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

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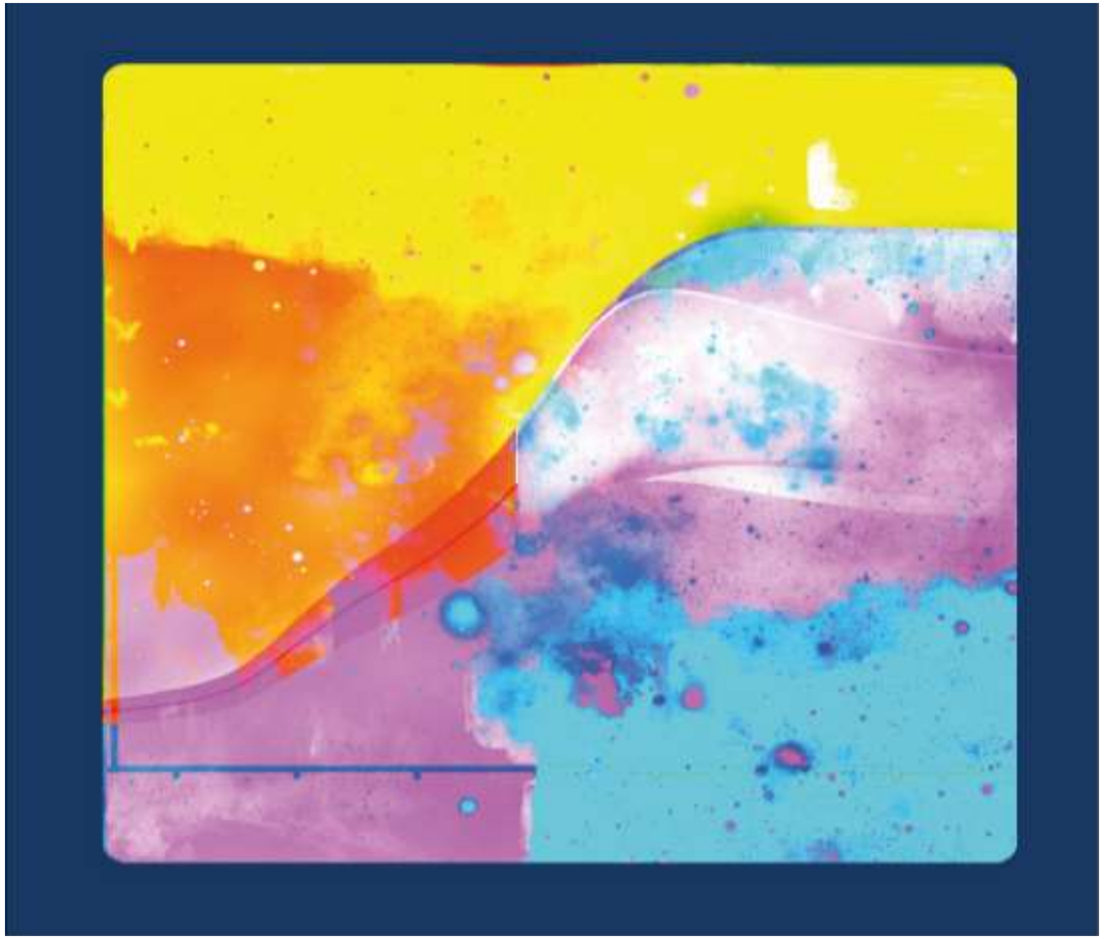
Dr Michael Whiston, Carnegie Mellon University: What are the potential co-benefits of and pathways for growth in renewables, energy storage, and fuel cells?

Chair: Dr Rob Gross, Imperial College London

What role do renewables play in keeping warming to 1.5°C?

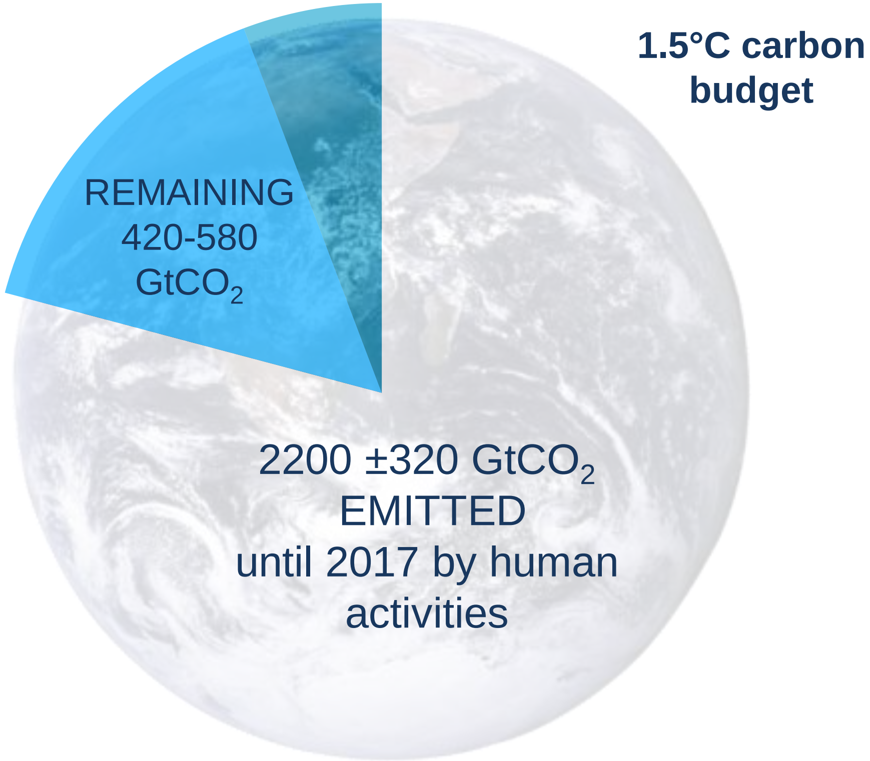
Insights and lessons from the IPCC Special Report on Global Warming of 1.5°C

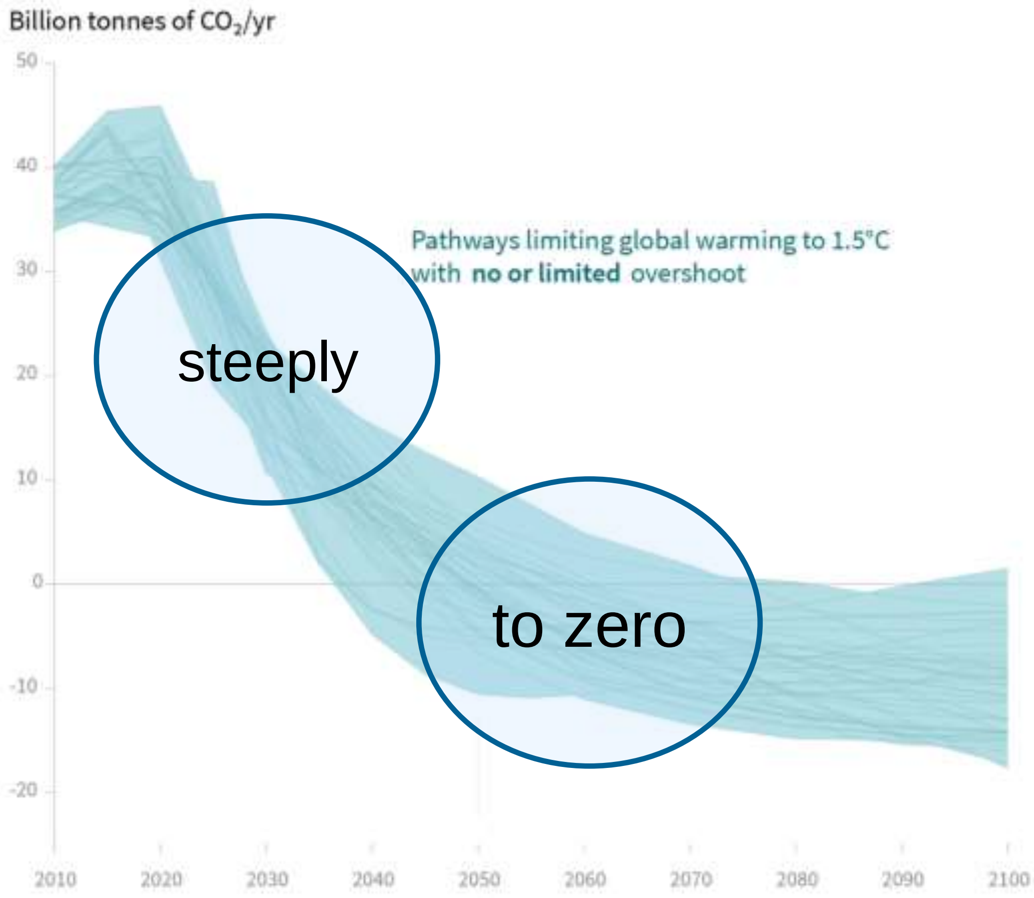
Joeri Rogelj
Grantham Institute for Climate Change and the Environment



IPCC SR15

Necessity of reductions in 1.5°C compatible pathways





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)

Robert van Waarden / Aurora Photos

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%)

Ted Wood / Aurora Photos

What role for electricity storage?

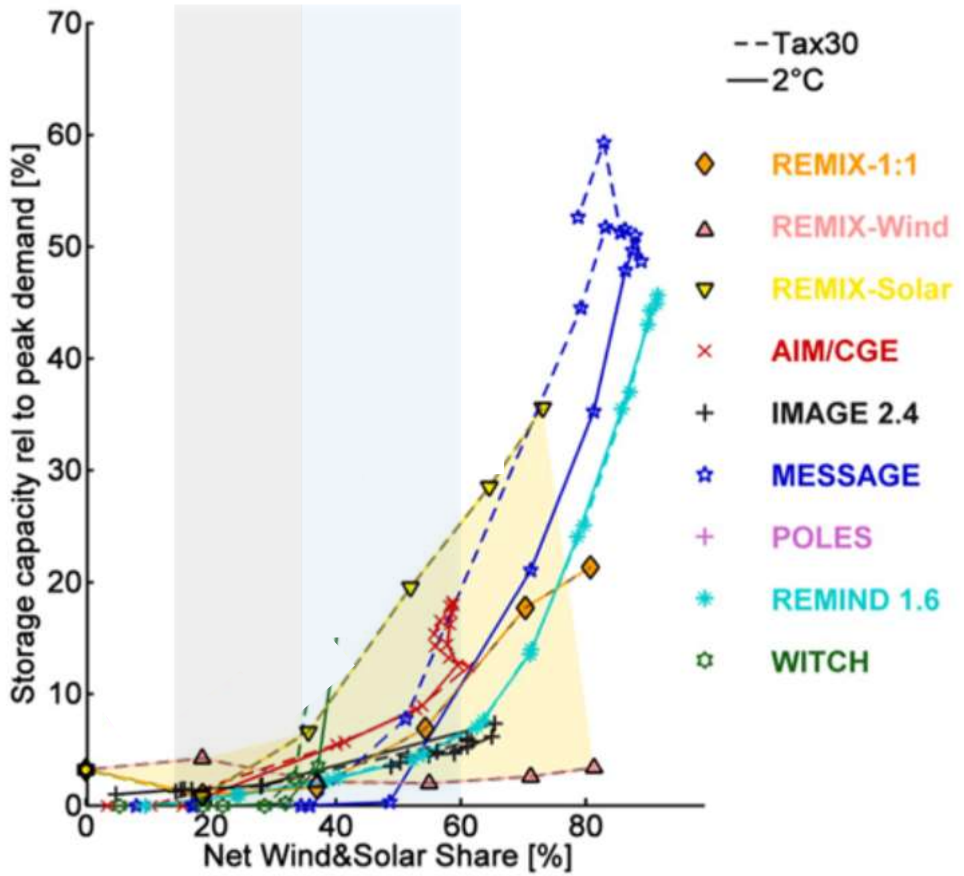
Wind and solar supply

- 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



Pietzcker et al (2017) Energy Economic

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

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Wind Force 10 – Global Wind Energy Outlook

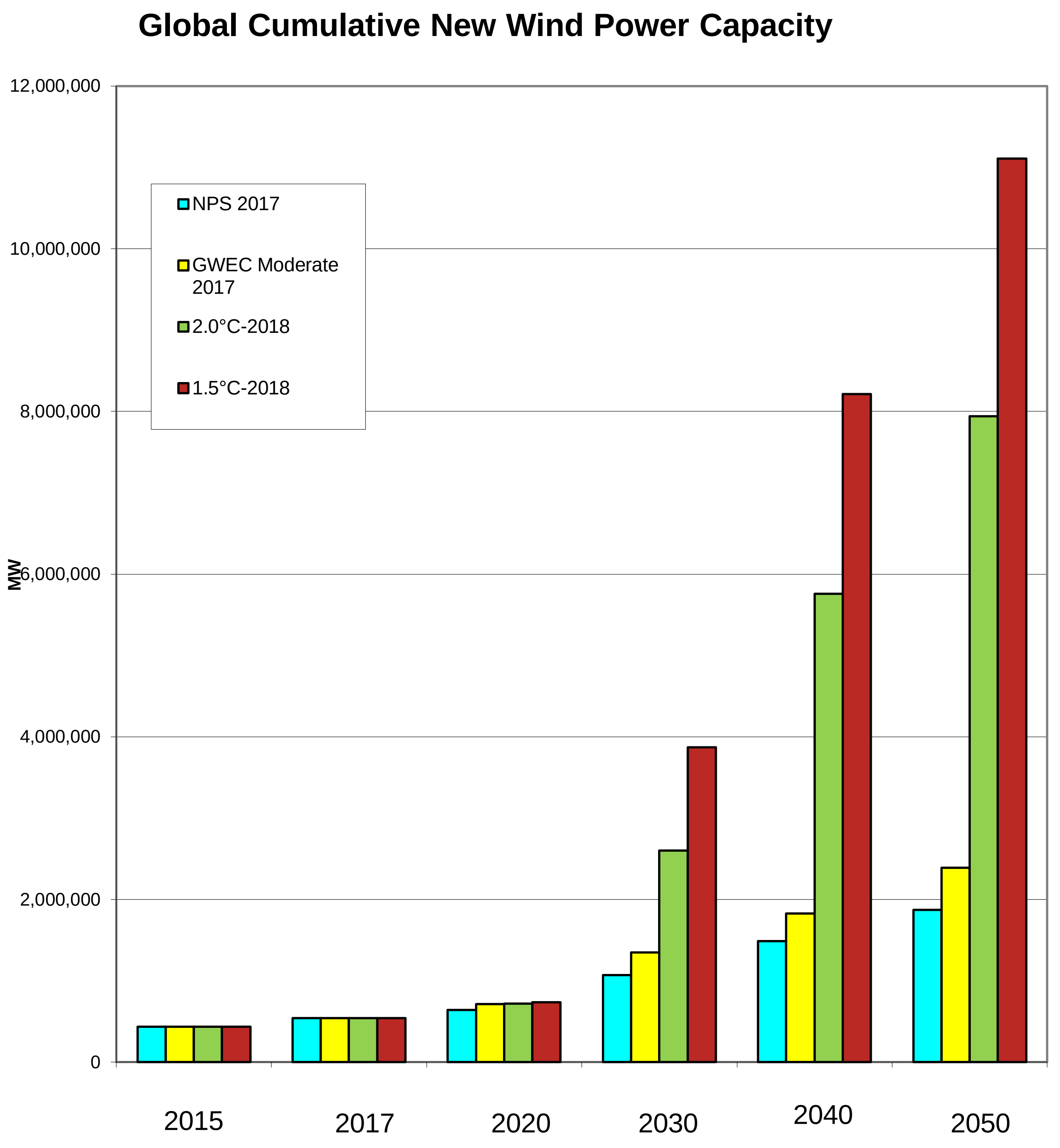
Outline of Scenarios

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*



Cumulative Capacity		2015	2017	2020	2030	2040	2050
Wind market growth - NPS 2017							
	[MW]	432,680	539,137	640,002	1,069,418	1,488,201	1,874,235
	[TWh/a]	868	1,302	1,643	3,878	6,465	9,327
Wind market growth - GWEC Moderate 2018							
	[MW]	432,680	539,137	713,308	1,347,031	1,825,513	2,387,529
	[TWh/a]	868	1,324	1,750	3,540	4,797	6,274
Wind market growth - 2.0°C							
	[MW]	432,680	539,137	717,674	2,603,614	5,758,927	7,939,614
	[TWh/a]	868	1,324	1,760	6,842	15,134	20,865
Wind market growth - 1.5°C							
	[MW]	432,680	539,137	736,652	3,871,484	8,213,553	11,110,858
	[TWh/a]	868	1,324	1,807	10,174	21,585	29,199

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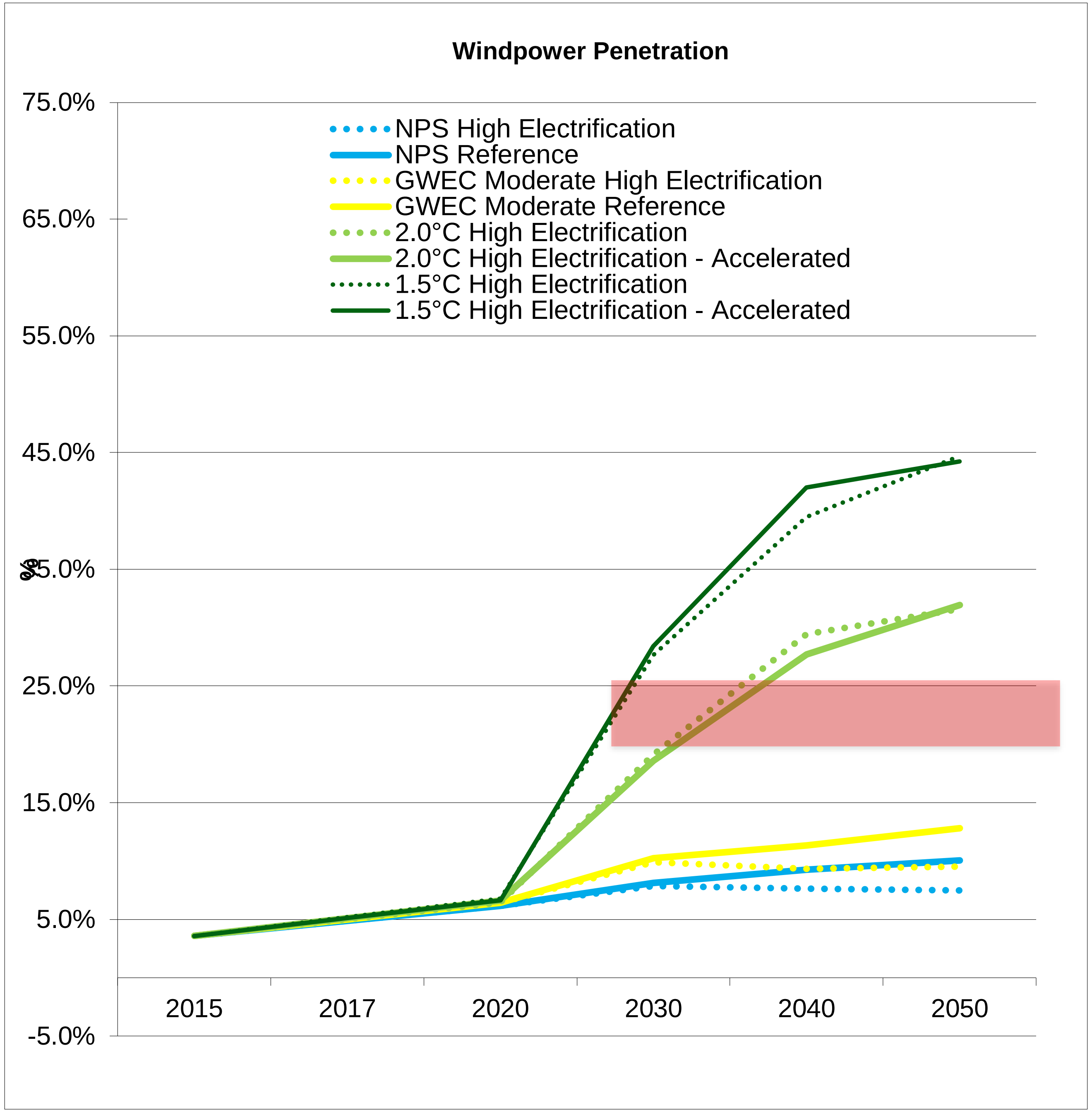


		2015	2017	2020	2030	2040	2050
Wind market growth - NPS 2017							
Wind power penetration of Worlds electricity in % - Reference	[%]	4%	5%	6%	8%	9%	10%
Wind power penetration of Worlds electricity in % - UTS/DLR (High Electrification)	[%]	4%	5%	6%	8%	8%	7%
Wind market growth - GWEC Moderate 2018							
Wind power penetration of Worlds electricity in % - Reference	[%]	4%	5%	6%	10%	11%	13%
Wind power penetration of Worlds electricity in % - UTS/DLR (High Electrification)	[%]	4%	5%	6%	10%	9%	10%
Wind market growth - 2.0°C							
Wind power penetration of Worlds electricity in % - (High Electrification - accelerated)	[%]	4%	5%	7%	19%	28%	32%
Wind power penetration of Worlds electricity in % - UTS/DLR (High Electrification)	[%]	4%	5%	6%	19%	29%	32%
Wind market growth - 1.5°C							
Wind power penetration of Worlds electricity in % - (High Electrification)	[%]	4%	5%	7%	28%	42%	44%
Wind power penetration of Worlds electricity in % - UTS/DLR (High Electrification - accelerated)	[%]	4%	5%	7%	28%	39%	45%

Uruguay – to 100% in 10 years

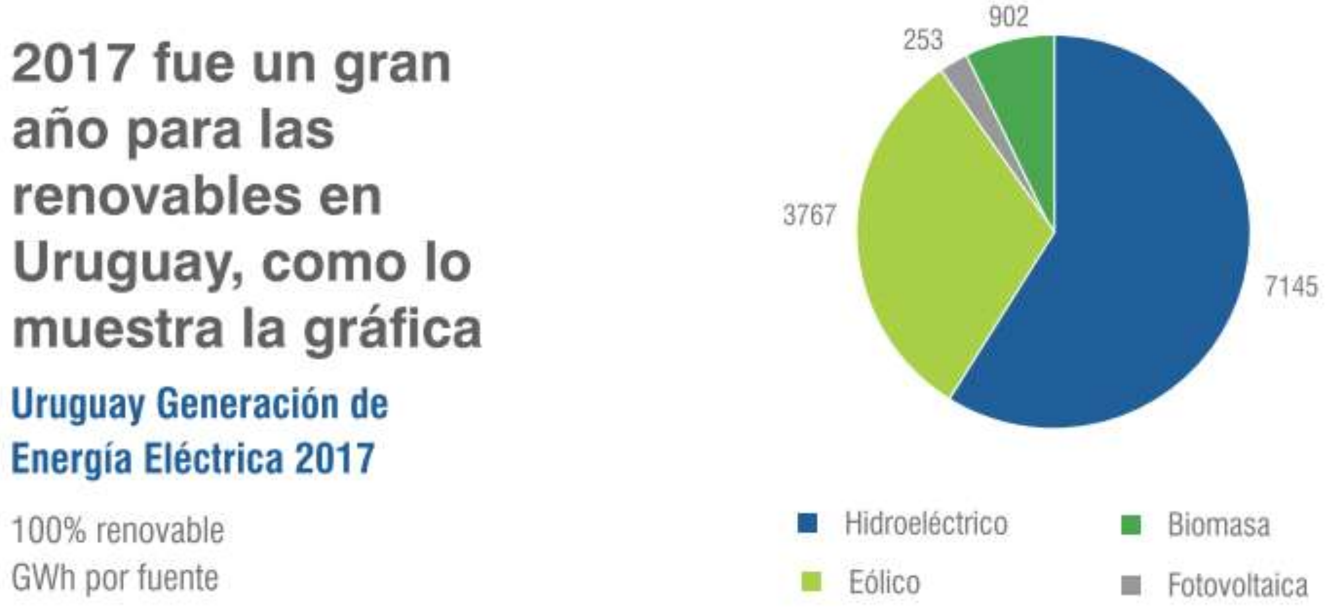
Before 2013:

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
2009: Government resolution 354/2009, establishes tax benefits for NCR Energy.
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.

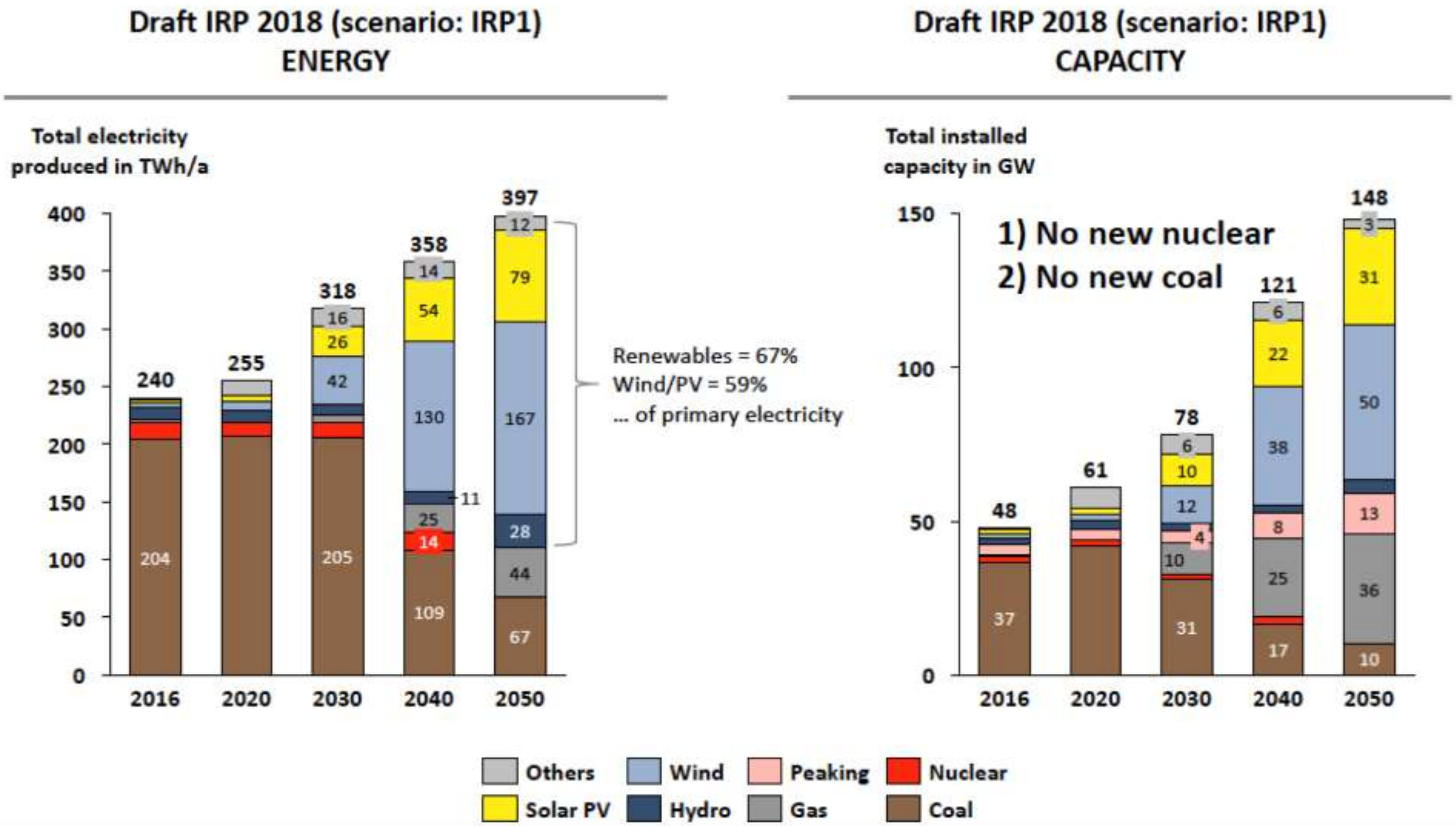
Today: 1505 MW of wind and 100% RE power!



59% hydro
31.2% wind
7.5% biomass
2.1% solar pv

South Africa:

all least-cost model scenarios pick mostly solar and wind with no new coal or nuclear



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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?

Batteries – followed wind/pv model: European/N.American tech + Chinese volume = competitiveness. Not only transport, but utility scale (i.a. Tesla S.A.) and wind/solar/storage hybrids.

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

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Thank you!

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REN21 Renewable Energy Policy Network for the 21st Century

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

7 December 2018
Katowice, Poland

Rana Adib
Executive Secretary, REN21

REN21 Renewable Energy Policy Network for the 21st Century

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

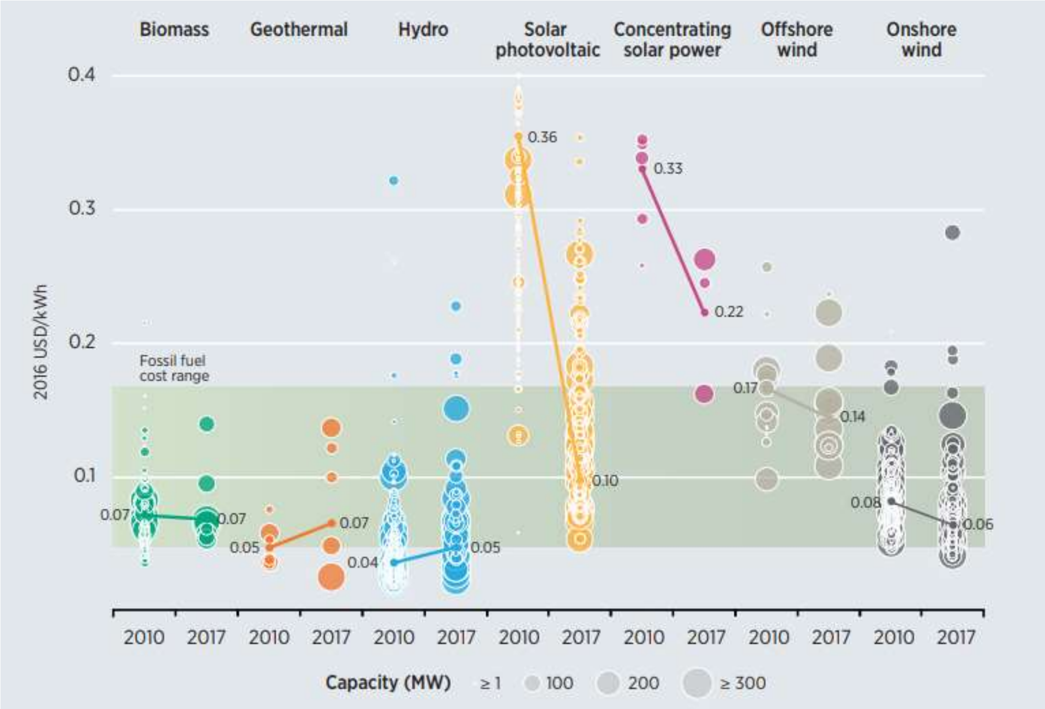
Science & Academia:
Fundacion Bariloche, IIASA, ISES, NREL, SANEDI, TERI

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

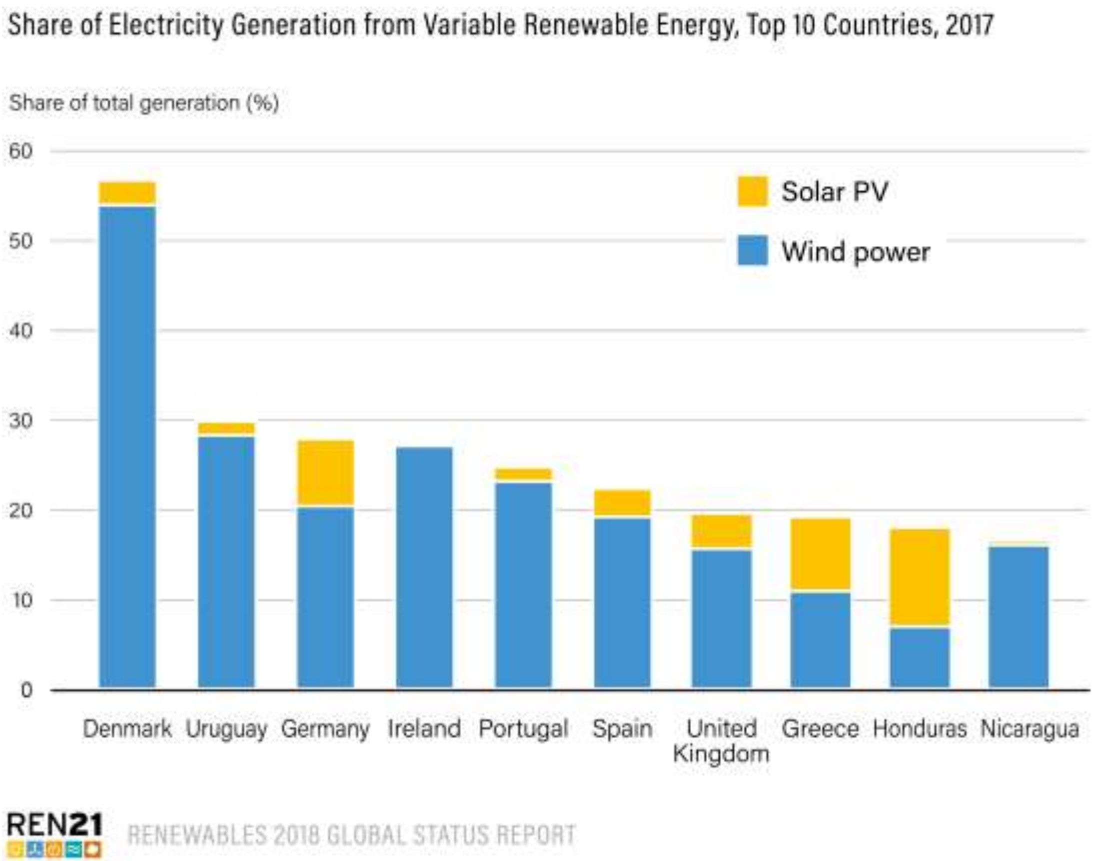
Governments:
Afghanistan, Brazil, Denmark, Germany, India, Mexico, South Africa, Spain, UAE, USA

A global multi stakeholder network dedicated to the rapid uptake of renewable energy.

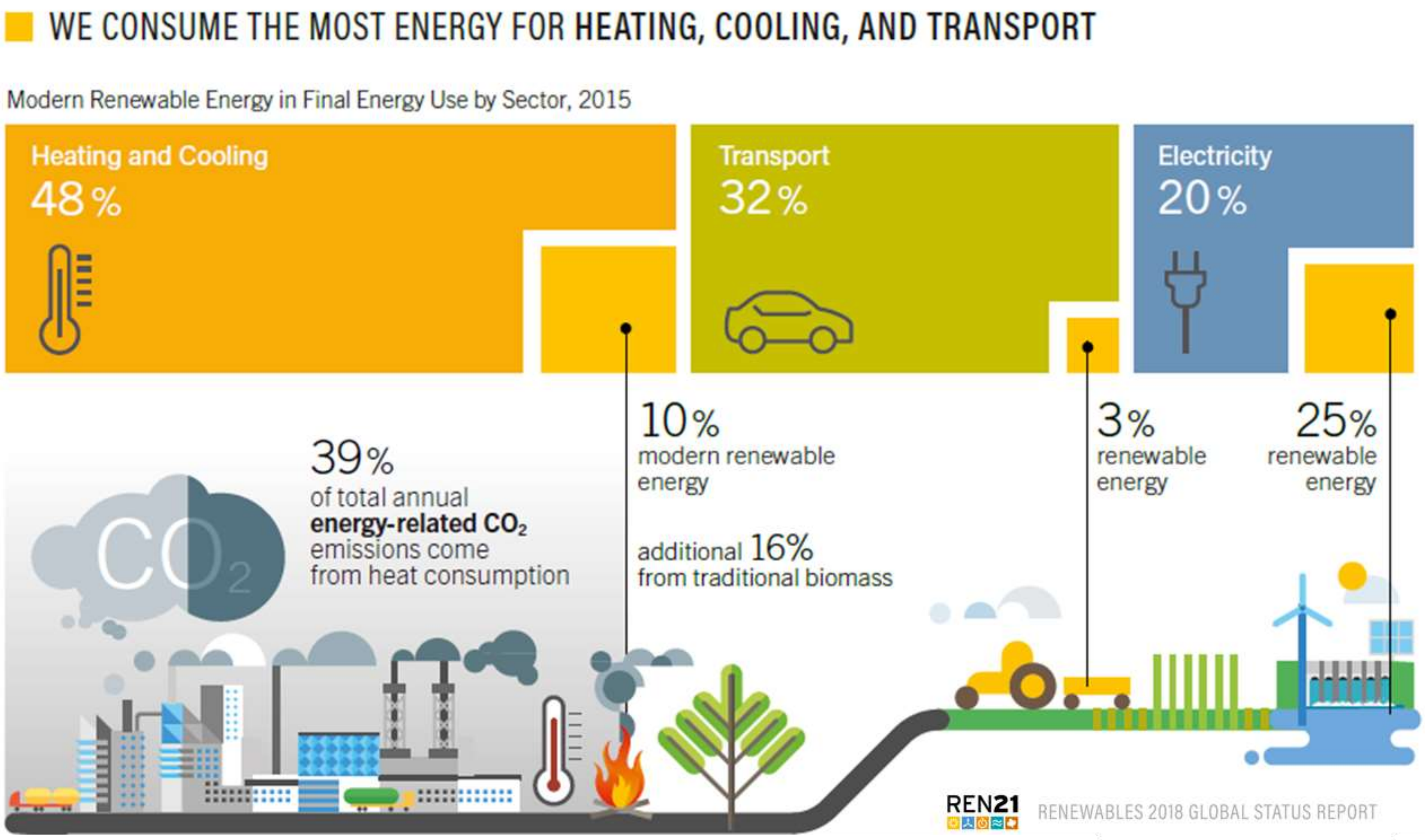
Global levelised cost of electricity from utility-scale renewable power generation technologies, 2010-2017



IRENA, Renewable Power Generation Costs in 2017



Renewable electricity – the renewable energy success story



- 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

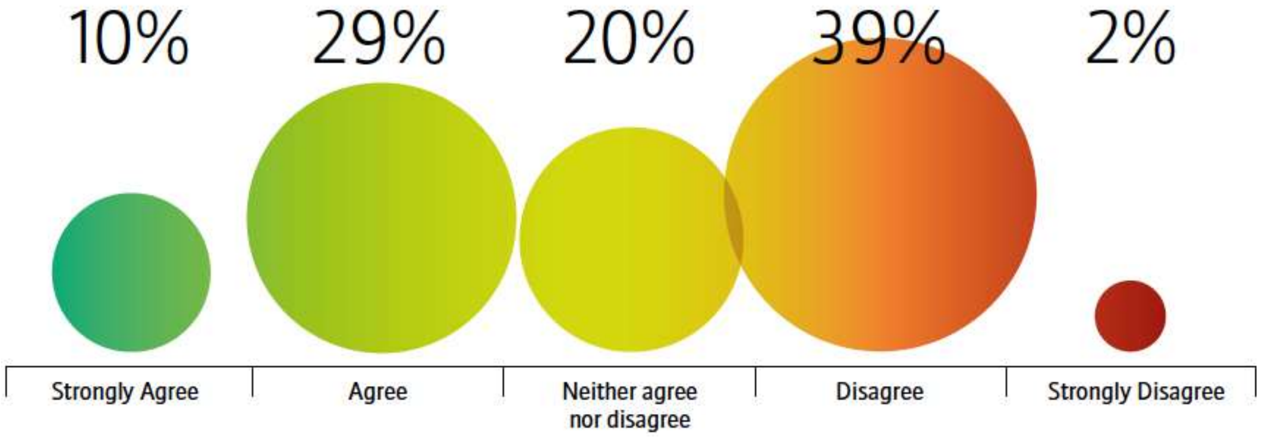
What is the role of electricity and storage to advance the renewable uptake in heating and transport ?

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."

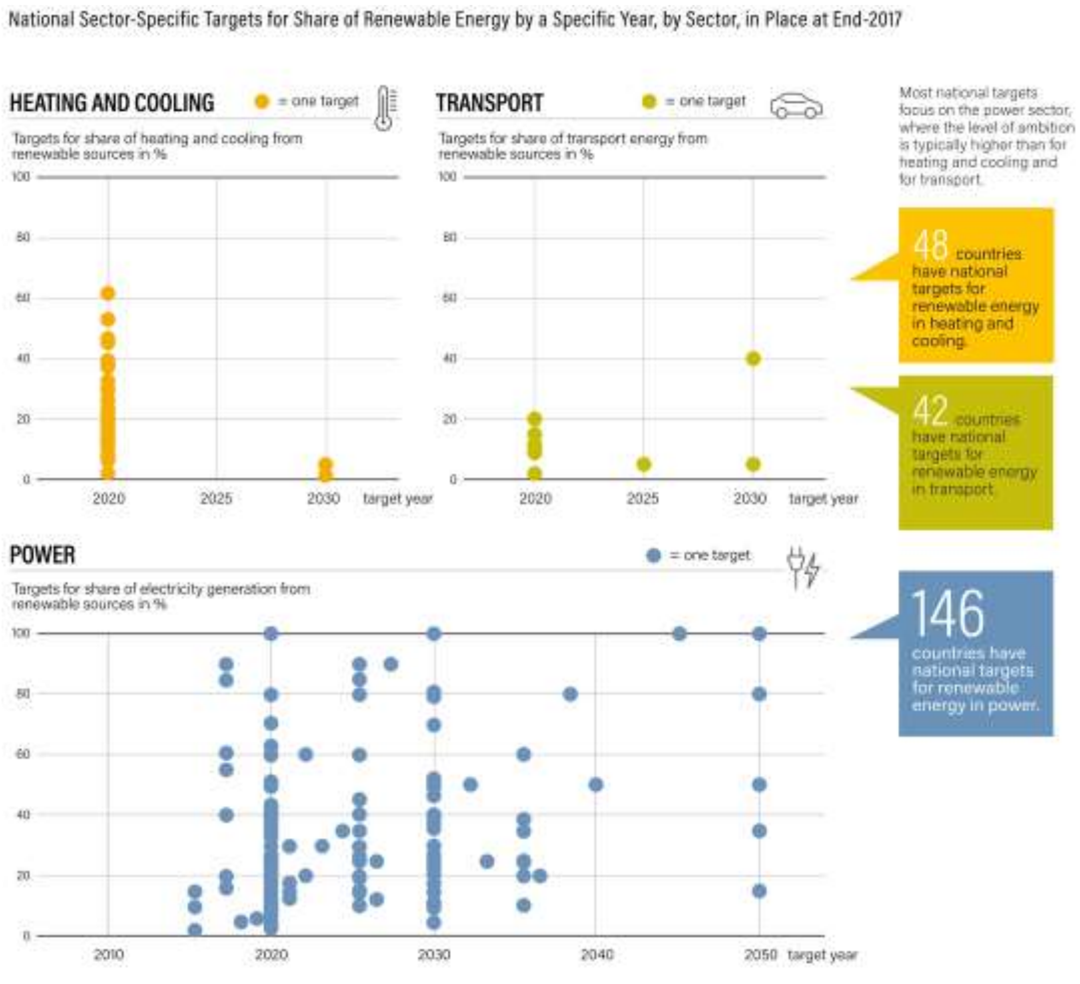


REN21 Renewables Global Futures Report

There is a lack of reliable data on renewable energy heating

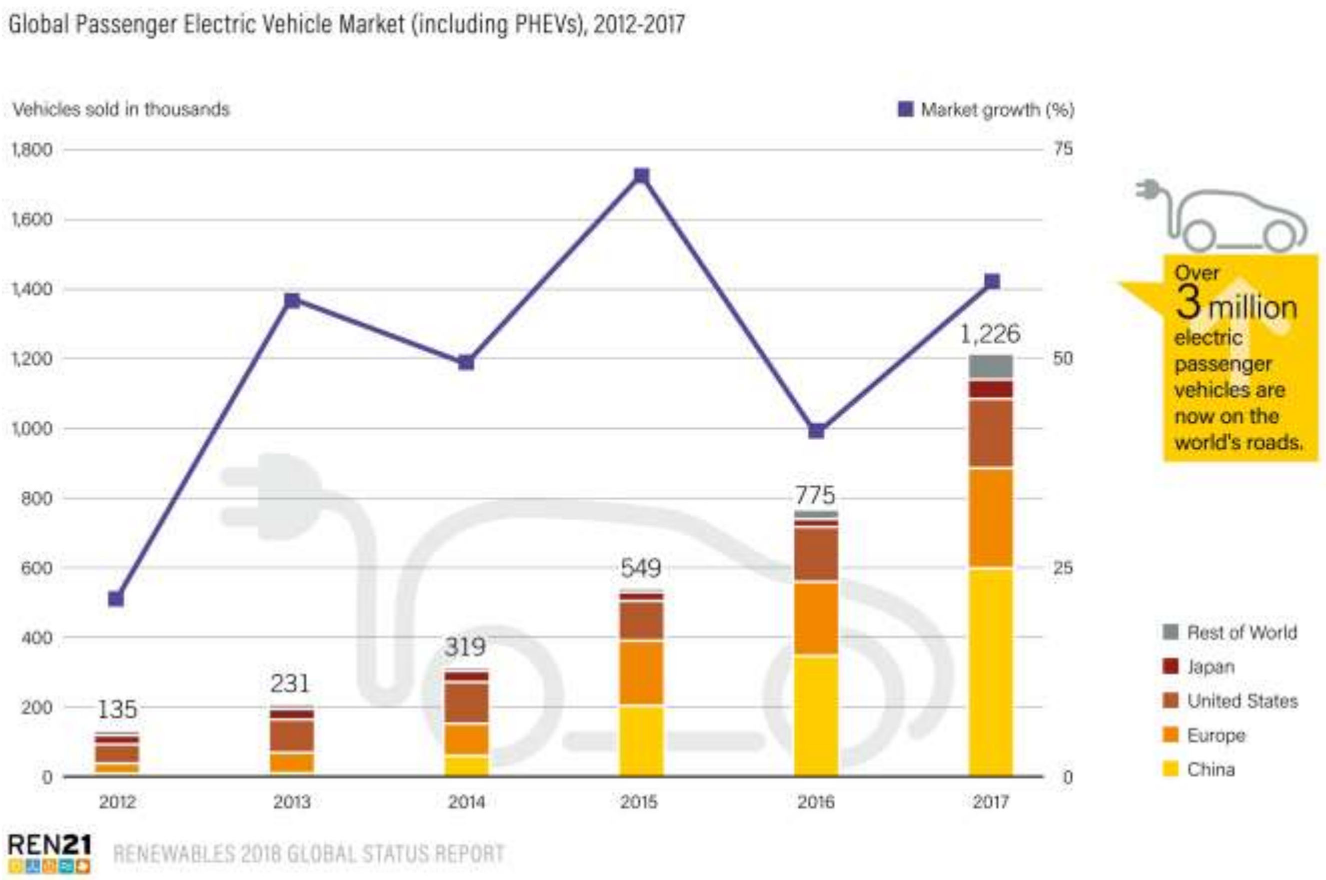
Storage in the heat sector

- 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



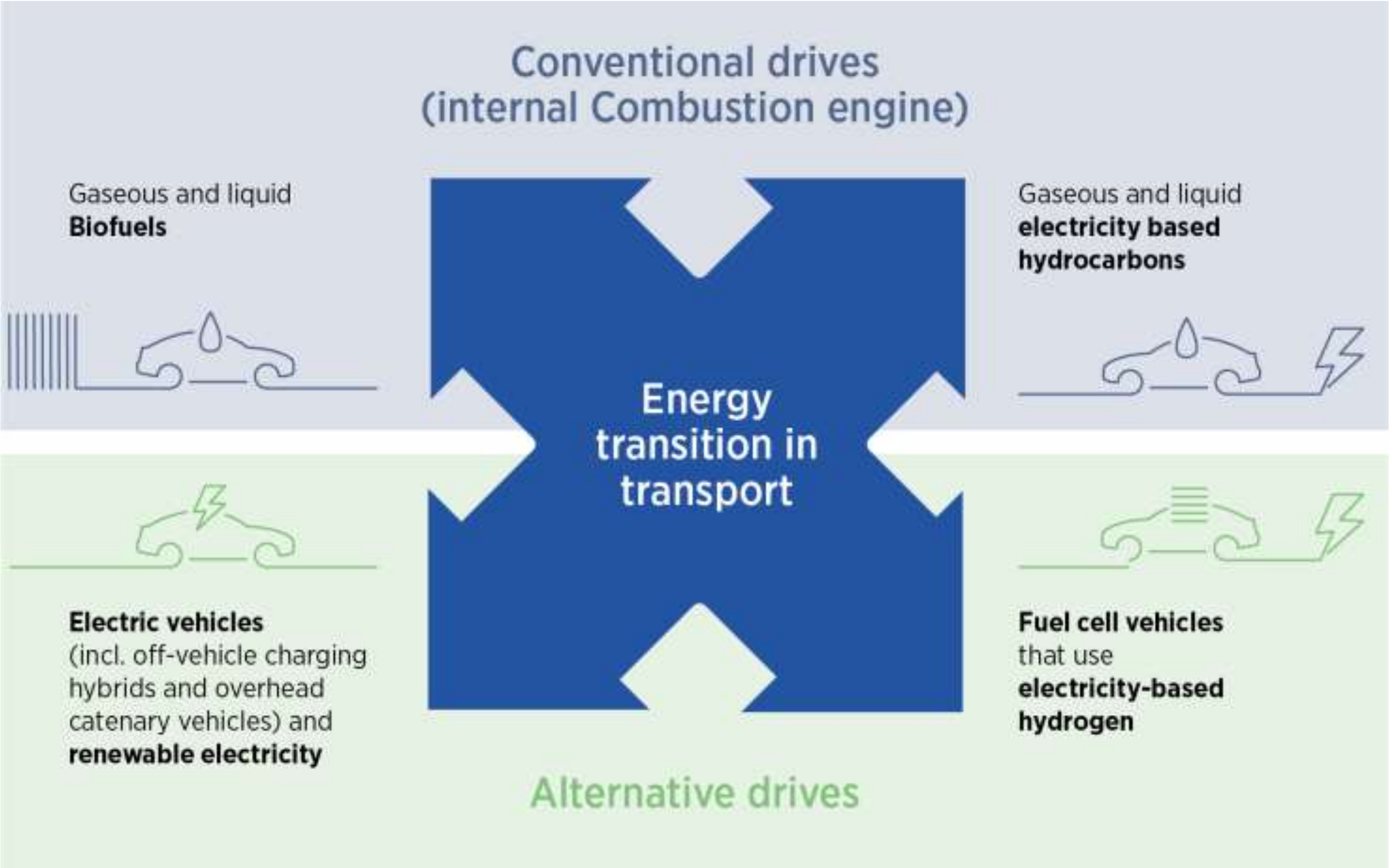
Need to increase policy attention on heating to drawn on the potential for better integration

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 = Mobillity Security



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

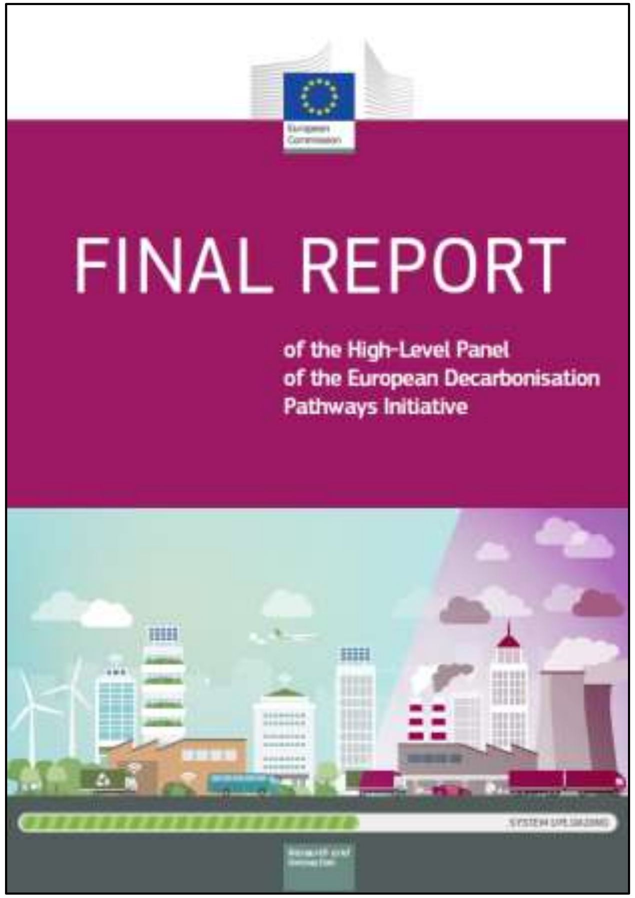
Renewable electricity-based mobility vs Electric mobility

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

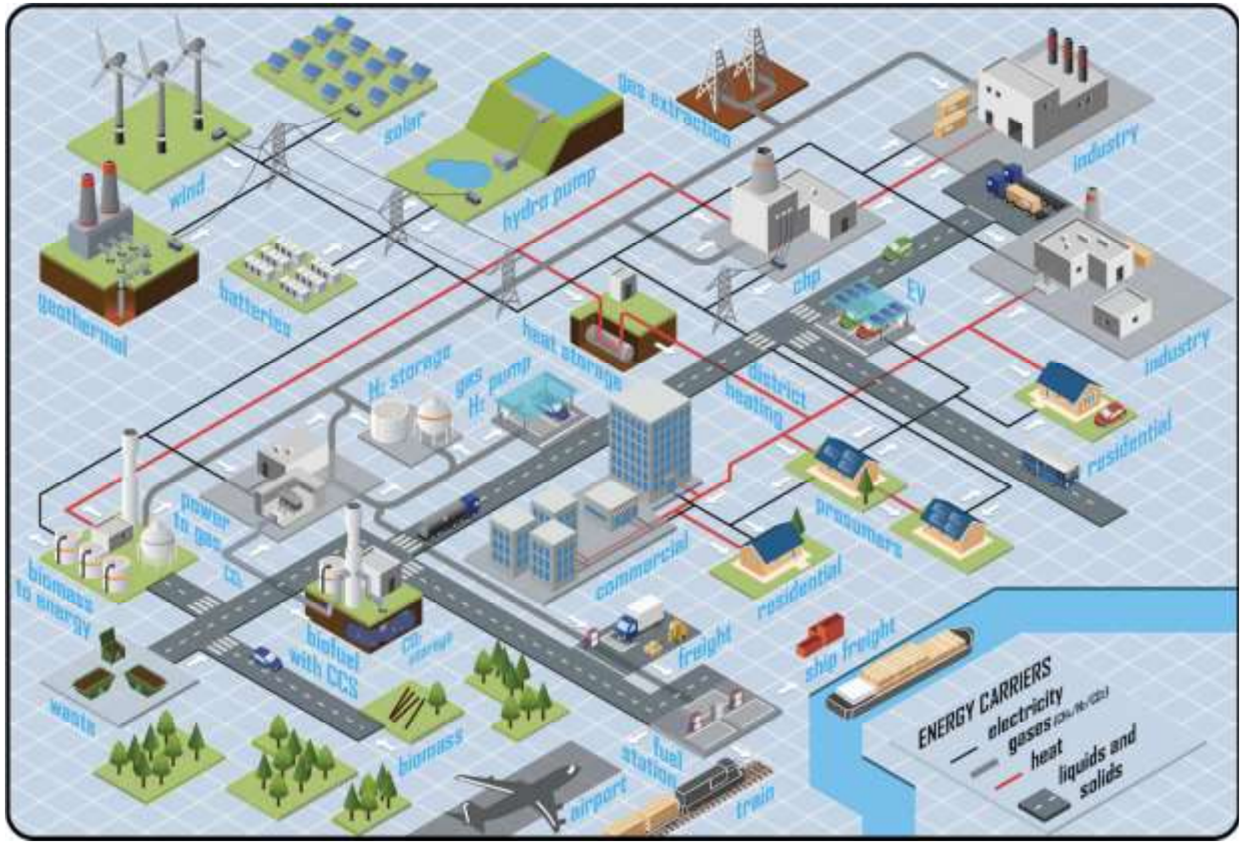
Two key challenges: climate neutrality and the systemic change needed for that

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

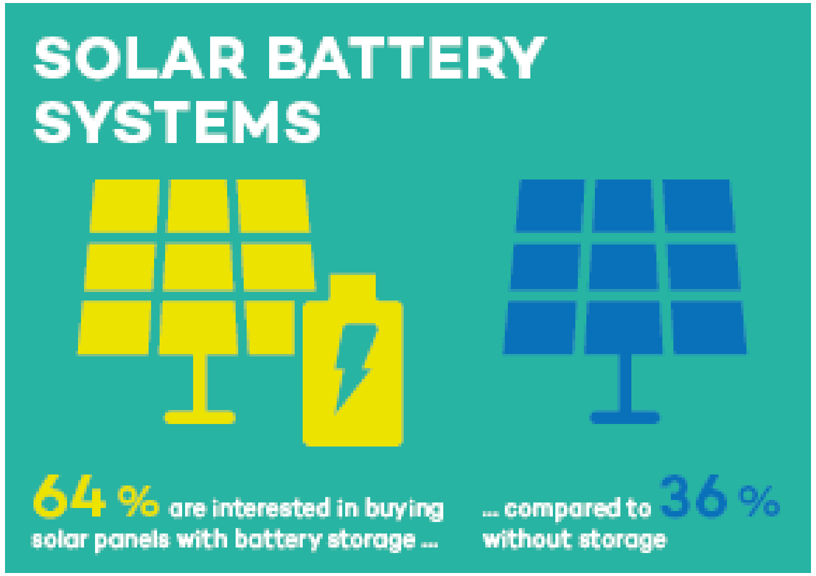


socio-economic change
awareness
citizen engagement
governance and planning
regulation and policies
markets
business models
jobs

Source: HLP report of EDPI, 2018

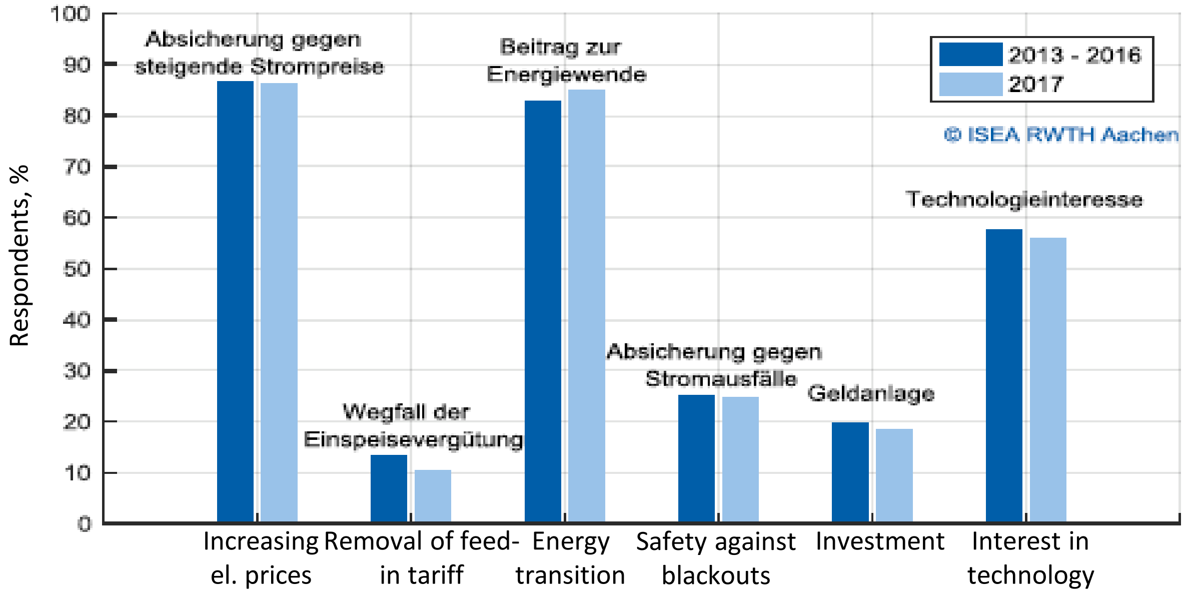
Social innovation is more than acceptance

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?

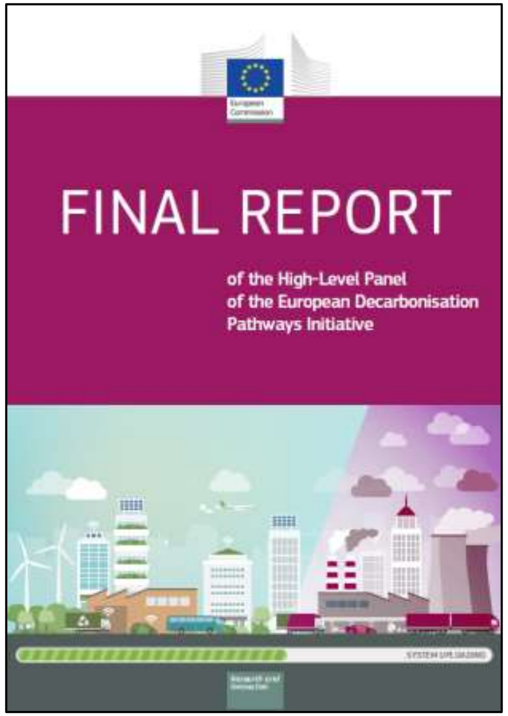
Mining-industrial complex?

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?



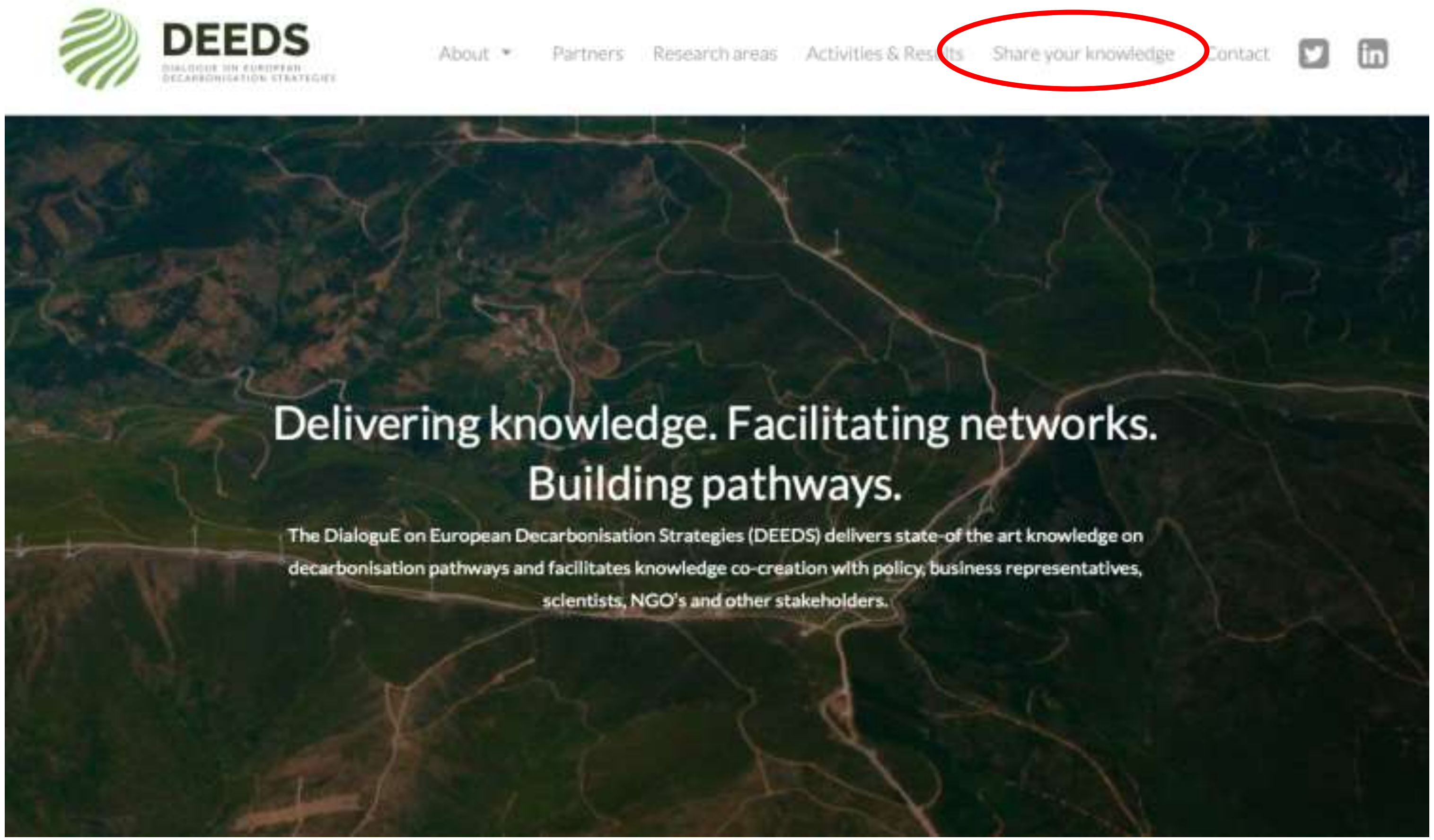
- **Deeply integrated zero-carbon energy system needs** zero-carbon electrons, zero-carbon 'molecules,' zero-carbon heat, and various types of storage

- **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 to share your thoughts



Thank you!

Prof. Evelina Trutnevyte
Renewable Energy Systems,
University of Geneva

Email: evelina.trutnevyte@unige.ch
Website: www.unige.ch/res
Twitter: @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

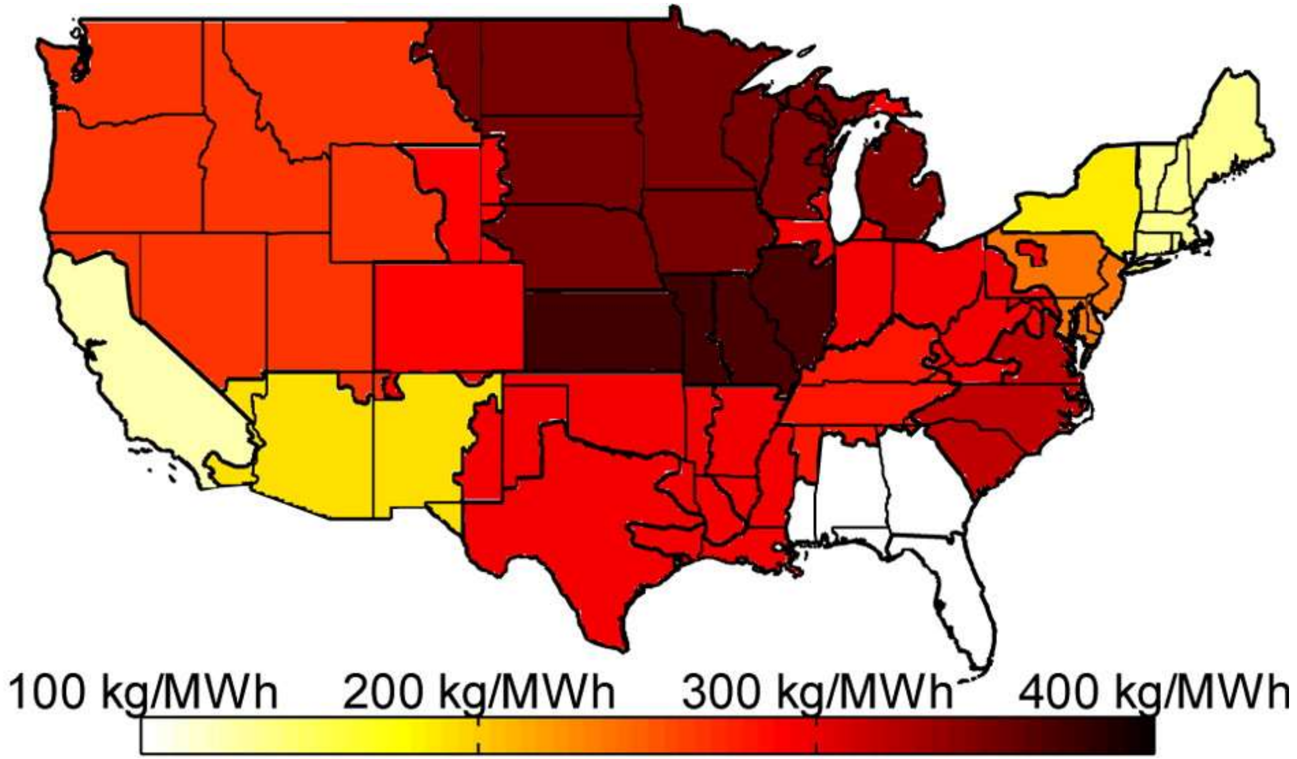
Alfred P. Sloan FOUNDATION

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)

CO_2 emissions intensity from storage energy arbitrage operations

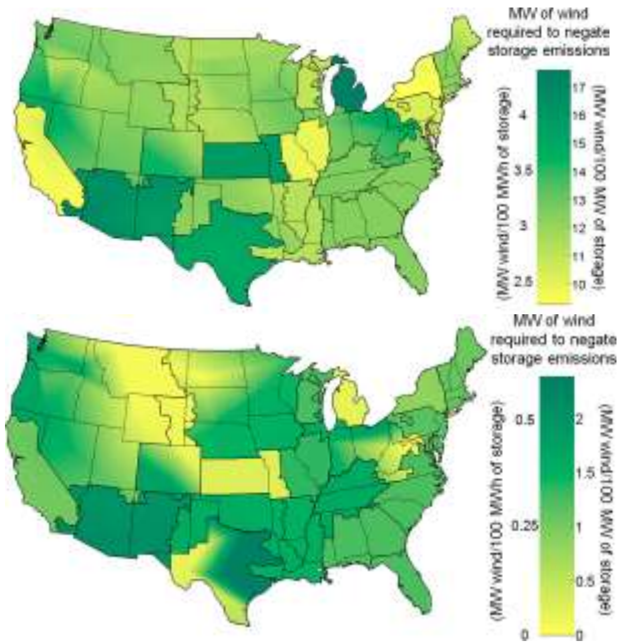


Hittinger, E. S. and Azevedo, I. M. L. Environmental Science and Technology, 2015, 49(5), pp. 3203–3210.

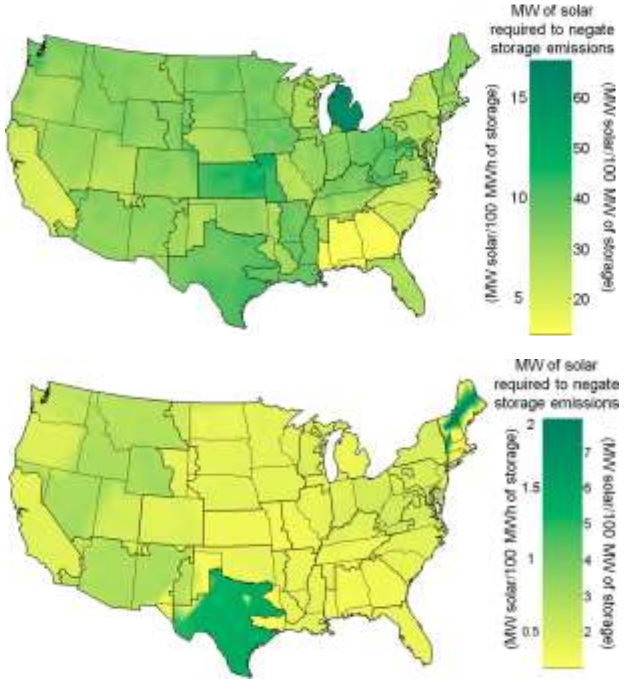
Wind and solar displace storage-induced emissions

- **Renewables displace** storage-induced **emissions,** depending on location and operation (Hittinger & **Azevedo**, 2017)

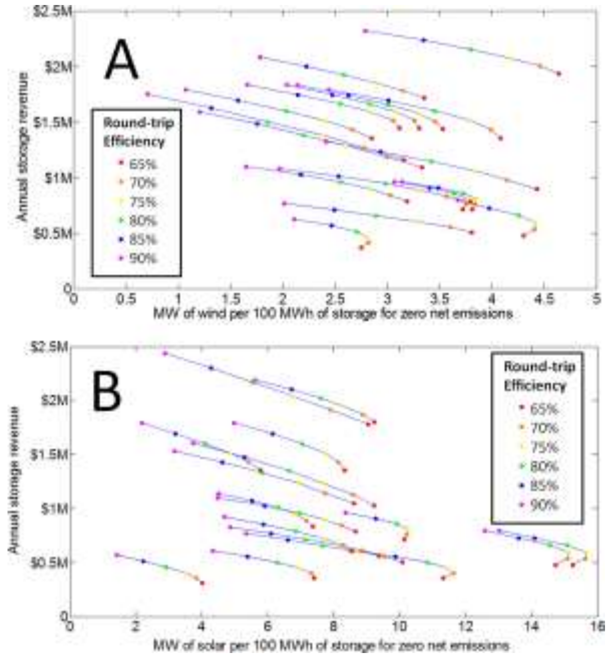
- **0.1–18 MW of wind power** required to offset emissions induced by 100 MW storage



- **1–67 MW of solar power** required to offset emissions



- **Increasing storage efficiency** reduces amount renewables

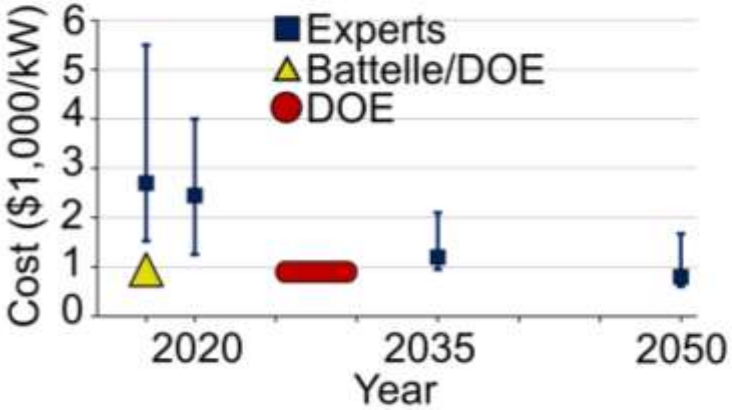


Hittinger, E. and Azevedo, I. M. L. Environmental Science and Technology, 2017, 51(21), pp. 12988–12997.

Fuel cells’ continuous power can balance renewables

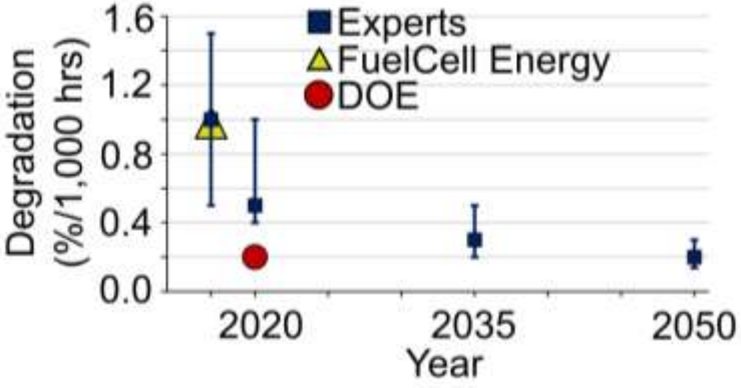
- We elicited **27 experts’ assessments** of solid oxide fuel cell (SOFC) cost and performance, and conducted a follow-up workshop on market viability

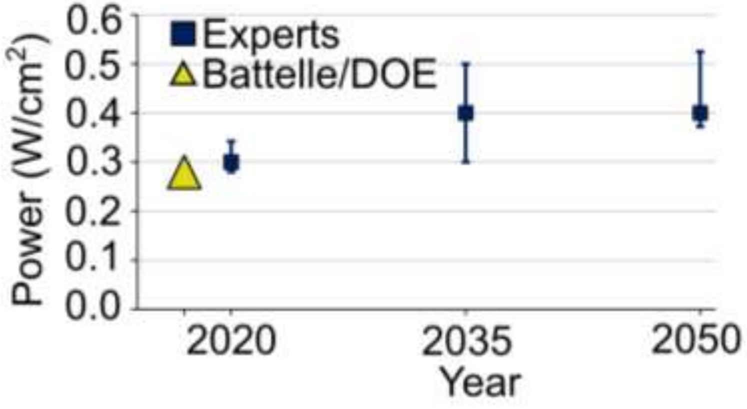
- Performance **trajectory?**
- How to **reduce cost?**
- Favorable **markets?**



	Ranking		
	1st	2nd	3rd
Cost of material	13	8	5
Cost of machinery	7	8	7
Cost of labor	5	5	7
Cost of scrap	1	3	3
Cost of tooling	1	3	1

	U.S. Ranking	
	1st	2nd
Medium (5–500 kW)	11	9
Small (0.5–5 kW)	8	9
Large (500 kW–10 MW)	3	2
Grid support (>10 MW)	1	2





	Global Ranking	
	1st	2nd
Small (0.5–5 kW)	18	5
Medium (5–500 kW)	5	13
Large (500 kW–10 MW)		3
Grid support (>10 MW)		1

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 H_2 generated by renewables
- Fuel cell cost could decline to **$1,000/kW by 2035**, material costs significant

Thank you!

mwhiston@andrew.cmu.edu

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

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?

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Chair: Dr Rob Gross, Imperial College London