Comparison of different energy storage systems for renewable energies on a Caribbean island

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Research approach

Problem
➔ Intermittent nature of renewable energies requires storage
➔ Special conditions on Caribbean islands (hot, only two seasons)

Object
➔ Energy supply system of Petite Martinique

Method
➔ Literature research
➔ HOMER Energy Simulation

Objective
➔ Finding the optimal energy supply and **storage** system for PM regarding renewable energies

Agenda

- Introduction – Petite Martinique
- Storage technologies
- Results
- Conclusion

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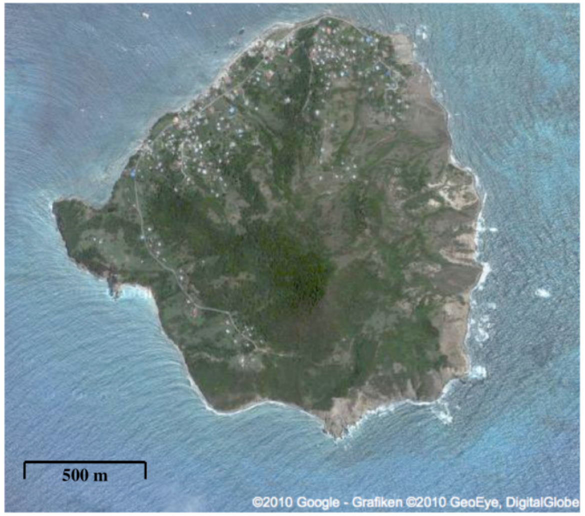
Petite Martinique

Sources:
CIA (2011),
Google (2010)

Petite Martinique

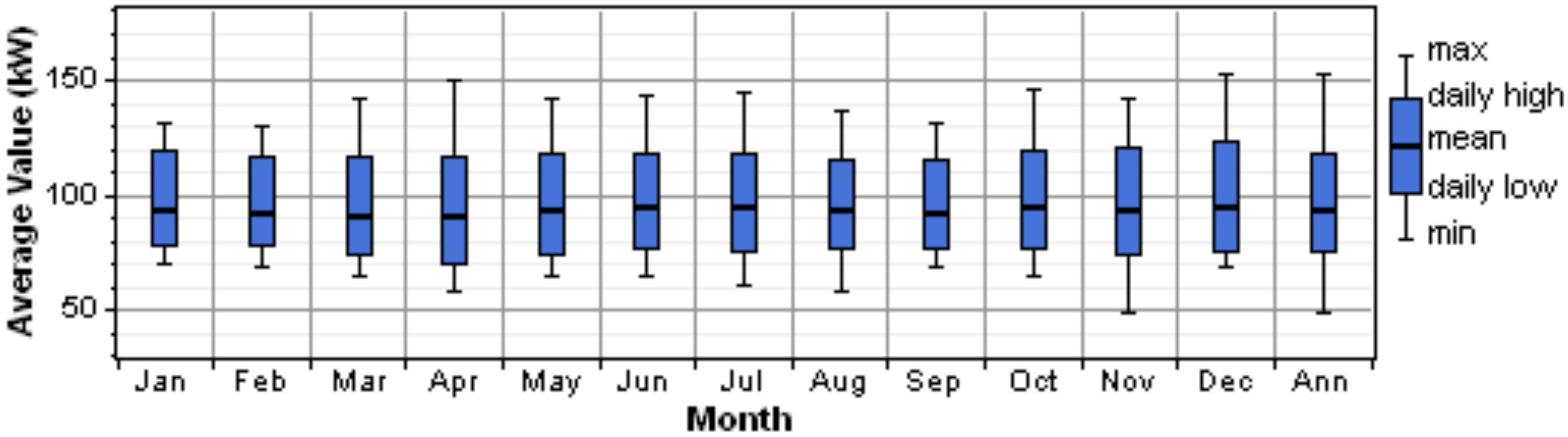


Category	Value / Explanation
Surface area	2.4 km^2
Highest point	230 meter
Population	Approximately 1,000
Climate	Subtropical
Average temperature	25 degree celsius
Economic sectors	Fishing, boat building, agriculture, tourism

Sources:
CIA (2011),
Google (2010)

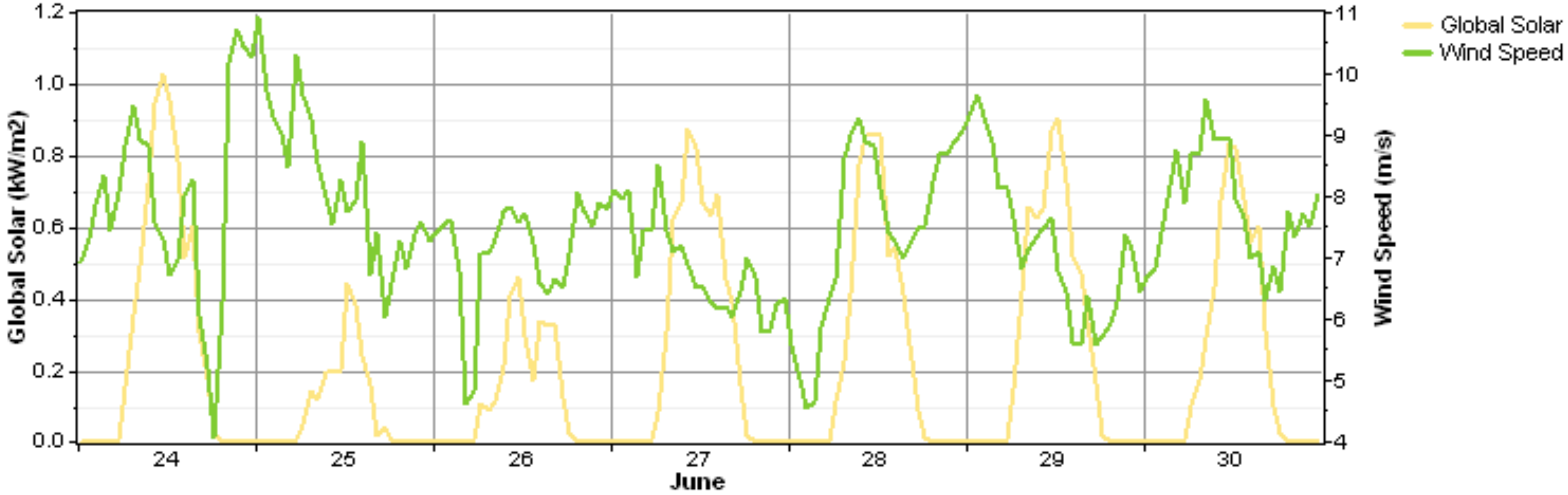
Energy supply system

Category	Energy
Yearly demand	800 MWh
Peak demand	152 kW
Supply system	2 Diesel GenSets (240 kW / 210 kW)



Sources:
LogSheet (2010),
NASA (2010),
Gerlach (2011)

Energy supply system



Sources:
LogSheet (2010),
NASA (2010),
Gerlach (2011)

- No seasonal changes in load profile or solar radiation
- Wind and solar often complementary

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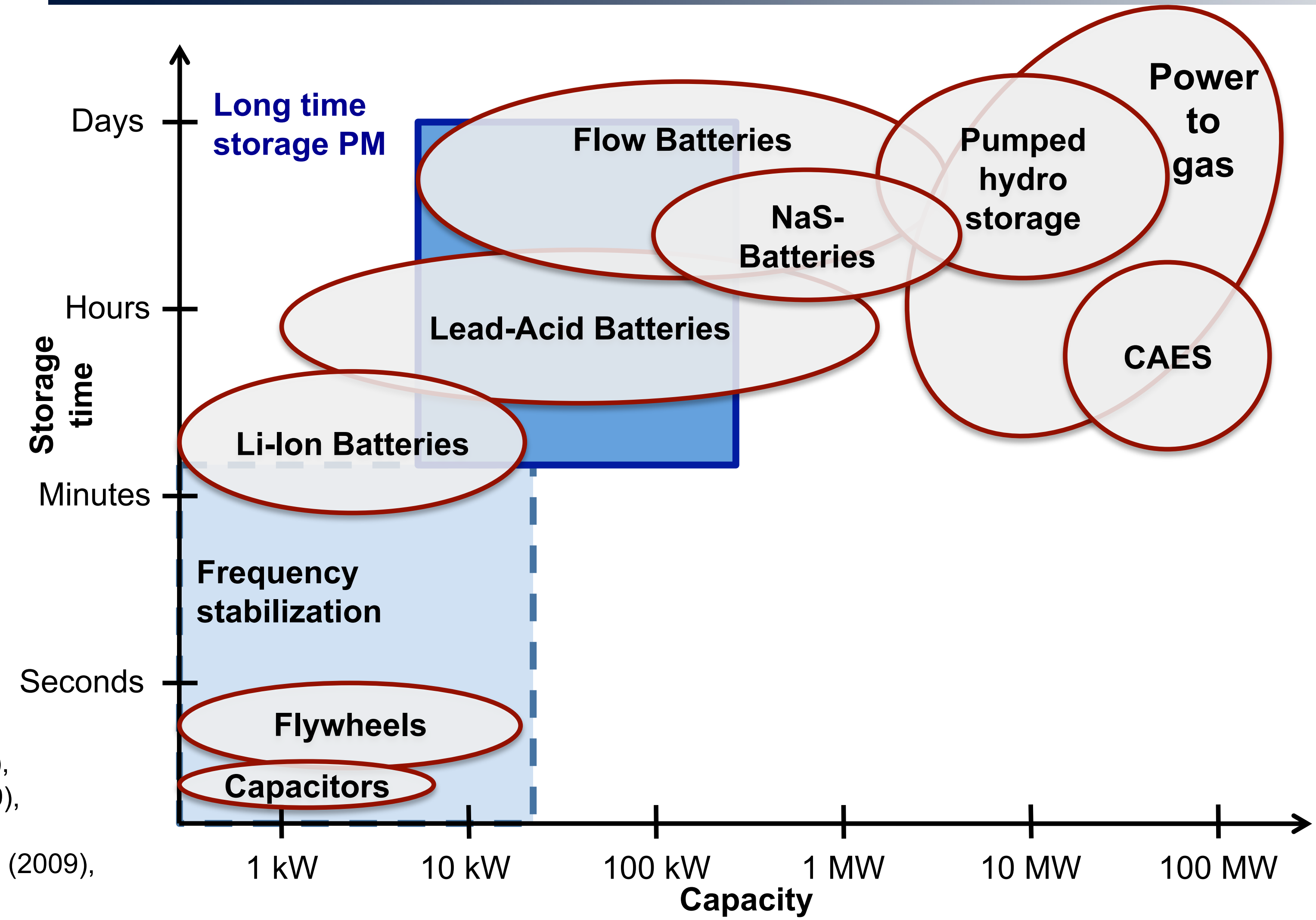
Storage technologies for small islands



Sources:
Ibrahim (2008),
Kaldellis (2009),
Hall (2008),
Hadjipaschalis (2009),
ESA (2011),
Sterner (2009)

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Lead-Acid batteries vs vanadium redox flow

	Lead-Acid	Vanadium redox flow
Advantages	• Relatively cheap • Mature technology	• Flexible combination of storage power and capacity • Long lifetime
Disadvantages	• Difficult waste management • Vulnerable to high temperatures	• High initial costs • Maintenance effort for pumps and membranes

Sources:
Toledo (2010), Schiffer (2007),
Sauer (2008), Bopp (2000),
Boyes (2011), Jossen (2007)

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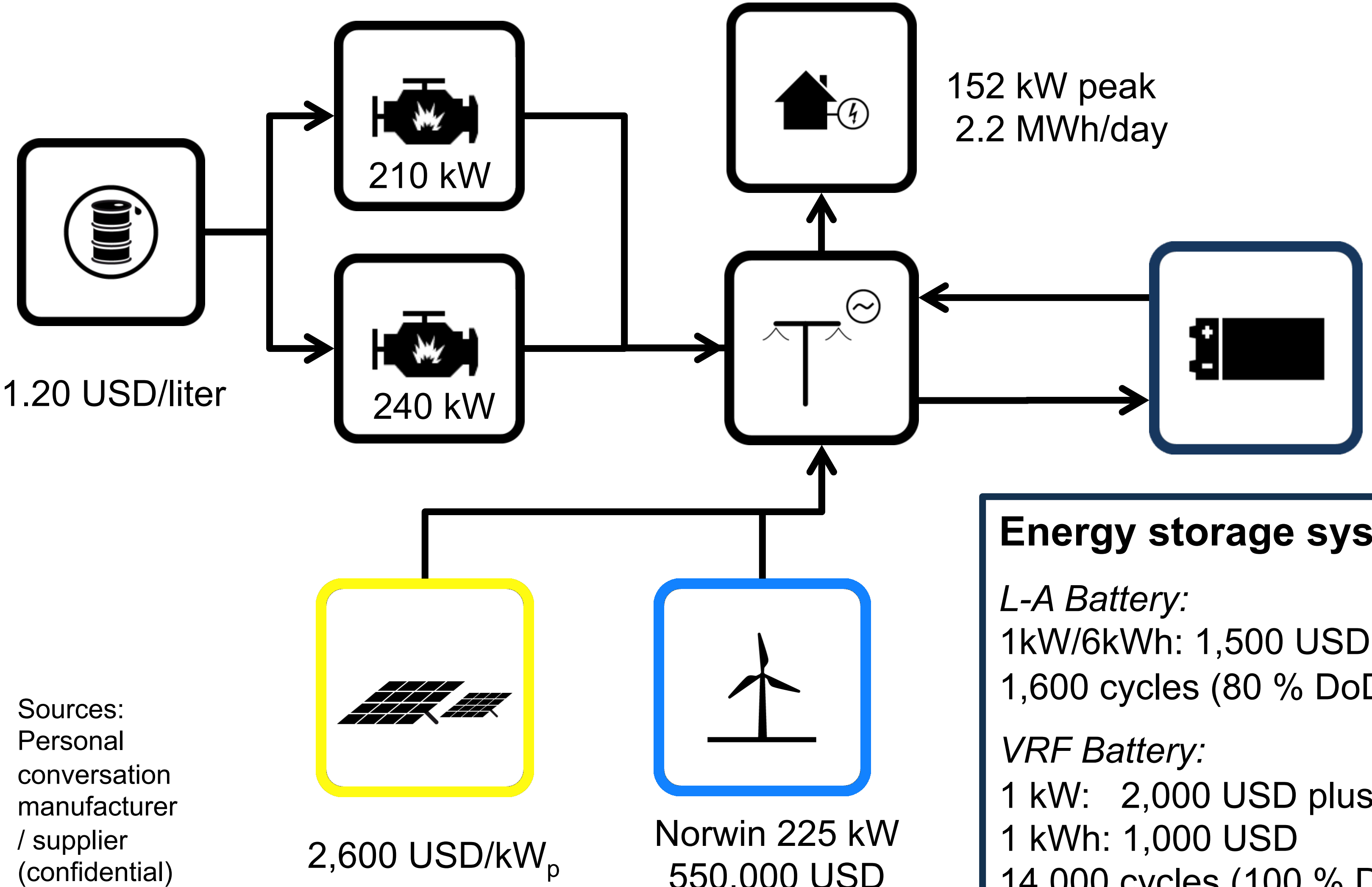
Energy supply system simulation: Input



Energy storage system:

L-A Battery:
1kW/6kWh: 1,500 USD
1,600 cycles (80 % DoD)

VRF Battery:
1 kW: 2,000 USD plus
1 kWh: 1,000 USD
14,000 cycles (100 % DoD)

Sources:
Personal conversation manufacturer / supplier (confidential)

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Optimization of energy supply system: Results

Optimized energy supply system
➔ 1 Wind turbine (225 kW)
➔ 140 kW_p photovoltaic
➔ 100 kW / 600 kWh **L/A Battery**

Name	LCOE	Capex	Diesel consumption	Renewable Fraction	CO_2-Emissions
Current system	0.53 US-$/kWh	0 USD	335,800 liter/yr	0 %	884,000 kg
Optimized system	0.29 US-$/kWh	1,100,000 USD	66,700 liter /yr	81 %	176,000 kg

Energy storage system
➔ Storage costs included into levelized cost of energy
➔ Storing renewable energy is partly more economical than diesel power generation
➔ **VRF Battery** not competitive at these initial costs

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Detailed analysis of storage costs

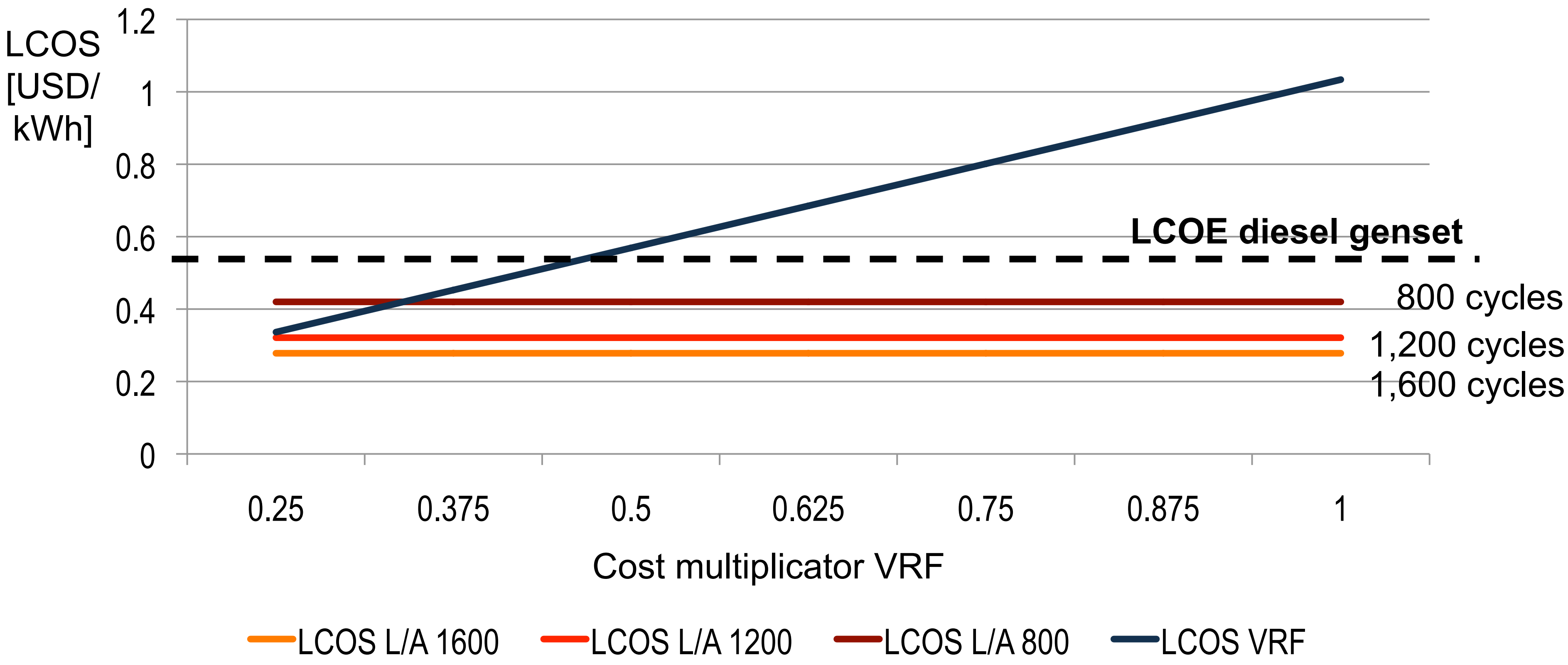
Levelized cost of storage (LCOS)

$$LCOS = \frac{capex * crf + opex}{E_{output}}$$

capex: Capital expenditures per battery
crf: Capital recovery factor
opex: Annual operation and maintenance expenditures per battery
E_{output}: Annual battery output (η*n*C*DoD)
C: Installed capacity
n: Annual full cycles (input energy divided by C*DoD)
DoD: Maximum depth of discharge
η: Roundtrip efficiency

Sources:
Lambert (2006),
Nair (2011)

Sensitivity analysis of storage costs



- Only significant cost reduction of VRF battery can make it competitive
- Reduction of lifecycles of L/A batteries not as crucial as change in initial costs of VRF batteries

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Conclusion

Energy storage system

- L/A more economical for small Caribbean island than redox flow at the moment
- Flow batteries only advantageous due to environmental reasons

Energy supply system

- Renewable energies combined with storage are already competitive compared to conventional systems on islands
    - Lower levelized cost of energy
    - Less CO2-emissions
- Many other islands with similar conditions
    - Same load profile
    - Excellent renewable resources

=> Enormous market potential!

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THANK YOU.

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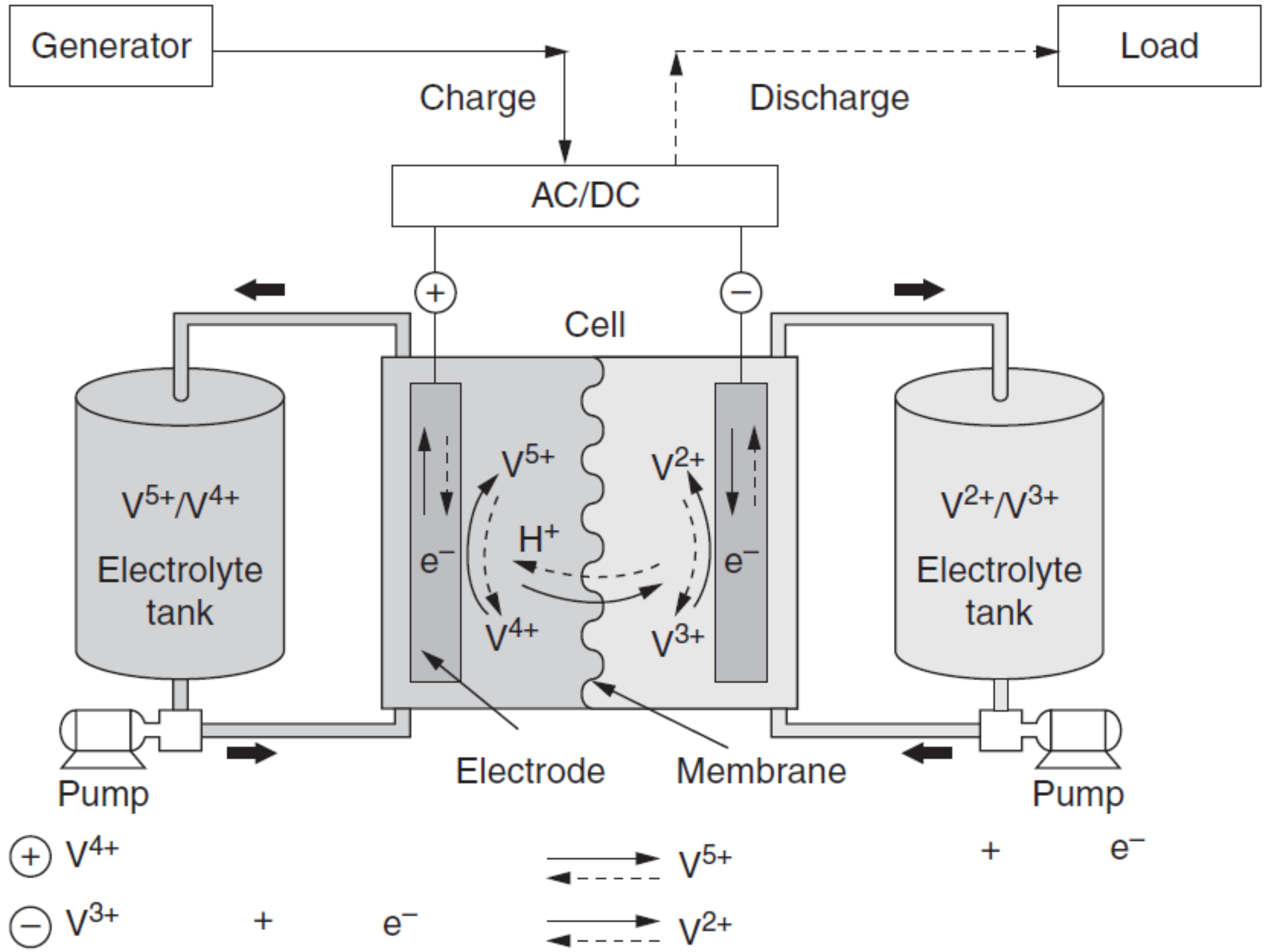

Sources:
Tokuda (2000)