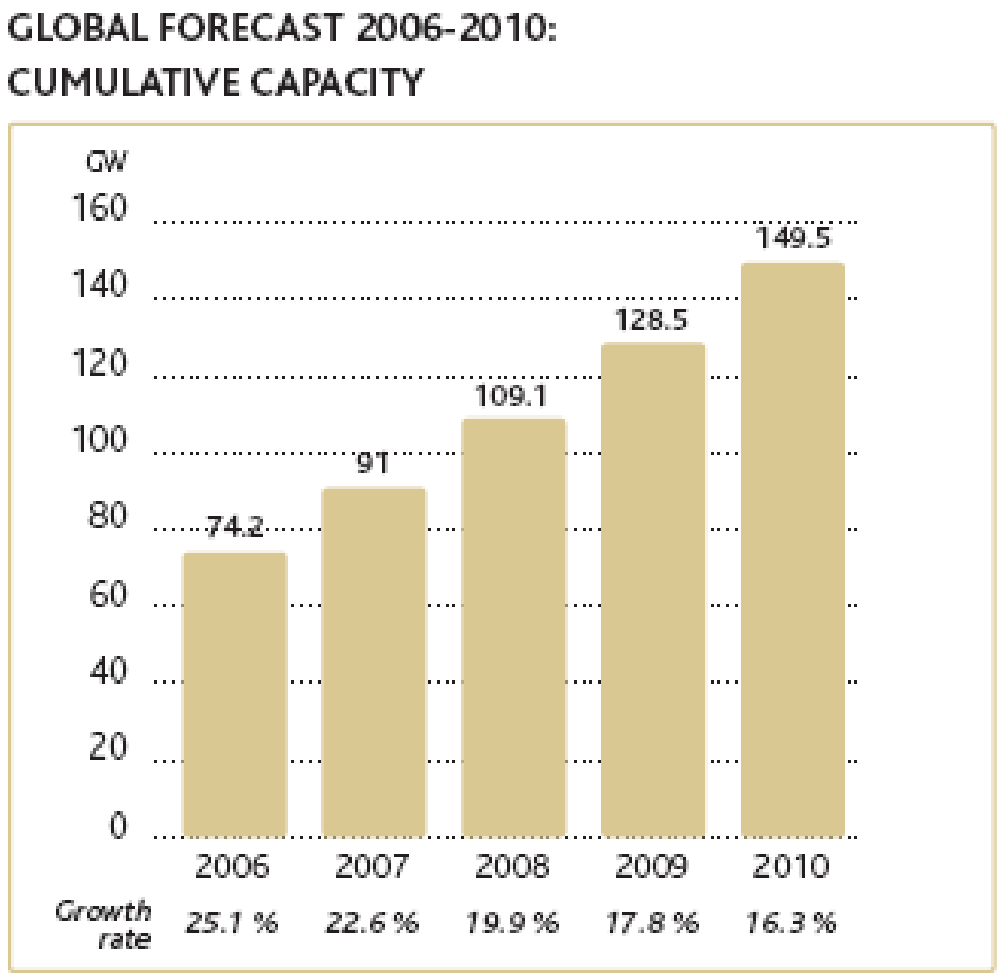
Source: GWEC, 2007

Status of the global wind power industry

- Employs around 200,000 people
- Has an annual revenue of more than € 18 billion (US$ 23 billion)
- Has been growing at an annual rate of more than 28 % for the last 10 years
- Meets the electricity needs of more than 25 million households
- Is concentrated in Europe, which accounts for 65 % of total capacity and most of the major turbine manufacturers
- Over 100,000 wind turbines installed today in 70 countries
- Over 74,000 MW of installed capacity

Source: GWEC, 2007

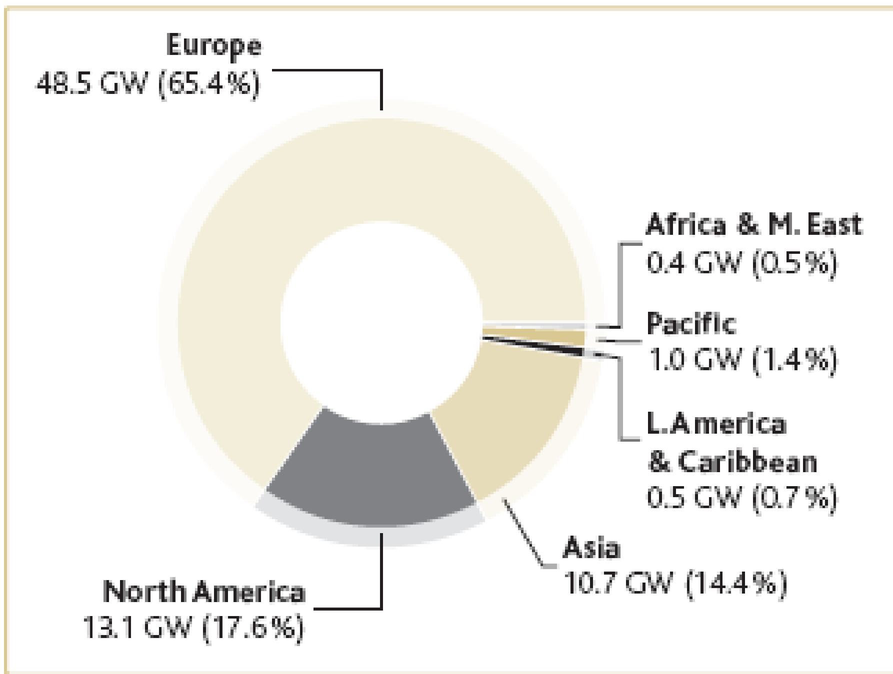
Wind energy market forecast



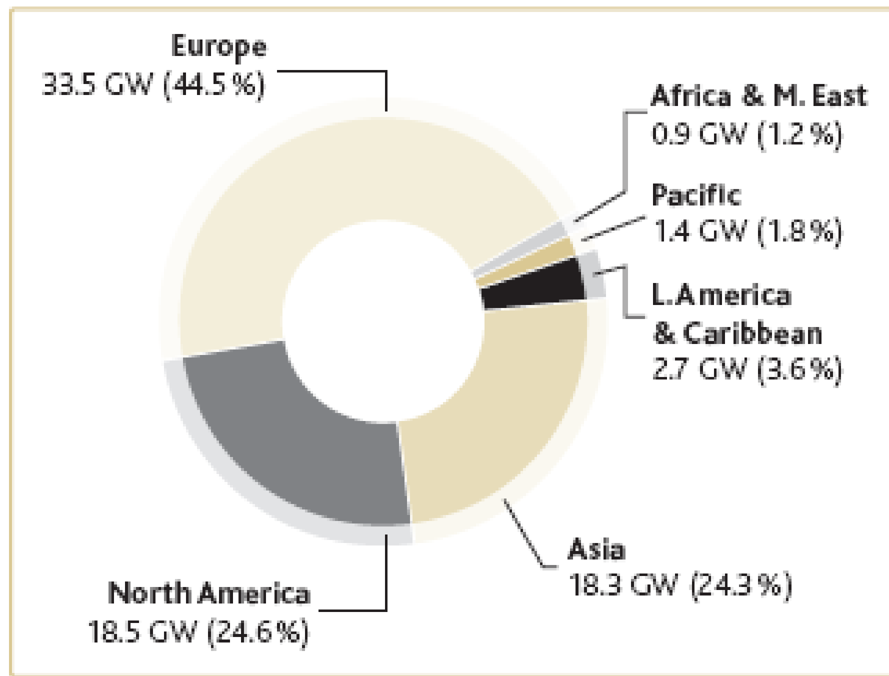
Source: GWEC, 2007

Wind energy market forecast

TOTAL CAPACITY END 2006



PROJECTED CAPACITY 2007-2010



Source: GWEC, 2007

Extended forecast: the scenarios

- The most conservative **“Reference”** scenario:
  - is based on the projection in the (2004) World Energy Outlook report from the International Energy Agency (IEA).

- The **“Moderate”** scenario:
  - takes into account all policy measures to support renewable energy either under way or planned around the world. It also assumes that the targets set by many countries for either renewables or wind energy are successfully implemented. The assumption here is that the success achieved in Europe in meeting the goals for wind energy implementation set by the European Union will be repeated globally.

- The most ambitious scenario, the **“Advanced”** version:
  - follows a similar development path to that outlined in the series of Wind Force 10 and 12 reports produced since 1999 by the European Wind Energy Association (EWEA), the Global Wind Energy Council (GWEC) and Greenpeace. These examined how feasible it would be for 10%, and later 12%, of the world’s electricity to come from wind power by 2020. The assumption here is that all policy options in favour of renewable energy, along the lines of this report’s recommendations, have been selected, and the political will is there to carry them out.

Source: GWEC, 2007 and IEA Energy Outlook 2006

Extended forecast: the scenarios

- These three scenarios for the global wind energy market are then set against two trajectories for the future growth of electricity demand.

- Most importantly, these projections do not just assume that growing demand by consumers will inevitably need to be matched by supply options.

- On the basis that demand will have to be reduced if the threat of climate change is to be seriously tackled, they take into account an increasing element of energy efficiency.

Source: GWEC, 2007 and IEA Energy Outlook 2006

Extended forecast 2030-2050

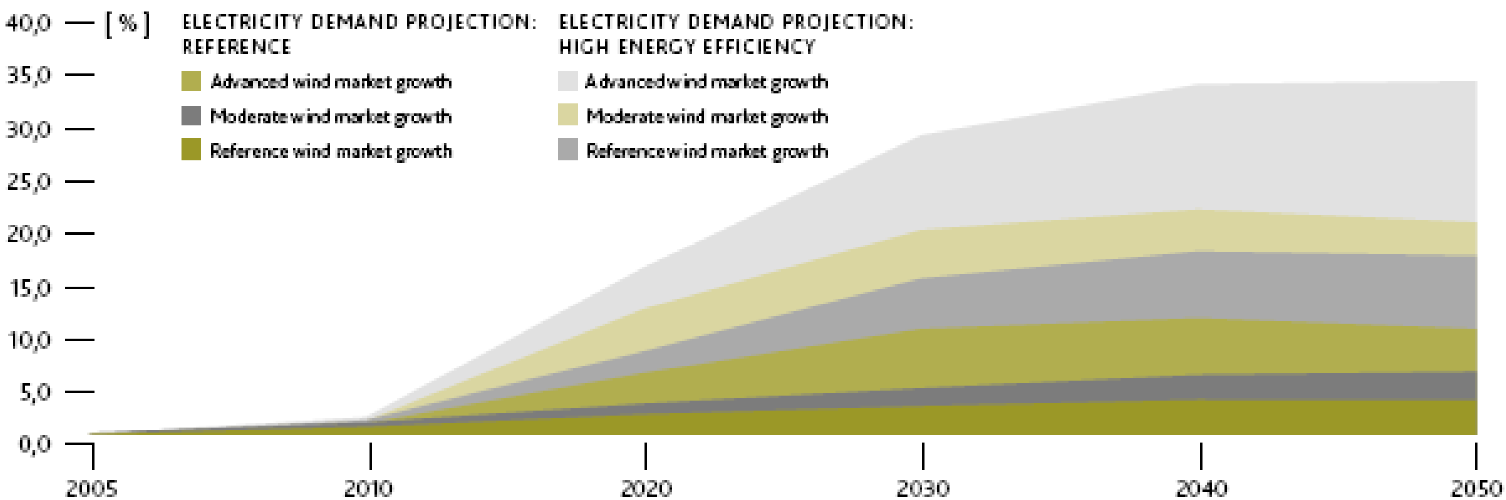
SUMMARY OF GLOBAL WIND ENERGY OUTLOOK SCENARIO FOR 2030							
Global Scenario	Cumulative wind power capacity (GW)	Electricity output (TWh)	Percentage of world electricity (High Energy Efficiency)	Annual installed capacity [GW]	Annual investment (€ bn)	Jobs [million]	Annual CO_2 saving (million tonnes)
Reference	364	892	5 %	24.8	21.2	0.48	535
Moderate	1,129	2,769	15.6 %	58.3	45.0	1.14	1,661
Advanced	2,107	5,176	29.1 %	129.2	84.8	1.44	3,100

SUMMARY OF GLOBAL WIND ENERGY OUTLOOK SCENARIO FOR 2050							
Global Scenario	Cumulative wind power capacity (GW)	Electricity output (TWh)	Percentage of world electricity (High Energy Efficiency)	Annual installed capacity [MW]	Annual investment (€ bn)	Jobs [million]	Annual CO_2 saving (million tonnes)
Reference	577	1,517	6.6 %	34.3	28.8	0.65	910
Moderate	1,557	4,092	17.7 %	71.0	54.2	1.39	2,455
Advanced	3,010	7,911	34.3 %	168.6	112.0	2.80	4,747

Source: GWEC, 2007 and IEA Energy Outlook 2006

Extended forecast 2030-2050

WIND POWER PENETRATION OF WORLDS ELECTRICITY SUPPLY

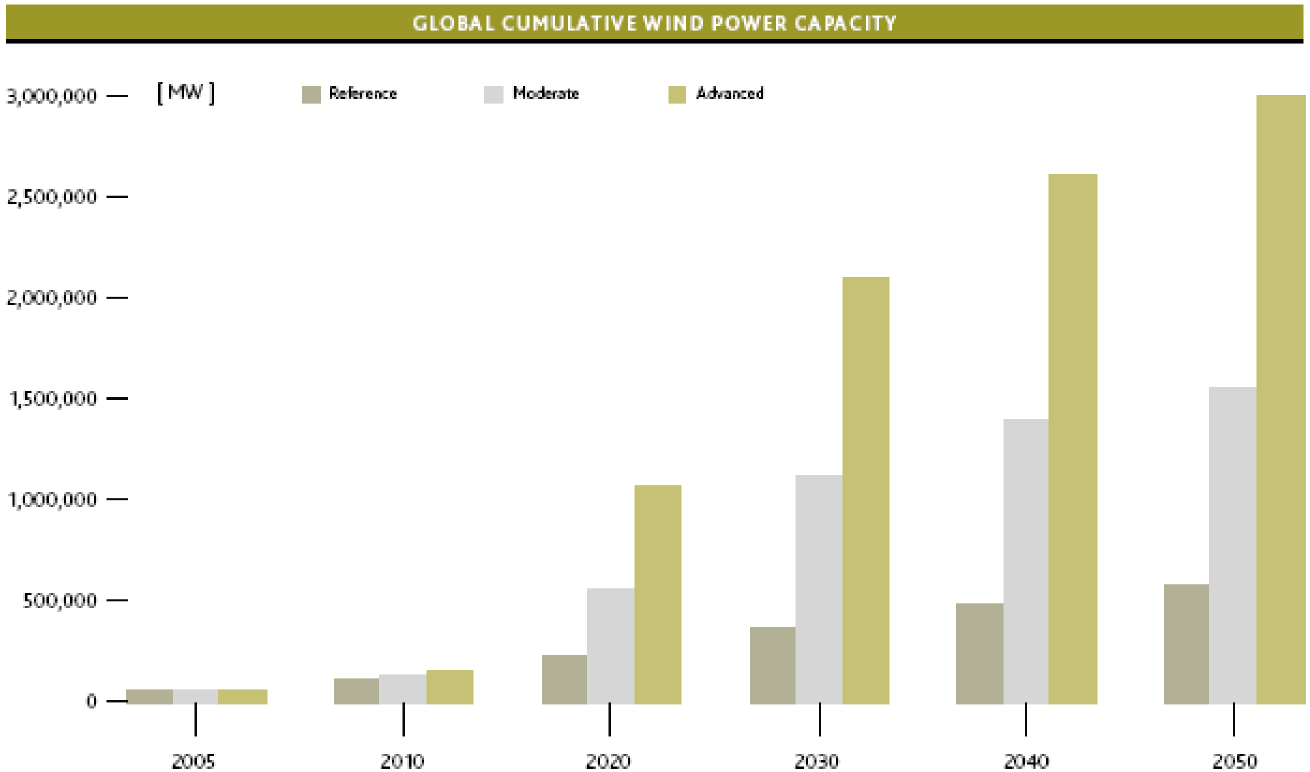


3 DIFFERENT WIND MARKET DEVELOPMENT SCENARIOS - WITH DIFFERENT WORLD ELECTRICITY DEMAND DEVELOPMENTS

		2005	2010	2020	2030	2040	2050
WIND MARKET GROWTH - IEA PROJECTION ("REFERENCE")							
Wind power penetration of Worlds electricity in % - Reference (IEA Demand Projection)	%	0.8	1.5	2.7	3.5	4.1	4.0
Wind power penetration of Worlds electricity in % - High Energy Efficiency	%	0.8	1.8	3.6	5.0	6.3	6.6
MODERATE WIND MARKET GROWTH							
Wind power penetration of Worlds electricity in % - Reference	%	0.8	1.8	6.6	10.8	11.8	10.8
Wind power penetration of Worlds electricity in % - High Energy Efficiency	%	0.8	2.2	8.6	15.6	18.1	17.7
ADVANCED WIND MARKET GROWTH							
Wind power penetration of Worlds electricity in % - Reference	%	0.8	2.1	12.1	20.1	22.1	20.9
Wind power penetration of Worlds electricity in % - High Energy Efficiency	%	0.8	2.4	16.5	29.1	34.0	34.2

Source: GWEC, 2007 and IEA Energy Outlook 2006

Extended forecast 2030-2050



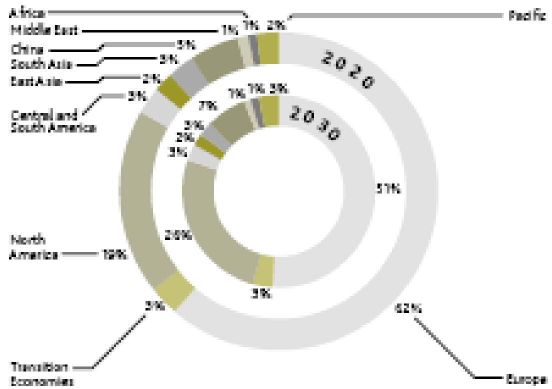
GLOBAL CUMULATIVE CAPACITY [MW] AND ELECTRICITY GENERATION [TWh]

Year		2005	2010	2020	2030	2040	2050
Reference	[MW]	59,078	112,818	230,658	363,758	482,758	577,257
	[TWh]	124	247	566	892	1,269	1,517
Moderate	[MW]	59,078	136,543	560,445	1.128,707	1.399,133	1.556,901
	[TWh]	124	299	1,375	2,768	3,677	4,092
Advanced	[MW]	59,078	153,759	1.072,928	2.106,656	2.616,210	3.010,302
	[TWh]	124	337	2,632	5,167	6,875	7,911

Source: GWEC, 2007 and IEA Energy Outlook 2006

Extended forecast regional breakdown

REGIONAL BREAK DOWN: REFERENCE SCENARIO [GW]



2020

Europe	142 GW
Transition Economies	7 GW
North America	43 GW
Central and South America	6 GW
East Asia	5 GW
South Asia	6 GW
China	11 GW
Middle East	2 GW
Africa	2 GW
Pacific	5 GW

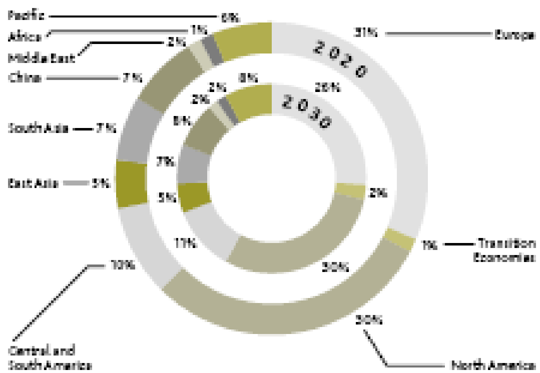
2030

Europe	186 GW
Transition Economies	12 GW
North America	94 GW
Central and South America	10 GW
East Asia	7 GW
South Asia	9 GW
China	25 GW
Middle East	4 GW
Africa	5 GW
Pacific	12 GW

Source: GWEC, 2007 and IEA Energy Outlook 2006

Extended forecast regional breakdown

REGIONAL BREAK DOWN: MODERATE SCENARIO [GW]



2020

Europe	174 GW
Transition Economies	7 GW
North America	167 GW
Central and South America	54 GW
East Asia	27 GW
South Asia	39 GW
China	41 GW
Middle East	9 GW
Africa	8 GW
Pacific	34 GW

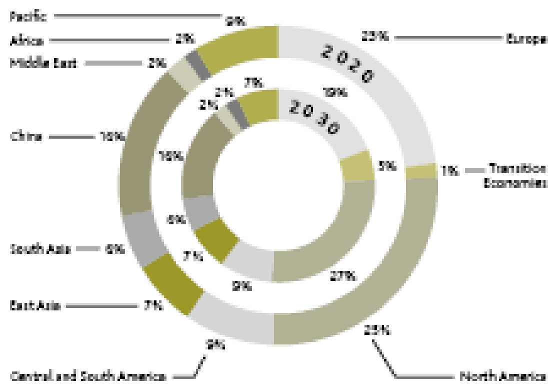
2030

Europe	295 GW
Transition Economies	28 GW
North America	334 GW
Central and South America	123 GW
East Asia (excl.Korea)	59 GW
South Asia	75 GW
China	67 GW
Middle East	18 GW
Africa	20 GW
Pacific	90 GW

Source: GWEC, 2007 and IEA Energy Outlook 2006

Extended forecast regional breakdown

REGIONAL BREAK DOWN: ADVANCED SCENARIO [GW]



2020

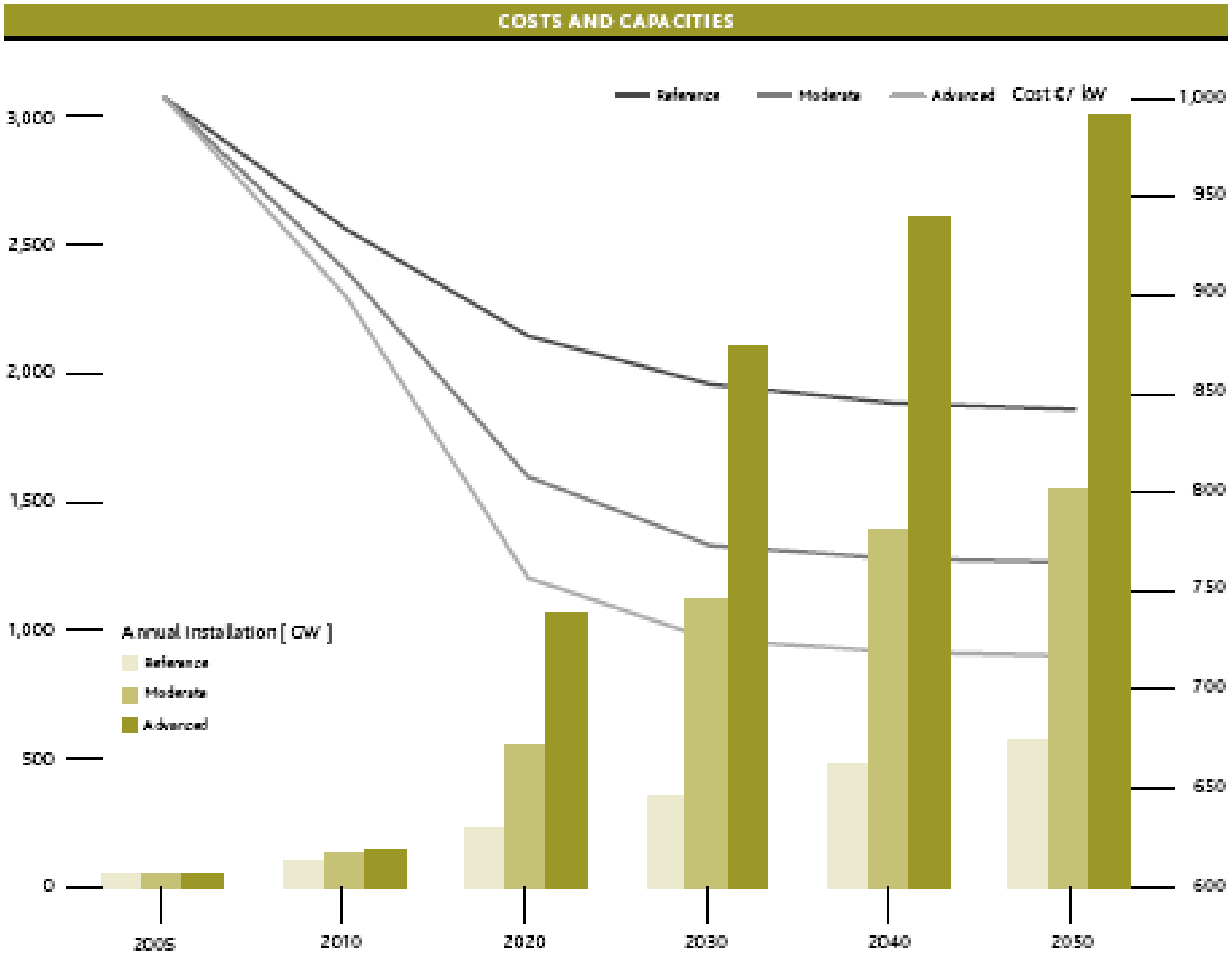
Europe	245 GW
Transition Economies	13 GW
North America	284 GW
Central and South America	100 GW
East Asia	71 GW
South Asia	61 GW
China	169 GW
Middle East	24 GW
Africa	17 GW
Pacific	90 GW

2030

Europe	392 GW
Transition Economies	116 GW
North America	570 GW
Central and South America	198 GW
East Asia (excl. Korea)	142 GW
South Asia	126 GW
China	328 GW
Middle East	47 GW
Africa	48 GW
Pacific	140 GW

Source: GWEC, 2007 and IEA Energy Outlook 2006

Extended forecast: costs and capacities



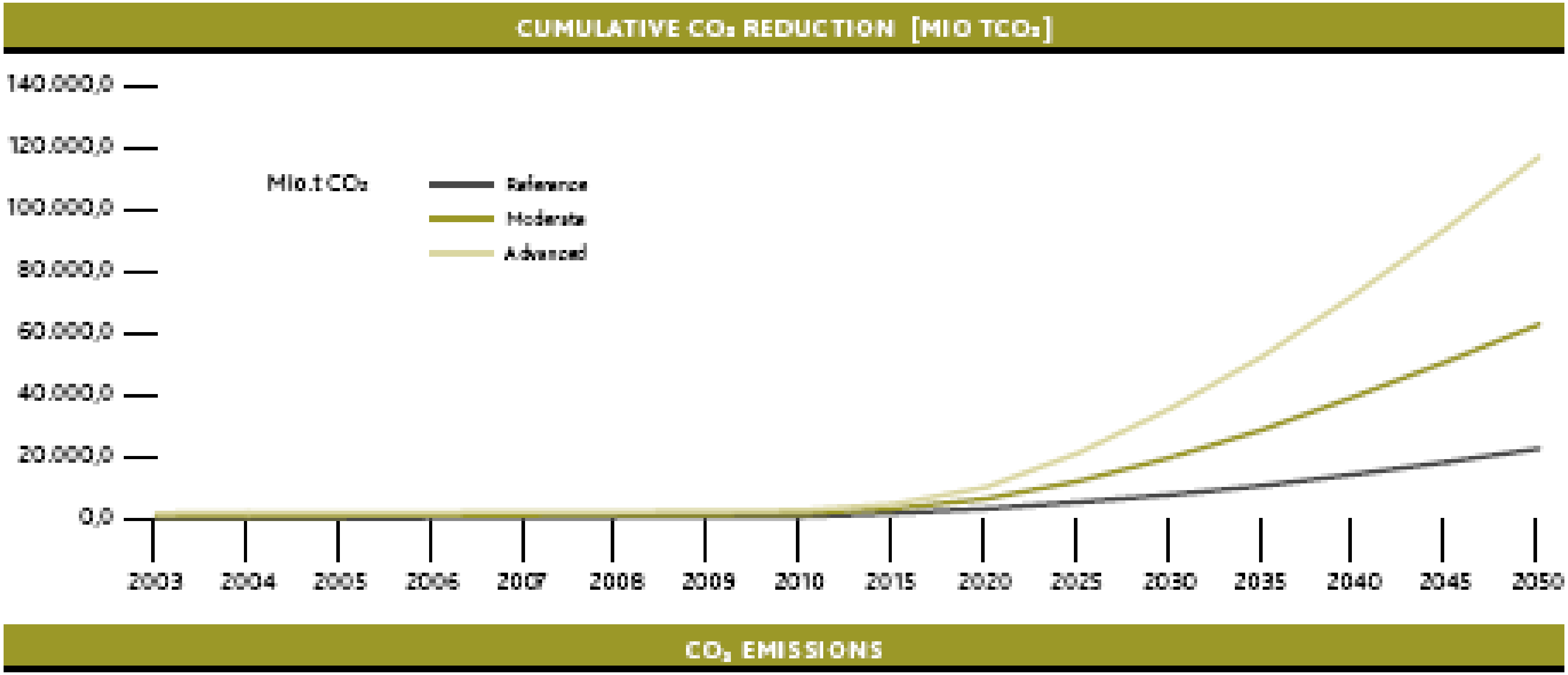
Source: GWEC, 2007 and IEA Energy Outlook 2006

Extended forecast: investment and employment

INVESTMENT AND EMPLOYMENT	2005	2010	2020	2030	2040	2050
REFERENCE						
Annual Installation (MW)	11,524	11,506	15,547	24,816	27,447	34,266
Cost € / kW	1,000	933	879	854	845	842
Investment € billion /year	11.524	10.732	13.662	21.205	23.185	28.841
Employment Job-year	150,120	241,484	322,729	481,624	531,723	653,691
MODERATE						
Annual Installation (MW)	11,524	19,906	77,365	58,260	97,737	70,957
Cost € / kW	1,000	912	807	773	766	764
Investment € billion /year	11.524	18.154	62.449	45.009	74.854	54.227
Employment Job-year	150,120	390,408	1.310,711	1.141,016	1.663,578	1.386,085
ADVANCED						
Annual Installation (MW)	11,524	25,831	186,825	117,014	142,260	156,423
Cost € / kW	1,000	899	756	725	719	717
Investment € billion /year	11.524	23.220	141.249	84.827	102.229	112.090
Employment Job-year	150,120	492,384	2.899,776	2.143,587	2.506,871	2795,873

Source: GWEC, 2007 and IEA Energy Outlook 2006

Extended forecast: carbon emissions savings



Source: GWEC, 2007 and IEA Energy Outlook 2006

Actions needed to further boost wind energy (I)

- **Targets for renewable energy & specific policy mechanisms:**
  - A number of countries have already established targets and policies for renewable energy.
  - However, for wind energy to realise its great potential, more countries around the world need to take action, set targets and develop the necessary regulatory frameworks in terms of fi nancial incentives, grid access regulation and planning and administrative procedures.

- **International action on climate change:**
  - There is an urgent need to start negotiations on a new round of emission reduction targets for the second commitment period of the Kyoto Protocol after 2012.
  - New targets are needed as soon as possible to allow governments to put emission reduction measures in place, including renewable energy policies.
  - Setting legally binding targets is crucial as a driving force behind successful political frameworks for wind power.

Actions needed to further boost wind energy (II)

- **Reform of international financing:**
  - Multi-lateral fi nancing mechanisms should include a defi ned and increasing percentage of lending directed to renewable energy projects, coupled with a rapid phase out of support for conventional, polluting energy projects.

- **Action by international bodies:**
  - Other international institutions, such as the G8 bloc of countries, the UN Commission on Sustainable Development (CSD), the International Energy Agency (IEA), the UN Environment Programme (UNEP) and the International Panel on Climate Change (IPCC) must be made aware of the potential of wind energy in order to support its large scale deployment.

- **Electricity market reform:**
  - Reforms are needed in the electricity sector to encourage renewable energy.
  - Market reform should include removing barriers to market entry, removing subsidies to fossil fuels and nuclear power and internalising the social and environmental costs of polluting.

IPCC – Fourth Assessment Report on wind energy

- Wind provided around 0.5% of the total 17,408 TWh global electricity production in 2004 (IEA, 2006b) but its technical potential greatly exceeds this (WEC, 2004d; GWEC, 2006).
- Installed capacity increased from 2.3 GW in 1991 to 59.3 GW at the end of 2005 when it generated 119 TWh at an average capacity factor of around 23%.
- New wind installation capacity has grown at an average of 28% per year since 2000, with a record 40% increase in 2005 (BTM, 2006) due to lower costs, greater government support through feed-in tariff and renewable energy certificate policies (Section 4.5), and improved technology development.
- Total offshore wind capacity reached 679 MW at the end of 2005 (BTM, 2006), with the expectation that it will grow rapidly due to higher mean annual wind-speed conditions offsetting the higher costs and public resistance being less.
- Various best-practices guidelines have been produced and issues such as noise, electromagnetic (EMF) interference, airline flight paths, land-use, protection of areas with high landscape value, and bird and bat strike, are better understood but remain constraints.
- Most bird species exhibit an avoidance reaction to wind turbines, which reduces the probability of collision (NERI, 2004).

IPCC – Fourth Assessment Report on technological aspects

- The average size of wind turbines has increased in the last 25 years from less than 50 kW in the early 1980s to the largest commercially available in 2006 at around 5MW and having a rotor diameter of over 120 m.

- The average turbine size being sold in 2006 was around 1.6–2 MW but there is also a market for smaller turbines <100 kW.

- In Denmark, wind energy accounted for 18.5% of electricity generation in 2004, and 25% in West Denmark where 2.4 GW is installed, giving the highest generation per capita in the world.

IPCC – Fourth Assessment Report on costs

- Capital costs for land-based wind turbines can be below 900 US$/kW with 25% for the tower and 75% for the rotor and nacelle, although price increases have occurred due to supply shortages and increases in steel prices.
- Total costs of an onshore wind farm range from 1000–1400 US$/kW, depending on location, road access, proximity to load, etc.
- O&M costs vary from 1% of investment costs in year one, rising to 4.5% after 15 years.
- This means that on good sites with low surface roughness and capacity factors exceeding 35%, power can be generated for around 30–50 US$/MWh (IEA, 2006c; Morthorst, 2004).

IPCC – Fourth Assessment Report on the potential

- A global study of 7500 surface stations showed mean annual wind speeds at 80 m above ground exceeded 6.9 m/s with most potential found in Northern Europe along the North Sea, the southern tip of South America, Tasmania, the Great Lakes region, and the northeastern and western coasts of Canada and the US.

- A technical potential of 72 TW installed global capacity at 20% average capacity factor would generate 126,000 TWh/yr (Archer and Jacobsen, 2005).

- This is five times the assumed global production of electricity in 2030 (IEA, 2006b) and double the 600 EJ potential capacity estimated by Johansson *et al*. (2004).

IPCC – Fourth Assessment Report on the market

- The main wind-energy investments have been in Europe, Japan, China, USA and India (Wind Force 12, 2005).
- The Global Wind Energy Council assumed this will change and has estimated more widespread installed capacity of 1250 GW by 2020 to supply 12% of the world's electricity.
- The European Wind Energy Association set a target of 75 GW (168 TWh) for EU-15 countries in 2010 and 180 GW (425 TWh) in 2020 (EWEA, 2004).
- Several Australian and USA states have similar ambitious targets, mainly to meet the increasing demand for power rather than to displace nuclear or fossil-fuel plants.
- Rapid growth in several developing countries including China, Mexico, Brazil and India is expected since private investment interest is increasing (Martinot *et al*., 2005).

IPCC – Fourth Assessment Report on the R&D needs

- The fluctuating nature of the wind constrains the contribution to total electricity demand in order to maintain system reliability.
- To supply over 20% would require more accurate forecasting (Giebel, 2005), regulations that ensure wind has priority access to the grid, demand-side response measures, increases in the use of operational reserves in the power system (Gul and Stenzel, 2005) or development of energy storage systems (EWEA, 2005; Mazza and Hammerschlag, 2003).
- The additional cost burden in Denmark to provide reliability was claimed to be between 1–1.5 billion € (Bendtsen, 2003) and 2–2.5 billion € per annum (Krogsgaard, 2001).
- However, the costs for back-up power decrease drastically with larger grid area, larger area containing distributed wind turbines and greater share of flexible hydro and natural-gas-fired power plants (Morthorst, 2004).

IPCC – Fourth Assessment Report on future trends

- A trend to replace older and smaller wind turbines with larger, more efficient, quieter and more reliable designs gives higher power outputs from the same site often at a lower density of turbines per hectare.

- Sites with wind speeds of less than 7–8 m/s are not currently economically viable without some form of government support if conventional power-generation costs are above 50 US$/Wh (Oxera, 2005).

- A number of technologies are under development in order to maximize energy capture for lower wind-speed sites.

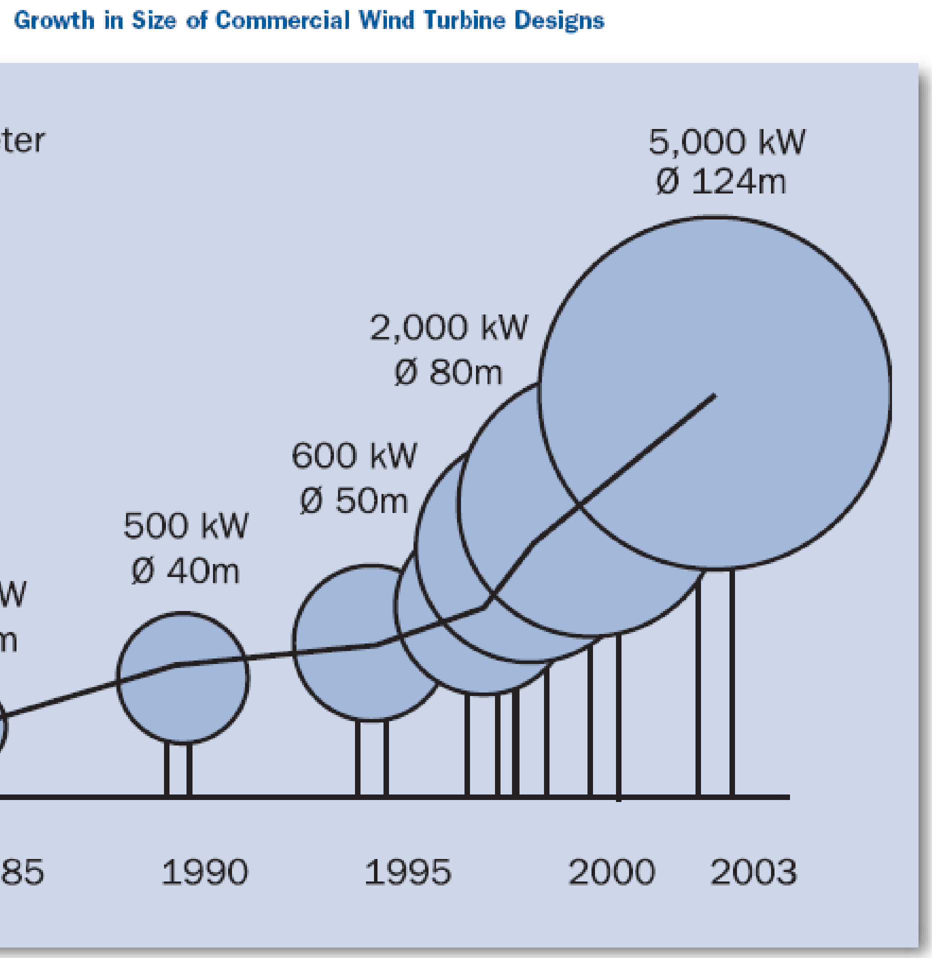
- These include: optimized turbine designs; larger turbines; taller towers; the use of carbon-fibre technology to replace glassreinforced polymer in longer wind-turbine blades; maintenance strategies for offshore turbines to overcome difficulties with access during bad weather/rough seas; more accurate aeroelastic models and more advanced control strategies to keep the wind loads within the turbine design limits.

State-of-the-art of wind energy technology

- Rotor diameters
- Tip speed
- Rotor mass
- Hub height
- Pitch vs. Stall control
- Variable speed
- Power electronics
- Gearbox vs. Direct transmission

Basic configuration of a wind turbine

Rotor diameter



Hub height

- There is trade-off between the benefits of extra energy from taller towers and the extra cost of these tower.
- Off shore wind shear is low then lower towers are suitable in this application since the extra benefits of taller towers diminish.

Rotor mass

- Rotos mass impacts on the cost of the turbine: tower, foundation, bearings, shaft, etc.
- There is trade off between the rotor mass and the cost of the material of the blades
- Blades are made of glass polyester, glass epoxy or carbon fibre reinforcement

Pitch vs. Stall control

- The two principal means of limiting rotor power in high operational wind speeds - stall regulation and pitch regulation
- Stall: As wind speed increases, providing the rotor speed is held constant, flow angles over the blade sections steepen. The blades become increasingly stalled and this limits power to acceptable levels without any additional active control.
- Pitch: The main alternative to stall regulated operation is pitch regulation. This involves turning the blades about their long axis (pitching the blades) to regulate the power extracted by the rotor.
- In contrast to stall regulation, pitch regulation requires changes to rotor geometry.

Variable speed vs. Fixed speed

- Operation at variable speed offer increased “grid frindliness”
- The electrical energy is generated at variable frequency (related to the speed of teh rotor) and then converted to the frequency of the grid
- It can be used with both syncronous and induction generators
- Variable speed reduces loads on the transmission system

Gearbox vs. Direct transmission

- Gear boxes have been the weakest link in the wind turbine technology
- They historically noisy, although now that problem has been abated in the most part
- Direct transmission to multipolar generators is pormising longer lifetime of wind turbines

Technical Specifications of Enercon E-82

- Rated power:
  2,000 kW

  Rotor diameter: 82 m
  Hub height: 78 - 138 m
  Wind class (IEC): IEC/NVN II

- **Turbine concept:** Gearless, variable speed, variable pitch control

- **Rotor**
  Type: Upwind rotor with active pitch control
- Direction of rotation: Clockwise
  Number of blades: 3
  Swept area: 5,281 m2
  Blade material: Fibreglass (epoxy resin);integrated lightning protection
  Rotational speed: Variable, 6 - 19.5 rpm
  Pitch control: ENERCON blade pitch system, one independent pitching system per rotor blade with allocated emergency supply
- **Drive train with generator**

  Hub: Rigid
  Main bearings: Dual-row tapered/single-row cylindrical roller bearings
  Generator: ENERCON direct-drive synchronous annular generator

- **Grid feeding:**
  ENERCON converter

- **Braking systems:**
  - 3 independent blade pitch systems with emergency supply
  - Rotor brake
  - Rotor lock

- **Yaw control:**
  Active via adjustment gears, load-dependent damping

- **Cut-out wind speed:**
  28 - 34 m/s (with ENERCON storm control)

- **Remote monitoring:**
  ENERCON SCADA

Wind energy environmental issues

- Visual impact
- Noise
- Flickering (shadows and electromagnetic fields)
- Birds collision
- Land use and sea use (for off-shore applications)
- GHG emissions
- Other social and political impacts

Priority R&D areas for the European Wind Industry

- 1.Economic,Policy & Market Issues
  - e.g. assessment affecting wind farm investments and market barriers
- 2.Environmental & Social Impacts
  - e.g. enhancing local incentives by developing participation models
- 3.Wind Turbine & Component Design Issues
  - e.g. basic research in aerodynamics, structural dynamics, structural design and control
- 4.Testing,Standardisation, & Certification
  - e.g. common accepted certification procedures for wind turbines and wind farms
- 5.Grid Integration, Energy Systems & Resource Prediction
  - e.g. forecast of wind resource
- 6.Operation & Maintenance
  - e.g. advanced condition monitoring
- 7.New Potentials
  - e.g. in complex terrain and remote areas where satellite technology can be used, among others, in the formulation of wind atlases –showing the wind resource
- 8.Offshore Wind Technology
  - e.g. research into the control and efficiency of very large wind farms and more cost effective foundations, transport and installation techniques
- 9.Mega Watt and Multi-Megawatt Wind Turbines
  - e.g. application of new materials with improved strength-mass ratio and development of lighter components

Source: European Wind Energy Association – January 2004

Summary of key EU R&D priorities

- **Resource estimation**:
  - maximum availability of wind resource data, in the public domain where possible, to ensure that financiers, insurers and project developers can develop high quality projects efficiently, avoiding project failure through inaccurate data.
  - Resource mapping of areas with a high probability of high wind resource potential, but as yet unexplored, including the Baltic, North and Black Seas.

- **Wind turbines**:
  - the availability of robust, low-maintenance offshore turbines, as well as research into the development of increased reliability and availability of off-shore turbines.
  - Integrated design tools for very large wind turbines operating in extreme climates, such as offshore, cold / hot climates and complex terrain;
  - State of the art laboratories for accelerated testing of large components under realistic external (climatological) conditions.

- **Wind farms**:
  - the research and development of wind farm level storage systems.
  - Understanding the flow in and around large wind farms;
  - Control systems to optimise power output and load factor at wind farm level;
  - Development of risk assessment methodologies.

Summary of key EU R&D priorities

- **Grid integration**:
  - planning and design processes for a trans-European grid, with sufficient connection points to serve future large-scale wind power plants. This task should be undertaken by the wider energy sector.
  - Control strategies and requirements for wind farms to make them fully grid compatible and able to support and maintain a stable grid.

- **Environment and public support**:
  - a European communication strategy for the demonstration of Research results on the effects of large-scale wind power plants on ecological systems, targeted at the general public and policy makers. To include specific recommendations for wind park design and planning practices.
  - Effects on ecology adjacent to wind energy developments;
  - Development of automatic equipment to monitor in particular bird collisions, and sea mammals‘ reaction to underwater sound emissions.

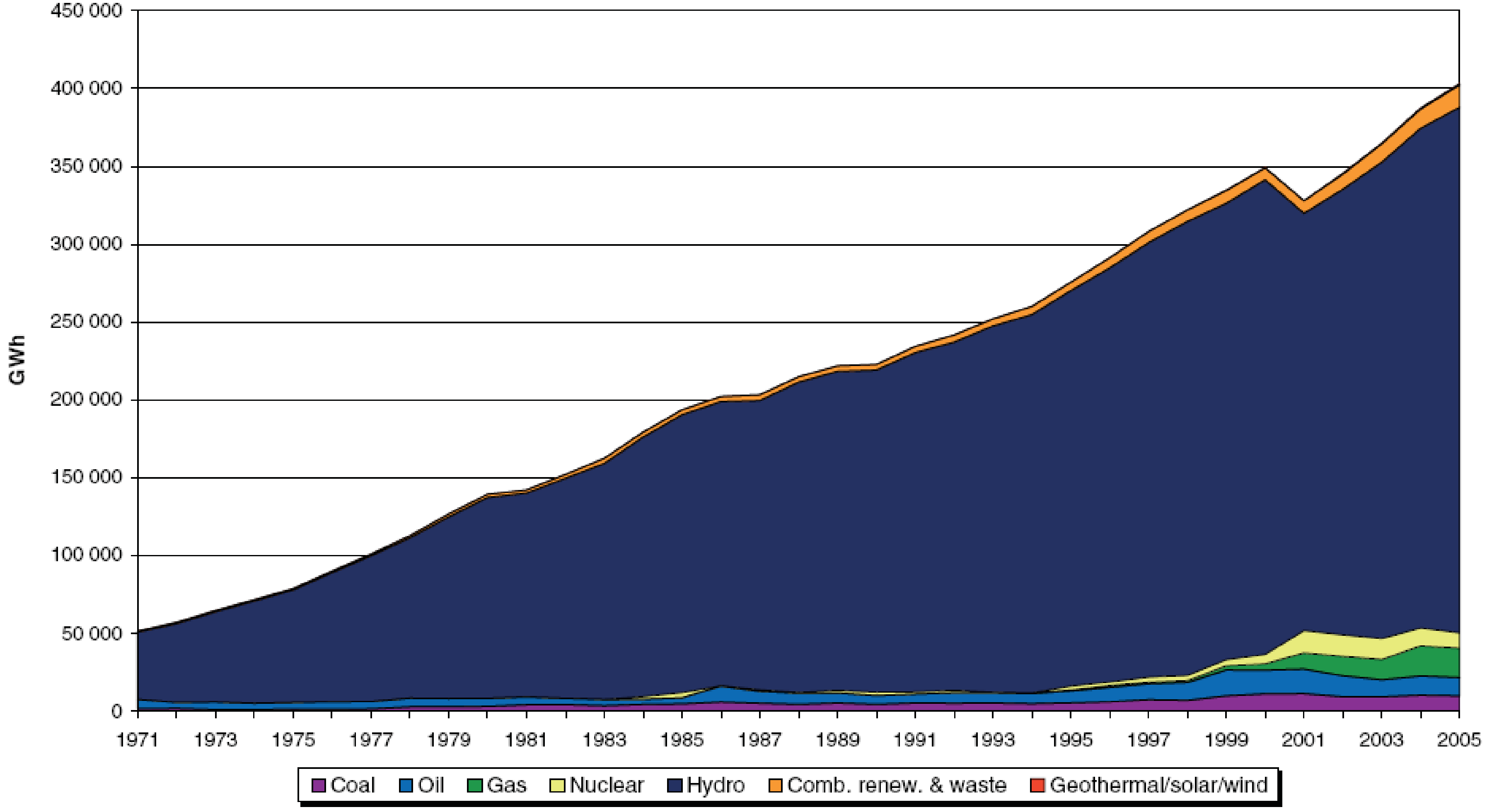
- **Standards and Certification:**
  - Energy yield calculation;
  - Grid connection protocols and procedures;
  - Risk assessment methodology;
  - Design Criteria for components and materials;
  - Standardisation of O&M mechanisms

Other short-term EU R&D topics

- Wind Resource:
  - Development of cost effective measuring units, including communications and processing, and which are easily transportable, for the assessment of wind resource characteristics, such as LIDAR, SODAR and satellite observation.
- Wind Turbines:
  - Development of component level design tools and multiparameter control strategies.
- Grid Integration:
  - Development of electric and electronic components and technologies for grid connection.
- Environment and Public Support:
  - International exchange and communication of results of R&D into ecological impacts.
- Standards and Certification:
  - Accelerated finalisation of ongoing standards development activities (certification processes and test procedures, design criteria for offshore wind turbines, project certification).

Country profiles

Brazil: Evolution of Electricity Generation by Fuel from 1971 to 2005

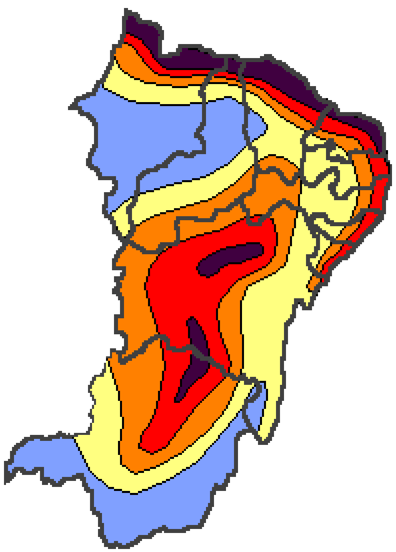


Source: IEA 2007

Brazil: CBEE Wind Energy Center

In 1998, the Brazilian Wind Center, CBEE, published the WANEB - Wind Atlas for the Northeast of Brazil with support of the National Regulatory Agency of Electricity, ANEEL. The objective of the WANEB was to provide a methodology for wind power assessment of large areas in Brazil.

The CBEE is currently working on the Brazilian Wind Atlas. The main objective of this new project is to select and process representative high quality wind data and elaborate wind resource maps with 30-20Km resolution covering the whole country, with finer resolution (1km) on selected windy areas.



Wind resources at 50m above ground level for five different

Class	Shelter terrain	Open plain	Sea coast	Open sea	Hills ridge
(dark purple)	> 6.0	> 7.5	> 8.5	> 9.0	> 11.5
(red)	5.0 - 6.0	6.5 - 7.5	7.0 - 8.5	8.0 - 9.0	10.0 - 11.5
(orange)	4.5 - 5.0	5.5 - 6.5	6.0 - 7.0	7.0 - 8.0	8.5 - 10.0
(yellow)	3.5 - 4.5	4.5 - 5.5	5.0 - 6.0	5.5 - 7.0	7.0 - 8.5
(blue)	< 3.5	< 4.5	< 5.0	< 5.5	< 7.0

Wind speed in m/s.

Brazilian Wind Energy Center: Academic Programs

- CBEE offers 4 courses
  - Wind data measurements and analysis
  - Dynamic aspects about wind turbine operation and maintenance
  - Economic assessment and Brazilian wind energy policy
  - Grid connection

Brazilian Wind Energy Center: International Cooperation

- British Council;
- Risø National Laboratory, Denmark;
- National Renewable Energy Laboratory - NREL, University of Massachusetts, USA.;
- Folkecenter for Renewable Energy, Denmark;
- Centre for Renewable Energy Systems Technology - CREST, Loughborough University, England;
- West Texas University, USA.
- CBEE offers 4 courses

Brazilian Wind Energy Center: Research Areas

- Wind characterization
  - Wind Data logging
  - Statistical analysis of wind data
  - Wind mapping and Wind Atlas
  - Atmospheric modelling, using MM5 meso-scale model and WAsP

- Large wind turbines
  - Large wind turbines design
  - Determination of main loads (extreme and fatigue) under Brazilian wind conditions
  - Strategies for the control of fixed speed wind turbines
  - Aerodynamics of wind turbine rotors
  - Structural analysis of wind turbines
  - Aeroelasticity
  - Experimental analysis of wind turbines in real operation conditions
  - Determination of power curve
  - Optimization of wind turbines to the wind conditions of the northeast region of Brazil

- Wind farms
  - Micrositing and layout of wind farms
  - Wind power production simulation

Brazilian Wind Energy Center: Research Areas

- Small wind turbines
  - Wind turbines for irrigation and rural electrification
  - Wind turbines for battery charging
  - Wind turbines for special applications (desalinization, telecommunications, etc.)
  - Controllers for wind turbines
  - Standards for testing small wind turbines

- Hybrid power systems
  - Design of large wind/diesel systems
  - Design of hybrid wind/solar/battery systems
  - Modelling of hybrid power systems
  - Supervisory controllers and control strategies
  - Experimental testing and analysis

- Power quality
  - Grid connection setup and strategies
  - (Electrical) Modelling of wind turbines and wind farms
  - Integration of wind farms in the Brazilian hydroelectric system
  - Experimental analysis - testing and monitoring

Brazilian Wind Energy Center: Facilities

- Test centre for wind turbines with all instrumentation for certification (cooperation with Risø National Lab - Denmark).

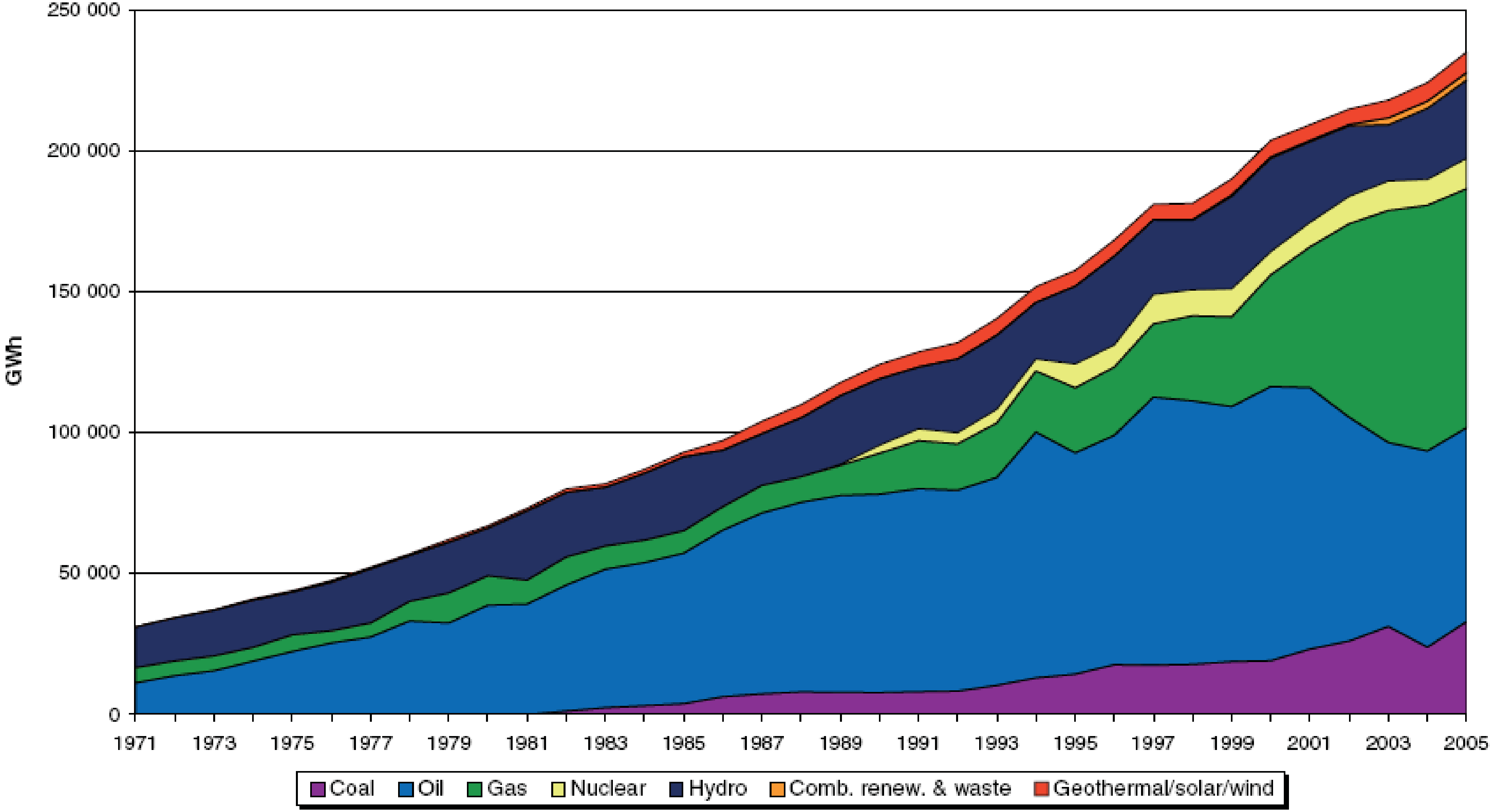
- Desalination plant using wind and solar energy to be applied in arid regions.

- Large wind-diesel hybrid systems with all instrumentation for the analysis of operational data of wind turbines and diesel sets. This hybrid system is operational since 1992 in the island of Fernando de Noronha (Atlantic Ocean) and is generating electricity for 3,000 habitants

Brazil: the PROINFA

- In 2002 the Brazilian government established the PROFINA programme in order to stimulate the development of biomass generation, wind and small hydro generators.
- In a first step, the programme guarantees power sale contracts to 3’300 MW of projects using these technologies.
- Once the 3,300 MW objective has been met, PROINFA aims to increase the share of the three renewable sources to 10 % of annual electricity consumption within 20 years.
- Despite the high expectations, the scheme has, to date, failed to deliver the great number of wind projects the government had aimed for

Mexico: Evolution of Electricity Generation by Fuel from 1971 to 2005



Source: IEA 2007

Mexico

- Among Latin American nations, Mexico is one of the most promising areas for wind energy development.
- The Mexican Wind Energy Association (AMDEE) currently estimates the development of at least 3,000 MW in the 2006-2014 period, with transmission availability representing the major obstacle.
- Currently, Mexico has a total installed capacity of 87 MW.

Mexico

- 2005 was characterized by some positive initiatives for renewable energy development in Mexico.
- A new provision was added to Federal Tax Laws that allows for 100 % depreciation on capital in the first year for all investments made toward the development of renewable energy.
- Besides, the initiative for the Renewable Energy Utilization Law (LAFRE), which aims at establishing a Renewable Energy Utilization Programme was approved in the same year.
- Moreover, the government set a target of 8 % of the national power production to come from renewable energy by 2012 (excluding large hydro).
- The law also enforces the creation of a Trust to support RE projects, rural electrification, biofuels and technological R&D.
- In addition to this Trust, there are other means such as the GEF (Global Environmental Fund), the UNDP (United Nations Development Program) and the World Bank and others to support large-scale power production from renewable energy, specially wind power and R&D.

Instituto de Investigaciones Energéticas: Líneas de Investigación

- *Recursos Energéticos del Subsuelo:* Realizar, investigación, desarrollos tecnológicos y servicios técnicos especializados que permitan un mejor aprovechamiento de los recursos energéticos del subsuelo.

- *Investigación y Desarrollo Tecnológico para el Aprovechamiento de las Fuentes de Energía no Convencionales:* Desarrollo de la capacidad para:
  - a) la realización de estudios sobre aplicaciones potenciales de las fuentes no convencionales de energía (FNCE);
  - b) el diseño, integración construcción, evaluación, y pruebas del laboratorio y de campos de sistemas conversores de FNCE;
  - c) la evaluación del comportamiento y el seguimiento operacional de aplicaciones piloto, y la caracterización de sistemas comerciales; y
  - d) el conocimiento a fondo de la problemática y la búsqueda de mecanismos para diseminación de las FNCE.

Instituto de Investigaciones Energéticas: Instalaciones

- *División de Energías Alternas:*
  - Cuenta con 20 laboratorios, 5 estaciones de prueba y montajes experimentales, los cuales están distribuidos en diferentes partes del territorio nacional.
  - En Palmira, Mor., se tienen los siguientes laboratorios: Geoquímica, rayos x, petrografía, petrofísica, lodos, cementos, yacimientos, mediciones en pozos geotérmicos, fotovoltaico, termodinámico de baja entalpía, anemometría, túnel de viento, isotopía.
  - En el Gavillero, Hgo., se tiene una estación experimental de energía eólica.
- *División de Sistemas Eléctricos:*
  - Dispone de siete laboratorios en Palmira, Mor., ferromagnético, cables, aisladores, ambiente contaminado, pruebas mecánicas, fisicoquímico, vibraciones y esfuerzos, laboratorio móvil para diagnóstico de equipos en línea.

Universidad Nacional Autónoma de México
Centro de Investigaciones de la Energía

- El CIE es el principal centro de investigación en energías renovables en México, participa en la formación de recursos humanos de alto nivel y en docencia en programas de la UNAM y de otras instituciones de educación superior del país, principalmente del Estado de Morelos.

- En el CIE se realizan además acciones de relevancia en la vinculación y divulgación con los sectores público, privado y social

Universidad Nacional Autónoma de México
Centro de Investigaciones de la Energía

Departamento de Sistemas Energéticos

- Departamento de Sistemas Energéticos
- Concentración Solar
- Geoenergía
- Planeación Energética
- Refrigeración y Bombas de Calor

Universidad Nacional Autónoma de México
Centro de Investigaciones de la Energía

Departamento de Materiales Solares

- Departamento de Materiales Solares
- Recubrimientos Ópticos y Optoelectrónicos
- Solar - Hidrógeno, Celdas de Combustible
- Superficies, Interfaces y Materiales Compuestos

Universidad Nacional Autónoma de México
Centro de Investigaciones de la Energía

Departamento de Termociencias

- Física Teórica
- Transferencia de Energía y Masa

Cuba

- Un desarrollo importante de la energía eólica tiene lugar en Cuba durante los últimos años.
- En 1999 se instaló el **Parque Eólico Demostrativo** de la Isla de Turiguanó con dos aerogeneradores de 225 kW cada uno, en la provincia de Ciego de Ávila.
- Se ha elaborado el **mapa eólico**, el cual ha permitido conocer las potencialidades eólicas de Cuba, siendo el punto de partida para iniciar un programa de construcción de parques eólicos en todo el país.
- En febrero pasado se inauguró el **parque eólico de los Canarreos** en la Isla de la Juventud, donde los seis aerogeneradores instalados producen 1,65 megawatts, casi el 10 por ciento del consumo de energía en esa zona del país.
- Actualmente se construye otro cerca de la ciudad de **Gibara**, en la costa norte de Holguín, el cual tendrá seis aerogeneradores montados a 50 metros de altura, de 850 kW cada uno con una capacidad total de **5,1 megawatts**.
- También está previsto desplegar un tercero en esa propia provincia a inicios del año próximo.
- Se pronostica que durante el **2008** Cuba podría alcanzar los **12 MW** de potencia instalada total.
- El **objetivo** es llegar a los **100 megawatts** de potencia instalada en un futuro no lejano.
- En Cuba hay más **seis mil molinos** de vientos fundamentalmente para **bombeo de agua** en el sector agrícola-ganadero, mucho de ellos están fuera de servicio por falta de mantenimiento.
- El MINAZ (Ministerio del Azucar) ha anunciado los planes de instalación de **4000 nuevos molinos para el bombeo de agua**.

Center for the Study of Renewable Energy Technologies at the Technical University of Havana

- CETER is a university research center integrated within the Faculty of Mechanical Engineering in the Polytechnic Institute of Havana, “Instituto Superior José Antonio Echeverría” (ISPJAE).

- It was founded in 1992 following an initiative from the National Technology and Science Forum and the Ministry of Higher Education.

- The purpose of the Centre was to contribute to Cuba’s sustainable development through its activities in the fields of renewable energy, energetic efficiency and their interrelation with the environment.

Center for the Study of Renewable Energy Technologies at the Technical University of Havana

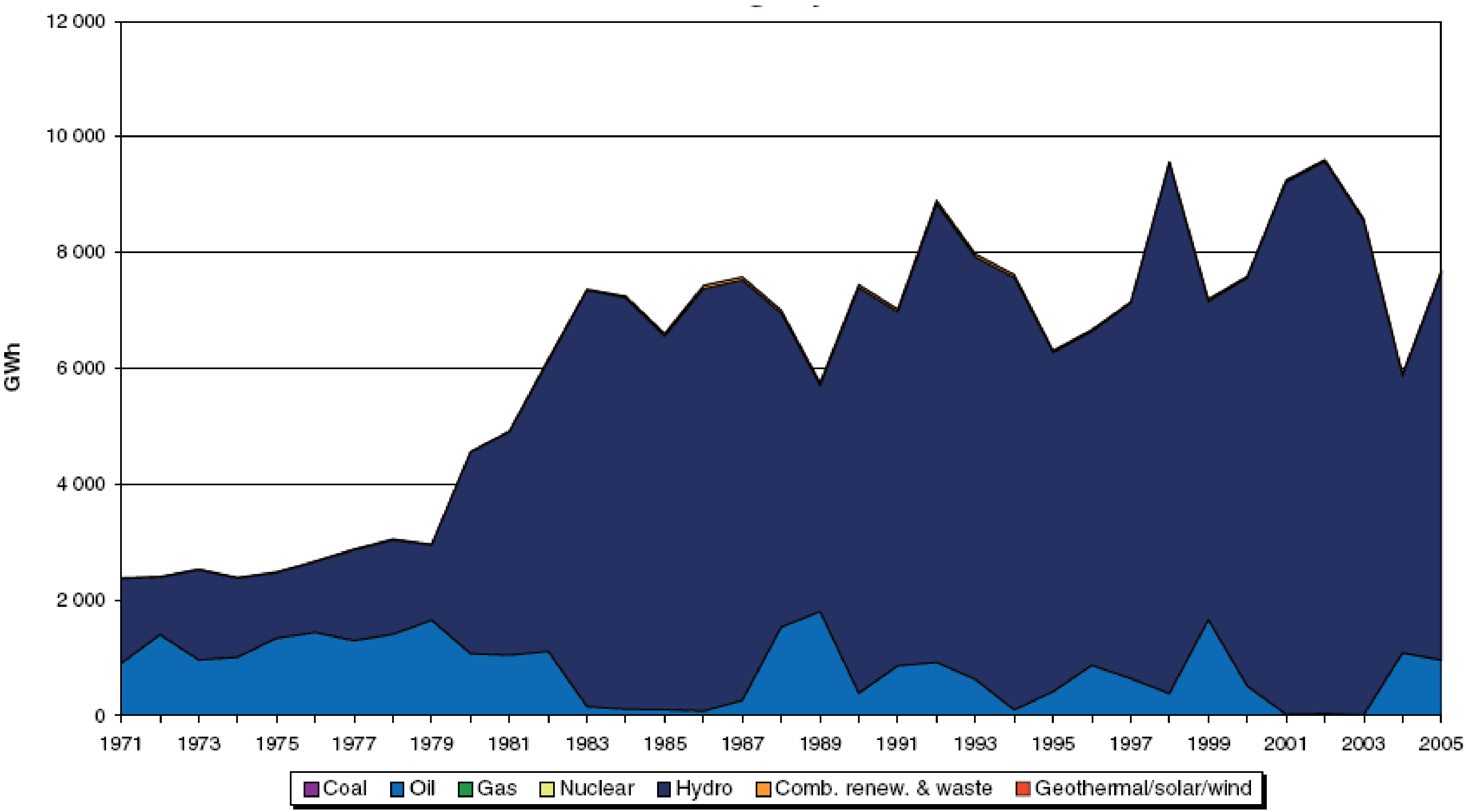
- Course I. Wind Energy
- Course II. Wind parks operating in severe climates
- Course III. Biogas
- Course IV. Solar Energy

Facilities at CETER

Hybrid Photovoltaic-Micro Wind Turbine System

- It is composed of:
- 8 50W PV-panels panels totalling to 400W, 1 50W micro wind turbine, 2 100Ah.
- Batteries, 2 Voltage Regulators, 1 800W inverter, 1 analogue multimiter.
- This system has the purpose to serve as a demonstrative installation for visitors and students about autonomous PV-Wind systems, similar to those installed in rural primary schools and clinics in Cuba.
- It is also used as a laboratory facility for undergraduate and graduate students, its only limitation being that it does not have a automatic data acquisition system.

Uruguay: Evolution of Electricity Generation by Fuel from 1971 to 2005



Source: IEA 2007

Universidad de la República

Investigaciones realizadas:

- **“Construcción de un túnel de viento abierto tipo capa límite”**. Proyecto de investigación CONICYT/BID Nº113/94. 1994-1996.
- **“Estudio de la factibilidad del suministro de energía de origen eólico al sistema eléctrico nacional: implementación de una planta piloto”**. Proyecto de investigación CONICYT/BID Nº116. 2000.
- **“Evaluación primaria de fenómenos locales que afectan las medidas históricas del parámetro viento en estaciones meteorológicas con vistas al ajuste de estudios de recurso eólico”**. Proyecto de Investigación Clemente Estable Nº 5087. 2000-2001.
- **“Proyecto regional de intercomparación de túneles de viento”**. Proyecto PROSUL, con el Instituto de Pesquisas Tecnológicas, San Pablo, Brasil, y Universidad Nacional de La Plata, La Plata, Argentina. Desde 2003.
- **“Energización Sustentable en Comunidades Rurales Aisladas con Fines Productivos”**. Financiado por OEA con participación de: Instituto de Investigaciones en Energía no Convencional de Argentina, Instituto Nacional de Tecnología y Normalización de Paraguay, Departamento de Ingeniería Mecánica Universidad de Chile, Universidad Nacional de Ingeniería Lima - Perú y Universidad de la República de Uruguay. 2004-2007.

Costa Rica: capacidad eólica instalada

Generación eólica en Costa Rica (1996-2004)

Año	Proyecto	Capacidad instalada (KW)	Generación eléctrica (MWh)
1996	PESA	16500	22590
1997	PESA	16499	75783
1998	PESA y AEROENERGÍA	23250	64795
1999	Parques privados (PESA, AEROENERGÍA y MOVASA)	42550	101282
2000	Parques privados	42550	182709
2001	Parques privados	42550	185088
2002	Tejona	19800	59127
	Parques privados	42450	199748
2003	Tejona	19800	81551
	Parques privados	48750	148435
2004	Tejona	19800	79386
	Parques privados	48750	178152

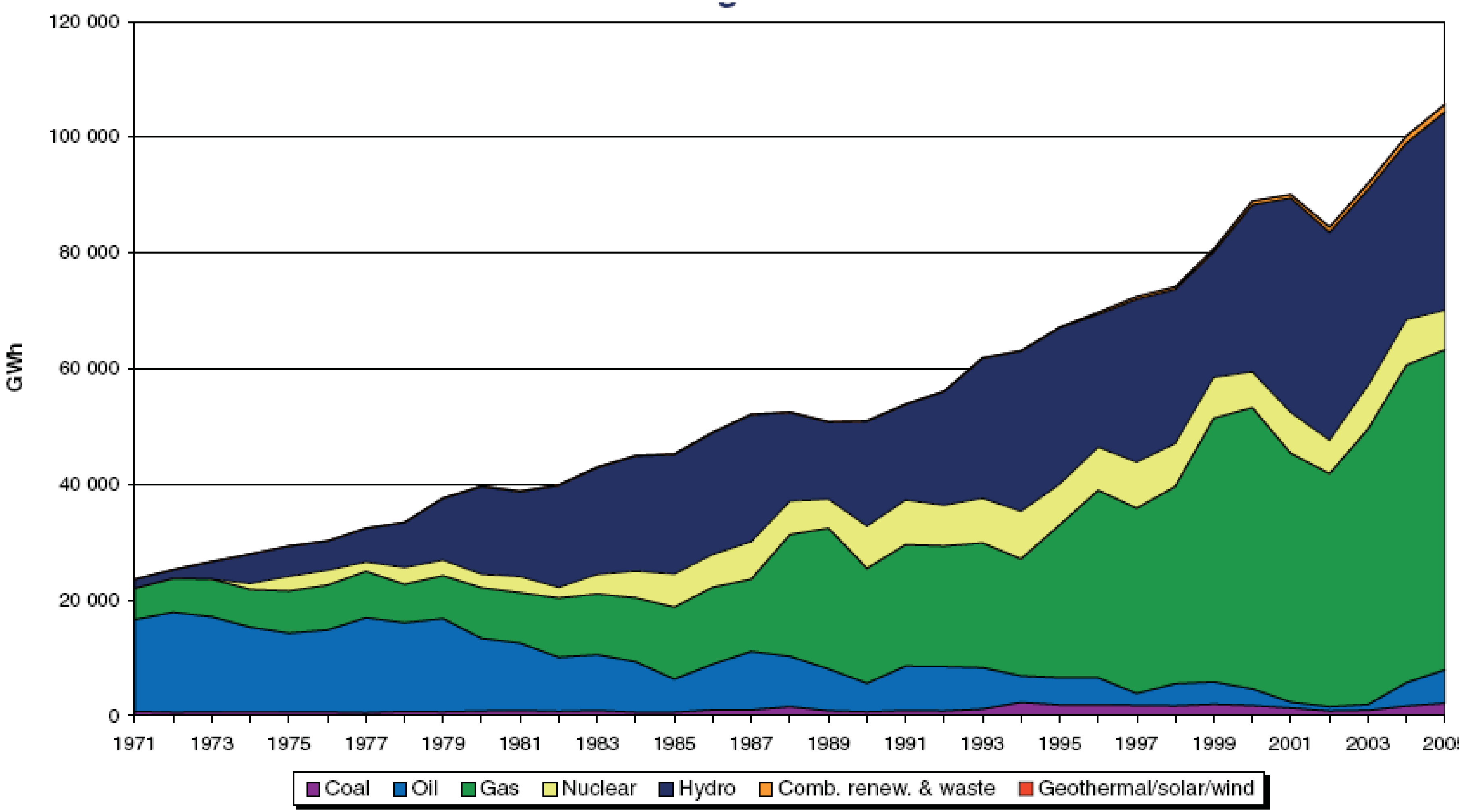
Fuente: ICE (1997-2005)

Escuela de Ingeniería Eléctrica, Universidad de Costa Rica

- Programa de Bachillerato con Enfasis en Sistemas de Energía

- El Programa de Posgrado en Ingeniería Eléctrica conduce al grado académico de Magister Scientiae en todas las áreas de la Ingeniería Eléctrica, a saber:
  - Sistemas de Potencia,
  - Sistemas Digitales,
  - Ingeniería de Comunicaciones,
  - Control Automático,
  - Electrónica y
  - Planificación Energética.

Argentina: Evolution of Electricity Generation by Fuel from 1971 to 2005



Source: IEA 2007

Instituto de Investigación en Energías No Convencionales (UNSa)

- Realizar investigaciones en el campo de la energías renovables y no contaminantes.
- Elaborar y ejecutar programas y planes para el estudio de los problemas de su especialidad en forma directa o en colaboración con otras instituciones.
- Prestar colaboración a otras instituciones calificadas interesadas en la investigación o en el conocimiento de los problemas relacionados con los fines específicos del Instituto, ya sea mediante la contribución de trabajos o mediante su asesoramiento.
- Organizar y cooperar en la realización de seminarios y cursos especiales en las materias de su competencia.
- Mantener relaciones con las instituciones del país dedicadas al estudio o investigación de problemas afines específicos, así como organismos similares extranjeros y con las instituciones internacionales que se ocupen del desarrollo de esas disciplinas.
- Difundir los resultados de su actividad por los medios y procedimientos que estime conveniente.

Instituto de Investigación en Energías No Convencionales

- Laboratorio de calibración
- Laboratorio de modelos de convección natural
- Laboratorio de termodinánica de soluciones
- Laboratorio de espectrofotometría y termografía
- Laboratorio de secado de productos agrícolas
- Laboratorio de estudios ambientales
- Campos de ensayo de equipos solares

Instituto de Investigación en Energías No Convencionales

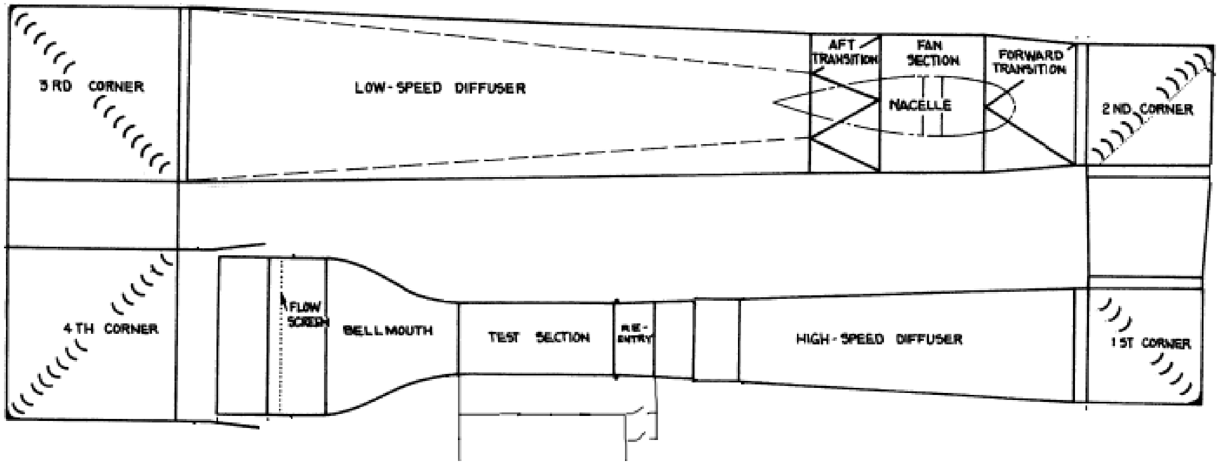
- Aplicaciones Rurales de la Energía Solar
- Pozas Solares
- Climatización de Edificios
- Bioenergía y contaminación ambiental
- Termodinámica de Soluciones
- Aplicaciones Rurales en Catamarca
- Cálculo Numérico en Fluídos
- Generación de energía mecánica por vía térmica
- Preparación de programas de computación

Instituto Universitario Aeronáutico

- Plan de Estudios **2007:**
  - Aerodinámica de Superficies Portantes y Cuerpos
  - Métodos numéricos
  - Mecánica de Materiales Avanzada
  - Dinámica de los Sistemas Mecánicos
  - Aeroelasticidad
  - Dinámica de Gases Avanzada
  - Dinámica de Vehículos Aeroespaciales
  - Mecánica de los Fluidos
  - Mecánica de Estructuras Aeroespaciales
  - Métodos Numéricos Avanzados
  - Diseño e Ingeniería de Vehículos Aeroespaciales
  - Métodos Experimentales Avanzados

Instituto Universitario Aeronáutico

- El Túnel de Viento Subsónico Mayor es un túnel de viento de circuito cerrado, atmosférico con una cámara de ensayos de 3.2 [m] de ancho, 2.4 [m] de alto y 5 [m] de largo.
- Su instalación data de 1955, y sus sistemas de medición fueron completamente actualizados en 1983, incluyendo un sistema para el control de ensayos computarizado.
- Esto reduce el tiempo necesario para la ejecución de los ensayos y aumenta la confiabilidad de los resultados



Centro Regional de Energía Eólica

- Gestión integral de proyectos;
- Estudios técnicos;
- Estudios económico-financieros;
- Estudios de impacto ambiental;
- Obtención de autorizaciones;
- Operación y mantenimiento;
- Certificación de calidad de WTG;
- Diseño de centrales eólicas de baja, mediana y alta potencia;
- Desarrollo de software para la determinación de lugares óptimos de una central eólica y el ruido que produce la misma;
- Organización de cursos a nivel nacional e internacional;
- Capacitación de profesionales y sistemas de pasantías;
- Evaluación de recurso eólico por medio de monitoreo (micrositing);
- Implementación de programas de electrificación rural;
- Electrificación a pobladores rurales dispersos;
- Proyectos con sistemas híbridos diesel-eólicos, diesel-eólico-solar;
- Electrificación a aldeas escolares

Universidad Nacional del Centro de la Provincia de Buenos Aires

Grupo Intelymec:

- Actualmente se encuentra integrado por quince docentes y aprovecha la infraestructura del Departamento, a la que contribuye también con los fondos de subsidios que el INTELYMEC obtiene. Los docentes investigadores realizan sus pruebas experimentales en el Laboratorio Industrial de Máquinas Eléctricas (LIDME), el Laboratorio de Automatización y Robótica (LAR), el Laboratorio de Mecánica (LAMEC), y el Laboratorio de Electricidad y Electrónica (LABEYEL).

- El perfil del Grupo es claramente de investigación aplicada e interdisciplinaria, intentando una fuerte inserción en el medio productivo, mediante transferencias y capacitación, como puede apreciarse en su breve historia de publicaciones y transferencias realizadas

Universidad Nacional del Centro de la Provincia de Buenos Aires

Actividades en Energías Renovables:

- Generación de biogás a partir de residuos sólidos urbanos y otros residuos de la agroindustria
- Evaluación del recurso eólico con fines energético en la región del Centro de la Provincia de Buenos Aires
- Proyecto piloto para la generación de hidrógeno a partir de energía eólica con la UNC y IUA.
- Desarrollo de seguidores solares para conversión fotovoltaica

Universidad Nacional de la Plata

Proyectos de I+D relacionados:

- Control y procesamiento de señales. Aplicaciones en sistemas electrónicos de potencia, generadores eólicos, arreglos de sensores y bioingeniería
- Estudio experimental en túnel de viento de capa límite del comportamiento aerodinámico de alas con perfiles de bajos Reynolds bajo la acción de una estructura vorticosa incidente
- Sistemas de Suministro de Energía Eléctrica. Operación y expansión. Compatibilidad electromagnética y calidad de suministro

IMPSA Wind: a local industrial initiative

- **IMPSA Wind** is a new business unit created by IMPSA to develop Wind Energy.

- **MISSION**
  - Promote integrated wind power development in the region with creativity, technological excellence and operating efficiency for the sustainable wellbeing and progress of the company and the community.

- IMPSA Wind is involved along the whole value chain of the wind energy business.

IMPSA Wind: a local industrial initiative

- **1985**: Product research begins.
- **1998**: Survey of composite materials: Blade manufacturing
- **2003**: R&D – Project PI1-58
- **2004**: Product engineering and prototype development
- **2005**:Creation of the “IMPSA Wind” Business Unit
- **2006**: Factory – R&D Project IWP77
- **2007-2008**:Commercial Production - EPC construction – Generation investments

IMPSA Wind: a local industrial initiative

- IMPSA Wind has adopted the most innovative, reliable and efficient technology for its wind turbines: DDPM WEC.

- Main features:

  - Direct-coupled turbine with no speed multiplier, which increases efficiency and reduces maintenance requirements.

  - High-efficiency, low-maintenance variable speed multipole generator, with permanent magnet excitation; does not consume reactive power.

  - Inverter system control with SVPWM (Space Vector Pulse Width Modulation) output, IGBTs (Insulated Gate Bipolar Transistors) for voltage, current, power factor and frequency control – great flexibility.

IMPSA Wind: a local industrial initiative

Designing a wind turbine is a complex and multidisciplinary process that involves:

- Aerodynamic Engineering
- Mechanical and Structural Engineering
- Power and Control Electronics
- Civil and Construction Engineering
- Climate and Atmospheric studies
- Basic design decisions are made concerning the main operation parameters: power and wind characteristics, turbulence and intensity.
- It is then necessary to design blade profiles and to determine main loads, turbine parameters, main mechanical features, and control strategy.

IMPSA Wind: a local industrial initiative

- **Mendoza – Argentina**
  - Located in the Department of Godoy Cruz, Province of Mendoza, Argentina, the IMPSA Wind manufacturing plant houses the development laboratories, test benches for blades and generators, as well as the workshop where blade models and molds are made.
  - At full capacity, the plant is equipped to produce 100 turbines per year.
- **Brasil**
  - Through WPE –its subsidiary in Brazil– **IMPSA Wind** is building a new plant at the SUAPE industrial port in the State of Pernambuco.
  - This plant will have a manufacturing capacity of 200 turbines per year and is scheduled to start operations in the first quarter of 2008.

IMPSA Wind: a local industrial initiative

IMPSA Wind activities in this field include:

- General project analysis and search for the most suitable area based on the interpretation of wind atlases, power grids, etc.
- Calculation and installation of anemometer towers for wind measurement designed to minimize measurement errors.
- Wind measurement campaigns, tower data collection and processing.
- Wind data analysis and determination of relevant characteristics for wind projects
- Site classification according to IEC 61400-1, 3rd edition.
- Optimization of wind turbines layout at site.
- Wind energy forecasts and uncertainty assessment.

Experiencia de Pico Truncado, Santa Cruz, Argentina

- Planta Experimental de Hidrógeno, ubicada junto al Parque Eólico Jorge Romanutti, a sólo dos kilómetros de la ciudad de Pico Truncado

- La planta experimental que costó 500.000 dólares y cubre 800 metros cuadrados obtiene la energía de las cuatro turbinas eólicas que generan 2400 kW por hora, suficiente para dar electricidad a la mitad de la población de Pico Truncado (8000 habitantes).

- El complejo no sólo funcionará en forma experimental, sino que en breve se ampliará a fase semiindustrial en los procesos generadores de hidrógeno y en el manejo más eficiente de esta tecnología.

- El laboratorio equipado con un quemador de hidrógeno, un almacenador de hidruro y un sistema electrolizador, consta además de oficinas, una biblioteca y aulas de capacitación para que científicos del país del Mercosur se especialicen en el uso del hidrógeno como combustible del futuro.

- Los avances de la flamante planta experimental posibilitó que las Naciones Unidas y el Centro Internacional Tecnológico de Energías e Hidrógeno, con sede en Estambul, Turquía, hayan elegido al pueblo Nuestra Señora de los Dolores de Koluel Kaike, distante 23 kilómetros de Pico Truncado, para convertirse en una de las cinco localidades en el mundo en funcionar a base de hidrógeno.

University Programs & Research Institutes

- **University of Alaska**
- Alaska Cooperative Extension
- PO Box 756180
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Thank you

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