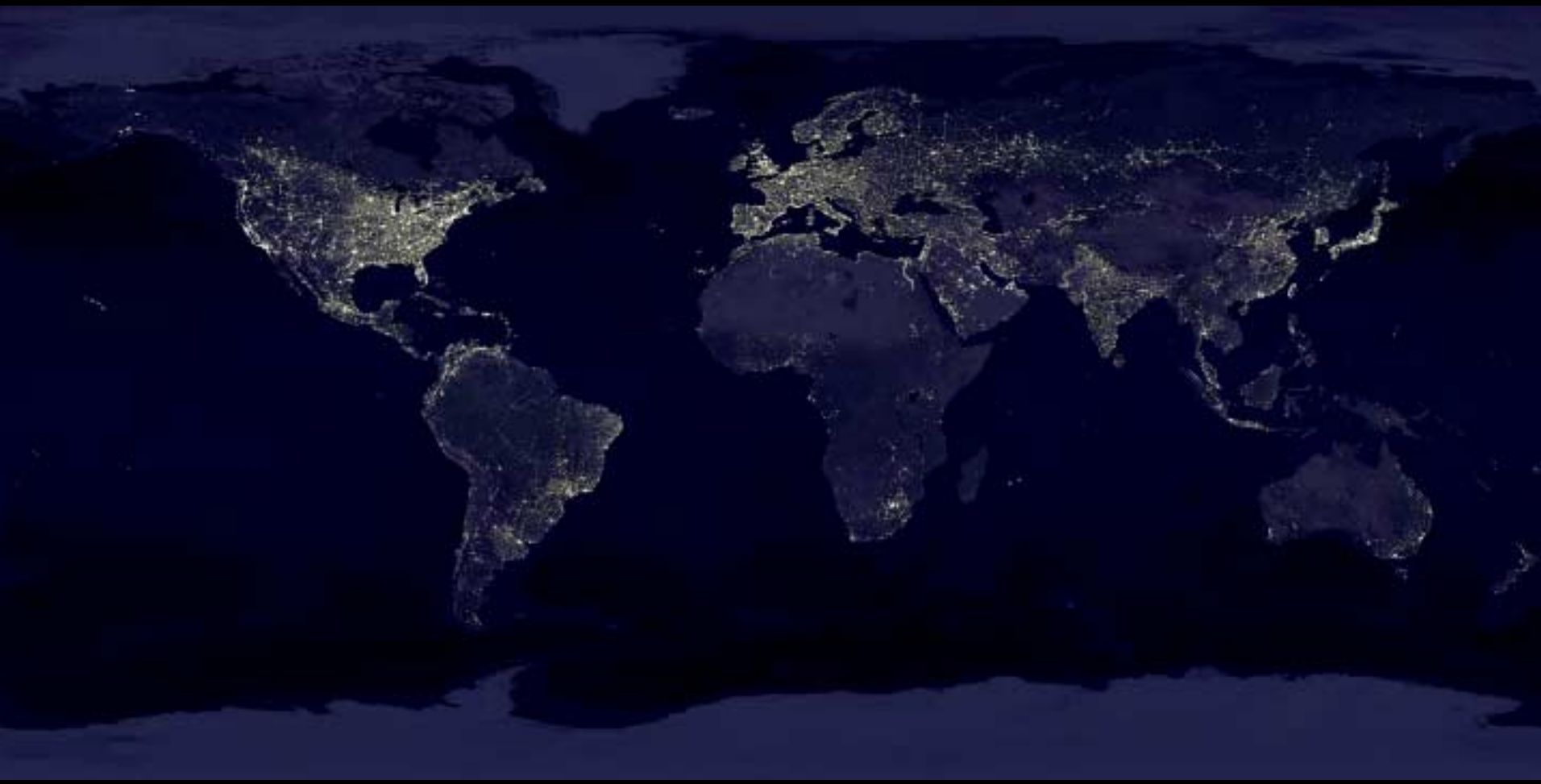
National Renewable Energy Laboratory

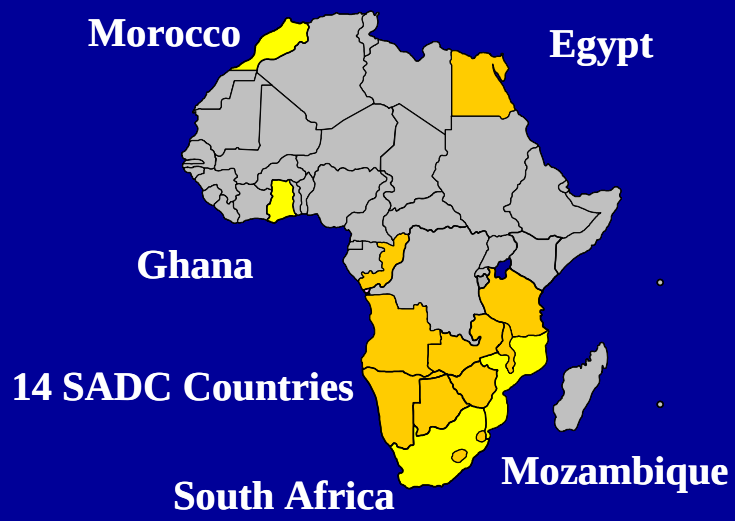
Renewable Hybrid System Applications around the World

NREL – NETL – DOE
Natural Gas/Renewable Energy Hybrids Workshops
#2 held at NREL
August 21-22, 2001

Roger Taylor
Manager, International Programs
National Renewable Energy Laboratory



Key Countries



Rural Electrification Options

- Traditional Rural Electrification
  - Grid extensions, diesels or micro-hydro
- New and Renewable Alternatives
  - Small-Scale Individual DC Systems
    - 12-48V PV and/or Wind Systems
  - Hybrid AC Power Systems
    - Wind, PV, Biomass, μ-Hydro, Battery, Gen-sets
    - Mini-grids, Micro-Enterprise Zones, Motor Loads
  - Distributed Generation Grid-Connected

Small Scale Individual DC Systems

Examples

Solar Home Systems

Public Area Lighting

Schools

- Lights
- Computers
- VCRs
- Distance Learning
- Adult Education

South Africa

Health Clinics

Water Pumping

India

Brazil

Water Purification

Bangladesh

Philippines

Mexico

Nigeria

Microenterprise Development

Ghana

India

China

Rural Telephony

Brazil

Inner Mongolia, Wind/PV Home Systems

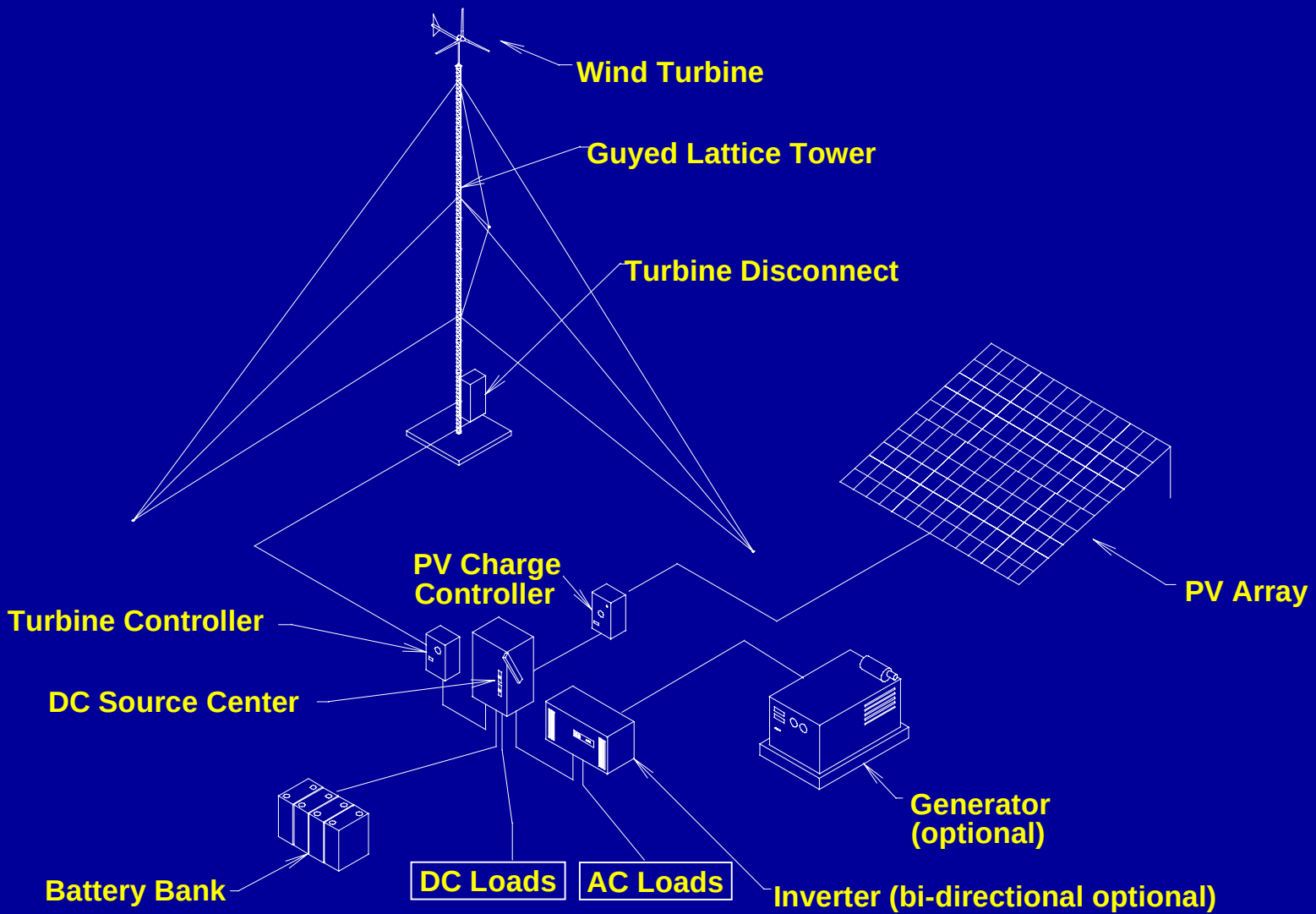
Why AC Renewable Hybrids for Village Power?

- **Higher Availability**
  - **Hybrids reduce daily & seasonal resource variations**
- **Lower Cost of Energy**
  - **Resource diversity minimizes battery size and fuel usage**
- **Higher Power Motor Loads**
  - **Refrigeration, grain grinding, carpentry**
- **Existing Diesel & Distribution System Investment**
- **Higher "Quality" of Service (maybe 24 hour)**

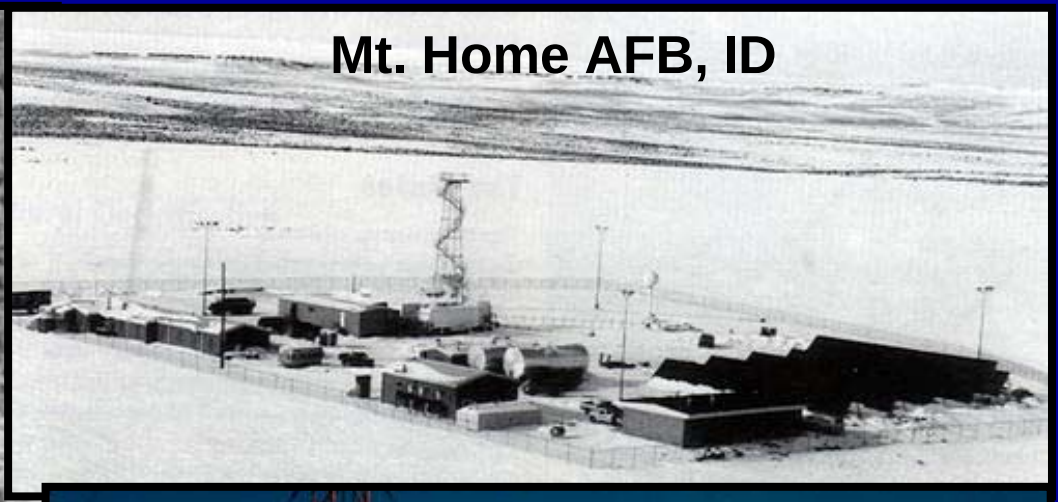
Renewable Hybrid Village Power Systems

- **Power Spectrum of Interest**
  - **10's of W_{dc} to 100's of kW_{ac}**
- **Technical Configuration**
  - **Parallel operation (generation diversity)**
- **Most Utilities are Hybrid Power Systems**
  - **Single resource utilities (diesel, hydro) have higher supply risks**
- **Technical maturity is not the deployment constraint**
  - **But reliability and integration need additional work**

Typical Hybrid Village Power System



Hybrid Power System Examples: "Communications"



Hybrid Power System Examples: "Parks"

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

Hybrid Power System Examples: Xcalac, Mexico

Now Running on Diesel Only

60 kW Wind, 12 kW PV, 40 kW Inverter

Hybrid Power System Examples: Campinas, Brazil

Probably Running on Diesel Only

50 kW PV
50 kVA Inverter
300 kWh Batteries

San Juanico, Mexico

Remote fishing & tourism community of 400 people

Power System

- **17 kW PV**
- **70 kW wind**
- **80 kW diesel generator**
- **100 kW power converter/controller**
- **Advanced monitoring system**

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

DC

AC

Battery Bank
240 VDC, 130 Ah
~30 kWh

Rotary Converter
156 kVA

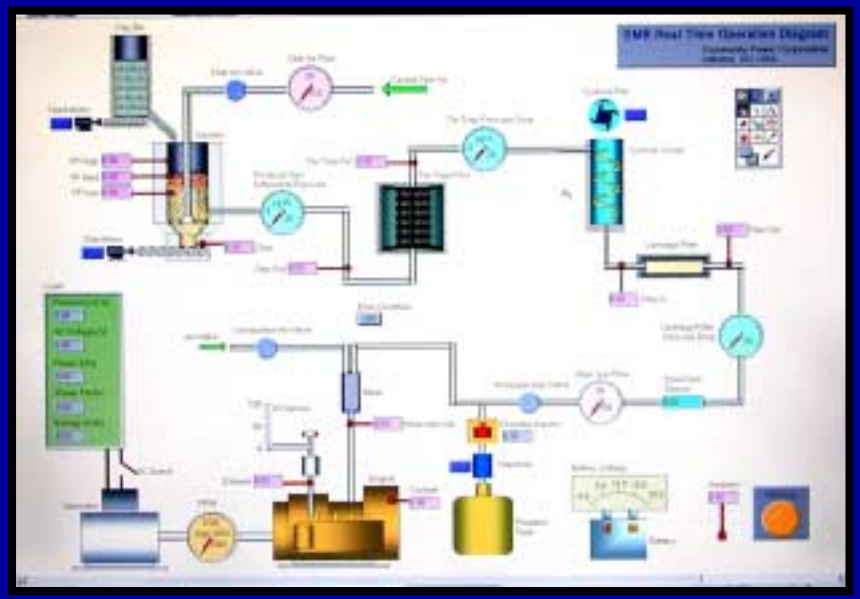
Secondary Load
Controllers

School Heating
System

Resistance
Heaters

Diesel
Plant
Hydronic
Loop

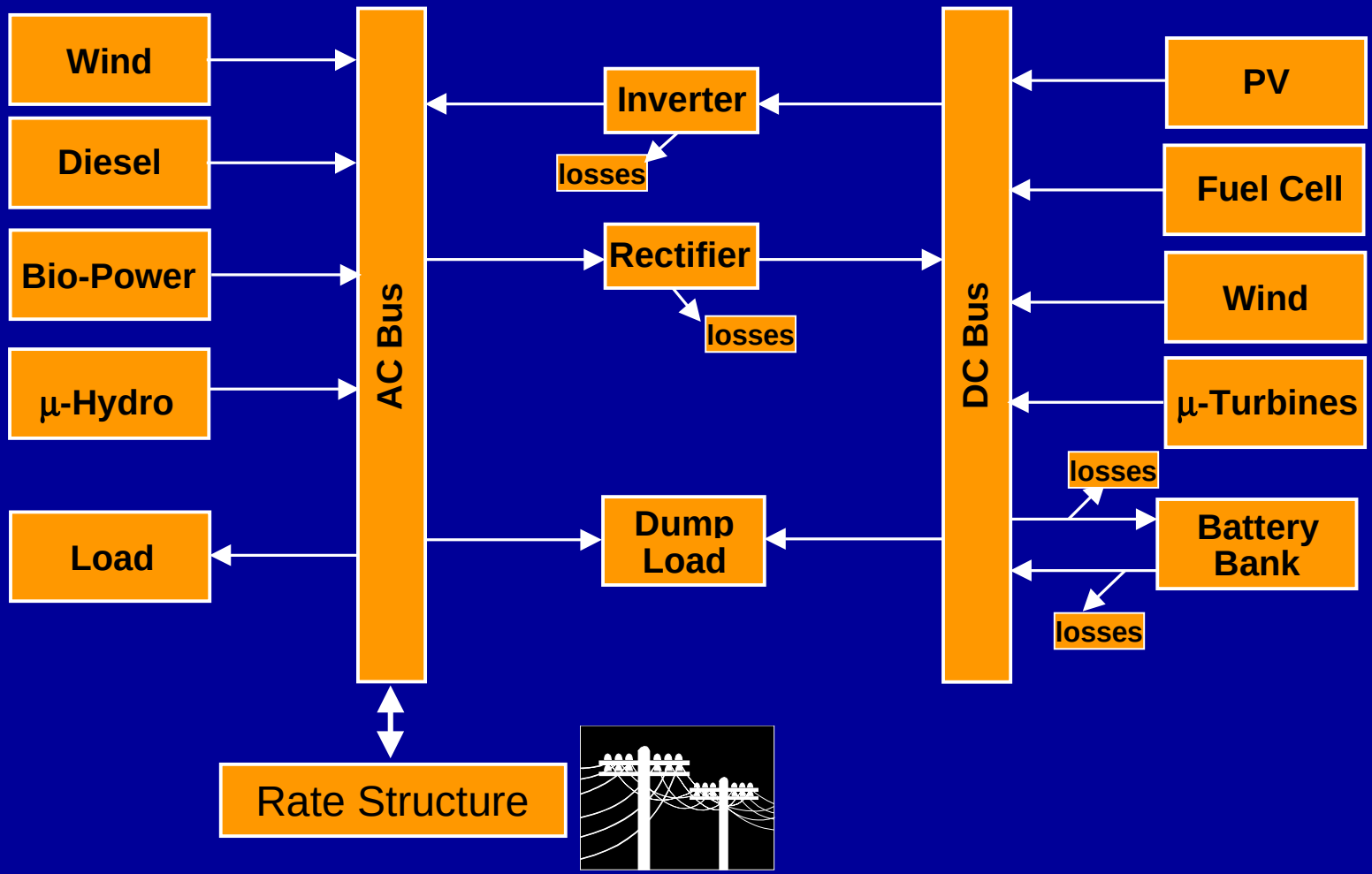
CPC's 5 to 25kWe Small Modular Biopower System



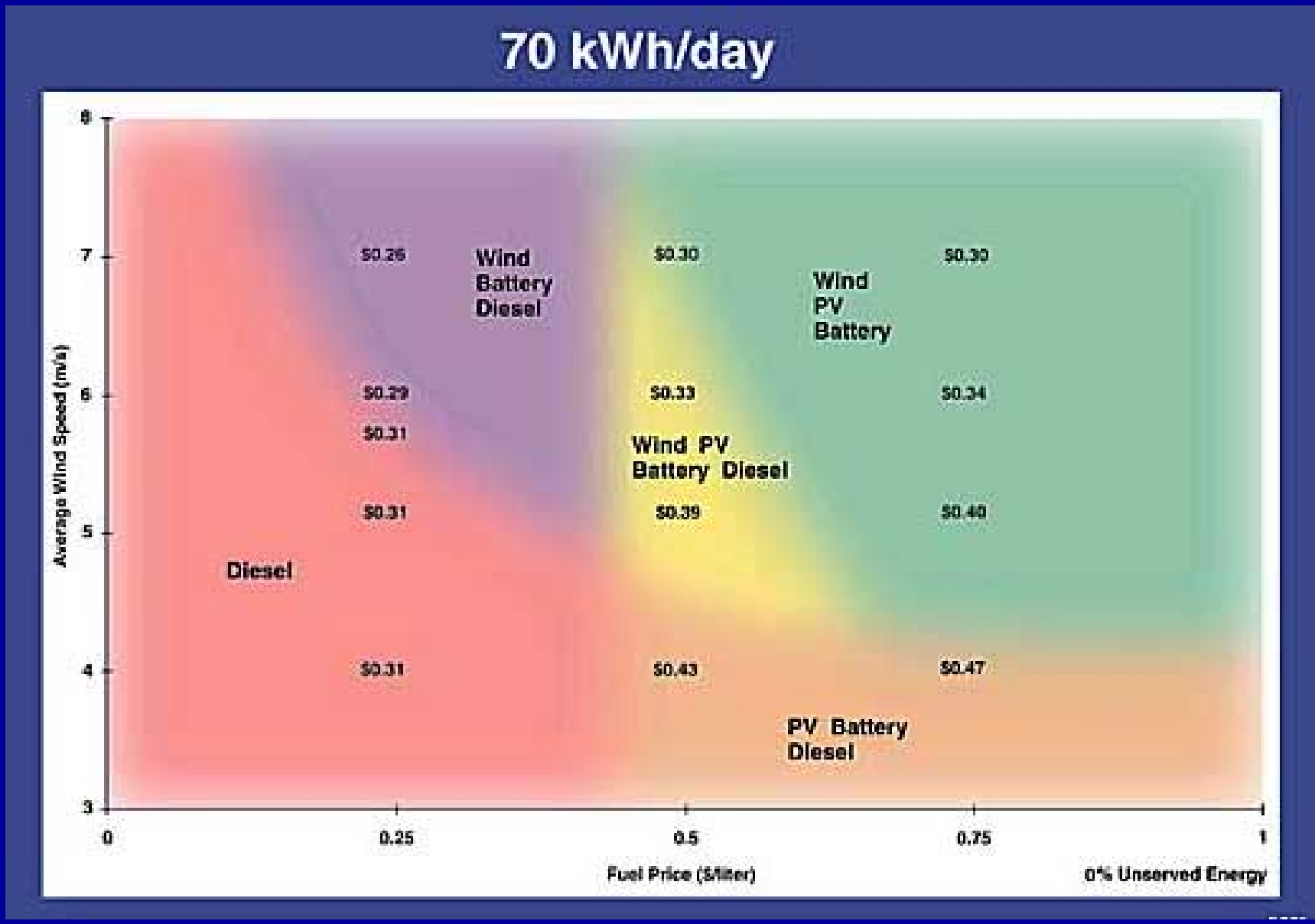
Distributed Generation Hybrid Power System

Parker Ranch, HI

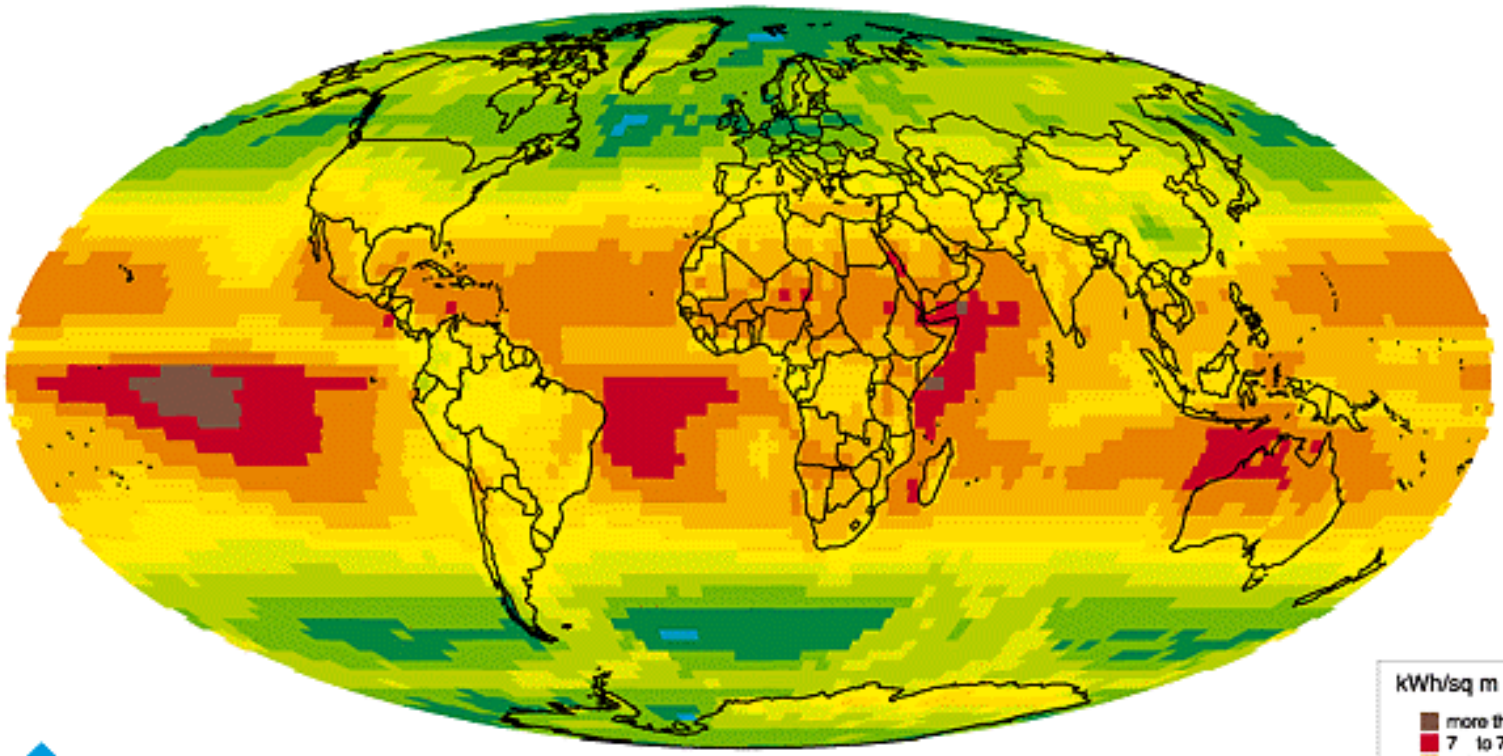
Village Power Hybrids
Simulation Models for Options Analysis



Diesel Retrofits: Options Analysis



Resource Assessment

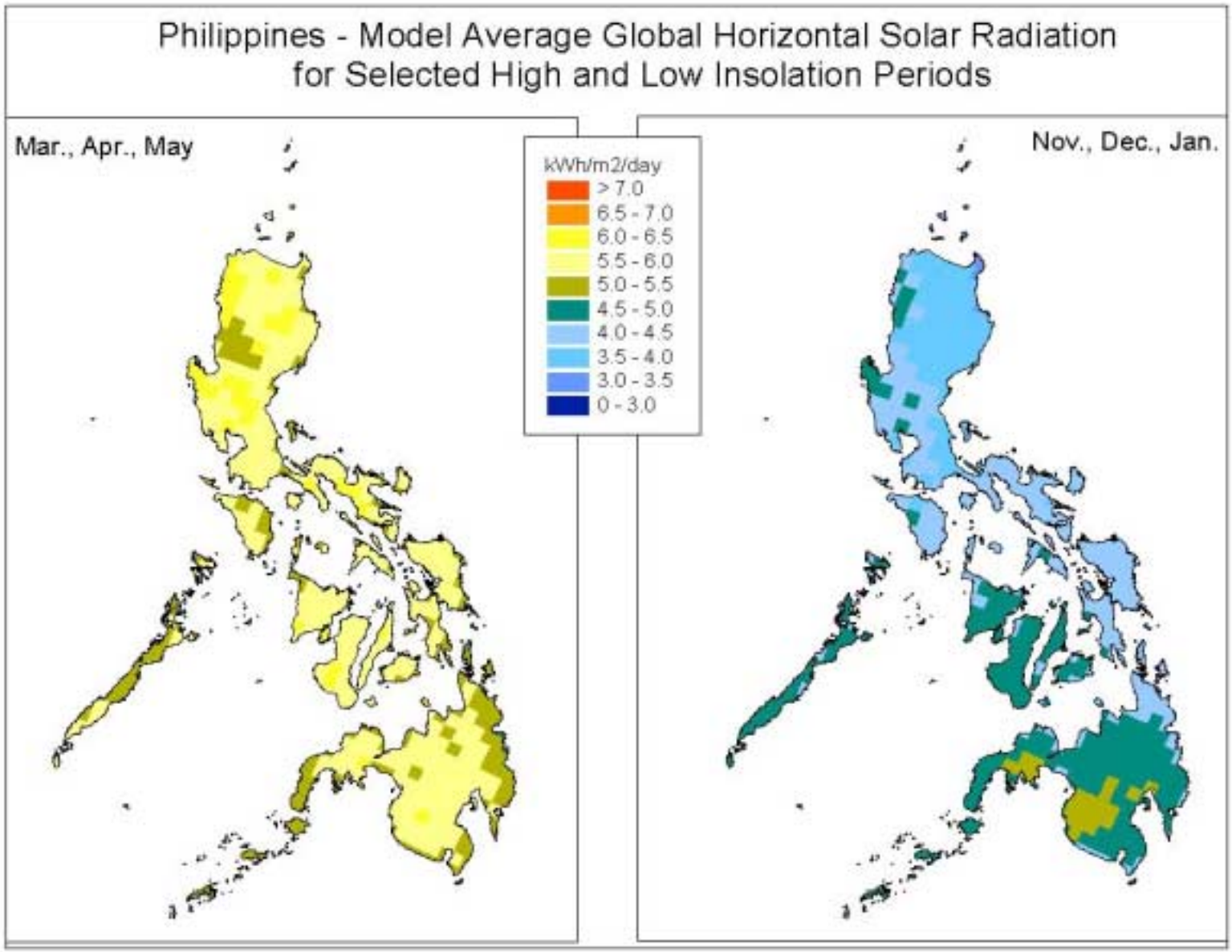


Preliminary satellite-derived estimates based on the method of Dr. Rachel Pinker, University of Maryland

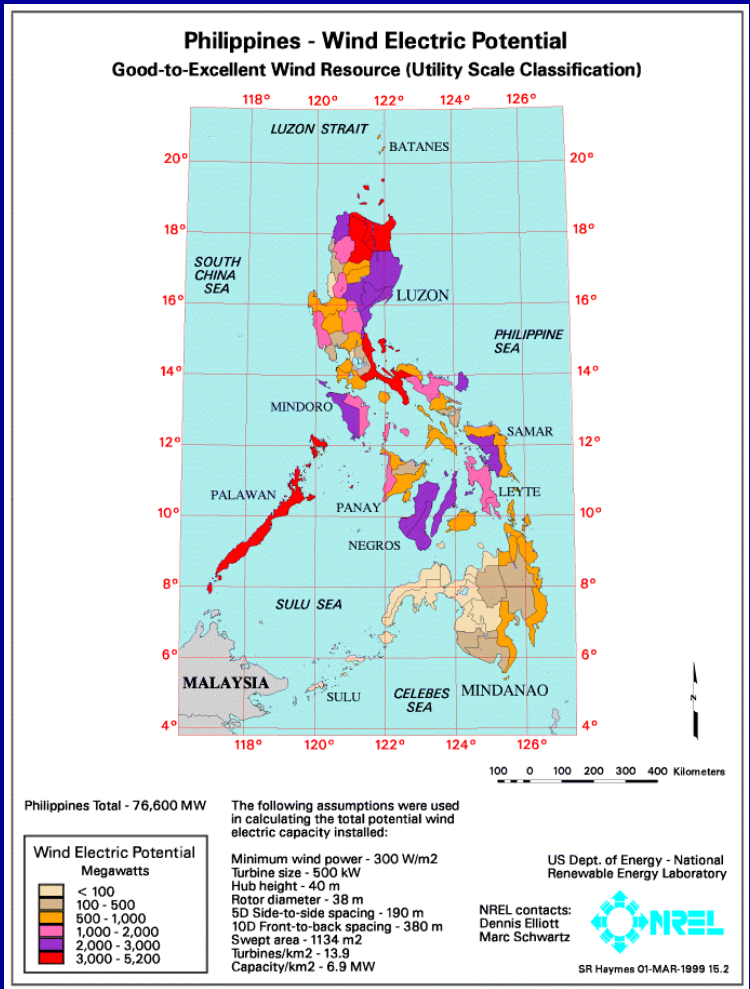
Data source: World Climate Research Program data available from the NASA Langley DAAC
NREL contact: Dave Renne (303) 275-4648
Date: December 14, 1994

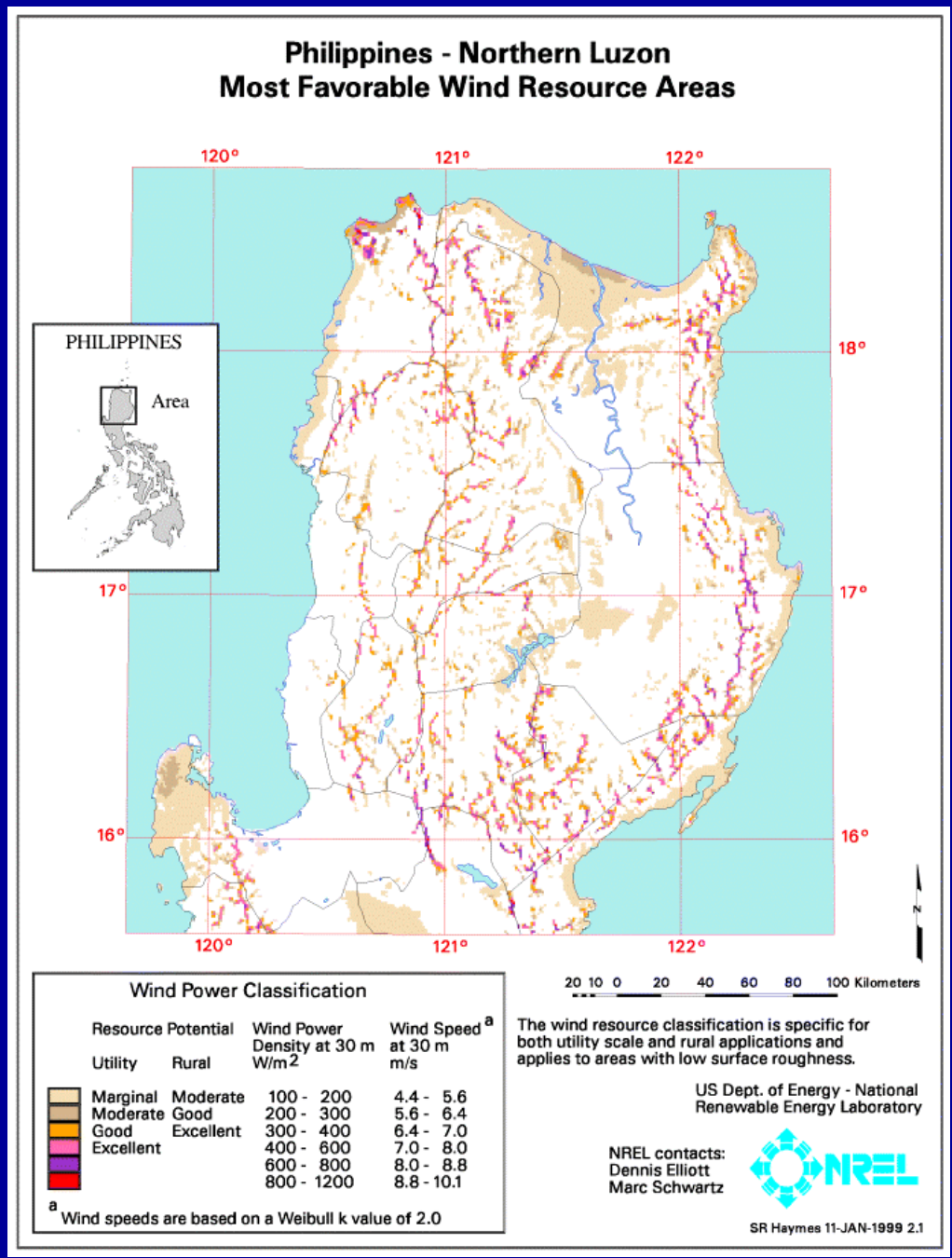
NREL #9500020-001 14DEC94 SRH

Renewable Resource Options: Solar

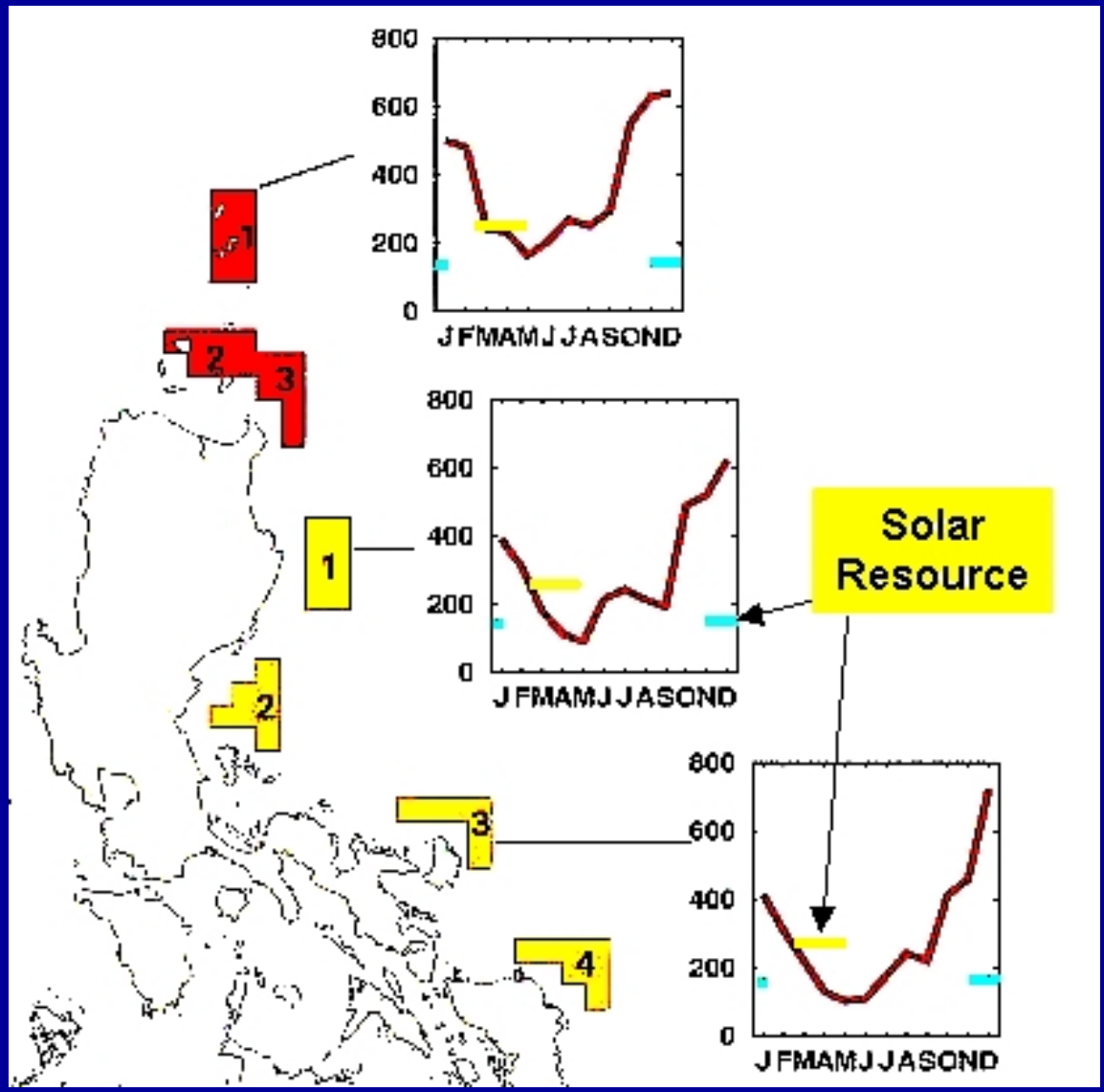


Renewable Resource Options: Wind

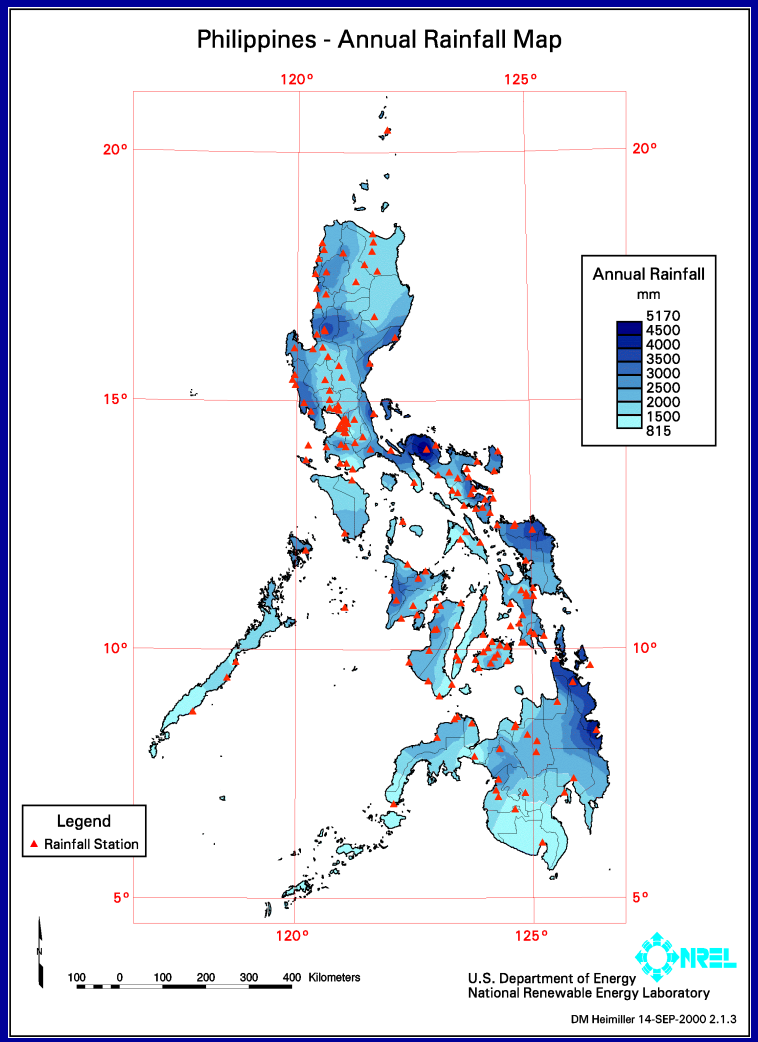


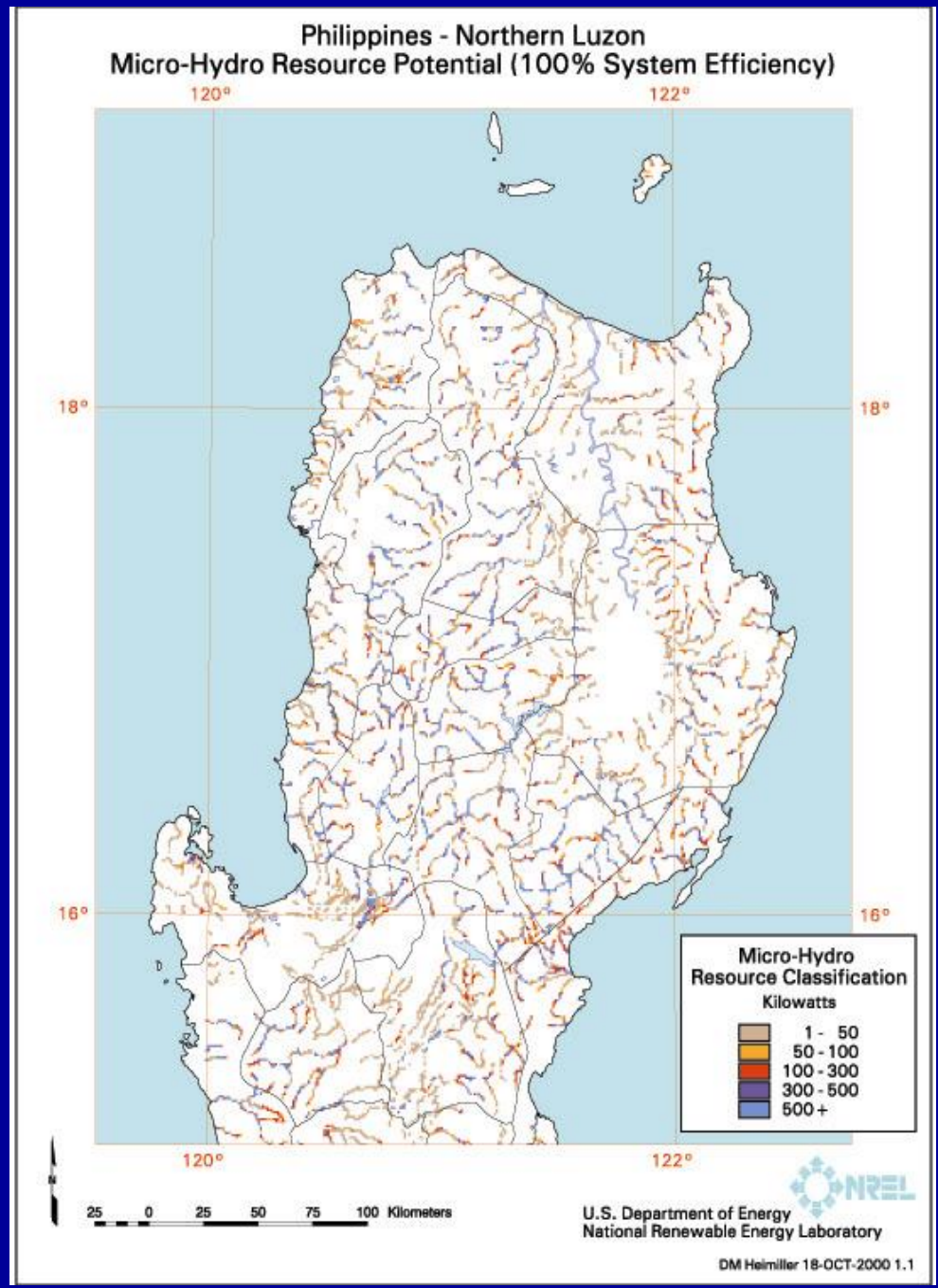


Wind & Solar Counter-Correlation

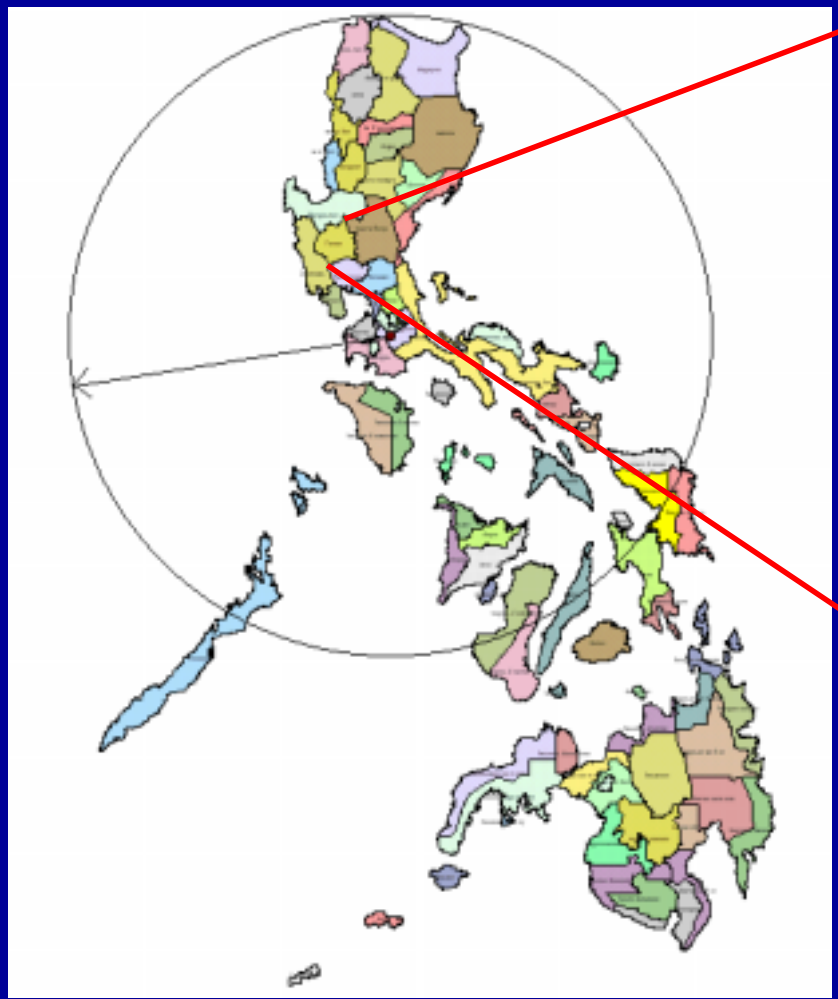


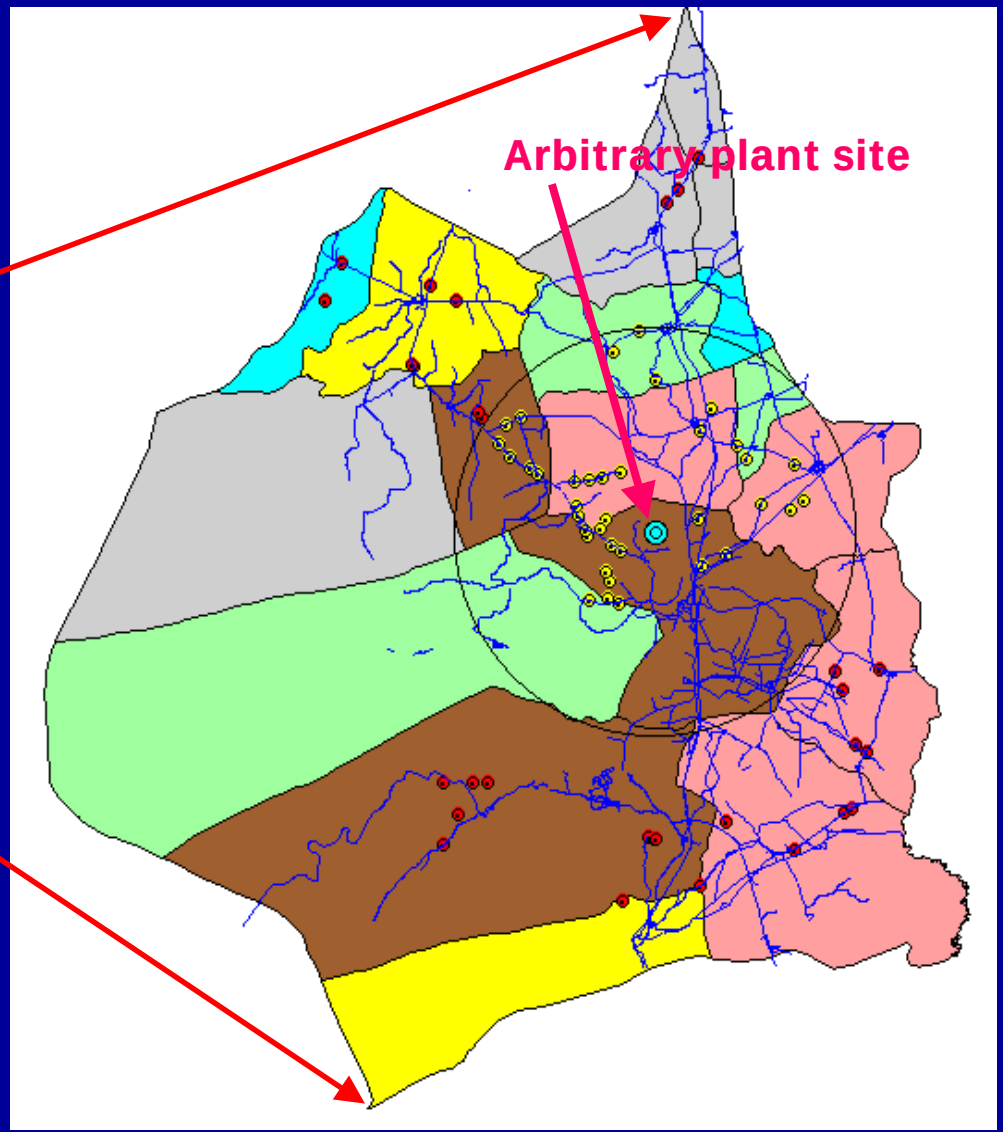
Renewable Resource Options: Hydro





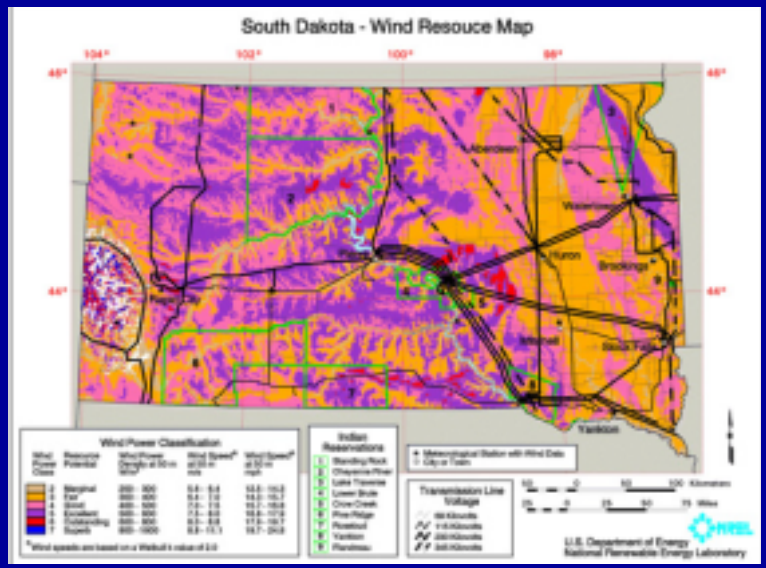
Renewable Resource Options: Biomass



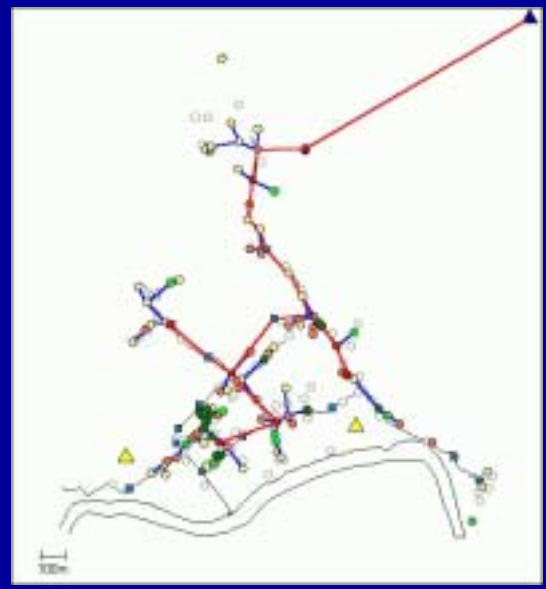


Integration of Resource, T&D, and Technology Options Analysis

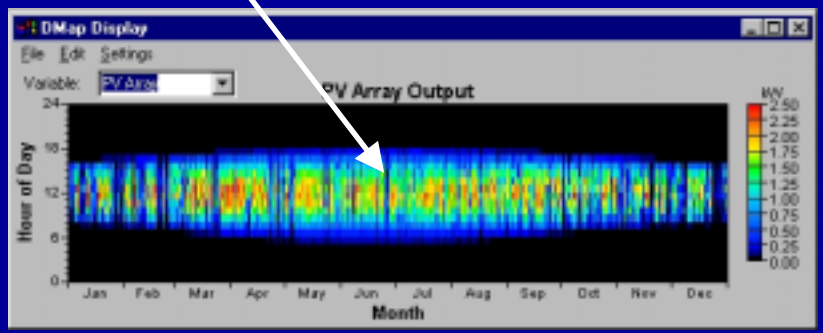
Automated siting knowing resource availability, T&D investments and constraints



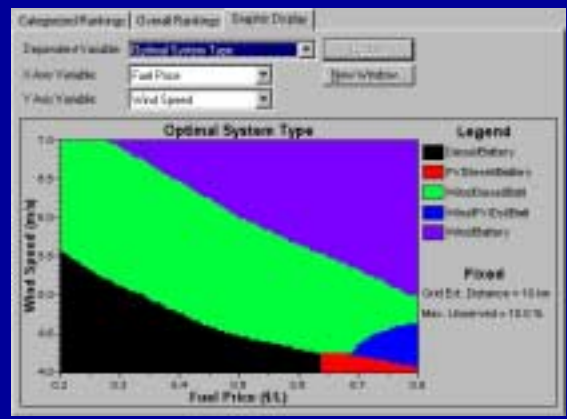
Stand-alone, hybrid, or grid connection?



Evaluation of "solar outage" effects



Transparent Options Analysis



Village Power Systems Lessons Learned

Institutional Aspects

- Partnering
- Maintenance
- Tariff design (grid systems)
- Tariff design (stand-alone systems)
- Development coordination
- Planning tools
- Economics
- Language

Pilot Project Characteristics

- Performance
- Energy efficiency
- Quality of Service
- Replication mind-set
- One-of-a-kind demonstrations
- Loads
- Diesel retrofits
- Performance monitoring
- Buy-down

Implementation Process

- Political will
- Duration
- Commercial replication
- Needs-drive approach
- Local Administration

Technology & Development Needs

- Hybrid systems
- Controls
- Lightning/corrosion
- Meters
- Resource data
- Integrators/packaged systems

Hybrid Power Systems Lessons Learned

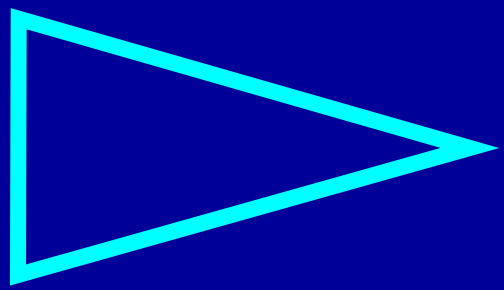
- Nothing is maintenance-free. A maintenance support infrastructure must be established and nurtured from the very conception of a project.
- Repairing equipment in remote locations is difficult and expensive. Multiple systems in a region are required to develop and sustain a cost-effective support infrastructure.
- Retrofitting expensive hybrid power systems in a village without first addressing end-use appliances, metering and switches is a mistake.
- Hybrids have large swings in short-run marginal costs. Tariff structures or load management can be important tools.
- In pilot projects, robustness and reliability are more important than energy conversion efficiency.

Hybrid Power Systems Lessons Learned

- Resist the temptation to field the “latest and greatest” until it has been thoroughly tested under controlled conditions.
- The transition from the pilot phase to commercial replication can be difficult. The more the pilot project can be set up to look and act like a business, the easier the transition.
- It is often more economic to install a new, appropriately sized diesel than to use the existing, oversized, poorly maintained one.
- There is no substitute to a dedicated, influential, local champion.
- The time from initial interest in renewables to commercial replication takes 4-6 years, in a positive institutional climate.
- Hybrid systems are a potentially significant solution to rural ac electricity needs, but further technology development, systems integration, simplification, and industry expansion will be required.

Keys to Commercial Success

Technology
- 25 years of research
- manufacturing expansion



In-Country
Marketing
Distribution
Sales/Financing
Service
Maintenance
Revenue collection
INFRASTRUCTURE

Billions Cost-Effective Applications

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

Joint Ventures

Integrated Applications
Products

Training
Standards

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

Possible Institutional Pathways

- **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**
- **Non-Government and Private Voluntary Organizations**