Diesel Basics – For integrating Wind

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NORTHERN POWER SYSTEMS
power without limits

Northern Power Systems

- Worldwide power system integrator and innovator
- 30 years of experience in on-site power systems
- 840 projects installed in 45 countries on all 7 continents
- Advanced R&D in Energy Technology Laboratory
- 120+ employees (over 50% with engineering degrees)

Power Generation Options

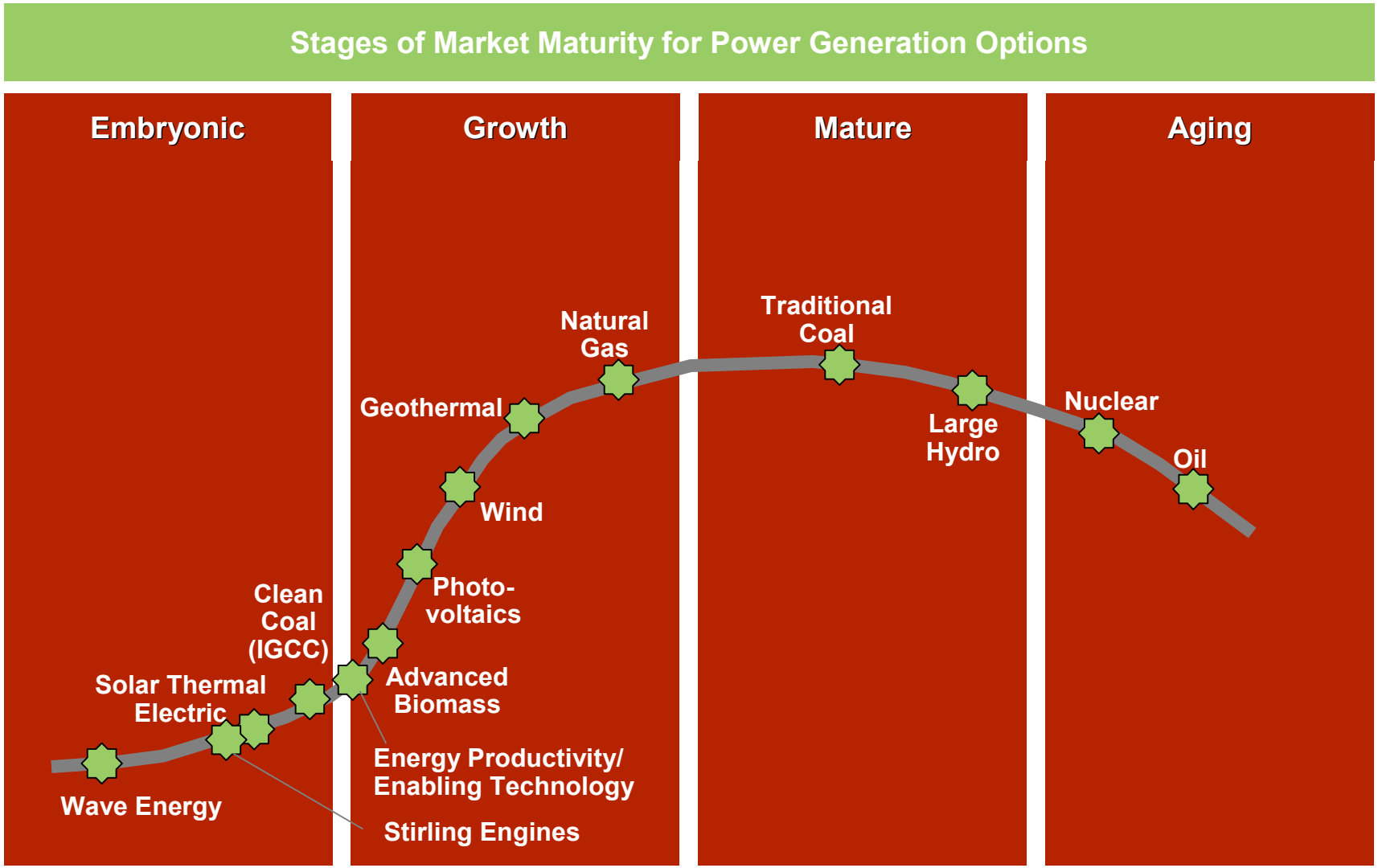
Reciprocating Engines

Microturbines

Fuel Cells

Diesel Engines

Stages of Market Maturity



Diesel Engine Characteristics

- Rudolph Diesel Cycle
- Otto Cycle

- Compression Ignition
- Spark ignited

- Combustion characteristics
- Power (torque) characteristics

Diesel Engine – The Prime Mover

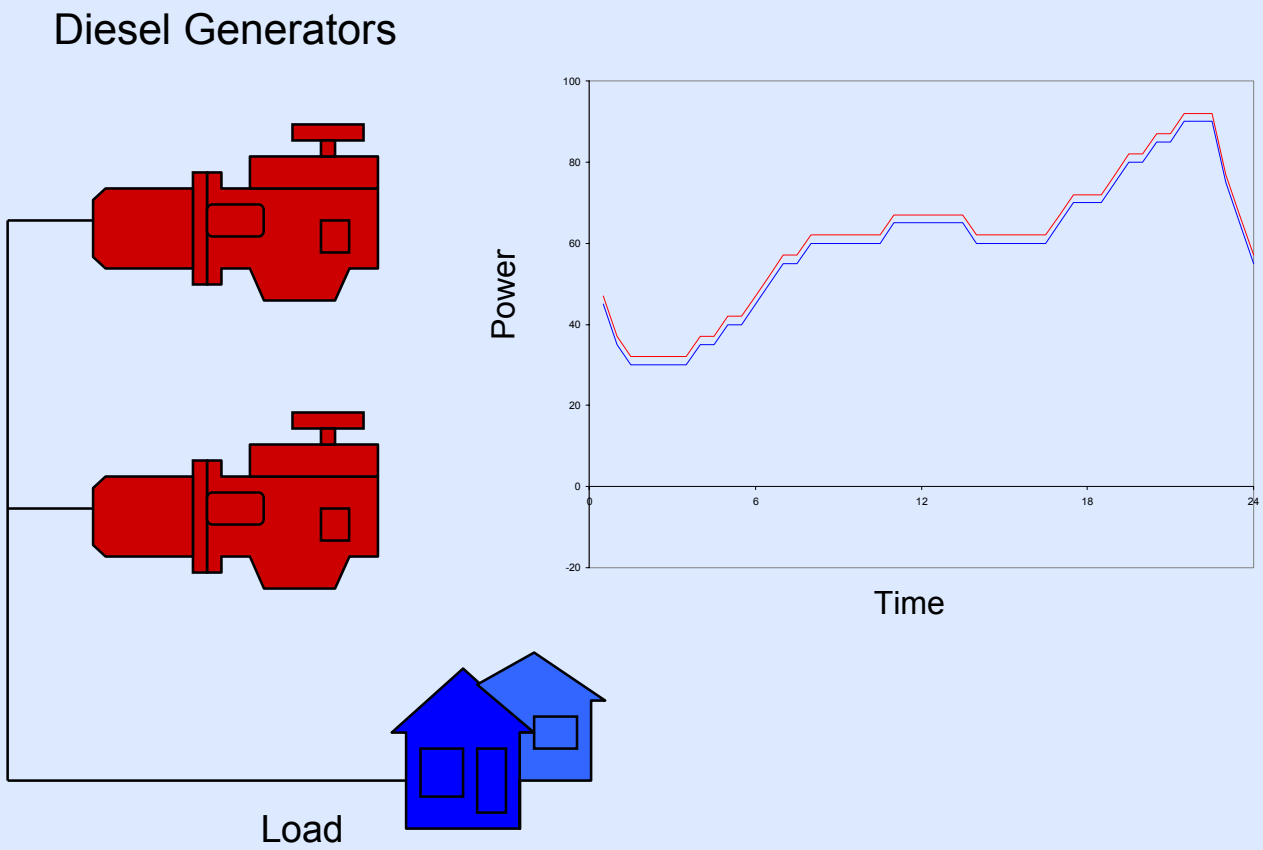
Diesel Engines are great

- Reliable
- Efficient
- Well understood
- Fuel –easily transported, stored, and High density

Diesel Engines burn fossil fuel


TOM'S SHELL
Self Serve
Cash or Credit
Regular
ARM 9
Plus
LEG 9
Premium
First 9 Born

“Diesel Generation

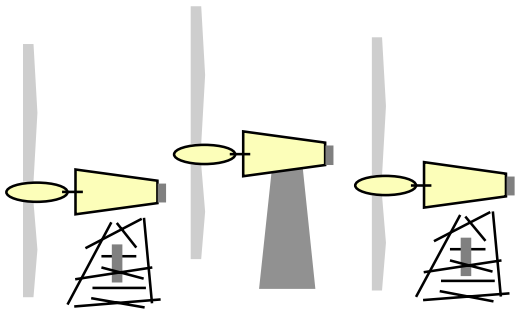


Wind - Diesel Compatibility

“Fuel Diversity”

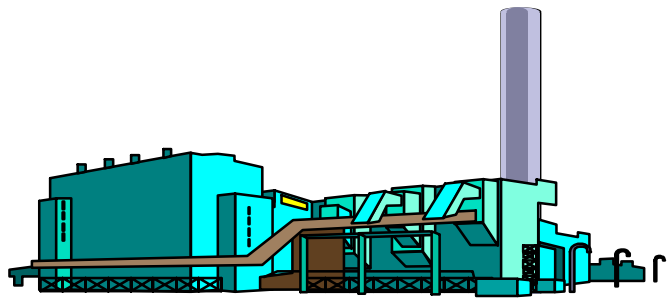
Wind

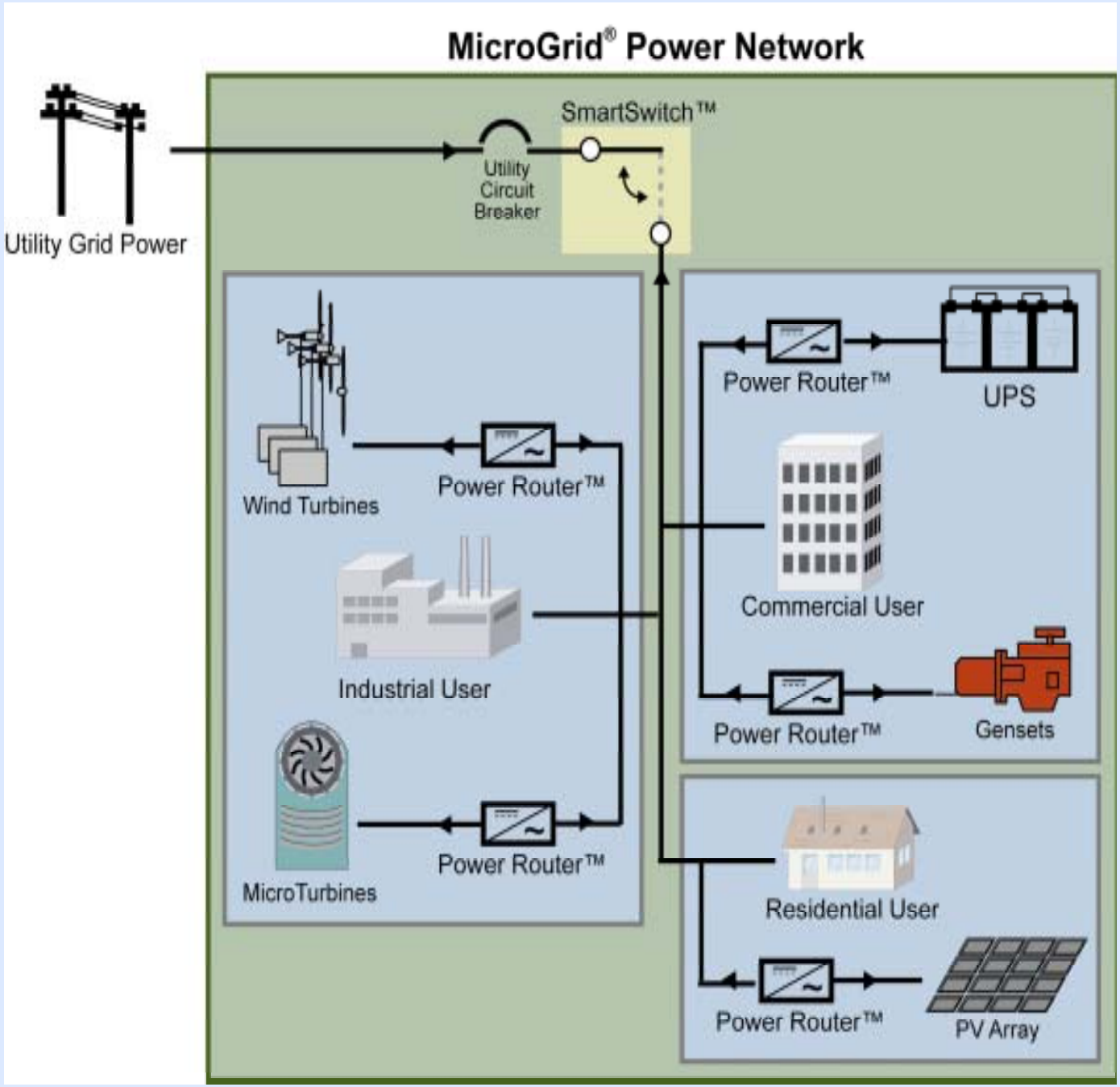
Low Operating Cost
High Capital Cost
Non-Dispatchable
No Fuel Supply/Cost Risk
No Emissions



Diesel/Oil

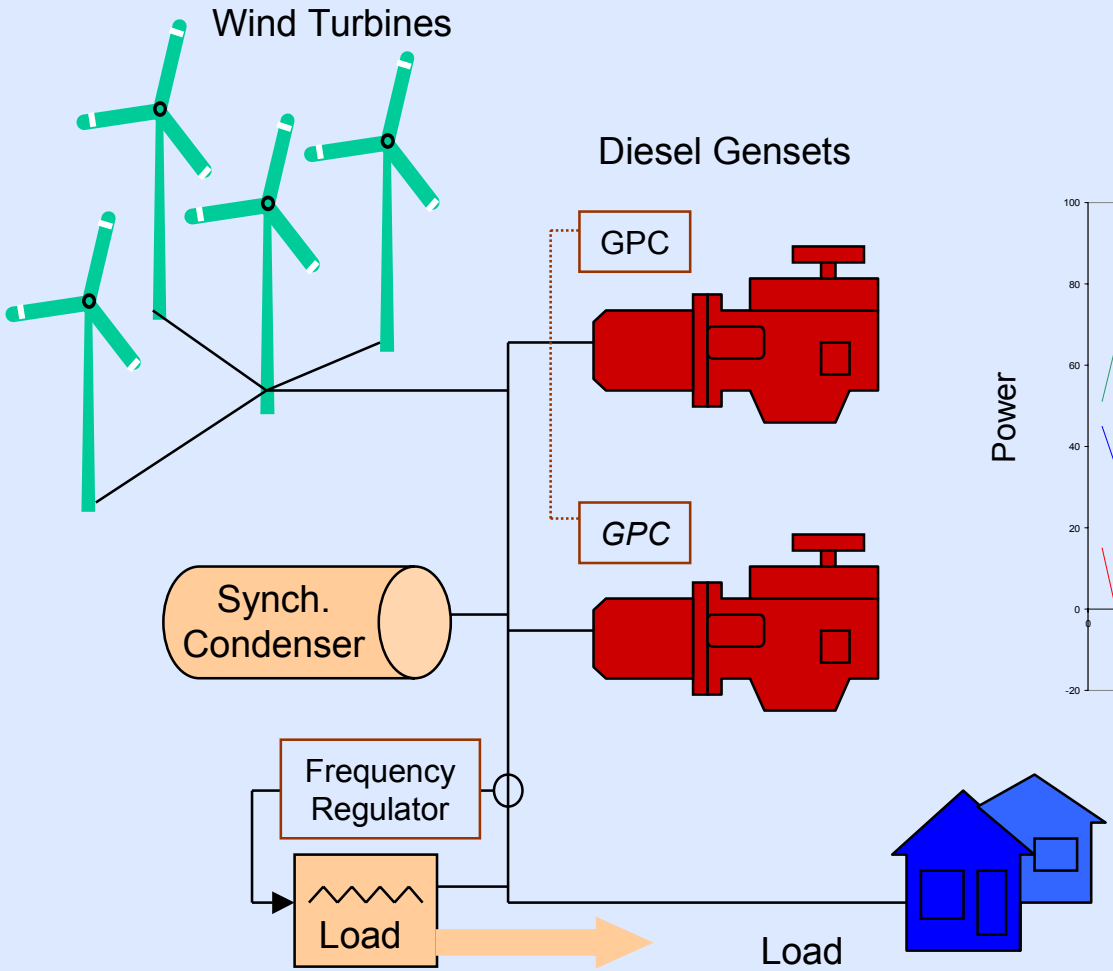
High Operating Cost
Low Capital Cost
Dispatchable
Fuel Supply/Cost Risk
Smog/GHG Emissions

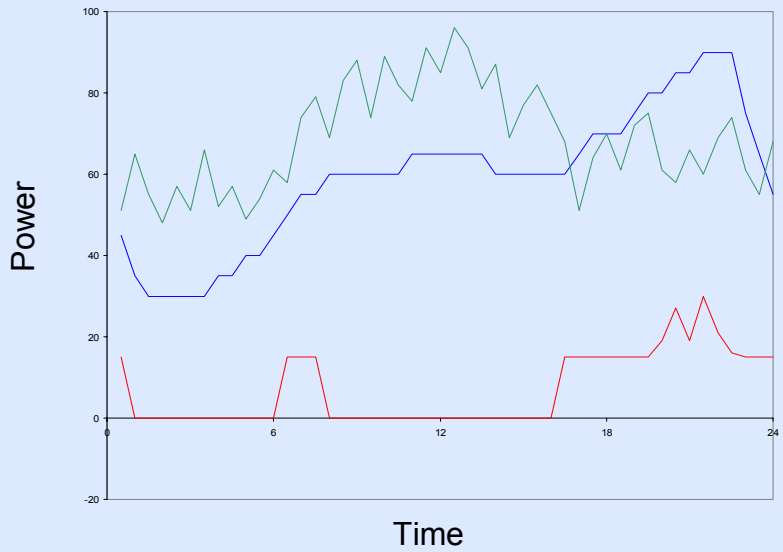



MicroGrid® Power Network
Utility Grid Power
Utility Circuit Breaker
SmartSwitch™
Wind Turbines
Power Router™
Industrial User
MicroTurbines
Power Router™
Power Router™
UPS
Commercial User
Power Router™
Gensets
Residential User
Power Router™
PV Array

Wind-Diesel Architecture

High Penetration

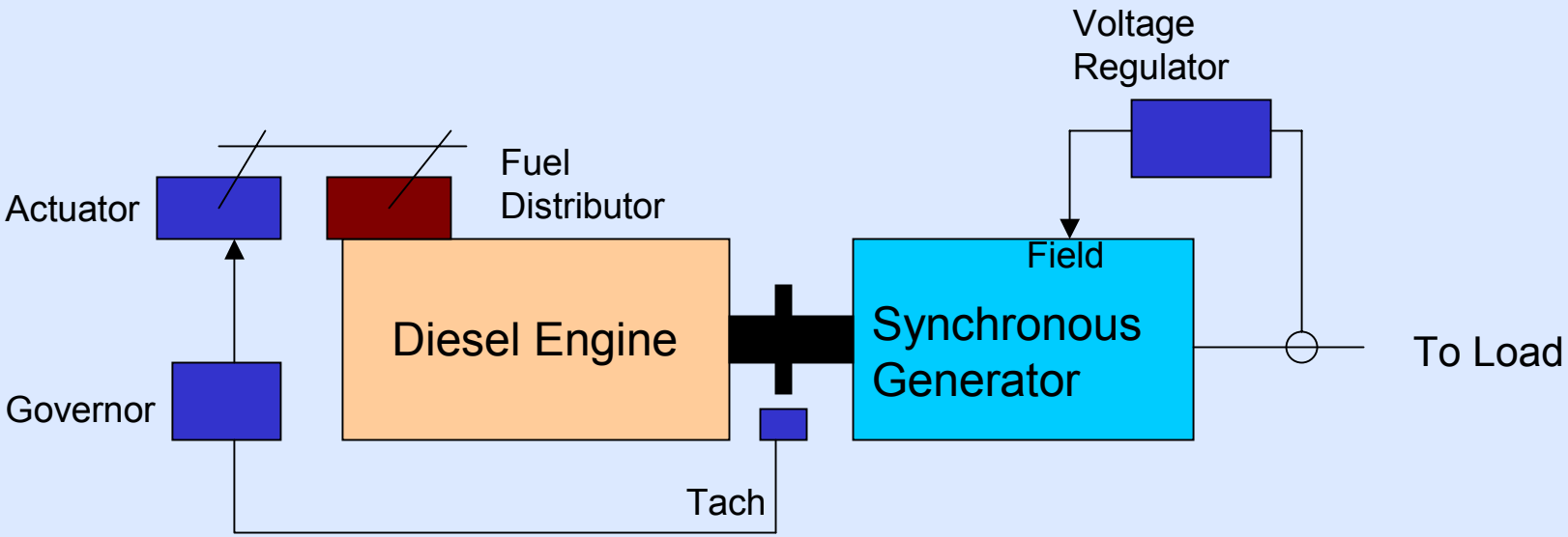




Criteria to operate Diesel Engine

- Keep warm (get warm)
- Minimum load levels
  - Corrosives
  - Moisture
  - Coking
  - Piston slap
  - Oil contamination

Generator Control



Frequency Control

Voltage Control

Power without limits




NORTHERN
POWER SYSTEMS

Reliable power. Proven worldwide.

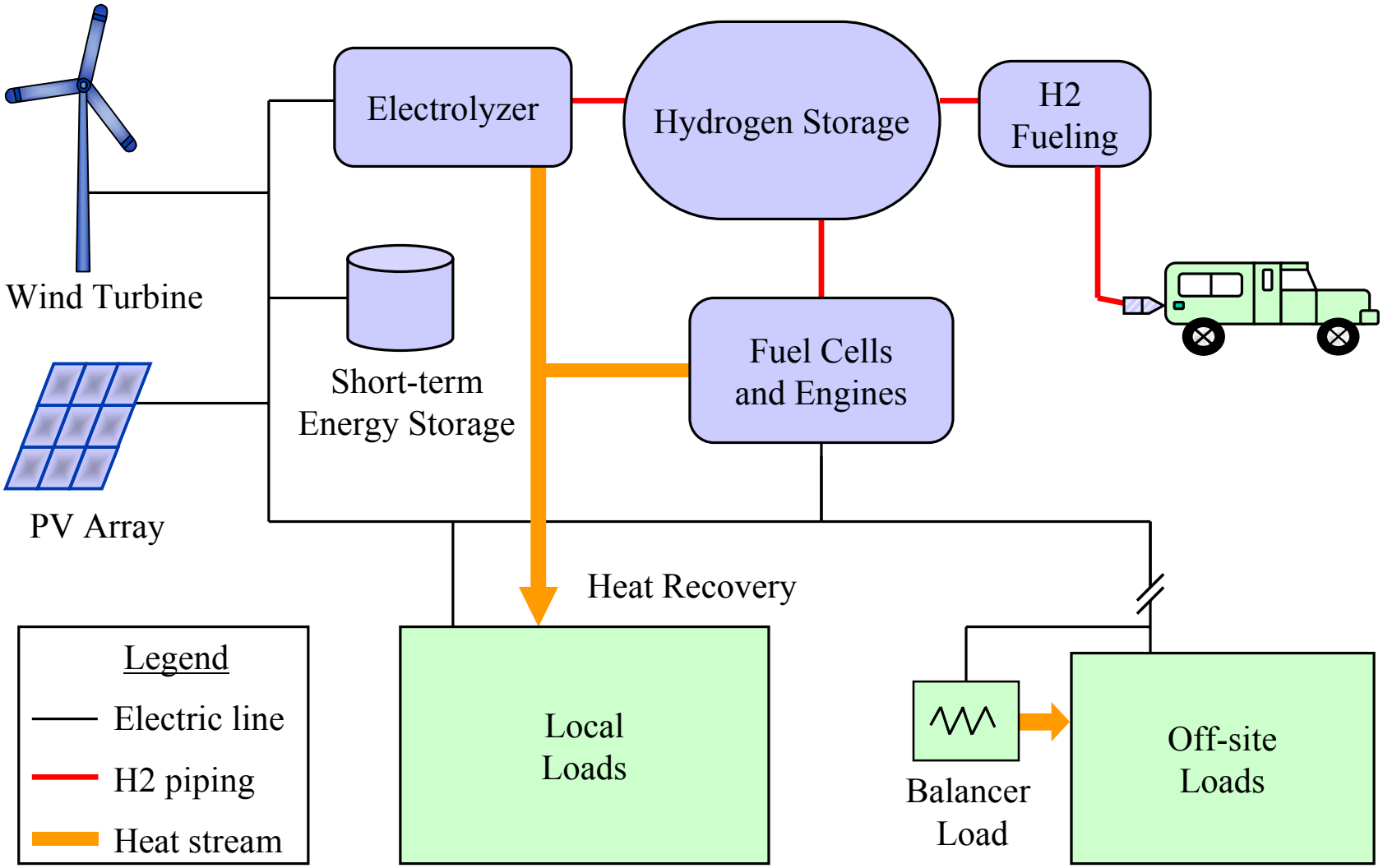
Key Driver: Energy Security

HAVE OIL		USE OIL	
Saudi Arabia	**26%**	**U.S.**	**26%**
Iraq	**11%**	**Japan**	**7%**
Kuwait	**10%**	**China**	**6%**
Iran	**9%**	**Germany**	**4%**
UAE	**8%**	**Russia**	**3%**
Venezuela	**6%**	**S. Korea**	**3%**
Russia	**5%**	**France**	**3%**
Mexico	**3%**	**Italy**	**3%**
Libya	**3%**	**Mexico**	**3%**
China	**3%**	**Brazil**	**3%**
Nigeria	**2%**	**Canada**	**3%**
U.S.	**2%**	**India**	**3%**

The U.S. uses more than the next 5 highest consuming nations combined.

Updated August 2002 Source: International Energy Annual 1999 (EIA), Tables 1.2 and 8.1.

Renewable H2 Energy System



NW100 Wind Turbine

- 100kw Direct Drive generator
- 19m, 3 bladed rigid rotor
- Upwind, active yaw
- Variable speed, 40-60 rpm
- Protected service access
- Modern power electronics
- -46C to 50C operating range

Technology Comparison Chart

Source	Typical Capacity Range	System Costs Installed	O & M $/kWh	Typical Fuel Cost	Cost of Lifetime Energy Produced	Hedge Against Energy Price Volatility	Emissions (lb/MWh)			Special Considerations
							CO2	SO2	NOx	
Engine-Biodiesel	50 kW – 2 MW	$1,200-$2,000 /kW	$0.007-$0.015 /kWh	$4.24 MCF	$0.08-$0.12 /kWh	Medium – dependant on fuel price	300-400 lb/MWh	0	4.9 – 22.8 lb/MWh	Because the biodiesel market is still immature, the ability to secure a reliable and quality fuel source is an issue.
Engine-Natural Gas	50 kW – 2 MW	$1,000-$2,000 /kW	$0.007-$0.015 /kWh	$4.24 MCF	$0.06-$0.08 /kWh	Medium – dependant on fuel price	1,100 – 1,400 lb/MWh	0.006 lb/MWh	0.5 – 2.2 lb/MWh	The benefits of cogeneration need to be analyzed against existing and potential fuel and electricity rates at a given site.
Microturbine	30 kW – 250 kW	$2,500-$4,000 /kW	$0.015 – $0.02 /kWh	$4.24 MCF	$0.10-$0.20 /kWh	Medium – dependanton fuel price	1,600 lb/MWh	0.008 lb/MWh	0.44 lb/MWh	Microturbine technology has not improved as rapidly as expected.
Photovoltaics	Modular	$8,000-$10,000 /kW	$0.003	0	$0.20-$0.30 /kWh	High – solar energy is free	0	0	0	Space considerations- rooftopsolar yields roughly 4 to 5 watts/sq. ft. of rooftop when aligned at a 20 degree angle.
On-site Wind Generation	100 kW – 10 MW	$1,000-$1,500 /kW	$0.008-$0.015	0	$0.05-$0.10 /kWh	High – wind energy is free	0	0	0	Site-specific wind conditions, siting and permitting issues are key factors in determining cost of energy.
Fuel Cells	1 kW – 250 kW	$4,000-$7,000 /kW	$0.005 – $0.01	$4.24 MCF	$0.25-$0.35 /kWh	Medium – dependant on fuel price	950 – 1,100	0.006	0.01 – 0.03	Fuel Cells are expensive and only a small number of units are actually in use. Incentive grants are available, but may require dedicated research efforts.
Green Tags	Unlimited	NA	NA	NA	$0.02-$0.05 /kWh premium	None – tags are an addition to regular costs	0	0	0	Purchases need to be negotiated based on size and source of tags. Special consideration should be given to the source and location of the green energy producing the tags.
Green Power Purchase	Unlimited	NA	NA	NA	$0.02-$0.05 /kWh premium	Medium – dependent on length of agreement	0	0	0	Purchases need to be negotiated based on amount of energy purchased and length of contract. Special consideration should be given to the source and location of the green energy.

The World is NOT Running Out of Energy

But it *is* running out of…

- Cheap oil
- Environment
- Tolerance for inequity
- Money for better options
- Time for a smooth transition
- Leadership to do what is required