Distributed Generation Technologies
A Global Perspective

NSF Workshop on
Sustainable Energy Systems

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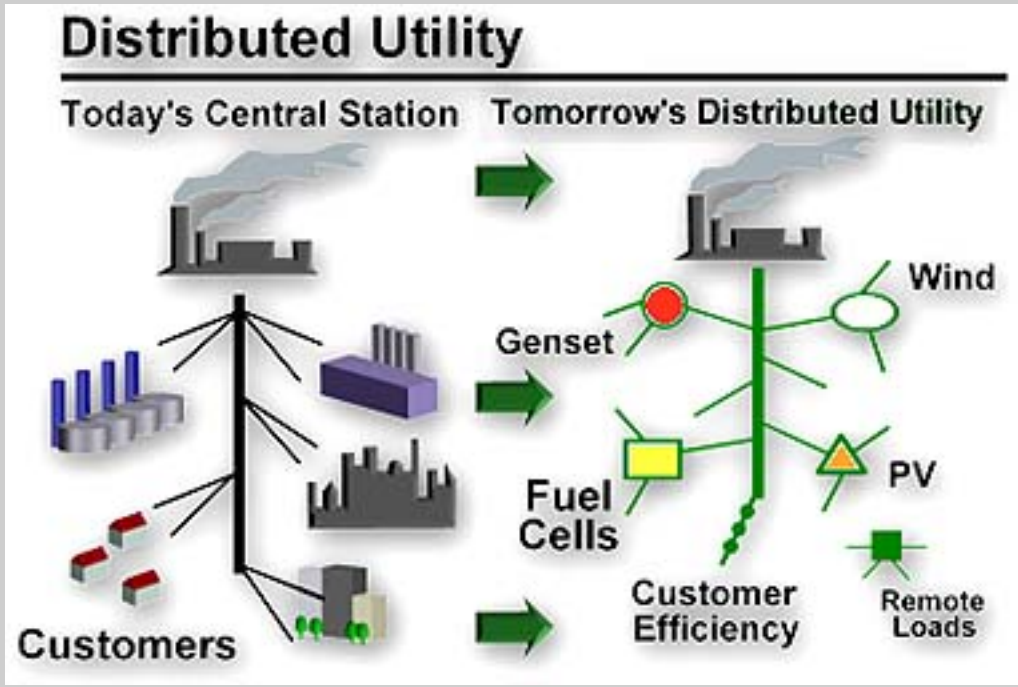
Nuclear Power Plant

Central Station Thermal Power Plant

Central Station Thermal Power Plant

Concerns about High Voltage lines

Transition from Central to Distributed



Wind Energy Based Power Plant

Distributed Capacity

Distributed generation reduces the capital investment and improves the overall conversion efficiency of fuel to end use electricity by reducing transmission losses. In high growth or remotely located load demands, distributed generation could reduce or eliminate transmission and distribution problems by reducing the need for new capacity or siting new lines.

Presently at least 8-10 percent of the generated electrical power is also lost between the generating station and the end user. Distributed generation will result in many smaller units distributed throughout the system resulting in a statistically more reliable system.

Distributed Generation Technologies

Solar Energy Systems

Wind Energy Systems

Mini-hydro Power Plants

Geothermal Power Plants

Biomass-based Electricity

Fuel Cells

Opportunities from Renewables

- **Major contributions from large-scale hydropower is uncertain**
- **Low-head hydropower may be easier to develop**
- **Geothermal energy is a small local contributor**
- **Biomass will present modest opportunities**
- **Wind and solar will play more important roles**

Hydropower Development

Large scale hydropower development in the industrialized world has almost come to a halt.

China, India, Turkey, Brazil, Nepal and some African countries have ongoing programs of large hydro projects, but significant environmental concerns.

Large areas are inundated requiring huge population movements.

Concerns about ecological damage and loss of biodiversity.

Small scale hydropower

- **Generally up to 25 MW,**
- **Mostly low head,**
- **Does not require large dams,**
- **Flooding impacts are minimal,**
- **Does not impact the watershed,**
- **Equipment is less expensive, widely available**

Geothermal Electricity

- **Site-specific**
- **Land-use effects can be significant**
- **Potential for environmentally-damaging discharge**
- **Equipment cost can be high**
- **Conversion efficiency may be low**
- **Not all geothermal wells are suitable for electricity production**

Solar Energy

- Solar Thermal (heating/drying applications)
- Solar Thermal Electricity
- Solar Photovoltaics

FUEL CELLS

Fuel cells are an environmentally clean, quiet, and highly efficient method for generating electricity and heat from natural gas and other fuels.

They are vastly different from other power systems. A fuel cell is an electrochemical device that converts the chemical energy of a fuel directly to usable energy - electricity and heat - without combustion.

The fuel cell works by processing a hydrogen-rich fuel - usually natural gas or methanol - into hydrogen, which, when combined with oxygen, produces electricity and water.

A fuel cell has few moving parts, and produces very little waste heat or gas.

Fuel cells are the ideal technology for small power plants 200 kW to 2 MW, serving an emerging distributed generation market.

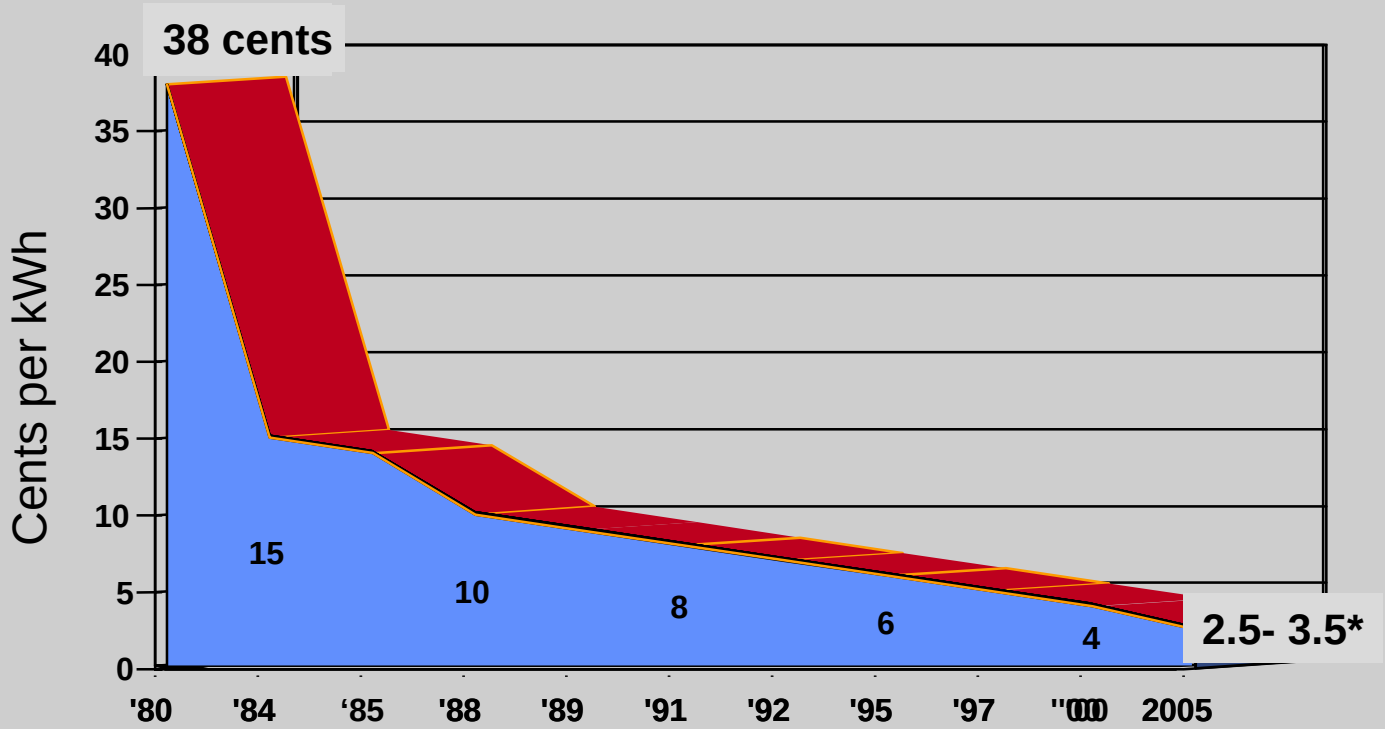
Larger advanced, ultra-high efficiency fuel cell / gas turbine sizes (1-100+MW) is designed to serve industrial and new, more central, or repowering units.

Today's natural gas-fueled fuel cell power plants operate with an electrical conversion efficiency of 40 to 50 percent and are predicted to climb to the 50 to 60 percent in the near future. Fuel cells operate at high efficiency, regardless of size and load.

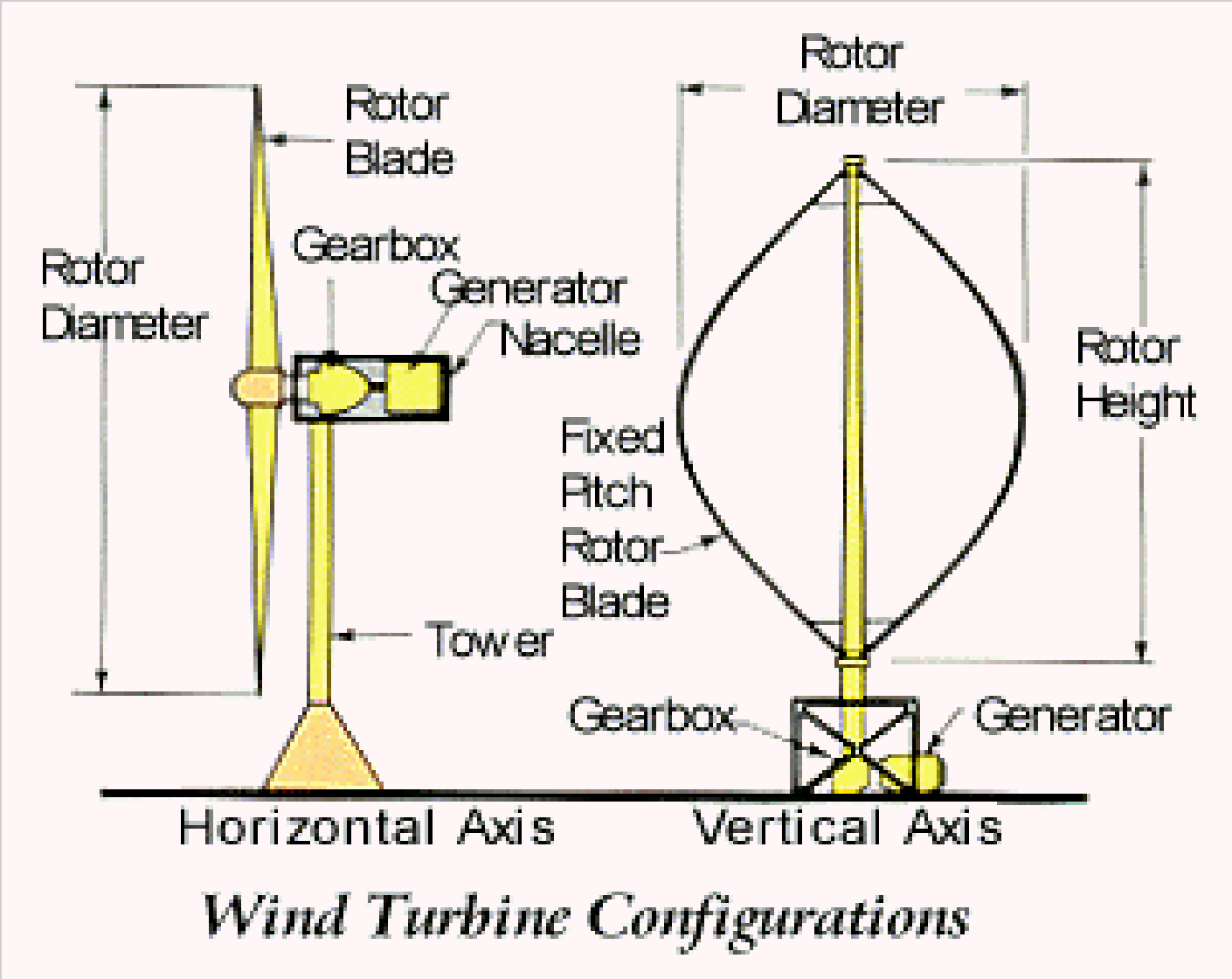
In comparison, high efficiency gas turbines operate at efficiencies of 33 to 35 percent.

Wind Energy:

Cost of Wind-Generated Electricity
1980 to 2005 Levelized Cents/kWh



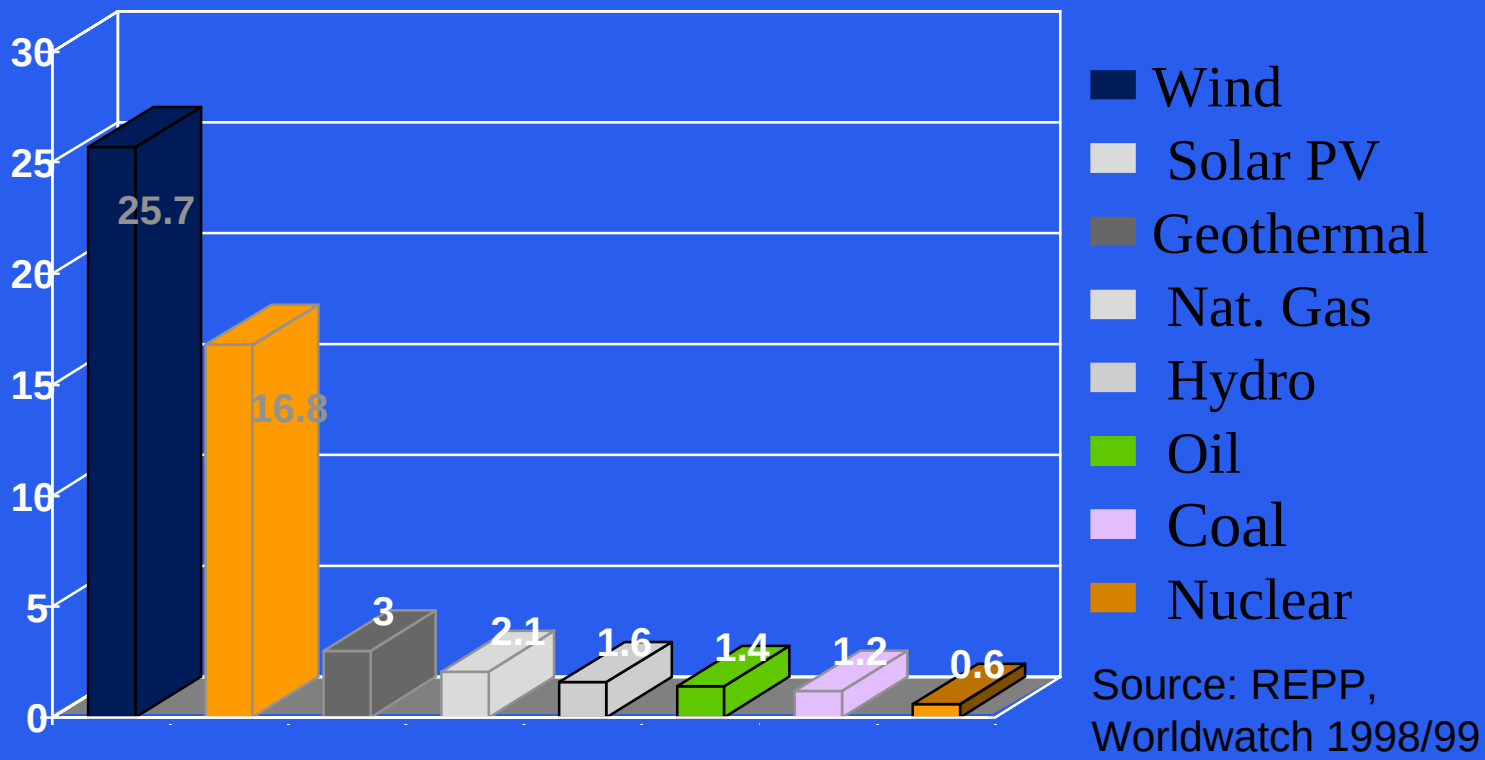
* Assumptions: Levelized cost at excellent wind sites, large project size, (post 1994)



Wind Turbine Configurations

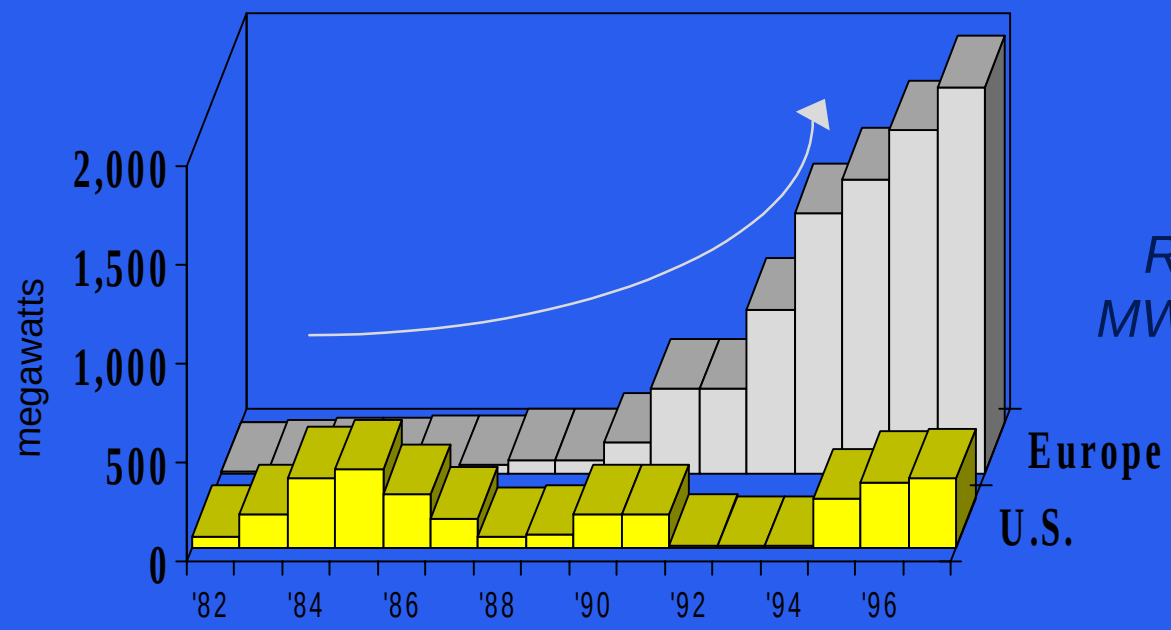
Fastest Growing Energy Source in the World

Global % Growth by Energy Source, Annual Average,1990-98



Source: REPP, Worldwatch 1998/99

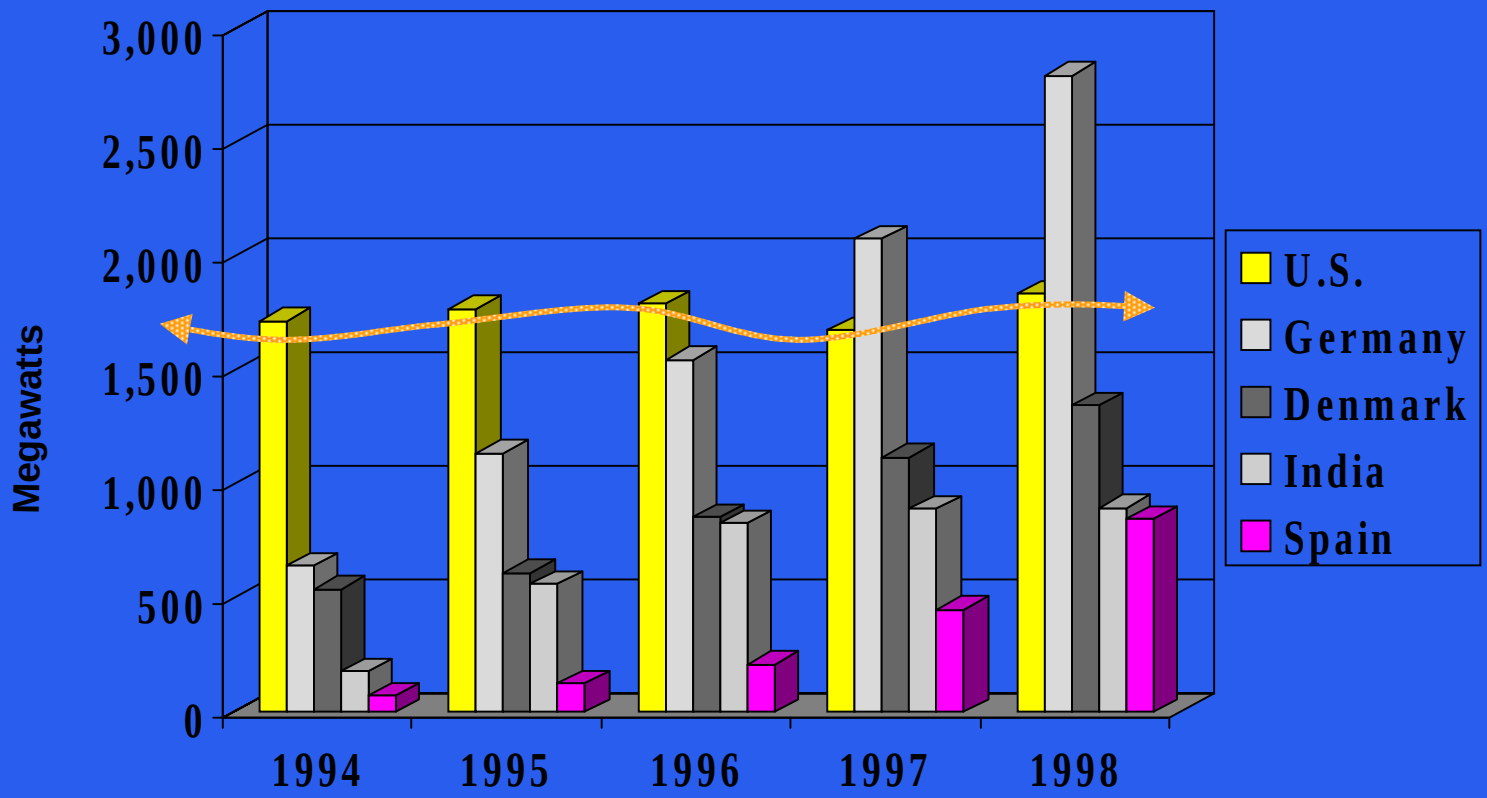
Comparing American and European Growth



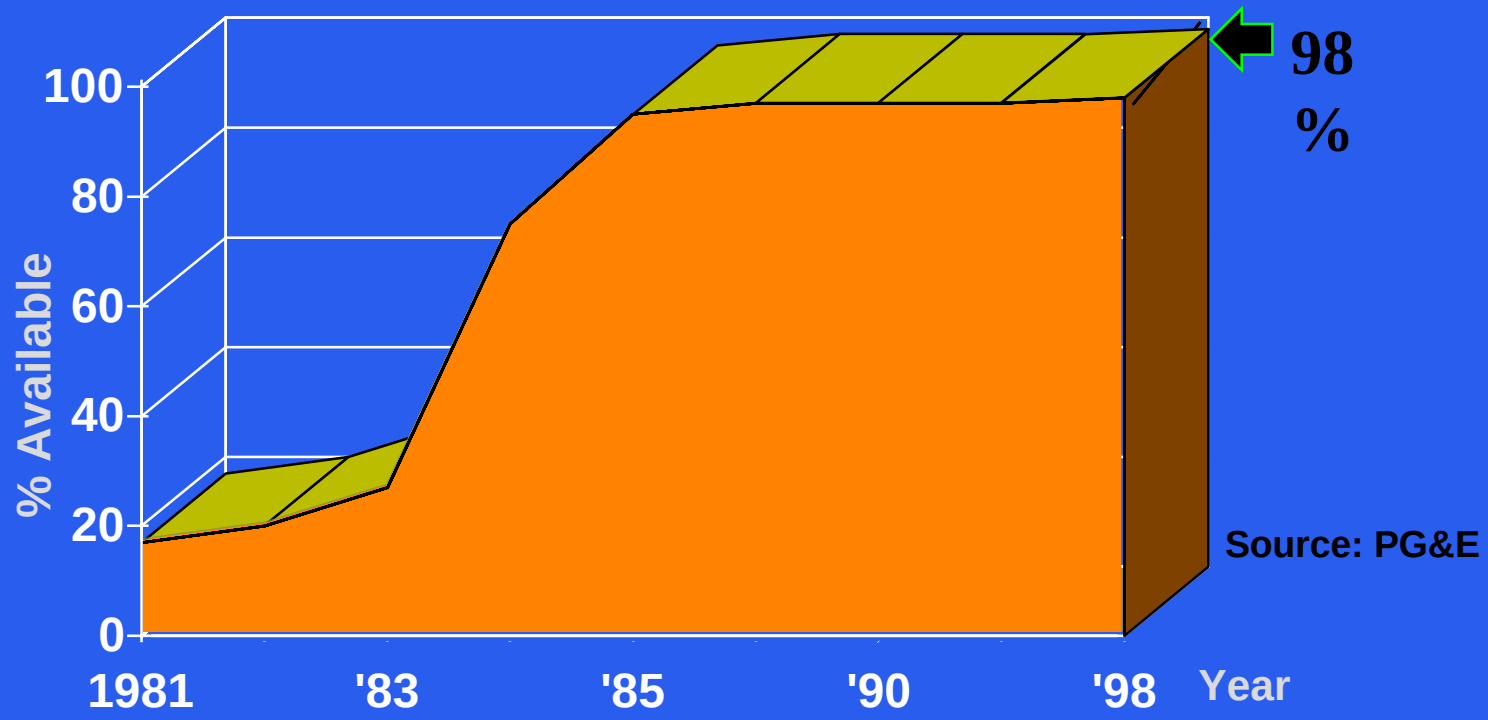
Bar Graphs Represent new MW Capacity Each Year

Worldwide Wind Energy

Cumulative Wind Capacity 1994-1998



Technology Trends—Improved Reliability



Average Percent of Turbines Available for Operation at Any Given Time

Key Market Strategies

- Pricing Support/Policies
  - Tax Subsidies
  - Min Fixed Payment Prices
  - Mandates
- Cost Reductions/
  Technology Advances
- New Applications

Cost Reductions

- Financing Strategies
- Manufacturing Economy of Scale
- Better Sites and “Tuning” Turbines for Site Conditions
- Technology Improvements

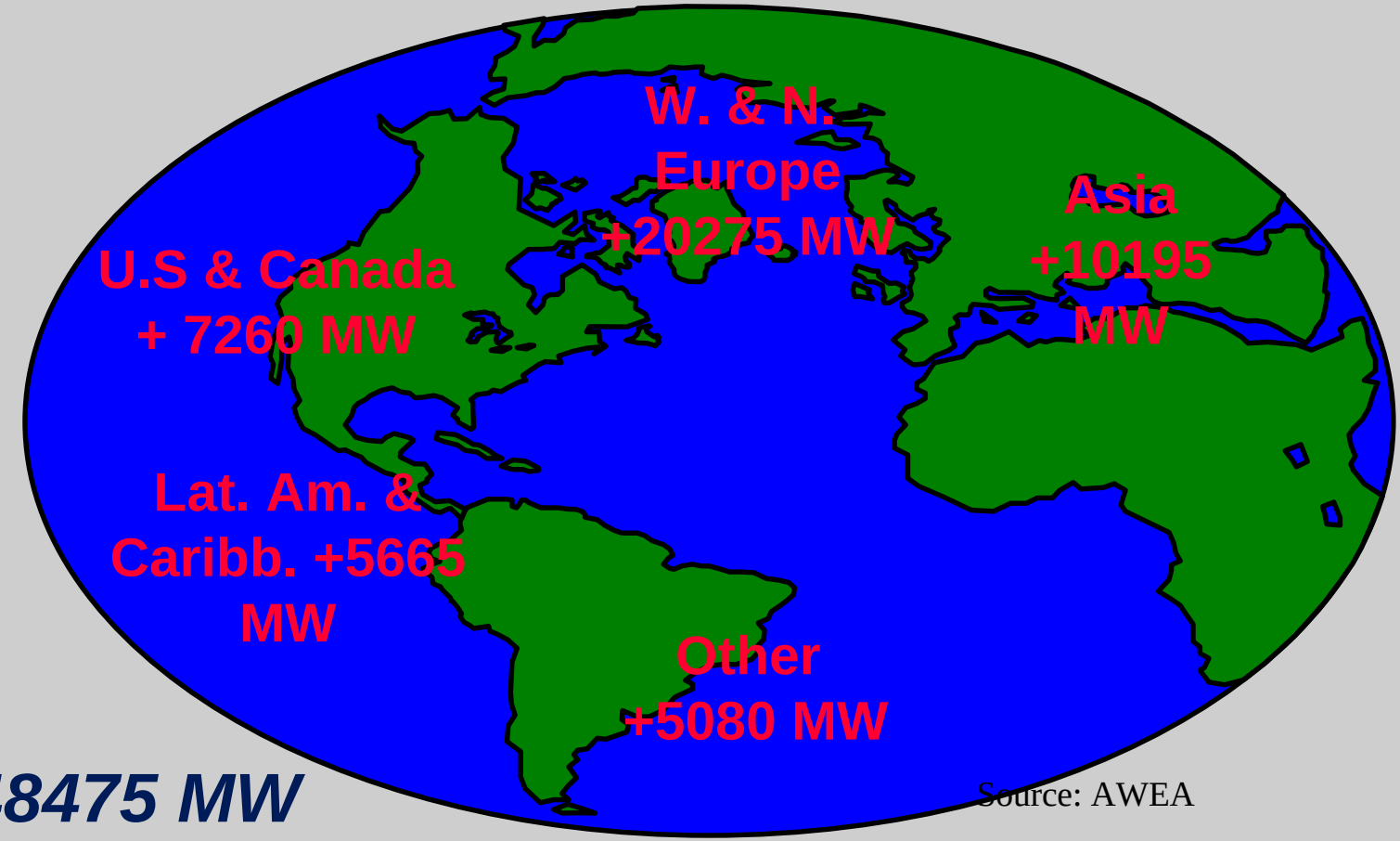
New Applications

- Offshore Installations
- Cold Climates
- Low Wind Turbine Designs
- High Wind, Turbulence
- Weak Grids

Market Barriers

- Public Acceptance/ Siting Issues
  - **Noise**
  - **Aesthetics**
- Transmission and Intermittence
- Knowledge of Wind Resource
- Familiarity with the Technology

Projected Wind Growth Worldwide through 2007



Total: + 48475 MW

All capacity is additional to current levels

Source: AWEA

Gross Generation in World			(TWH)
	1996	2000	2010
OECD	8,177	8,698	10,446
Non-OECD	5,559	6,423	10,151
World Total	13,736	15,121	20,596

Electricity Consumptions per Person per Year

- **United States: 12,000 kWhr**
- **China: 1,200 kWhr**
- **India: 550 kWhr**

Over 2 billion out of 6 billion people have no access to electricity

Remaining Fuels for Electricity and other Energy Uses

- **Oil:** **20-30 years**
- **Natural Gas:** **30-50 years**
- **Coal:** **100 years or less**

Resources are located in a few selected countries

NSF Workshop on Sustainable Energy Systems ??

So, what sources are left?

Hydropower?

$2 trillion has been invested

80 million people have been displaced

25% of GHG has been emitted by vegetation rotting in hydro reservoirs

Sustainable Energy Systems ??

Wind?	**Small, but meaningful**
Solar?	**High potential with inexpensive storage**
Fossil fuel?	**Highly efficient plants**
Nuclear?	**Yet to be determined form**