ITEN-DOE/NREL
Strategic Planning Meeting

4-5 December 2001

Golden, Colorado

Roger Taylor

Manager, International Programs

Renewable Energy Technology Overview and Strategic Planning Challenges for Indian Country

An International Perspective on American Indian Country Renewable Energy Opportunities

International: *adj.*

1. Between or among nations: as, an *international* treaty.
2. Concerned with relations between nations: as, an *international* collaboration.

The Challenge of International Clean & Renewable Energy Activities

- Currently 6 billion people on the planet
- 1.2 billion living in developed (OECD) countries
- 4.8 billion, 80%, in developing countries
  - Three billion of them live on under $2 a day
  - Two billion of them live in rural areas
  - Two billion of them don't have any power

- 6 billion today, will grow to 8 billion people in 25 years
  - 97 percent of the growth will be in the developing world = 6.8 billion in developing countries

Key Countries

In the RE Business, There are Two, Totally Different Economic Worlds

- **On-Grid – Competition for new economic generation, and cost-effective reductions in load.**

- **Off-Grid – Services and economic development for disadvantaged rural populations.**

Perspective on Renewables for the International Marketplace

- The off-grid markets in the developing world are enormous, and growing. The challenge is cost-effective service delivery at a scale that can make a difference in global energy needs.

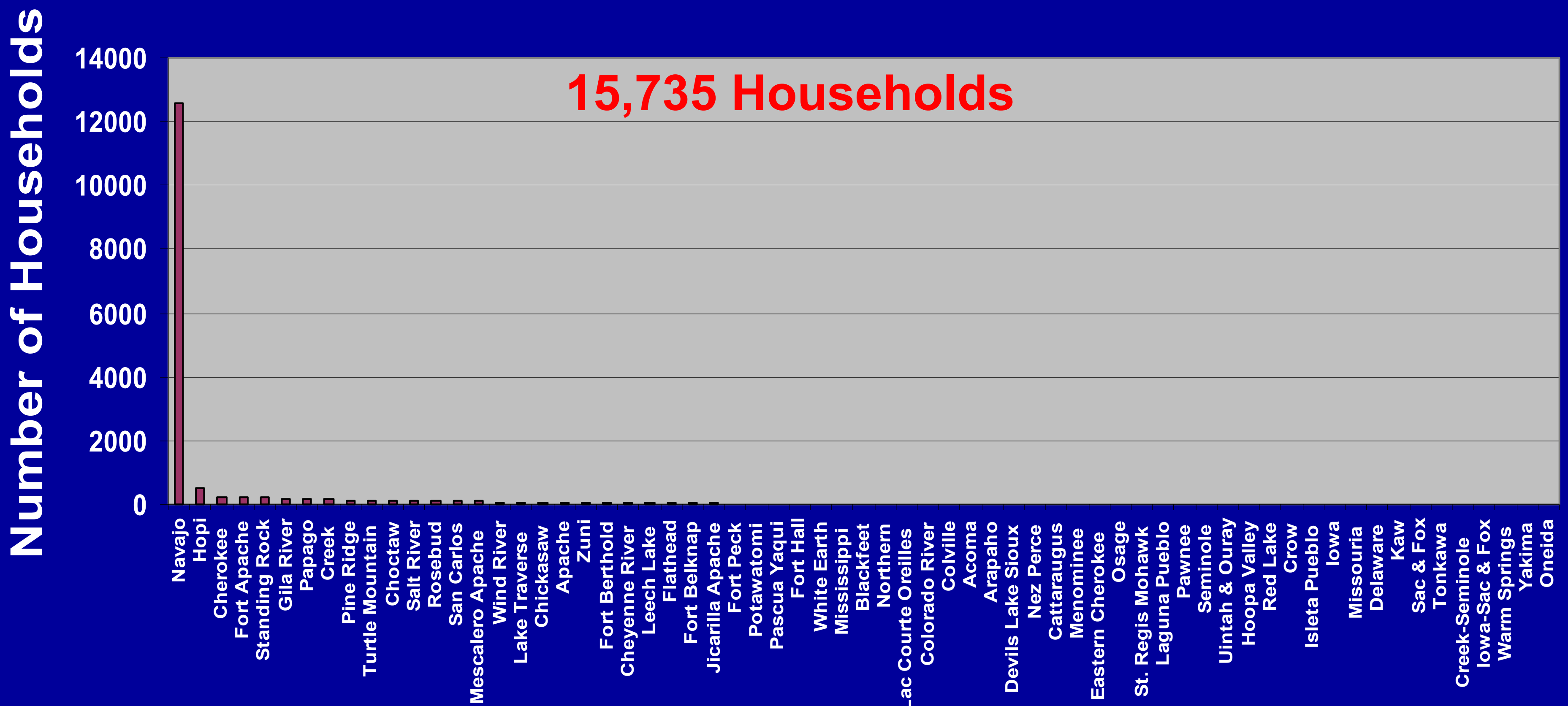
- The on-grid markets throughout both the developed and developing world are enormous and growing. The challenge is effective identification and implementation of large-scale projects.

SR/CNEAF/2000-01
April 2000

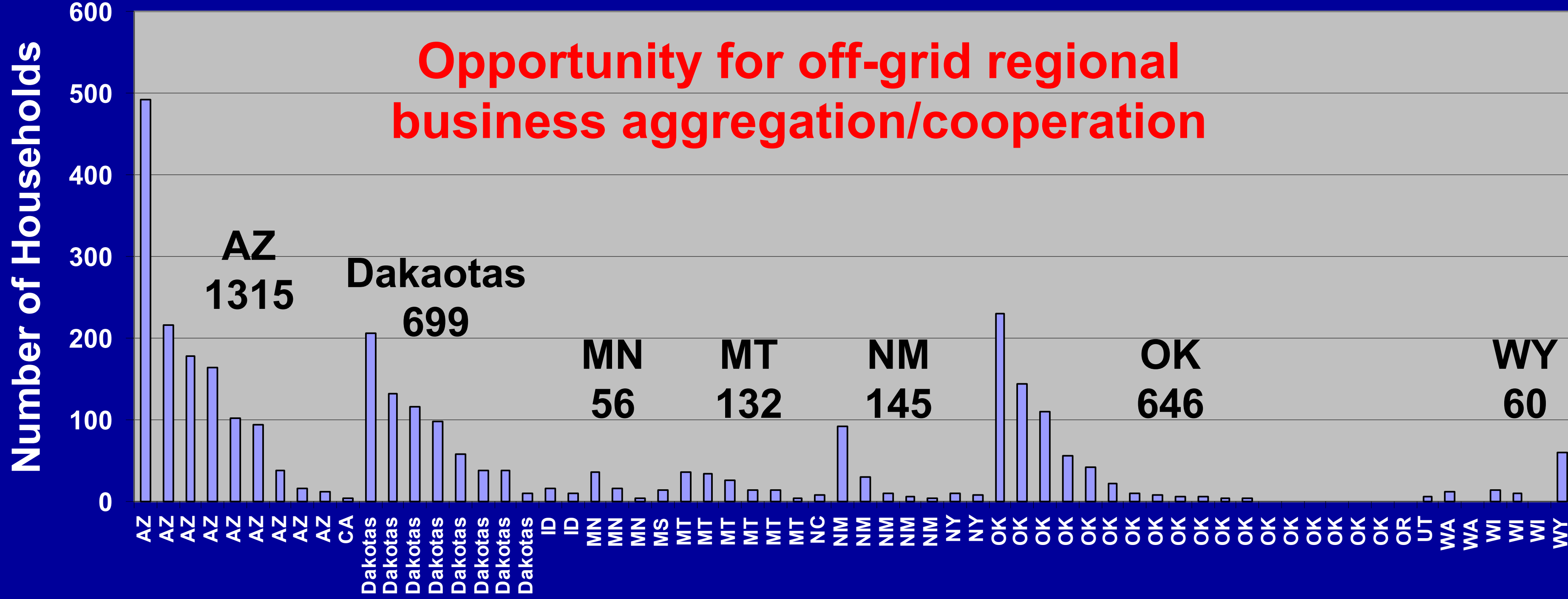
Energy Consumption and Renewable Energy Development Potential on Indian Lands

www.eia.doe.gov
eia Energy Information Administration

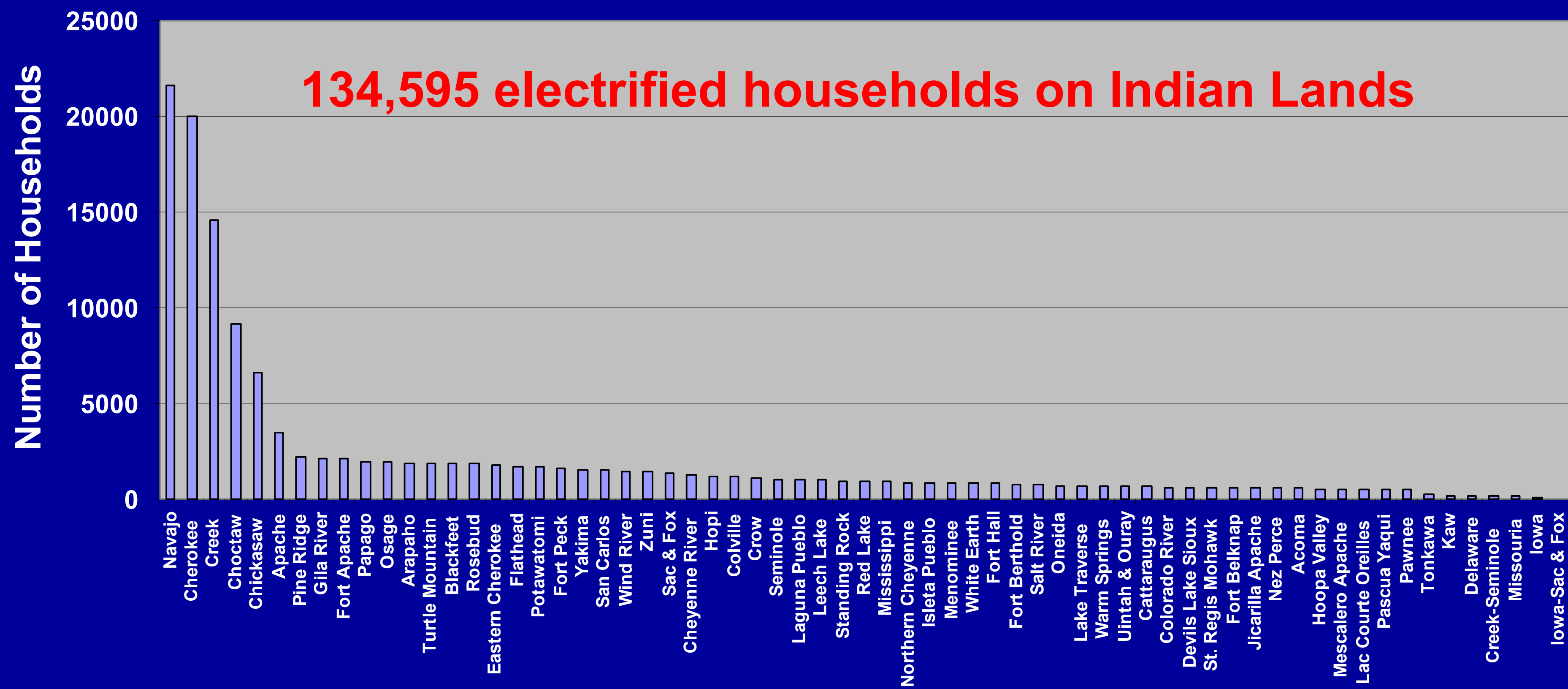
Indian Households: No Electricity Access



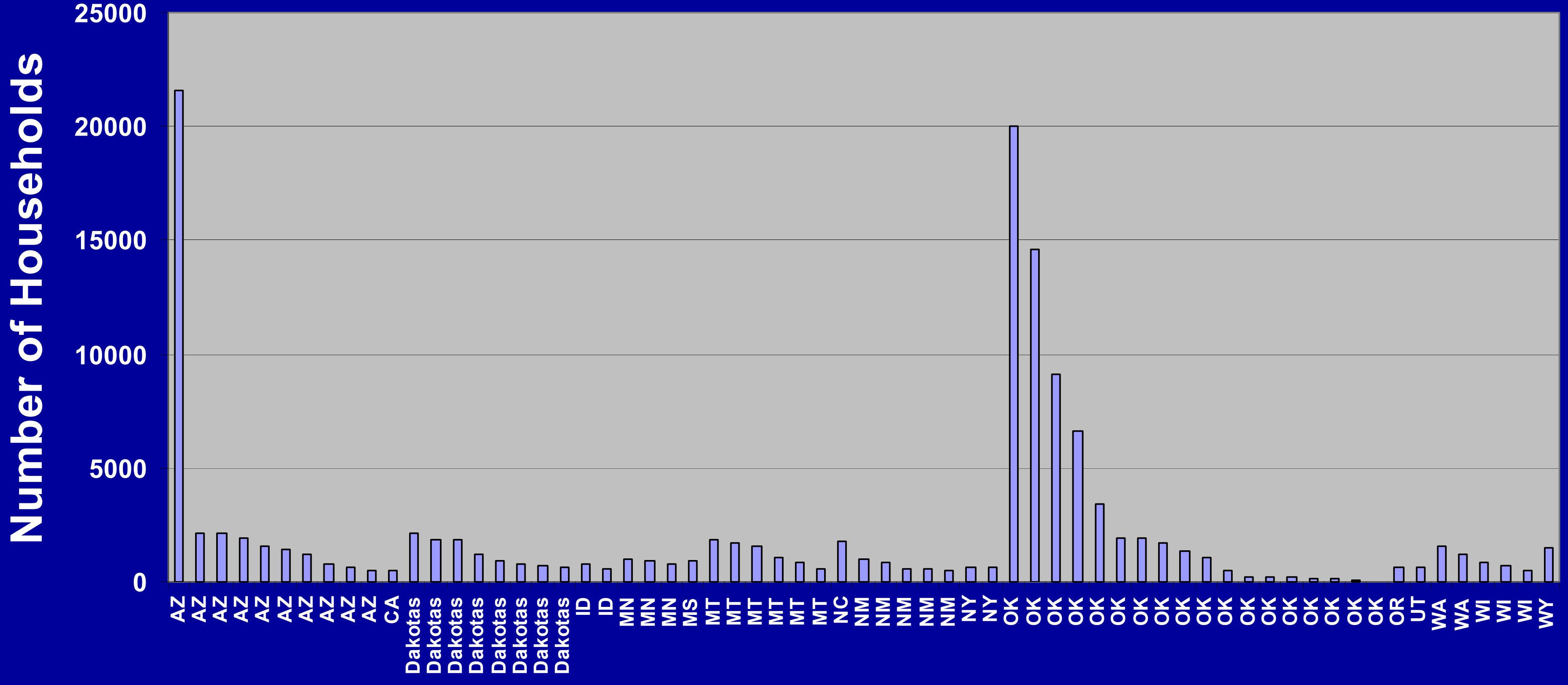
Indian Households - No Electricity Access (less Navaho)



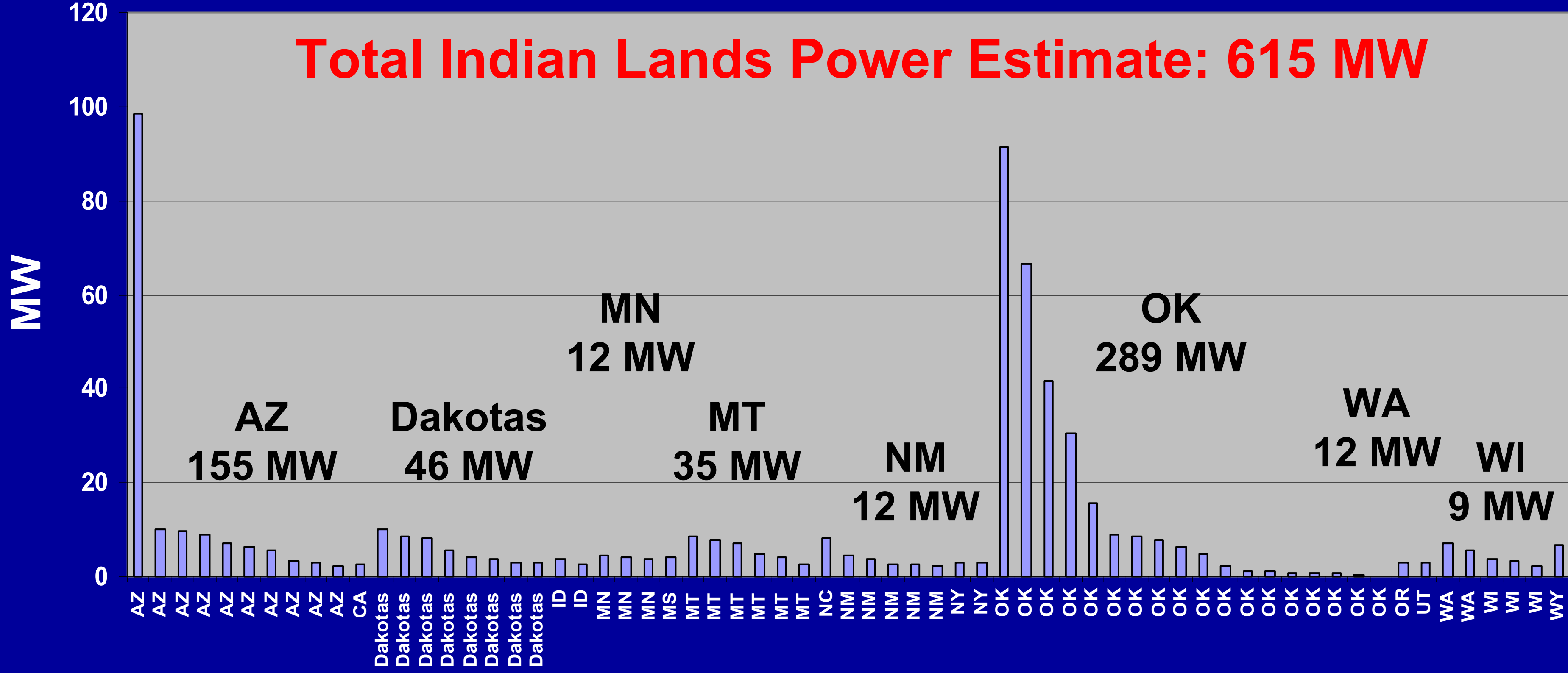
Indian Lands Households - Electrified



Electrified Households by State



MW Estimate for Electrified Households



Assumptions: 1000kWh/Household/Month, 30% Capacity Factor on Generation

Perspective on Renewables for the Indian Country Marketplace

- The off-grid markets in Indian Country are important, but not pervasive and probably declining. The challenge is cost-effective development and delivery of sustainable projects that meet the economic development needs of particular, isolated populations.

- The on-grid markets in Indian Country are regionally important, but limited (by population and economic development). However, electricity supply opportunities from Indian Country to the U.S. are very large. The challenge is identification and implementation of projects that meet both Indian Country and U.S. energy needs in a win-win arrangement.

Sources of Renewable Energy

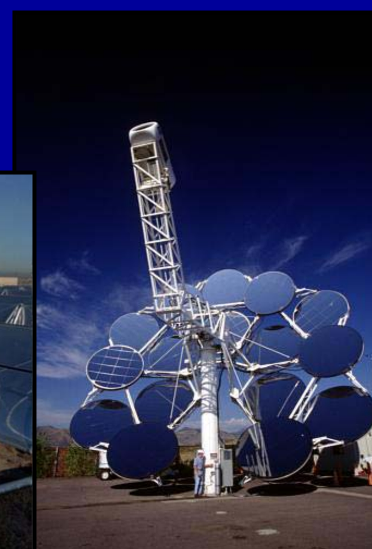
02556025

Life Cycle Cost (LCC): Total Lifetime Cost of System Designed to Meet Specific Load

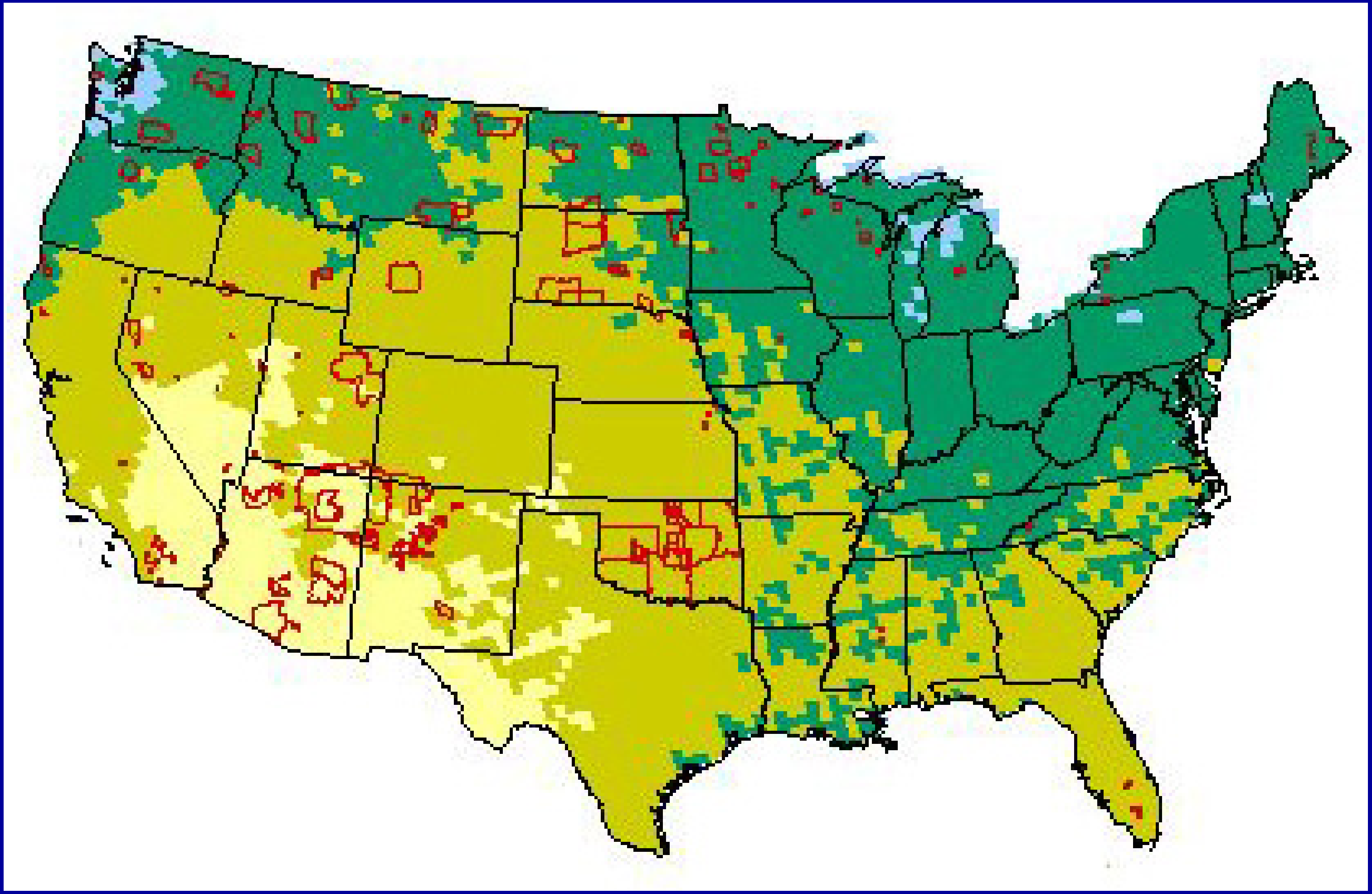
$$LCC = (\text{Initial Costs} + \text{O\&M Costs} + \text{Major Repairs} + \text{Fuel Costs} - \text{Salvage Value})_{PW}$$

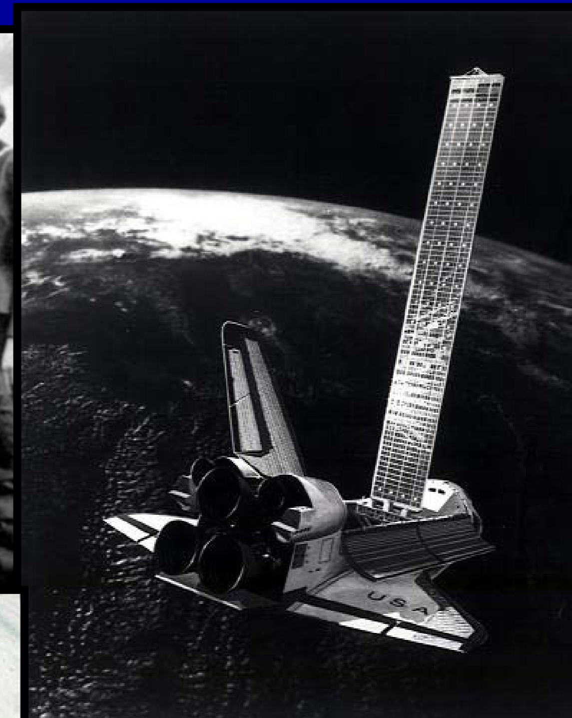
- <u>Initial Costs</u> Determined by <u>System Size</u> to Meet Loads
- <u>System Size</u> Determined by <u>Resource Availability</u>

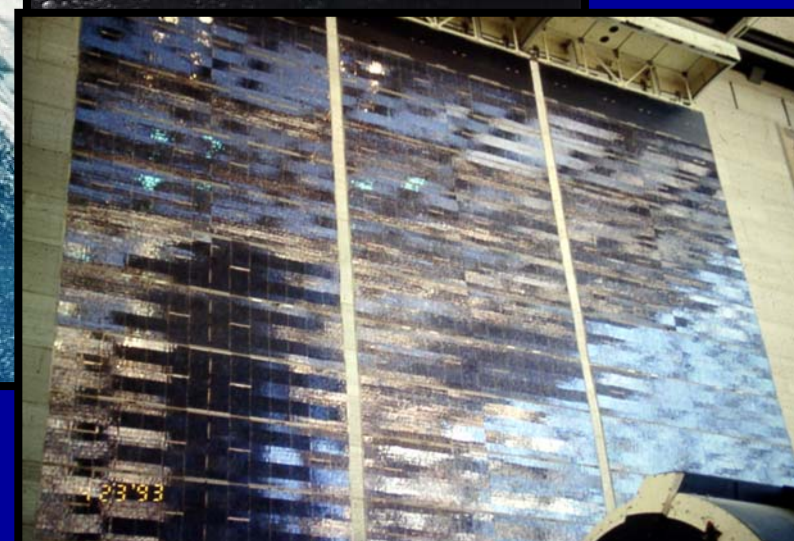
Solar-based Technologies and Applications



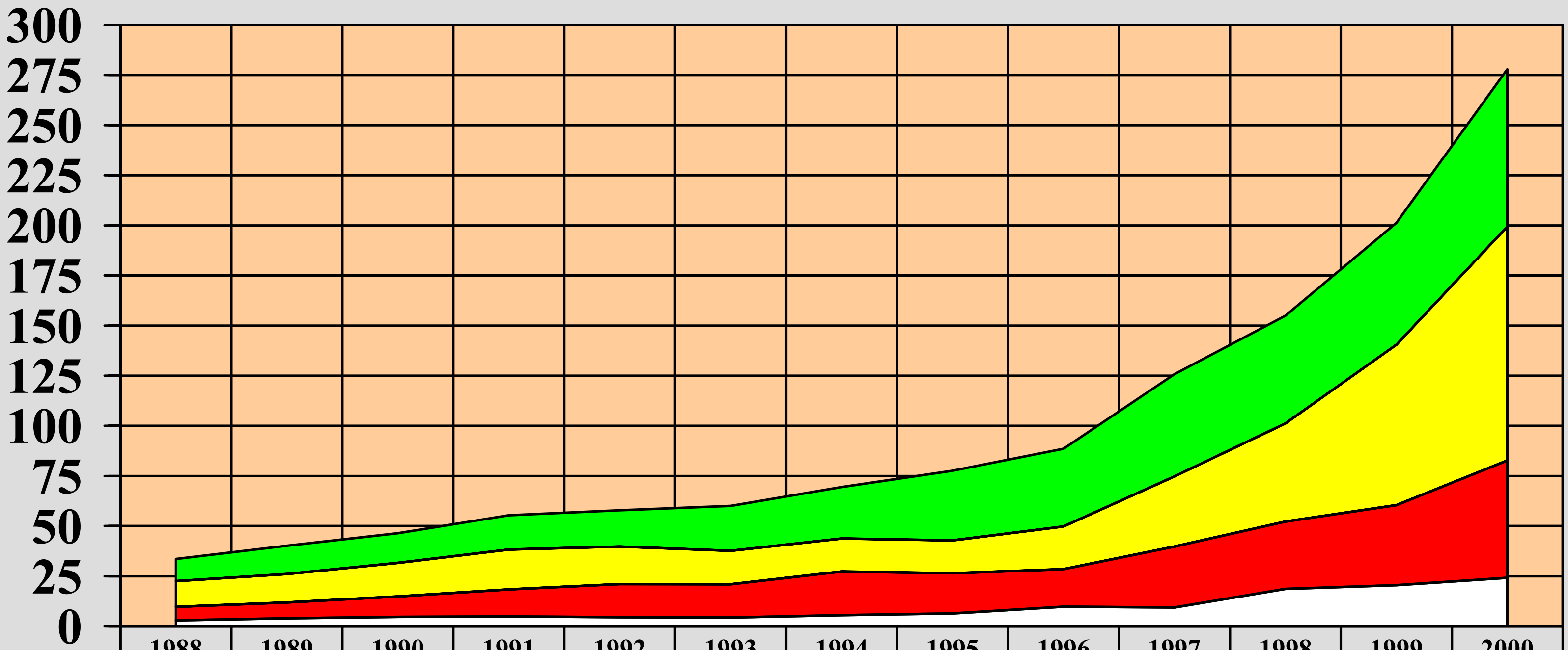
Solar Resource – Flat Plate Applications




USA

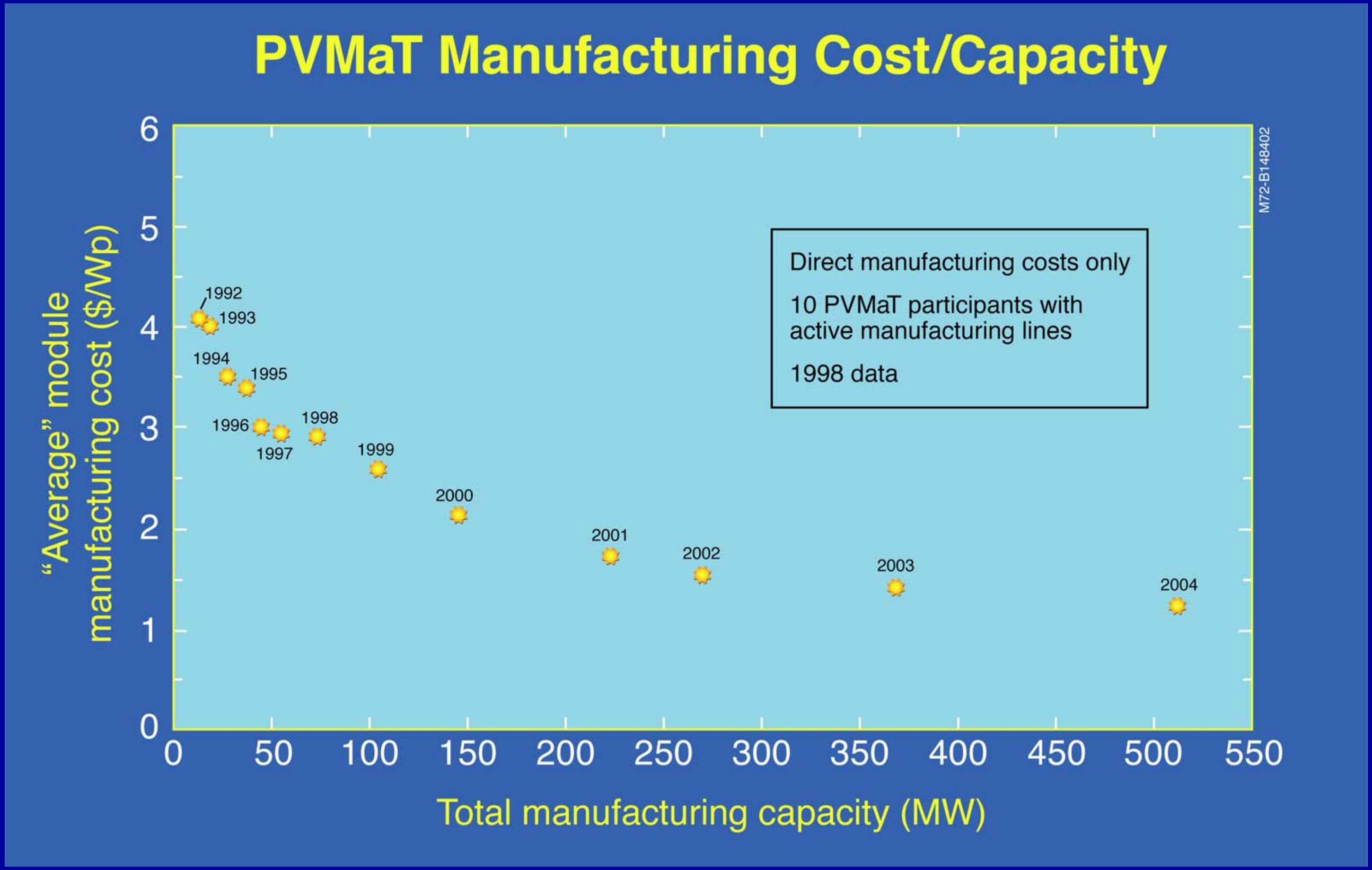


World PV Cell/Module Production (1988-2000)
(in Megawatts)



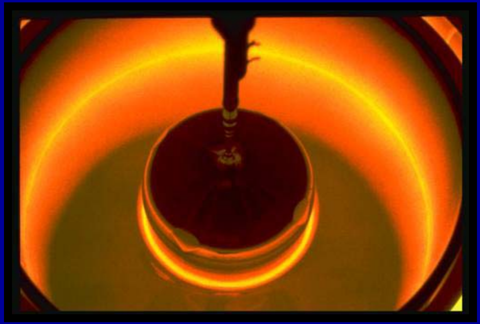
	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
United States	11.1	14.1	14.8	17.1	18.1	22.44	25.64	34.75	38.85	51	53.7	60.8	78.5
Japan	12.8	14.2	16.8	19.9	18.8	16.7	16.5	16.4	21.2	35	49	80	116.7
Europe	6.7	7.9	10.2	13.4	16.4	16.55	21.7	20.1	18.8	30.4	33.5	40	58.5
Rest of World	3	4	4.7	5	4.6	4.4	5.6	6.35	9.75	9.4	18.7	20.5	24.2

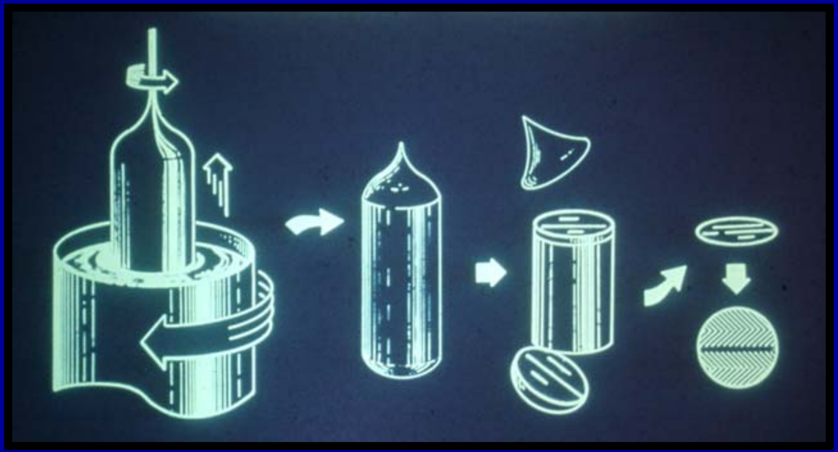
From PV News, Paul Maycock, editor; yearly February editions.

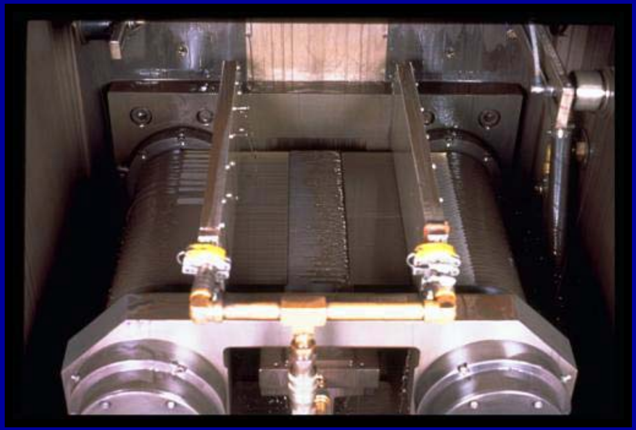


- **PV works, reliable, competitive in many rapidly-growing markets**
- **Continuing technical advances: higher efficiencies and lower costs**
- **Significant manufacturing expansions underway: few 100s of MW in near term**
- **Crystalline silicon dominates markets**
- **Many challenges for new technologies: technical, market, and financial risks**

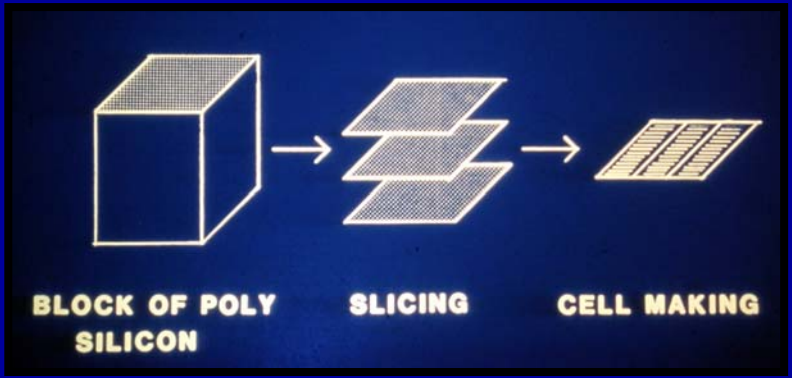
“Czochralski” Technology

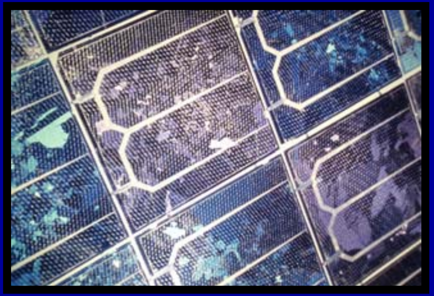


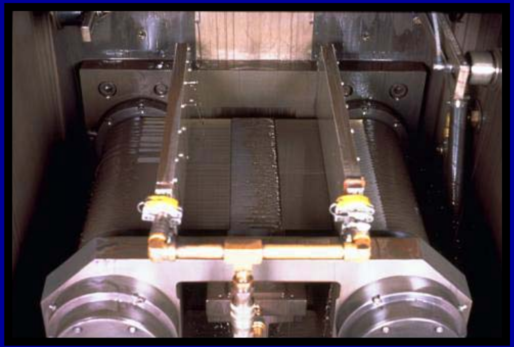




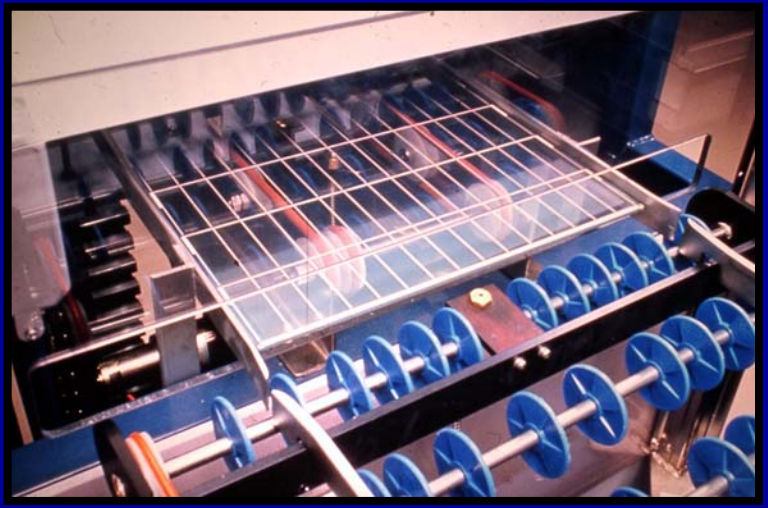
Cast Polycrystalline Technology

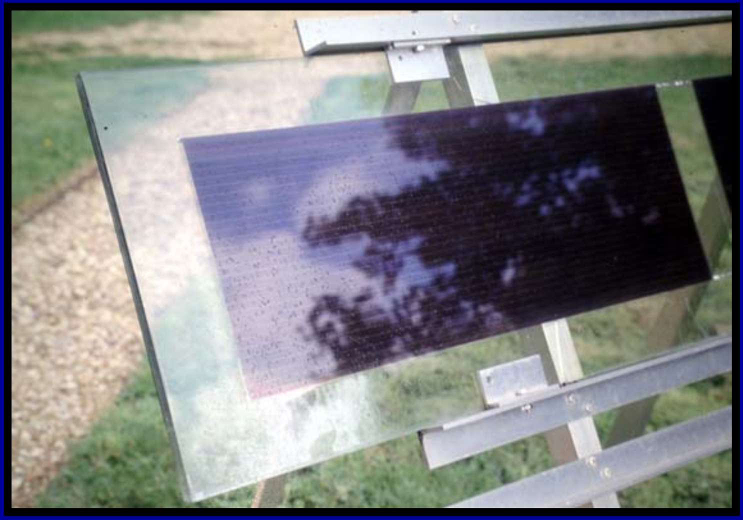






Thin Film Technologies On Glass





Thin Film Technologies On Flexible Substrates

Solar Home Systems

Brazil

India

China

Ghana

Public Area Lighting

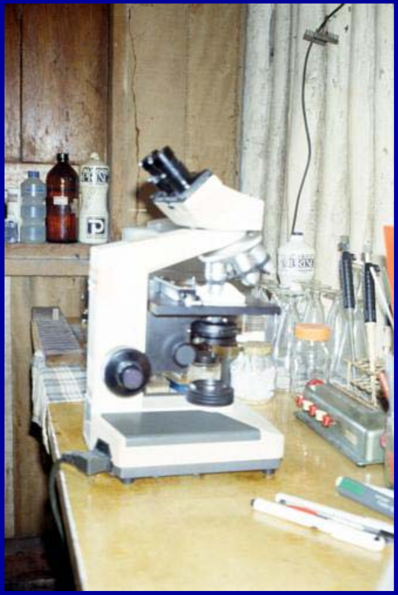
Schools

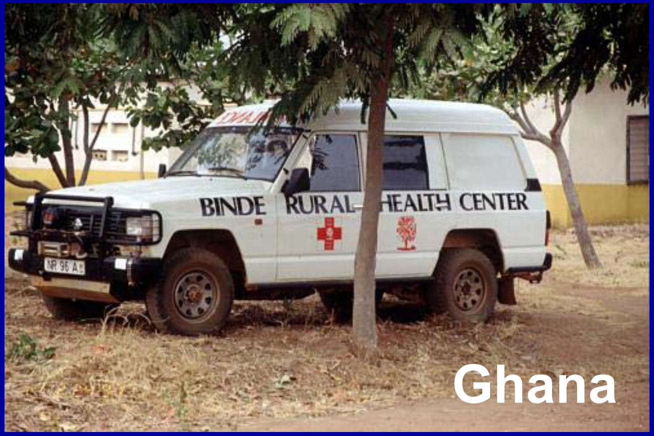
Lights
Computers
VCRs
Distance Learning
Adult Education

Brazil

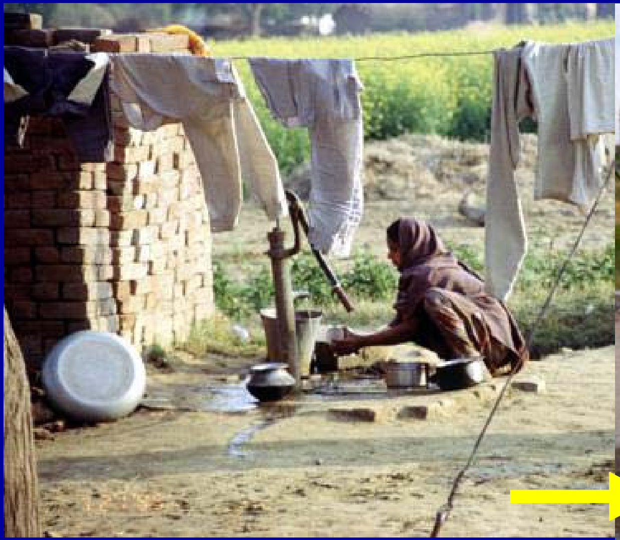
South Africa

Health Clinics



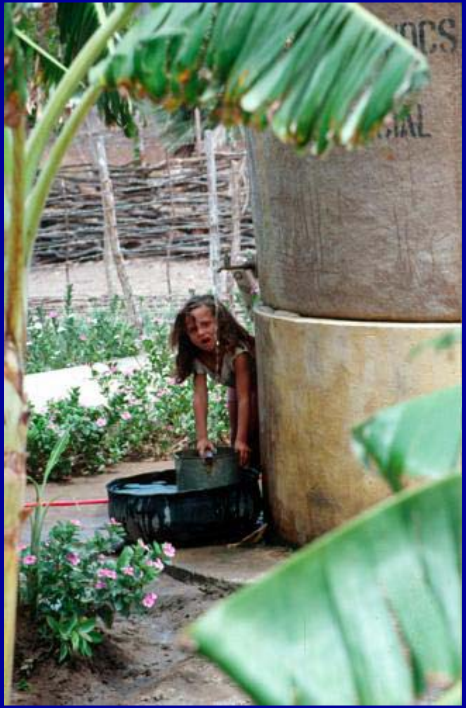


Water Pumping



India

Brazil



Water Purification

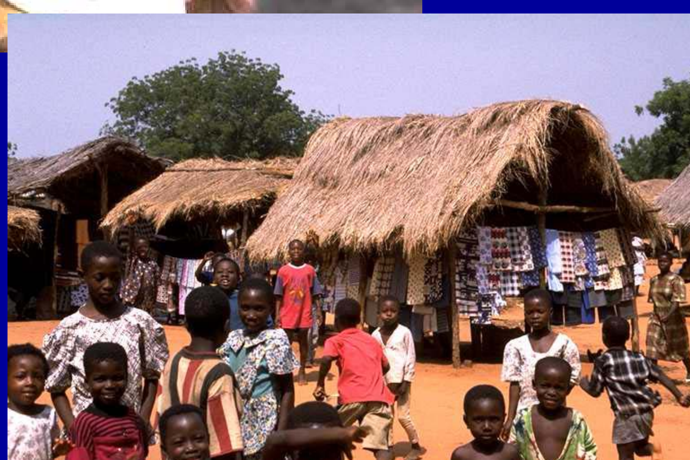
Philippines

Bangladesh

Nigeria

Mexico

Microenterprise Development



Ghana

India

China

Rural Telephony

Brazil

Central Station PV

Solar Thermal Applications

- Low Temperature (> 30C)
  - Swimming pool heating
  - Ventilation air preheating
- Medium Temperature (30C – 100C)
  - Domestic water and space heating
  - Commercial cafeterias, laundries, hotels
  - Industrial process heating
- High Temperature (> 100C)
  - Industrial process heating
  - Electricity generation
- Solar thermal and photovoltaics working together

Solar Water Heating Is Not New!

- Before the advent of gas pipelines and electric utilities, the technology gained footholds in Florida and California before the 1920's
- Over 1,000,000 systems are in use in American homes and business
- The technology is in widespread use in:
  - Caribbean basin
  - China
  - Israel
  - Greece
  - Japan
  - Australia

Typical Low Temperature Application

Low Temperture Example:
Barnes Field House, Fort Huachuca, AZ

- 2,000 square feet of unglazed collectors
- 3,500 square feet indoor pool
- Installed cost of $35,000
- Meets 49% of pool heating load
- Saves 835 million Btu/ year of natural gas
- Annual savings of $5,400
- Installed by the Army in June, 1980.

Mid-Temperature Example:
Chickasaw National Recreation Area, OK

Small Comfort Stations
- 195 square feet of flat plate collectors
- 500 gallon strorage volume
- Cost $7,804
- Delivers 9,394 kWh/year
- Saves $867 / year

Large Comfort Stations
- 484 square feet of flat plate collectors
- 1000 gallon strorage volume
- Cost $16,100
- Delivers 18,194 kWh/year
- Saves $1,789 / year

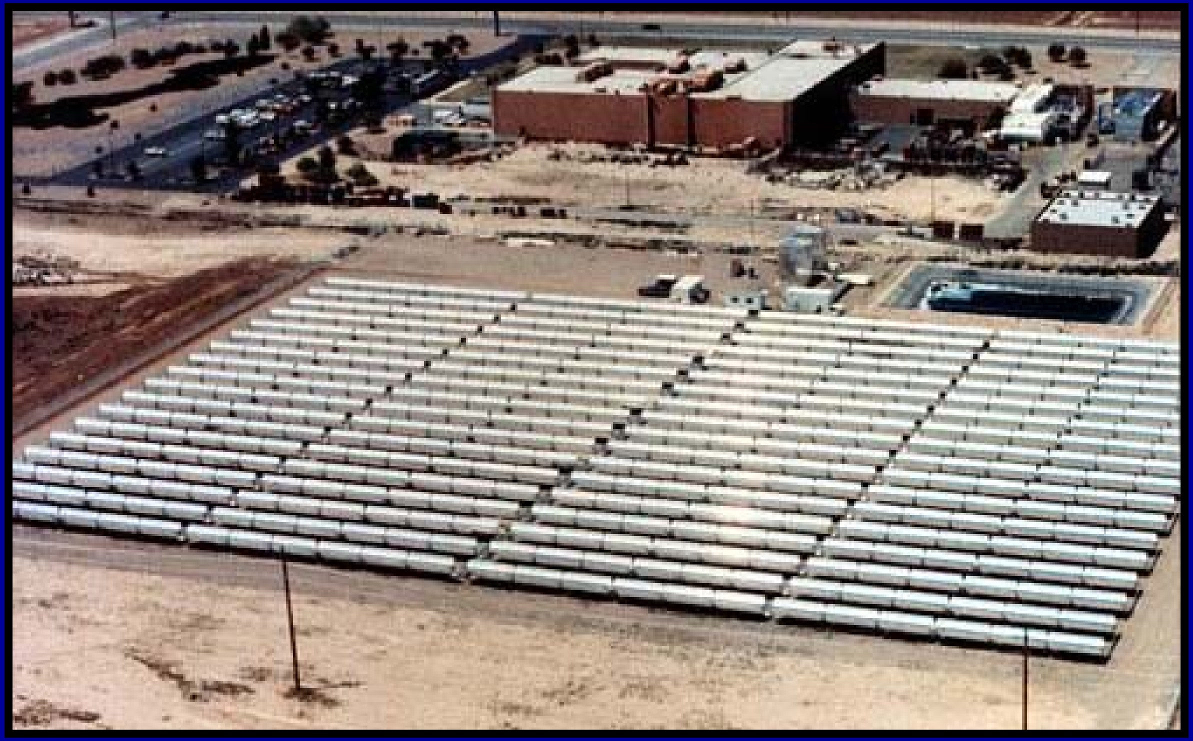
Mid Temperature Example:
USCG Kiai Kai Hale Housing Area, Honolulu HI

- 62 units installed 1998
- Active (pumped), Direct systems
- Average cost $4,000 per system
- 80 sf per system
- $800 per system HECO rebate
- Savings of 9,700 kWh/year and $822/year per system
- Simple Payback 4 years (with rebate)

High Temperature Example:
State Prison in Tehachapi, California

This system heats water for the kitchen, bathing, and laundry facilities, supplying 7.2 billion BTUs of thermal energy annually to the 5100-inmate prison.

Industrial Process Heating



Gould Electronics of Chandler, Arizona, has had its parabolic-trough collector system since 1982. The system uses oil for heat transfer for higher-temperature uses. The system provides process water for copper foil production.

Building Design

"Whole Buildings" Strategy:

Existing R&D programs, building technologies, and components tied together by Systems Integration and Computerized Design Tools.

Passive Solar Strategies

Siting and orientation, glazing size and location, and shading strategies contribute to a passive solar, or "climate-responsive," building.

Advanced Technologies

Energy-saving appliances, advanced energy controls and thermostats, efficient heating and cooling systems, photovoltaics, and solar water heating systems.

Energy-Efficient Materials

Superior building materials, including high-efficiency windows, insulation, brick, concrete masonry, and interior finish products.

Renewable Energy for Buildings

- Daylighting
- Passive Solar Heating
- Cooling Load Avoidance
- Natural Ventilation
- Solar Ventilation Air Preheating
- Solar Water Heating
- Building Integrated Photovoltaics

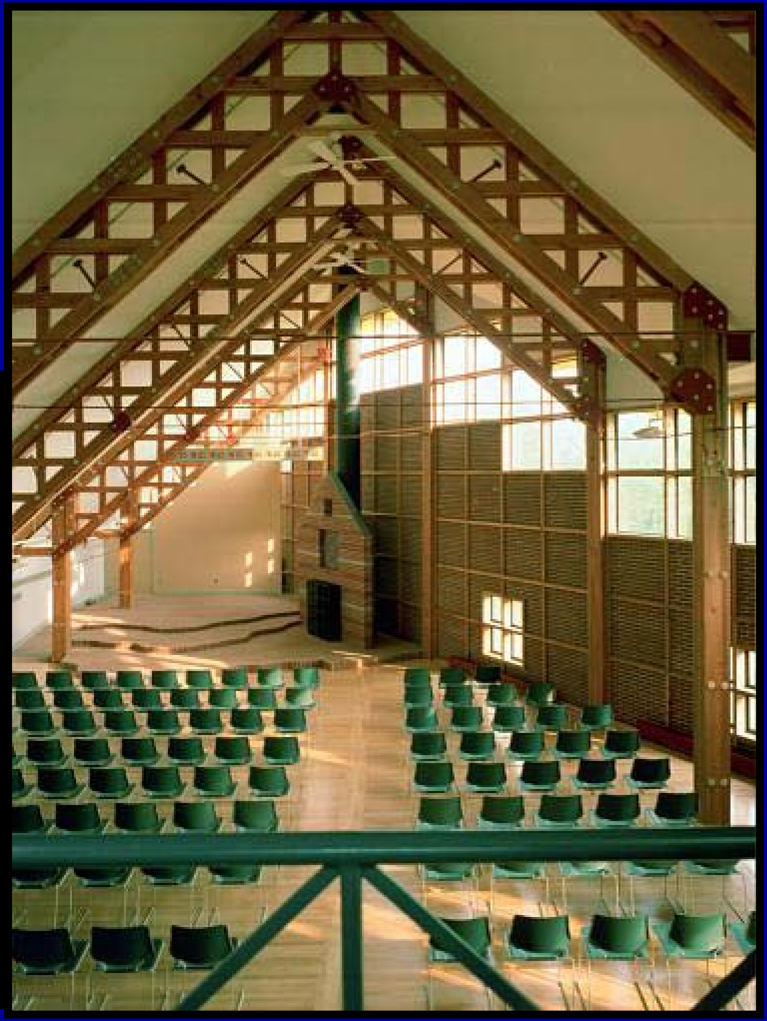
Daylighting: Light Shelves

Daylighting: Windows

North: best

South: good with overhangs

East and West: summer heat gain



Shelly Ridge Girl Scout Center

Daylighting: Skylights

Solar Heat Gain is Maximum in summer!!!

Shades and reflectors

Passive Solar Heating
Sunspace

Cooling Load Avoidance
Vegetation

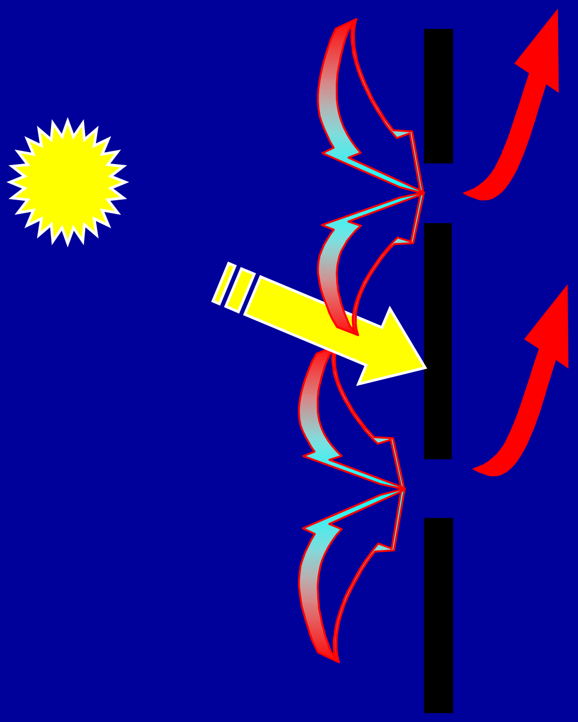
Cooling Load Avoidance
Reflective Roof

Natural Ventilation

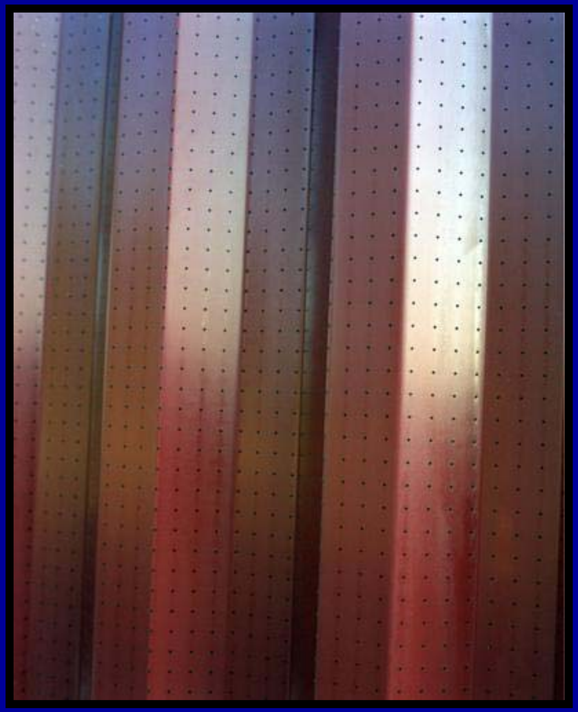
- Stack Effect (bouyancy)
  - effective in winter (temperature difference)
- Wind
- Evaporative Cooling
  - dry: heavy, humid:light
  - cold:heavy, warm:light

Zion National Park, UT

Transpired Collector Principle



- Sun warms the surface
- Heat conducts from surface to thermal boundary layer of air 1 to 3 mm thick
- Velocity boundary layer of air is drawn into hole before heat can escape by convection

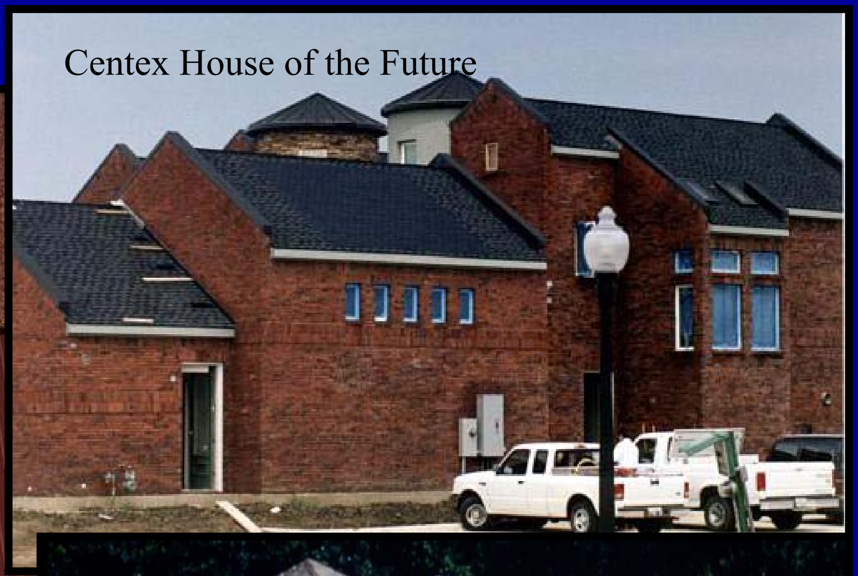


Federal Express Distribution Center Littleton, Colorado

- 5,000 ft^2 of "Colonial Red" panels
- Installed cost: $55,000 ($11/ft^2)
- Estimated annual natural gas savings: 230 million BTU
- Estimated value of gas savings: at least $7,000/year
- System start up date: June 1996

Federal Express in Denver

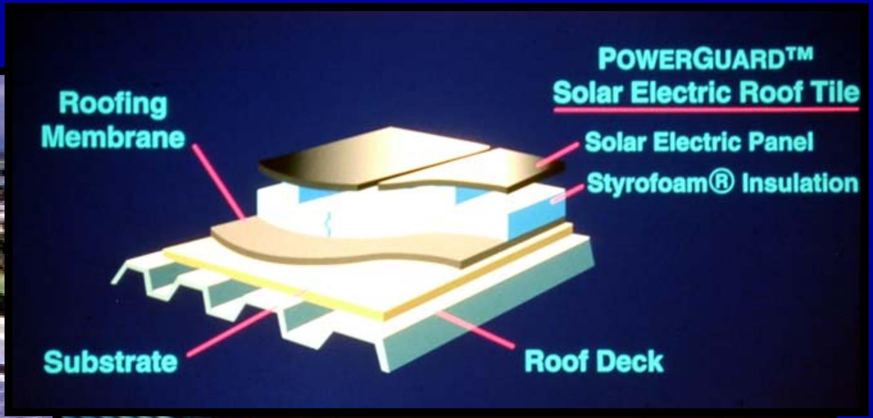
BIPV: Shingles



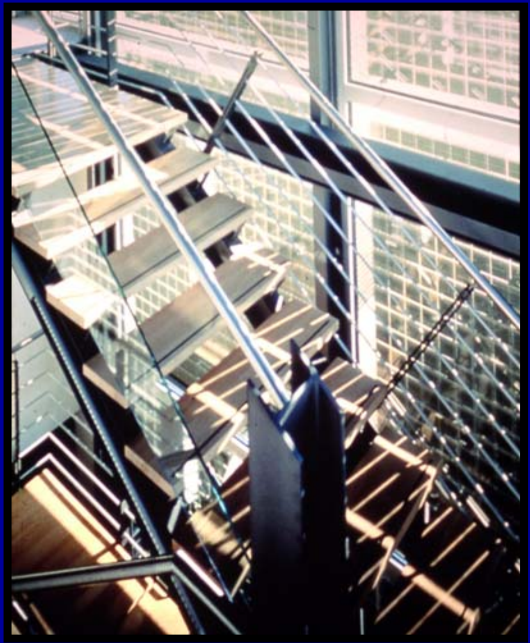
BIPV: Spandrel Glass

BIPV: Standing Seam Metal Roofing

BIPV: Roofing Pavers



BIPV: Facades

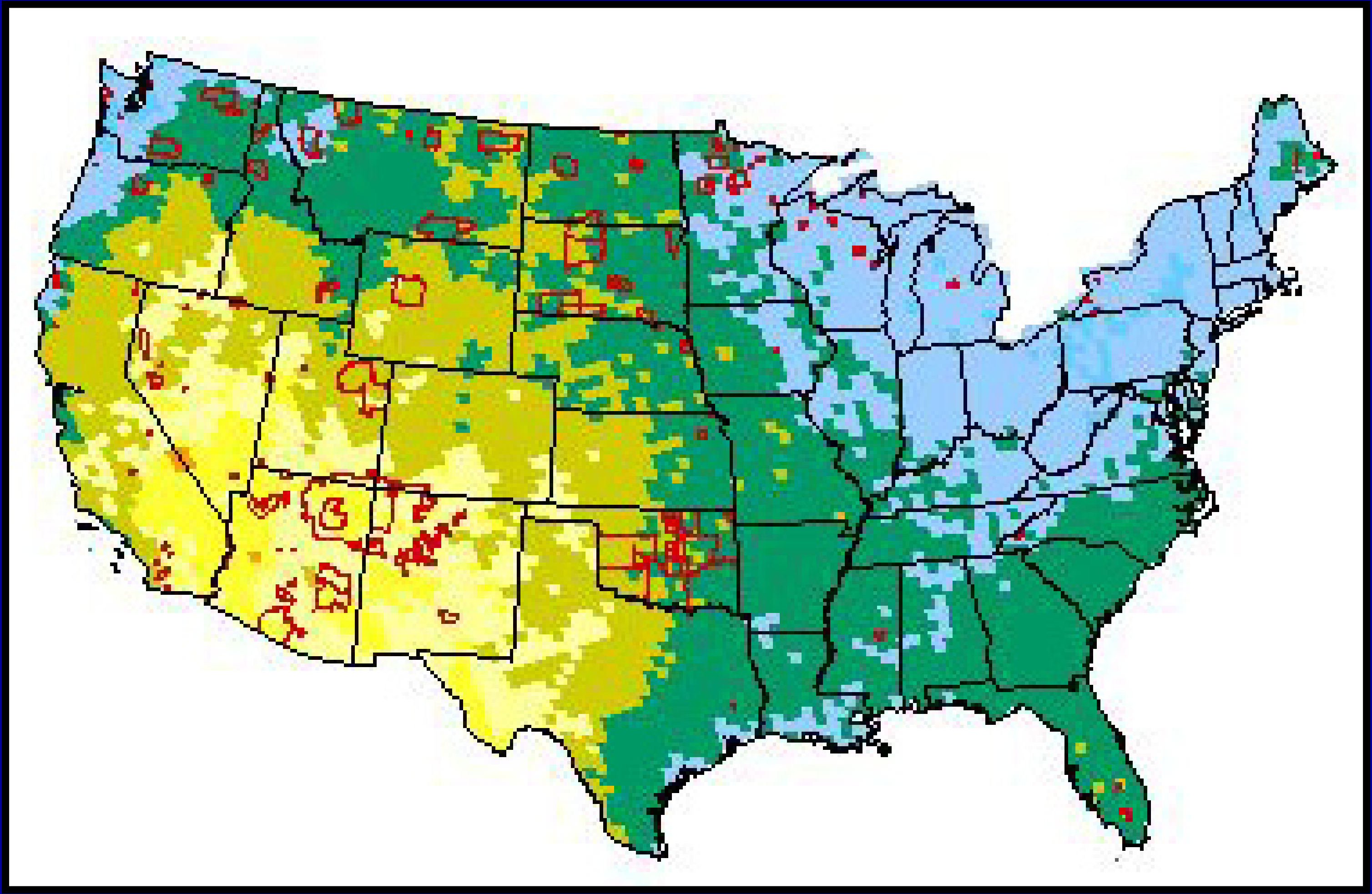


BIPV: Roof System

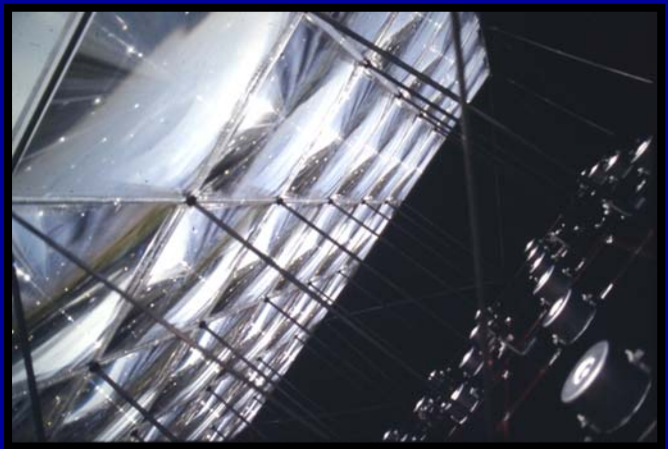
BIPV: Shaded Parking

Indian Pueblo Cultural Center, Albuquerque

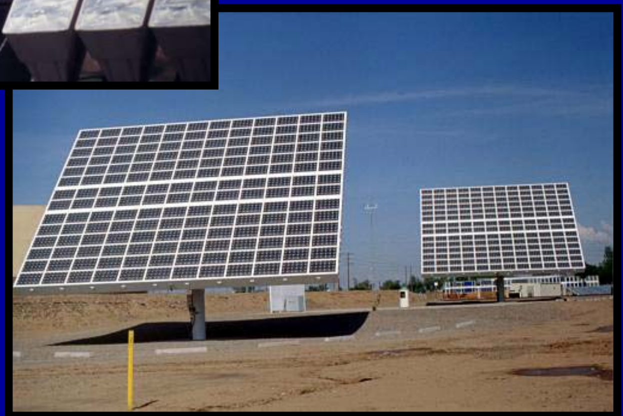
Solar Resource – Concentrator Applications



Concentrating PV Systems



Point
Focus
100-1000X



Line
Focus
30-50X

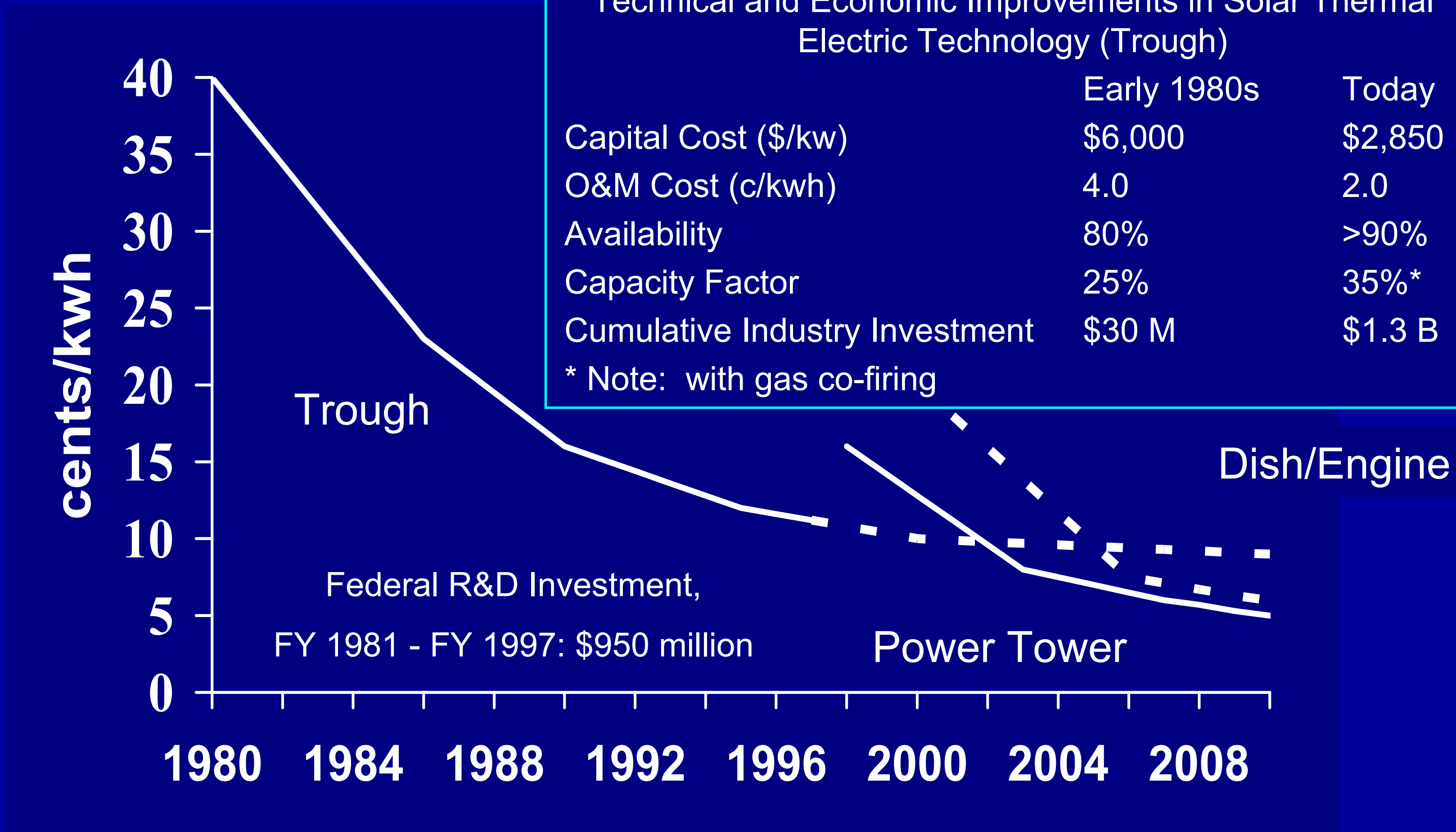
CSP Technology Options

Trough

Power Tower

Dish

Electricity Cost from Solar Thermal Electric Systems



Technical and Economic Improvements in Solar Thermal Electric Technology (Trough)

	Early 1980s	Today
Capital Cost ($/kw)	$6,000	$2,850
O&M Cost (c/kwh)	4.0	2.0
Availability	80%	>90%
Capacity Factor	25%	35%*
Cumulative Industry Investment	$30 M	$1.3 B

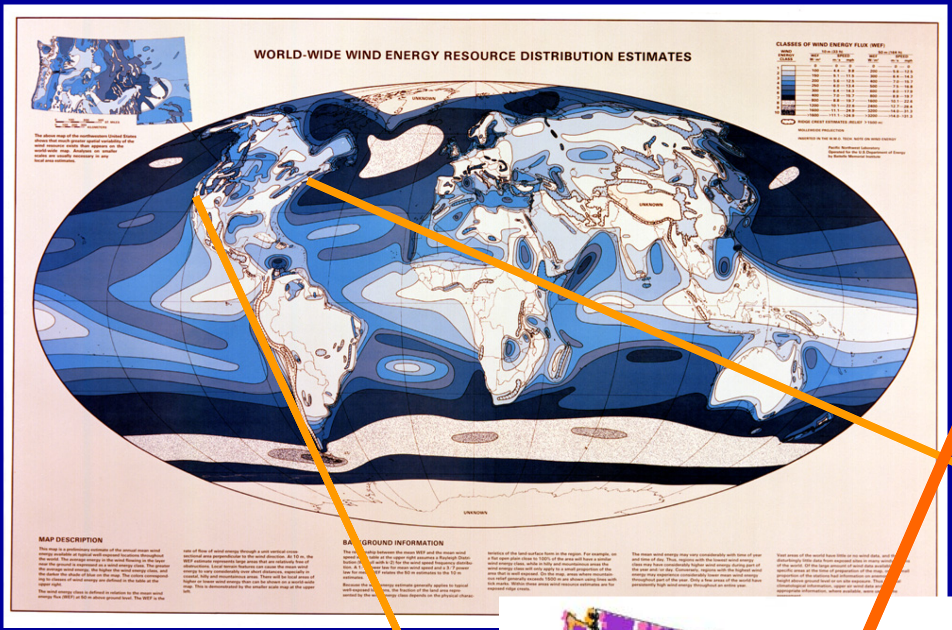
* Note: with gas co-firing

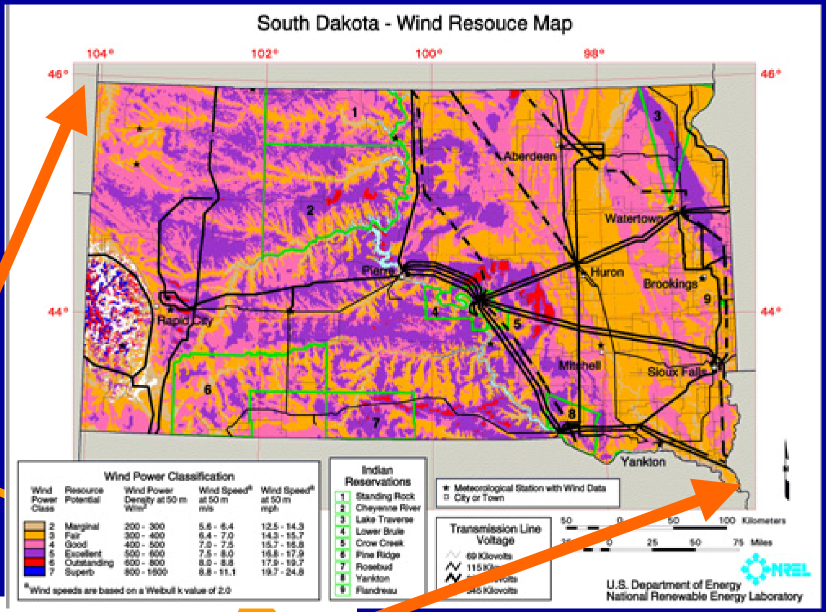
Source: *A Strategic Plan for Solar Thermal Electricity: A Bright Path to the Future*, December 1996, and NREL technology manager, November 1997

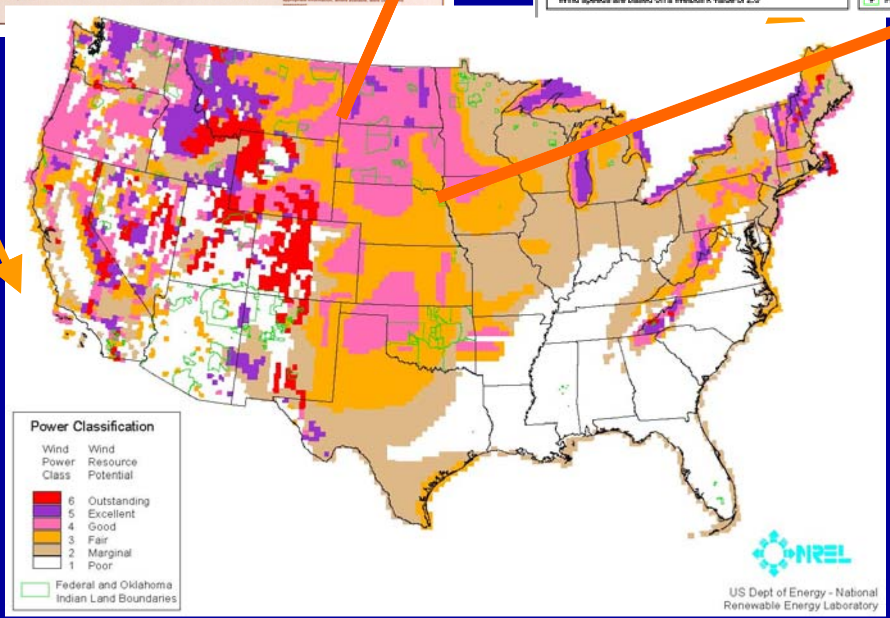
Concentrating Solar Thermal Power Conclusions

- Concentrating Solar Power is reliable and demonstrated in large-scale commercial systems
- While costs are still high for widespread deployment, significant cost reductions can be achieved
- Numerous attractive features for future deployment in sunbelt regions of the world
- Industry and market development continues to be a challenge

Wind Resource

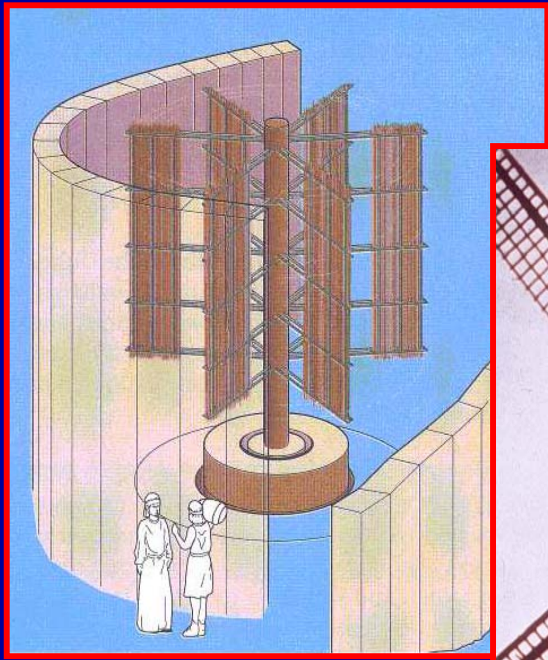






Wind Power History

1400-1800 years go,
in the Middle East



800-900 years ago,
in Europe

140 years ago,
water-pumping
wind mills

70 years ago,
electric power

What is Wind Power?

Wind Energy Conversion Device

Literally converts energy in wind to electrical or mechanical energy

Power in the wind increases with the cube of the wind speed

$$Power = SweptArea \; \frac{1}{2} \rho V^3$$

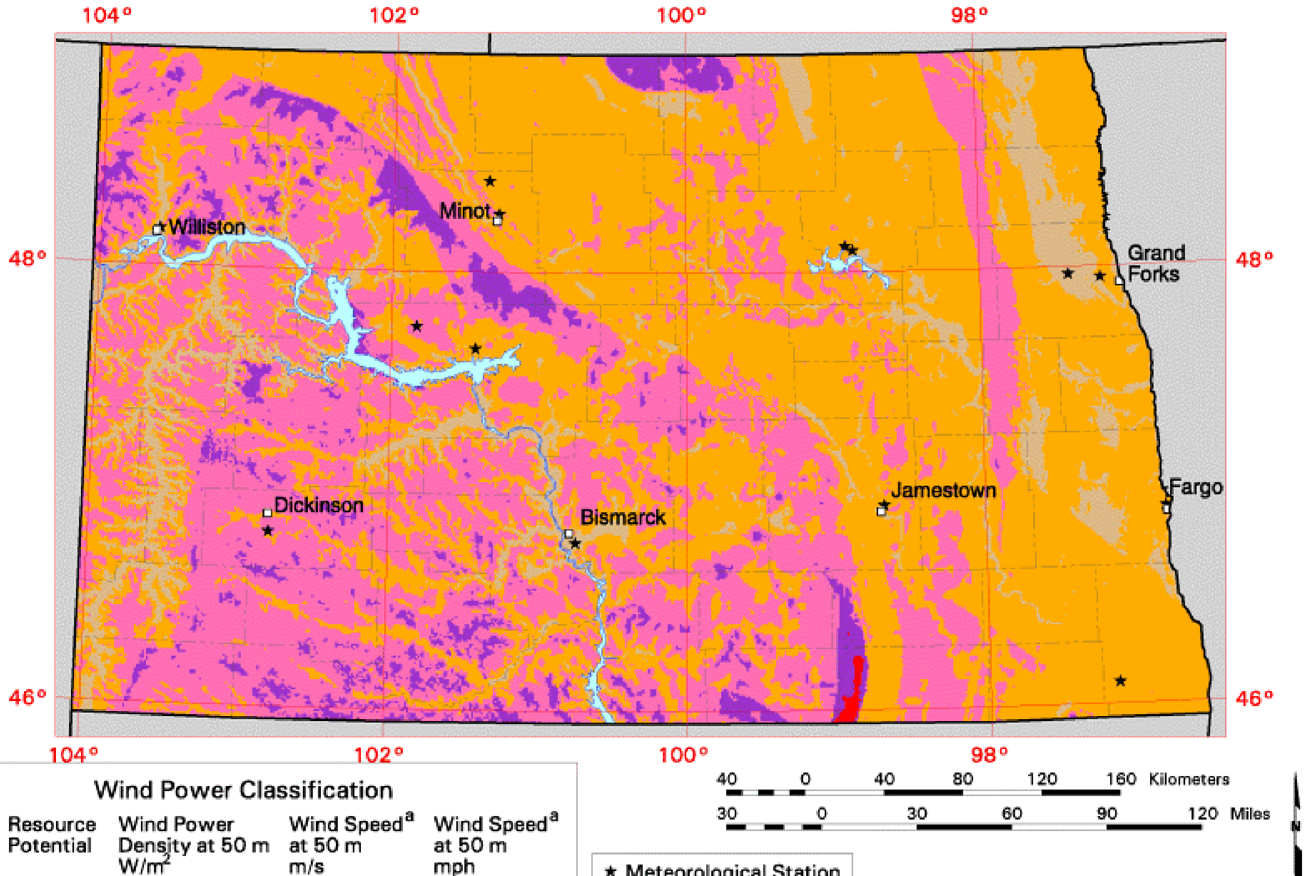
Marginal wind of 5 m/s → 150W/m2

Outstanding wind of 10 m/s → 1200 W/m2

Average solar power is 200 – 300 W/m2

Wind Power is Concentrated Sunshine

North Dakota - Wind Resource Map



Wind Power Classification

Wind Power Class	Resource Potential	Wind Power Density at 50 m W/m²	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	Moderate	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		600 - 800	8.0 - 8.8	17.9 - 19.7

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

★ Meteorological Station with Wind Data
■ City or Town

The wind resource classification is for utility scale applications and applies to areas of low surface roughness.

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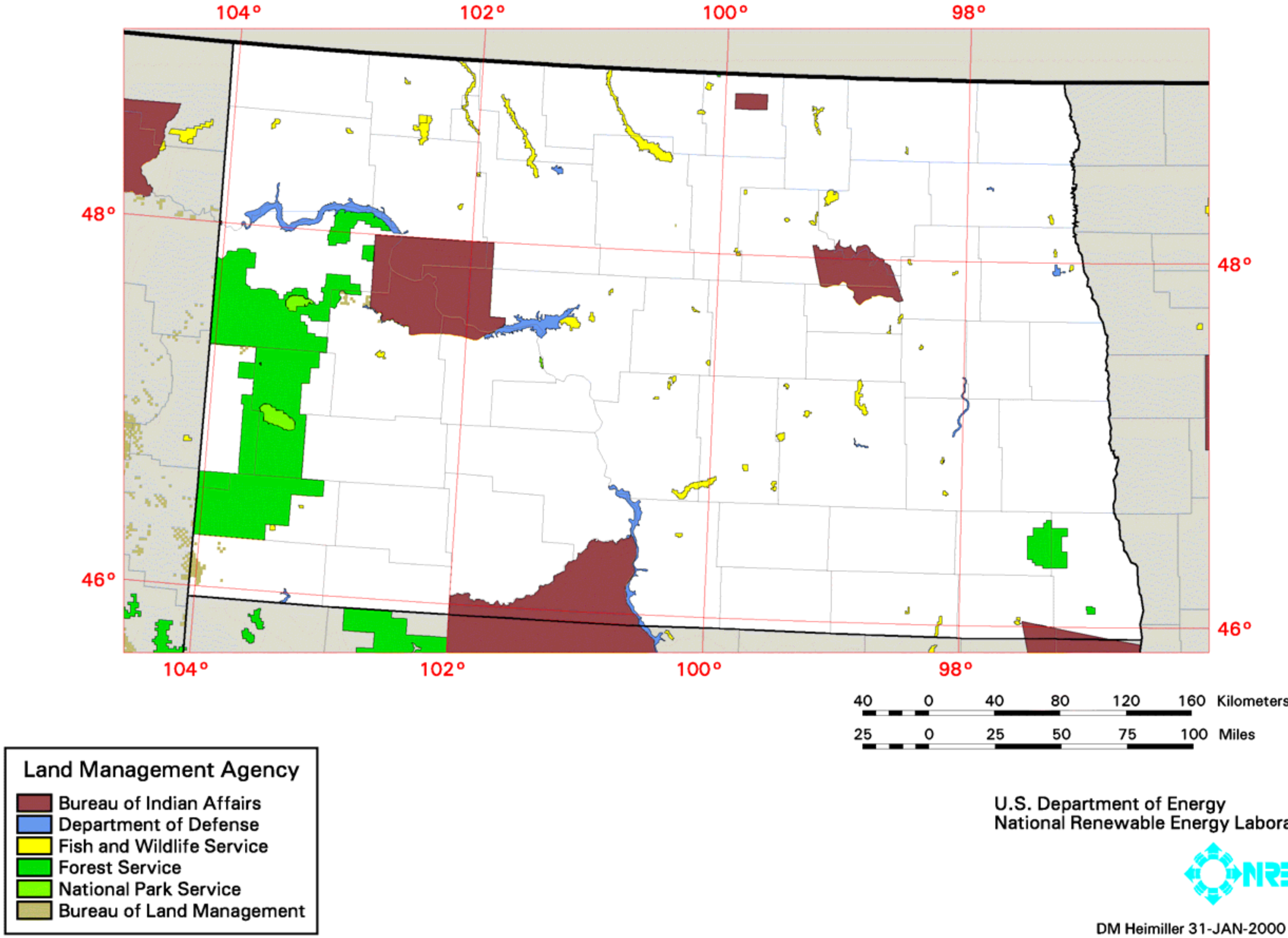
North Dakota - Federally Managed Lands



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National Renewable Energy Laboratory

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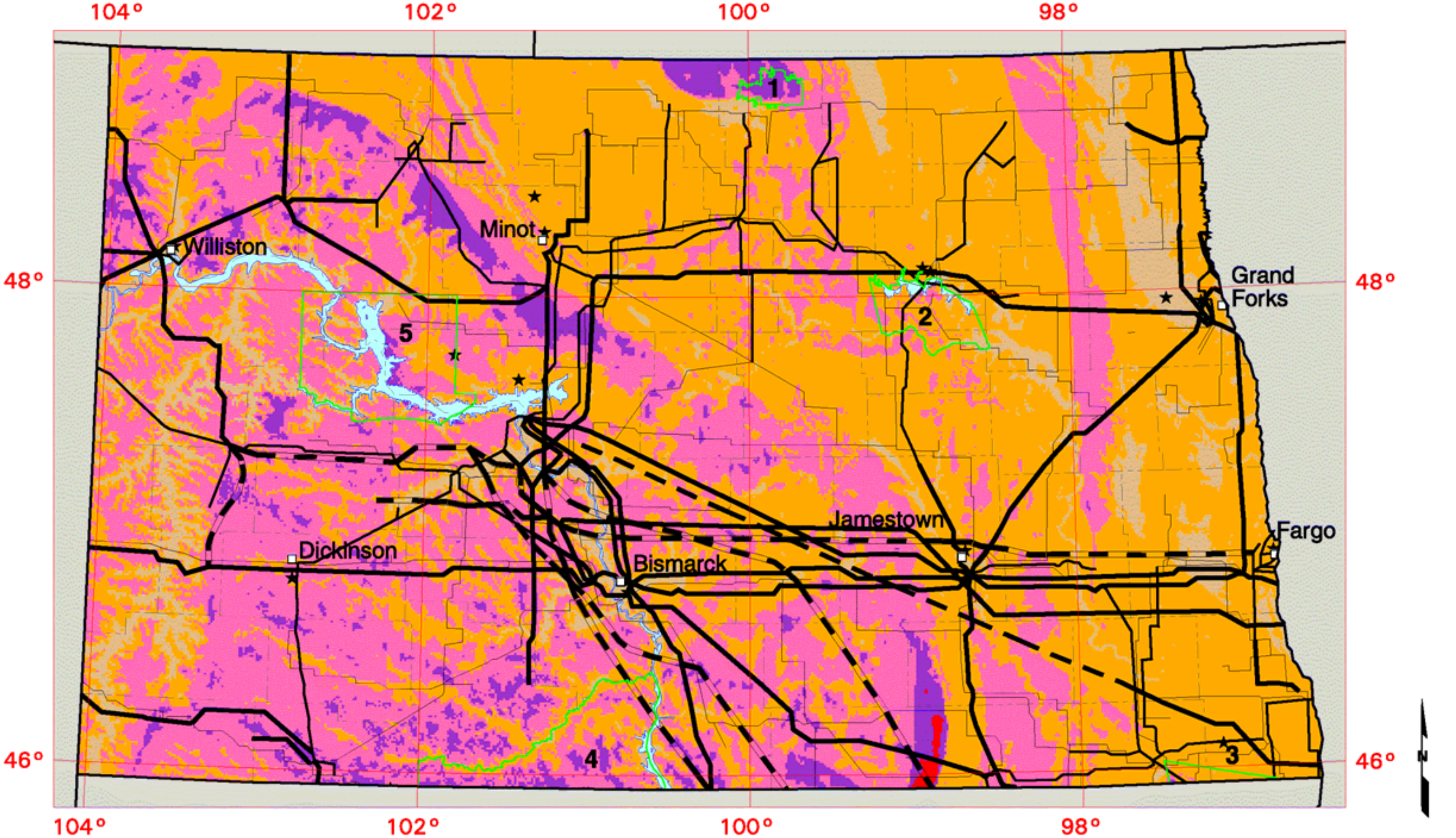
North Dakota - Wind Resource Map



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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

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

★ Meteorological Station with Wind Data
□ City or Town

Transmission Line Voltage

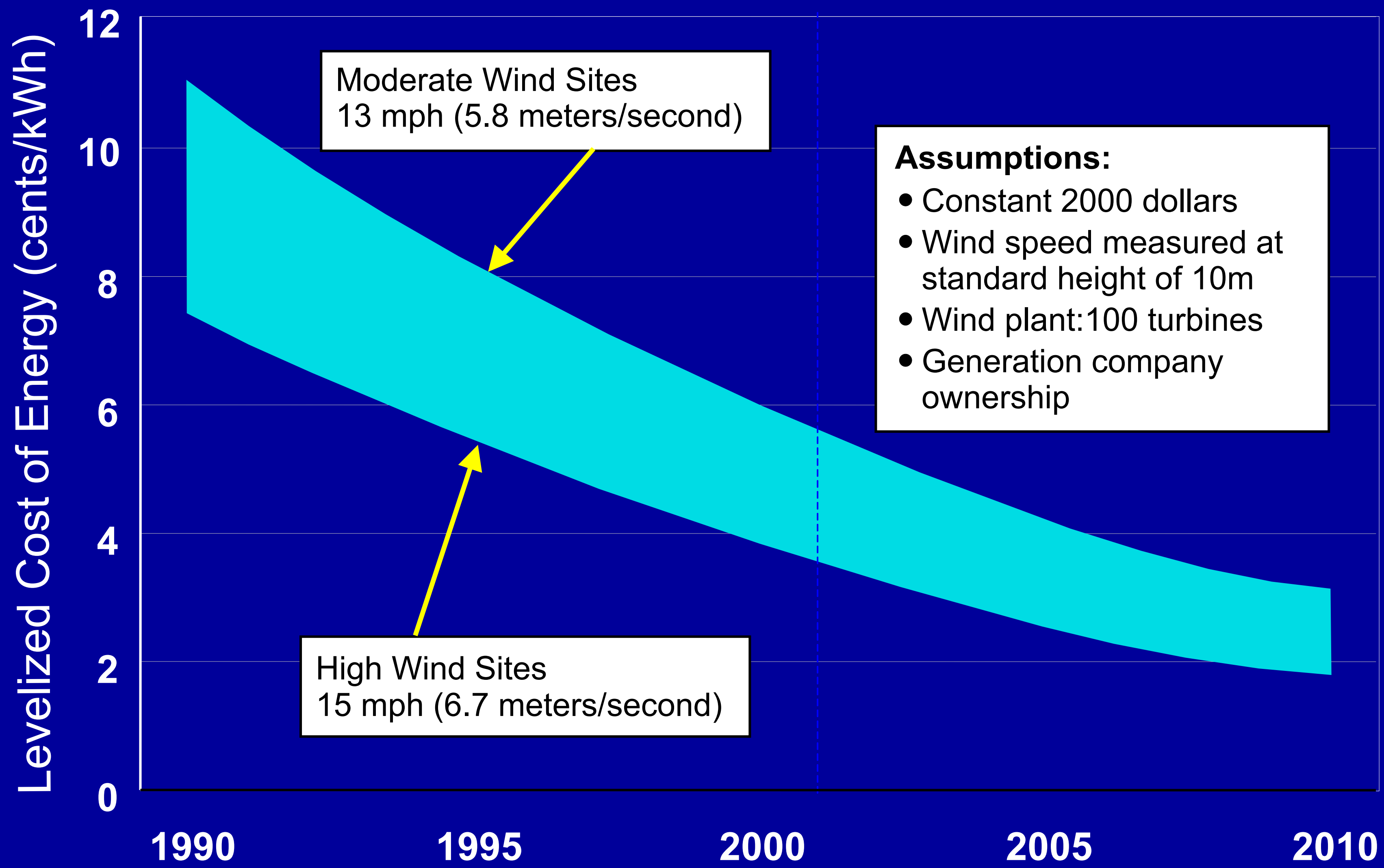
- 69 Kilovolts
- 115 Kilovolts
- 230 Kilovolts
- 345 Kilovolts
- Under Construction

Indian Reservations

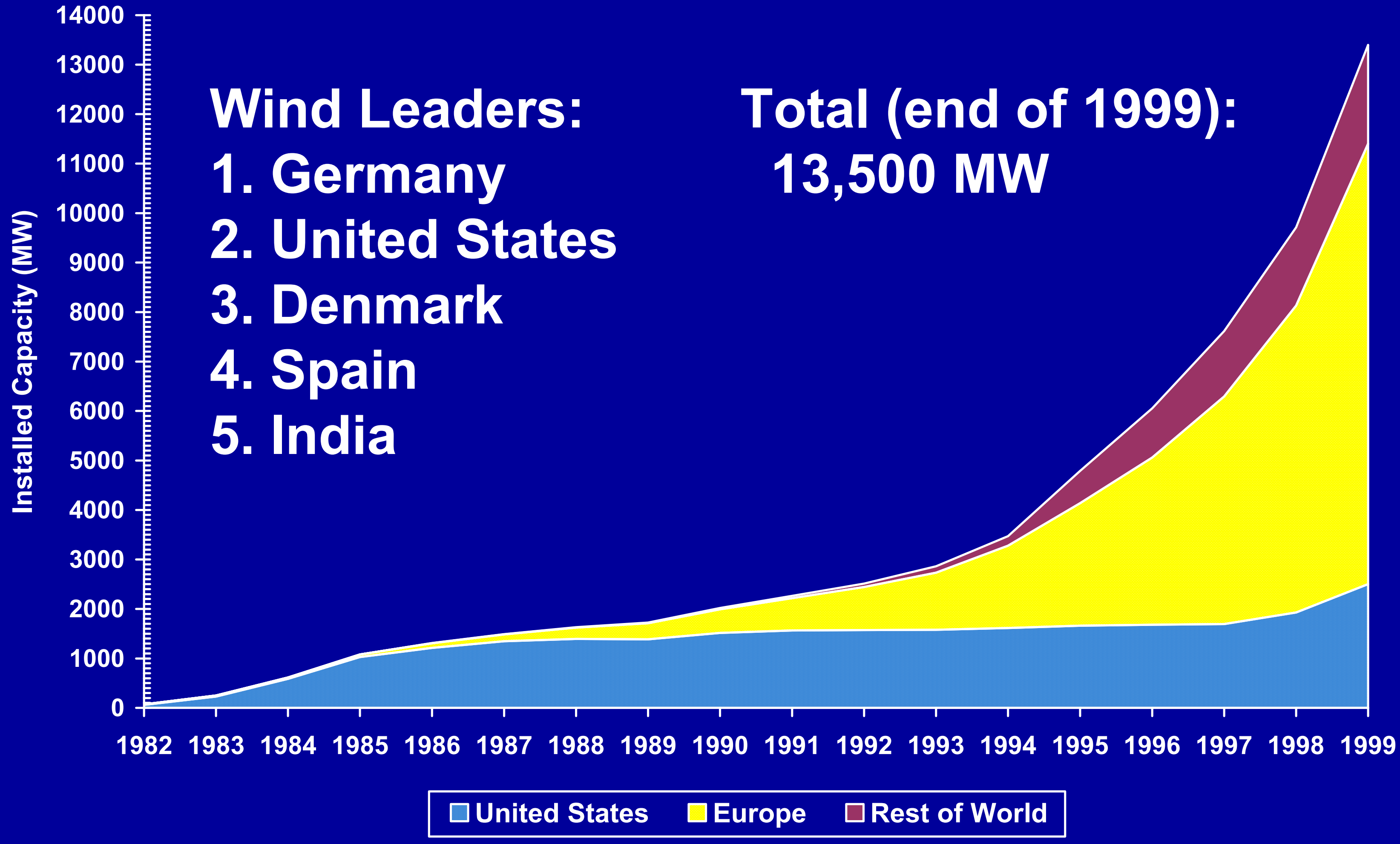
1. Turtle Mountain
2. Devil's Lake Sioux
3. Lake Traverse
4. Standing Rock
5. Fort Berthold

U.S. Department of Energy
National Renewable Energy Laboratory

Cost of Energy for Large Wind Farms



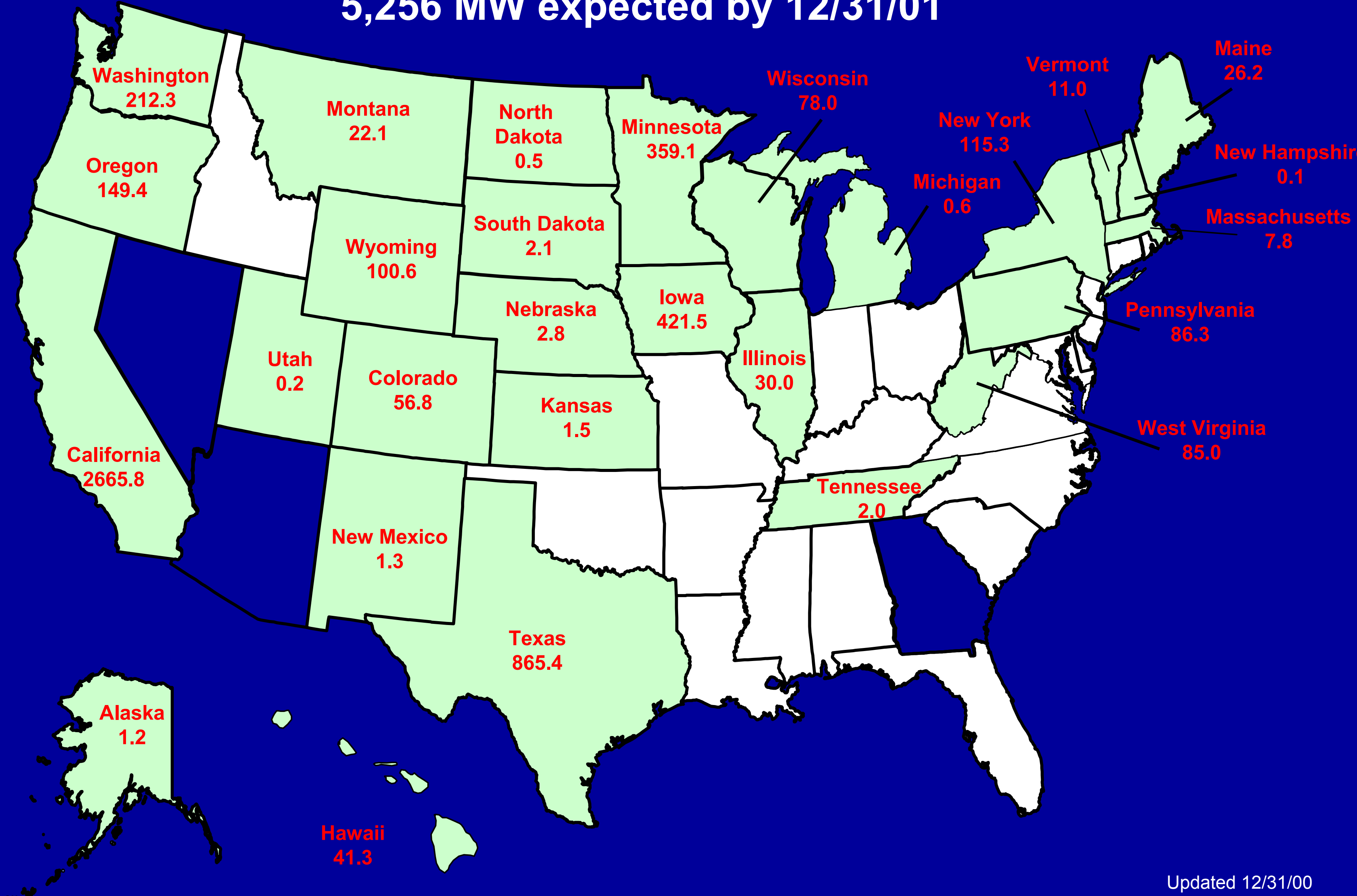
Taking Off Worldwide



Based on information supplied by International Energy Agency.

U.S. Wind Power - Expected by end of 2001 (MW)

5,256 MW expected by 12/31/01



Updated 12/31/00

Sizes and Applications

Small (≤10 kW)

Homes

Farms

Remote Applications (e.g. water pumping, telecom sites, icemaking)

Intermediate (10-250 kW)

Village Power

Hybrid Systems

Distributed Power

Large (250 kW – 2+ MW)

Central Station Wind Farms

Distributed Power




Wind Farm Issues

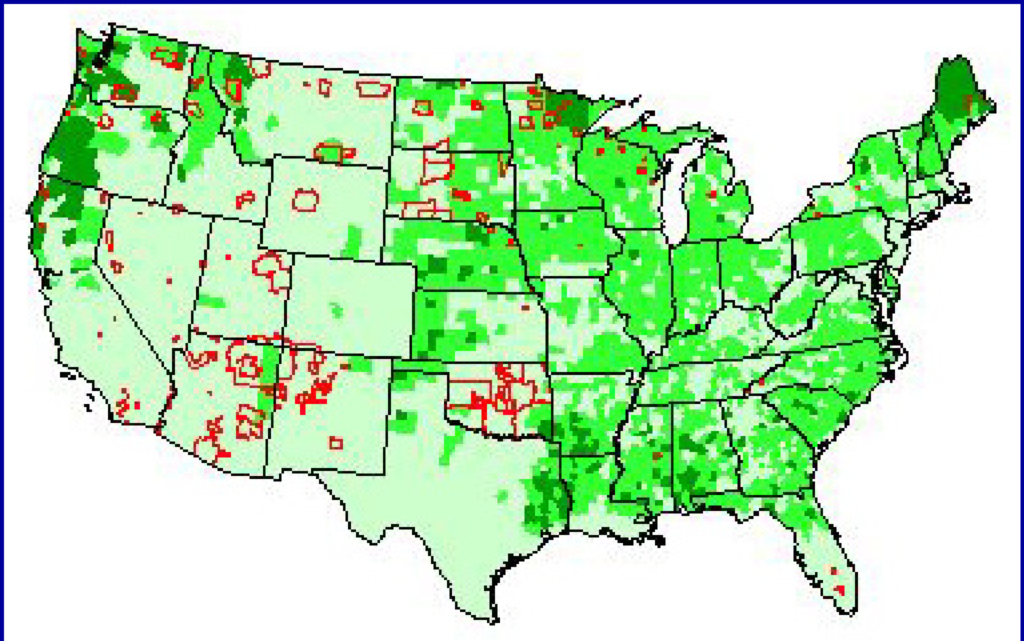
- Policy
- Siting
- Standards
- Transmission
- Hardware
- Intermittency

Small Wind Turbines

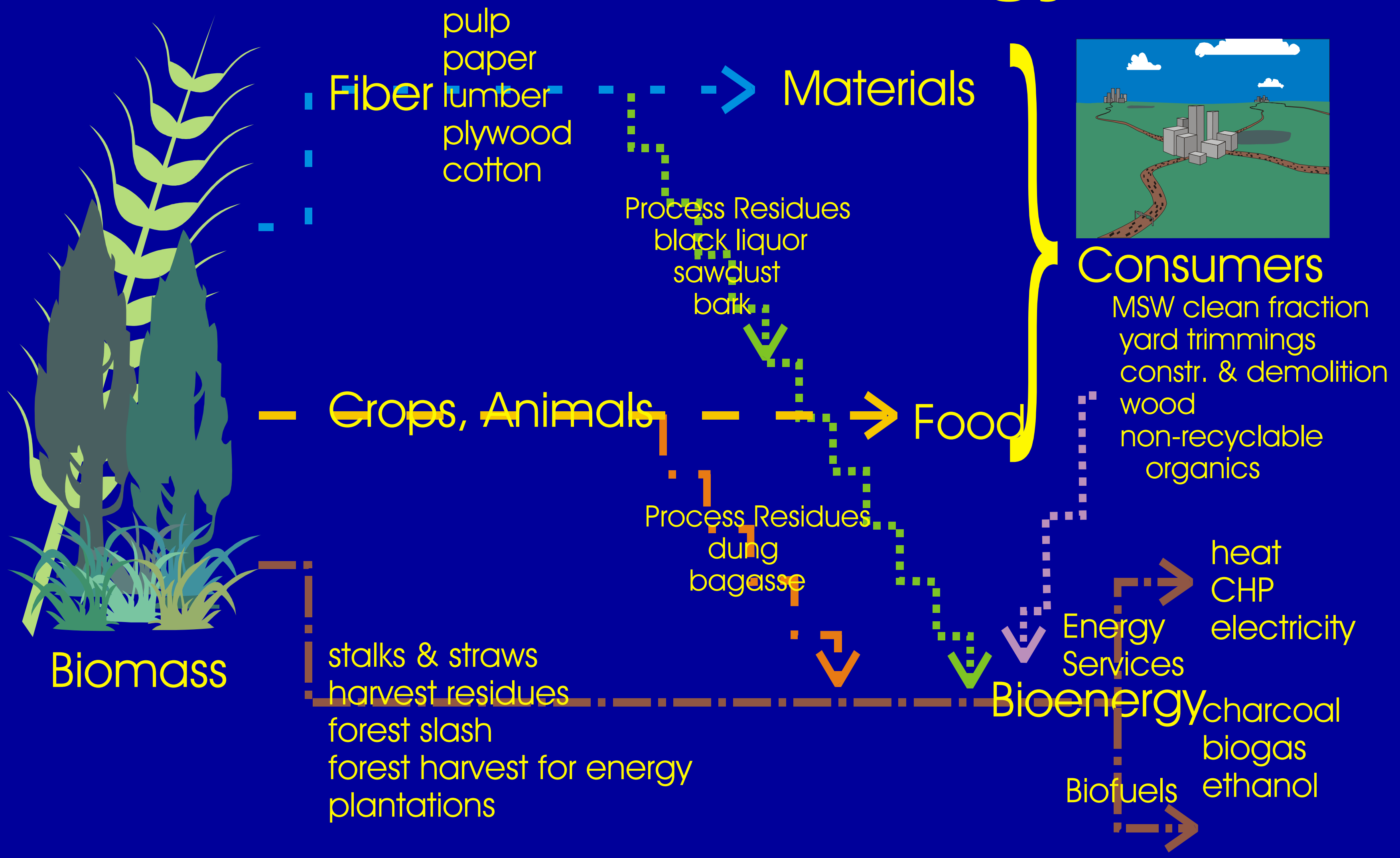
- Configuration: Up-wind, horizontal axis,
  2 or 3 blades, aligned with wind by the tail
- Blades: Fiber-reinforced plastics, fixed pitch, either twisted/tapered, or straight (pultruded)
- Generator: Direct-drive permanent magnet
  alternator, no brushes, 3-phase AC, variable-speed operation
- Overspeed Protection: Passive furling (rotor turns out of the wind), no brakes
- Result:
  - Simple, rugged design
  - Only 2–4 moving parts
  - Little regular maintenance required

Bergey EXCEL, 10 kW

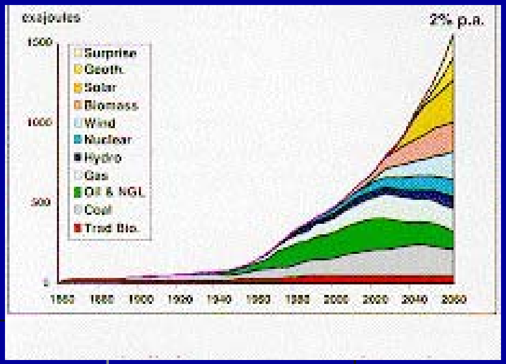
Biomass Resource
Agricultural and Forest Products Residual

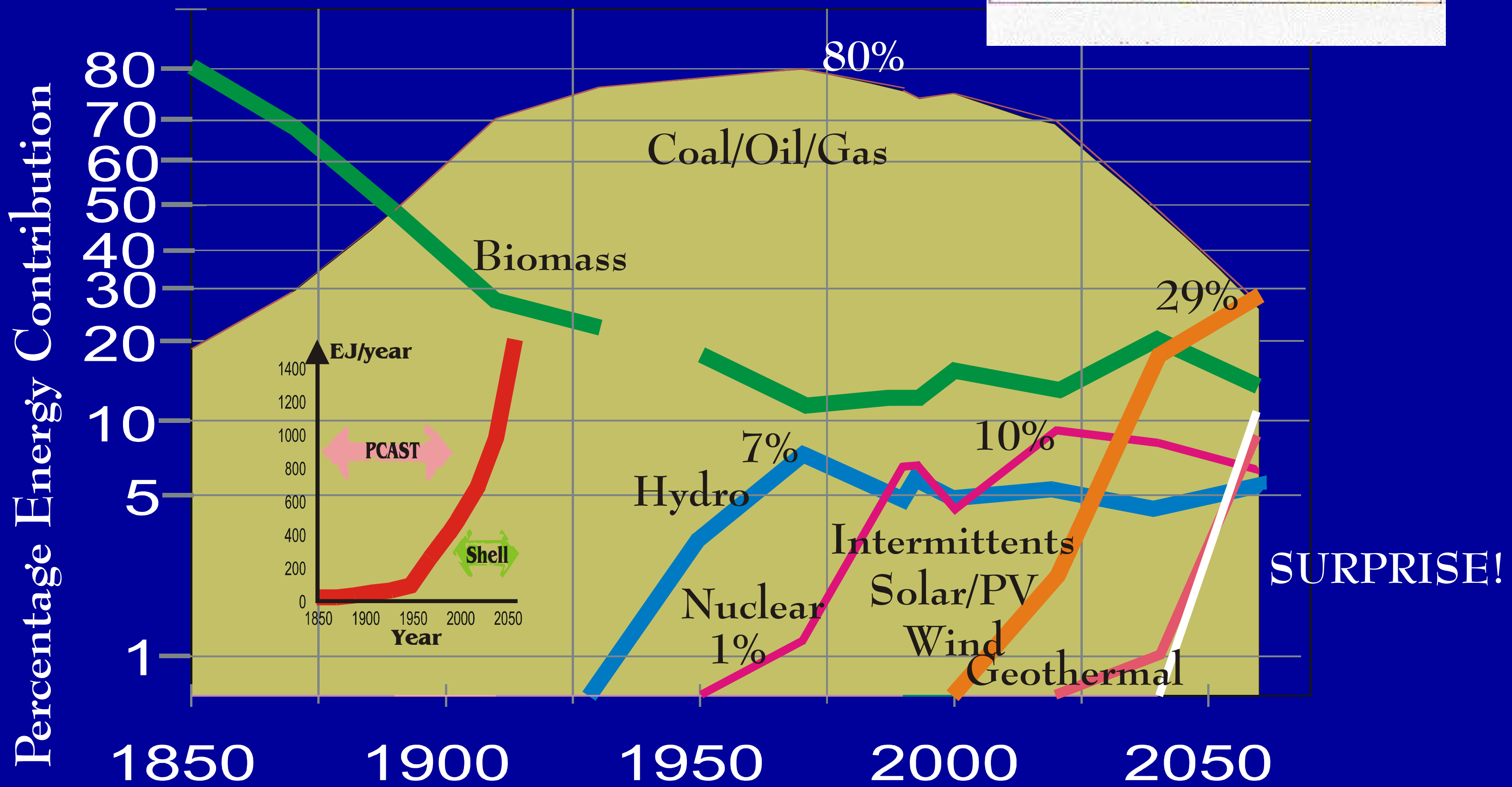


Biomass & Bioenergy Flows



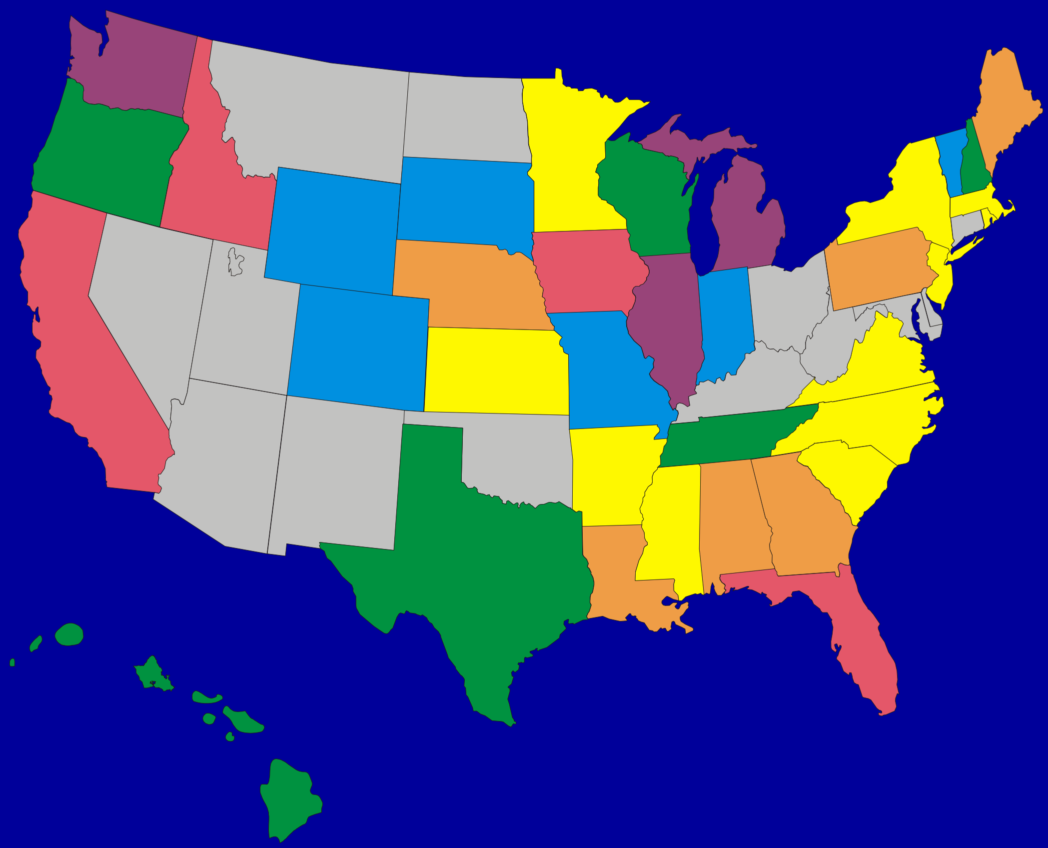
Shell and other Futures





Composed from PCAST data < 1990, with Shell futures scenario. All fossil combustion is combined, as are wind and solar electricity in the term intermittents.

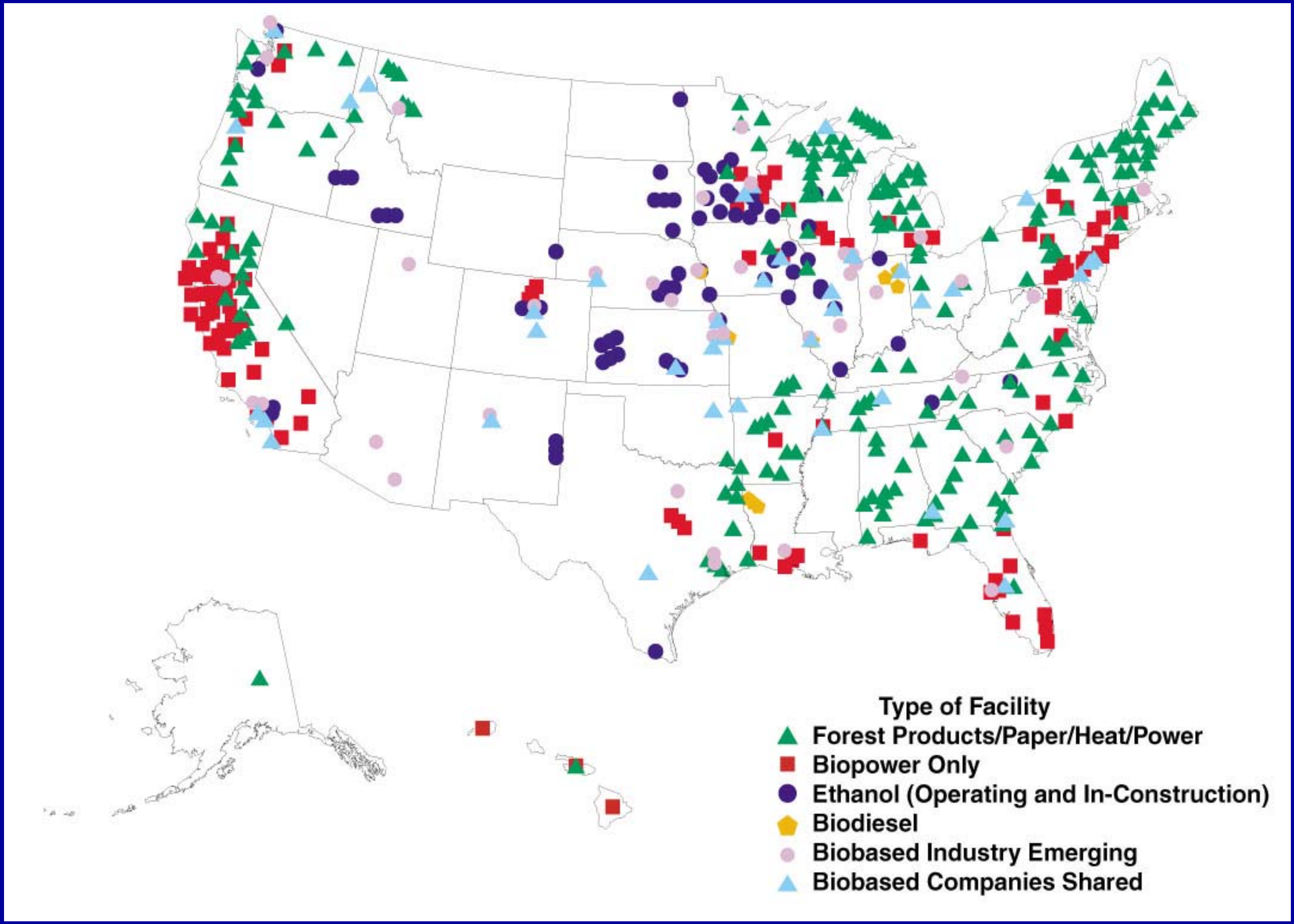
Biomass Electricity Production
Wood Residues, Landfill Gas, MSW



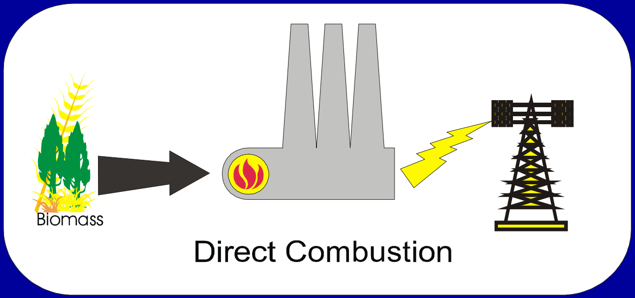
Total = 61 TWh/a

- > 5TWh/a
- > 2.5 TWh/a
- >1.25 TWh/a
- >625 GWh/a
- > 325 GWh/a
- < 130 GWh/a

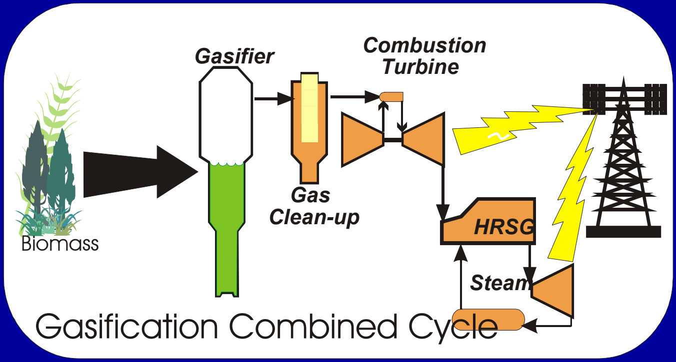
Biomass-Bioenergy-Biobased Industry



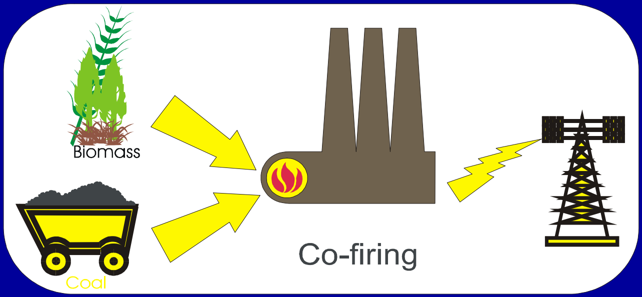
Paths to Biopower



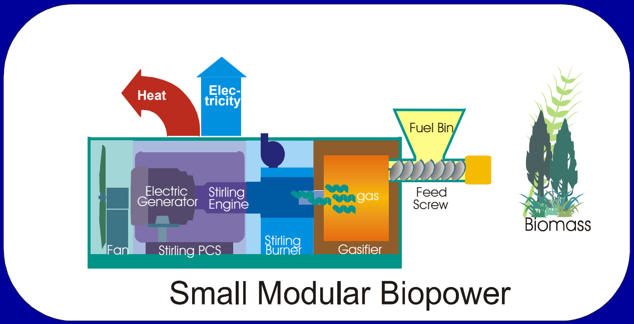
Existing Industry
7,000 MW
Average 20% Efficiency
100% Residue Based



High Efficiency Options
Gas Turbines, Fuel Cells
40+% Efficiency
Significant Interest by Cogenerators
e.g. Pulp & Paper industry
Small Demo's in Europe& U.S.

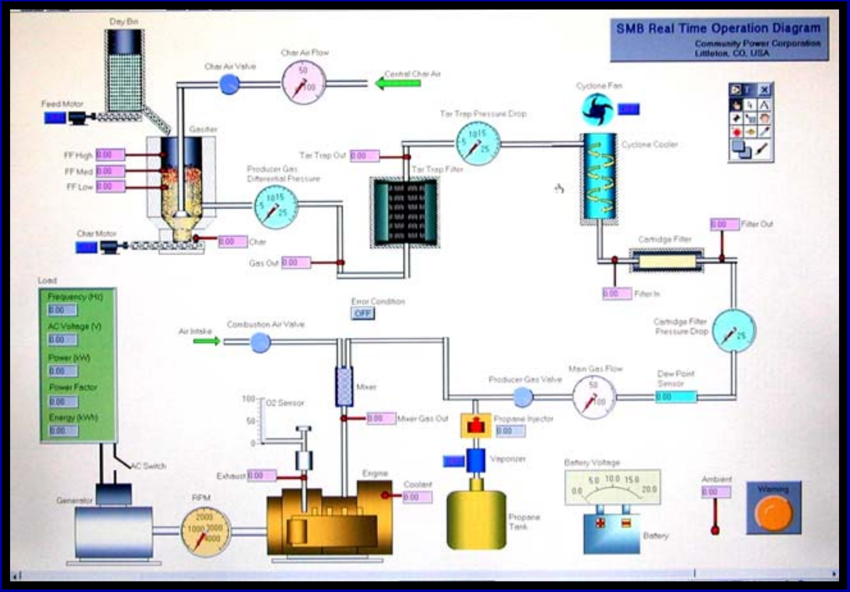


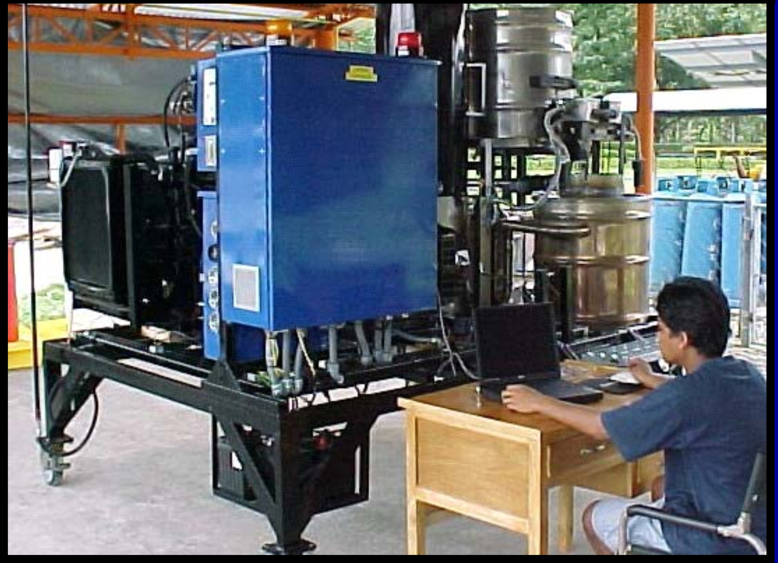
Offsetting Emissions of Existing Fossil Generation - A Low Cost Option
Several successful Demo's
35% Efficiency
SOx and Some NOx Reduction
Market Encourages Energy Crops
Results in No Capacity Addition



Distributed Generation/Village Power
Micro-Turbines, Fuel Cells, Stirling Engines
Fuel Flexible; Efficient
Simple to Operate
Minimal Environmental Impacts

CPC's 5 to 25kWe Small Modular Biopower System





Combined Heat & Power, Distributed Generation Application
Hoopa Indian Tribe   Hoopa, California

77,000 Acres Douglas Fir

Tsemeta Forest
Regeneration Complex

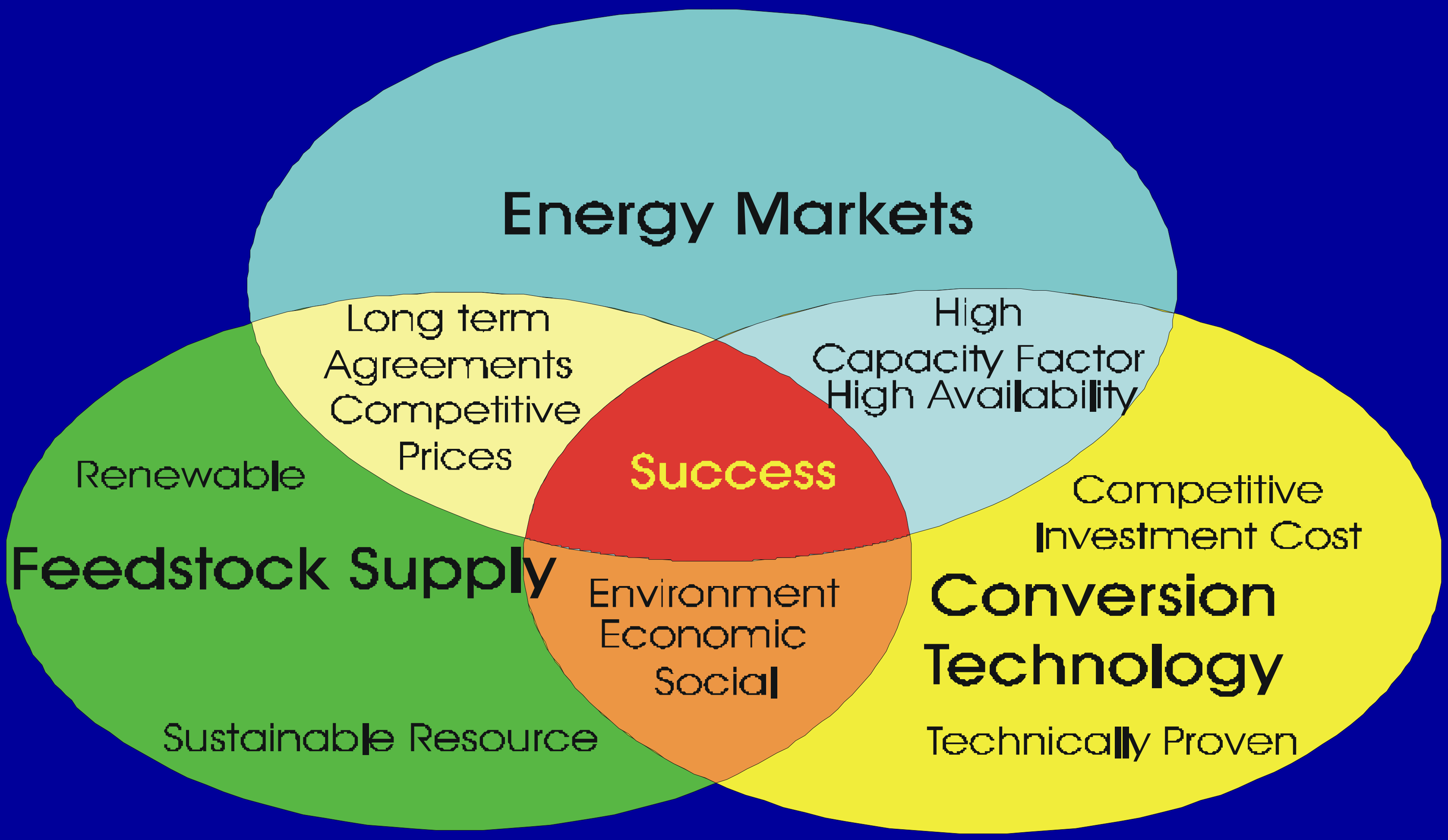
40,000 Tons/year Slash

Add wood chipper and
Gasifier/Engine
August 8, 2001

Heat &
Power

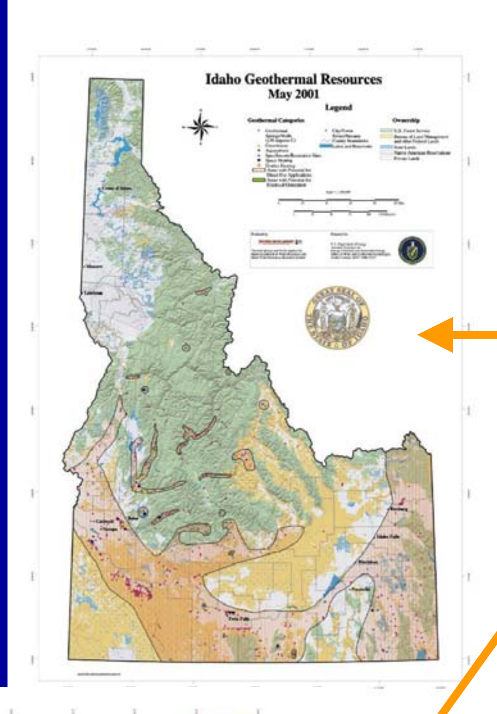
Biomass and Bioenergy

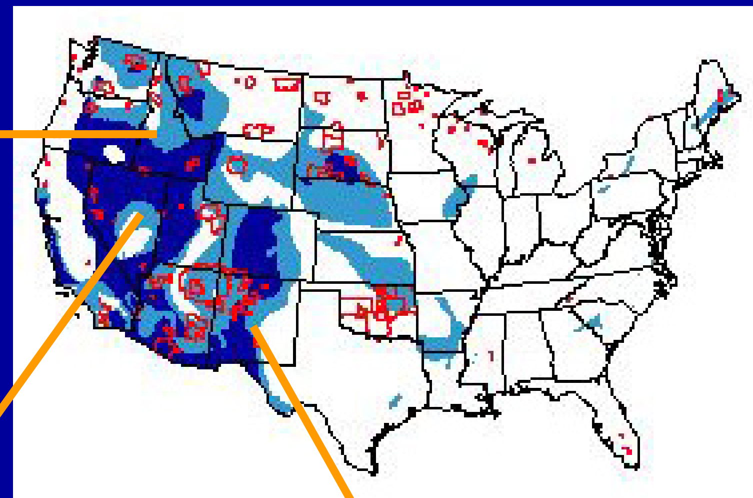
Criteria for Success

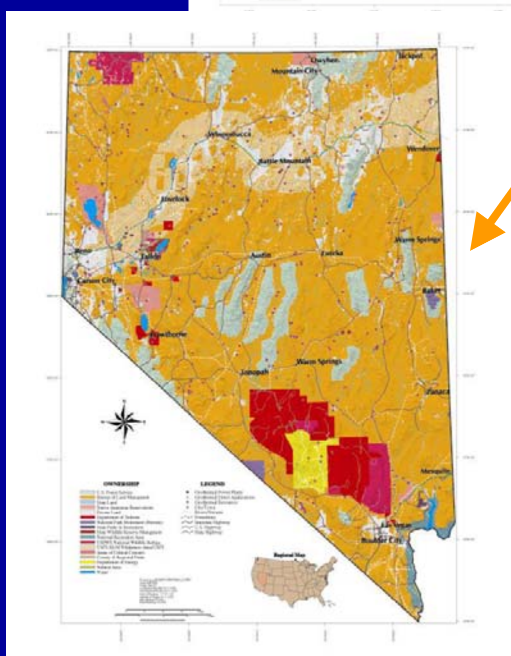


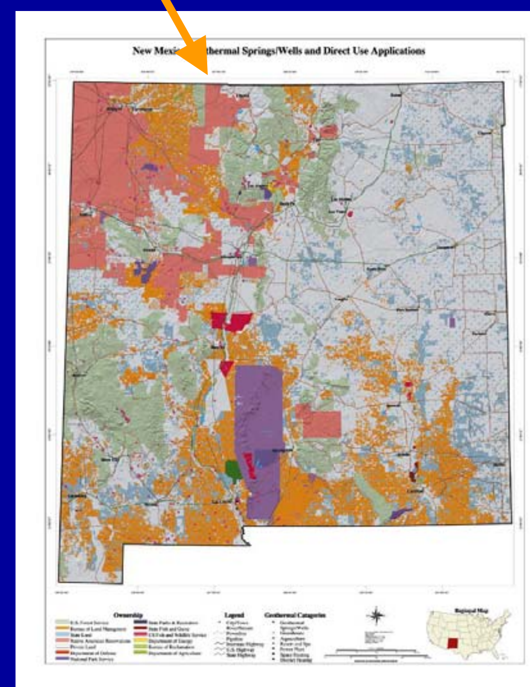
Icepag

Geothermal Resource



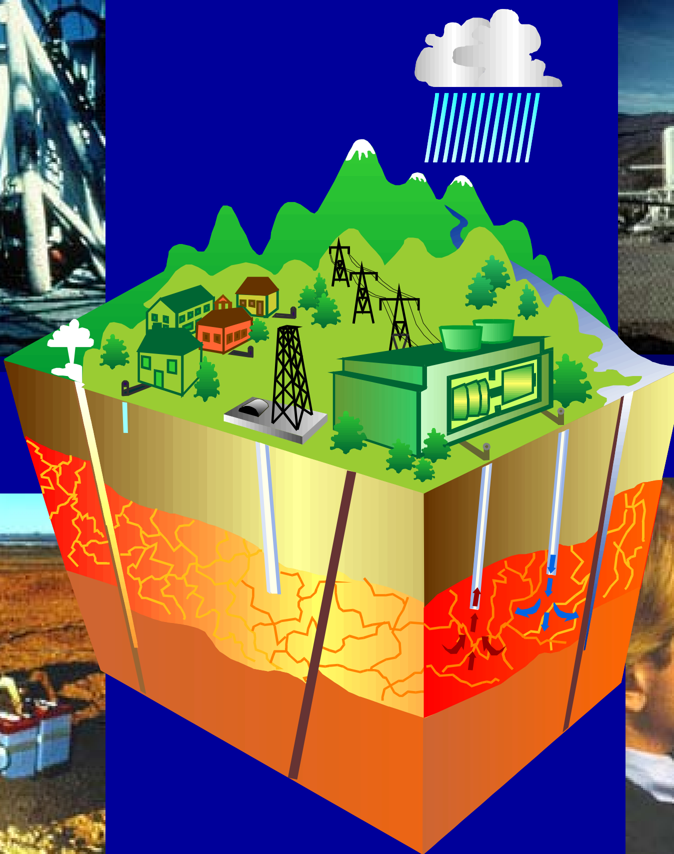






Geothermal Technology

Drilling

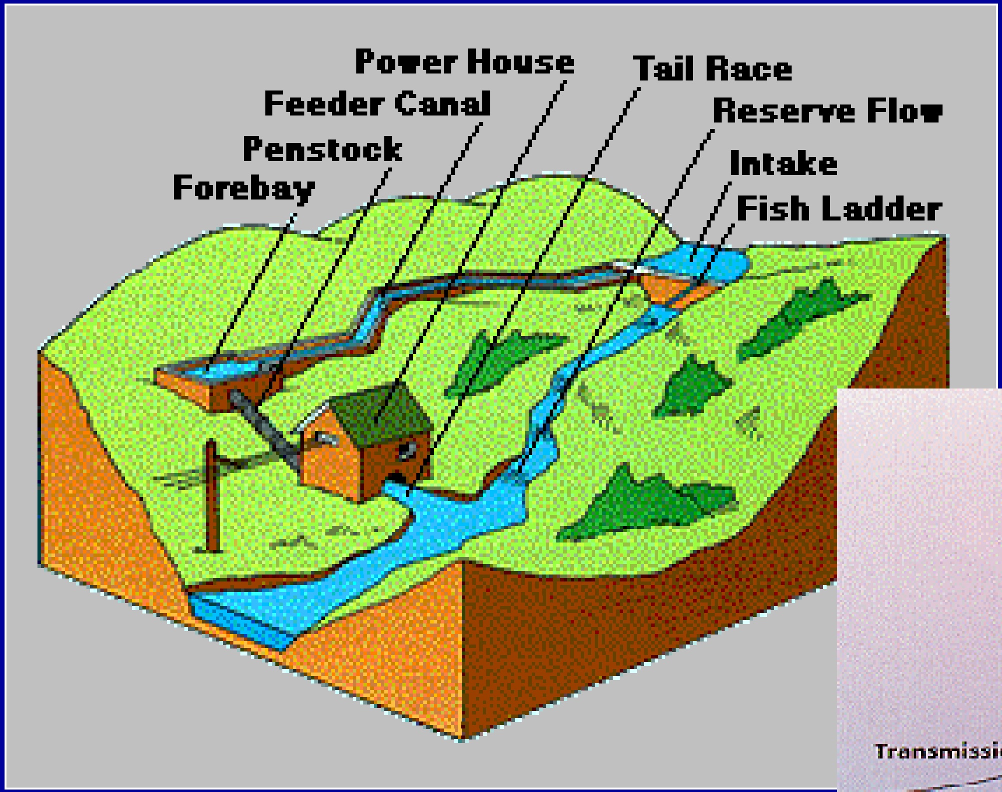


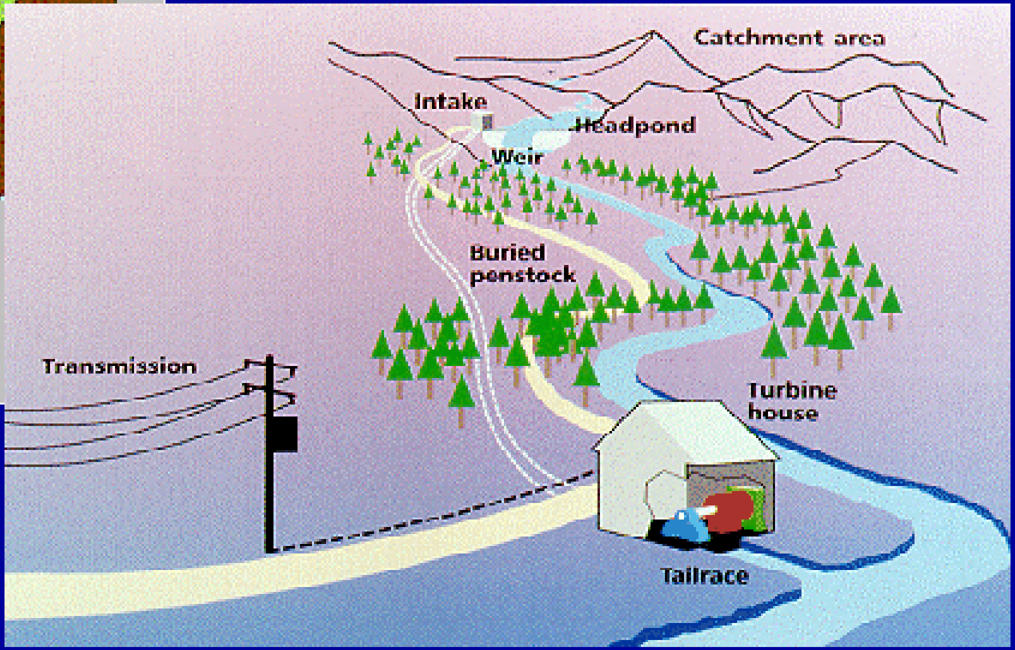
Energy Conversion

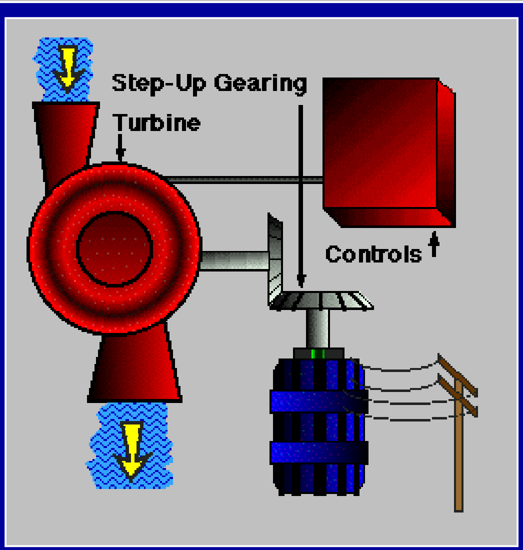
Exploration

Reservoir Technology

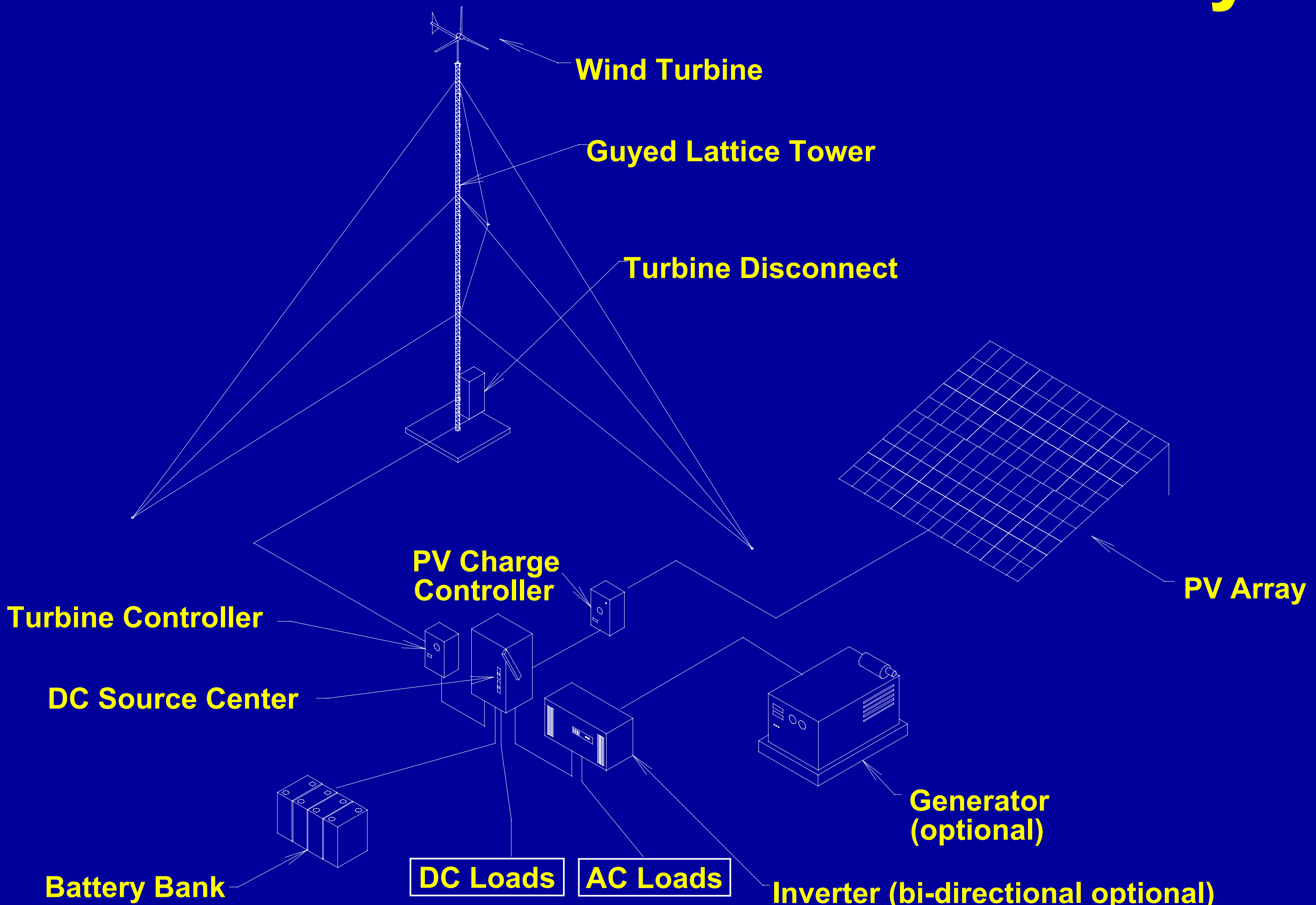
Small Hydro System Elements



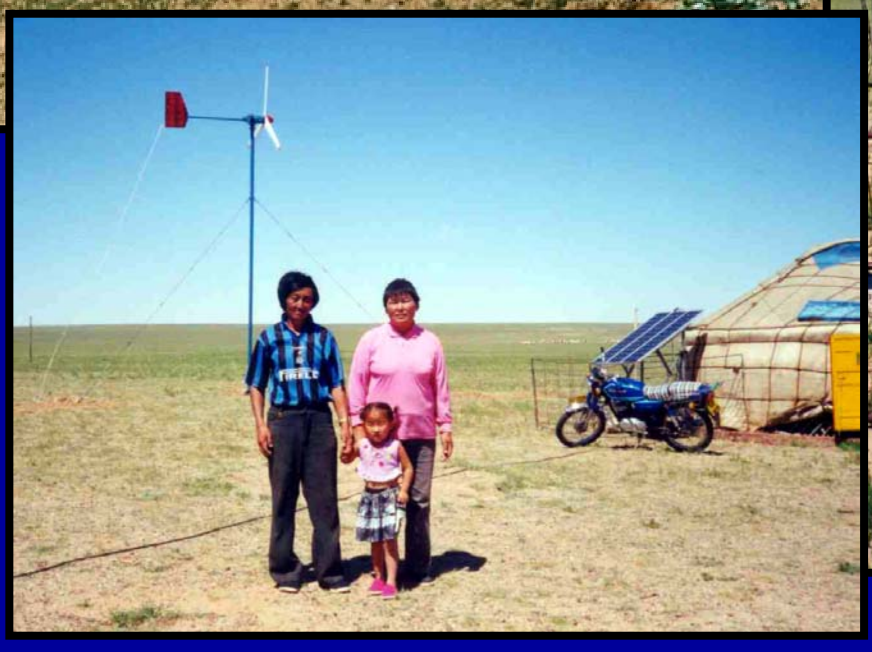




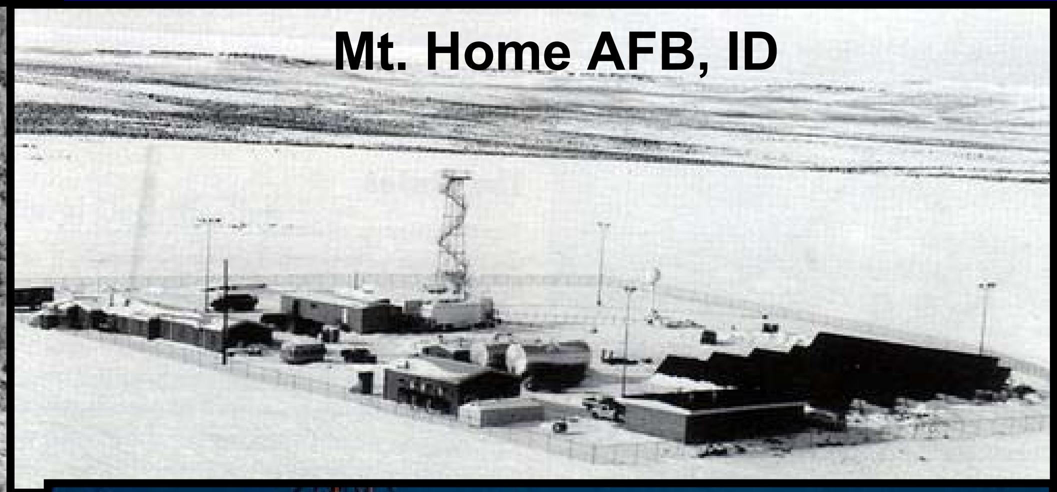
Typical Hybrid Village Power System



Inner Mongolia, Wind/PV Home Systems



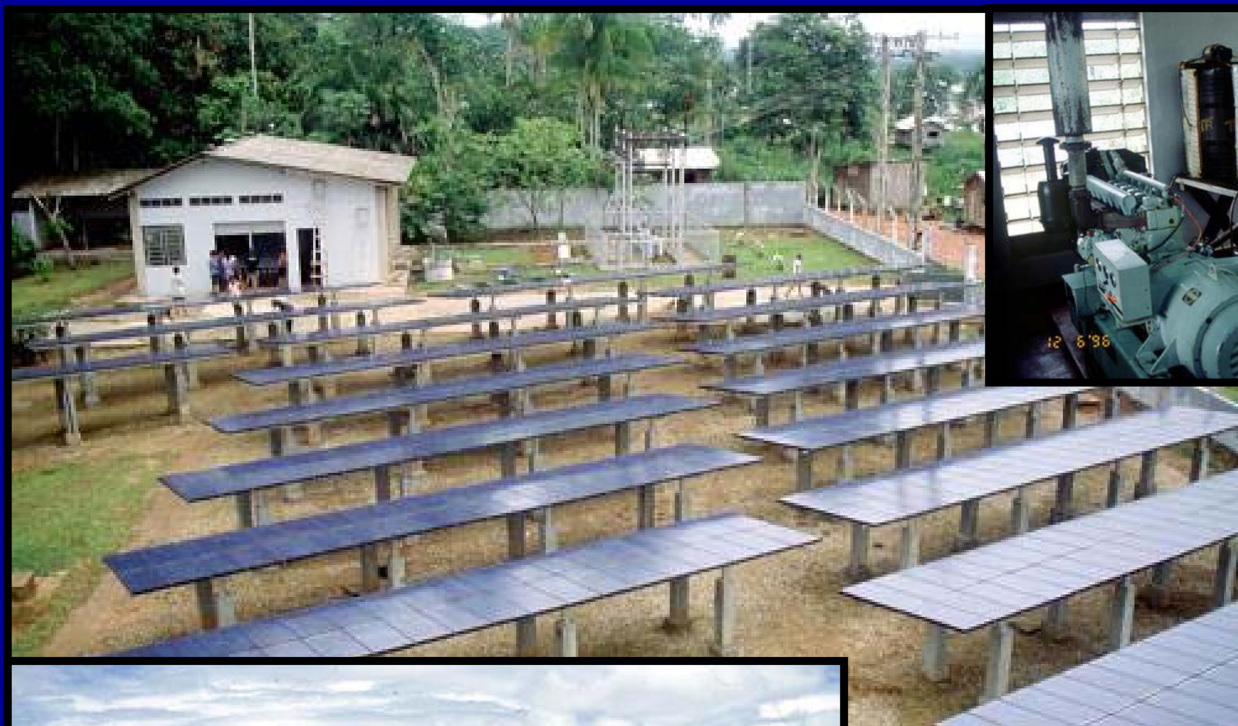
Hybrid Power System Examples: "Communications"

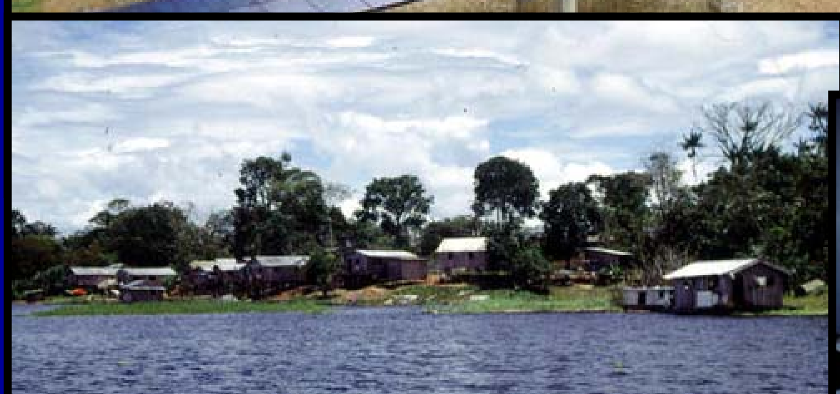


Hybrid Power System Examples: "Parks"

Dangling Rope Marina, Lake Powell, UT (160 kW)

Hybrid Power System Examples: Campinas, Brazil





50 kW PV
50 kVA Inverter
300 kWh Batteries

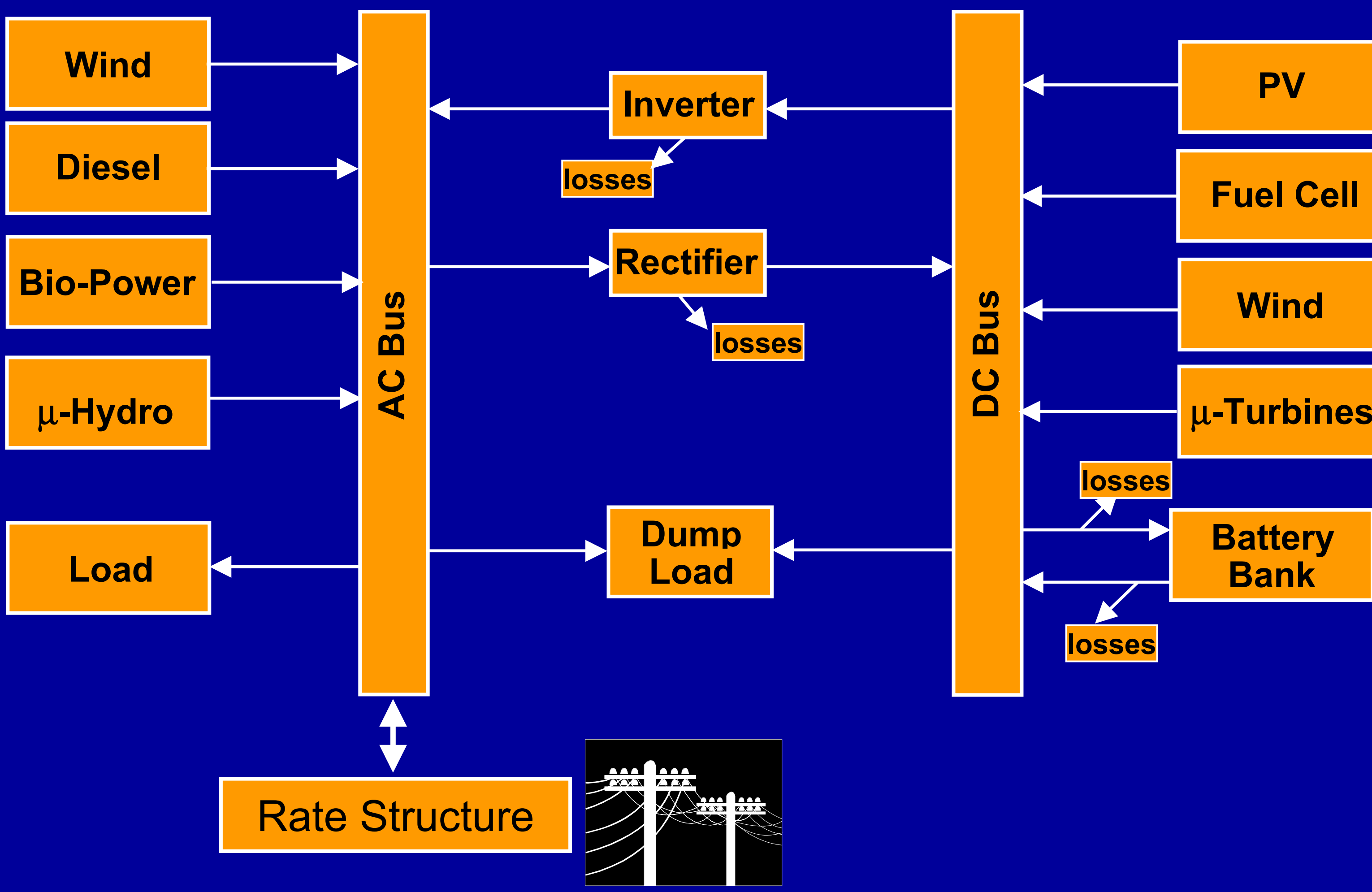

Wales
Alaska
Wind Turbines
(Induction, Stall-Regulated)
2 X 65 KW = 130 KW
Diesel #1
142 kW
Diesel #2
75 kW
Diesel #3
148 kW
Battery Bank
240 VDC, 130 Ah
~30 kWh
DC
AC
Rotary Converter
156 kVA
Secondary Load
Controllers
School Heating
System
Resistance
Heaters
Diesel
Plant
Hydronic
Loop
Primary Village Load
40-120 kW

Distributed Generation
Hybrid Power System
Parker Ranch, HI

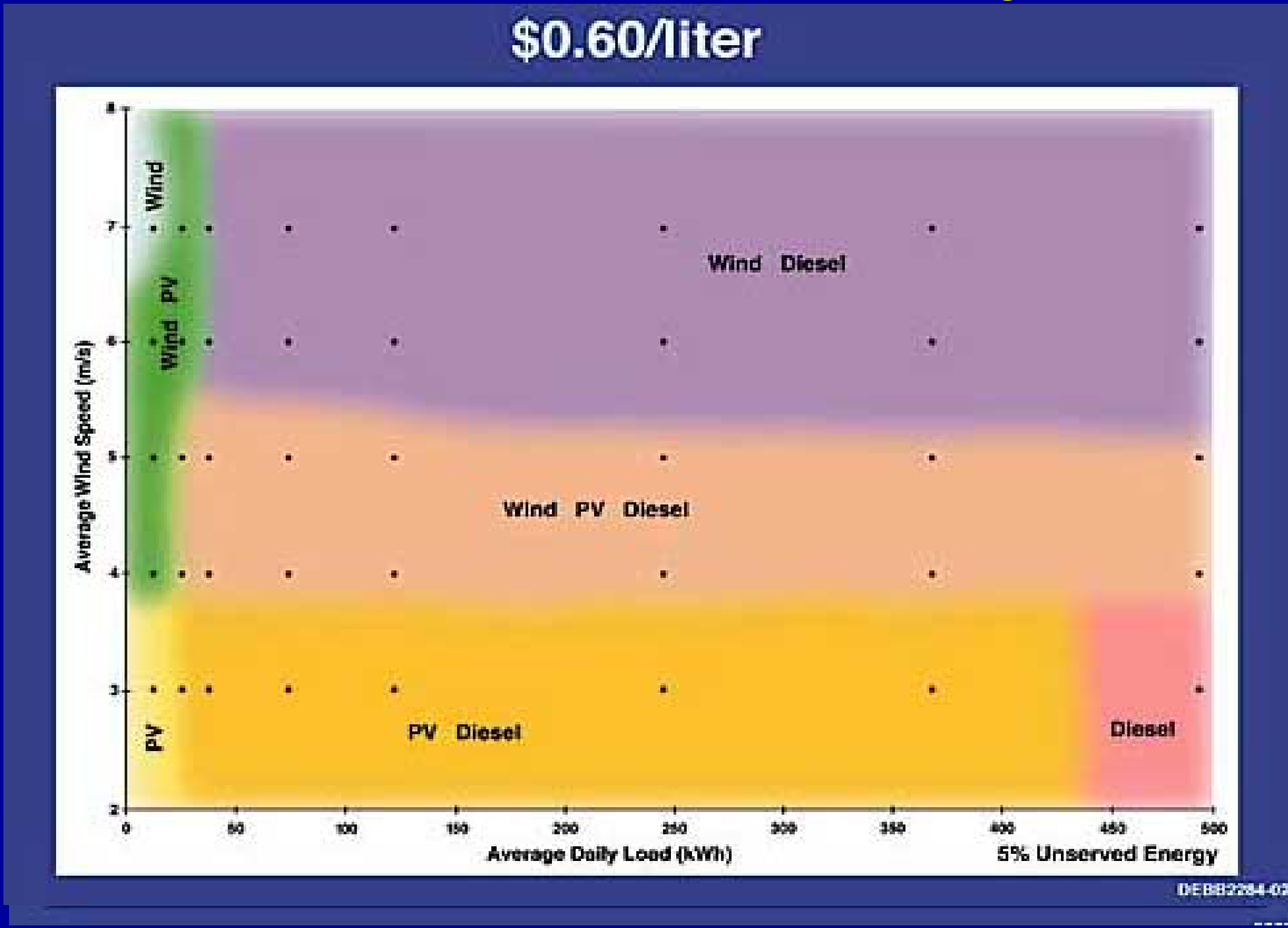



Village Power Hybrids

Simulation Models for Options Analysis



Diesel Retrofits: Options Analysis



Process for Strategic Planning

1. Where do you want to get to?

   Done! Set targets – Energy sufficiency

   Need to bring down to tribal level

2. Where are we now?

   This meeting today: Present situation

3. How do we get there?

   First pass, this meeting tomorrow:

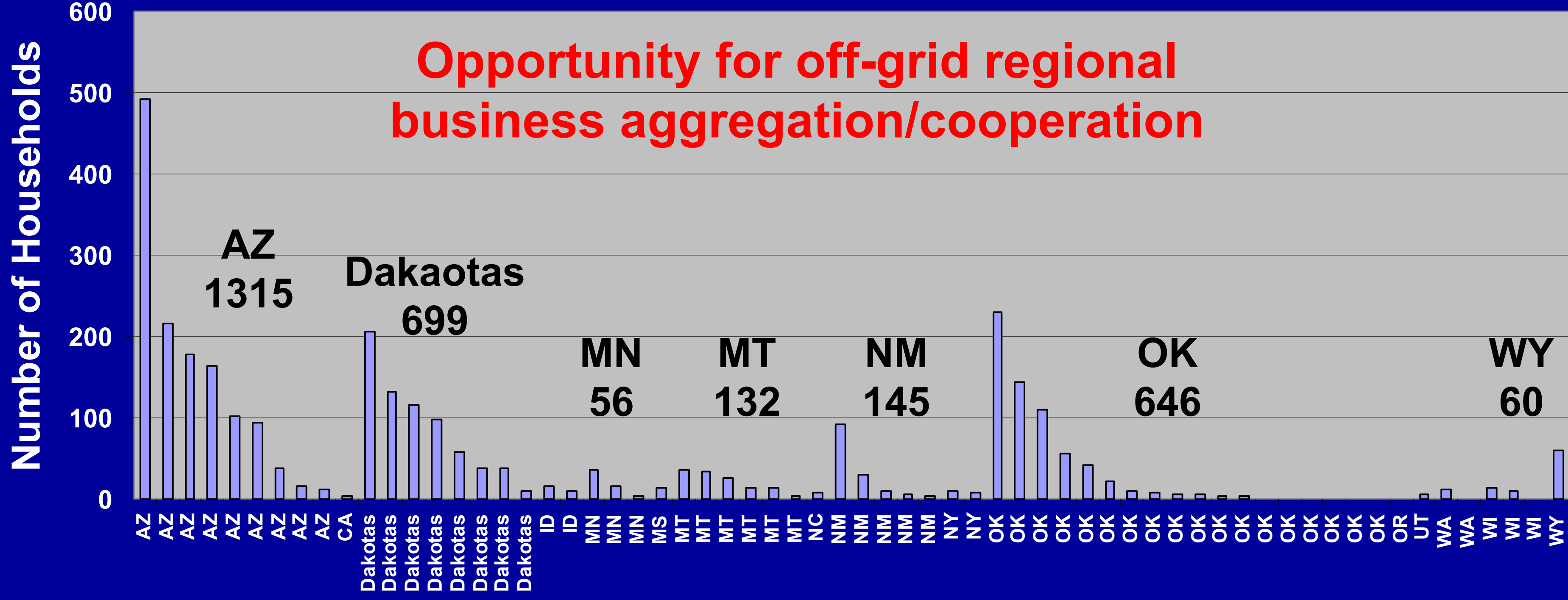
   Pathways, Policies, Supply, Delivery

In the RE Business, There are Two, Totally Different Economic Worlds

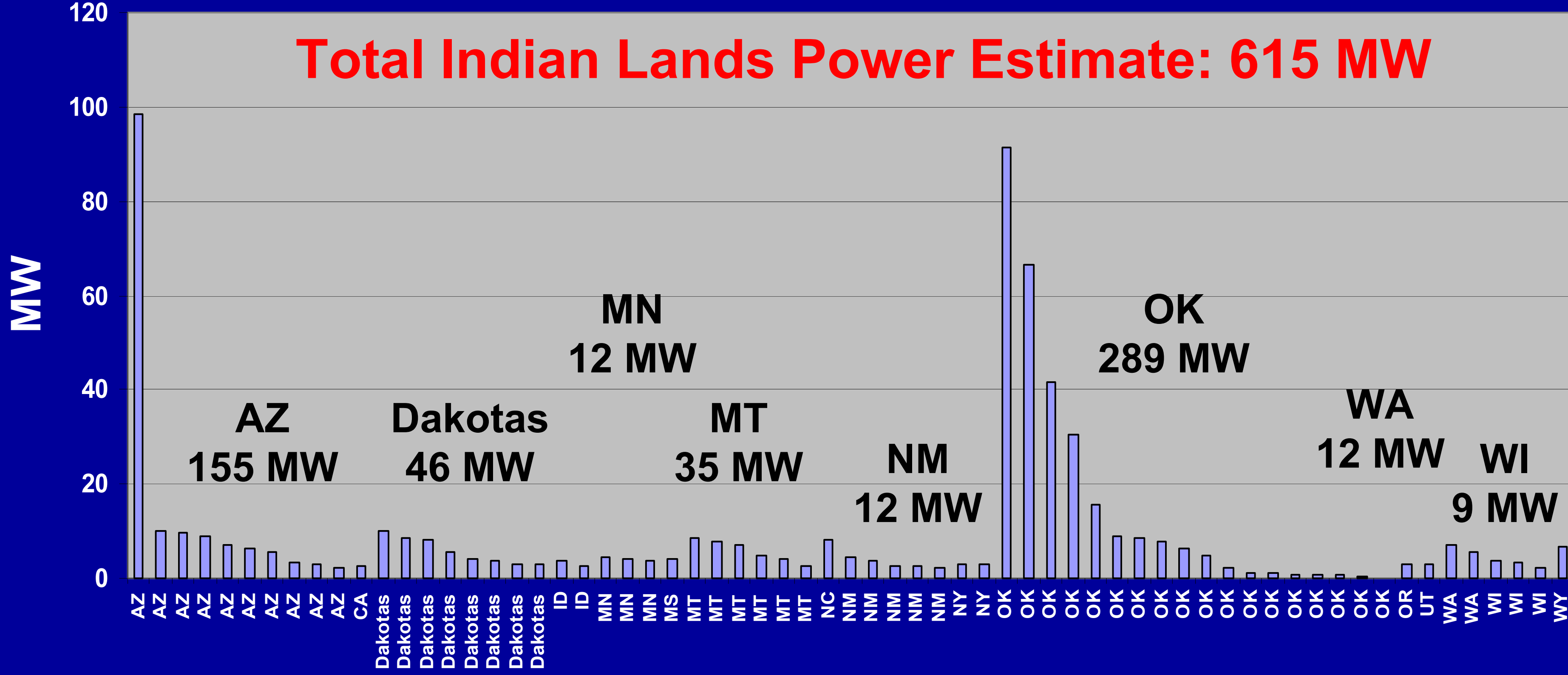
- **On-Grid – Competition for new economic generation to meet Tribal and U.S. electricity needs, and implementation of cost-effective reductions in load.**

- **Off-Grid – Services and economic development for disadvantaged Indian Americans.**

Indian Households - No Electricity Access (less Navaho)



MW Estimate for Electrified Households



Assumptions: 1000kWh/Household/Month, 30% Capacity Factor on Generation

Keys to Market-based Success in Rural Electrification

Technology
- 25 years of research
- manufacturing expansion

Financing
- IFC (SDC, REEF)
- W.B. country loans
- UNDP development assistance
- GEF environmental buy-downs
- Foundations
- Private Investors
- Country $$

In-Country

Marketing
Financing
Distribution
Sales
Service
Maintenance
Revenue collection

INFRASTRUCTURE

Industry Joint Ventures

Integrated Applications
Products

Training
Standards

→ *Billions Cost-Effective Applications*

The Challenge: A large enough quantity of equipment, in a geographically tight enough area, to reach the cash flow needed for local business viability.

Keys to Tribal Rural Electrification Success

Technology
- 25 years of research
- manufacturing expansion

Financing
??
Interior/BIA?
Commercial Loans
Social Development Investments

Tribal

Marketing
Financing
Distribution
Sales
Service
Maintenance
Revenue collection
INFRASTRUCTURE

Industry Joint Ventures

Training
Standards

→ *Hundreds of Cost-Effective Applications*

The Challenge: A large enough quantity of equipment, in a geographically tight enough area, to reach the cash flow needed for local business viability – Regional Tribal Collaboration?

Next Steps

What is right for Indian Country?

- Regional and Tribal needs?
- Tribal renewable resources?
- Tribal priorities?
- Existing institutions to build on?
- Local champions?
- Coordination and management?

Individual Tribal or regional strategic plans:

Reasserting control over Tribal destinies

Project identification and implementation