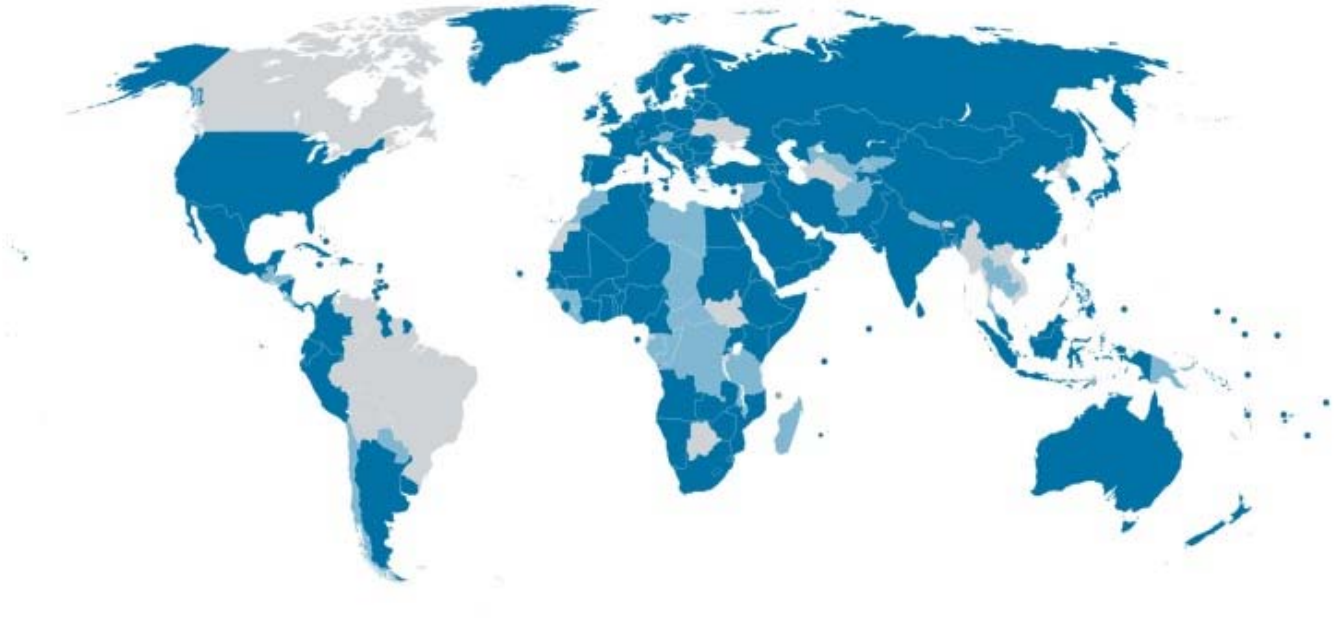
INTERNATIONAL RENEWABLE ENERGY AGENCY

Electricity storage for island transitions: A Strategic Nice?

IEA EGRD Island Energy – Status and Perspectives
5 October 2015

International Renewable Energy Agency

The Voice, Advisory Resource and Knowledge Hub for 170 Governments



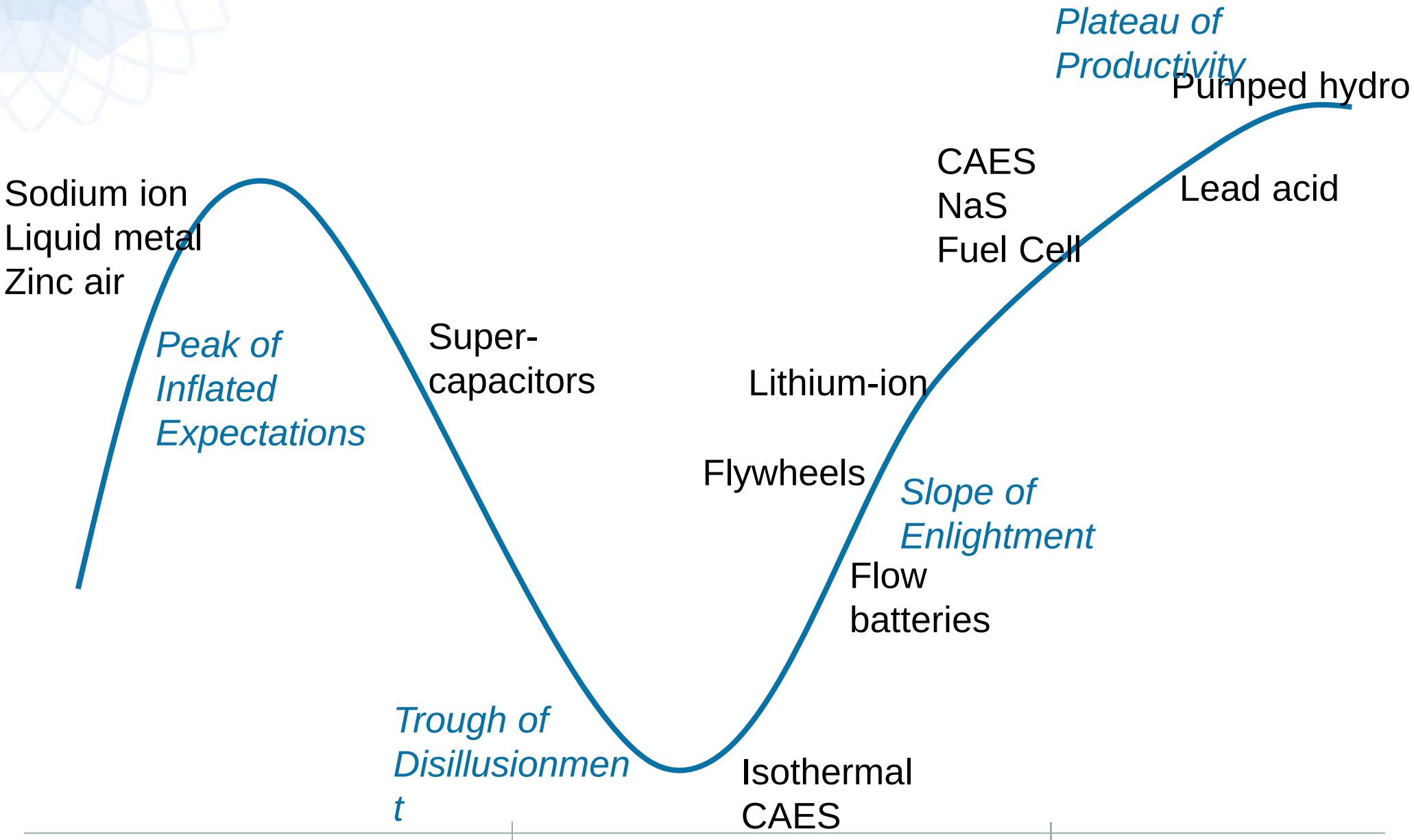
Renewable energy can:

- Meet our goals for ***secure***, ***reliable*** and ***sustainable*** energy
- Provide ***electricity access*** to 1.3 billion people
- Promote ***economic development***
- At an ***affordable cost***

Electricity storage technologies

Principle	Subcategory	Technology
Mechanical		Pumped hydro Compressed air (CAES) Flywheels
Chemical		Hydrogen
Electro-chemical	Conventional	(Advanced) Lead acid Nickel Cadmium (NiCad) Lithium ion (Li-ion)
	High temperature	Sodium Sulphur (NaS) / Nickel / Aluminiumchloride
	Flow batteries	Vanadium Redox (VRB) Zinc Bromine (ZnBr)
	Metal air	Zinc / Aluminium / Lithium / Iron
Electric field		Supercapacitors
Magnetic		Superconducting magnetic coils

Curve of Inflated Expectations

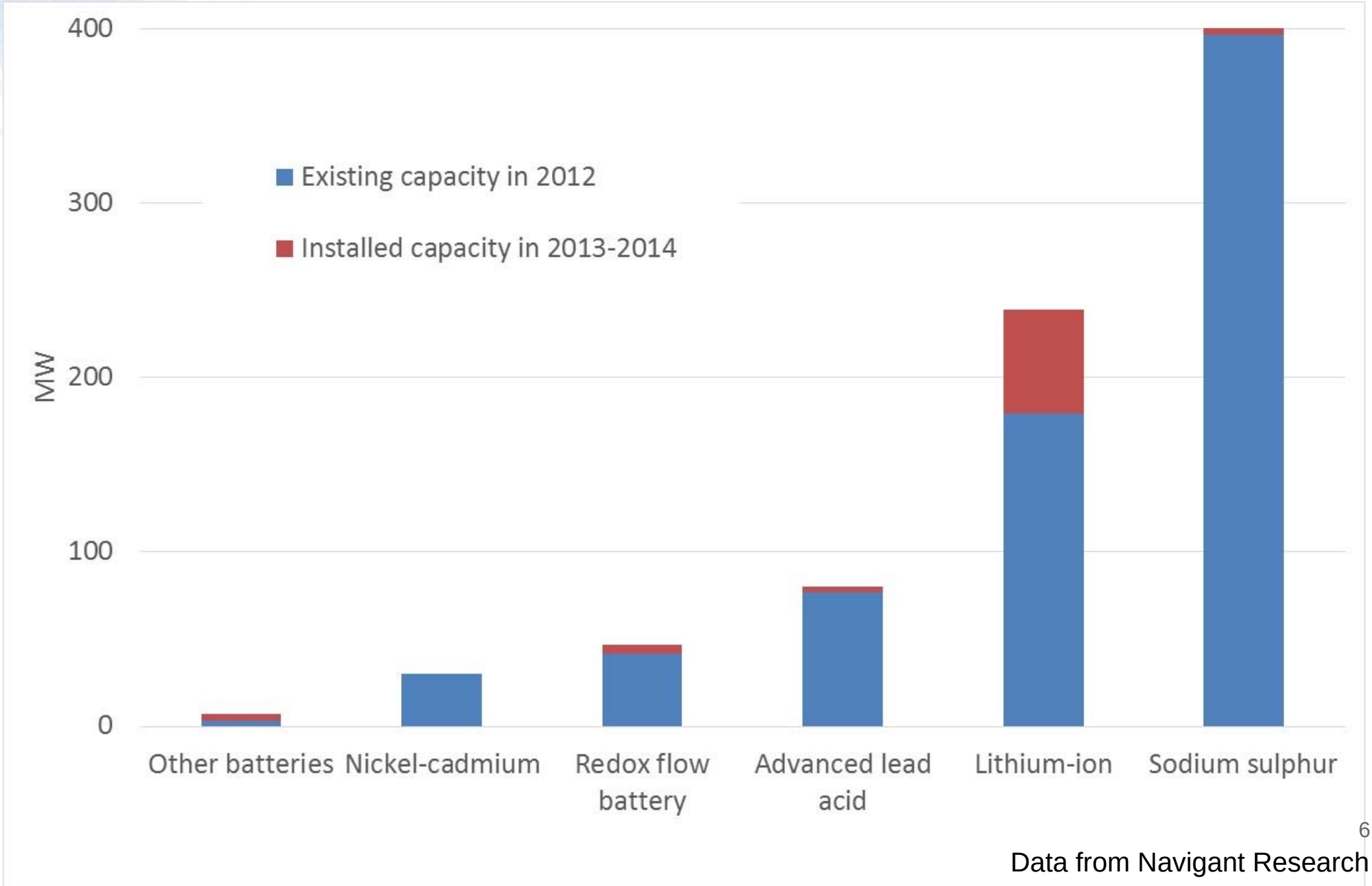


Diversity within technologies

	Cathode	Anode	Electrolyte	Energy density	Cycle life	2014 price per kWh	Prominent manufacturers
Lithium iron phosphate	LFP	Graphite	Lithium carbonate	85-105 Wh/kg	200-2000	USD550-USD850	A123 Systems, BYD, Amperex, Lishen
Lithium manganese spinel	LMO	Graphite	Lithium carbonate	140-180 Wh/kg	800-2000	USD450-USD700	LG Chem, AESC, Samsung SDI
Lithium titanate	LMO	LTO	Lithium carbonate	80-95 Wh/kg	2000-25000	USD900-USD2,200	ATL, Toshiba, Leclanché, Microvast
Lithium cobalt oxide	LCO	Graphite	Lithium polymer	140-200 Wh/kg	300-800	USD250-USD500	Samsung SDI, BYD, LG Chem, Panasonic, ATL, Lishen
Lithium nickel cobalt aluminum	NCA	Graphite	Lithium carbonate	120-160 Wh/kg	800-5000	USD240-USD380	Panasonic, Samsung SDI
Lithium nickel manganese cobalt	NMC	Graphite, silicon	Lithium carbonate	120-140 Wh/kg	800-2000	USD550-USD750	Johnson Controls, Saft

Data from Navigant Research

Deployment levels



Data from Navigant Research

Electricity storage costs

2012 data

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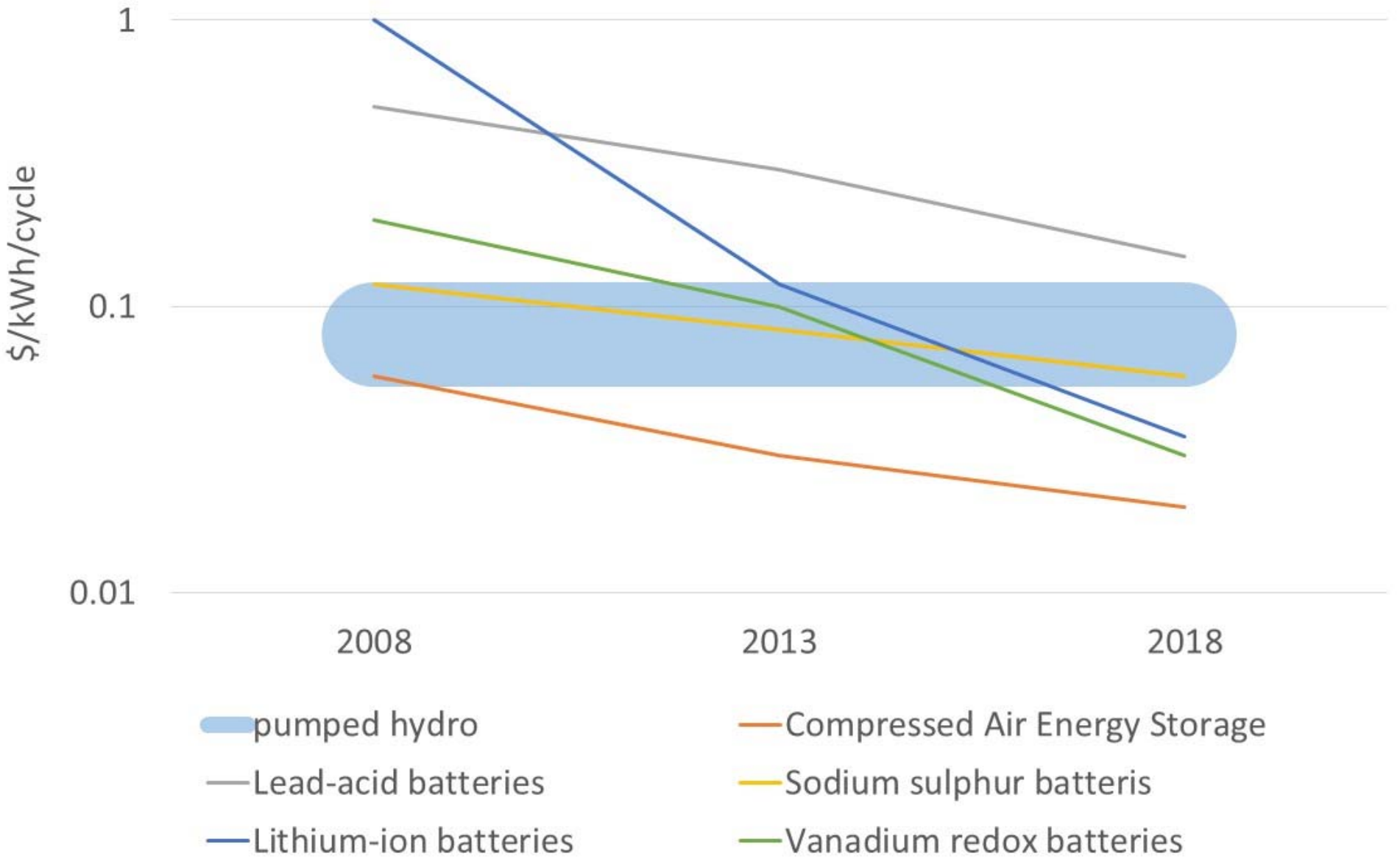
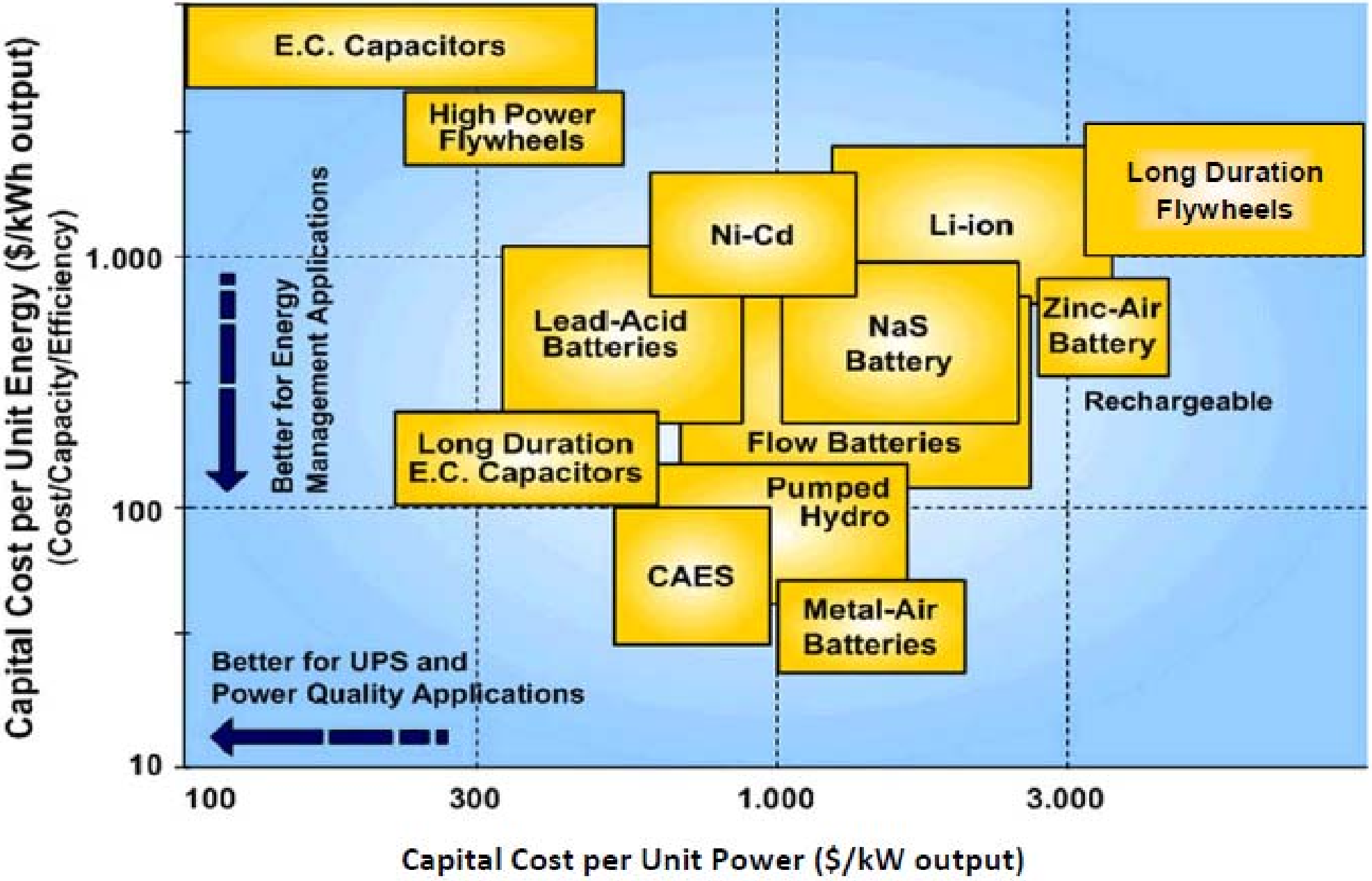
battery technology	lead-acid	li-ion	li-ion
battery power (kW)	5	5	5
battery capacity (kWh)	14.4	5.5	8
Depth of Discharge	50%	80%	100%
usable capacity (kWh)	7.2	4.4	8
cycles	2800	3000	6000
price (EUR)	8900	7500	18900
EUR/kW	1780	1500	3780
EUR/kWh	618	1364	2363
EUR/useable kWh	1236	1705	2363
EUR/useable kWh/cycle	0.44	0.57	0.39

Outlook – costs



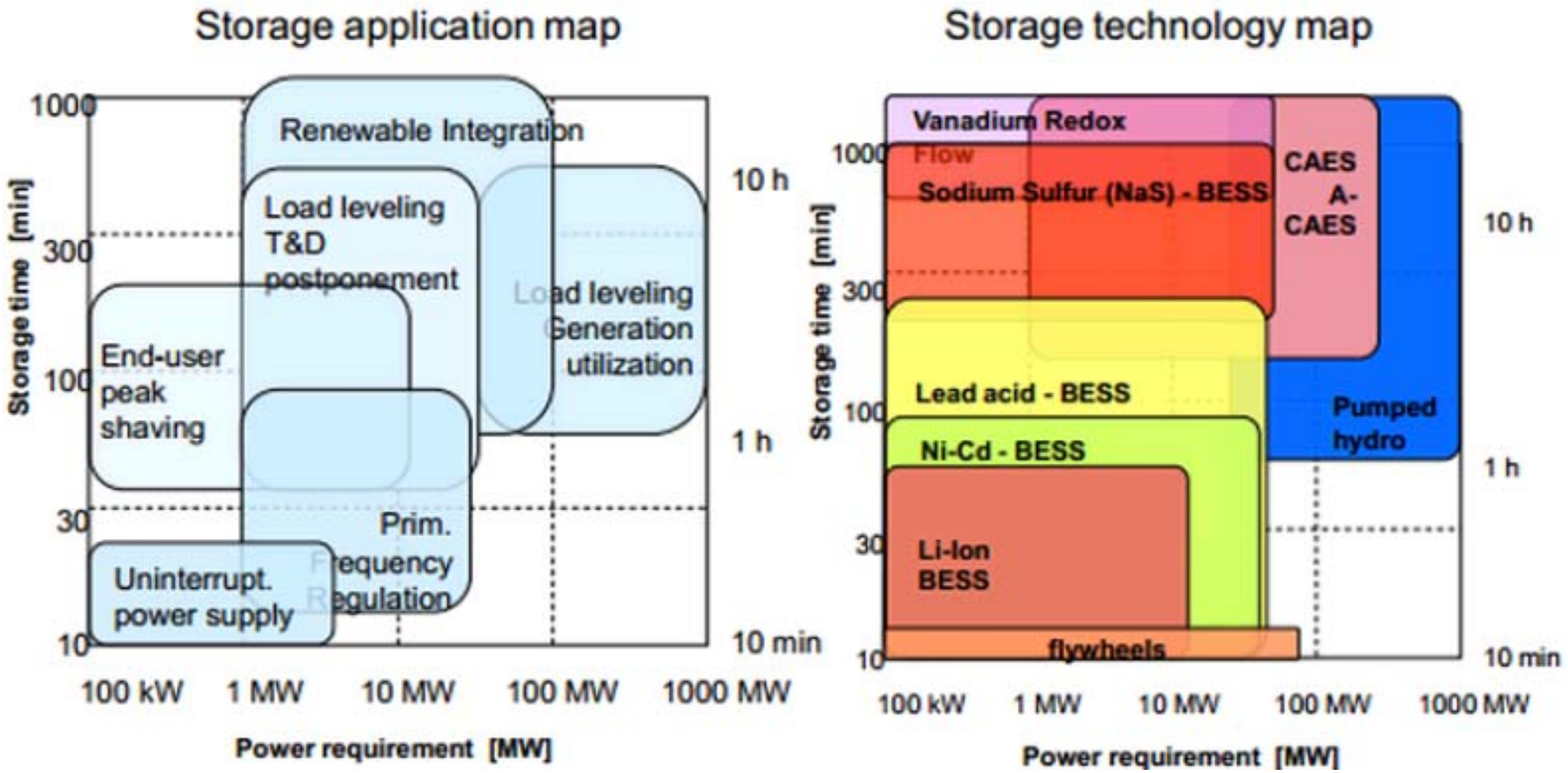
Comparing storage options



Electricity storage to support RE integration in islands

Service	Operational Issue	Time Frame
Load shifting	Load following / Increase RE use	Hours
Operational reserves	Adequate reserve allocation	Minutes to 1 hour
Regulation	Adequate regulation capacity	Minutes
Primary Control	Rapid frequency response i.e. adequate governor action	Seconds to minutes
RE Output Power Smoothing / Ramp Management	Rapid frequency response and regulation requirements / Power quality	Milliseconds to minutes

Storage functions in mini-grids

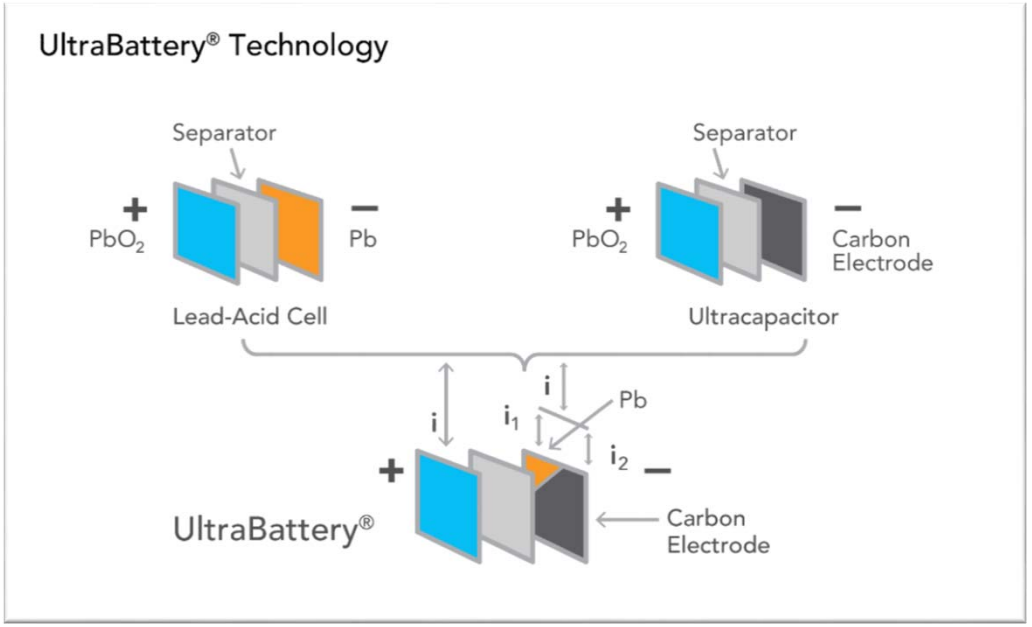


Source: Carnegie *et al.* 2013

Hybrid options

Braderup: 2 MWh li-ion battery +
1 Mwh vanadium redox flow battery

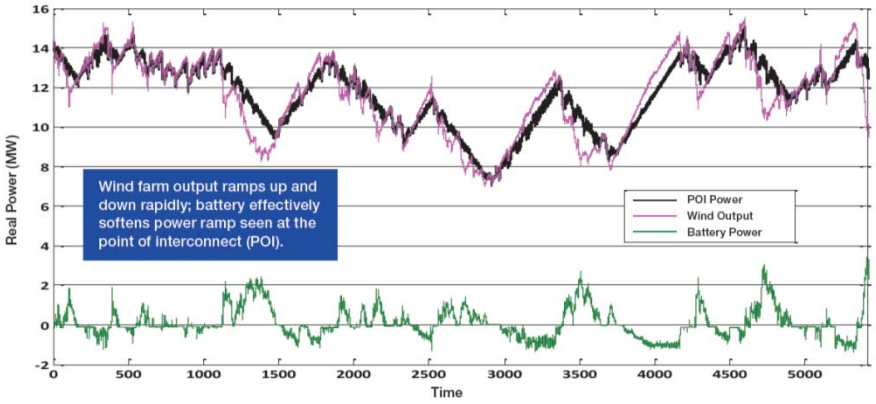
Aachen: 5 MW hybrid facility with li-ion and lead-acid



Electricity storage to support RE integration in islands a few examples…

Auwahi Wind Farm, Maui Hawaii

- Load in Maui between ~ 200 and 100 MW
- 21 MW installed in Auwahi Wind farm (2012)
- 11 MW / 4,4 MWh Battery system for ramp rate management (power smoothing) (2012)



Source: NEC

Kodiak Island Alaska

- Load between ~ 27 and 11 MW
- 9 MW of Wind Generation Capacity
- 3 MW / 750 kWh advanced lead acid battery storage for frequency response and regulation (2012)
- 1 MW flywheel power smoothing / extended life of batteries (2015)

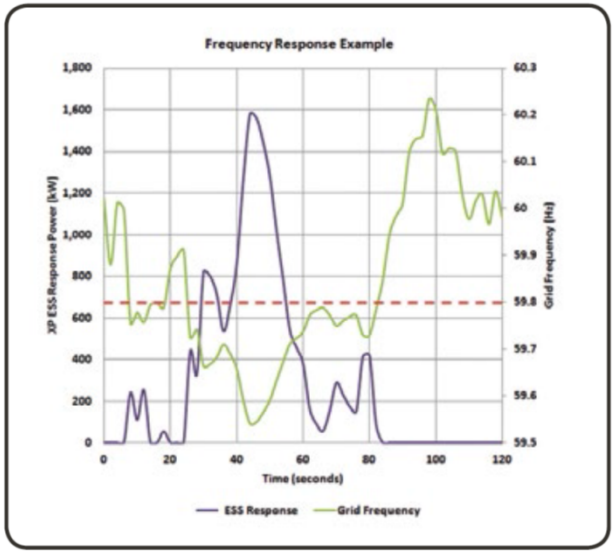


Figure 1: ESS discharges (purple line) when grid frequency (green line) drops below 59.8 Hz (red line)

Source: Younicos

Electricity storage to support RE integration in islands a few examples…

Gorona del Viento, El Hierro, Spain

- Hydroeolic project
- 11,5 MW Wind Farm
- 11,3 MW hydro power
- 6 MW Pumping station
- 200.000 m3 total water storage capacity
- 100% RE instantaneous penetration possib

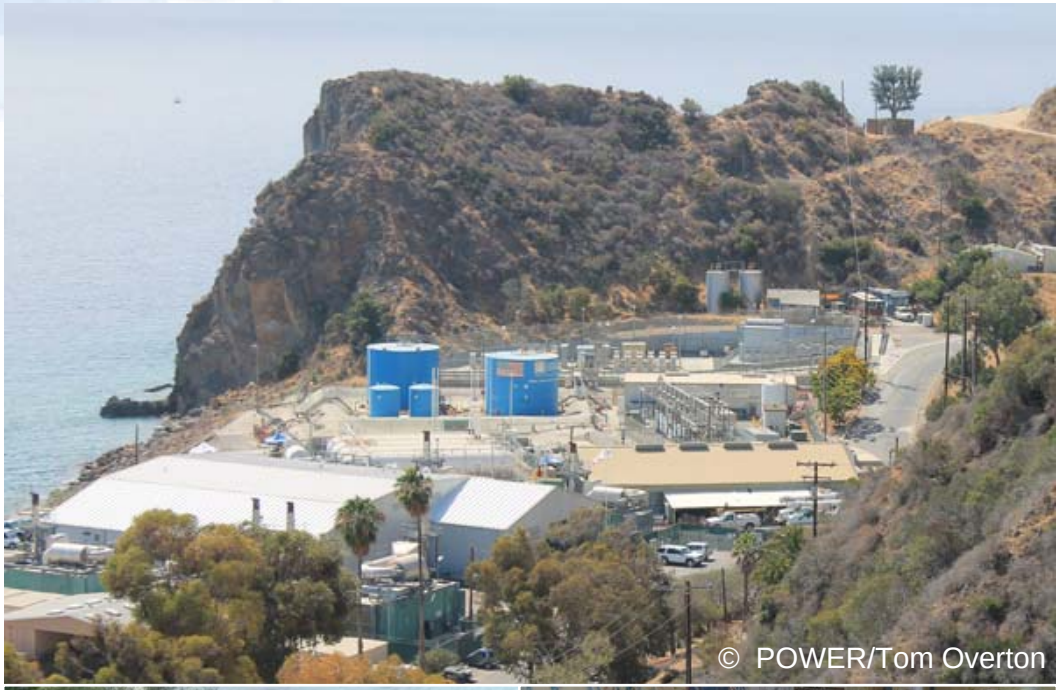
Source: AFP, El Mundo Spain, http://www.elmundo.es/ciencia/2015/08/12/55ca2c7e22601d600a8b458d.html

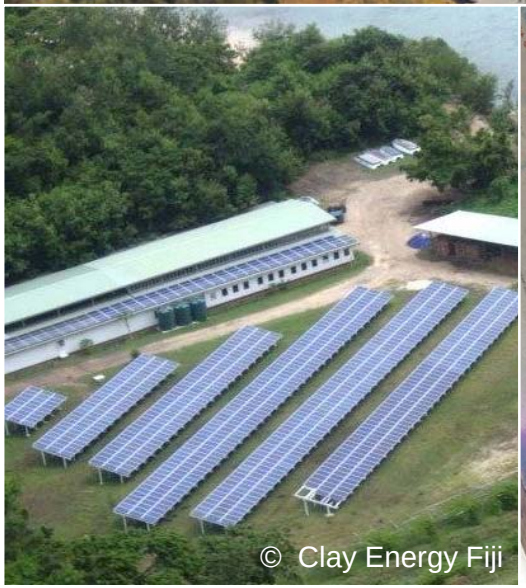
Tokelau, Pacific Islands

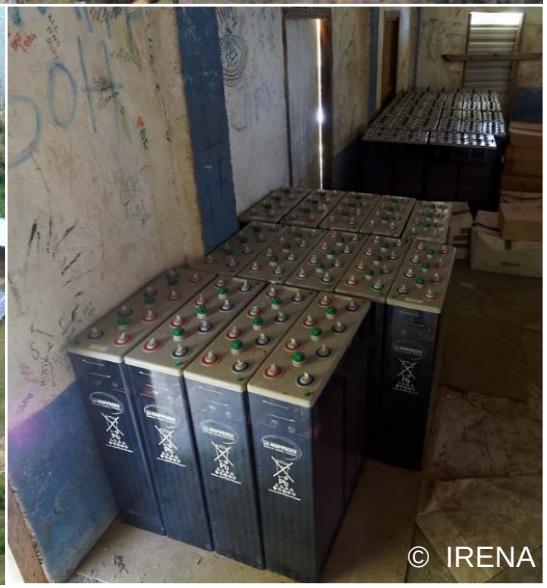
- Objective: achieving 100 % RE supply
- Peak load ~ 0,2 MW
- Daily demand ~ 2,36 MWh
- 3 PV systems total ~ 1 MW
- Storage capacity (nominal) ~ 8 MWh

Source: New Zealand, MFAT, 2013

Storage in islands and remote areas







- **Facilitate financing**
- **Create local value chains**
- **Develop a global database with practical example**
- **Guide policy makers to the required tools**

In conclusion…

- Electricity storage technologies are rapidly developing, and reducing in costs
- R&D should broaden
- Address inflated expectations
- System considerations and local value chain are more important than individual characteristics
- Hybrid functions can be interesting options for providing multiple grid functions

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Island analysis