



# How to Implement Renewable Energy

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**Operated for the U.S. Department of Energy by  
Midwest Research Institute • Battelle • Bechtel**



# Sources of Renewable Energy





# Two Different RE Worlds

- **Grid-connected World** (focus on low  $\phi$ /kWh)
  - Competition between renewables & conventional options
  - Competition and complementarity among renewable options
- **Off-grid, Rural Electrification World** (focus on provision of basic energy services)
  - Small-Scale Individual DC Systems for Specific Loads
    - 12-48V PV and/or Wind Battery Charging Systems
  - Hybrid AC Power Systems for Village Mini-grids
    - Wind, PV, Biomass,  $\mu$ -Hydro, Battery, Gen-sets
    - Mini-grids, Micro-Enterprise Zones, Motor Loads



# Basic Steps

## Technology

- Resource Assessment
- Load Assessment
- Technical Options Analysis

## Policies

- Delivery Pathways  
(government, private sector)
- Incentives (subsidies)

## Programs & Projects

- Definition and Implementation



# Resource Assessment

**Solar**

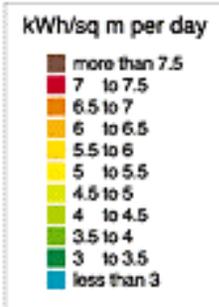
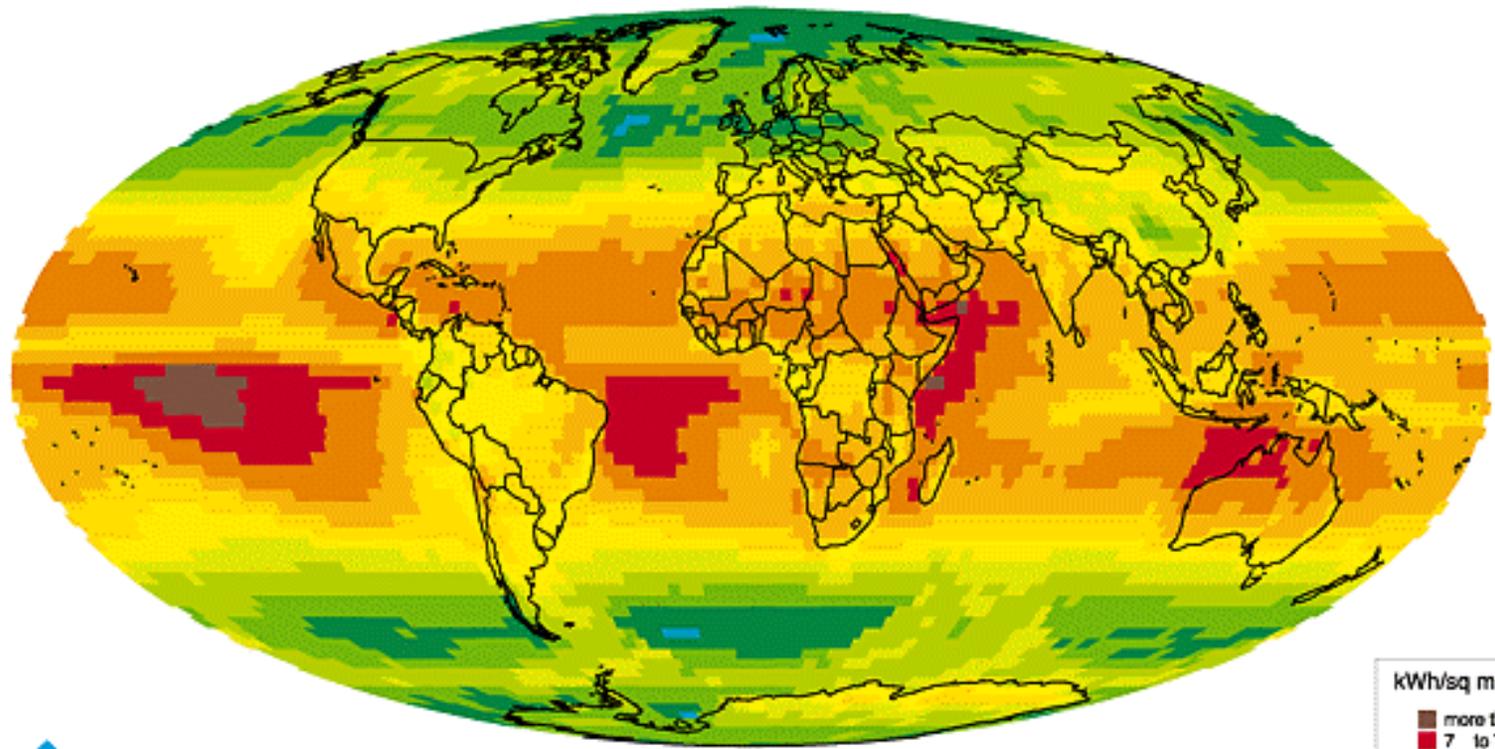
**Wind**

**Biomass**

**Hydro**

**Geothermal**

# Resource Assessment



Preliminary satellite-derived estimates based on the method of Dr. Rachel Pinker, University of Maryland

Data source: World Climate Research Program data available from the NASA Langley DAAC  
NREL contact: Dave Renne (303) 275-4648  
Date: December 14, 1994

## WORLD-WIDE WIND ENERGY RESOURCE DISTRIBUTION ESTIMATES



The above map of the northwestern United States shows that much greater spatial variability of the wind resource exists than appears on the world-wide map. Analyses on smaller scales are usually necessary to any local area estimates.

### CLASSES OF WIND ENERGY FLUX (WEF)

WIND ENERGY CLASS	WEF @ 50 m (164 ft)		WEF @ 100 m (328 ft)	
	W. m <sup>2</sup>	W. ft <sup>2</sup>	W. m <sup>2</sup>	W. ft <sup>2</sup>
1	0	0	0	0
2	100	9	200	18
3	100	9	200	18
4	200	18	400	36
5	200	18	400	36
6	400	36	800	72
7	400	36	800	72
8	800	72	1600	144
9	1200	108	2400	216
10	1600	144	3200	288
11	1600	144	3200	288
12	1600	144	3200	288

BASED ON ESTIMATES BY THE U.S. DEPARTMENT OF ENERGY  
 WIND-ENERGY PRODUCTION  
 INFORMATION IN THE U.S. IS FROM THE U.S. DEPARTMENT OF ENERGY  
 Pacific Northwest Laboratory  
 Prepared for the U.S. Department of Energy  
 by Battelle Memorial Institute



### MAP DESCRIPTION

This map is a preliminary estimate of the annual mean wind energy available at typical well-exposed locations throughout the world. The average energy in the wind flowing in the layer near the ground is expressed as a wind energy class. The greater the average wind energy, the higher the wind energy class, and the darker the shade of blue on the map. The colors corresponding to classes of wind energy are defined in the table at the upper right.

The wind energy class is defined in relation to the mean wind energy flux (WEF) at 50 m above ground level. The WEF is the

rate of flow of wind energy through a unit vertical cross-sectional area perpendicular to the wind direction. At 50 m, the WEF estimate represents large areas that are relatively free of obstructions. Local terrain features can cause the mean wind speed to vary considerably over short distances, especially in coastal, hilly and mountainous areas. There will be local areas of higher or lower wind energy than can be shown on a world-wide map. This is demonstrated by the smaller scale map at the upper left.

### BACKGROUND INFORMATION

The relationship between the mean WEF and the mean wind speed in the table at the upper right assumes a Rayleigh Distribution (Weibull with  $k=2$ ) for the wind speed frequency distribution. A 1.7 power law for mean wind speed and a 3.7 power law for mean WEF relates the 50 m estimate to the 10 m estimate. Because the wind energy estimate generally applies to typical well-exposed locations, the fraction of the land area represented by the wind energy class depends on the physical characteristics

of the land surface form in the region. For example, on a flat open plain close to 100% of the area will have a similar wind energy class, while in hilly and mountainous areas the wind energy class will only apply to a small proportion of the area that is well exposed. On the map, areas where mountainous relief generally exceeds 1500 m are shown using lines with tick marks. Within these areas wind resource estimates are for exposed ridge crests.

The mean wind energy may vary considerably with time of year and time of day. Thus, regions with the lowest wind energy class may have considerably higher wind energy during part of the year and/or day. Conversely, regions with the highest wind energy may experience considerably lower mean wind energy throughout part of the year. Only a few areas of the world have permanently high wind energy throughout an entire year.

Most areas of the world have little or no wind data, and there is disturbingly little data from exposed sites in many windy regions of the world. Of the large amount of wind data available from specific areas at the time of preparation of the map, only a small proportion of the stations had information on anemometer height above ground level or on site exposure. Thus regional climatological information, upon an wind data and other appropriate information, where available, were used in the assessment.



## Other RE Resources

- Biomass, Hydro, and Geothermal are highly site-specific
- Need to assess local inventory and quantify specific opportunities



# Load Assessment

- **Grid:**
  - Inter-connection requirements and power distribution limitations
  - Purchase power rates and requirements
  - Need for systems perspective at a national level, independent of local political interests
- **Off-grid:**
  - Specifics of insulated dc-powered loads.
  - Specifics of individual village mini-grid ac power loads.



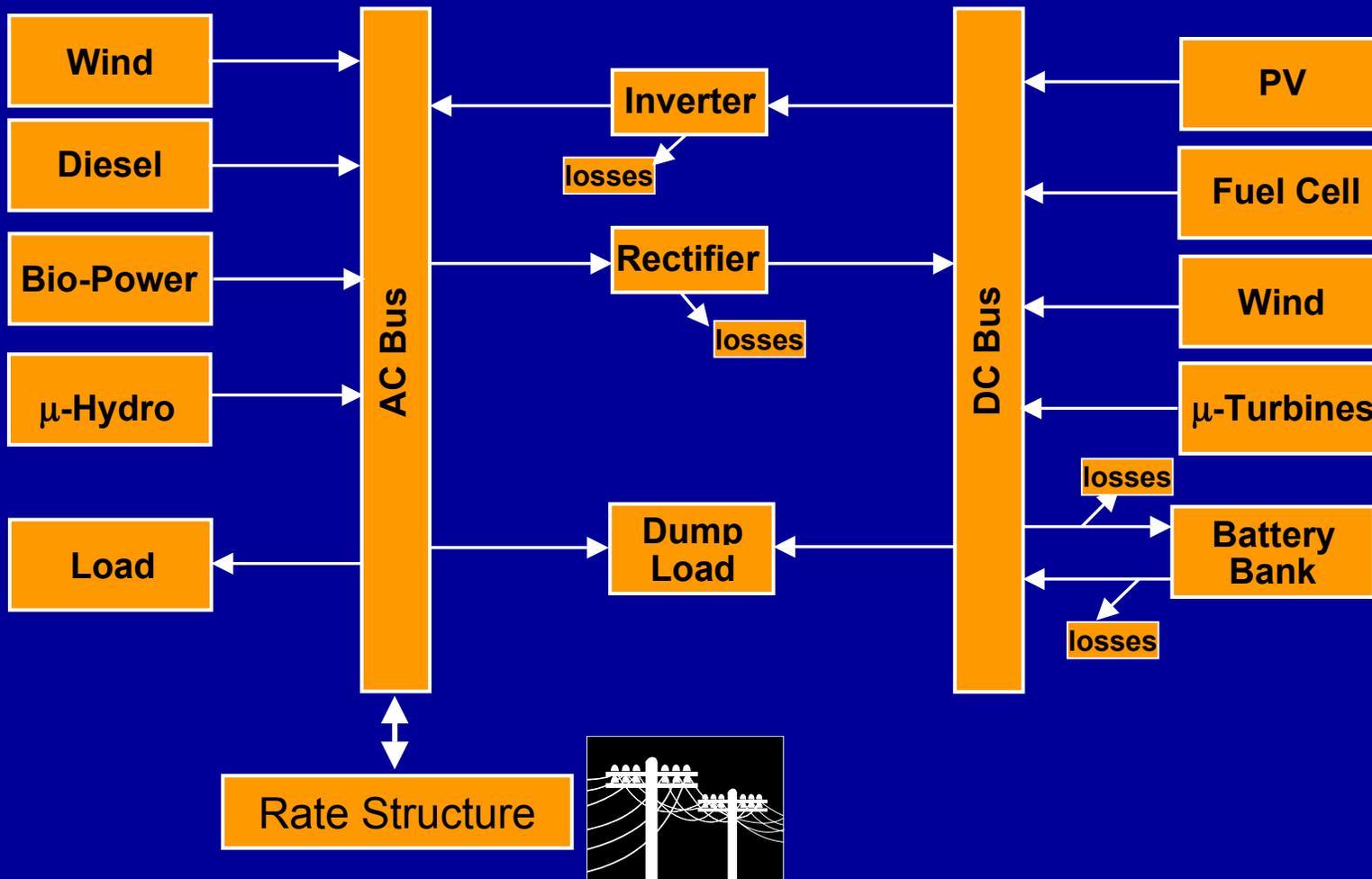
# Technical Options Analysis

- **Grid:**
  - Strategic planning time-horizon
  - Competition among other investment options
  - Synergistic operation with existing and future national system
- **Off-grid:**
  - New computer-based approaches to system optimization



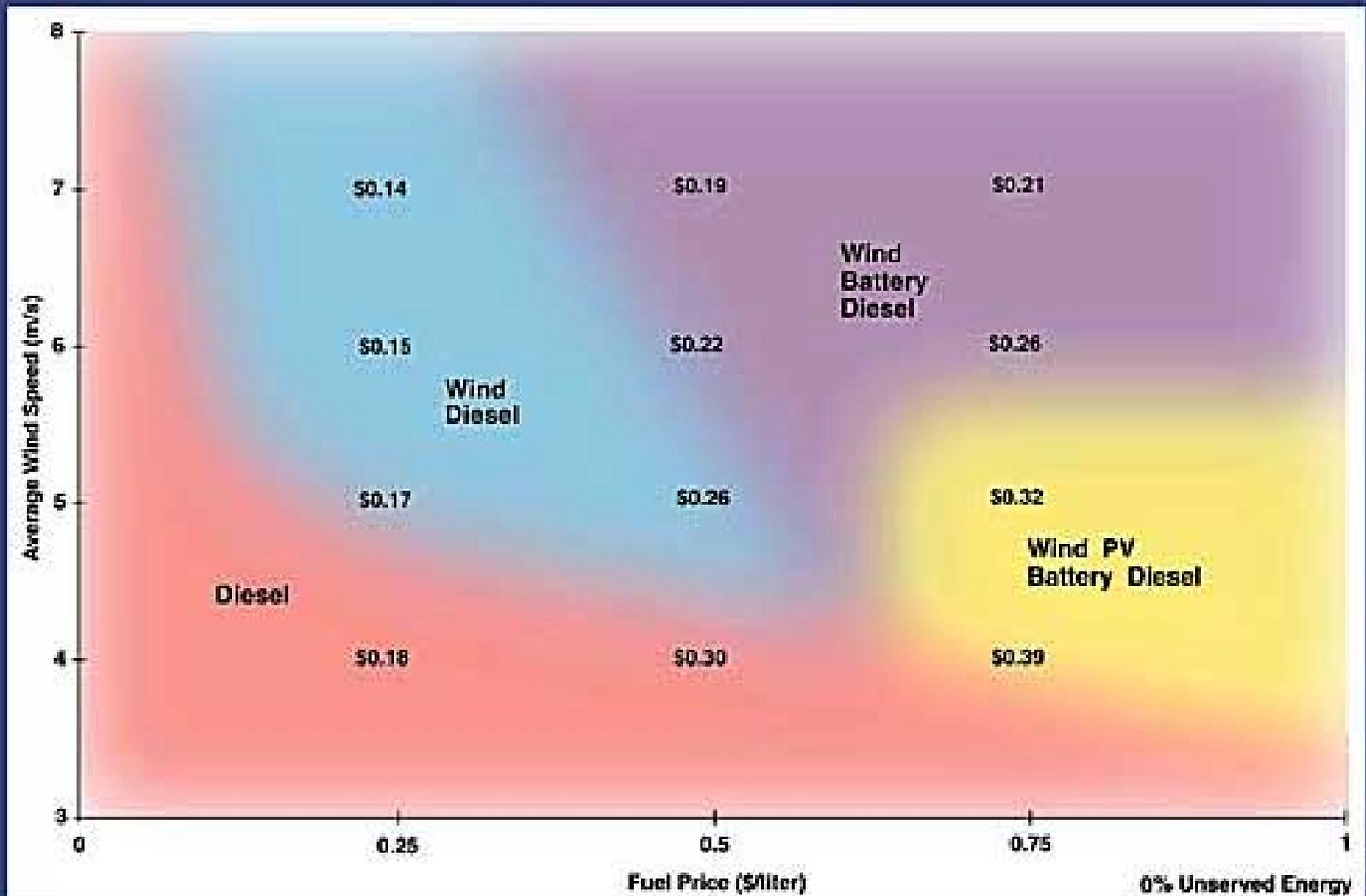
# Village Power Hybrids

## Simulation Models for Options Analysis



# Diesel Retrofits: Options Analysis

900 kWh/day





# National Incentive Programs

## Large-Scale Grid Connected Power

### **RE implementation usually requires some combination of:**

- Government Will and/or Private Sector Encouragement
- Direct incentives/subsidies (tax credits, buy-down program)
- IPP Incentives (purchase power rate, long term contracts)
- Green Pricing (consumer contributions)
- Renewable Portfolio Standard (requires utility privatization and regulation)



## **Focus on Delivery Pathways is the Key to Success for Rural Electrification**

- **Retailers, Individual Entrepreneurs** (manufacturer-linked?)
- **“McSolar”** (Franchise Model)
- **Traditional Rural Electric Cooperatives** (member owned)
- **Local or Municipal Power Association**
- **Rural Energy Service Companies** (very small to very large)
- **National Utility – Diesel Group, Rural Electrification Group**
- **Non-Government and Private Voluntary Organizations**
- **Independent Power Production**

**Focus on the “How”**

**Delivery of energy services on a sustainable (business-like) basis.**



## Sustainable RE Programs and Projects

- Establish National Priorities
- Assess Resource and Technology Options
- Develop Separate, Independent Programs for On-grid and Off-grid Energy Needs
- Focus on Life-Cycle Economics
- Focus on Long-term Maintenance and Service
- Focus on Cost-Recovery, and Business Financial Viability