Integrated Hydrogen Utility Systems for Remote Northern Communities

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Integrated Hydrogen Utility Systems

- Hydrogen as a utility energy storage medium.
  - To buffer the intermittency and phase differences of renewables an loads.
  - Where current electricity values are high (premium power).
  - Niche applications in isolated locations.
  - Permits full autonomy from a fossil fuel supply infrastructure.
  - Provides utility AND transportation functions

- Storage function of hydrogen systems is more complex than either battery storage systems or fossil fueled fuel cell systems.
  - Batteries have one power/energy element.
  - Fossil fuel cell system have two power elements and a simple energy element.
  - Four separate power or energy elements permit optimization in H2 system.

- The technologies necessary for an integrated renewable hydrogen power system are available, and close to the costs needed for full economic use in remote applications.

- Models are yet to be developed for optimization of design and control of a hydrogen system.

Energy Demographics

Country	Population (millions)		Per capita energy use (Bbls oil$_{(equiv.)}$/year/person)	
USA	270	(4.5%)	23.6	**(5.7 x W.A.)**
China	1200	(37%)	0.79	**(0.19 x W.A.)**
India	1000			
Indonesia	202			
World	**6000**		**4.12**	**(W.A.)**

Two billion people on earth do not have electricity.

The relationship between renewable energy sources and fuel cells is generally through hydrogen

The primary fuel for a fuel cell is hydrogen

Hydrogen can be produced from:

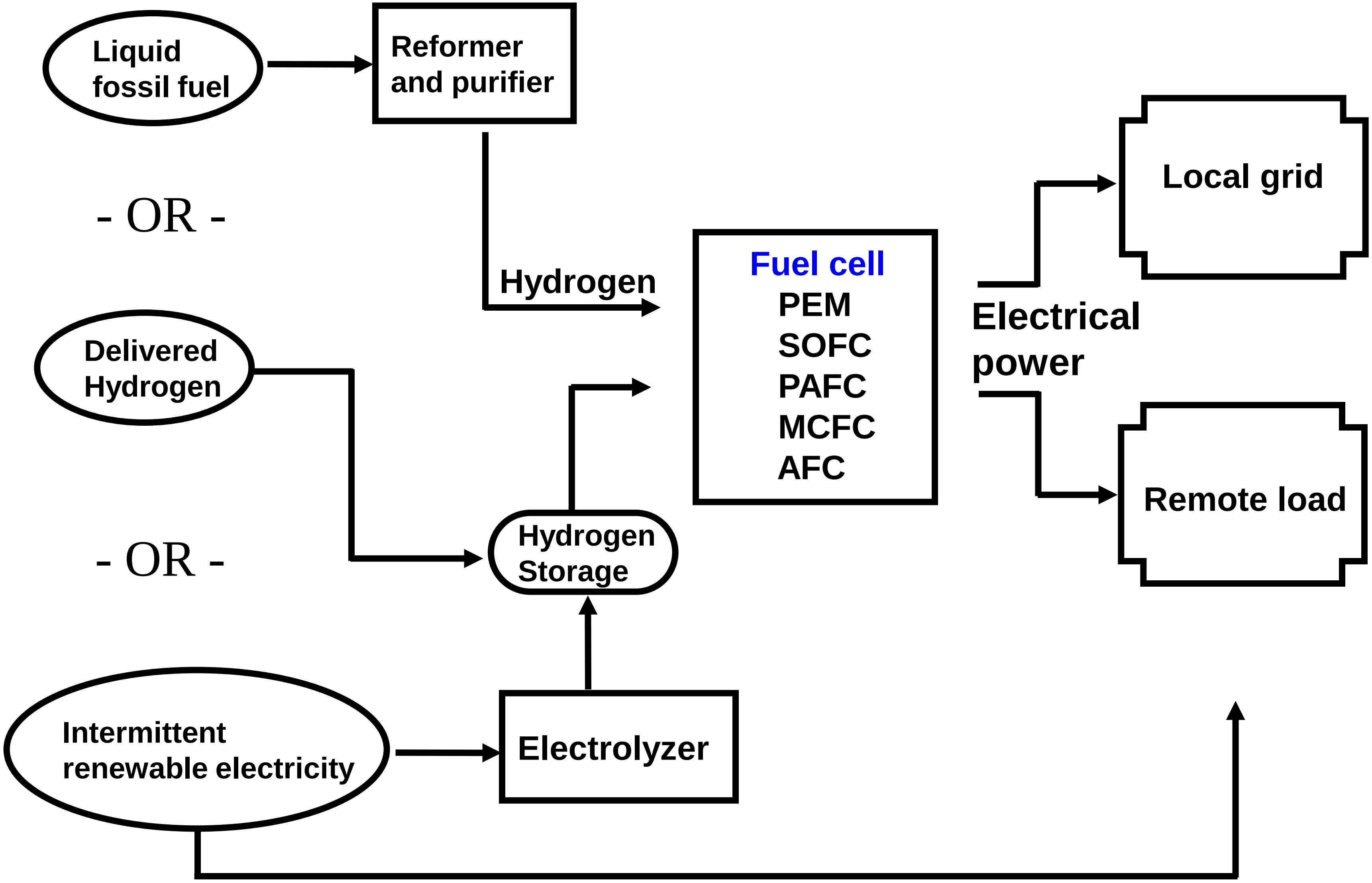
Gasoline Diesel fuel Propane Coal	**Nonrenewable**
Wind, solar, hydroelectric and geothermal electricity Biomass Municipal solid waste and LFG	**Renewable**
Natural gas, Methanol, Ethanol	**Either**

In isolated communities, the most likely indigenous resource that can produce *local-energy-economy quantities* of hydrogen are:

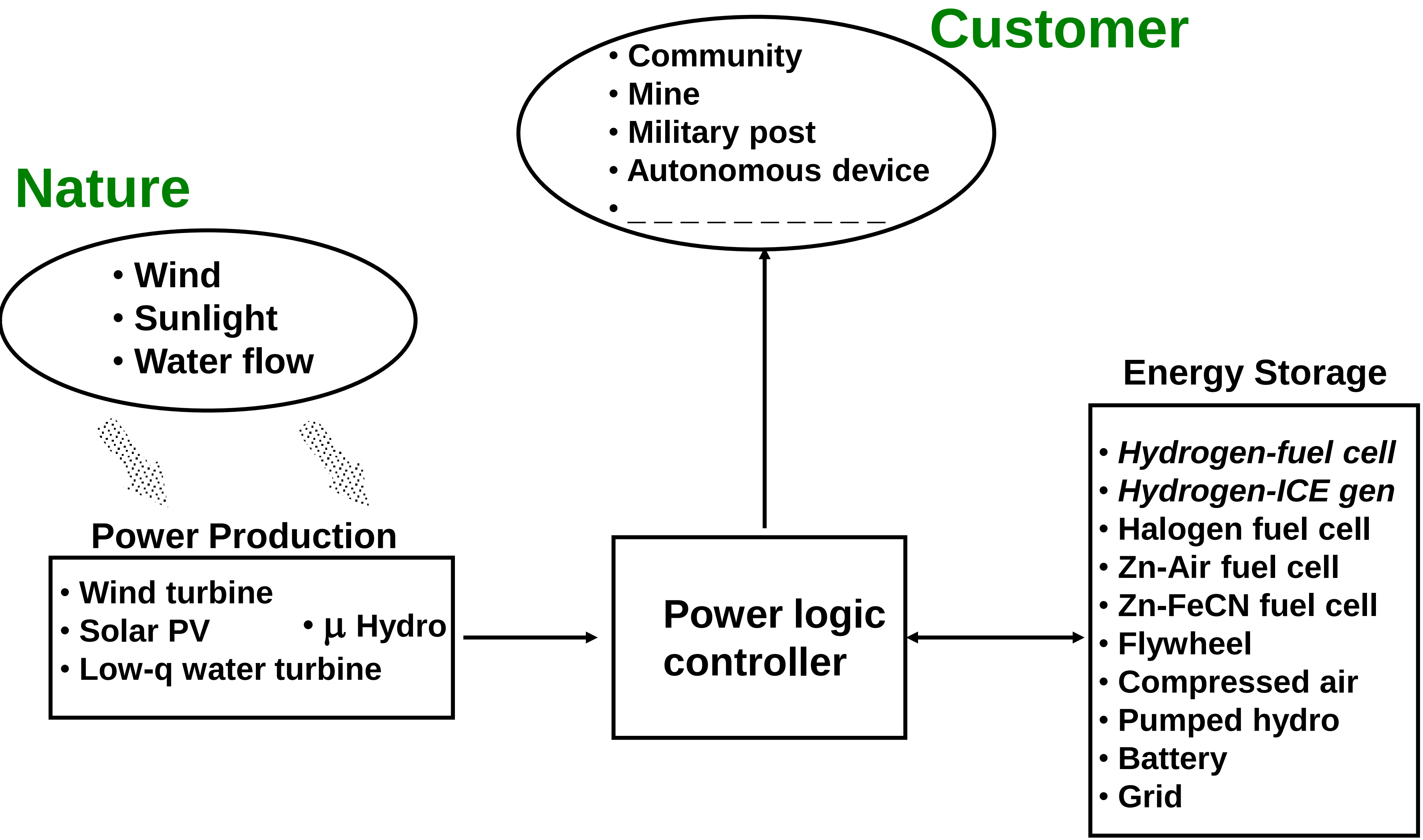
- **Wind, solar, hydroelectric and geothermal electricity**
- **Diesel, propane may have a delivery infrastructure**
- **Natural gas *may be* locally available or deliverable as LNG**

Fuel Cell Utility Power Systems

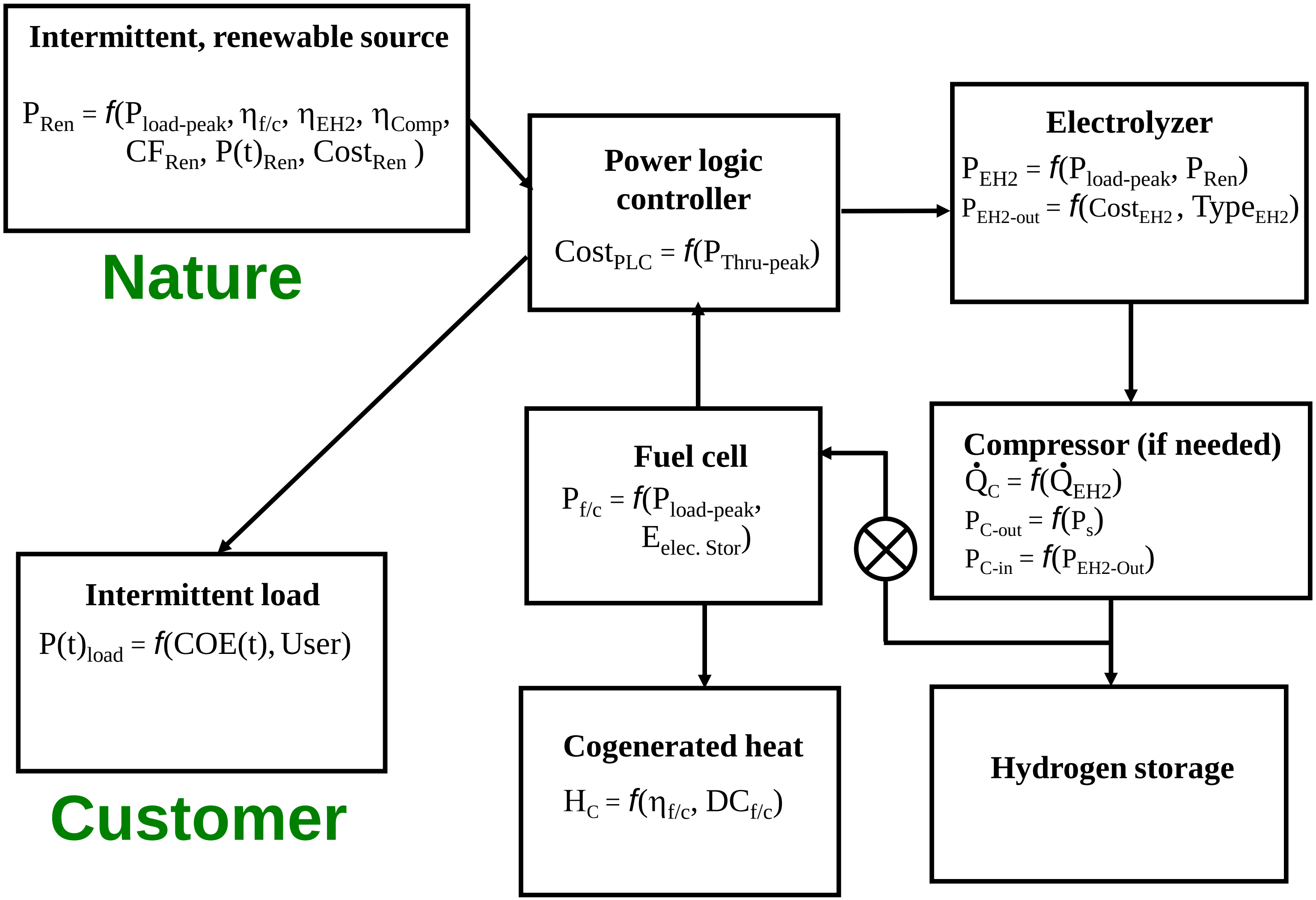
Configuration options



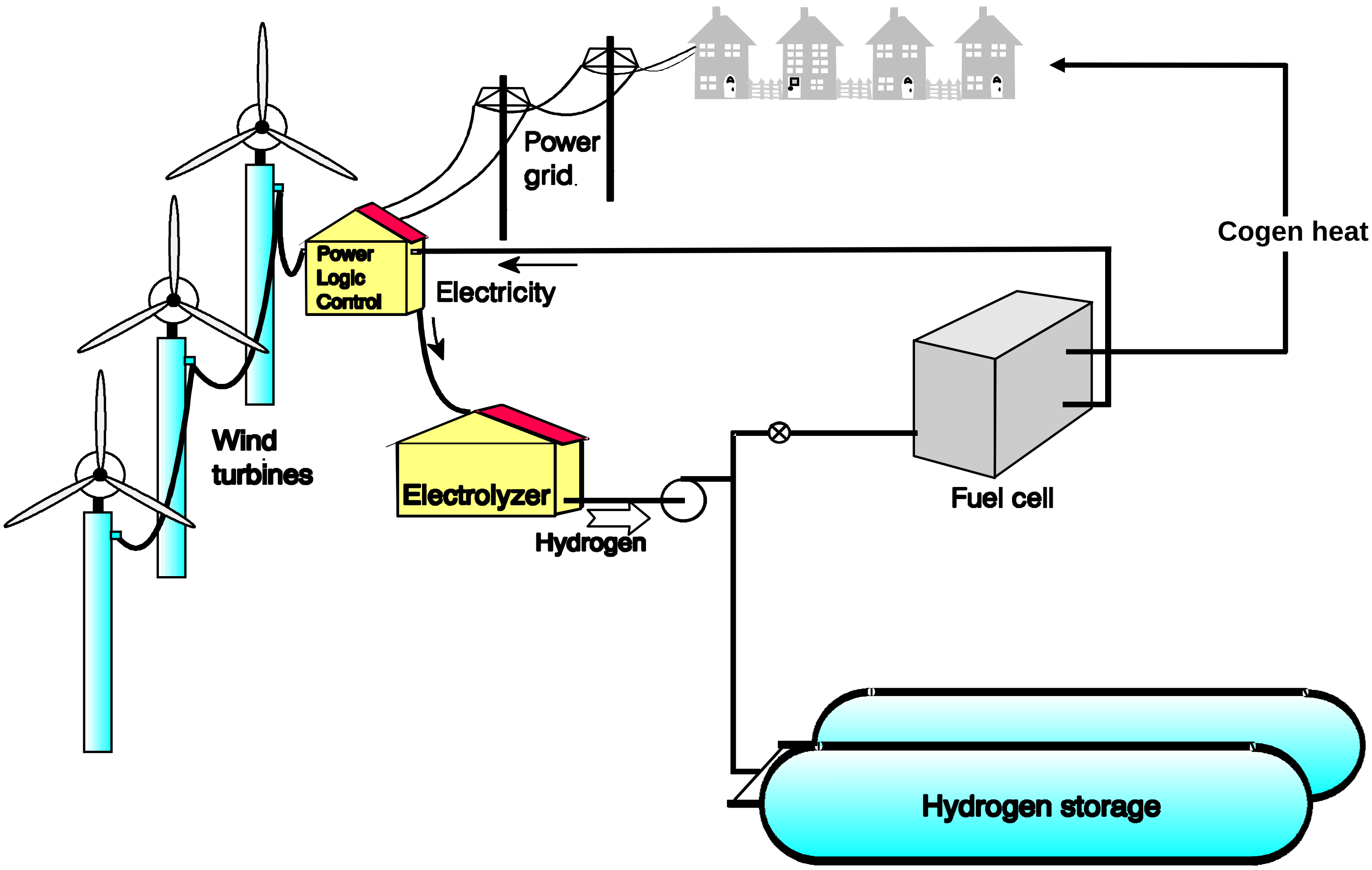
Source, process, storage and load options



Design criteria for remote hydrogen fuel cell utility power system



Wind, hydrogen, fuel cell isolated power system



Relationship of load, capacity factor, efficiencies to the power of renewable and electrolyzer

$$P_E = P_R = \frac{(1 - Cf_R)\ Pl_{AV}}{Cf_R\ \eta_E\ \eta_{FC}\ \eta_C}$$

P_E = Electrolyzer rated power

P_R = Renewable peak capacity

Pl_{AV} = Average load power

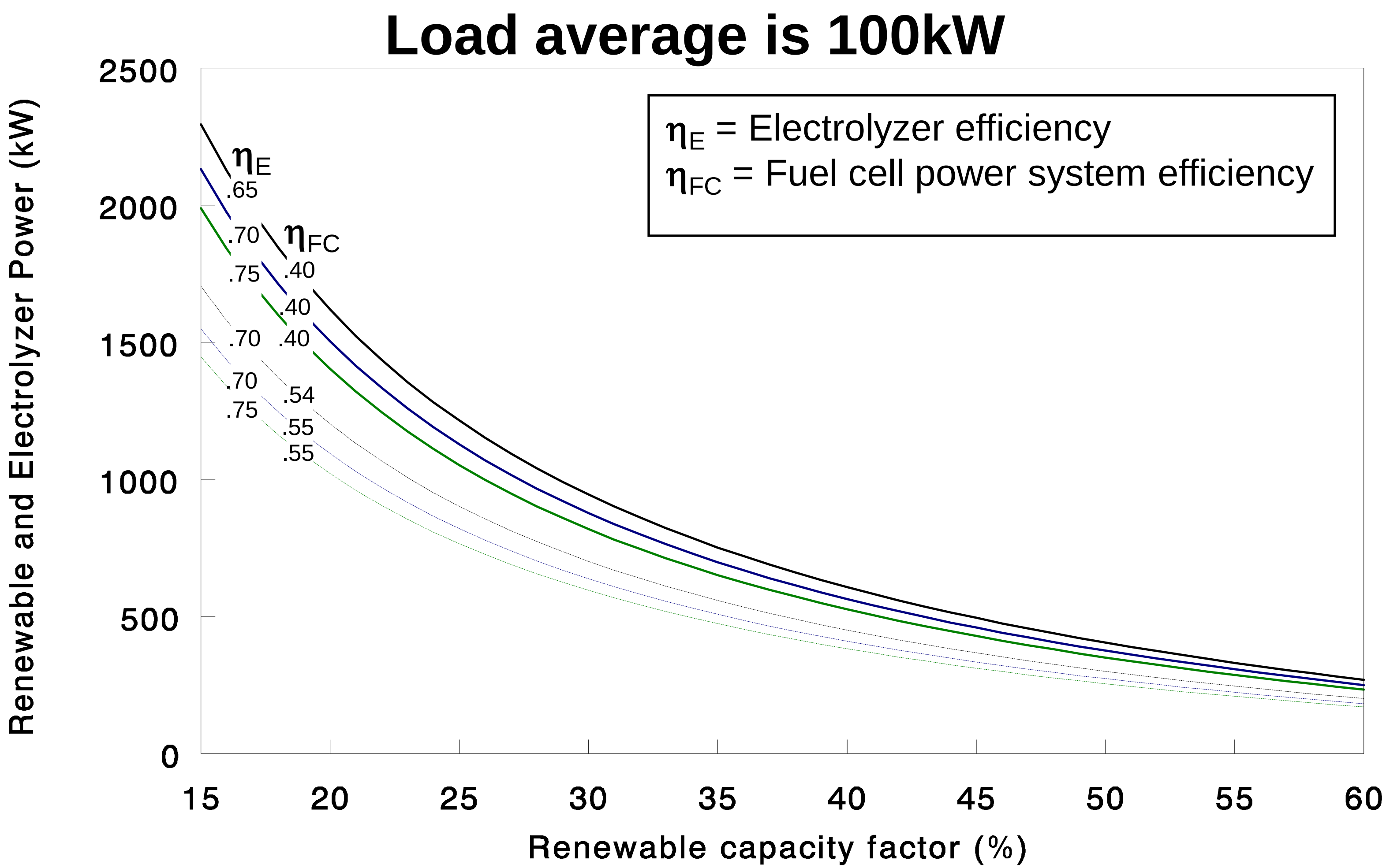
Cf = Capacity factor

η = Efficiency (<1)

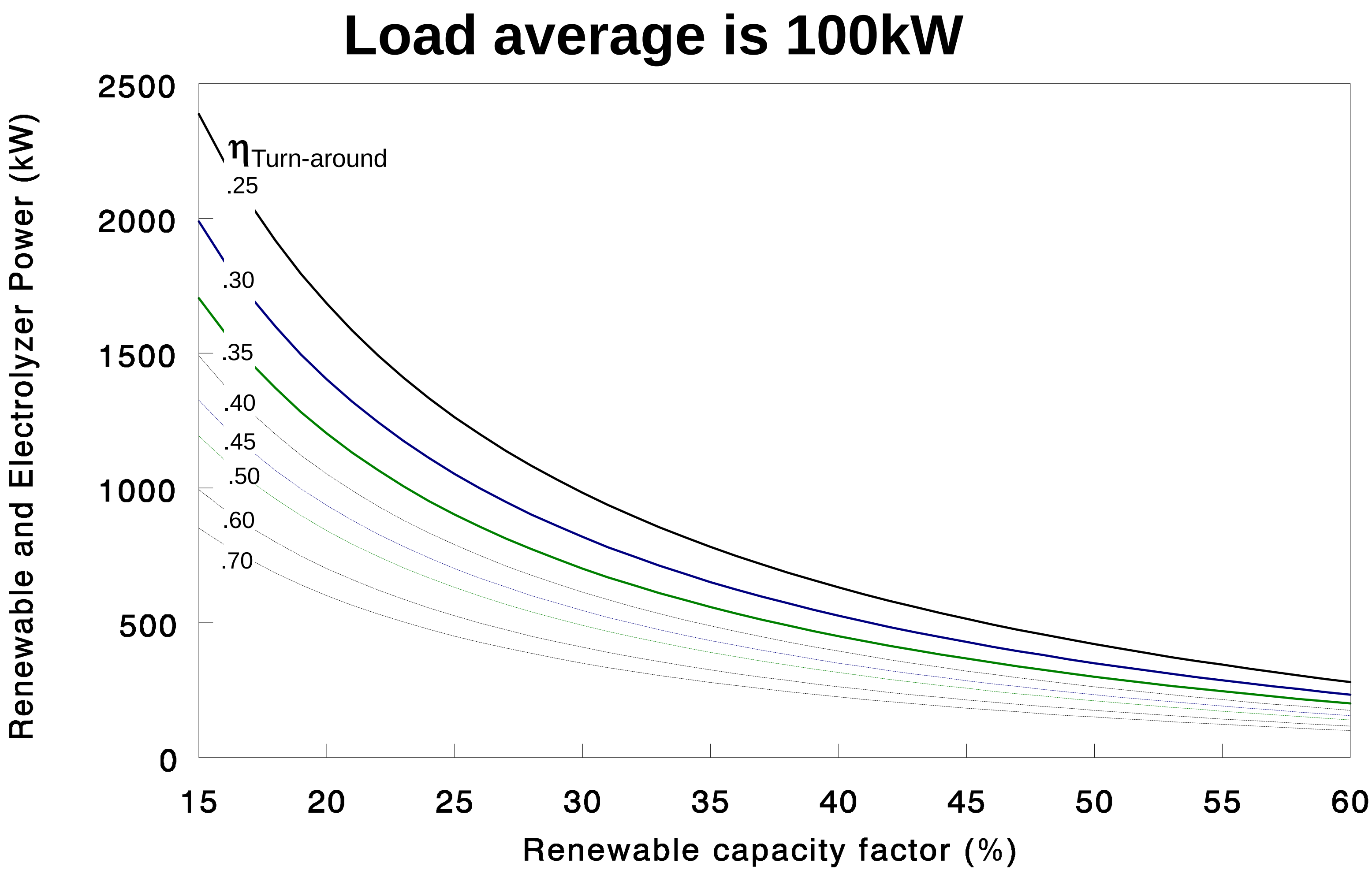
FC = Fuel cell system

C = Compressor

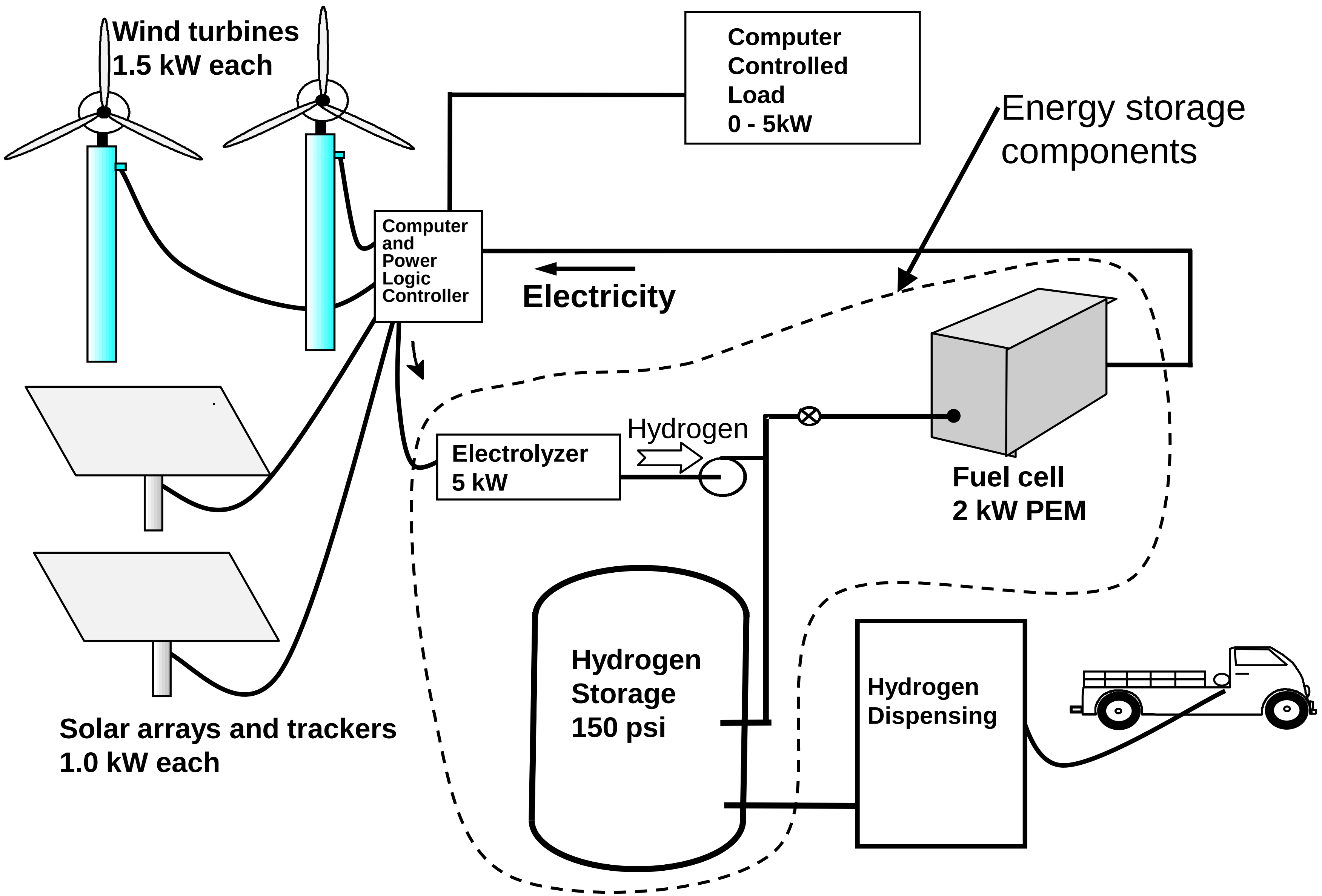
Effects of renewable capacity factor, electrolyzer efficiency and fuel cell system efficiency on renewable power and electrolyzer power needed



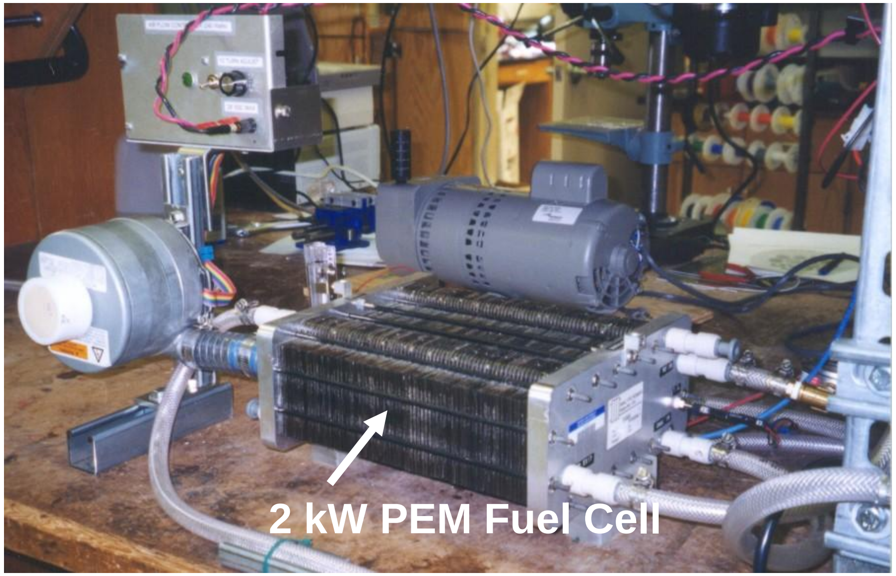
Effects of renewable capacity factor and turn-around efficiency on renewable power and electrolyzer power needed

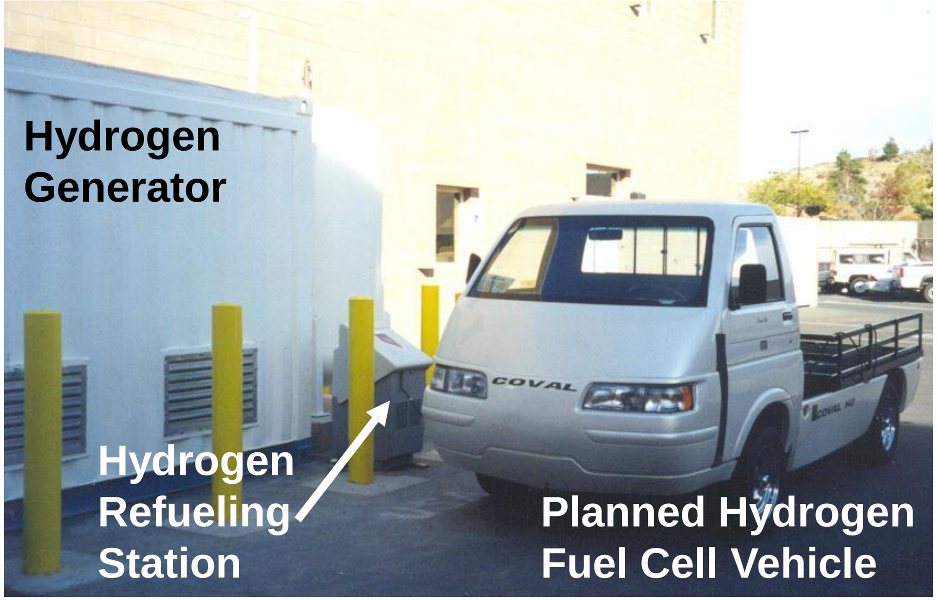


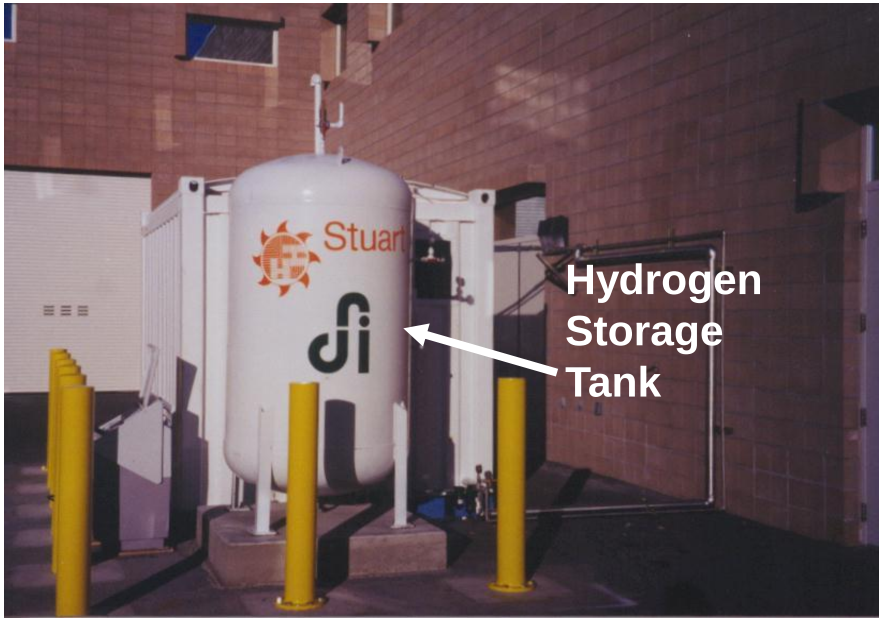
DRI residential scale, renewable hydrogen, fuel cell test facility and refuel station



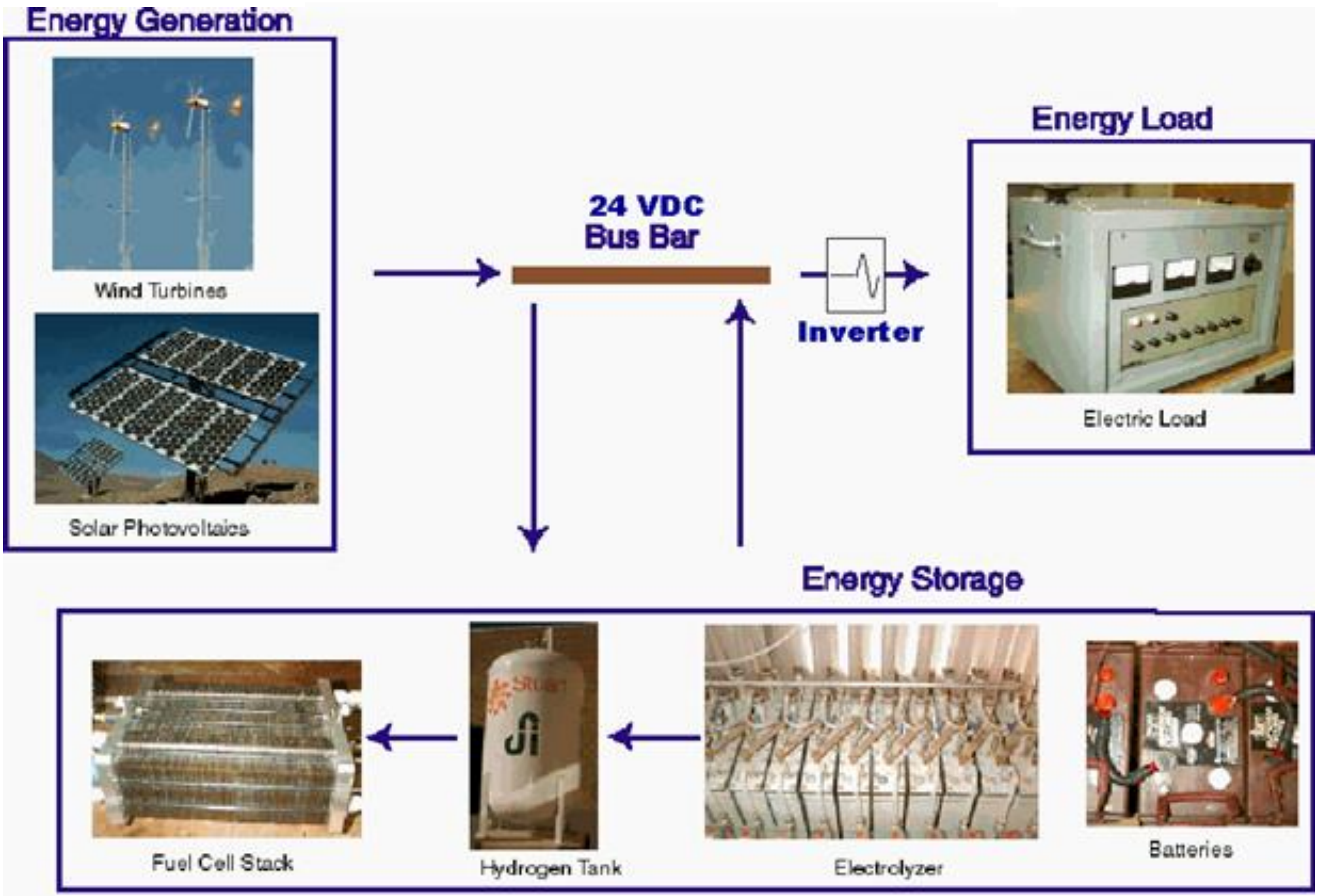
Components of DRI renewable hydrogen, fuel cell test facility



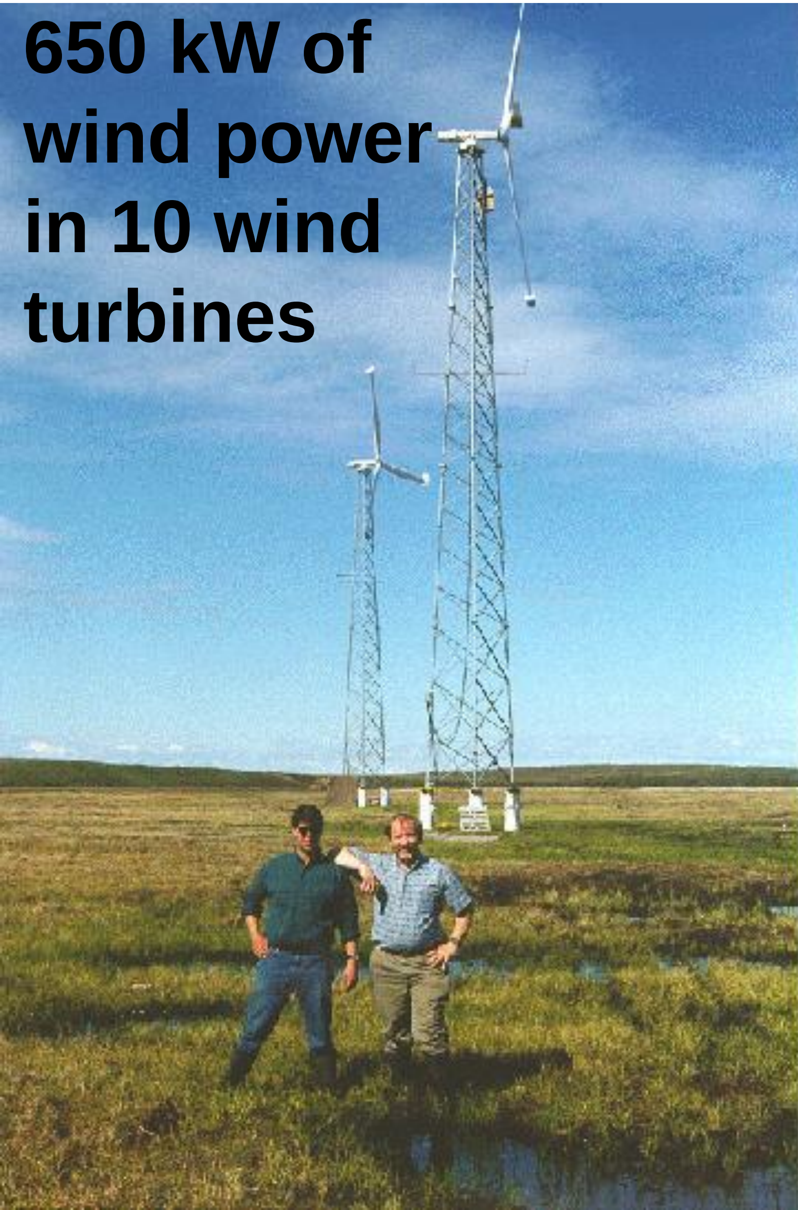


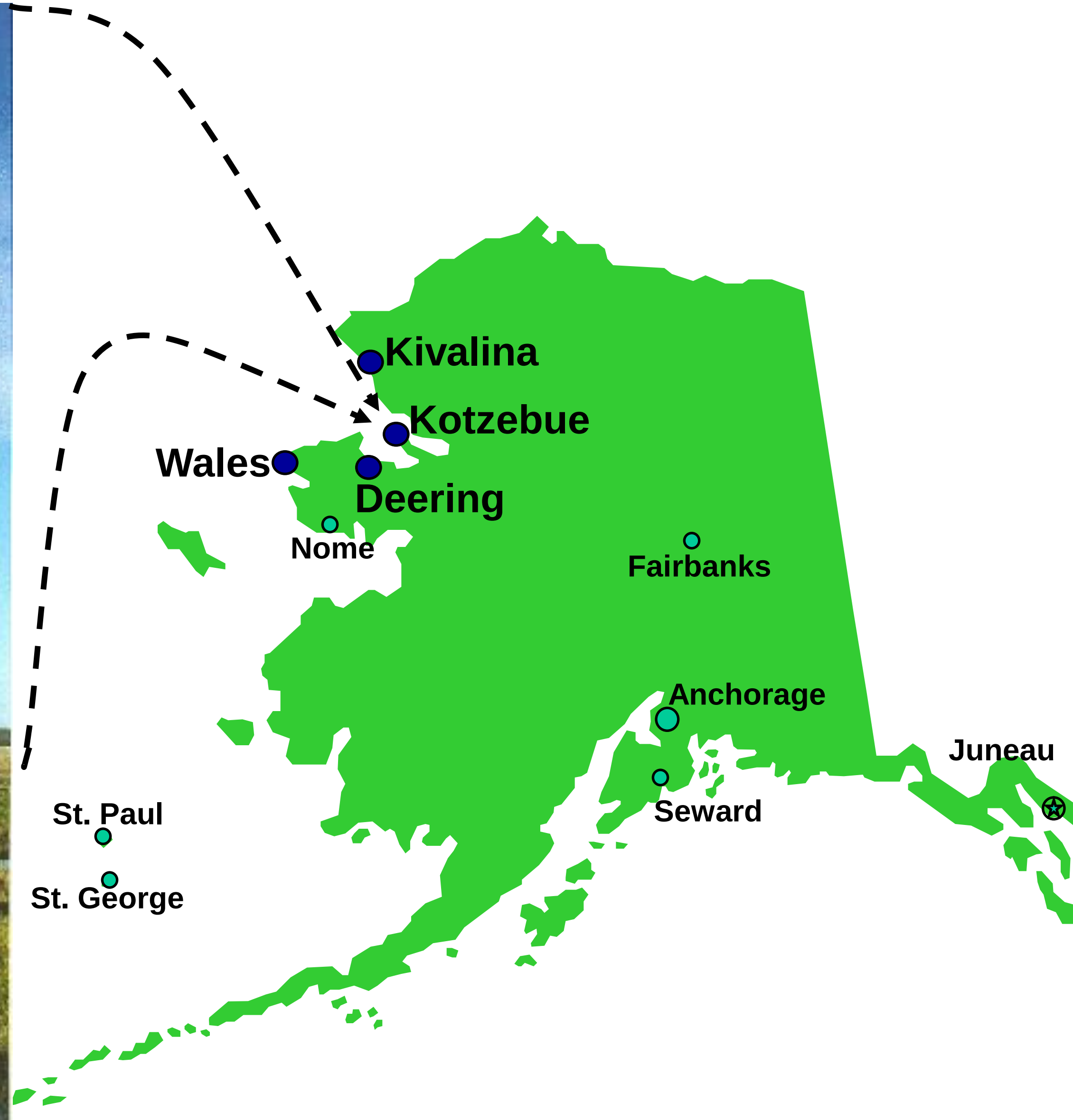


Renewable Hydrogen Energy Research System at DRI

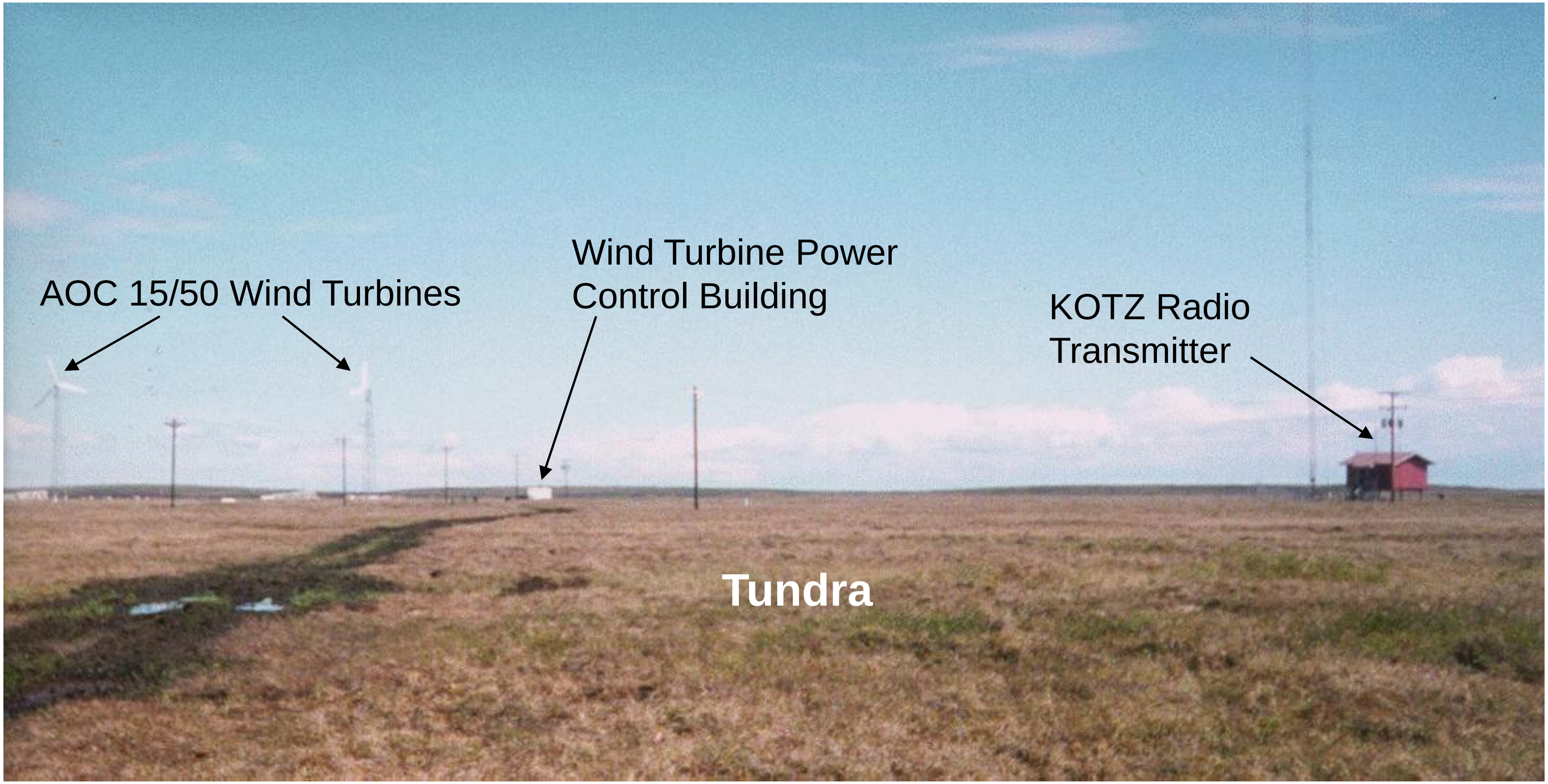


Kotzebue, Alaska wind turbine site



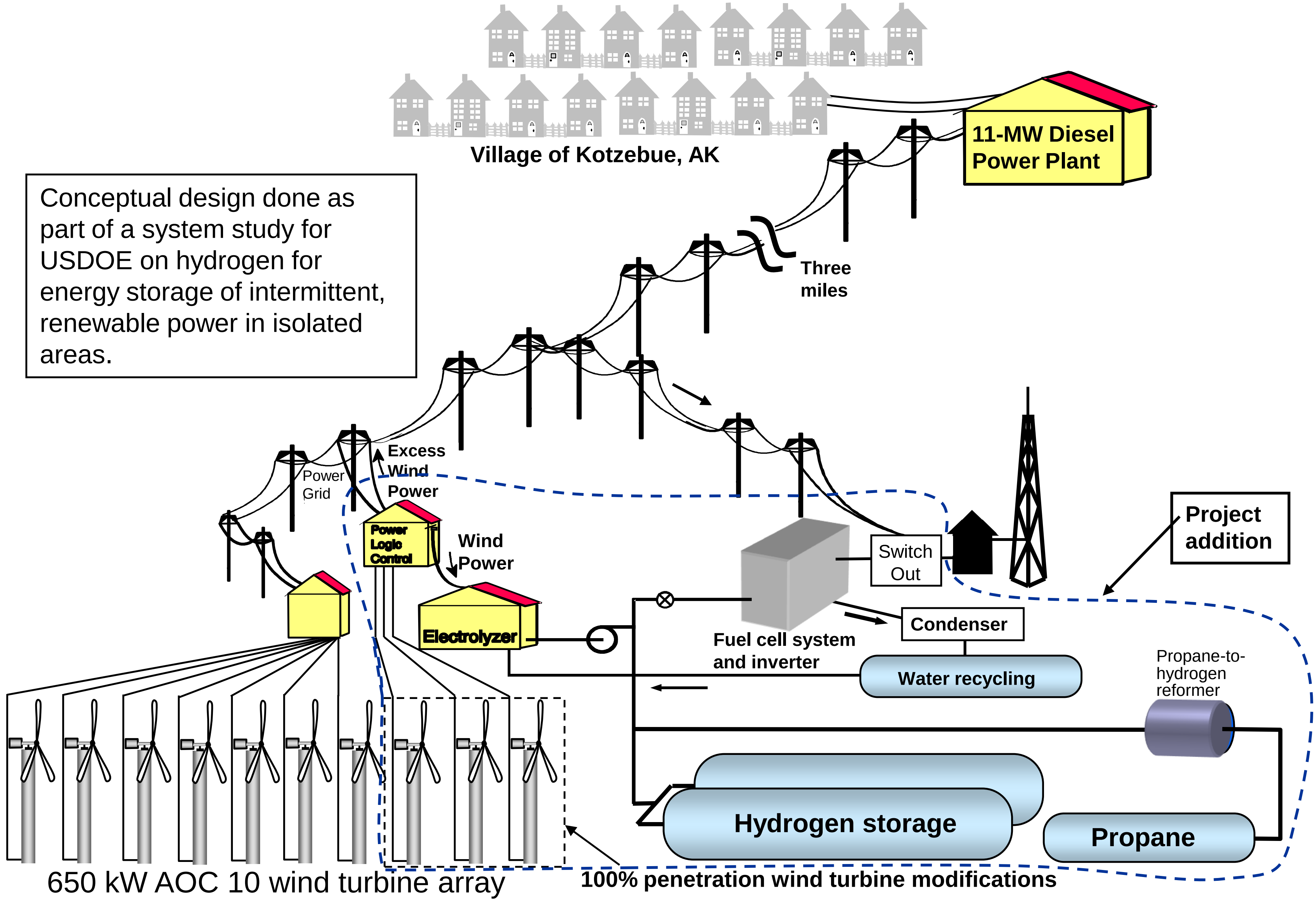


Kotzebue, AK wind turbine site

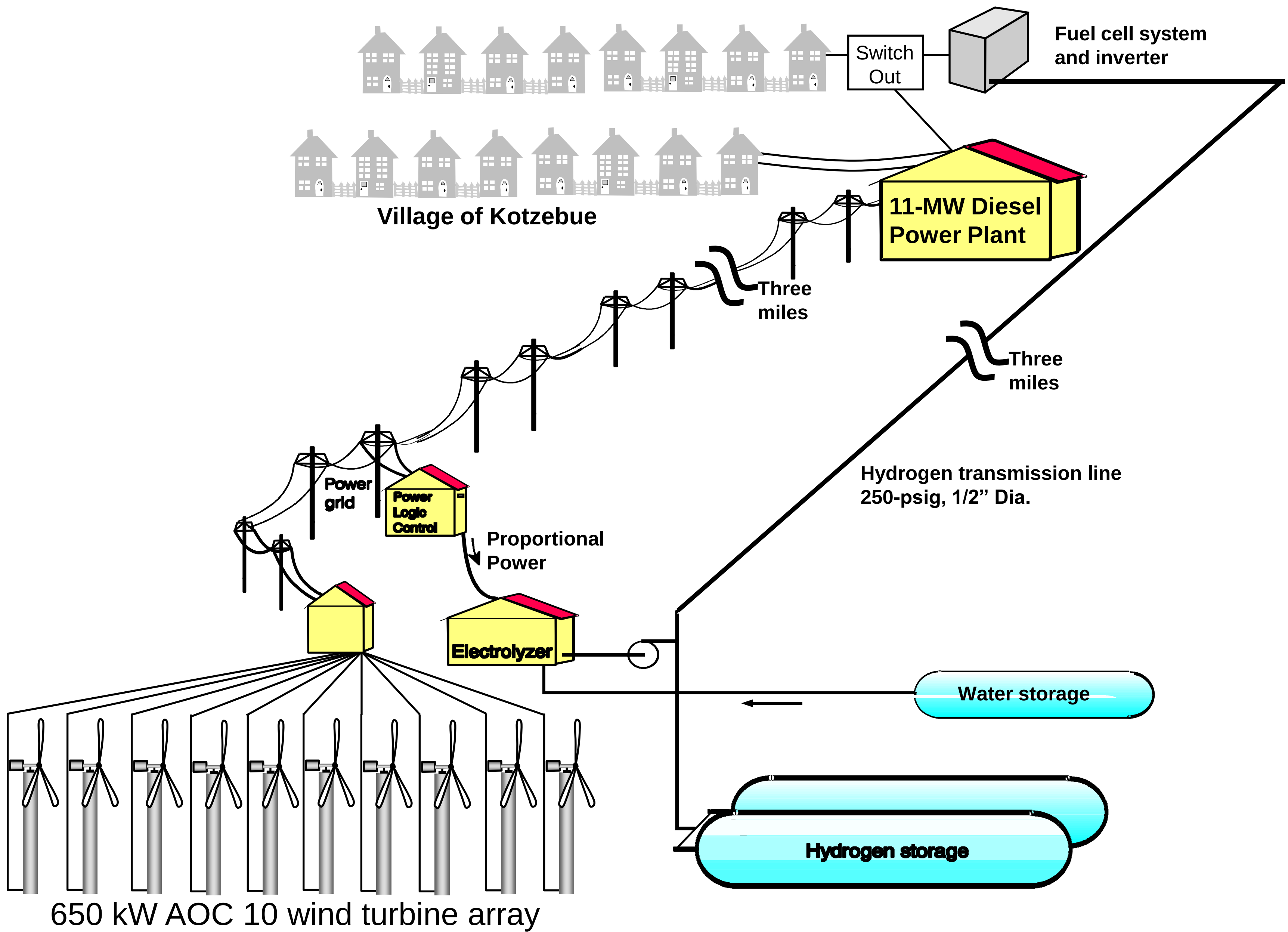


Wind, hydrogen, fuel cell power for KOTZ Radio Transmitter

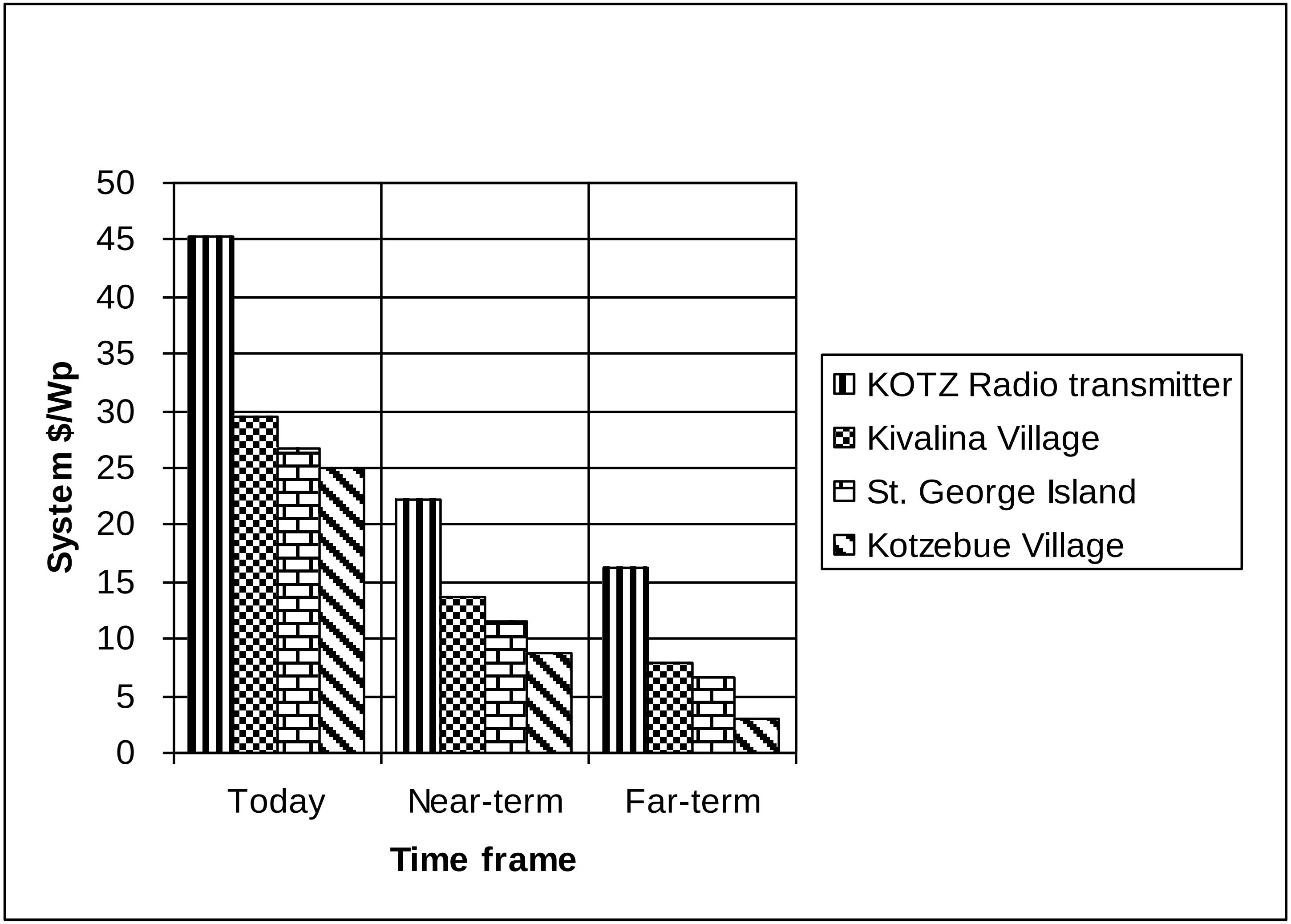
Conceptual design done as part of a system study for USDOE on hydrogen for energy storage of intermittent, renewable power in isolated areas.



Wind, hydrogen, fuel cell power for village loads



Evolution of system capital costs for different loads



Summary

- Integrated hydrogen utility systems are an ultimate goal for future power systems.
  - The inclusion of transportation fuel in remote locations adds significant value.
  - Other storage systems include pumped hydro and batteries.

- Wind power, micro-hydroelectric and low-q water current are promising power input stream sources for northern communities.

- The technologies necessary for an integrated renewable hydrogen power system are available, and close to the costs needed for full economic use in remote applications.
  - Cost is a greater challenge than technological development at this point.

- New system models are key enablers to permitting development of the market for integrated hydrogen systems

How do we implement hydrogen in the near term?

- ***Implement***: To render commercially practical. To get into the mainstream of society. To transition from exclusively publicly funded research to successful private enterprise.

- Test out implementation ideas for hydrogen with people who want to make money in the *commercial* marketplace, not the *research* marketplace.
  - With what we now know, can we think of a way to convince financing sources to invest in selling any niche product?
    - Niche is where it's at!
  - How much of this is an individual activity? How much is a group (NHA?) activity?

- Niche markets. (High value, small production runs)

- Past the "valley of death" for new technologies, from early adopters to small, sustained commercial support.

Implement hydrogen? ***Find the beginning. Start there.***

Carbon management

CO_2 sequestration:

- Sequester CO_2 from the atmosphere in the form of biomass. (50 - 500 million years ago)
- Convert biomass into chemically and physically stable form of sequestered carbon.
- Maintain ***chemically <u>and</u> physically stable*** form of carbon (coal and oil) for 10s to 100s of millions of years.

CO_2 recovery:

- Recover sequestered carbon and call it hydrocarbon fuel.
- Convert it into energy and the original CO_2 to power a few 10's of decades of humanity.

CO_2 resequestration:

- Collect CO_2 from power systems.
- Reinsert into oceans, earth, aquifers, ***only a physical process*** away from the environment.
  - Since any CO_2 resequestered remains as CO_2 forever, the resequestering needs to last longer than the sequestering of nuclear waste.

Ponderous points to ponder

- **An automobile engine is made in the U.S. every 2.1 seconds, 24 hours a day, 7 days a week. (15 million/year)**

- **The U.S. pays $1 billion a week to import foreign oil. (more than 1/3 of trade deficit)**

- **The U.S. spends over $50 billion a year to defend our oil interests in the Persian Gulf, not counting periodic conflicts. (over 65¢/gallon)**

- **Health care costs in the U.S. related to fossil fuel combustion are in excess of $50 billion a year. (over 65¢/gallon)**

- **2 billion people (1/3 of the world population) have yet to benefit from utility electricity.**

- **The US and the world are beginning to become customer bases for new energy technologies. Who will be the purveyors?**