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Smart Technology Markets in Intermittency-Friendly Energy Systems

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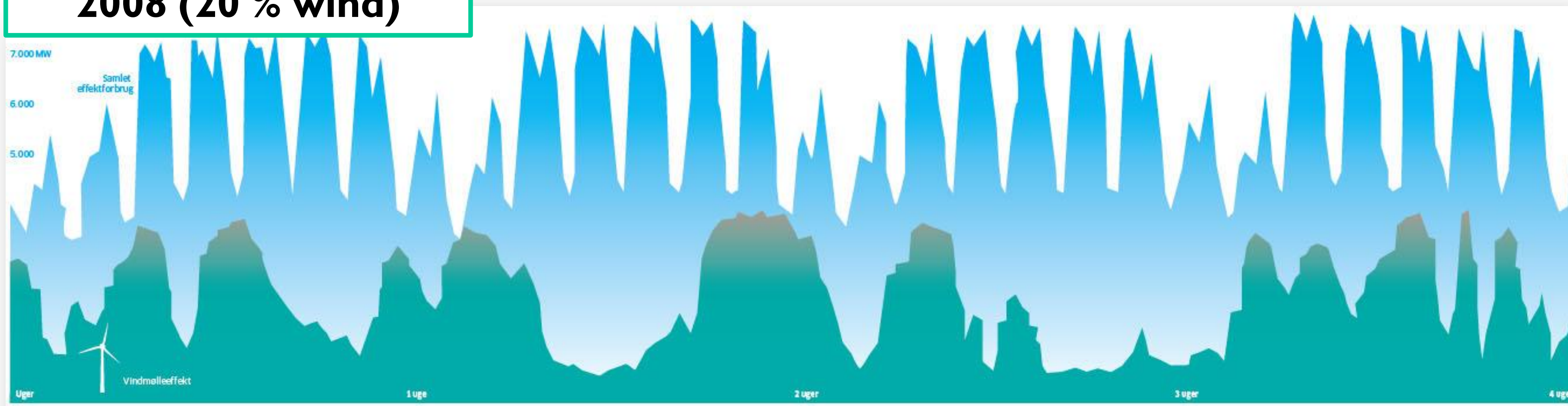
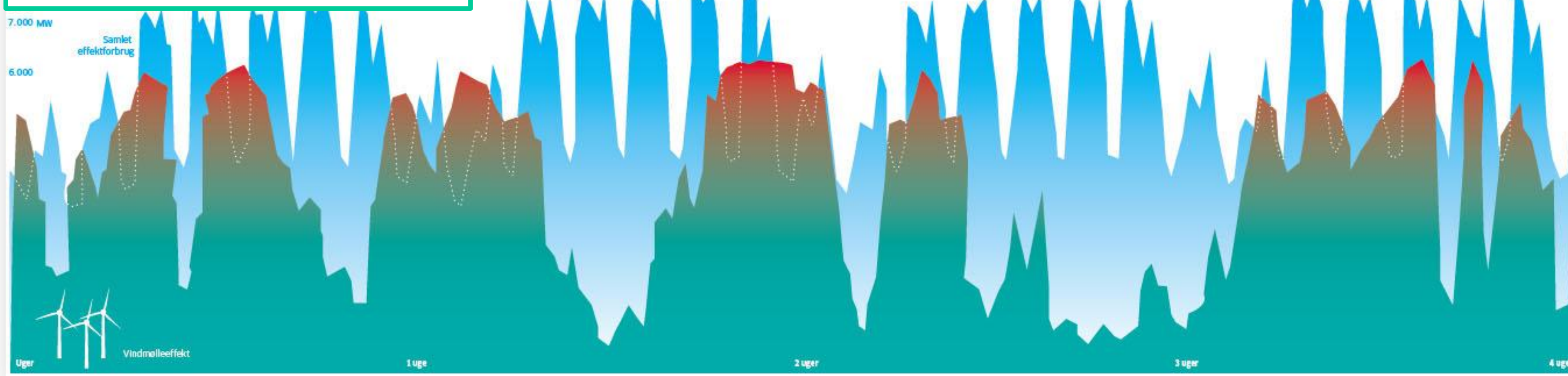
The Intermittency Challenge

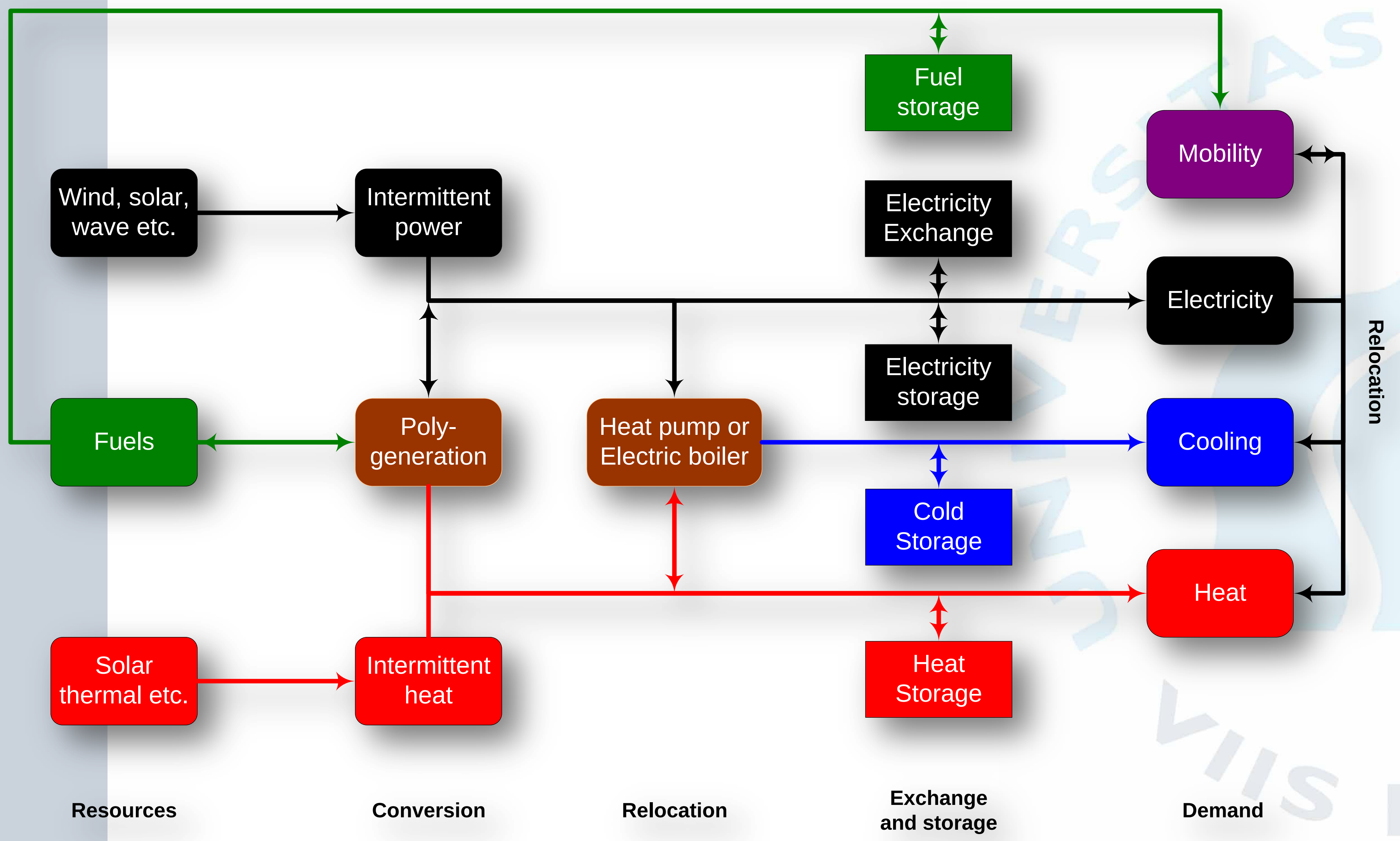
2008 (20 % wind)



2025 (50 % wind)

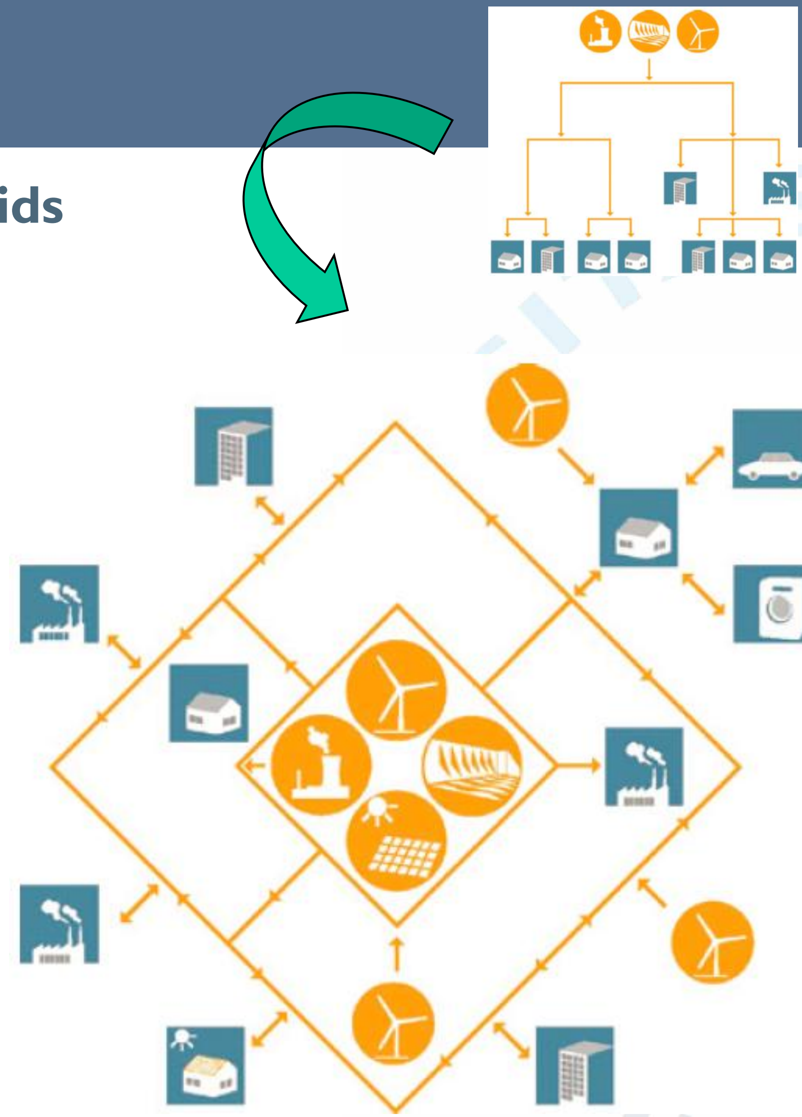


The Intermittency-Friendly Energy System



The rage is on about SmartGrids - but is the course sound?

- First academic reference to a SmartGrid in 1997 as a "Self-Managing And Reliable Transmission Grid" that would use ICT to conduct "an automated system of monitoring, control, and protection" (Vu et al., 1997).
- Recent literature tends to refer to the control and communication technology dimension of the SmartGrid. Notably (Katz et al., 2011), who proposes an "information-centric energy infrastructure" where pervasive information is suggested to be the key to the integration of intermittent resources.
- The "Smart Grid Dictionary" (Hertzog, 2011) defines SmartGrid as a "bi-directional electric and communication network that improves the reliability, security, and efficiency of the electric system for small to large-scale generation, transmission, distribution, and storage."



ABB, 2009

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SmartGrid focus makes a happy power sector – but is the power grid focus serving society and end-users effectively?

- According to a study prepared by Electronics.ca in March 2011, the value of the global market for SmartGrid enabling technologies reaches USD 23 billion in 2011.
- Projected to increase to USD 33 billion per year by 2016.
- In 2011, Pike Research projected that the market for SmartGrid investments in Europe alone may reach USD 80 billion by 2020.

- But market's for what? And for whom?

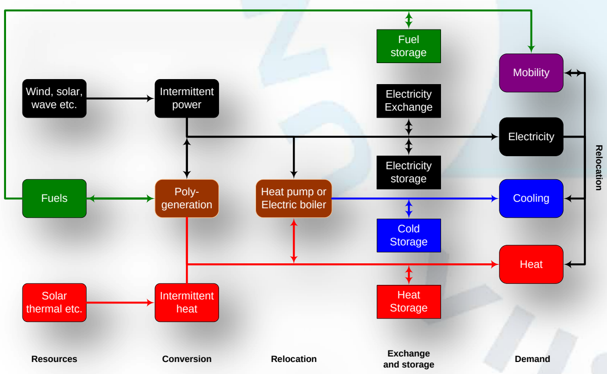
Market	Annual volume
Communication Tech.: Smart Meters, network infrastructure, etc.	$20B in 2015 (Cisco)
Energy (!) Storage: Advanced batteries, flow batteries, etc.	$1.3B in 2013 (TechNavio)
Power Electronics: MOSFETs, solid-state transformers, etc.	$3.1B in 2016 (Electronics.ca)
Security: Cyber security hardware services and software	$3.7B in 2015 (Pike Research)

"Ignore forecasts. Maximize optionality!"
Vinod Khosla June 26th 2011, Founder of Sun Microsystems
@ InnovationDenmark workshop at AOL

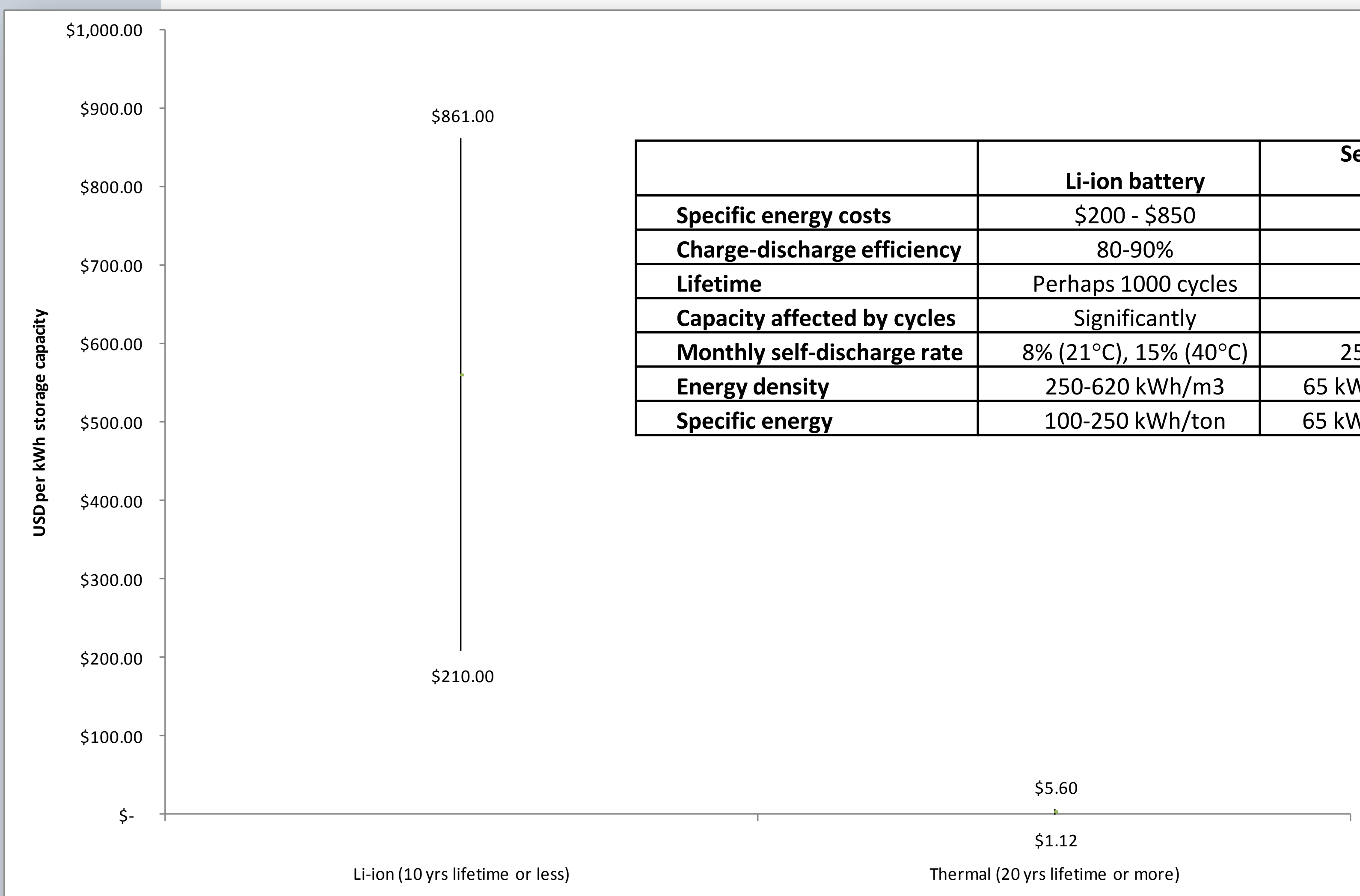
SmartGrid is an energy system design – not just a power grid

- Conventional SmartGrid perception reflects power sector thinking, ignores end-use servicers, and energy system features like co-generation
- A narrow SmartGrid understanding does not facilitate the best solutions

- An integrated system approach suggest that SmartGrid should be perceived as a distributed energy system that does not rely excessively on the capacity of the transmission and distribution grid
- A system's view on SmartGrid helps better to identify end-use oriented and cost-effective options, particularly options for thermal storage



Thermal storage is likely to be cheaper than any mechanical or electro-chemical storage

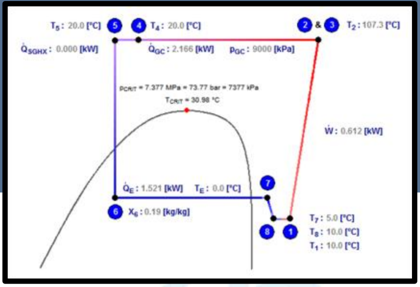


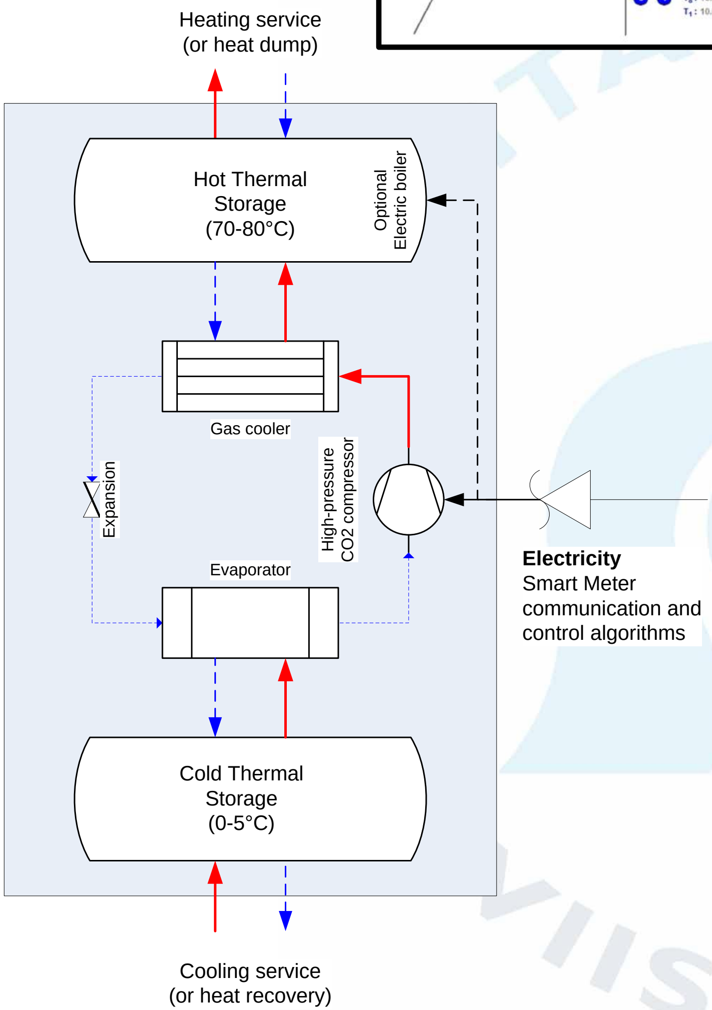
	Li-ion battery	Sensible water storage
Specific energy costs	$200 - $850	$1 - $5
Charge-discharge efficiency	80-90%	95%
Lifetime	Perhaps 1000 cycles	30 yrs +
Capacity affected by cycles	Significantly	No
Monthly self-discharge rate	8% (21°C), 15% (40°C)	25% (1000 m3)
Energy density	250-620 kWh/m3	65 kWh/m3 (dT=50°C)
Specific energy	100-250 kWh/ton	65 kWh/ton (dT=50°C)

Specific investment costs (USD/kWh) for li-on battery data versus sensible water thermal storage. Li-on data: Delucchi, M.A., Jacobson, M.Z., 2011. Thermal storage data: Author.

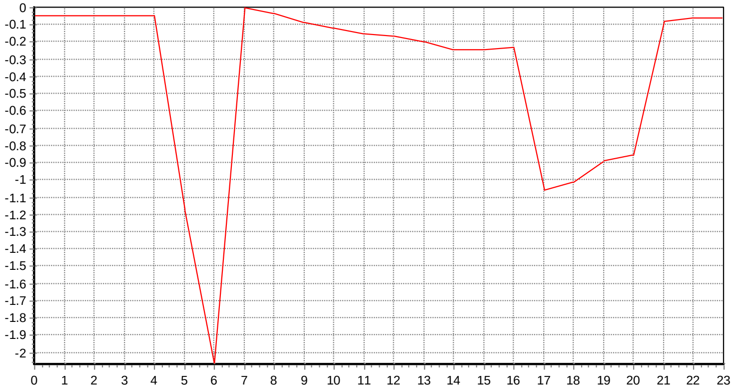
The Thermal Battery

- A SmartGrid technology intended to enter into distributed energy supply where both cold and hot thermal energy services are required:
  - *e.g. households replacing central A/C and hot water heaters (both gas and electric)*
  - *distributed cogeneration/trigeneration*
- An electrical high-pressure compression heat pump (or theoretically a thermoelectric heat pump) that provides useful heating and cooling services simultaneously.
- Double thermal storage system featuring both hot and cold thermal storage allowing for operational flexibility and intermittency-friendly operation (system perspective)

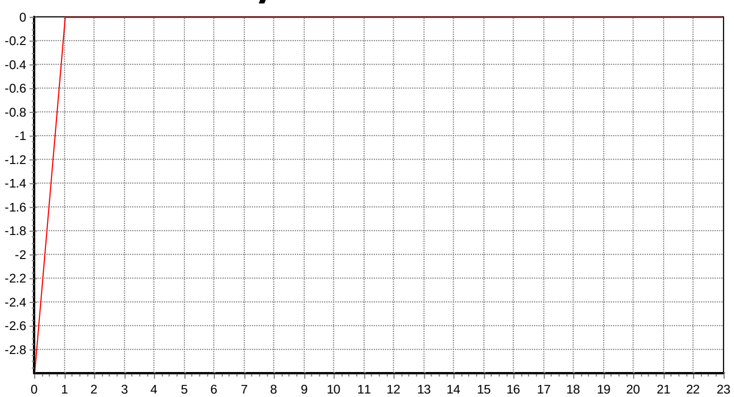




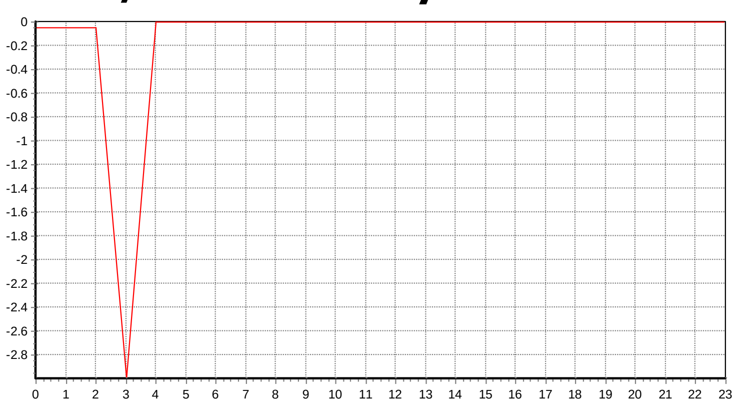
Conventional



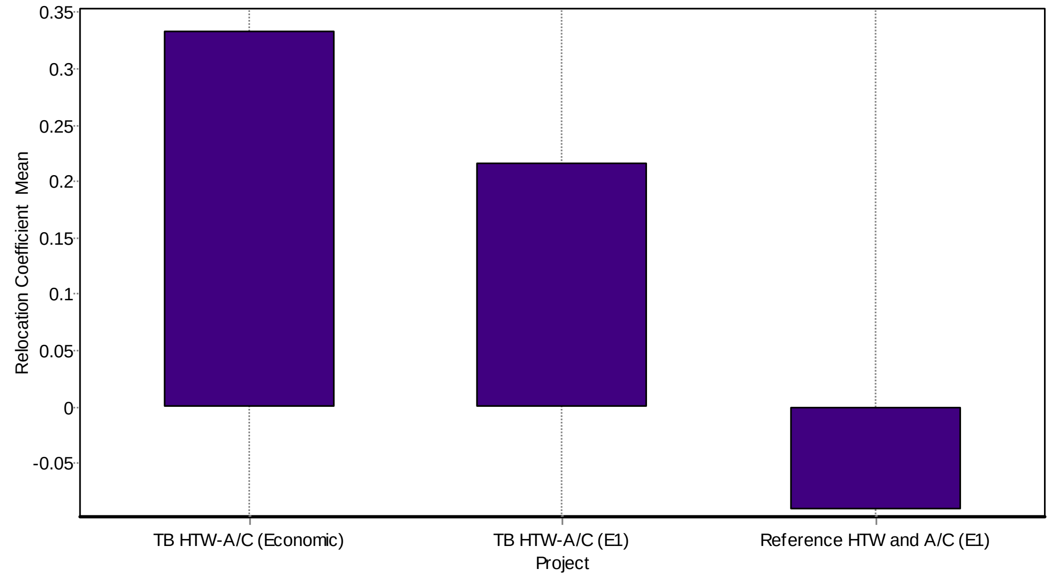
TB w/ PG&E E1-tariff



TB w/ real-time day-ahead tariffs



Intermittency-friendliness Rc



- The conventional system meets demands, but is not sensitive to costs, and has no storage (and no need for)
- Using existing tariffs, the Thermal Battery meets demands using storage, but is not sensitive to real costs
- Using real-time day-ahead tariffs, the Thermal Battery meets demand using storage, and is sensitive to real costs

- The net electricity exchange (consumption) with the electricity identifies the intermittency-friendliness

- Conventional has negative intermittency-friendliness Rc
- Thermal battery with existing tariffs improves Rc
- Thermal battery with real-time tariffs has the highest Rc

Conclusion: Toward Smart Technology Markets

- SmartGrid goes beyond power grid and communication technology (more *energy*, less *grid*)
- A system's view on SmartGrid indicate a great potential for new intermittency-friendly solutions in end-use and distributed generation
- If costs are important (sic) – we should see a breakthrough for pervasive thermal storage
- If utilities are serious about the SmartGrid objectives – real-time day-ahead prices should be the default option for Smart Meter programs
- Policy makers and utilities must widen options for building *smart energy infrastructure* – easing the addiction to power grids and gas pipelines