Renewables and energy storage: An ideal marriage for a low carbon world?

Dr Joeri Rogelj, Grantham Institute for Climate Change and the Environment: What role do renewables play in keeping warming to 1.5°C?

Steve Sawyer, Global Wind Energy Council: An energy system dominated by wind and solar: How can it work?

Rana Adib, REN21: Renewable energy and storage – a driver for the electrification of heat and transport?

Prof Evelina TrutnevYTE, University of Geneva: How can we pioneer systemic innovation for renewable energy and storage?

Dr Michael Whiston, Carnegie Mellon University: What are the potential co-benefits of and pathways for growth in renewables, energy storage, and fuel cells?

Chair: Dr Rob Gross, Imperial College London
What role do renewables play in keeping warming to 1.5°C?

Insights and lessons from the IPCC Special Report on Global Warming of 1.5°C

Joeri Rogelj
Grantham Institute for Climate Change and the Environment
Necessity of reductions in 1.5°C compatible pathways

2200 ±320 GtCO₂ emitted until 2017 by human activities

1.5°C carbon budget

REMAINING 420-580 GtCO₂

Source: IPCC Special Report on Global Warming of 1.5°C
What does this mean for the energy system?

I. **Improve energy efficiency**
   - Limiting final energy demand in 2050 to +20 to -10% rel. to 2010 levels

II. **Electrify energy end use**
    - (mobility, buildings, industry)

III. **Decarbonize the power sector**
    - (carbon-intensity of electricity about zero or negative in 2050)

IV. **Substitute residual fossil fuels with low-carbon options**
    - (e.g. bio-based fuels for transport)
What does 1.5°C mean for electricity from renewables?

**Renewables** supply
- about 25% of electricity in 2020
- about 55% of electricity in 2030 (range: 45-65%)
- more than 75% of electricity in 2050 (range: 70-85%)

**Wind and solar** supply
- less than 5% of electricity in 2020
- about 10% of electricity in 2030 (range: 5-15%)
- about 20% of electricity in 2050 (range: 15-35%)
What role for electricity storage?

Wind and solar supply
- about 20% of electricity in 2050 (range: 15-35%)
- but full range up to 60%

If achieved
- with mainly wind: less than 5% of peak demand
- with mainly solar: up to 20% of peak demand

Strong upscaling of (variable) renewables required, and depending on strategy also a lot of storage

Scaling up renewables to meet the climate challenge:

An energy system dominated by wind and solar: How can it work?

Steve Sawyer
Senior Policy Advisor
Outline of Scenarios

IEA – NPS – central IEA/WEO scenario based on existing policies and those likely to be enacted

GWEC Moderate – bottom up scenario built on existing short-term market forecast

2.0° - wind component of soon-to-be-published scenario from UTS/Kyoto/DLR/Melbourne

1.5° - wind component of soon-to-be-published scenario from UTS/Kyoto/DLR/Melbourne

Wind Force 10 – Global Wind Energy Outlook
Global Cumulative New Wind Power Capacity

Cumulative Capacity

<table>
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<tr>
<th>Year</th>
<th>2015</th>
<th>2017</th>
<th>2020</th>
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<td>GWEC Moderate 2018</td>
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Wind market growth - NPS 2017

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Wind market growth - GWEC Moderate 2018

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<td>[TWh/a]</td>
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Wind market growth - 2.0°C

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Wind market growth - 1.5°C

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<td>[TWh/a]</td>
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Wind market growth - NPS 2017

Wind power penetration of World's electricity in % - Reference

Wind market growth - GWEC Moderate 2018

Wind power penetration of World's electricity in % - UTS/DLR (High Electrification)

Wind market growth - 2.0°C

Wind power penetration of World's electricity in % - (High Electrification)

Wind market growth - 1.5°C

Wind power penetration of World's electricity in % - (High Electrification - accelerated)
Uruguay – to 100% in 10 years

Before 2013:

Approx. 2000 MW of peak power consumption.
Annual demand of 11,000 GWh, from:

1500 MW Hydro.
80 MW fuel oil reciprocating engines.
215 MW steam turbines (today are being dismantled)
500 MW a set of gas turbines (fuelled basically with diesel).

2007: UTE installed 17 wind measurement stations throughout the country.
2008: New policy from government to promote RE
2010: These policies became State Policy with the agreement of all political parties. Most important: simplicity!!
2010: First tender for 150 MW of wind power, PPA mode, average price: 84 USD/MWh.
2011: 2nd. and 3rd. Tender, PPA mode, contracts for 800 MW are signed, with an average price of 63.5 USD/MWh.
2013: UTE signed contracts for 275 MW in 6 wind farms
2014: 3 PPAs were duplicated: 150 MW were added.
Small wind farms (less than 10 MW each) to the spot market, total: approx. 70 MW.

Today: 1505 MW of wind and 100% RE power!
South Africa:
all least-cost model scenarios pick mostly solar and wind with no new coal or nuclear
Conclusions

Until very recently, storage technologies were at or near the bottom of the list of options to integrate large quantities of VRE. Still not an issue in existing high penetration markets (Denmark, Spain, Portugal, Ireland, Uruguay, Iowa), but it will come sooner or later...

Question: Which storage technologies will reach market readiness and in what order?


Will others (heat, power to gas, power to liquids, etc.) follow the same model?

Thank you!
Renewable energy and storage – a driver for the electrification of heat and transport?

7 December 2018
Katowice, Poland

Rana Adib
Executive Secretary, REN21
Renewable energy and storage – a driver for the electrification of heat and transport?

**NGOs:**
- CAN, CEEW, FER, GACC, GFSE, Greenpeace International, ICLEI, ISEP, MFC, SLoCaT, REI, WCRE, WFC, WRI, WWF

**Industry Associations:**
- ARE, ACORE, ALER, APREN, CREIA, CEC, EREF, GOGLA, GSC, GWEC, IREF, IGA, IHA, RES4MED, WBA, WWEA

**Science & Academia:**
- Fundacion Bariloche, IIASA, ISES, NREL, SANEDI, TERI

**International Organisations:**
- ADB, APERC, ECREEE, EC, GEF, IEA, IEC, IRENA, RCREEE, UNDP, UN Environment, UNIDO, World Bank

**Governments:**
- Afghanistan, Brazil, Denmark, Germany, India, Mexico, South Africa, Spain, UAE, USA

A global multi stakeholder network dedicated to the rapid uptake of renewable energy.
Renewable energy and storage – a driver for the electrification of heat and transport?

Global levelised cost of electricity from utility-scale renewable power generation technologies, 2010-2017

IRENA, Renewable Power Generation Costs in 2017

Share of Electricity Generation from Variable Renewable Energy, Top 10 Countries, 2017

IRENA, Renewables 2018 Global Status Report

Renewable electricity – the renewable energy success story
What is the role of electricity and storage to advance the renewable uptake in heating and transport?

- In 2017, renewable electricity was the second largest source of renewable heat, following modern bioenergy.
- District heating covers 11% of space and water heating needs globally.
Electrification of the heating sector

Drivers for electrification

- Reduced cost of PV, wind and heat-pumps
- Abundance of renewable power and VRE
- Electricity is more ‘mobile’ than thermal energy carriers (district heating only covers 11% of space and water heating needs globally)
- Electricity can facilitate efficiency in heat, e.g. by changing the ‘quality’ of heat (low, medium, high temperature) or co-generation

“The electrification of the heating sector will continue and will lead to an almost complete electrification.”

There is a lack of reliable data on renewable energy heating
Need to increase policy attention on heating to drawn on the potential for better integration

Storage in the heat sector

- Providing flexibility
- Matching supply and demand
  - Electric grid
  - Thermal demand
  - Quality of heating/cooling (LT, MT, HT)
- Thermal energy storage is 50-100 times cheaper than electricity storage
- Storage provides a support function to energy efficiency
Electrification trends in transport

- Rail and light rail
- EVs on the road: +70% compared to 2016, but only 1% of light vehicle market
- Potential to create a new market for renewable energy and facilitate the integration of higher shares of VRE

Energy Security = Mobility Security
Renewable energy and storage – a driver for the electrification of heat and transport?

IRENA-IEA-REN21, Renewable Energy Policies in a Time of Transition

Renewable electricity-based mobility vs Electric mobility

COP24, 7 December 2018
How can we pioneer systemic innovation for renewable energy and storage?

Prof. Evelina Trutnevyte
Renewable Energy Systems, University of Geneva

COP24 side event «Renewable energy and storage», 7 December 2018, Katowice
Report of the High-Level Panel of the European Decarbonisation Pathways Initiative

Members of the High-Level Panel:
Hans Joachim Schellnhuber, Germany
Catia Bastioli, Italy
Paul Ekins, UK
Beata Jaczewska, Poland
Barbara Kux, Switzerland
Christian Thimann, Germany
Laurence Tubiana, France
Maria van der Hoeven, Netherlands
Karin Wanngård, Sweden
Two key challenges: climate neutrality and the systemic change needed for that

*deeply integrated zero-carbon energy system*

- **zero-carbon electrons**, pumped storage, batteries, vehicle-to-grid
- **zero-carbon ‘molecules’** power-to-x
- **zero-carbon heat** daily and seasonal heat storage

- **socio-economic change**
  - awareness
  - citizen engagement
  - governance and planning
  - regulation and policies
  - markets
  - business models
  - jobs

Source: HLP report of EDPI, 2018
Social innovation is more than acceptance

Interest of households in buying solar PV in Switzerland

Source: University of St. Gallen, 2018

Motivation to purchase PV storage with policy support in Germany

Source: ISEA & RWTH Aachen, 2018
How can we pioneer a systemic innovation for rapid decarbonization?

Polluted metropolitan area?  Conventional agricultural area?  Mining-industrial complex?

Transition super-labs – very-large-territory initiatives of real-life transition to zero-carbon economy

➢ Co-design the transition with research, businesses, administration, and civil society
➢ Implement, monitor, revise, and then scale it up

Source: HLP report of EDPI, 2018
How can we pioneer systemic innovation for renewable energy and storage?

- Deeply integrated zero-carbon energy system needs zero-carbon electrons, zero-carbon ‘molecules,’ zero-carbon heat, and various types of storage

- Systemic innovation goes beyond technology and acceptance, it is a social and economic change too

- Transition super-labs could be an ‘instrument’ for real-life systemic innovation

Source: HLP report of EDPI, 2018
Register at [www.deeds.eu](http://www.deeds.eu) to share your thoughts

Thank you!

Prof. Evelina Trutnevyte  
Renewable Energy Systems,  
University of Geneva

Email: [evelina.trutnevyte@unige.ch](mailto:evelina.trutnevyte@unige.ch)  
Website: [www.unige.ch/res](http://www.unige.ch/res)  
Twitter: [@etrutnevyte](https://twitter.com/etrutnevyte)
What are the potential co-benefits of and pathways for growth in renewables, energy storage, and fuel cells?

Michael M. Whiston, Postdoctoral Researcher
Engineering and Public Policy
Carnegie Mellon University

Inês Azevedo, Professor
Engineering and Public Policy
Carnegie Mellon University

Shawn Litster, Professor
Mechanical Engineering
Carnegie Mellon University

Constantine Samaras, Associate Professor
Civil and Environmental Engineering
Carnegie Mellon University

Kate S. Whitefoot, Assistant Professor
Mechanical Engineering
Engineering and Public Policy
Carnegie Mellon University

Jay F. Whitacre, Professor
Engineering and Public Policy
Materials Science and Engineering
Carnegie Mellon University

Carnegie Mellon
Electricity Industry Center
Storage is not a green silver bullet.

Our group has shown that using storage for energy energy arbitrage increases CO$_2$, NO$_x$ and SO$_2$ emissions almost everywhere in the US (Hittinger & Azevedo, 2015)

Wind and solar displace storage-induced emissions

- **Renewables displace** storage-induced emissions, depending on location and operation (Hittinger & Azevedo, 2017)
- 0.1–18 MW of wind power required to offset emissions induced by 100 MW storage
- 1–67 MW of solar power required to offset emissions
- Increasing storage efficiency reduces amount renewables

Fuel cells’ continuous power can balance renewables

- We elicited 27 experts’ assessments of solid oxide fuel cell (SOFC) cost and performance, and conducted a follow-up workshop on market viability

- Performance trajectory?
- How to reduce cost?
- Favorable markets?

![Graph showing cost and degradation over years]

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<th>Cost of material</th>
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Storage, renewables, and fuel cells: Opportunities

- **Bulk energy storage** is may be economical and allows for the integration of renewables but could induce U.S. electricity system emissions.

- Improving **storage efficiency** could significantly reduce emissions.

- Scaling-up wind and solar offsets storage-induced emissions; 0.1–18 MW of wind and 1–67 MW of solar required to offset emissions for 100 MW storage.

- **Fuel cells** could provide clean, continuous, distributed generation to balance renewables, and fuel cells can operate on H₂ generated by renewables.

- Fuel cell cost could decline to $1,000/kW by 2035, material costs significant.

Thank you!

mwhiston@andrew.cmu.edu
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