NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Supported by the U.S. Department of Energy

# Latest in Village Scale Clean Energy Technology

**E. Ian Baring-Gould**

**April 29, 2014**

***Alaska Native Village Energy Development Workshop***

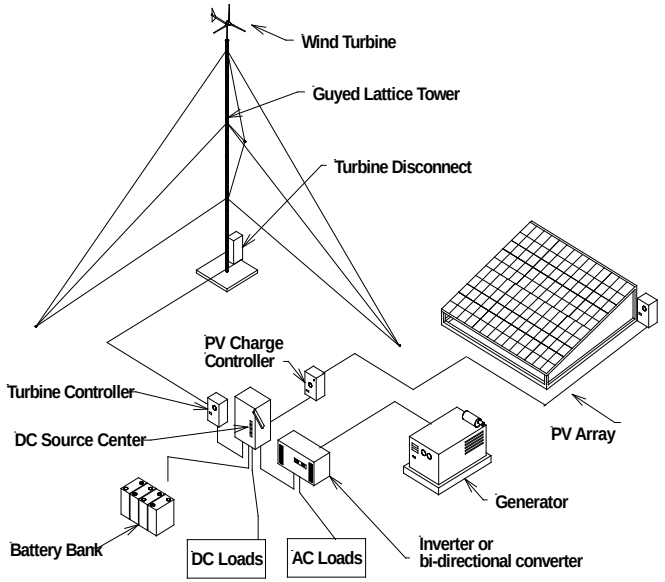
# Range of Power Systems

Renewable power system can be used to cover a wide range of needs, including:

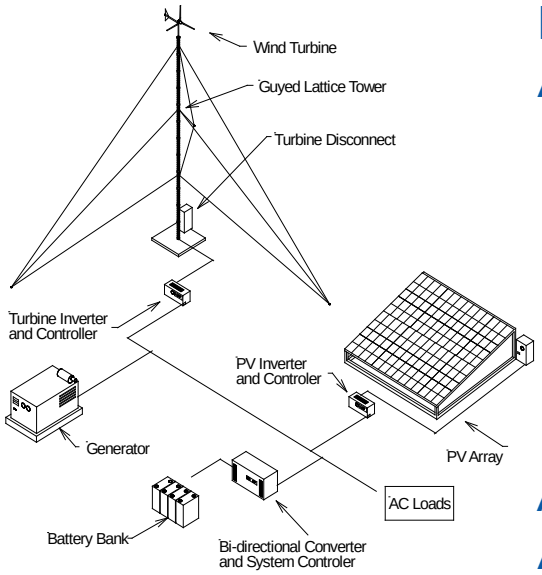
- **Dedicated use:** Power being used at point source without regulation such as water pumping and ice making.
- **Small or Simple systems:** Power systems for small communities, individual buildings, and dispersed energy needs.
- **Community Power Systems:** Power provided to large communities and isolated loads.
- **Integrated Systems:** Large islanded systems integrating conventional and large scale renewable generation.

# Small and Community Power Systems

- Small scale power systems that use a centrally located power plant and distribute AC power to a small number of connected loads, homes and/or buildings
- Incorporate dispatchable generators to “insure” power availability
- Single point of service and maintenance
- Usually use larger or multiple generation units to improve operation performance and benefit from quantities of scale benefits
- Provide “grid” style power and are sometimes called “Micro or Mini-grids”

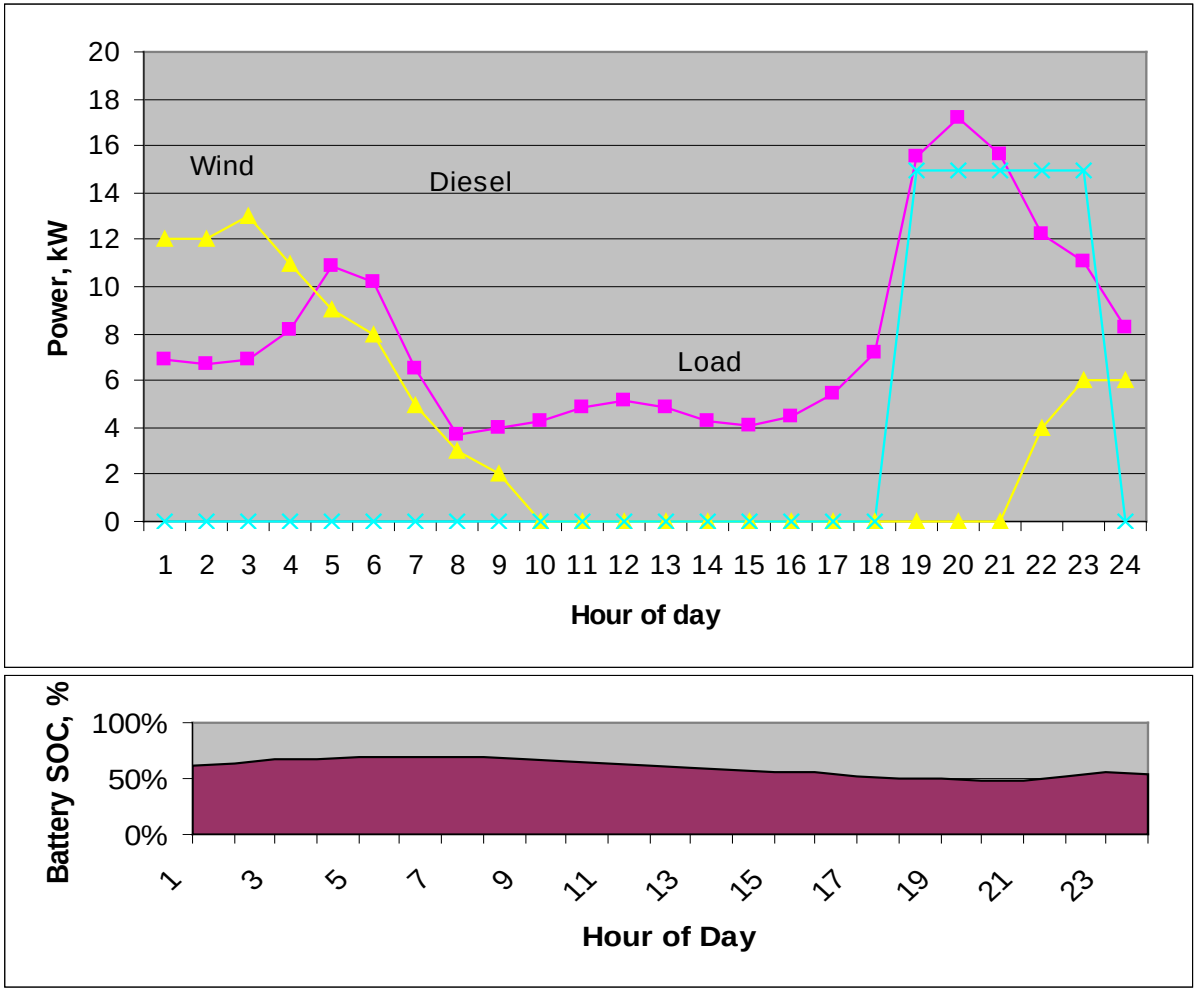



DC Based Architecture




AC Based Architecture

# Systems With Energy Storage




Renewable Energy is used to cover “most” energy needs and a large battery system is used to provide energy stability. Dispatachable generators are used to provide any additional energy needs.

# Recent Technology Developments

- Dropping cost of RE technologies on a kWh basis, mostly PV but other technologies as well
- Continued development in less mature technologies, marine hydro-kinetic (MHK) for river and ocean deployment
- More advanced inverters with more advanced controls
- Advancements in battery technology (Li-ion) and battery control
- More examples of operating systems with different development and technology approaches
- Real integration of energy efficiency into the development of projects

NPS Alcatraz PV system – a 307 kW PV Array, 2000 ah battery, inverter array and diesel system that can operate diesel off

# Australia's Remote Solar Systems

Water and Power Corp.

- Operate remote diesel microgrid utilities throughout rural Australia (~50 grids)
- Integrates power & water & larger grids
- >90% PV contribution w/ diesel backup
- Batteries, low-load/high efficiency diesels, PV trackers
- As simple as possible – reduce O&M

# First All Solar Nation - Tokelau

1 MW distributed PV systems, SMA inverters, 1344 batteries and coconut oil based dispatchable power – Meets all electrical needs for 1,411 people on three islands.

# Renewable Energy - Diesel Power Systems

Based on an AC bus configurations using renewable turbines and diesel engines as an integrated power system.

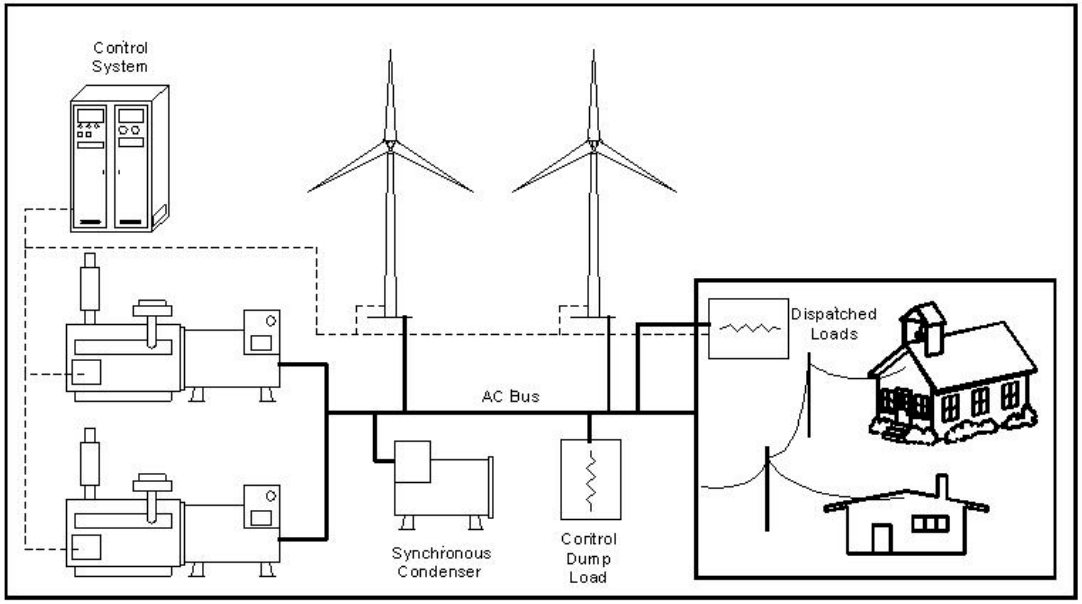
Designed to reduce the consumption of diesel

- Trades cost of RE power against cost of diesel power
- Reduces diesel storage needs (maybe)
- Reduced environmental impact; fuel transport & emissions
- Diversifies fuel risk

Storage, if used, store power to cover short lulls in RE power and to switch to diesel

Historically has been wind dominated but outside of AK, solar is starting to be implemented

Much more complex



# Renewable Contribution

One of the critical design factors is how much energy is coming from the wind – called wind contribution – as this helps determine the level of system complexity

$$\text{Instantaneous Penetration} = \frac{\text{Wind Power Output (kW)}}{\text{Primary Electrical Load (kW)}}$$

- Used to understand control requirements
- Reactive power needs, voltage and frequency regulation

$$\text{Average Penetration} = \frac{\text{Wind Energy Produced (kWh)}}{\text{Primary Energy Demand (kWh)}}$$

- Generally calculated on monthly or annual basis
- Total energy savings
- Loading on the diesel engines
- Spinning reserve losses/efficiencies

# AC Based Hybrid System

Low Contribution systems - Wind acts as a negative load, very little control or integration of wind turbines into the power system is needed.

Mid Contribution systems - Wind becomes a major part of the power system but diesel engines still provide much of the system power control. Additional components and limited supervisory control required to assist diesels in maintaining power quality.

High Contribution systems - Completely integrated power system with advanced control. Diesel generators shut off when not needed. Limited operational control of system by plant staff.

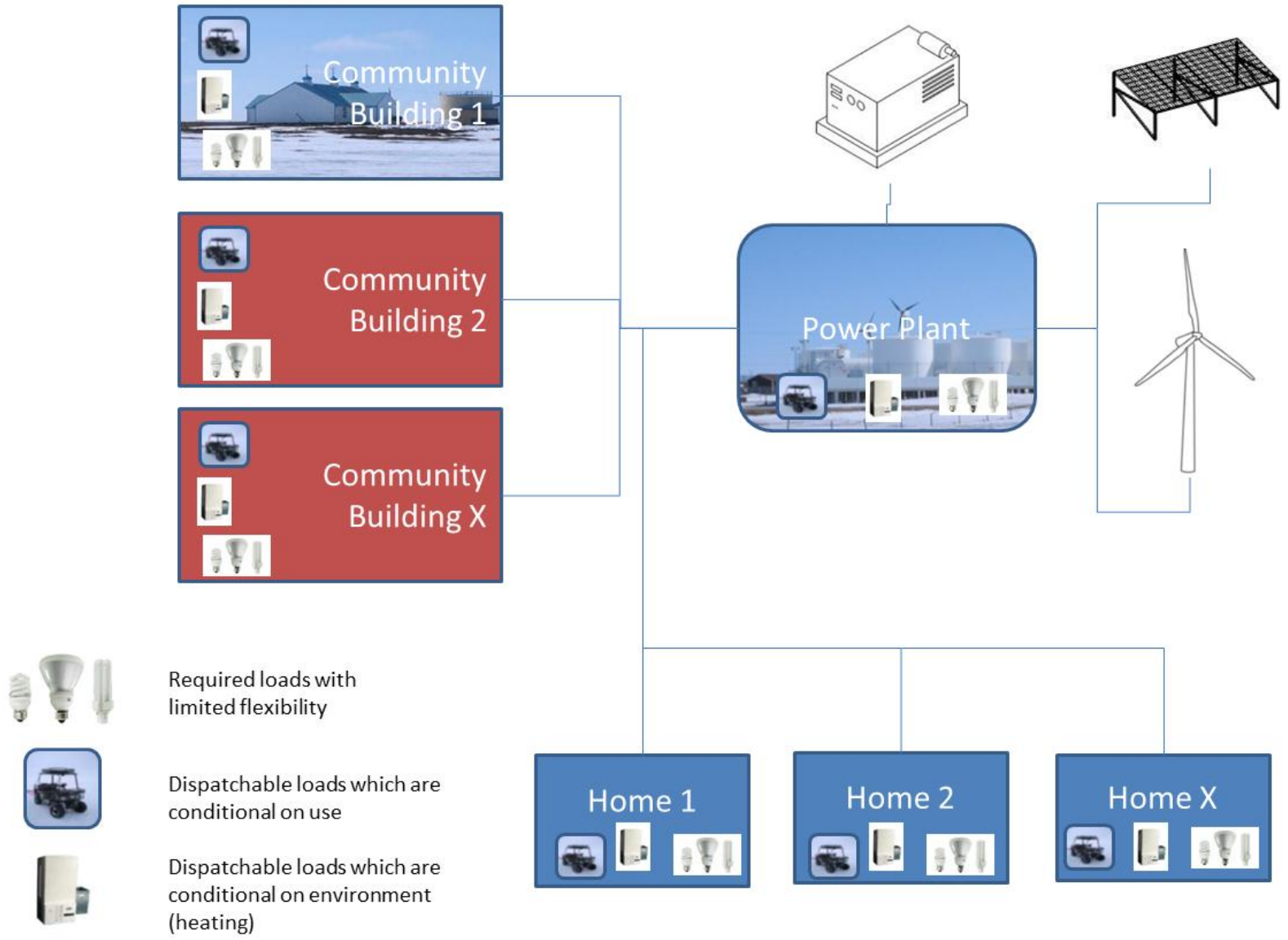
# Technology Advancements

Fewer applications, but many of the same technology trends

- Developments in storage technology – flywheels, batteries, and control
- Expanded diesel control – faster response, lower load operation, automation
- More operational experience with higher contributions of RE
- Gaining experience with distributed loads being used as a control mechanism
- More wind turbine options

Ross Island, Antarctica – high instantaneous contribution using flywheel storage

# Where is the Technology Going?



# Current Status of Small Hybrid/Micro-grids

Step by step improvements…

- Continued technology development– no game changers yet
- Expansion of telecom and in the military have increased reliability – but have not really improved the price point for community power
- Large decreasing cost in wind, power converters and most specifically PV has improved system economics and reliability, but not really up front costs.
- Increased access to renewable resource information is very helpful
- Smart Grid concepts have a great deal of promises, little organized implementation

But the challenges continue…

- Grant and project based development still rules - maintenance and long term sustainability remains an ongoing issue
- Every system is typically a one off design
- Industry learning is still very limited – standards including those for users – incredibly still lacking
- Energy storage remains a weak link
- Struggle between import and local products
- Link between power and productivity lacking

Abandoned 21 kW PV hybrid
Isla Floreana , Galapagos, Ecuador

# Progress is Being Made

**Technical advancement underway**

- Alaska Emergency Technology Fund
- Remote Community Renewable Energy Partnership - DOI/DOE/DOS/DOD
  - A simpler, scalable, modular solutions for off-the-grid communities
  - Support for industry standardization of processes and systems
  - Streamline the process, from engineering and construction through operations and maintenance
- Expanded resource assessment tools – mostly wind and solar
- Companies with a good understanding of the issues and tools that are becoming available to support decision making
- Better understanding of large scale electrical integration challenges
- Expanded testing facilities available, such as NREL ESIF and ACEP hybrid test bed
- Small Wind Certification Council certifying

**Market advancements underway**

- More interesting business models being developed
- DOE work in consumer standards for isolated power systems
- Many NGO's working in this space (IRENA, Carbon War Room, Clinton Foundation, etc.)

# Distributed Wind Market Report

## Second year with expanded scope

- 2013 report covers small (≤ 100 kW), mid-size (> 100 kW – 1 MW), and utility-scale turbines (> 1 MW) used in distributed applications
- Previous reports only covered small wind
- Expanded scope matches DOE's expanded definition of distributed wind

## Prepared for U.S. DOE's Energy Efficiency & Renewable Energy Office's Wind and Water Power Technologies Office

- By PNNL and eFormative Options with contributions from American Wind Energy Association and Distributed Wind Energy Association

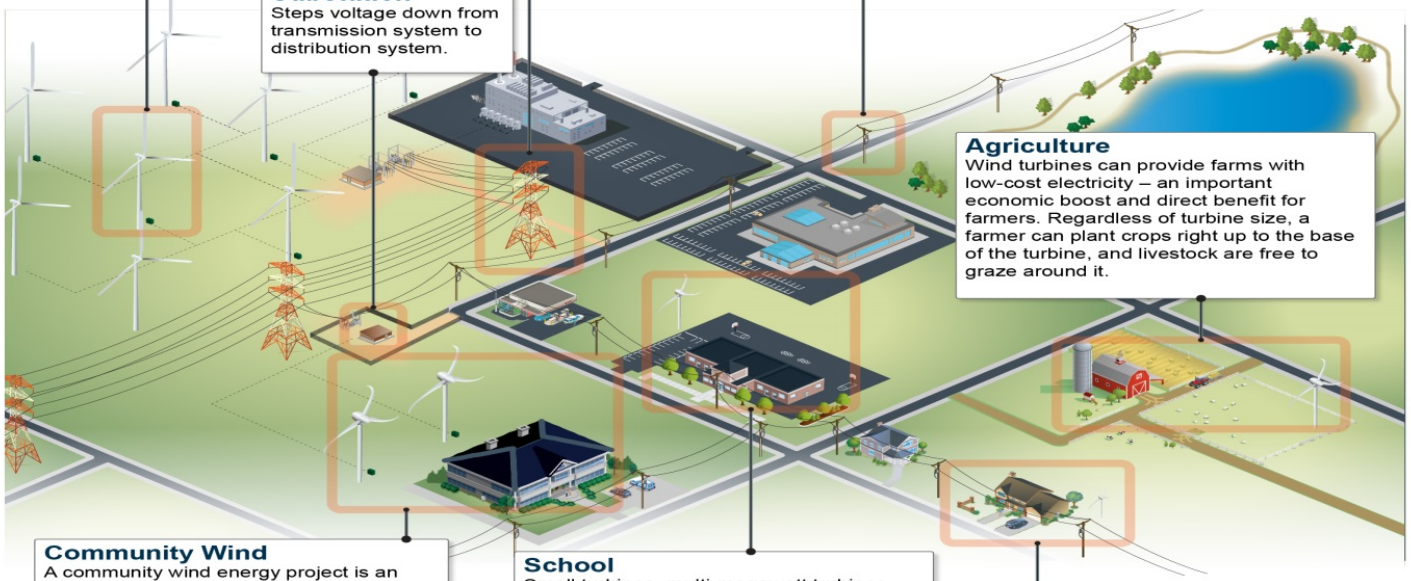
## Report data comes from

- AWEA database, eFormative database, U.S. Treasury Section 1603 payments, U.S. Department of Agriculture (USDA) Rural Energy for America Program (REAP) grants, news publications and press releases about projects, state agency reports, and manufacturer and supplier sales reports

## 2013 Report due out in June

Photo Credit: Foundation Windpower

# What is Distributed Wind?



**Wind Farm**
A wind farm is a group of utility-scale wind turbines in the same location used to produce electricity sent over transmission lines. Wind farms are typically greater than 20 MW and may consist of dozens to several hundred individual wind turbines over a large area, but the land between the turbines may be used for agriculture or other purposes. A wind farm may also be located off-shore.

**Transmission**
Transmission lines conduct large amounts of electricity across long distances, linking various regions of the country together. The transmission system connects to the distribution system through a substation.

**Distribution**
The electric distribution system moves energy from a transmission substation to houses, businesses, and other energy users within a local area.

**Substation**
Steps voltage down from transmission system to distribution system.

**Agriculture**
Wind turbines can provide farms with low-cost electricity – an important economic boost and direct benefit for farmers. Regardless of turbine size, a farmer can plant crops right up to the base of the turbine, and livestock are free to graze around it.

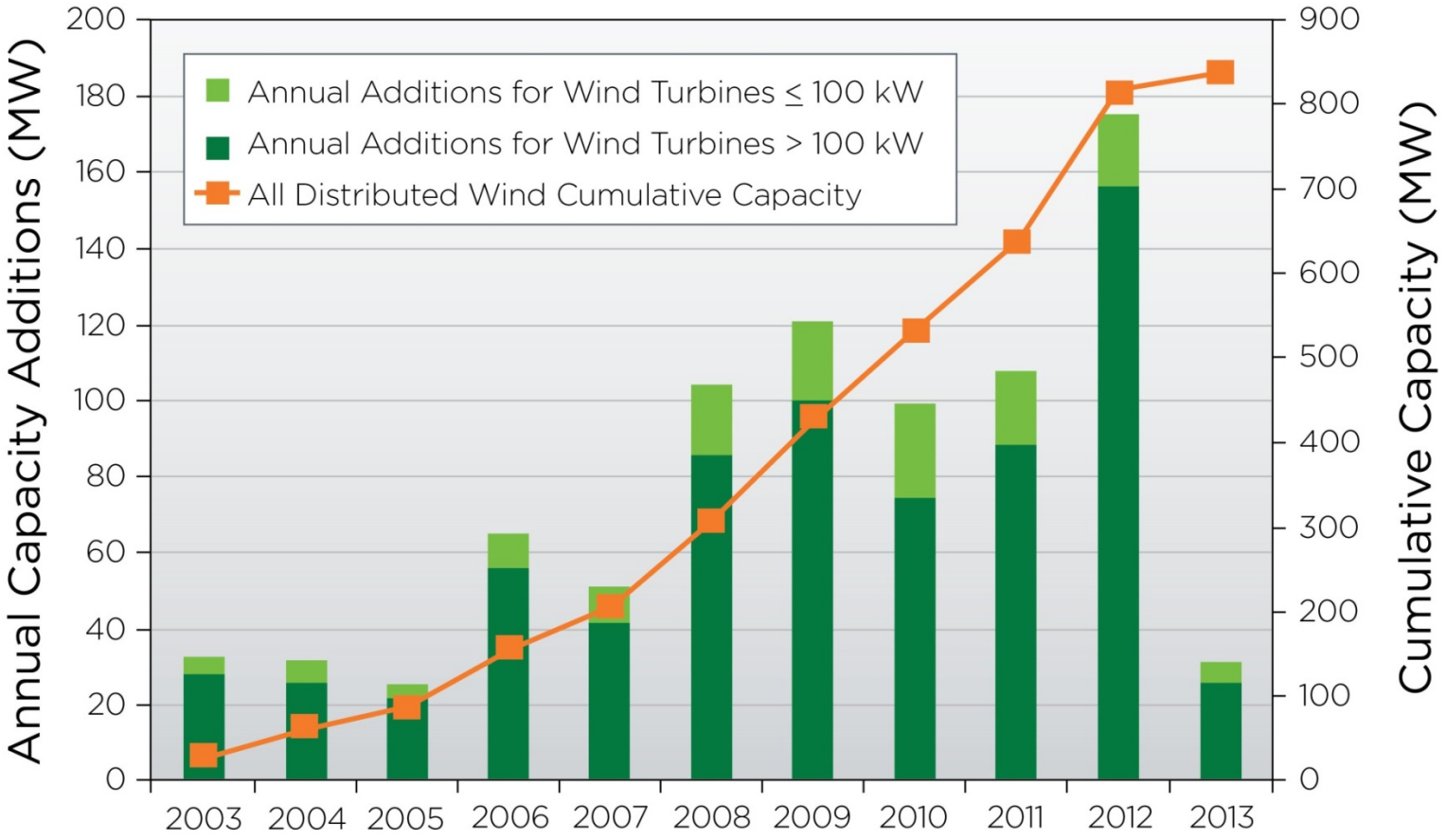
**Community Wind**
A community wind energy project is an asset owned by a local community. It is defined by an ownership model rather than by the application or size of the wind energy system. Depending on point of interconnection and proximity to end use, community wind projects can also be characterized as distributed.

**School**
Small turbines, multi-megawatt turbines, and even a cluster of small turbines can be used to power schools with clean energy and provide economic benefits. School districts can take advantage of savings on energy bills and in some cases generate revenue. Wind projects provide a great educational opportunity for students.

**Residential**
Smaller wind turbines can be used in residential settings to directly offset electricity usage using net metering, where power that is not used by the home is credited to the customer as it flows back to the distribution system, or support a completely off-grid home. These turbines can sometimes be integrated with other components, such as PV systems and storage.

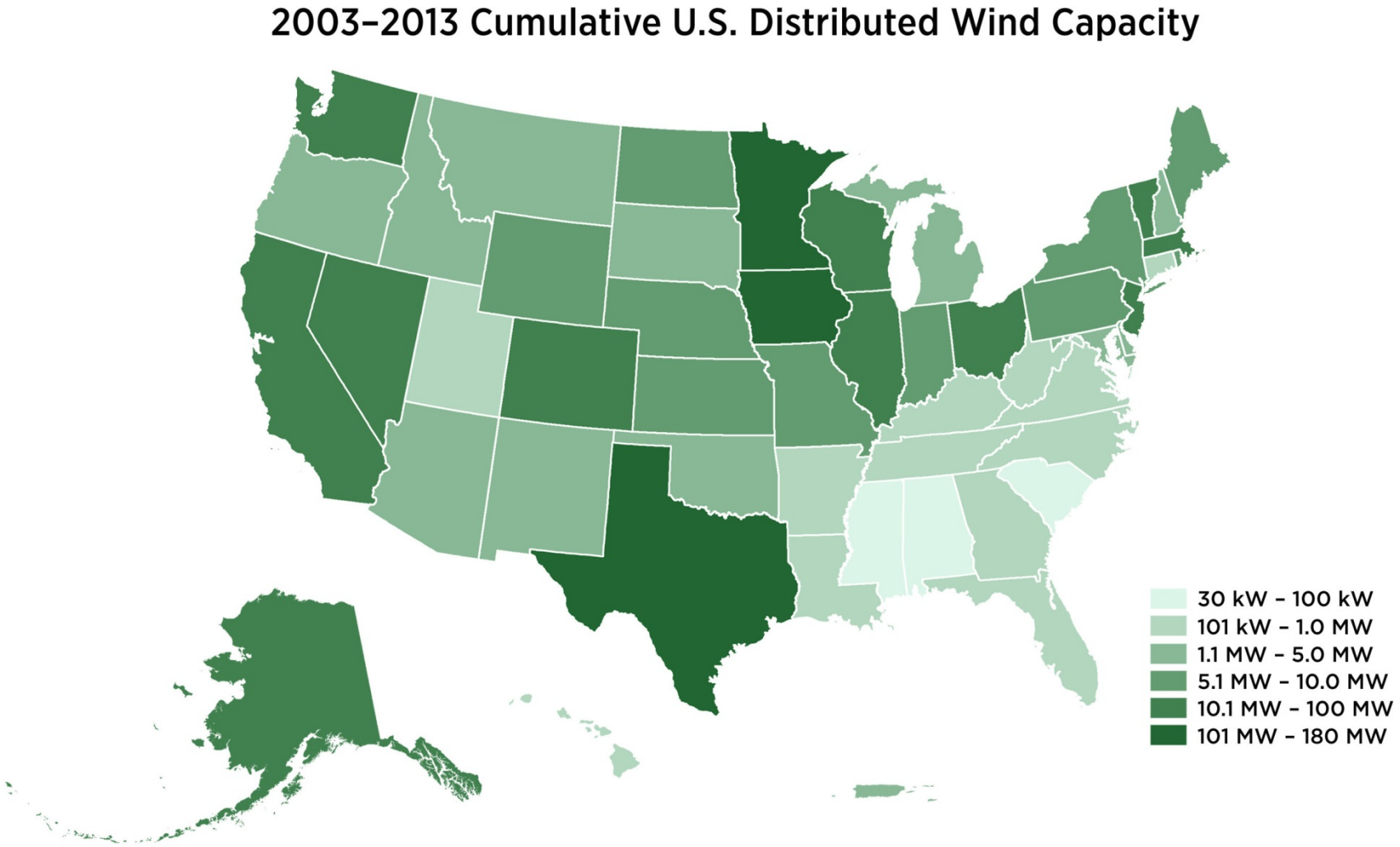
Graphic: NREL / DOE

# Cumulative Installed Capacity

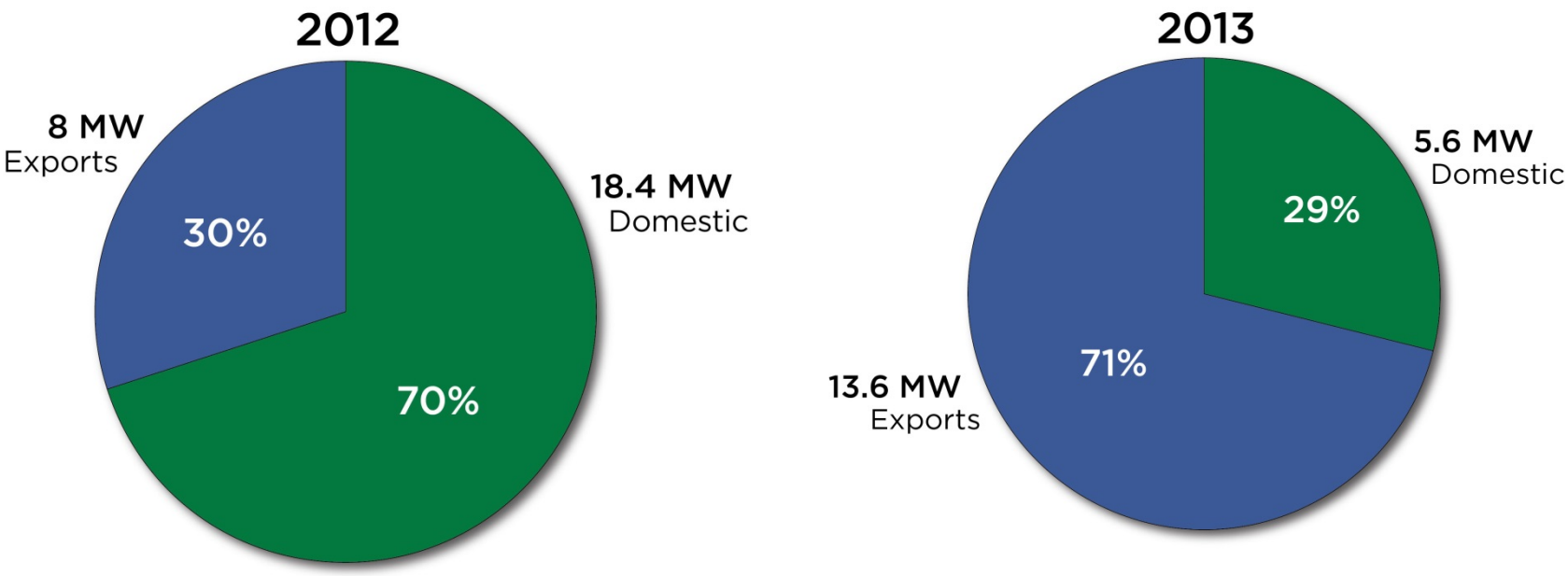



- 30.4 MW of new distributed wind capacity added, nearly 2,700 units.
- 24.8 MW are from 9 projects above 100 kW in size, for a total of 18 units
- 31 different domestic and foreign manufacturers and refurbishers, including those from Canada, Mexico, Europe, China, and South Africa
- 9 turbines certified through the Small Wind Certification Council

# Cumulative Installed Capacity



# U.S. Small Wind Turbine Manufacturers Exports Increase over 2012




- U.S. wind turbine manufacturers shifted their focus to international markets in 2013 to compensate for weaker domestic sales.
- Exports from U.S.-based small wind turbine manufacturers increased 70% from 2012
- U.S. small wind turbines (those up through 100 kW in size) were exported to more than 50 countries in 2013
- top export markets identified as Italy, UK, Germany, Greece, China, Japan, Korea, Mexico, and some countries in Africa

NREL
NATIONAL RENEWABLE ENERGY LABORATORY


# E. Ian Baring-Gould

**Technology Deployment Manager**

**National Wind Technology Center &**
**Deployment and Industrial Partnerships**

**303-384-7021**

**Ian.baring-gould@nrel.gov**