Role of Energy Storage in Future Energy Systems

Christian Breyer
Tekes Seminar on Energy Storage
Helsinki, 25.4.2016
Agenda

- Recent Storage News
- Storage for the Finnish Energy System
- Storage for the Global Energy System
- Sector Coupling Results
- Conclusions
Very high EV Dynamics

LG Chem looks to lift car battery sales 70%

KENTARO OGURA, Nikkei staff writer

SEOUL -- South Korea’s LG Chem expects its car battery business to reap 1.2 trillion won ($1 billion) in sales in 2016, a roughly 70% jump driven by expanded supplies to U.S., European and Chinese carmakers.

Sales will likely surpass the break-even point this year, allowing the segment to post profit for a full fiscal year by 2017, the company said Monday.

Tesla Model 3: most successful product launch in industrial history, worth 14 bnUSD

Electrek

Tesla Vice President says Model 3 reservations are ‘approaching 400,000’, real success will be delivery

Fred Lambert - 1 week ago @FredLambert
Solar PV Dynamics

Mehr als die Hälfte der neuen Photovoltaikanlagen werden mit Energiespeichern ausgestattet

Im Zuge der fünften Auflage des Endkunden-Monitors des Bonner Marktforschungsinstituts EuPD Research zeigt sich, dass mehr als die Hälfte der in 2014 und 2015 installierten Photovoltaikanlagen bereits mit Batteriespeicher ausgestattet sind oder noch werden sollen.


Lappeenranta University of Technology
• both systems on the right are part of a 220 kWp commercial solar PV system
• it is financially beneficial for the university


Role of Energy Storage in Future Energy Systems
Christian Breyer » christian.breyer@lut.fi
PtG/ PtX

- currently on the level of demonstration plant
- technology ready for industrial scale-up
- demand currently low (no regulations, low CO₂ price, etc.)
- first industrial applications based on hydrogen and in industry
- net zero emissions without PtG/PtX (electrolysers) wishful thinking
Agenda

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- Storage for the Global Energy System
- Sector Coupling Results
- Conclusions
Flows of energy – Basic 100% RE scenario


Role of Energy Storage in Future Energy Systems
Christian Breyer & christian.breyer@lut.fi
Annual production and consumption data

**Key insights:**
- Seasonality of solar PV is complemented somewhat by wind power generation
- CHP generation in colder months also complements solar PV
- Storage technologies add considerable flexibility to system

source: Child M. et al., 2015. The role of solar PV for 100% renewable energy supply in Finland, 31st EU PVSEC, Hamburg, September 14-18
Hourly electricity production (MW)

Key insights:
- Seasonal complement of solar PV and wind energy
- Variable RE production also complemented by seasonal use of CHP
- Hydro power utilised most during winter months, but can complement other forms of variable RE on a short and long-term basis

source: Child M. and Breyer Ch., 2016. The role of energy storage solutions in a 100% renewable Finnish energy system, 10th IRES 2016, Düsseldorf, March 15-17
Electricity production (MW)

April 22-28 (Min RE)

May 24-30 (Max RE)

Key insights:

• Minimum variable RE (Hour 2763) characterised by very low onshore and offshore wind as well as low hydro reserves
• Solar PV was at an annual maximum during same period
• Thermal power plants using biomass and stored gas provide further energy security
• Strong role of V2G connection during both periods
• Maximum variable RE during (Hour 3539) characterised by high wind power and solar PV

source: Child M. and Breyer Ch., 2016. The role of energy storage solutions in a 100% renewable Finnish energy system, 10th IRES 2016, Düsseldorf, March 15-17
Electricity demand (MW)

April 22-28 (Min RE)  May 24-30 (Max RE)

Key insights:
• End-user demand still lower than supply at lowest RE production
• Use of flexible demand and V2G batteries significant during noon peaks of solar PV
• At times of highest RE, curtailment of wind necessary due to max. power limitations of electrolysers and V2G batteries being exceeded
  • Assumption of battery energy/power ratio of 6 hours
  • Lower ratio could result in less curtailment, but may present technical barriers or additional costs

source: Child M. and Breyer Ch., 2016. The role of energy storage solutions in a 100% renewable Finnish energy system, 10th IRES 2016, Düsseldorf, March 15-17
Key insights:
• Strong cycles of daily charging and evening discharging of V2G batteries associated with solar PV production
Thermal storage capacity (MWh)

April 22-28 (Min RE)  
May 24-30 (Max RE)

Key insights:
• Full thermal energy storage during times of high and low RE production

source: Child M. and Breyer Ch., 2016. The role of energy storage solutions in a 100% renewable Finnish energy system, 10th IRES 2016, Düsseldorf, March 15-17
Gas storage capacity (MWh)

April 22-28 (Min RE)

May 24-30 (Max RE)

Key insights:
- Gas storage levels high during periods of low RE
- Gas storage levels near maximum levels during periods of high RE
- Daily cycles of charge and discharge still visible

source: Child M. and Breyer Ch., 2016. The role of energy storage solutions in a 100% renewable Finnish energy system, 10th IRES 2016, Düsseldorf, March 15-17
## Summary of results

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total energy consumption</strong></td>
<td>TWh</td>
<td>170.3 (105 electric + 65.3 thermal)</td>
</tr>
<tr>
<td><strong>V2G discharge</strong></td>
<td>TWhₜₑ</td>
<td>19.4</td>
</tr>
<tr>
<td><strong>Stationary Batteries discharge</strong></td>
<td>TWhₑ</td>
<td>0.1</td>
</tr>
<tr>
<td><strong>Electricity from stored gas</strong></td>
<td>TWhₑ</td>
<td>2.7</td>
</tr>
<tr>
<td><strong>Heat from stored gas</strong></td>
<td>TWhₜₜ</td>
<td>2.6</td>
</tr>
<tr>
<td><strong>DH storage discharge</strong></td>
<td>TWhₜₜ</td>
<td>0.2</td>
</tr>
<tr>
<td><strong>1. Solar PV and wind directly consumed</strong></td>
<td>TWhₑ</td>
<td>63.5 (47% of total solar PV and wind production)</td>
</tr>
<tr>
<td><strong>Solar PV and wind to electric storage</strong></td>
<td>TWhₑ</td>
<td>69.3 (51% of total solar PV and wind production)</td>
</tr>
<tr>
<td><strong>Solar PV and wind to curtailment</strong></td>
<td>TWhₑ</td>
<td>3.5 (2% of total solar PV and wind production)</td>
</tr>
<tr>
<td><strong>2. Total storage discharge</strong></td>
<td>TWh</td>
<td>25.0 (15% of total energy consumption)</td>
</tr>
<tr>
<td><strong>3. Electricity storage discharge</strong></td>
<td>TWhₑ</td>
<td>22.2 (21% of electricity consumption)</td>
</tr>
<tr>
<td><strong>V2G discharge</strong></td>
<td>TWhₑ</td>
<td>19.4 (87% of all electric storage discharge)</td>
</tr>
<tr>
<td><strong>4. Thermal storage discharge</strong></td>
<td>TWhₜₜ</td>
<td>2.8 (4% of heat consumption)</td>
</tr>
<tr>
<td><strong>5. Gas storage discharge</strong></td>
<td>TWhₜₕ₉</td>
<td>14.0 (26% of grid gas consumption)</td>
</tr>
</tbody>
</table>
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Key Objective

Definition of an optimally structured energy system based on 100% RE supply

- optimal set of technologies, best adapted to the availability of the regions’ resources,
- optimal mix of capacities for all technologies and every sub-region of Eurasia,
- optimal operation modes for every element of the energy system,
- least cost energy supply for the given constraints.

LUT Energy model, key features

- linear optimization model
- hourly resolution
- multi-node approach
- flexibility and expandability

Input data

- historical weather data for: solar irradiation, wind speed and hydro precipitation
- available sustainable resources for biomass and geothermal energy
- synthesized power load data
- gas and water desalination demand
- efficiency/yield characteristics of RE plants
- efficiency of energy conversion processes
- capex, opex, lifetime for all energy resources
- min and max capacity limits for all RE resources
- nodes and interconnections configuration
Methodology

Full system

Renewable energy sources
• PV rooftop
• PV ground-mounted
• PV single-axis tracking
• Wind onshore/offshore
• Hydro run-of-river
• Hydro dam
• Geothermal energy
• CSP
• Waste-to-energy
• Biogas
• Biomass

Electricity transmission
• node-internal AC transmission
• interconnected by HVDC lines

Storage options
• Batteries
• Pumped hydro storage
• Adiabatic compressed air storage
• Thermal energy storage, Power-to-Heat
• Gas storage based on Power-to-Gas
  • Water electrolysis
  • Methanation
  • CO₂ from air
  • Gas storage

Energy Demand
• Electricity
• Water Desalination
• Industrial Gas
Key insights:

- Area-wide scenario shows small share of system PV capacities in most of the regions, prosumers share is significant
- Sunny conditions in Iberia lead to significant share of PV single-axis
- >50% wind share in Baltic, Denmark, British Isles, France, Poland, Ukraine

Key insights:

- PV plays a major role in Area-wide desalination gas scenario for Central and Southern Europe
- PV single-axis and wind are the main sources of electricity for water desalination and industrial gas production
- Resistance against new grids could drastically increase the PV share
Results: Europe
Storages Capacities – area-wide and area-wide open trade desalination gas

Key insights:
• Excess energy for area-wide open trade desalination gas lower than with independent sectors (from 141 TWh to 132 TWh, also relative shares of excess energy decrease from 3.2% to 2.2% of total generation).
• Existing PHS storages play significant role
• Relative share of prosumers’ batteries increase significantly in integration scenario in Northern Europe
• Absolute storage capacities increase in Southern Europe and decrease in Central and Northern Europe when sectors are integrated
Results
Net exporter region – North-West Russia

source: Bogdanov D. and Breyer Ch., 2015. Eurasian Super Grid for 100% Renewable Energy power supply: Generation and storage technologies in the cost optimal Mix
Results

Balancing region – Northwest China

source: Bogdanov D. and Breyer Ch., 2016. North-East Asian Super Grid for 100% Renewable Energy supply: Optimal mix of energy technologies for electricity, gas and heat supply options, Energy Conversion and Management, 112, 176-190
Results
Net exporter region – India East

Key insights:
- India East exports 6 TWh of electricity, i.e. the region is mainly a self-supplying region
- Energy mix is mainly based on PV plus some hydro dams and biomass
- Batteries shift PV based electricity in the afternoon and night
- Flexible biomass and hydro is used in evening and night hours

source: Gulagi A., et al., 2015. Electricity system based on 100% Renewable Energy for India and SAARC
Results

Net exporter region – India West (monsoon month)

Key insights:
- India West exports 22 TWh of electricity to the grid (neighbouring regions)
- Energy mix is mainly based on PV, wind, hydro dams and biomass
- Monsoon month shows reduced solar resource but increased wind
- Batteries shift PV based electricity in the afternoon and night
- Batteries support grid exports and continuous PtG operation in night hours

source: Gulagi A., et al., 2015. Electricity system based on 100% Renewable Energy for India and SAARC
Results
Net importer region - Venezuela

source: Barbosa L., et al. 2015. Complementarity of hydro, wind and solar power as a base for a 100% RE energy supply: South America as an example
# Overview on World’s Regions

<table>
<thead>
<tr>
<th>Regions</th>
<th>LCOE region-wide [€/MWh]</th>
<th>LCOE area-wide [€/MWh]</th>
<th>Integration benefit ** [%]</th>
<th>Storage %</th>
<th>grids regions' trade %</th>
<th>Curtailment [%]</th>
<th>PV prosumers [%]</th>
<th>PV system * [%]</th>
<th>Wind * [%]</th>
<th>Biomass * [%]</th>
<th>Hydro * [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northeast Asia</td>
<td>66</td>
<td>56</td>
<td>6.0%</td>
<td>7%</td>
<td>10%</td>
<td>5%</td>
<td>16.4%</td>
<td>35.4%</td>
<td>40.9%</td>
<td>2.9%</td>
<td>11.6%</td>
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<tr>
<td>Southeast Asia</td>
<td>67</td>
<td>64</td>
<td>9.5%</td>
<td>8%</td>
<td>3%</td>
<td>3%</td>
<td>7.2%</td>
<td>36.8%</td>
<td>22.0%</td>
<td>22.9%</td>
<td>7.6%</td>
</tr>
<tr>
<td>India/ SAARC</td>
<td>72</td>
<td>67</td>
<td>5.9%</td>
<td>22%</td>
<td>23%</td>
<td>3%</td>
<td>6.2%</td>
<td>43.5%</td>
<td>32.1%</td>
<td>10.9%</td>
<td>5.4%</td>
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<tr>
<td>Eurasia</td>
<td>63</td>
<td>53</td>
<td>23.2%</td>
<td>&lt;1%</td>
<td>13%</td>
<td>3%</td>
<td>3.8%</td>
<td>9.9%</td>
<td>58.1%</td>
<td>13.0%</td>
<td>15.4%</td>
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<tr>
<td>Europe</td>
<td>73</td>
<td>64</td>
<td>8.7%</td>
<td>6%</td>
<td>17%</td>
<td>2%</td>
<td>12.3%</td>
<td>14.9%</td>
<td>55.0%</td>
<td>6.6%</td>
<td>9.3%</td>
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<tr>
<td>MENA</td>
<td>64</td>
<td>57</td>
<td>10%</td>
<td>11%</td>
<td>4%</td>
<td>2.4%</td>
<td>43.2%</td>
<td>51.8%</td>
<td>1.4%</td>
<td>0.6%</td>
<td></td>
</tr>
<tr>
<td>Sub-Saharan Africa</td>
<td>61</td>
<td>58</td>
<td>16.2%</td>
<td>4%</td>
<td>8%</td>
<td>4%</td>
<td>16.2%</td>
<td>34.1%</td>
<td>31.1%</td>
<td>7.8%</td>
<td>8.2%</td>
</tr>
<tr>
<td>South America</td>
<td>62</td>
<td>55</td>
<td>7.8%</td>
<td>5%</td>
<td>12%</td>
<td>5%</td>
<td>12.1%</td>
<td>28.0%</td>
<td>10.8%</td>
<td>28.0%</td>
<td>21.1%</td>
</tr>
</tbody>
</table>

**Key insights:**

- 100% RE is highly competitive
- least cost for high match of seasonal supply and demand
- PV share typically around 40% (range 14-50%)
- hydro and biomass limited the more sectors are integrated
- flexibility options limit storage to 10% and it will further decrease with heat and mobility sector integration
- most generation locally within sub-regions (grids 3-23%)

* Integrated scenario, supply share
** Annualised costs

## Demand for solar PV (2030, integrated)

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<tr>
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<tbody>
<tr>
<td>Northeast Asia</td>
<td>1546</td>
<td>9878</td>
<td>13496</td>
<td>1509</td>
<td>2806</td>
<td>4315</td>
<td>6986</td>
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<td>Southeast Asia</td>
<td>646</td>
<td>1629</td>
<td>2635</td>
<td>150</td>
<td>609</td>
<td>758</td>
<td>1425</td>
<td>51%</td>
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<tr>
<td>India/SAARC</td>
<td>1922</td>
<td>2597</td>
<td>3376</td>
<td>145</td>
<td>815</td>
<td>960</td>
<td>1880</td>
<td>50%</td>
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<td>Eurasia</td>
<td>244</td>
<td>1450</td>
<td>2550</td>
<td>92</td>
<td>171</td>
<td>263</td>
<td>388</td>
<td>15%</td>
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<tr>
<td>Europe</td>
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<td>4000</td>
<td>5689</td>
<td>608</td>
<td>534</td>
<td>1142</td>
<td>1625</td>
<td>27%</td>
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<tr>
<td>MENA</td>
<td>529</td>
<td>1756</td>
<td>5837</td>
<td>87</td>
<td>1161</td>
<td>1248</td>
<td>2876</td>
<td>46%</td>
</tr>
<tr>
<td>Sub-Saharan Africa</td>
<td>1384</td>
<td>866</td>
<td>1223</td>
<td>130</td>
<td>215</td>
<td>345</td>
<td>636</td>
<td>50%</td>
</tr>
<tr>
<td>South America</td>
<td>445</td>
<td>1813</td>
<td>2780</td>
<td>268</td>
<td>496</td>
<td>764</td>
<td>1419</td>
<td>48%</td>
</tr>
<tr>
<td><strong>total</strong></td>
<td><strong>7391</strong></td>
<td><strong>23989</strong></td>
<td><strong>37586</strong></td>
<td><strong>2989</strong></td>
<td><strong>6807</strong></td>
<td><strong>9795</strong></td>
<td><strong>17235</strong></td>
<td><strong>46%</strong></td>
</tr>
<tr>
<td><strong>world</strong></td>
<td><strong>8500</strong></td>
<td><strong>33214</strong></td>
<td></td>
<td><strong>31%</strong></td>
<td><strong>69%</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>as of total</td>
<td><strong>87%</strong></td>
<td><strong>72%</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>projected</td>
<td><strong>33214</strong></td>
<td><strong>52040</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>13562</strong></td>
<td></td>
</tr>
</tbody>
</table>
Storage Demand – preliminary insights

- first insights based on 8 in all 9 regions in the world
- sector coupling includes: power, desalination, industrial gas demand – 45% of TPED
- batteries prosumer: 4920 TWh
- batteries system: 6130 TWh
- electrolysers for PtG: 370 GW (electricity only) 2260 GW (electricity, industrial gas)
- PHS: 2150 TWh
- A-CAES: 1120 TWh
- batteries (prosumer and system) account for about 70% of total storage energy
- impact of further sector integration (heat, mobility, industrial demand) not yet clear
- impact of storage cost decline vs power grids: the lower the storage cost the more decentral is the energy system, i.e. in an increasing number of cases low cost solar PV and wind energy plus storage is more competitive than long distance grids
- special insights on A-CAES: special storage in case grid coupling cannot be done, since it is a weekly storage which is mainly needed for wind energy, which could be otherwise balanced for lower costs by continental grids
Hybrid PV-Battery-GT Plant (hourly)

Hybrid Photovoltaic (PV) power plant:
- PV single-axis tracking system
- Lithium-ion batteries
- gas turbine (OCGT)

Coal-fired power plant:
- boiler
- steam turbine

Open cycle gas turbine power plant:
- gas turbine

Combined cycle gas turbine power plant:
- steam turbine
- gas turbine

source: Afanasyeva S., Breyer Ch., Engelhard M., 2016. The Impact of Cost Dynamics of Lithium-Ion Batteries on the Economics of Hybrid PV-Battery-GT Plants and the Consequences for Competitiveness of Coal and Natural Gas-Fired Power Plants, 10th IRES, Düsseldorf, March 15-17
Key insights:

• Results indicate advantage for hybrid PV-Battery-GT plant in Morocco in 2030
• Future battery cost development is the major unknown factor
• Implemented battery cost for power/energy 2020: 150/300; 2030: 100/150 per kW/kWh

source: Afanasyeva S., Breyer Ch., Engelhard M., 2016. The Impact of Cost Dynamics of Lithium-Ion Batteries on the Economics of Hybrid PV-Battery-GT Plants and the Consequences for Competitiveness of Coal and Natural Gas-Fired Power Plants, 10th IRES, Düsseldorf, March 15-17
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Methodology
RE-PtG-LNG Value Chain

Hybrid PV-Wind & Battery → Power-to-Gas → SNG Liquefaction → LNG Shipping → LNG Regasification

Key insights:
• Substitution of the fossil hydrocarbon value chain by a RE basis
• Utilization of downstream fossil infrastructure
• Integrated heating system
• Water recycling

source: Fasihi M., Bogdanov D., Breyer Ch., 2015. Economics of global LNG trading based on hybrid PV-Wind power plants, 31st EU PVSEC, Hamburg, September 14-18
Data

Plants’ Location

1) Patagonia, Argentina:
   • Hybrid PV-Wind Power Plant
   • PtG Plant
   • Liquefaction Plant

2) Japan:
   • Regasification Plant

Marine distance
   • Patagonia – Japan: 17,500 km
   • Patagonia – Hamburg: 14,000 km

source: Fasihi M., Bogdanov D., Breyer Ch., 2015. Economics of global LNG trading based on hybrid PV-Wind power plants, 31st EU PVSEC, Hamburg, September 14-18
Results
RE-PtG-LNG Value Chain - Energy & Mass Flow

- System integration benefits:
  - 87% of energy needed for CO\(_2\) capture plant is coming from excess heat
  - 48% of electrolyzer’s water demand coming out of methanation

- Heat exchanger eff.: 90%
- LNG value chain eff.: 89%
- Electrolyzer, the main electricity consumer
- Oxygen available for potential market

* Overall efficiency: 58%

source: Fasihi M., Bogdanov D., Breyer Ch., 2015. Economics of global LNG trading based on hybrid PV-Wind power plants, 31st EU PVSEC, Hamburg, September 14-18

*LT: low temperature
**HT: high temperature
Results
Final Cost and Market Potential: RE-PtG-LNG Value Chain

CO₂ emission cost:
- NG CO₂ emission: 56 t CO₂/TJ
- 0-50 €/t CO₂
- 0-23 USD/bbl

O₂ profit:
- O₂ market price: up to 80 €/t O₂
- Our most optimistic scenario: 20 €/t O₂
- LNG price in Japan: 102.3% of crude oil price.
- Regasification cost has been added

The first breakeven can be expected for produced RE-SNG with a WACC of 5% and O₂ benefit of 20 €/t CO₂ and NG price with CO₂ emission cost of 50 €/t CO₂ and a crude oil price of 87 USD/bbl.

A realistic breakeven can happen for the crude oil prices between 100-120 USD/bbl.

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source: Fasihi M., Bogdanov D., Breyer Ch., 2015. Economics of global LNG trading based on hybrid PV-Wind power plants, 31st EU PVSEC, Hamburg, September 14-18
Results

RE-PtL Value Chain - Energy & Mass Flow

- Electrolyser, the main electricity consumer
- FT the main source of energy for the CO₂ capture plant
- Oxygen available for potential market
- H₂tL eff.: 71.8%
- Heat exchanger eff.: 90%
- Heat loss: 4.2%

87% of energy demand supplied by excess heat

63% of water demand supplied by RWGS and FT process output

Overall efficiency: 57.5%

Source: Fasihi M., Bogdanov D., Breyer Ch., 2016. Techno-economic Assessment of Power-to-Liquids (PtL) Fuels Production and Global Trading Based on Hybrid PV-Wind Power Plants, 10th IRES, Düsseldorf, March 15-17
Role of Energy Storage in Future Energy Systems

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Results
Final Cost and Market Potential: RE-PtL Value Chain

The first breakeven can be expected for a produced RE-diesel with a WACC of 5% and an O₂ benefit of 20 €/tO₂ and a conventional diesel price with CO₂ emission cost of 50 €/tCO₂ and a crude oil price of 79 USD/bbl.

A realistic breakeven is expected for the crude oil prices between 90-120 USD/bbl.

Diesel cost in EU: 119% of Brent crude oil price

CO₂ emission cost:
• Diesel CO₂ emission: 74 tCO₂/TJ
• 0-50 €/tCO₂
• 0-30 USD/bbl

O₂ profit:
• O₂ market price: up to 80 €/tO₂
• Our most optimistic scenario: 20 €/tO₂

source: Fasihi M., Bogdanov D., Breyer Ch., 2016. Techno-economic Assessment of Power-to-liquids (PtL) Fuels Production and Global Trading Based on Hybrid PV-Wind Power Plants, 10th IRES, Düsseldorf, March 15-17
Clean water for all: RE-based desalination

Overview:
- clean water for all (and nearly everywhere) is no wishful thinking
- water crisis is rather a management failure than a techno-economic issue

source: Caldera U., Bogdanov D., Breyer Ch., 2016. Local cost of seawater RO desalination based on solar PV and wind energy - A global estimate, Desalination, 385, 207-216
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- Recent Storage News
- Storage for the Finnish Energy System
- Storage for the Global Energy System
- Sector Coupling Results
- Conclusions
Conclusions

- storage is important but only one flexibility option, besides grids, generation flexibility, demand side management and in particular energy sector coupling
- low cost batteries will change the mobility sector dramatically and very fast
- PtG/PtX is desperately needed for net zero emission society, but later than batteries
- 100% RE for Finland is possible and storage are important, but wind capacities first
- battery storage is the key energy storage technology
- PtG/ PtX (electrolysers) are the key bridging technology to utilize flexibility
- zero net emissions requires both batteries (EV and stationary) and electrolysers (PtX)
- global energy system may be finally almost fully electricity based
Thanks for your attention … … and to the team!

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