Energy Storage Options for the Electricity Network

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27 June 2018

Why Now?

- Energy Storage has always been a desired option. Pumped hydro plants represent over 95% of existing energy storage worldwide, however:
    - Round trip efficiencies around 70%
    - Environmental issues
    - Capital intensive – costs depend on location
    - Centralized storage not dispersed
    - LIMITED POTENTIAL FOR GROWTH
- Compressed air energy storage efficiencies around 50%
- Need to introduce more renewables in the mix implies need for new storage options to accommodate this. Renewables have lower cost and this may economically justify the use of storage.
- Progressive Electrification (electric vehicles, heat pumps, etc.) implies changes in load profiles and need for flexibility
- Advancements in electrochemical storage technologies are promising low cost solutions

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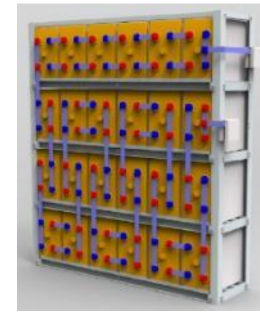
Enabling Storage Technologies

- Lead Acid – Lead Carbon
  - Mature technology – no great potential for performance improvement and drop in cost
  - Environmental restrictions
  - Cost depends on cost of Lead
  - Heavy batteries cannot be used for electric vehicles
- NaS
  - High cost
  - Very few companies produce it (NGK)
  - High temperature – complicated system
- Flow batteries
  - High cost
  - Not mature technology
  - Cannot be used for mobility
- Li Technologies
  - Use in mobile phones and hybrid vehicles resulted in technology advancement and cost drop
  - Today, kWh cost of battery is 3.5 times of Lead acid but more than 3,5 times the cycling
  - Low weight battery - can be used for electric vehicles



Cost of storage –rough calculations

- Lead Acid Batteries
  - (OPzV)
    - 100 €/kWh
    - 1200 cycles
    - 80% efficiency

    100 €/kWh / 1200 + 20% of the cost of electricity =

    = **100 €/MWh**
  - (Lead Carbon)
    - 150 €/kWh
    - 3000 cycles
    - 80% efficiency

    150 €/kWh / 3000 + 20% of the cost of electricity =

    = **67 €/MWh**

- Li Batteries
  - (LFP or NMC)
    - 250 €/kWh
    - 6000 cycles
    - 90% efficiency

    250 €/kWh / 6000 + 10% of the cost of electricity =

    = **50 €/MWh**
  - (near future)
    - 150 €/kWh
    - 8000 cycles
    - 90% efficiency

    150 €/kWh / 8000 + 10% of the cost of electricity =

    = **27 €/MWh**

Usages of Energy Storage / Classification

Primary Frequency regulation

- Helps electricity grid cope with quick changes in load / power generation
- Battery storage can be used in conjunction with power plants and improve their response characteristics. Power can be stored/released within few hundreds of milliseconds into the grid
- Real value for small power systems (e.g. island grids)
- Allows integration of more renewables when grid stability issues dictate to switch-off renewables
- Storage capacity can be from few minutes to a couple of hours
- Potential applications in SE Europe: Greek islands

Grid upgrade deferral

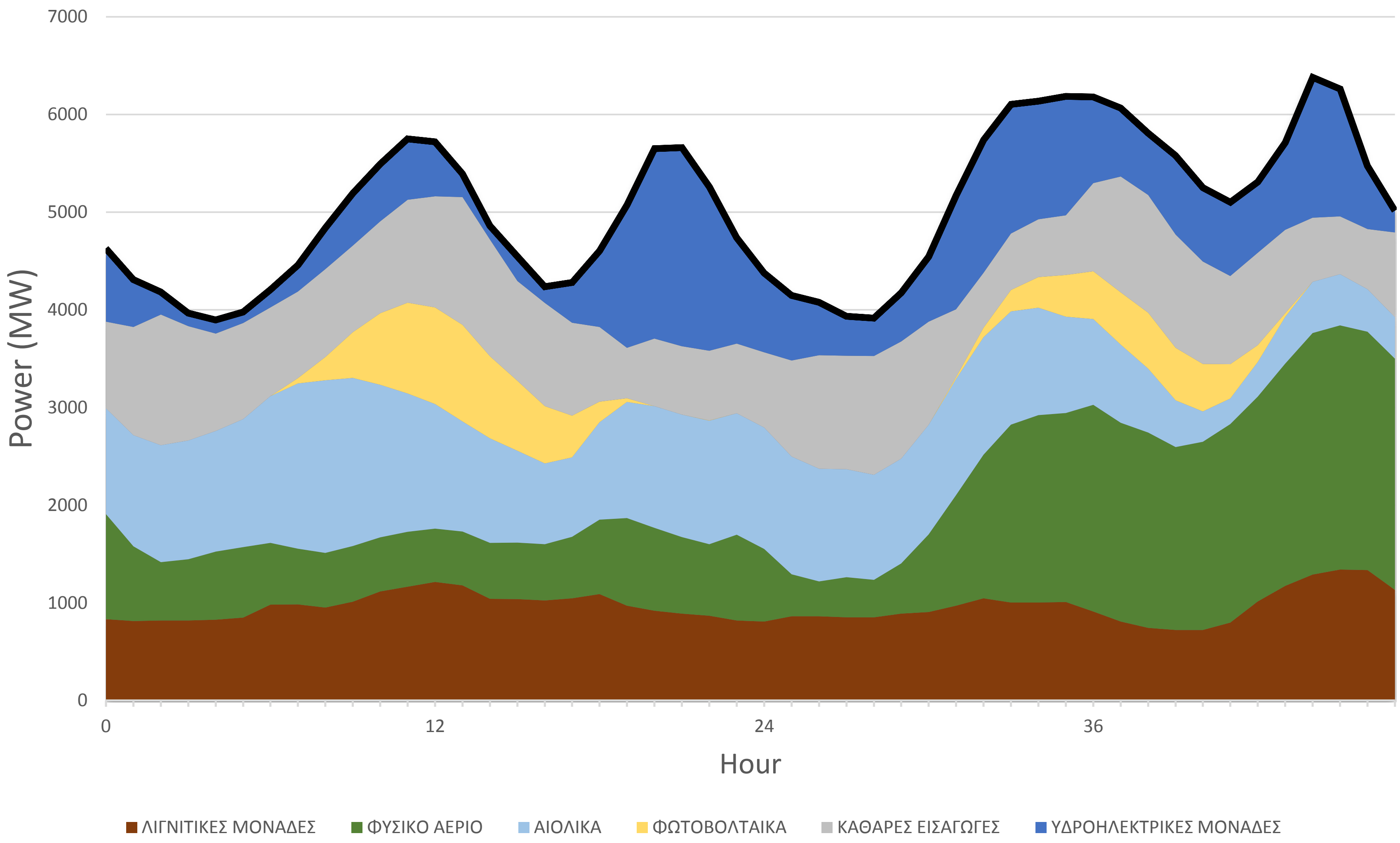
Storage elements help shave the peak loads in transmission / distribution lines (congestion management)

Applicability

- Countries with old distribution networks who need upgrade
- Countries with “weak” transmission and distribution systems (mainly in Africa)

Peak Load Shifting to allow for more renewables

Generation mix today



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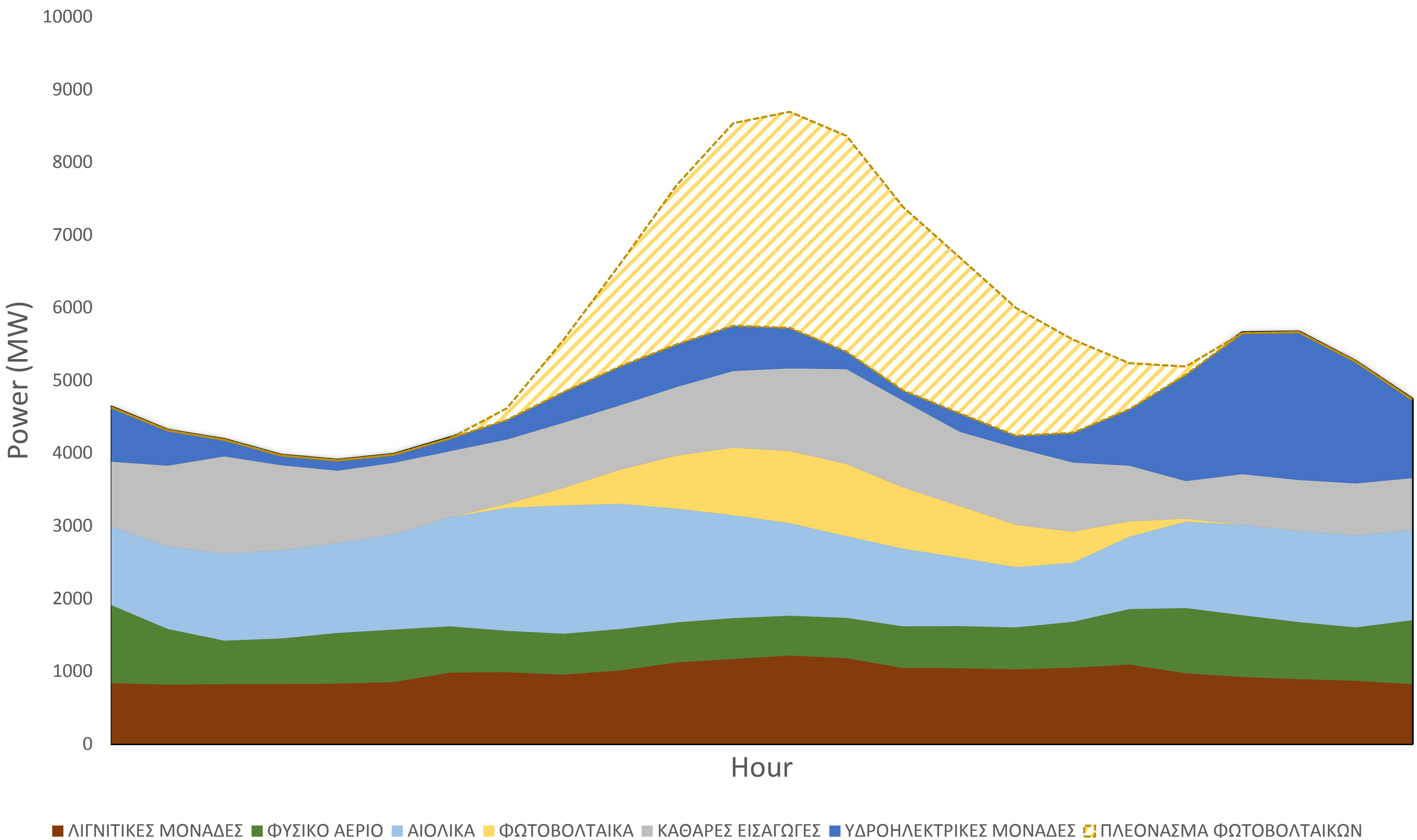
More PV implies need for storage



“Behind the Meter” storage

House and small business systems utilizing net-metering

- Electricity is stored and consumed at a later time so consumers do not have to feed the grid
- Economic viability depends on net metering regulations and price rates
- Germany is the leading country (subsidy)
  - 20,000 residential energy storage systems installed in 2016 and 30,000 in 2017.
  - 85,000 energy storage systems in operation.
  - Market size is 490 M€
  - Installed power expected to rise to 385 MW by end of 2018

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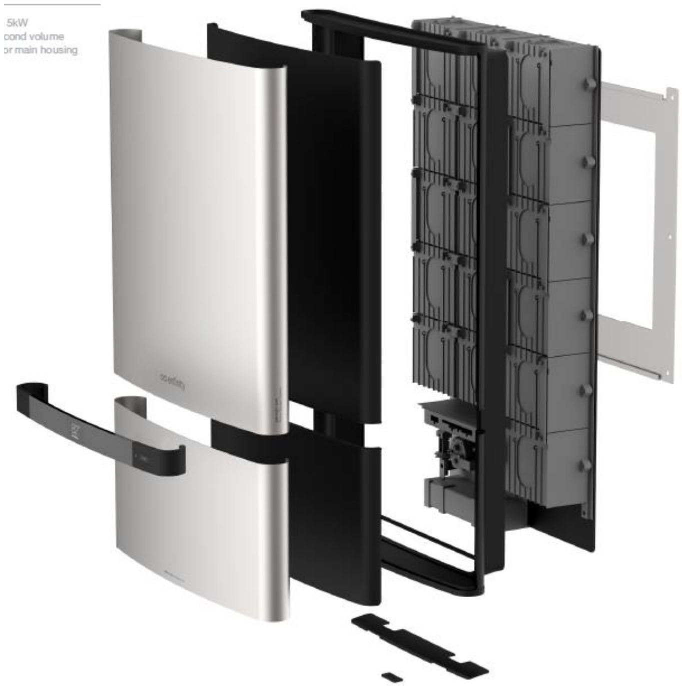
Batteries as household appliances



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Batteries as household appliances

Storage systems for small businesses

Towards grid defection?

Low cost mass housing in Philippines

- 1 kW PV
- 3+3 kWh Li storage
- Connection to the grid

- **NO net-metering**

  Homeowners are not allowed to sell to the grid. They use their own electricity and they buy from the grid in rare cases.

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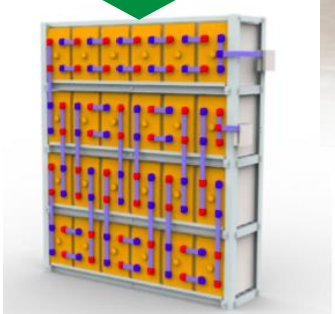
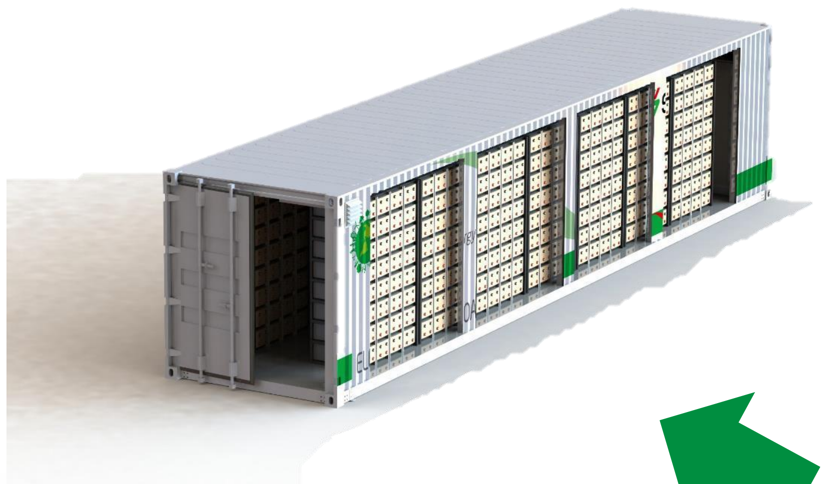
Containerized Systems

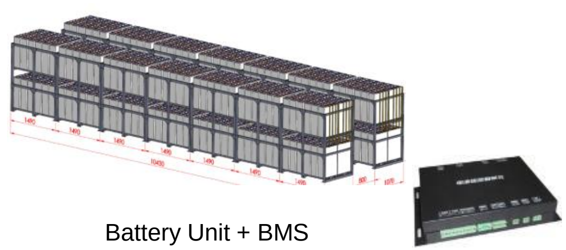
Battery



Battery Unit + BMU



- ✓ Air Conditioner
- ✓ Thermal Insulation Systems
- ✓ Fire-Extinguishing System
- ✓ Alarm System
- ✓ Energy Management System



Battery Unit + BMS

+

Bidirectional PCS

Storage plants at the substation level

USA

- Largest world market – Over 650 MW
- Landmark projects
  - 100 MWh in SCE territory
  - 10 MW / 40 MWh if Florida

Korea

- 500-megawatt frequency regulation energy storage procurement plan (KEPCO)
- Already installed:
  - 24-MW (9-MWh) – Lithium NMC
  - 16-MW (6-MWh)
  - 16-MW (50-MWh) – Lithium Titanate Oxide

China

- Largest battery storage plant under construction in Dalian China (expected end of 2019) is 200 MW / 800 MWh – Rongke Redox flow battery
- 300 MW under construction

Australia

- 129 MWH coupled with wind farm
- Planed 250 MW "virtual plant" (50.000 homes)

Japan

- Large number of subsidies projects to support the government goal of Japan controlling 50% of the global market share by 2020

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World markets

Electricity storage is needed to:

- Improve service to customers connected to bad grids (market needs TODAY)
  - Batteries and coupled with photovoltaics to replace diesel generation in households and businesses
  - Distribution network storage systems to help extend electrification hours in areas connected to congested transmission grids
  - Photovoltaic battery systems (at household or community level) to provide daytime electricity to diesel powered island grids.
- Implement mini-grids in non-electrified areas for:
  - Telecom and internet services
  - Village electrification

The mode of electrification in many areas will soon switch from diesel to photovoltaic – battery.

Big mini-grid demos in China

- Zhangbei

  60 MWh lithium and 12 MWh lead-acid battery, it is the largest wind + solar + storage demonstration project in China.

- Qinghai

  9 MWp PV, 3 MWh lithium battery and 28 MWh lead-acid battery

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Electric Vehicles

- The biggest controllable load ever to be introduced in the grid
- Questionable is feasible to utilize EVs to retrieve energy
- Second life batteries (used) could be an option, depending on new battery cost and battery management costs