# The Role of Grid-Connected Energy Efficiency and Renewable Energy in Reducing Emissions

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National Renewable Energy Laboratory

## Air Pollution as Climate Forcing: Second Workshop

Honolulu, Hawaii

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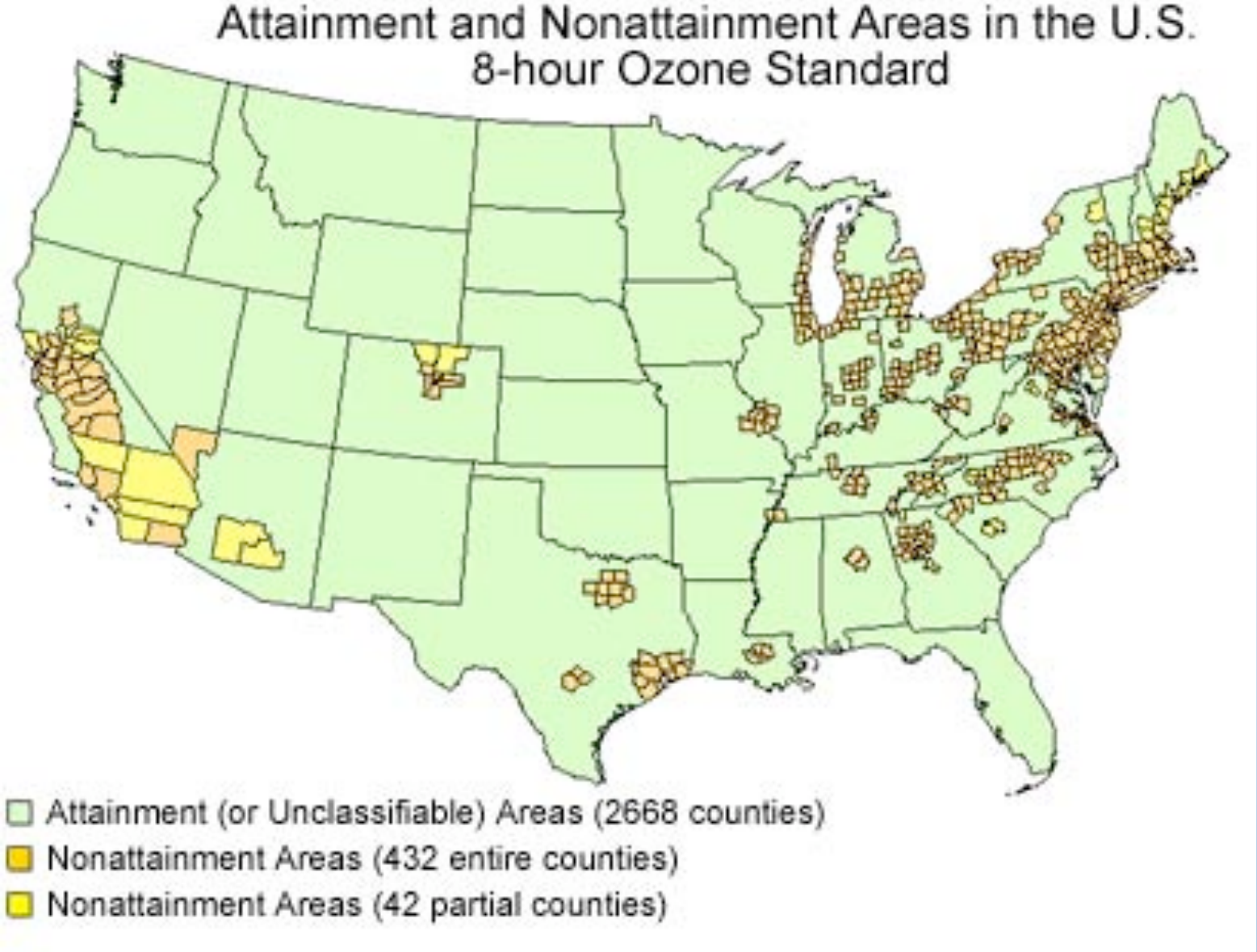
# Presentation Outline

- Renewable Energy Resources provide an opportunity for GHG and ambient air pollution emission reductions – wind focus
- It is cheaper to save electricity than to make it! – energy efficiency focus
- In a grid-connected environment, the benefits of EERE can be quantified with enough certainty to satisfy regulatory authorities – USEPA
- Future of EERE in displacing emissions (US and international)

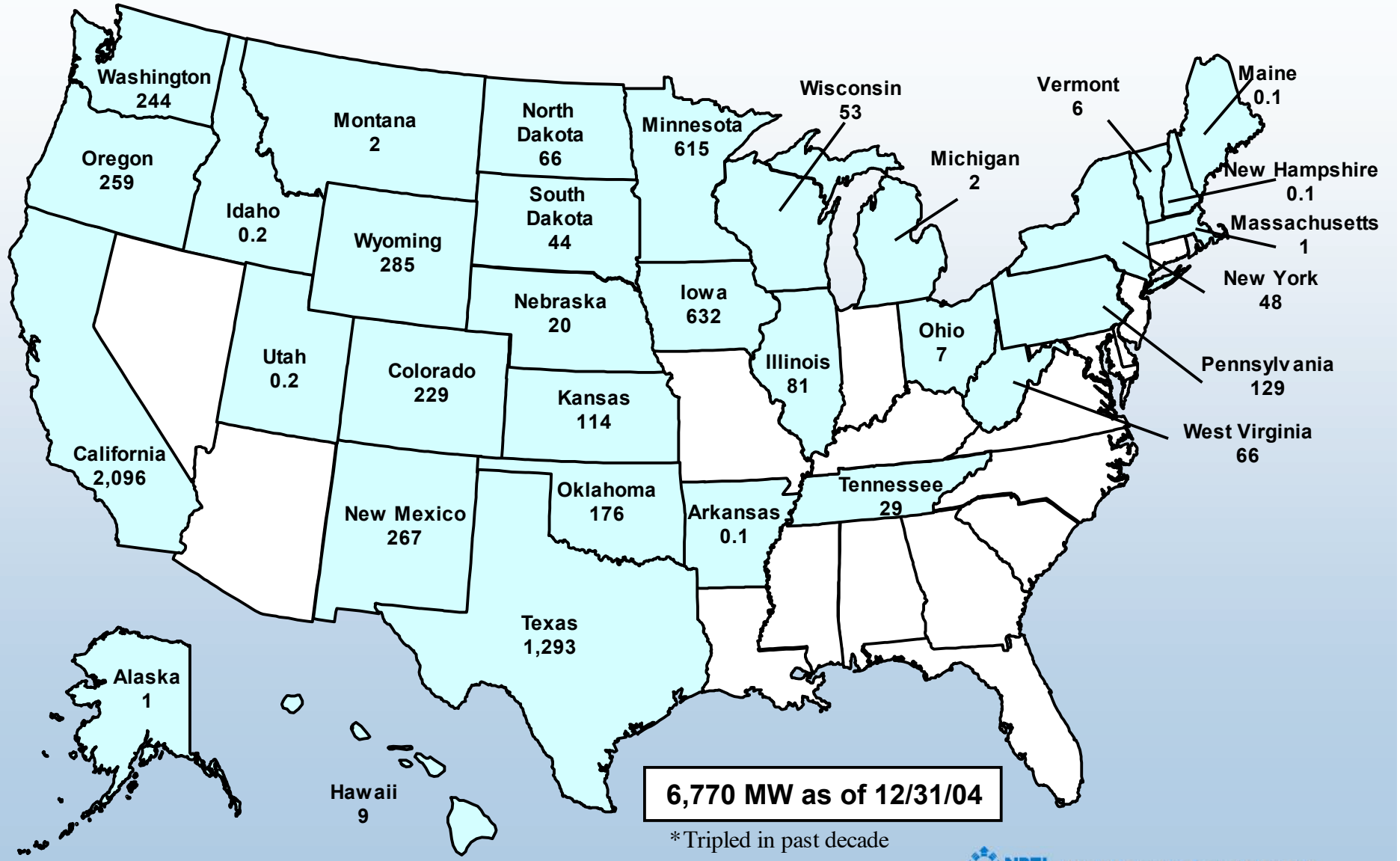



**Over 180 million people live in O3 non-attainment areas**

# EE/RE to Meet Air Quality Standards

- Innovative measures to meet tighter Ozone Standards
  - easily implemented “control” measures have already been implemented – 1-hour standard
  - more non-attainment areas
  - additional reductions required
- Benefits of EE/RE
  - multipollutant/multimedia environmental benefits
  - economic value
  - energy security
  - jobs
  - endorsement of using measures by EPA and DOE

# United States Wind Power Capacity (MW)

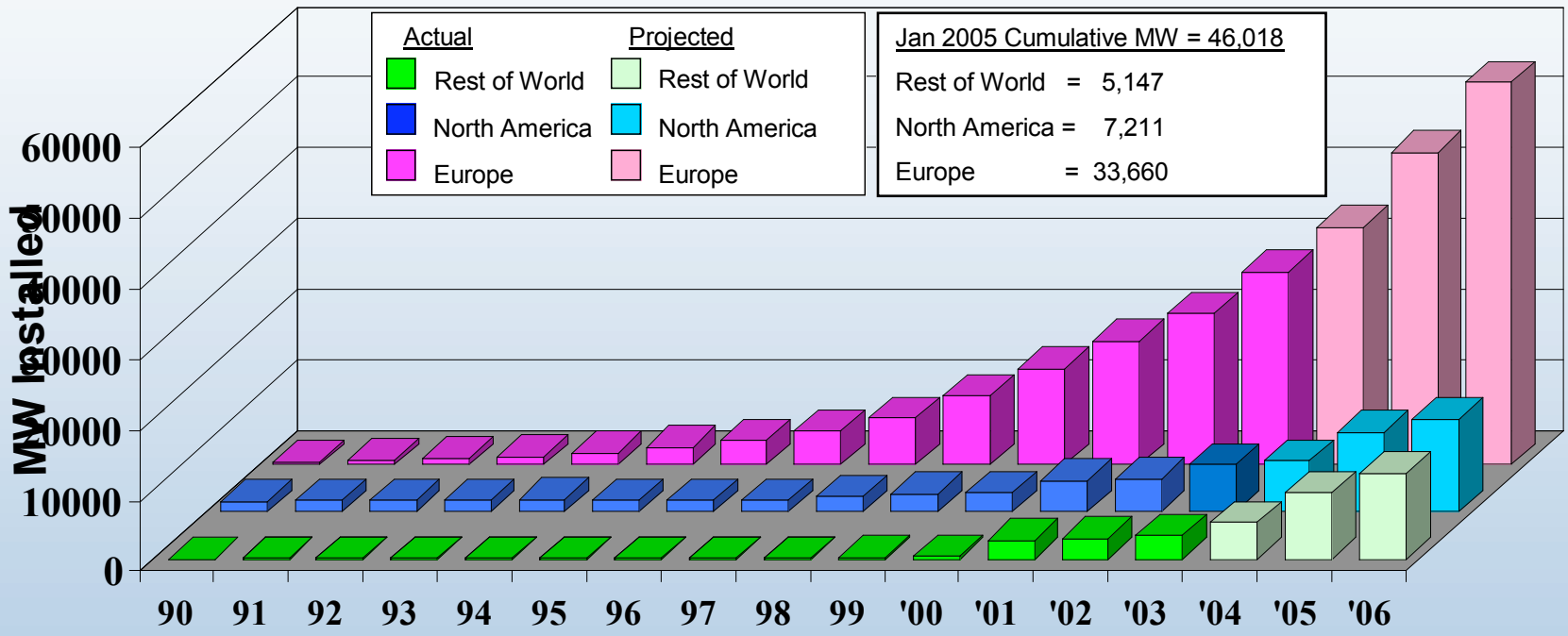



**6,770 MW as of 12/31/04**

*Tripled in past decade

NREL National Renewable Energy Laboratory

# Growth of Wind Energy Capacity Worldwide




Sources: BTM Consult Aps, March 2003
Windpower Monthly, January 2004
*NREL Estimate for 2004

# Negawatts – Every unit of electricity saved at the point of consumption saves 3 - 4 units of fuel

# Building-Integrated Photovoltaics

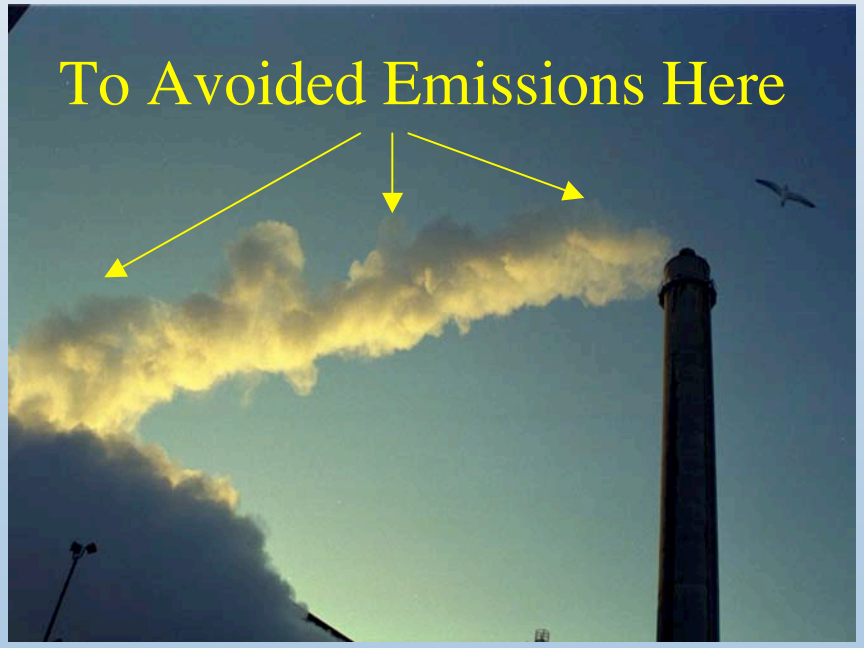
Church in Sacramento, California (01096)

PV Shingles (04566)

House in Hopewell, New Jersey (04474)

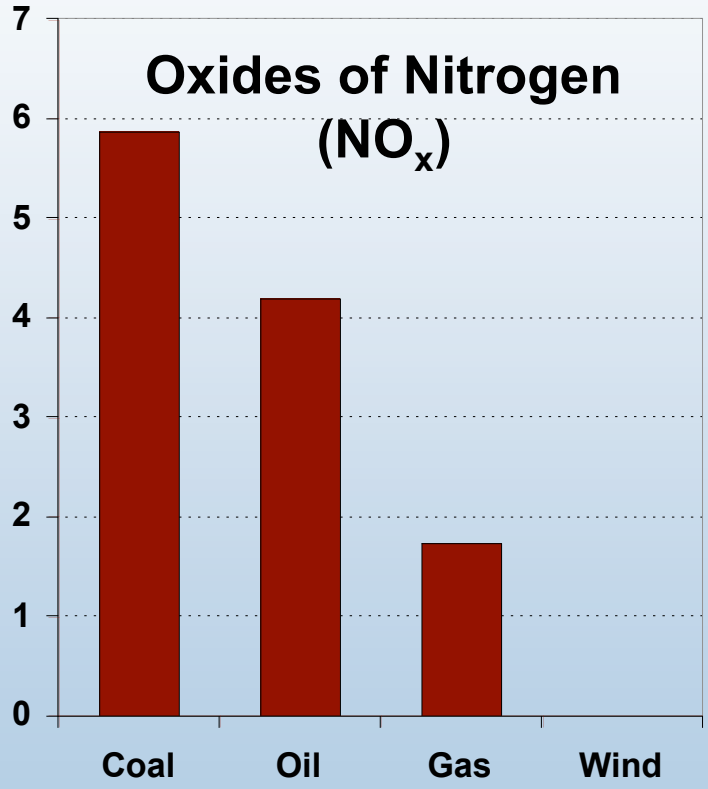
Fort Dix, New Jersey (05180)

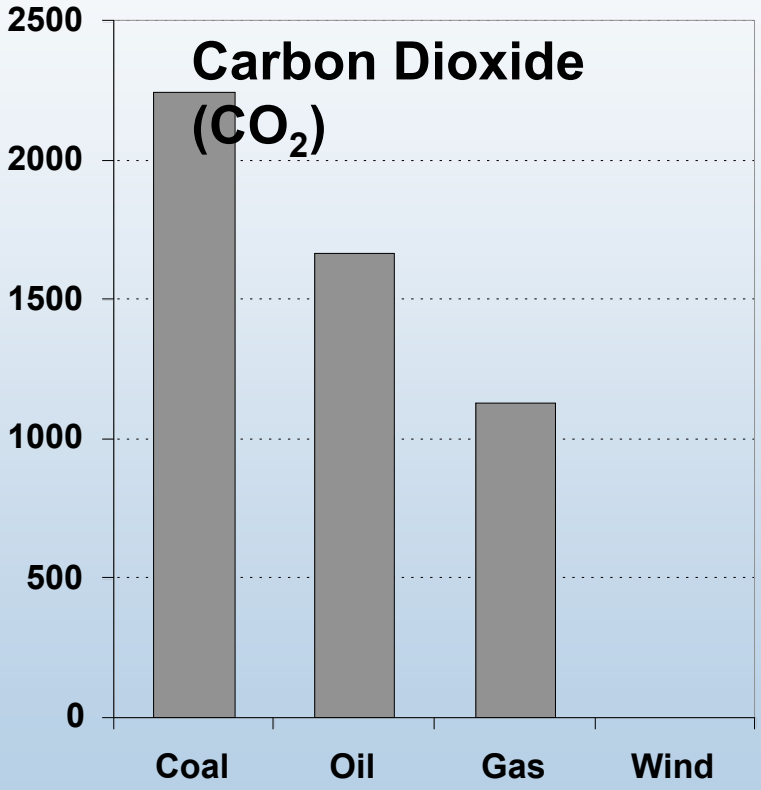
# How do we get from here



# Affect ambient air quality and GHGs

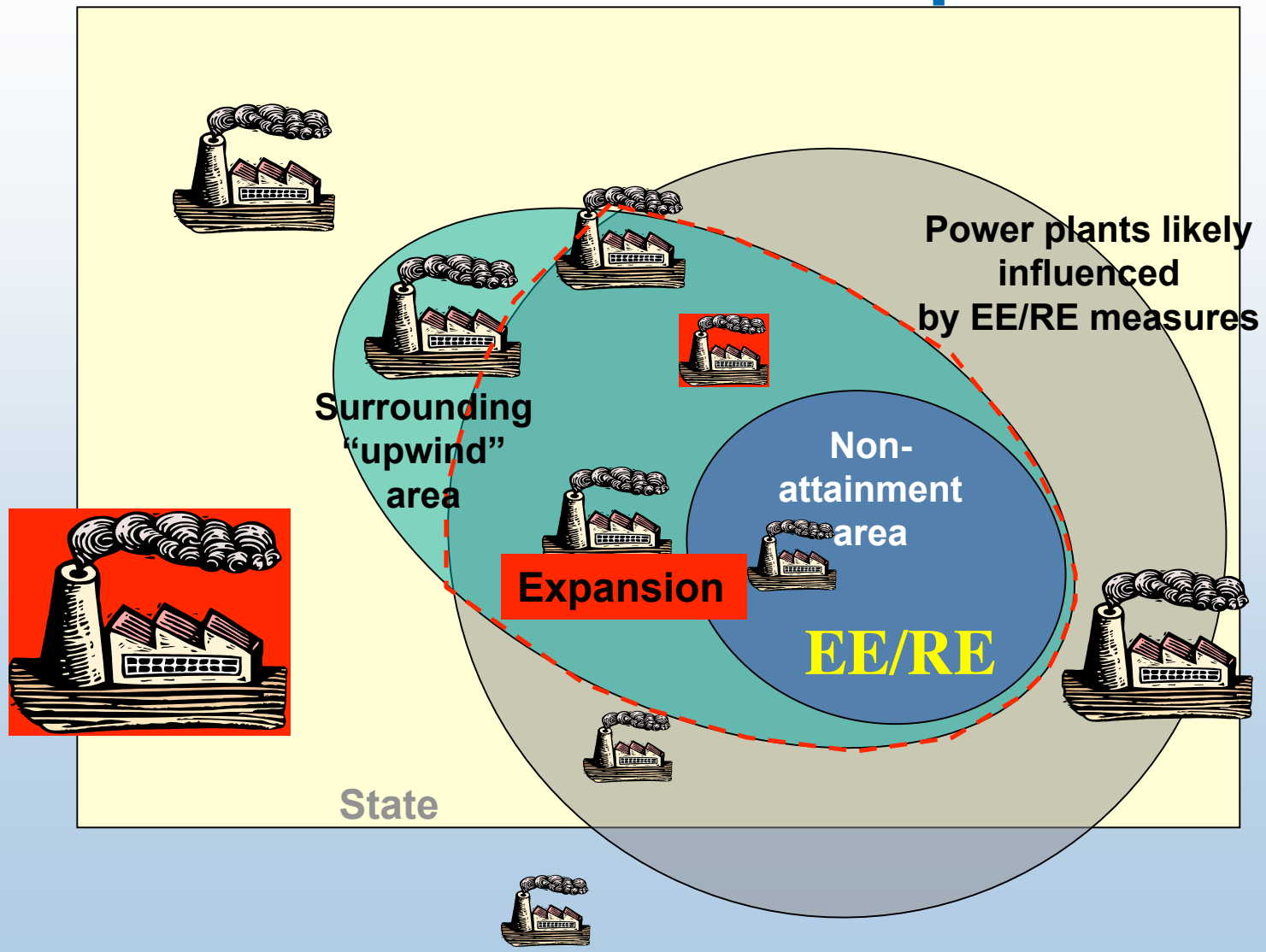
# Emission Rates: Fossil vs. Wind (lb/MWh) (Year 2000)




Data Source: E-GRID2002 v2.0
Prepared by Art Diem USEPA

# Efficient Growth vs. Expansion



# How do we calculate co-benefits and ancillary benefits?

- Dispatch Modeling (simple or complex)
  - Energy efficiency reduces marginal demand
  - Marginal plants are first to be offset with base load following
- Avoided Capacity Expansion
  - Can we actually avoid building new power plants through EERE?

# Dispatch Modeling

- Economic dispatch models
- Marginal dispatch models
- Various regional plant averages

## Avoided Capacity Expansion?

- Regulatory uncertainty
- Power plant retirement age
- Future fuel costs (particularly gas and oil)

# Case Study – Shreveport, LA

- Borderline O3 nonattainment area
- 33 municipal building retrofit with EE
- 20 year performance contract with Johnson Controls
- Guaranteed energy savings –
  - 9,121,335 KWh/yr
  - Base year 2000
  - Annual true-up to assure compliance

# Annual Emissions Savings

- Co-benefits
  - 3.3 lbs NOx/MWh ~ 116 lbs/day ~21 TPY
  - Jobs
  - Cost savings

- Ancillary benefits
  - SO2 - 41,228.4 lbs/yr or 20.6 TPY
  - CO2 - 16,377,265.8 lbs/yr or 8,188.6 TPY
  - Hg – 0.27 lbs/yr
  - PM – plant specific and difficult to quantify due to Efs
  - 228M gallons of water withdrawal avoided
  - Contribute to an avoided new power plant or unit?

# What about error?

- We are estimating emissions reductions at a 1:1 ratio
  - 1MWh avoided at the consumer = 1 MWh less produced at the power plant
  - This is not a silver bullet (YET) for air pollution control, at 500MWh/O3 season day or 150 GWh/year ~ 1 ton NOx/day

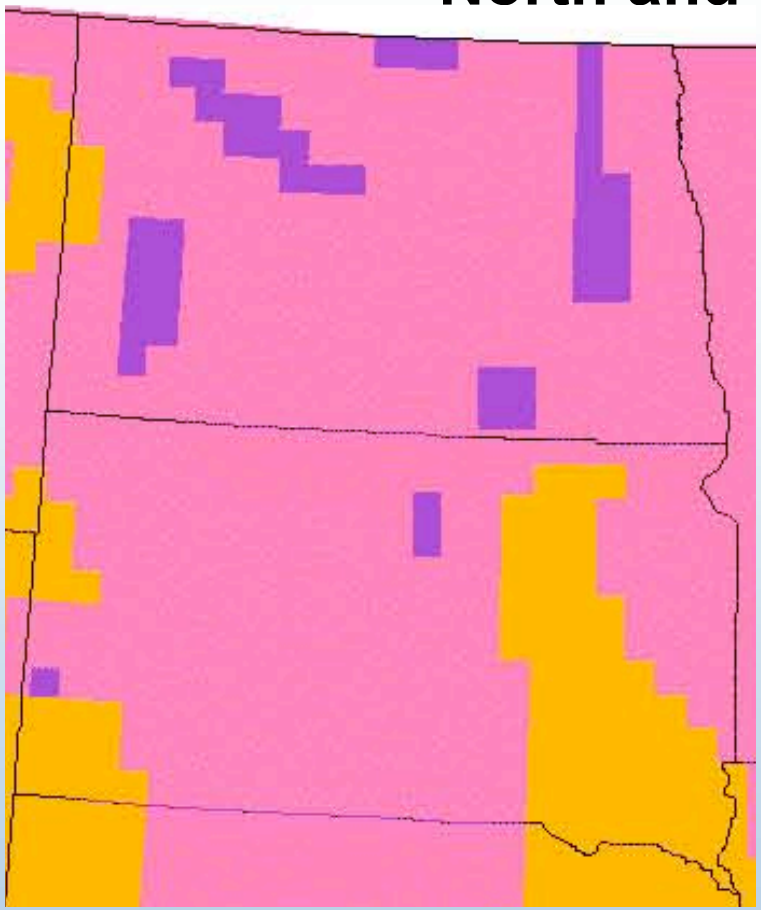
**IT IS CHEAPER TO SAVE ELECTRICITY THAN TO MAKE IT**

**Amory Lovins, Montreal 1989**

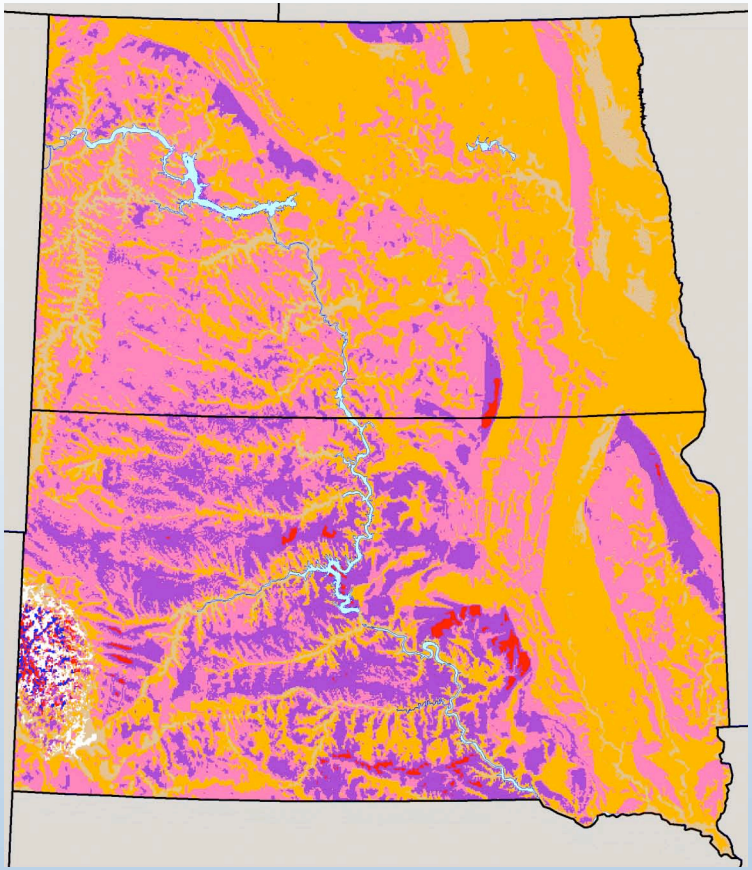
# Future of Co-benefits and Ancillary Benefits

- Co-benefits of EERE
  - Air Pollution Benefits
  - Energy Security
  - Jobs for the EERE industry
  - Meet Clean Energy Generation Requirements (RPS, etc.)
- Ancillary benefits
  - CO2 and non-CO2 GHGs
  - 25 gallons of water withdrawal to produce 1 kWh coal fired generation
  - KW of EERE results in avoided investment in new generation AND T&D losses

# Comparison of Digital Wind Map from 1987 U.S. Wind Atlas and New (2000) High-Resolution (1-km$^2$) Wind Map North and South Dakota



1987



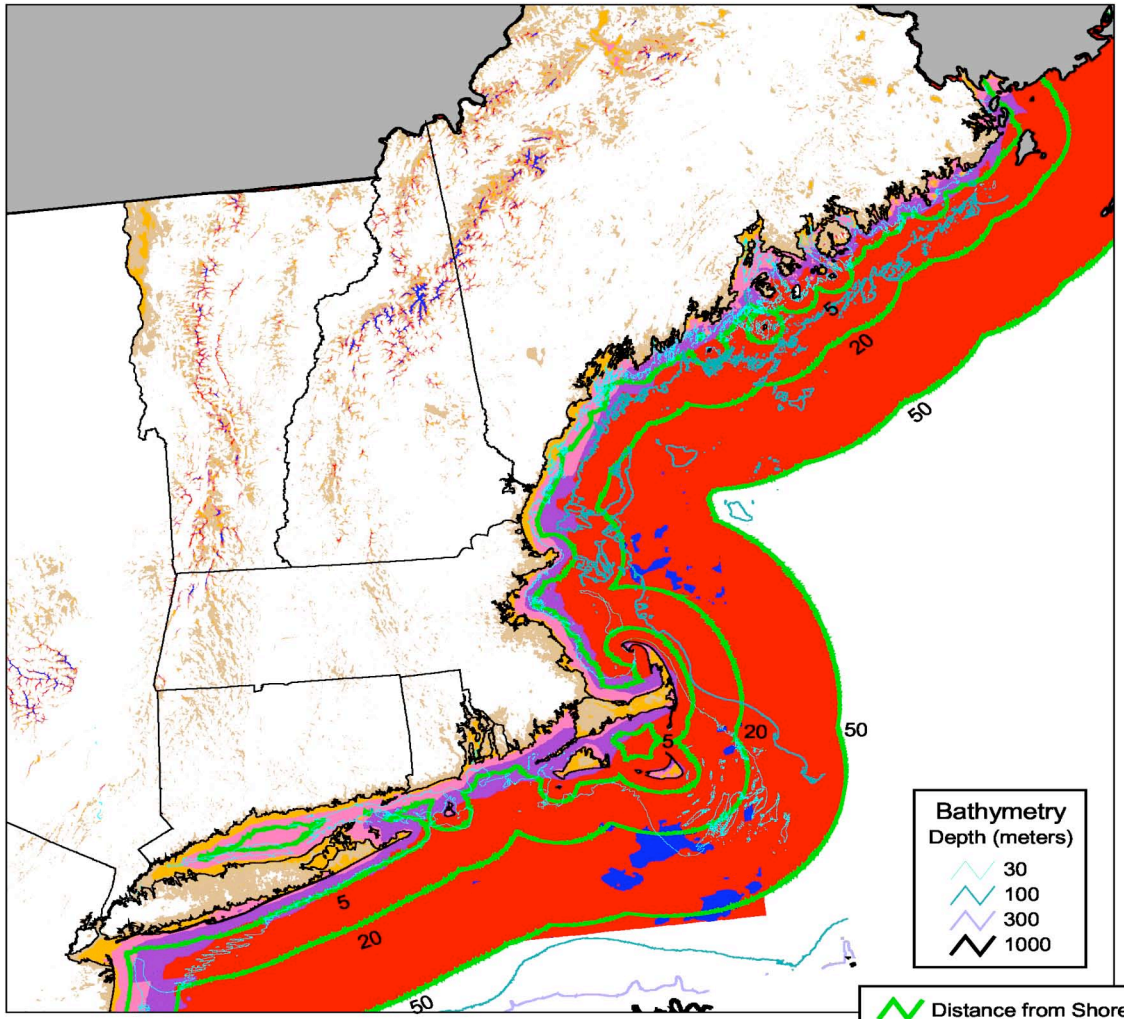
2000

**Wind Power Classification**

| Wind Power Class | Resource Potential | Wind Power Density at 50 m W/m$^2$ | Wind Speed[a] at 50 m m/s | Wind Speed[a] at 50 m mph |
|---|---|---|---|---|
| 2 | Marginal | 200 - 300 | 5.6 - 6.4 | 12.5 - 14.3 |
| 3 | Fair | 300 - 400 | 6.4 - 7.0 | 14.3 - 15.7 |
| 4 | Good | 400 - 500 | 7.0 - 7.5 | 15.7 - 16.8 |
| 5 | Excellent | 500 - 600 | 7.5 - 8.0 | 16.8 - 17.9 |
| 6 | Outstanding | 600 - 800 | 8.0 - 8.8 | 17.9 - 19.7 |
| 7 | Superb | 800 - 1600 | 8.8 - 11.1 | 19.7 - 24.8 |

[a] Wind speeds are based on a Weibull k value of 2.0

# Offshore Wind Potential for New England




## New England Offshore Wind Resource Potential

All areas > 5 nautical miles offshore likely to be class 4 resource or better.

Area 5-20 nautical miles from shore (67% excluded):
- 10,300 sq. km. (51,500 MW)
- 1,980 sq km (9,900 MW) <30m depth

Area 20-50 nautical miles from shore (33% excluded):
- 33,800 sq. km. (169,000 MW)
- 540 sq km (2,700 MW) <30m depth

The wind power resource data for this map was produced by TrueWind Solutions using the Mesomap system and historical weather data, and has been validated by NREL.

The bathymetry contour lines were derived from NOAA's coastal relief models (nominal resolution 1 km) from NOAA's National Geo-physical Data Center.

Wind Power Classification

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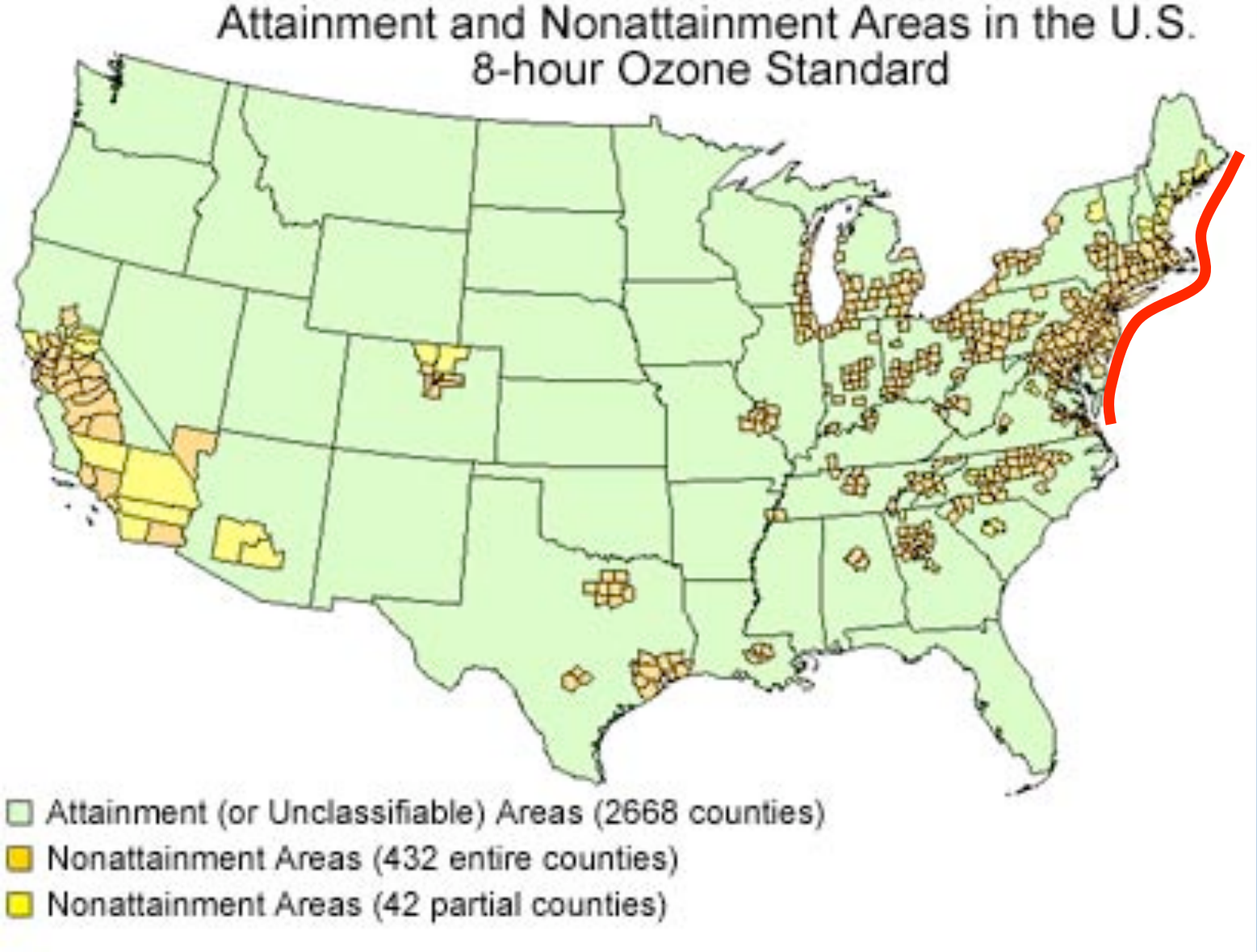
| 7 | Superb | > 800 | > 8.8 | > 19.7 |

[a] Wind speeds are based on a Weibull k value of 2.0

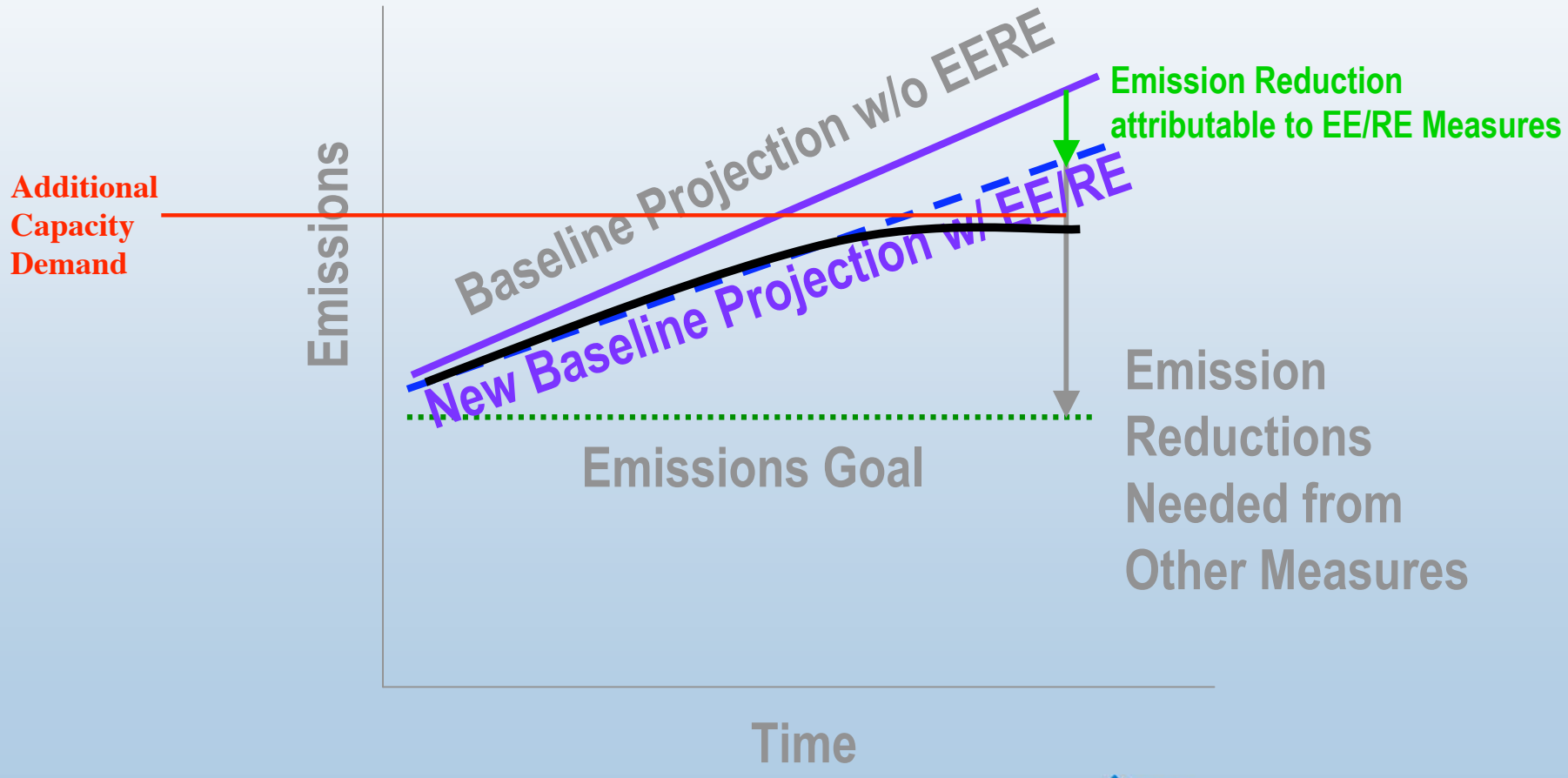
U.S. Department of Energy
National Renewable Energy Laboratory

30-JUL-2003 2.1.2




**Over 180 million people live in O3 non-attainment areas**

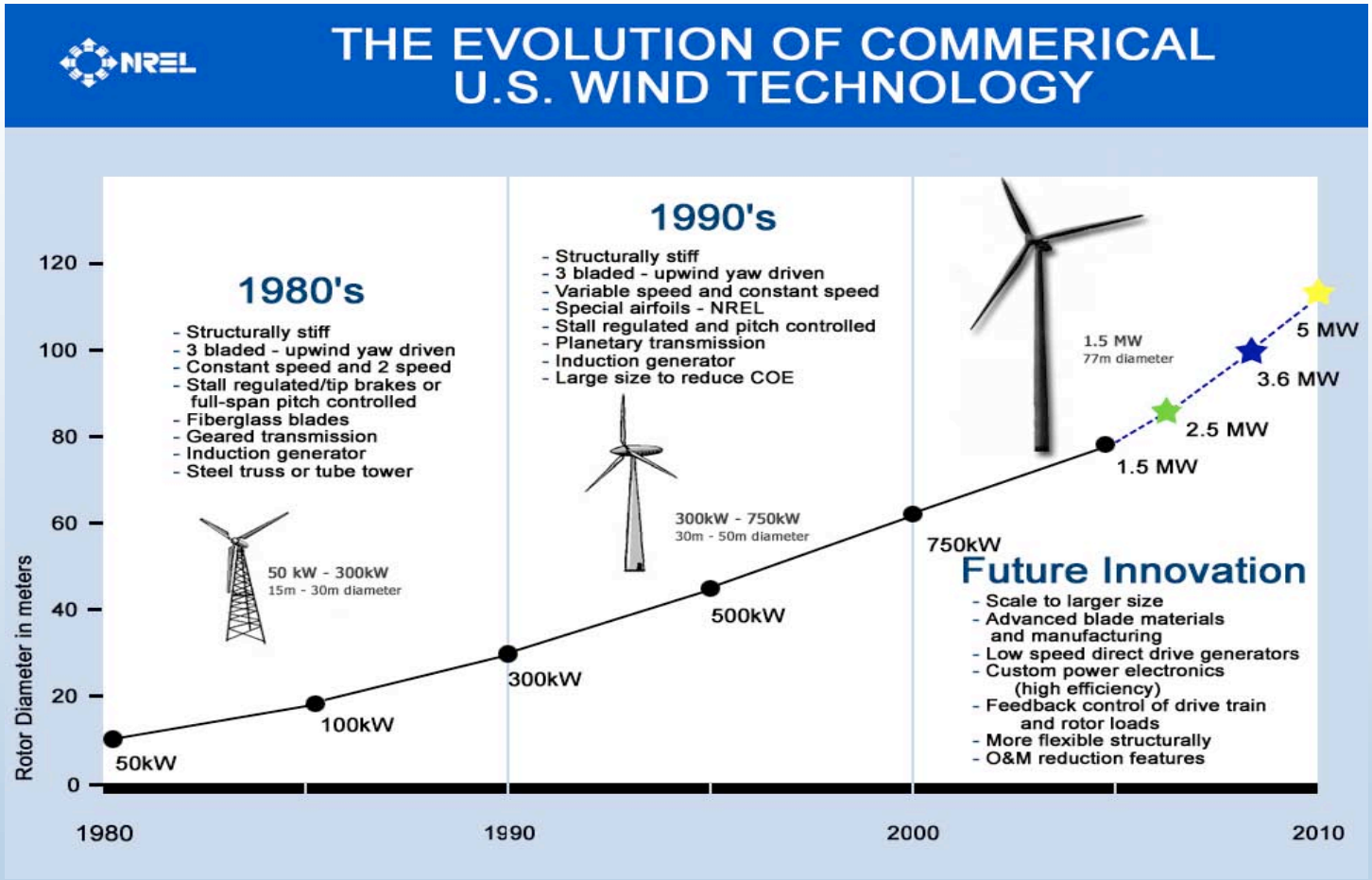
# Potential for incorporating EE/RE reductions in SIP Process



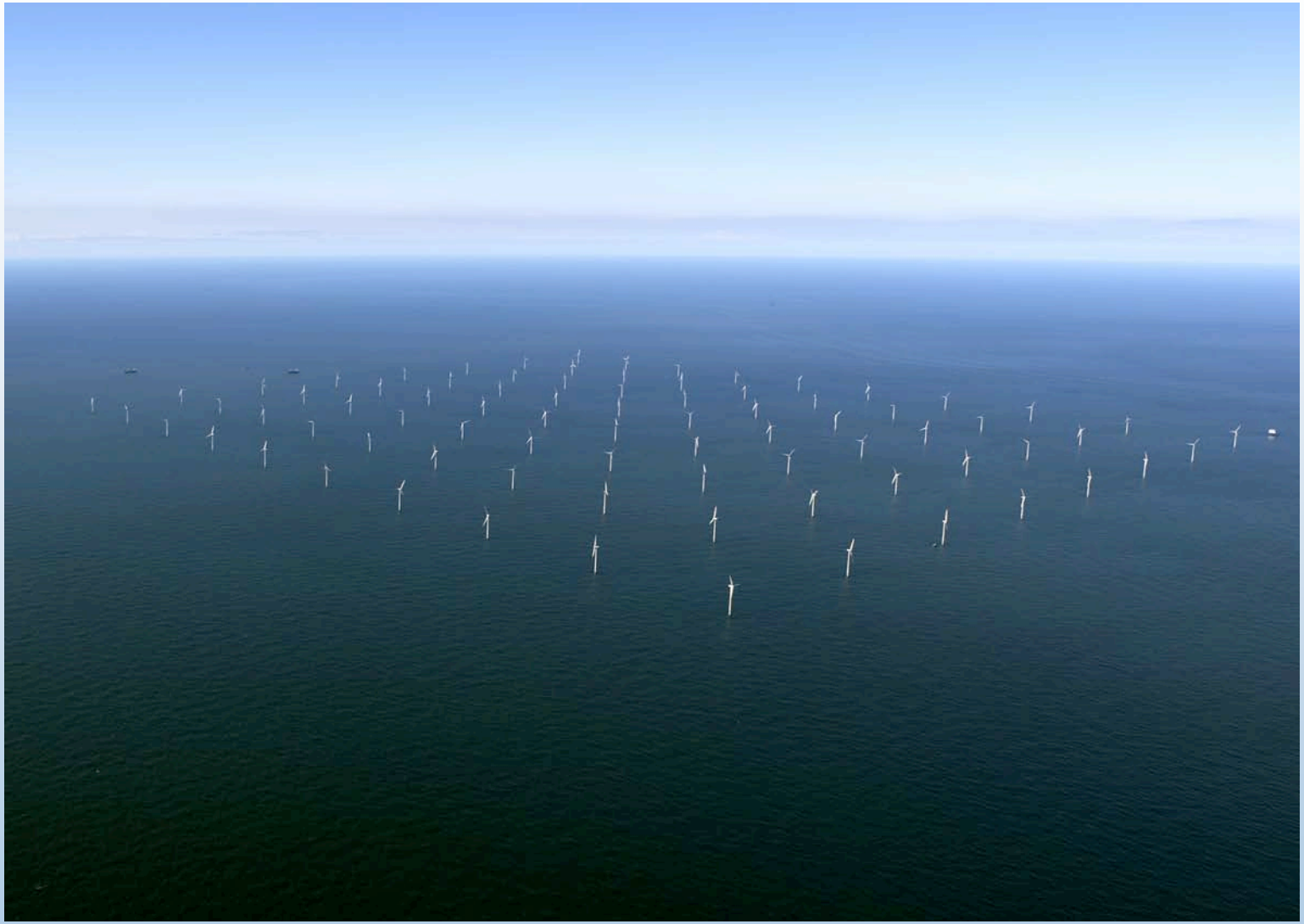
# Other EE/RE drivers

- System Benefit Charge Programs
- Renewable Portfolio Standards
- Energy Codes
- Appliance Standards
- Gov. purchase
  - Green Power
  - EE equipment standards
- Utility run Demand Side Management Programs
- More …

# Evolution of Commercial U.S. Wind Technology

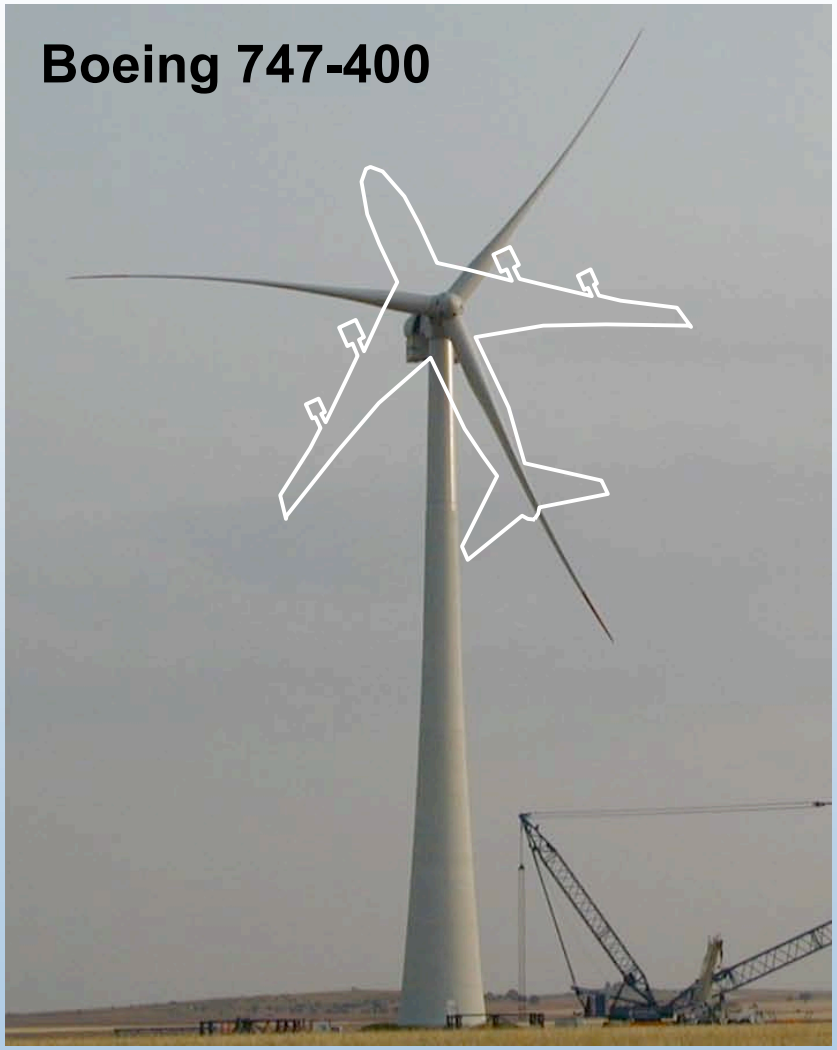


# Horns Rev 160MW

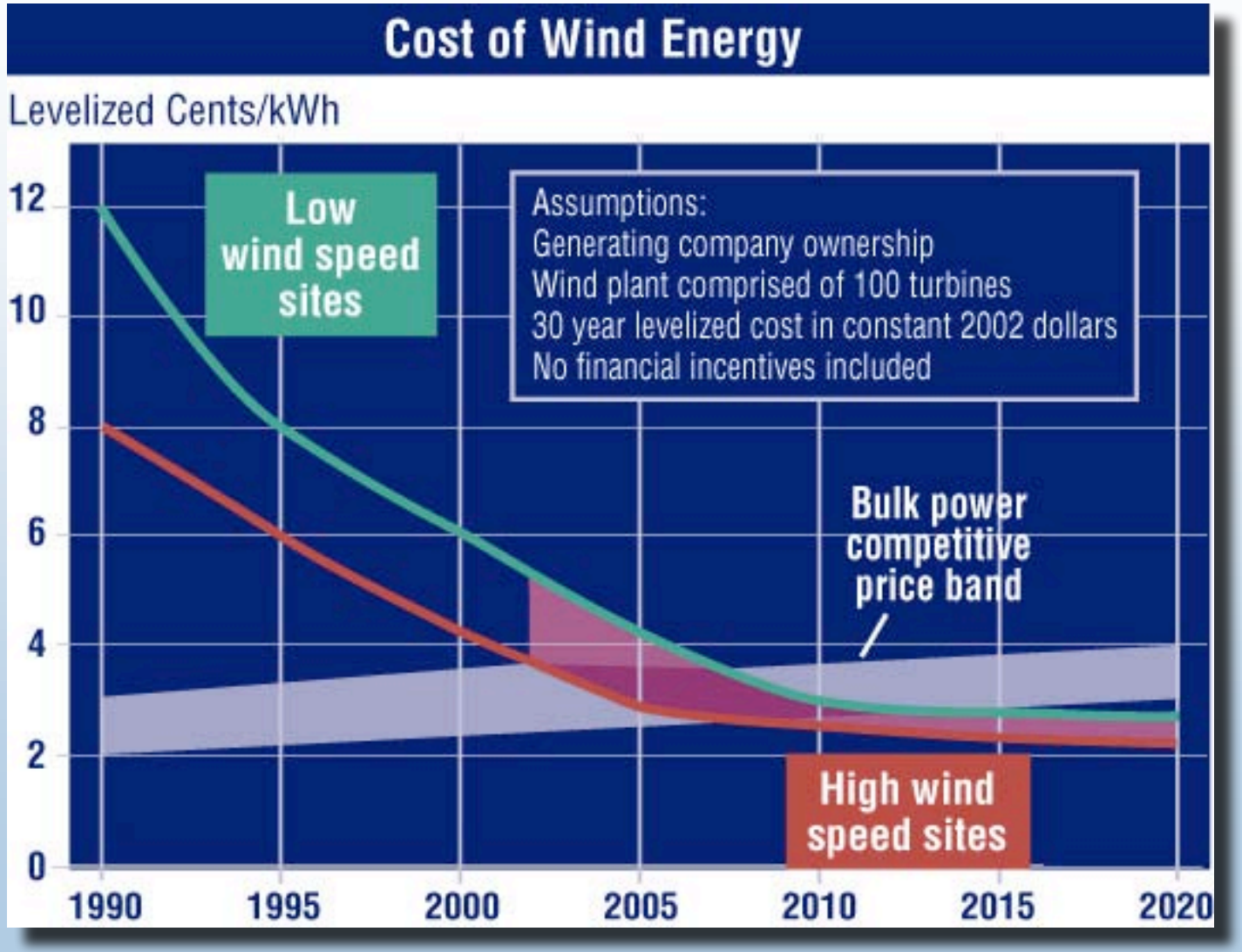


# Offshore GE Wind Energy 3.6 MW Prototype

- Offshore GE 3.6 MW
104 meter rotor diameter



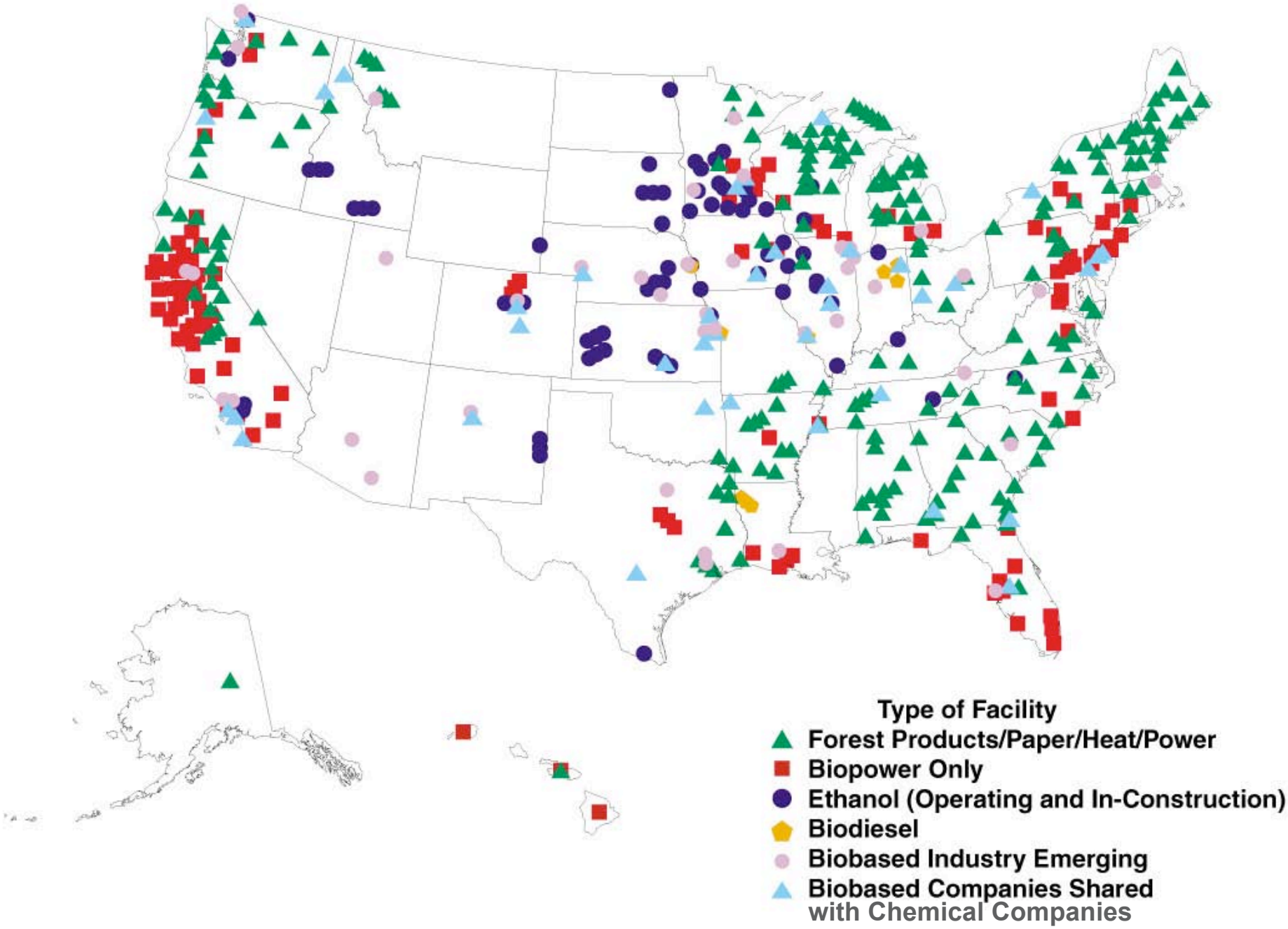
# Reducing the Cost of Energy



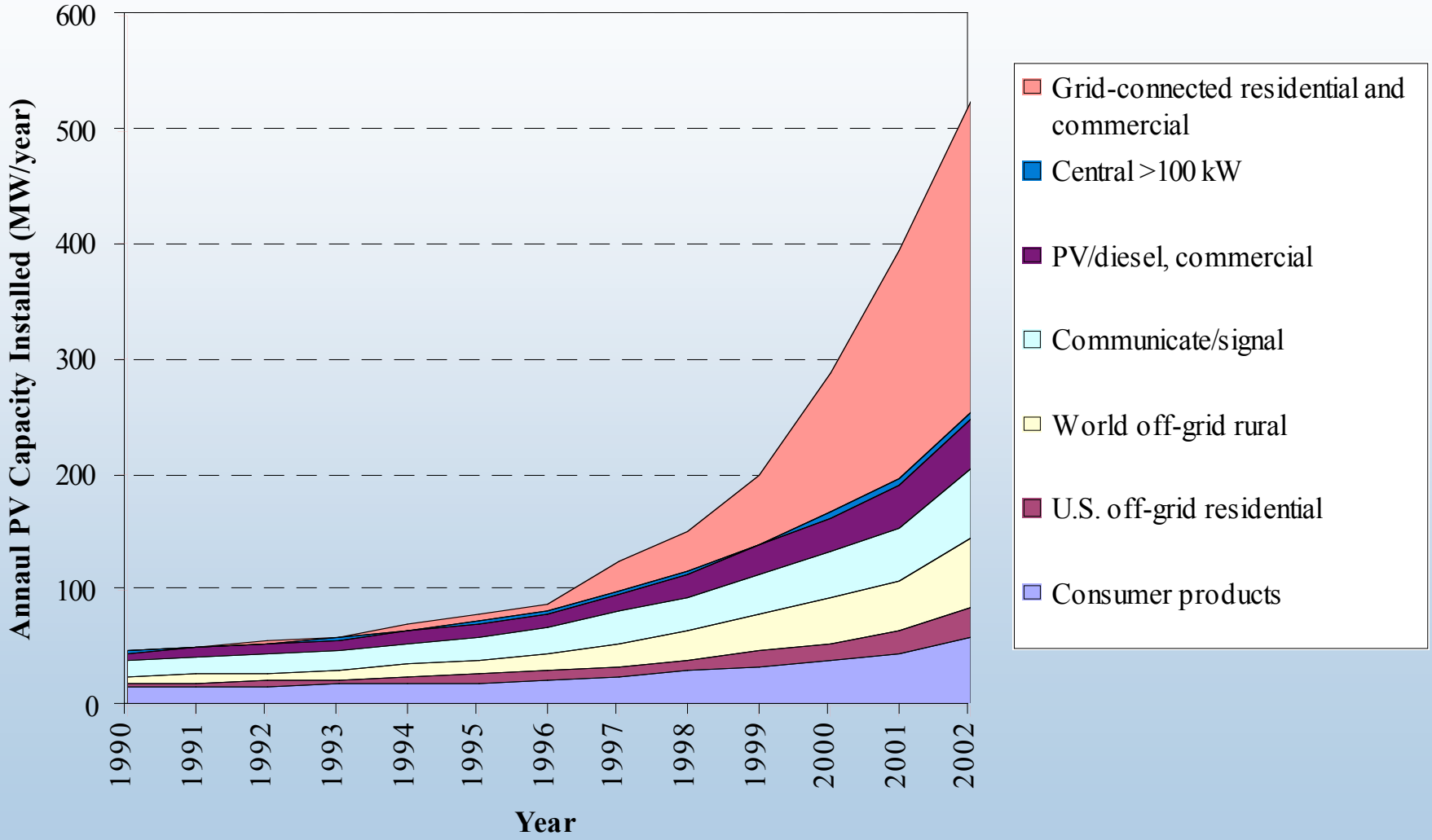
# Other Renewables with lower GHG emissions and can reduce ambient air pollutants

- Solar PV
- Geothermal
- Biomass Resources
- Biofuels

# Examples of Bioenergy and Biobased Products Facilities

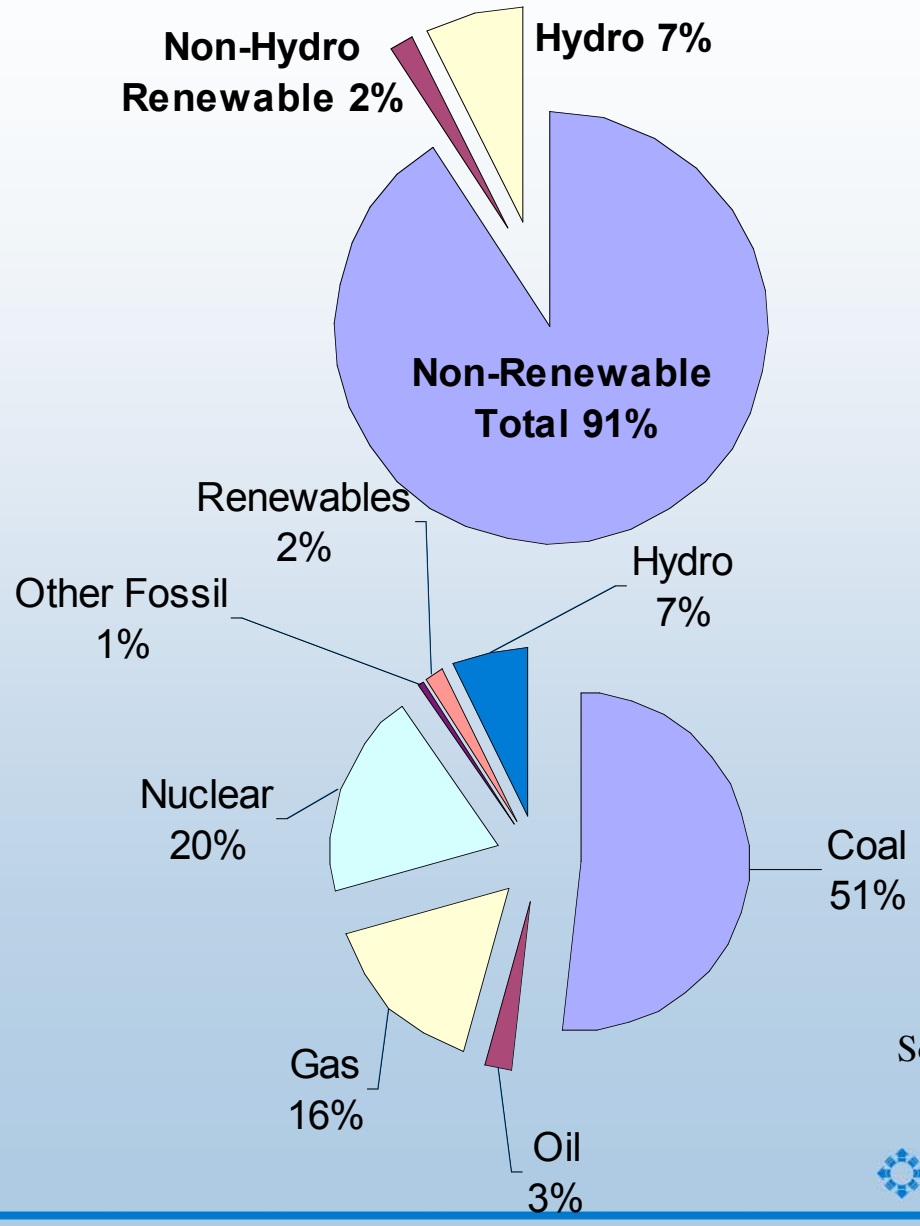


# World PV Market by Applications



# Geothermal Power Plant

# US Electricity Supply




Source: eGRID 2002PC

# Summary

- A carbon-emission-free energy world is probably easier than we tend to believe.
- Renewable resources more than adequate to supply a majority of energy needs
- Technologies are on performance and cost paths to provide that.
- Challenges include
  - Energy for transportation
  - Energy storage
  - Competing technologies

# Thank you

# Supplemental Slides

# Wind Energy

**Achievements and Status**

- Production costs about 4 cents/kWh
- Wind resources are vast, but also vary considerably on temporal, regional, and micro levels
- US wind energy capacity tripled in past decade, 6770 MW today
- Global capacity increasing 30% per year
- Green power programs have supported approximately 1,500 MW
- Recent energy costs are also accelerating interest in wind power,
- Environmental issues are minimal

**Likely Advances**

- Larger turbines - 3 MW+
- Expanding field experience will support both technology and business development
- Low wind speed turbines will expand range of sites
- Advanced power electronics
- Wind resource forecasting will enhance systems value
- Major transmission systems to tap Great Plains resources
- Offshore wind power plants, shallow and deep water

# Solar Thermal Electric

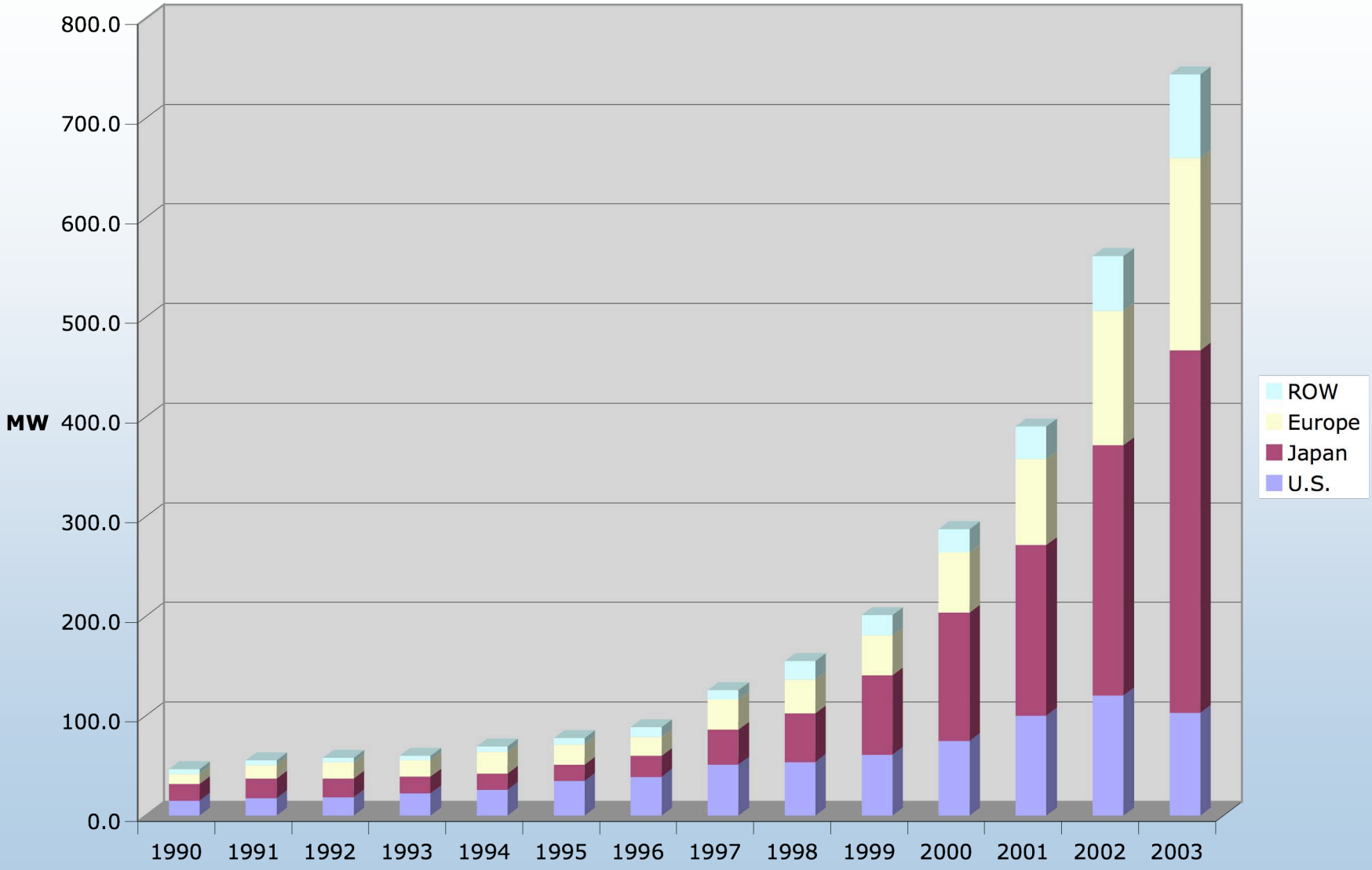
**Trough Technology (Bulk Power)**

**Dish/Engine Technology (Distributed Power)**

**Power Tower Technology (Bulk Power)**

**50-watt PV systems installed in homes in Brazilian village to provide lighting**

# Photovoltaics – Module Production



# PV Cost Information

- Module prices:
  - About $2.50 to $2.75/Wp commodity price
  - $3 to $3.25/Wp average price
- System costs:
  - $6 to $9/Wp
  - Anecdotes of systems below $4/Wp
- Customer-siting and peak load matching enhance value of PV power

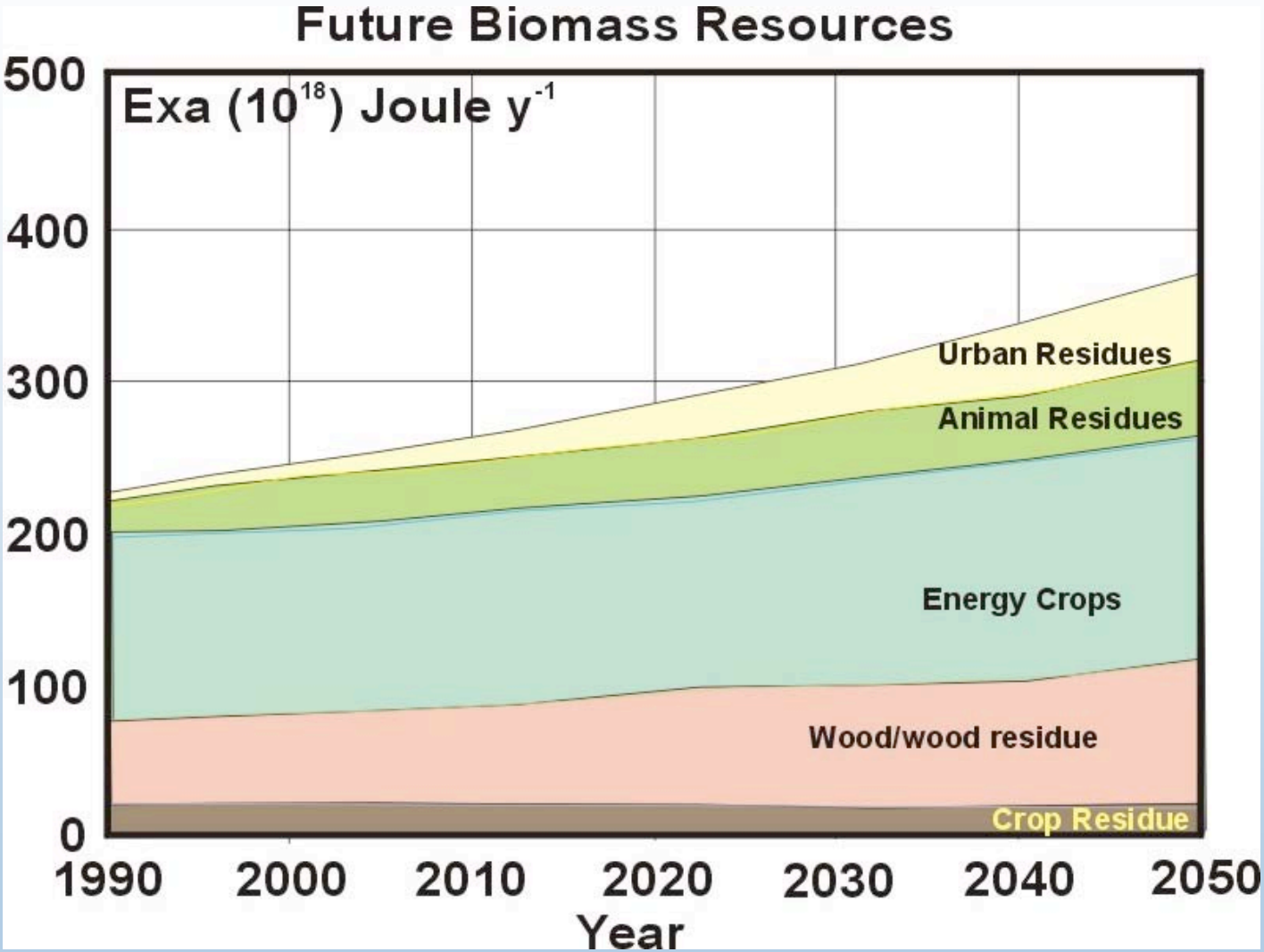
# Solar Photovoltaics

**Achievements and Status**

- Steady progress in
  - Increasing efficiencies
  - Module & system costs
  - Reliability & lifetimes
- Sales increasing 25% or more per year
- Major expansions of manufacturing capacities underway
- Value of building-integrated systems gaining recognition
- Widespread deployment in Japan and Europe

**Likely Advances**

- Significant technology and manufacturing advances.
- Significant efficiency gains
- System costs below $3/Wp, electricity 5 to 10 cents/kWh
- Standardized power controls & interconnection equipment
- Better understanding of PV's distributed resource and peaking load values
- Organic and polymeric cells
- PV in electric vehicles??

# IIASA Estimate

## (resource-based technical potential)