Isolated Hybrid Energy Systems:
Lessons from the Past, Options for the Present, Models for the Future

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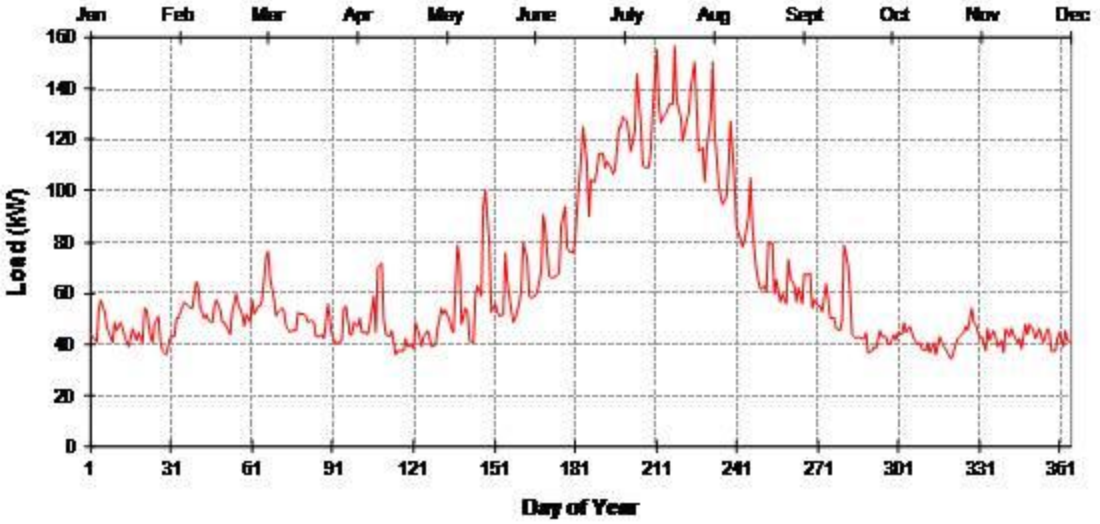
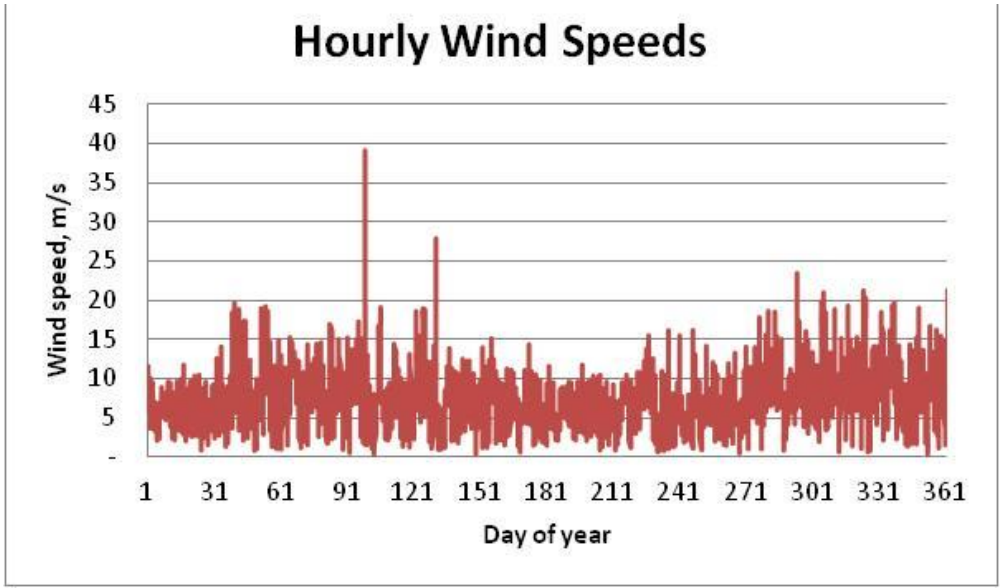
Evolution of Hybrid Power Systems for Isolated Grids

- Context
  - Isolated grids typically supplied by diesel generators
  - Diesel generation is expensive, dirty, noisy
  - Fuel needs to be barged or trucked then stored on site
  - Islands are often windy
  - Wind turbines were seen as logical complements to diesels
  - Can plausibly reduce fuel consumption significantly
  - Turbines of 1970s-1990s were of a size that were suited for many isolated grids
  - Photovoltaics were still very expensive then

Typical Remote Electrical Load and Wind

- Variable over many time scales
- This location has higher load in summer but higher winds in winter

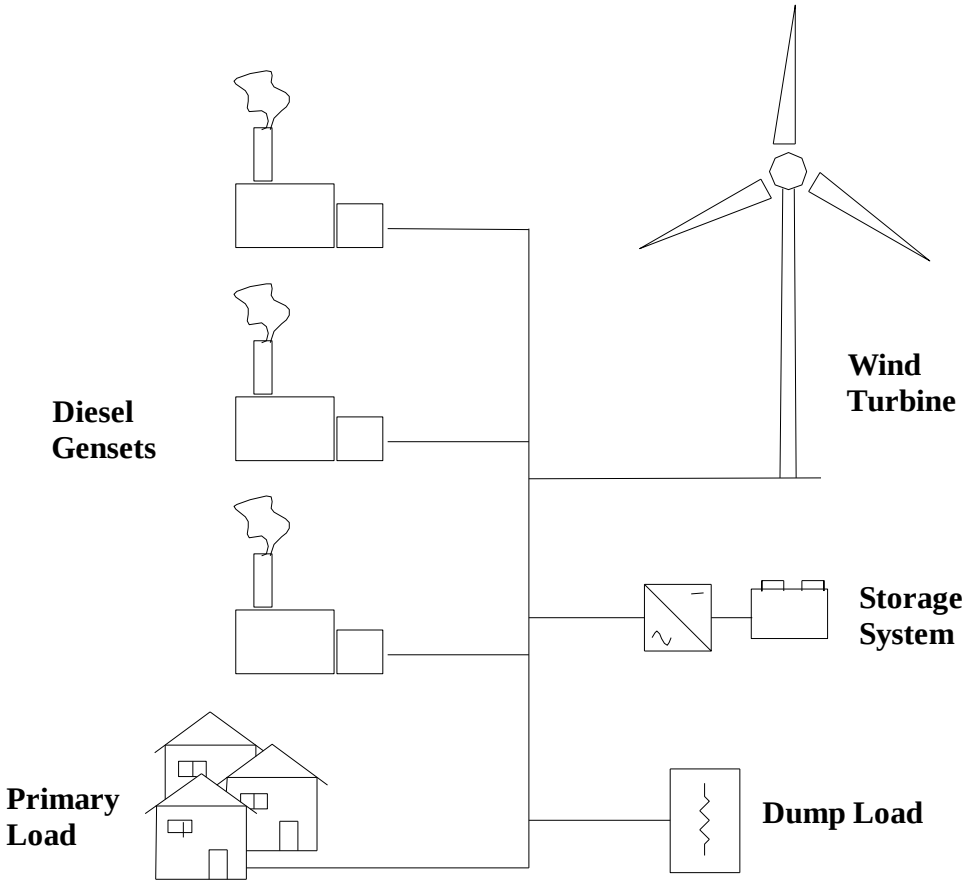




Cuttyhunk Island, MA

UMASS

Typical Hybrid Wind/Diesel System

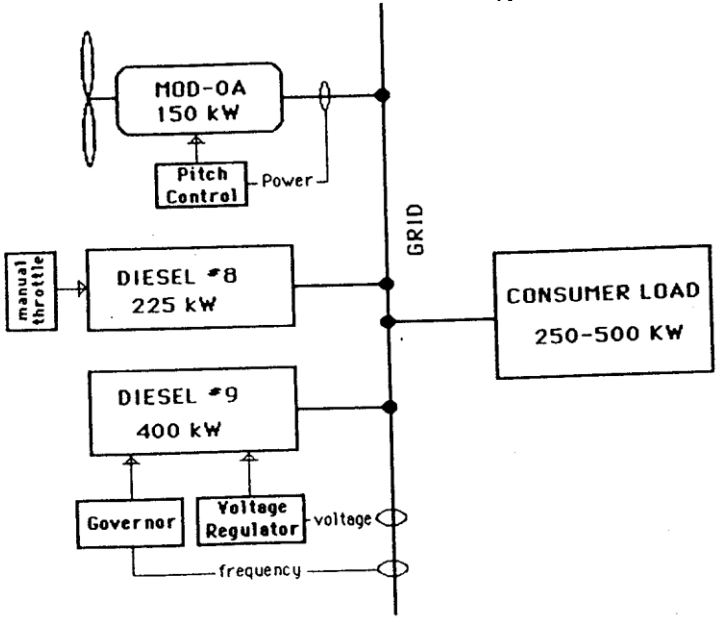


Cuttyhunk Wind/Diesel System

- Cuttyhunk Island (MA) had one of the world's first wind/diesel systems (mid 1970s)
- Based on Danish Gedser turbine, rated at 200 kW
- Difficulties with paralleling with diesel grid
  - Highlighted need for more comprehensive analysis and better technology!

Block Island Wind/Diesel System

- Block Island (RI) was host to a DOE MOD-0A, 150 kW wind turbine in the early 1980s



Produced much useful data!

Source: UMass, 1989

Source: http://www.dvidshub.net/

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Example: Foula Island, Scotland

Pictures: www.mini-grid.com/foula.htm

- Small island off the Shetland Islands
- Wind/pumped storage/diesel power system, late 1980's
- Peak power ~ 25 kW

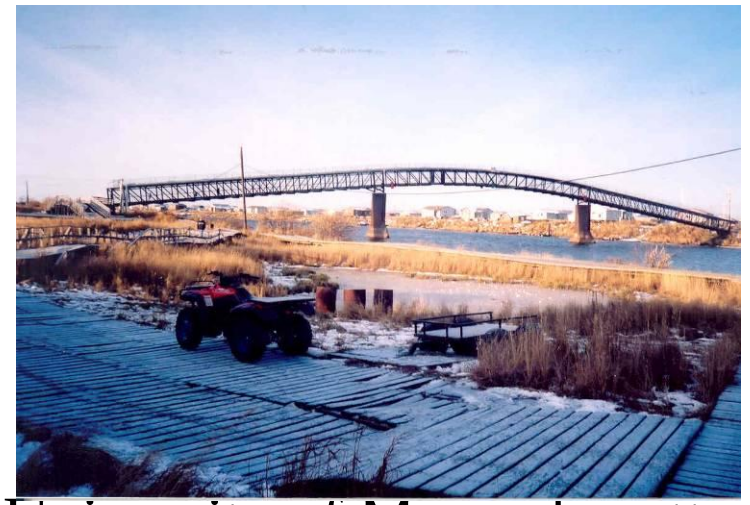
Example: Fair Isle, Scotland

Pictures: www.fairisle.org.uk/FIECo/

- Early wind/diesel system (began early 1980's)
- Now 2 turbines (60 kW, 100 kW)
- Innovative load management control strategies

Selawik, AK

Selawik



Selawik, AK (2)

- Four 60 kW wind turbines
- Multiple diesel generators
- Excess energy →heat
- Installed early 2000's

Diesels

Diesel plant and turbines

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Lessons from Experience (1)

- System Design Constraints
  - The load - magnitude and temporal profile
  - Existing power system - fuel consumption and electrical characteristics
  - The renewable resource - magnitude and temporal profile
  - Maintenance infrastructure
  - Site constraints

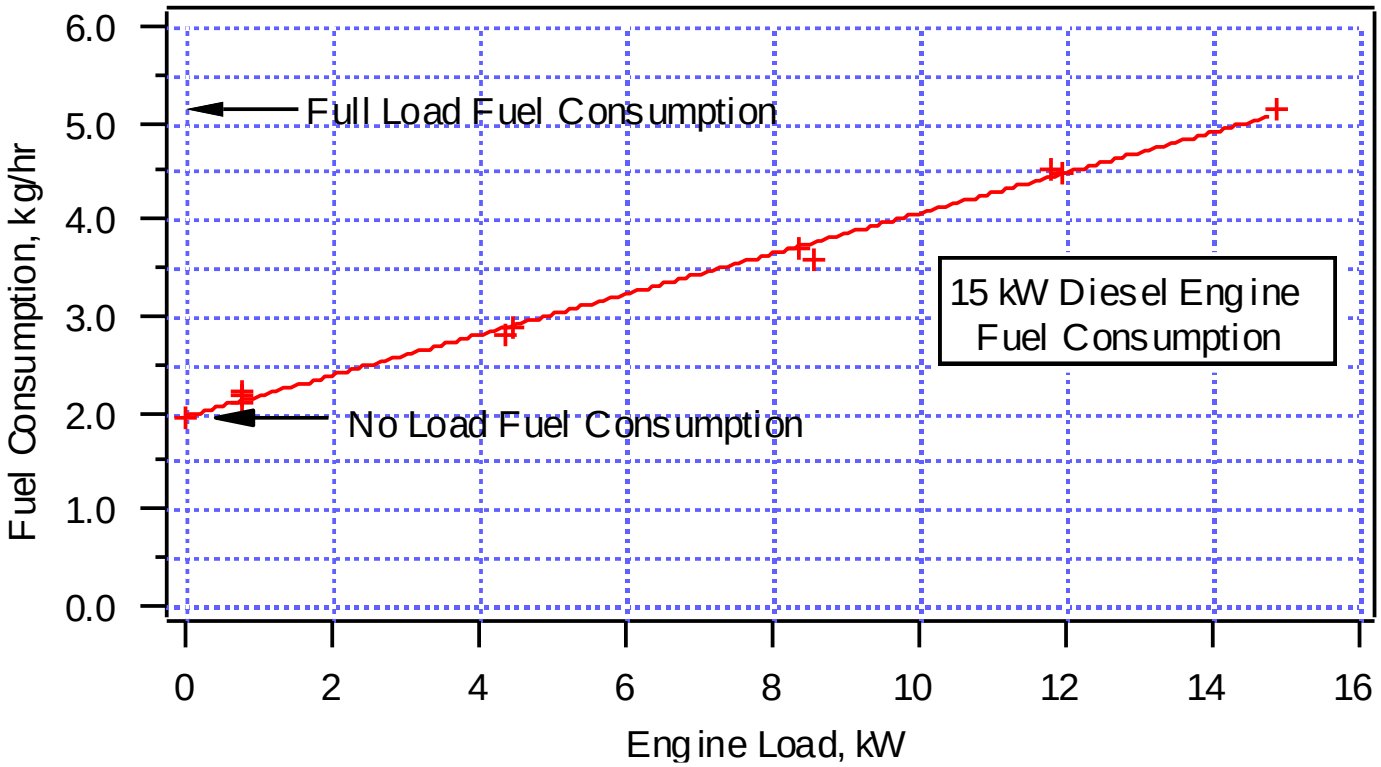
Lessons from Experience (2)

- Systems level design is needed!
  - Suitable components required
  - Key goal is reduction in overall cost of energy (primarily by reducing fuel consumption)
- Matching load and wind (or solar)
  - Improved with energy storage and/or load management

Diesel Generators

- Necessary component in most isolated grids!
- Typically provide (in addition to “real” power)
  - Frequency and voltage control
  - Reactive power
- Long life requires
  - Minimizing number of starts
  - Maximizing continuous rated-load operation
- Non-zero no-load fuel consumption must be considered!
- Multiple diesels provide backup and fuel savings

Typical Diesel Fuel Curve



Wind Turbines for Hybrid Systems

- Typically smaller then 500 kW
- Historically fixed pitch turbines with induction generators have been used
- Pitch controlled, variable speed turbines are preferable
- Ease of installation, operation, maintenance and repair are particularly important
- Many commercial turbines are now too large!
- Opportunities for newer technology in mid-size turbines

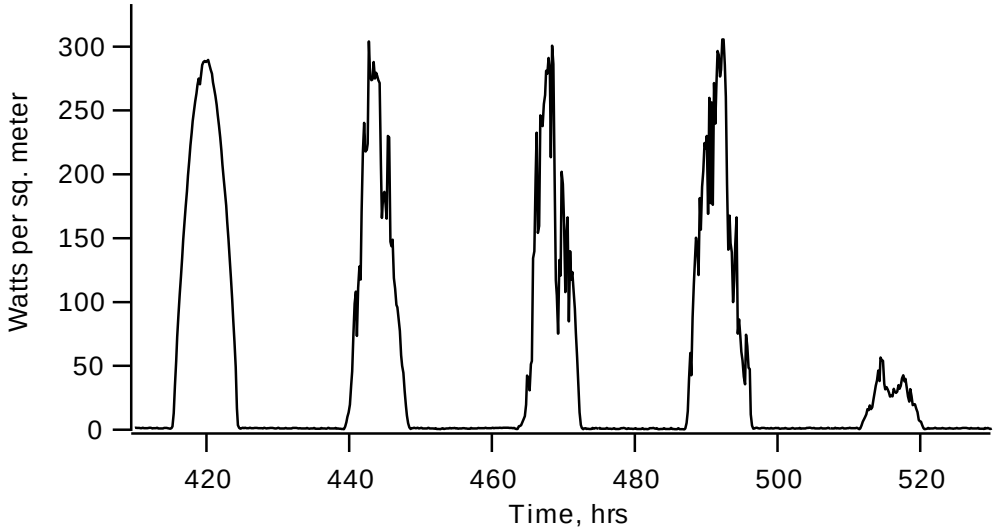
Photovoltaics (PV)

- Panels of semiconductors which convert sunlight directly to direct current (DC) electricity
- Output power primarily a function of →
  Solar radiation (and thus time of day and year)
- **Power electronic converters** used with AC systems are similar to devices used with wind turbines and, more generally, hybrid power systems
- Prices have dropped dramatically!
  – PVs are now attractive for many isolated grids

Solar Resource

- Maximum (solar constant); 1353 W/m^2
- Varies with time, season, weather
- No output at night!
  - Some energy storage may be beneficial

Typical example: Boston Harbor, MA



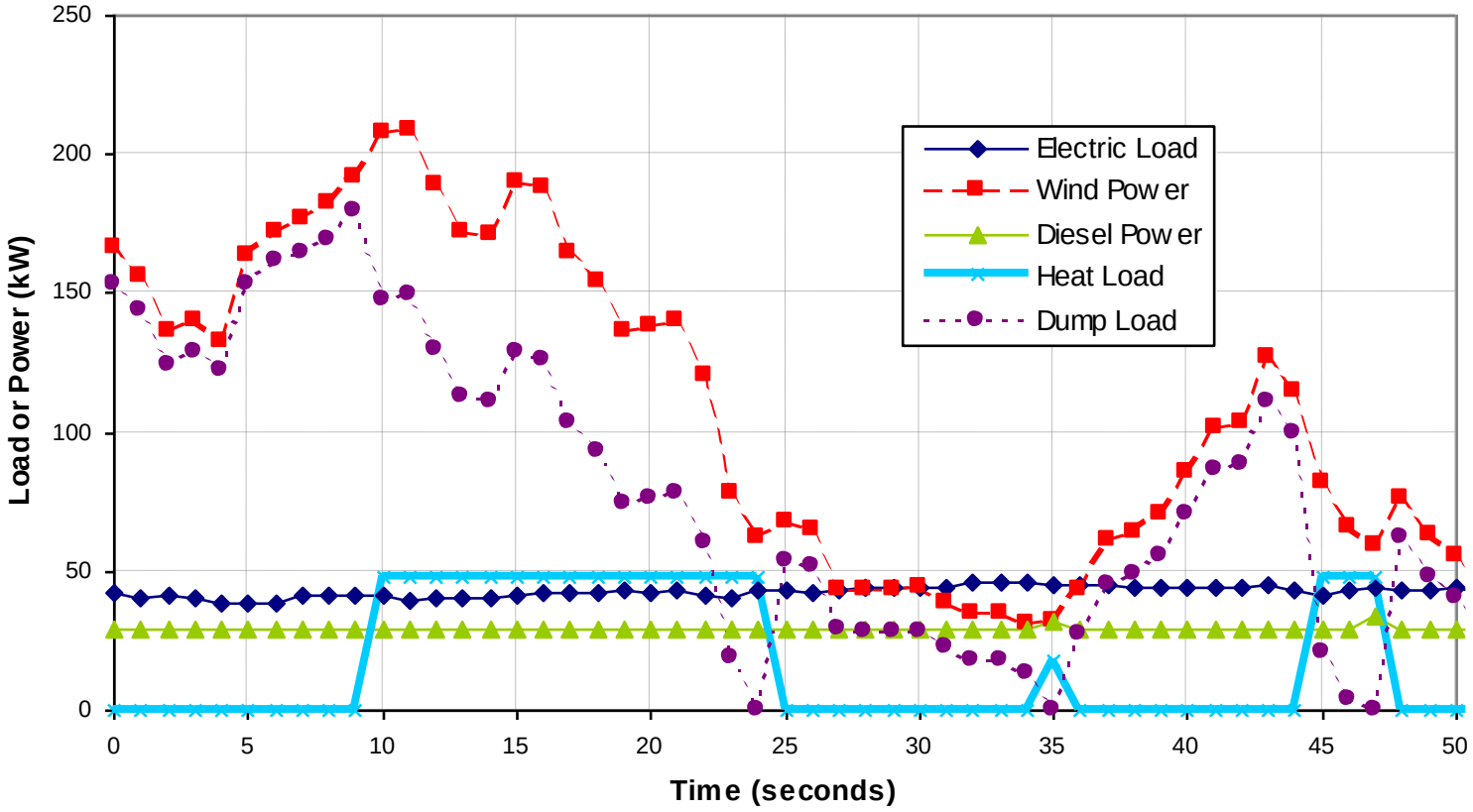
Hybrid System Extra Components

- Dump load
  - Used to balance power in/out; may control frequency (if all diesels are off)
- Supervisory controller
  - Turns on/off various components
- Load management devices
  - Maximizes usefulness of renewable source
- Synchronous condenser
  - Basically a synchronous machine
  - Provides reactive power
- Storage

Storage

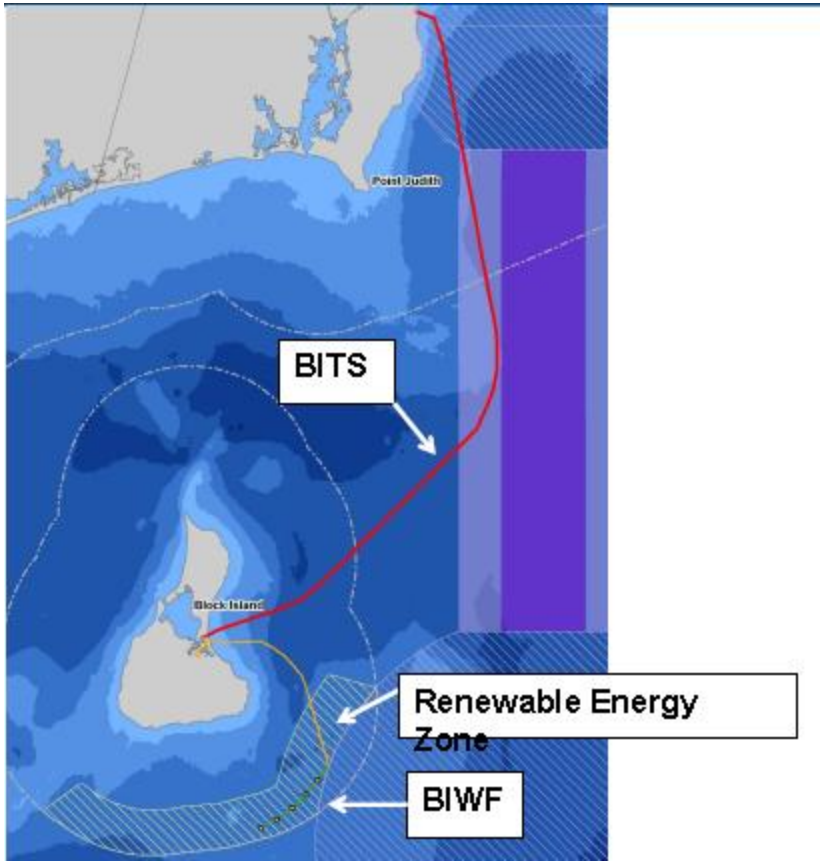
- Batteries
  - Short/medium term (time shifting)
  - Lead acid most common
  - NiCad has some advantages
- Flywheels
  - Short term → helps with control
- Pumped hydroelectric storage
  - Medium/long term (daily)storage possible
- End use (product)
  - Water
  - Heat

Sample Power Flows



Offshore Wind and Islands

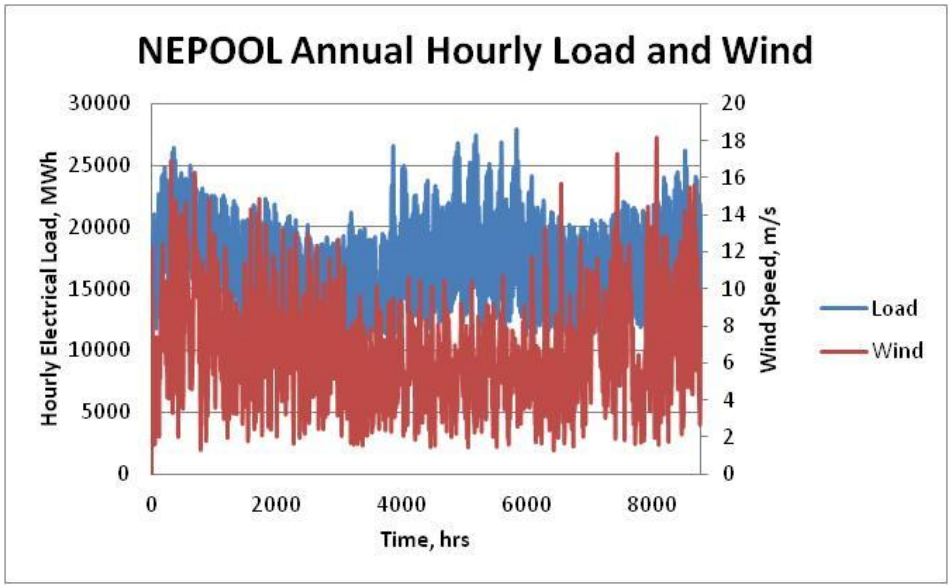
- A formerly isolated island may become a way station for the cable from an offshore wind farm!
- Block Island will become an example→



Source: Deepwater Wind

Wind and Load in Large Networks

- Hybrid power systems can serve as prototypes for large scale renewable energy in mainland grids
- Many options for generation, storage, load management, fuel production
- Principles are very similar



Typical year of New England hourly electrical load and wind speeds averaged over 6 locations

Conclusions

- Hybrid renewable energy/diesel power systems are attractive options for many isolated grids
- Improvements in technology will make these systems progressively more practical
- Fuel savings of 50% is a plausible goal
- Isolated hybrid systems can serve as models and prototypes for much larger grids in the future