Analyzing Storage and Distributed Renewables in Micro-grids with HOMER®

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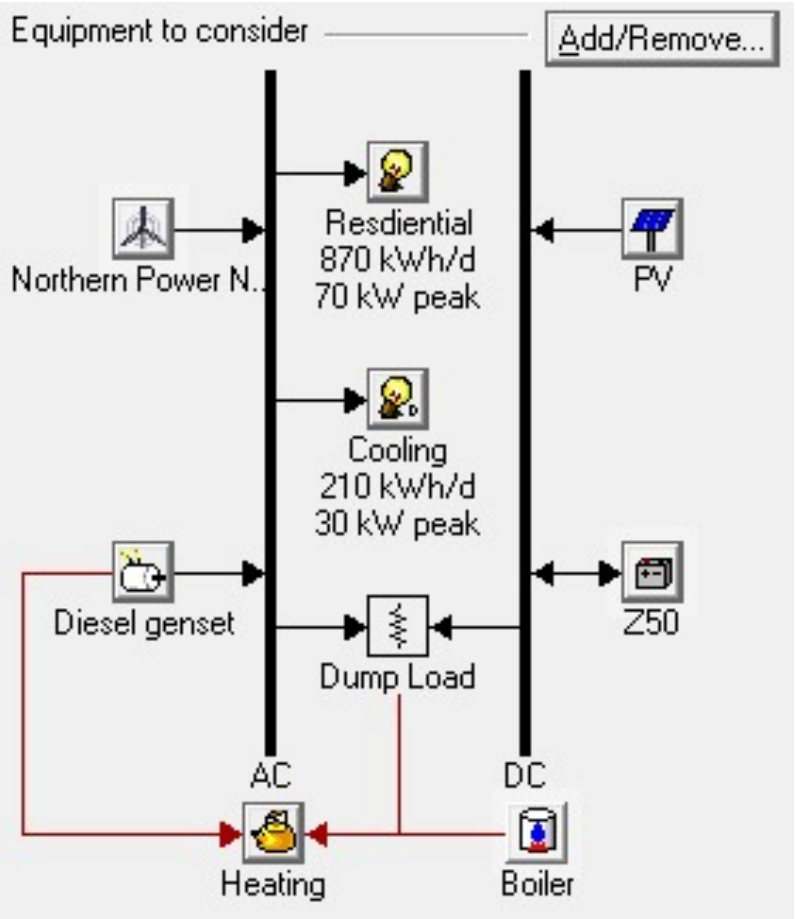
October 19,2010

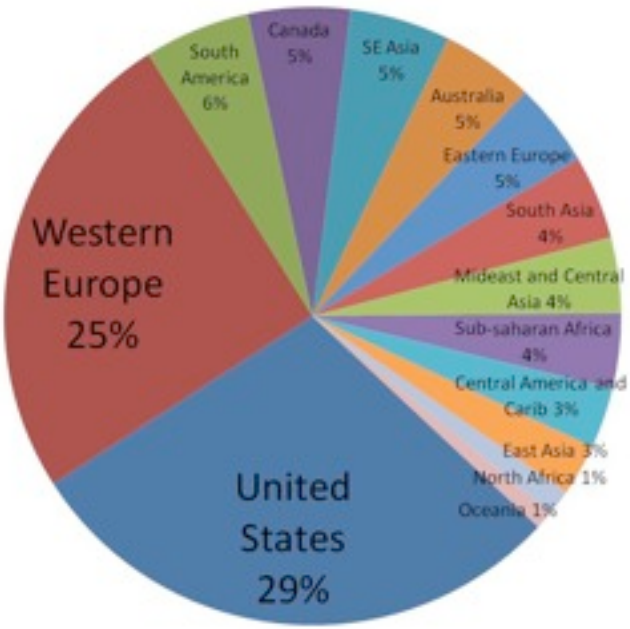
HOMER

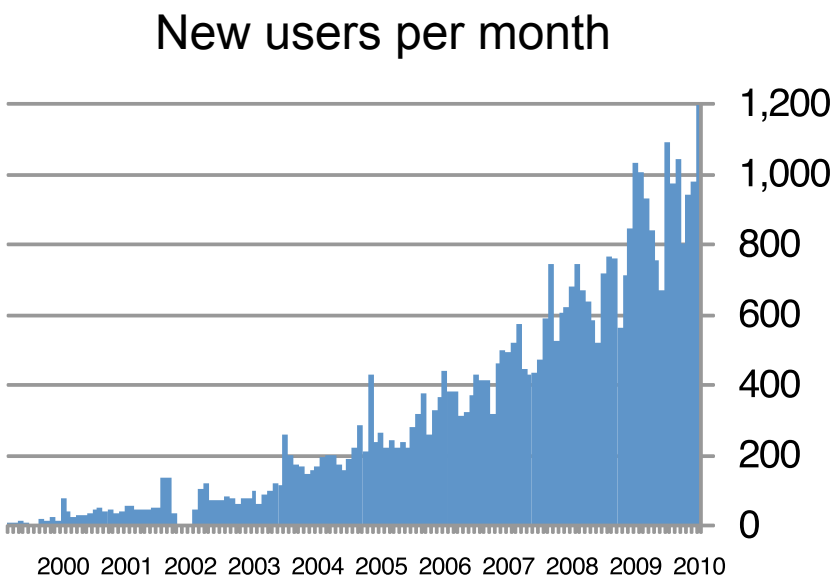
- Industry standard for optimizing the design of hybrid micro-grids with:
  - Conventional resources
    - Reciprocating gensets
    - Turbines
    - Grid connections
  - Renewable resources
    - Wind
    - Solar
    - Hydro
    - Biomass power
  - Storage
    - Lead-acid
    - Flow batteries
    - Flywheels
    - Hydrogen
  - Load Management
    - Deferrable loads
    - Multiple levels of priority loads
    - Thermal loads



HOMER

- Developed at National Renewable Energy Lab
  - 1992-2009
- Original developers now at HOMER Energy, LLC.
- 48,000 users in 193 countries





The Future of Power

Clean, distributed power with hybrid renewables and smart micro-grids

But how do we get there?

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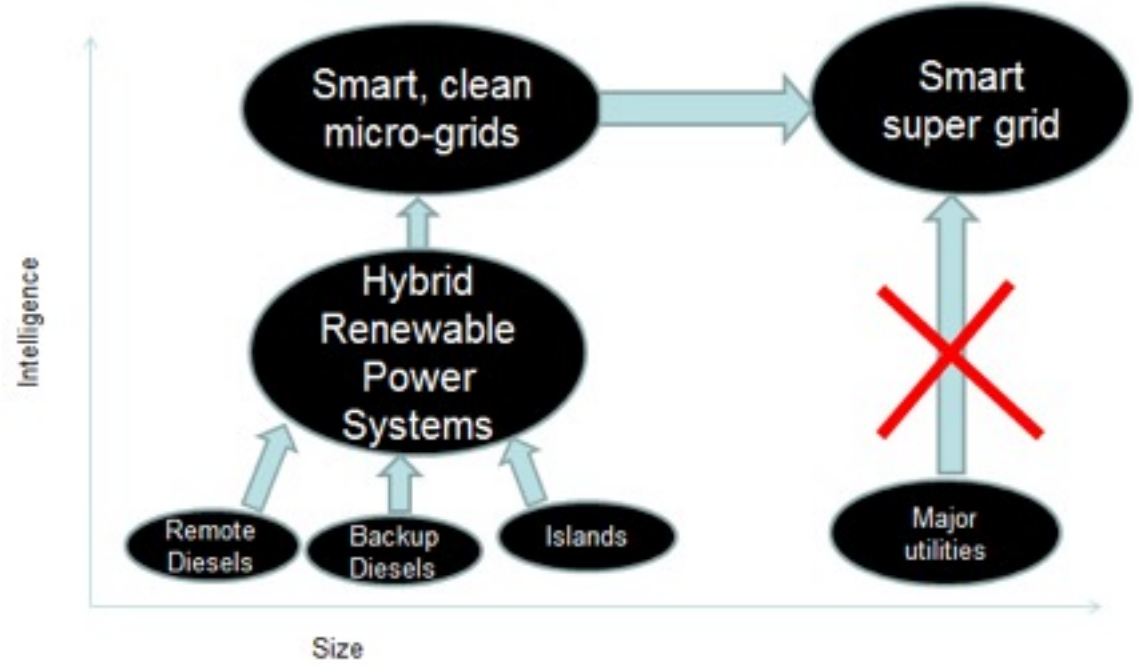
Unconventional Wisdom

- The real problem with wind and solar occurs when they produce too much power.
  - The problems with wind and solar is not what happens when the wind doesn't blow or the sun doesn't shine. That is an easy problem to solve because we just use our conventional resources just like we always have. What do we do with the excess power when they produce too much power? When can we take generators off-line?
- Baseload vs. peaking is an obsolete distinction
  - The important distinction going forward is variable vs. flexible. Storage is flexible, but so is load management and turbine manufacturers are trying to make their products more flexible.
- No single storage application is cost-effective.
  - This doesn't mean that storage is never cost-effective. There are multiple values that storage provides. Successful projects will have to find ways to capture more than one of those value streams.
  - Arbitrage won't pay for a storage project.
- Storage will not make wind act like coal.
  - There is a huge potential for hybridizing renewables and storage, but it still won't behave like a coal plant. Storage should be operated to maximize the benefit to the grid as a whole, not just an individual wind project.
- Small isolated grids will be the smart grid trailblazers

Clean Power Evolution



The security and regulatory obstacles for large interconnected utilities to create a smart grid with distributed controls are daunting.

Smaller, isolated grids have an economic imperative to reduce consumption of petroleum-derived liquid fuels. The impacts on them of high penetrations of renewable power and distributed "smart-grid" controls will be undiluted by regional power flows.

Distributed control technology will also be deployed in grid-connected micro-grids where security and reliability considerations require extended off-grid "islanded" operation.

Smart, clean micro-grids

- Capable of islanded operation
- Backup generation for reliability
  - Petroleum-derived liquid fuels
- Substantial renewables
  - Reduce fuel consumption for economic and environmental reasons
- Storage and load management
  - Absorb variability for grid stability and minimization of low-load generator operation

Too Many Choices

Solar

Fuel Cells

Wind

Hydro

Micro-turbines

Geothermal

Micro-grids

Biomass

Demand Response

New Storage Techs.

Load Management

Electric Vehicles

Smart grids

Too Many Choices

Solar

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Wind

Hydro

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Micro-grids

Biomass

Demand Response

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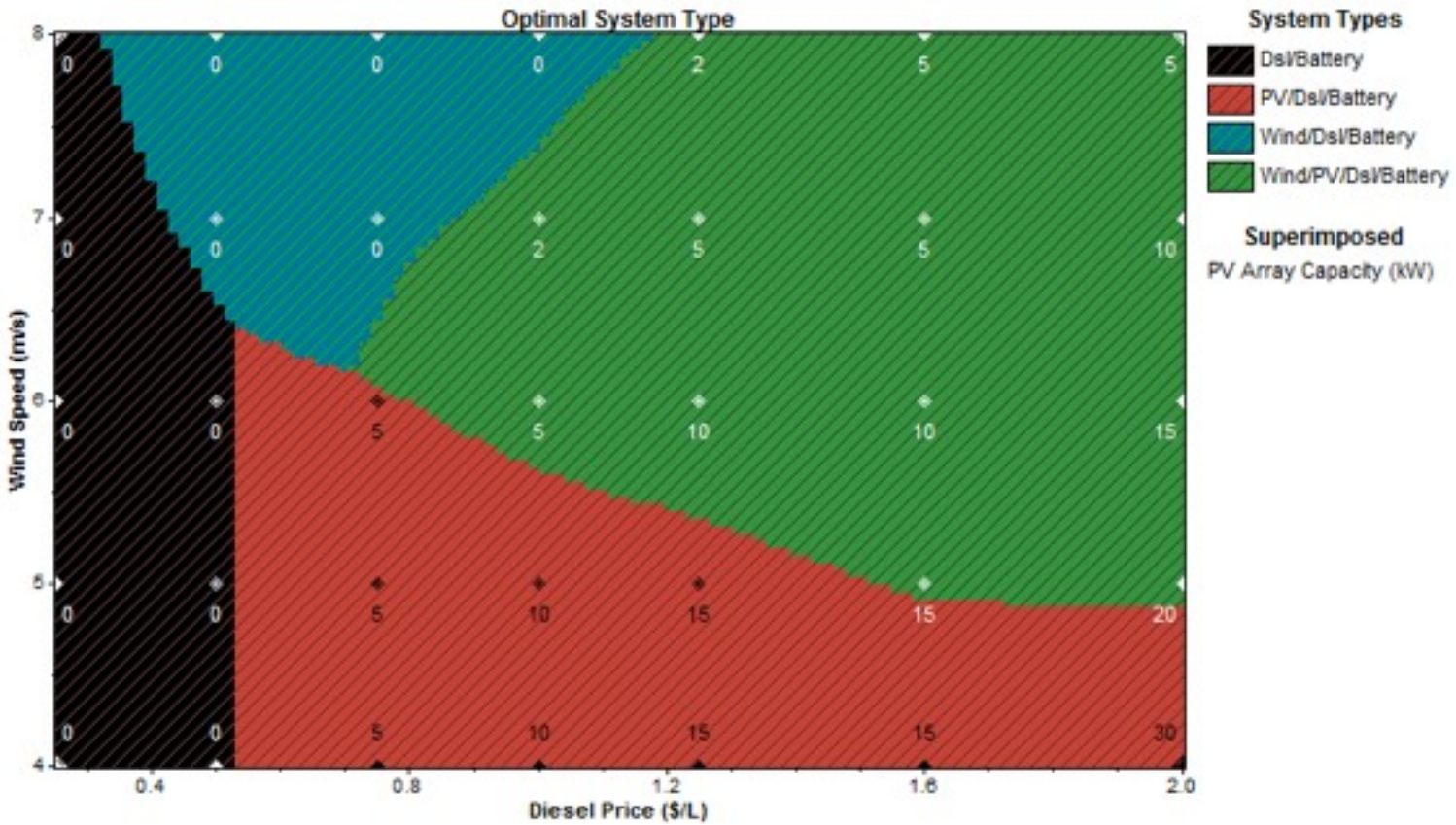
Smart grids

Sensitivity



HOMER identifies which system is best under what conditions?
Different penetration levels require different amounts of storage.

Levels of renewable regimes

Low	**No Storage**
Medium	**Minutes of storage for power quality**
High	**Hours of bulk storage**

Load management can supplement or replace some/all of the storage. This typically involves thermal storage. This is the real competition to electric storage.

System in St. Paul Alaska runs with just wind and load management of electric heating (no diesel or storage) for weeks at a time.

More renewables requires more intelligent controls

St. Paul, Alaska

Valuing Storage

- White papers list dozens of different applications of storage
- 3 broad categories
  - Improves reliability
    - Backup or reserves
  - Improves power quality
    - Frequency control, voltage control, VAR support
  - Reduces cost
    - Arbitrage, eliminate curtailments, prevent inefficient operation of other plants
- Locational issues
  - The only value that requires storage at the point of generation is when a renewable resource has interconnection constraints
  - Service reliability is best provided by distributed resources
    - The vast majority of outages are due to distribution system disturbances
  - Reactive power and voltage support are also local problems
  - Many sources of value, such as arbitrage and frequency control, have the same value to the system regardless of location.

Arbitrage

- Buy low / sell high is everyone's first answer to: Why storage?
  - It's a bad answer for most storage technologies.
- Assume $300/kWh, 1000 cycles to failure
- Each kWh of throughput costs $0.30/kWh in battery wear; ~$0.50 including input energy and losses.
- High arbitrage opportunity may only be for summer weekdays ~100 cycles per year.
- Could be a modest value adder if there are other values or with 10,000 cycle lifetime.

Micro-grids are the future

- Distributed storage has a huge role to play
- It may be in the form of electric vehicles
- Large variety of possible system designs
- Micro-grids allow experimentation at a reasonable scale.
- Already happening on islands and developing countries