Agenzia nazionale per le nuove tecnologie,
l'energia e lo sviluppo economico sostenibile

Power system: ongoing structural changes and implications on air pollution

Francesco Gracceva
ENEA

Joint Research Centre – European Commission
Expert Meeting "Addressing the unforeseen impact of structural changes on European air quality"
Warsaw, 11th and 12th February 2019

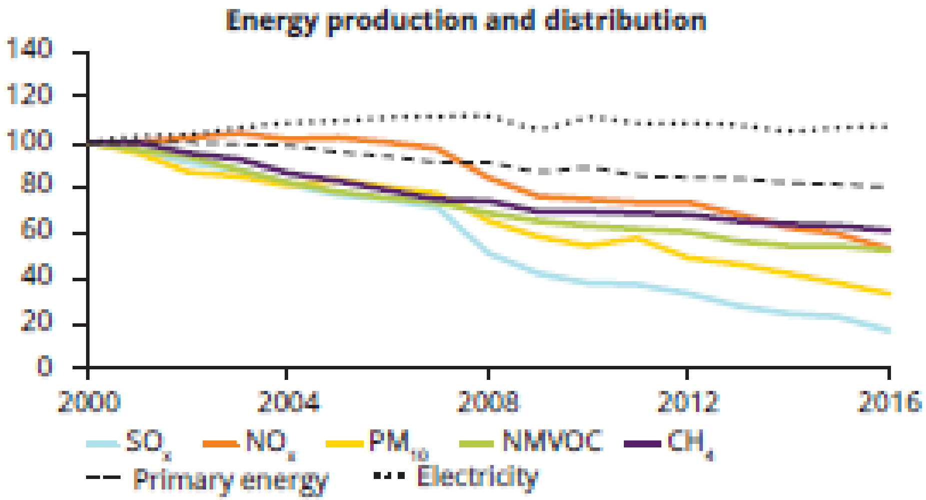
1. **Context: Air pollutant emissions from energy production and distribution**

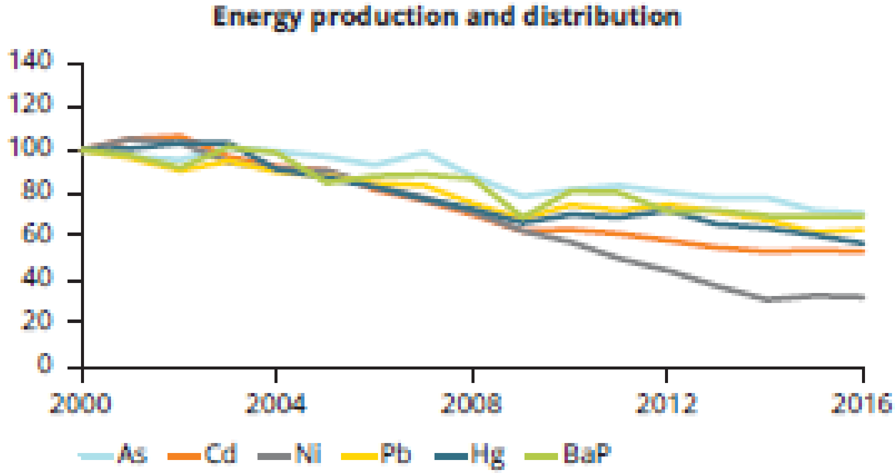
2. What's next

3. Challenges from ongoing structural changes in the power system: theory and insights from recent trends

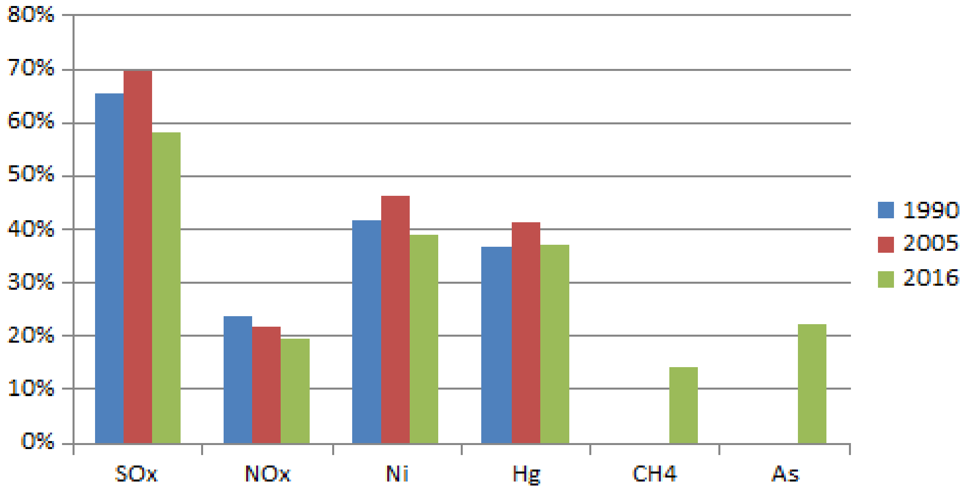
4. Is a 100% renewable European power system feasible by 2050?

Air pollution from energy production and distrib.: trends





Contribution to total EU-28 emissions from Energy production and distrib.



Air pollution from energy production and distrib.: trends / NOx

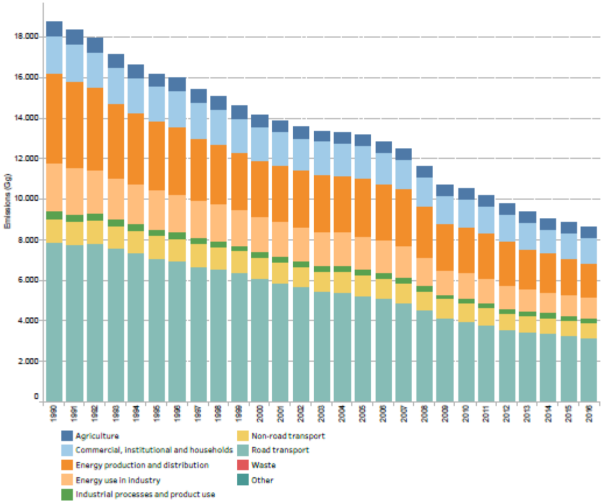
EU-28 emissions of NOx 1990-2016

NOx by country (2016)

Note: Please zoom in to see the results for small countries such as Lichtenstein.

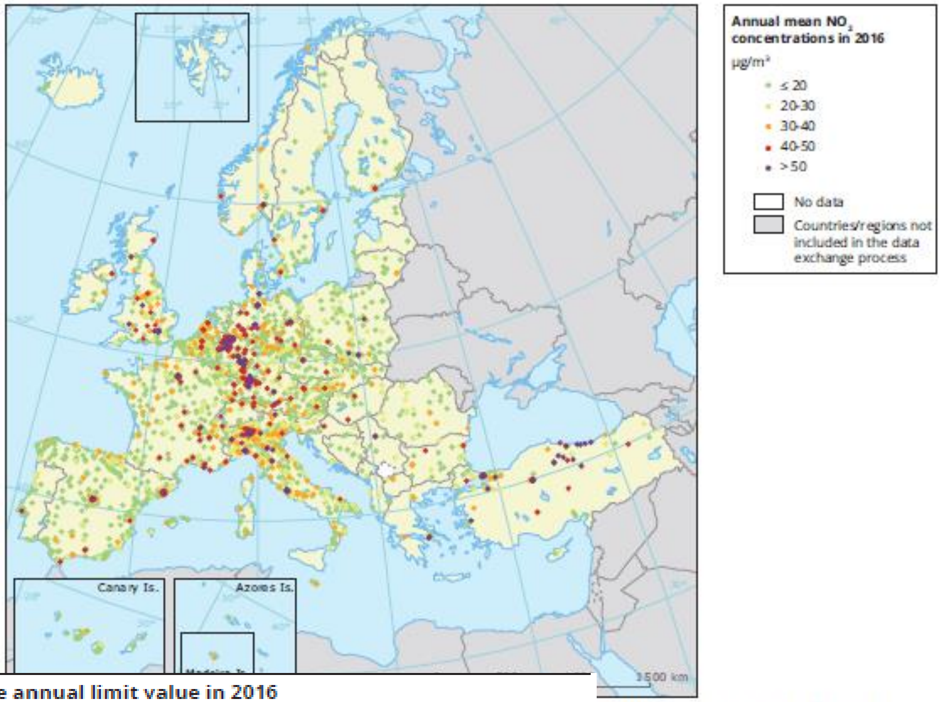
Map shows emissions for year: 2016

NOx by sector



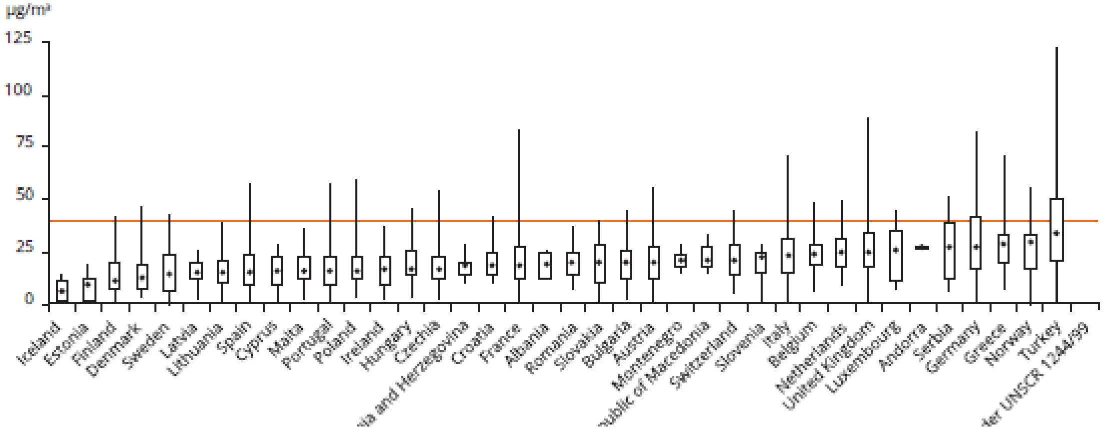
Status of concentrations

Map 6.1 Concentrations of NO_2, 2016



pond to values above the EU annual limit value and
included in the map. The French overseas territories'
ta-and-maps/dashboards/air-quality-statistics

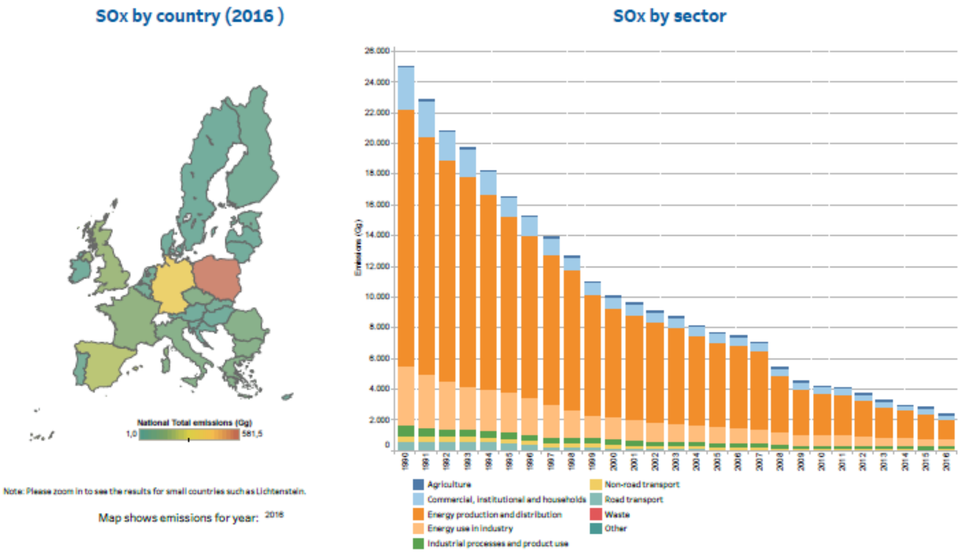
Figure 6.1 NO_2 concentrations in relation to the annual limit value in 2016



Source: EEA, 2018

Air pollution from energy production and distrib.: trends / SOx

EU-28 emissions of SOx 1990-2016



Source: EEA, 2018

Status of concentrations

- SO2 concentrations are generally well below the limit values for the protection of human health
- In 2016, 17 stations (out of about 1 600) registered concentrations above the hourly limit value, 23 stations registered concentrations above the daily limit value for SO2.
- On the contrary, 37% of all the stations reporting SO2 levels, located in 30 reporting countries, measured SO2 concentrations above the WHO air quality guideline of 20 µg/m3 for daily mean concentrations in 2016.

Acidification and vegetation exposure

- Strong reductions in emissions of SOx over the past three decades. Nitrogen compounds emitted as NOx are principal acidifying components in both terrestrial and aquatic ecosystems. However, SOx, have a higher acidifying potential.

Air pollution from energy production and distrib.: trends / Ni

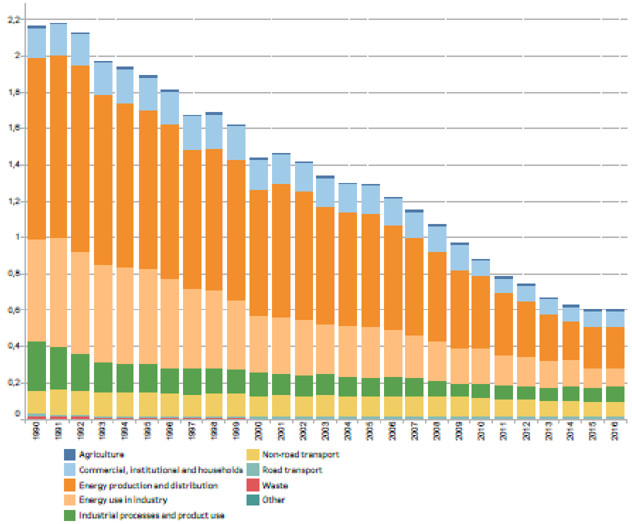
EU-28 emissions of Ni 1990-2016

Ni by country (2016)

Note: Please zoom in to see the results for small countries such as Lichtenstein.

Map shows emissions for year: 2016

Ni by sector



Status of concentrations - Ni

Annual mean nickel concentrations in 2016

ng/m³ ● ≤ 5 ● 5-10 ● 10-20 ● 20-30 ● > 30

☐ No data

▨ Countries/regions not included in the data exchange process

Air pollution from energy production and distrib.: trends / Hg and As

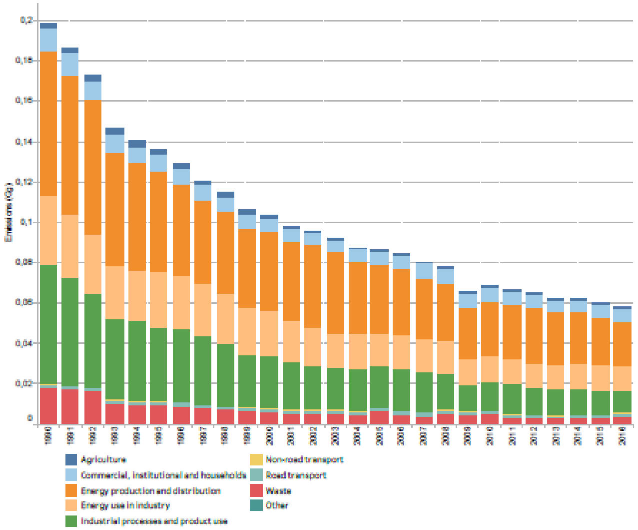
EU-28 emissions of Hg 1990-2016

Hg by country (2016)

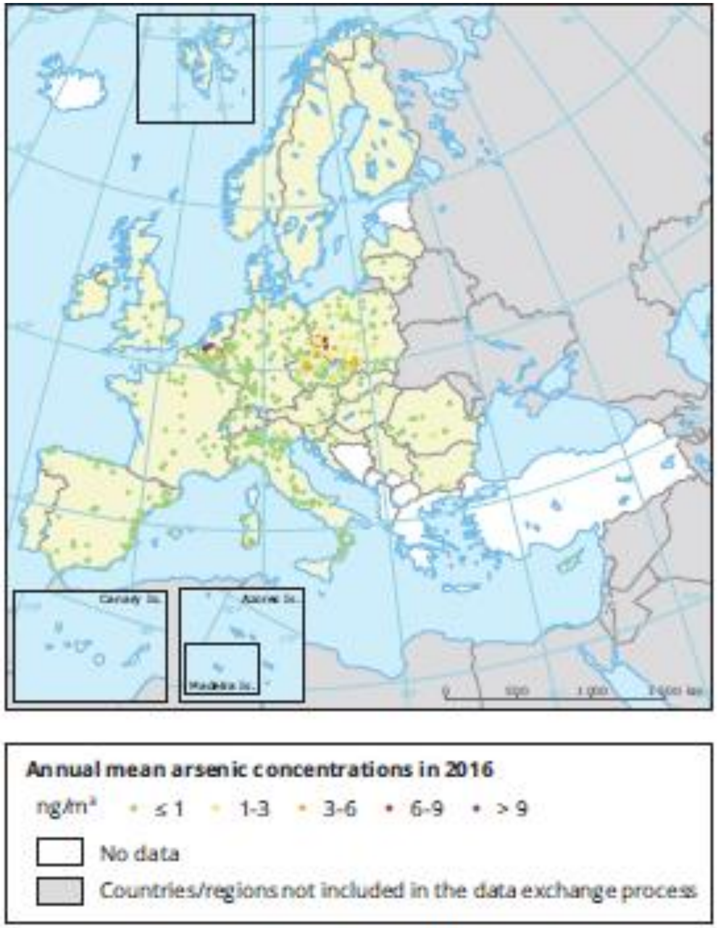
Note: Please zoom in to see the results for small countries such as Lichtenstein.

Map shows emissions for year: 2016

Hg by sector



Status of concentrations - As



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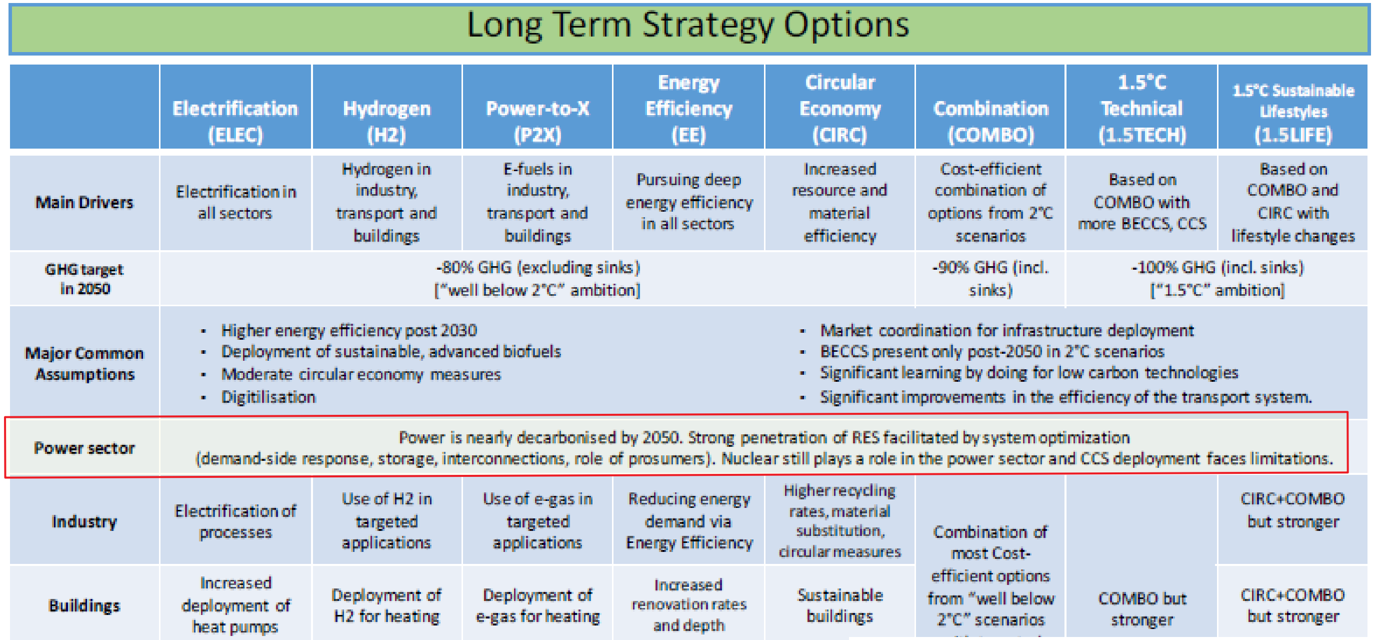
EU long-term strategy



Long Term Strategy Options

	Electrification (ELEC)	Hydrogen (H2)	Power-to-X (P2X)	Energy Efficiency (EE)	Circular Economy (CIRC)	Combination (COMBO)	1.5°C Technical (1.5TECH)	1.5°C Sustainable Lifestyles (1.5LIFE)
Main Drivers	Electrification in all sectors	Hydrogen in industry, transport and buildings	E-fuels in industry, transport and buildings	Pursuing deep energy efficiency in all sectors	Increased resource and material efficiency	Cost-efficient combination of options from 2°C scenarios	Based on COMBO with more BECCS, CCS	Based on COMBO and CIRC with lifestyle changes
GHG target in 2050	-80% GHG (excluding sinks) ["well below 2°C" ambition]					-90% GHG (incl. sinks)	-100% GHG (incl. sinks) ["1.5°C" ambition]	
Major Common Assumptions	• Higher energy efficiency post 2030 • Deployment of sustainable, advanced biofuels • Moderate circular economy measures • Digitilisation				• Market coordination for infrastructure deployment • BECCS present only post-2050 in 2°C scenarios • Significant learning by doing for low carbon technologies • Significant improvements in the efficiency of the transport system.			
Power sector	Power is nearly decarbonised by 2050. Strong penetration of RES facilitated by system optimization (demand-side response, storage, interconnections, role of prosumers). Nuclear still plays a role in the power sector and CCS deployment faces limitations.							
Industry	Electrification of processes	Use of H2 in targeted applications	Use of e-gas in targeted applications	Reducing energy demand via Energy Efficiency	Higher recycling rates, material substitution, circular measures	Combination of most Cost-efficient options from "well below 2°C" scenarios	COMBO but stronger	CIRC+COMBO but stronger
Buildings	Increased deployment of heat pumps	Deployment of H2 for heating	Deployment of e-gas for heating	Increased renovation rates and depth	Sustainable buildings			CIRC+COMBO but stronger
Transport sector	Faster electrification for all transport modes	H2 deployment for HDVs and some for LDVs	E-fuels deployment for all modes	Increased modal shift	Mobility servi			
Other Drivers		H2 in gas distribution grid	E-gas in gas distribution grid					

Source: IN-DEPTH ANALYSIS IN SUPPORT OF THE COMMISSION COMMUNICATION COM(2018) 773. European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy

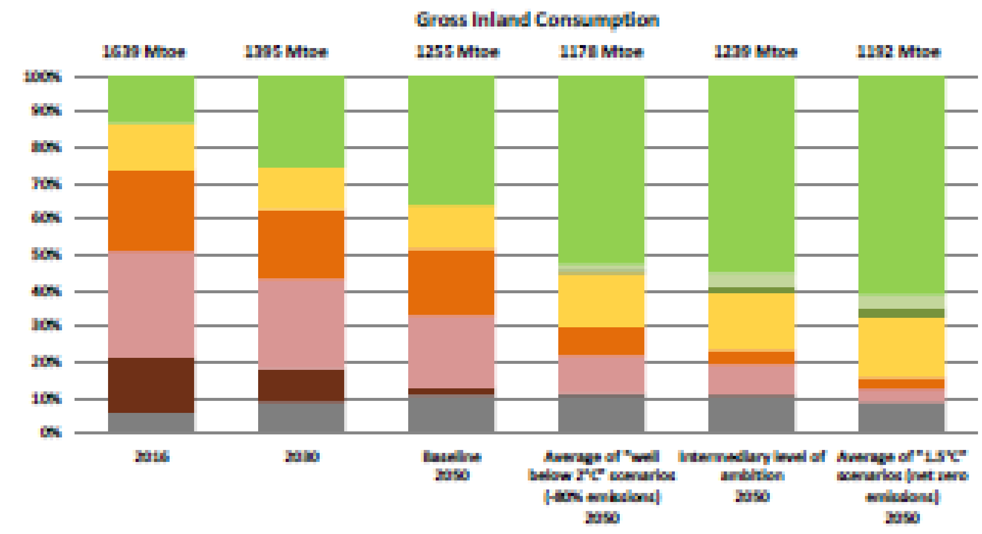
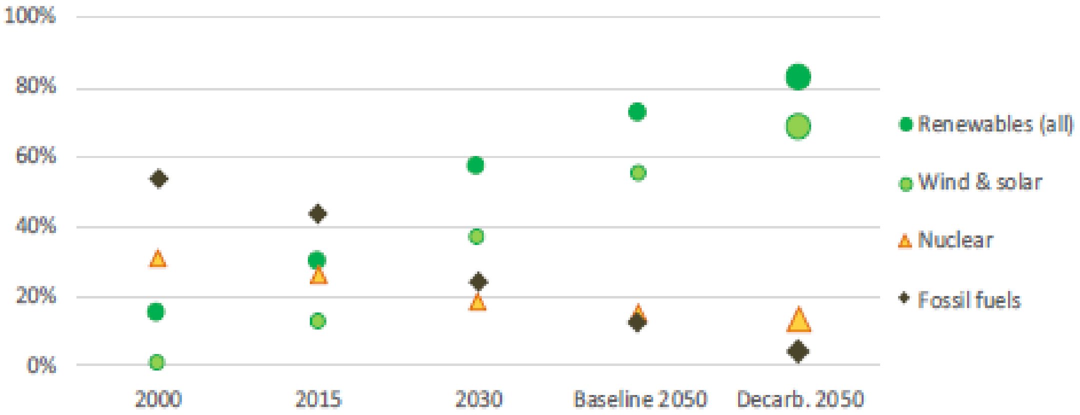


Figure 2. Fuel mix in Gross Inland Consumption

EU long-term strategy



Notes: 1. The shares of renewables, nuclear and fossil fuels sum to 100%. Wind & solar is a component of renewables. 2: The "Decarb. 2050" points are the averages across all decarbonisation scenarios per category. These scenarios provide very similar power mix in 2050, with renewables ranging from to 81% to 85% (wind & solar alone from to 65% to 72%), nuclear from 12% to 15% and fossil fuels from 2% to 6%.

Source: Eurostat (2000, 2015), PRIMES.

Results within the range of other studies:

- For EU values from slightly above 75% in 2050 (IEA ETP B2DS and Shell Sky scenario203) to an almost fully renewables power system (IRENA's global energy transformation, Greenpeace Energy Revoluti and the Öko-Institut Energy Vision).
- Consistent with IPCC Special Report on 1.5°C

Estimated implications of EU long-term strategy on air pollution

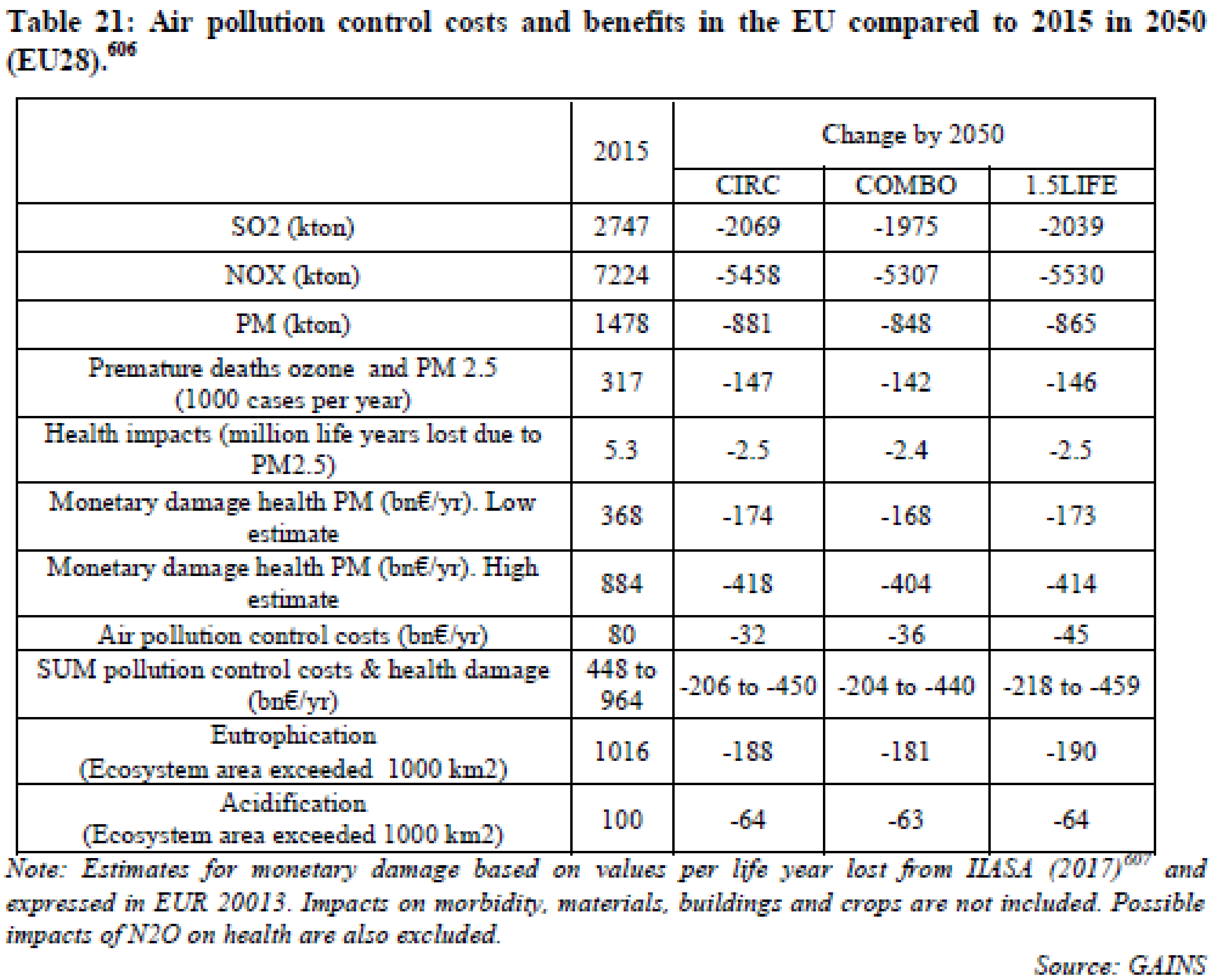


Table 21: Air pollution control costs and benefits in the EU compared to 2015 in 2050 (EU28).[606]

	2015	Change by 2050		
		CIRC	COMBO	1.5LIFE
SO2 (kton)	2747	-2069	-1975	-2039
NOX (kton)	7224	-5458	-5307	-5530
PM (kton)	1478	-881	-848	-865
Premature deaths ozone and PM 2.5 (1000 cases per year)	317	-147	-142	-146
Health impacts (million life years lost due to PM2.5)	5.3	-2.5	-2.4	-2.5
Monetary damage health PM (bn€/yr). Low estimate	368	-174	-168	-173
Monetary damage health PM (bn€/yr). High estimate	884	-418	-404	-414
Air pollution control costs (bn€/yr)	80	-32	-36	-45
SUM pollution control costs & health damage (bn€/yr)	448 to 964	-206 to -450	-204 to -440	-218 to -459
Eutrophication (Ecosystem area exceeded 1000 km2)	1016	-188	-181	-190
Acidification (Ecosystem area exceeded 1000 km2)	100	-64	-63	-64

Note: Estimates for monetary damage based on values per life year lost from IIASA (2017)[607] and expressed in EUR 20013. Impacts on morbidity, materials, buildings and crops are not included. Possible impacts of N2O on health are also excluded.

Source: GAINS

End of the story?

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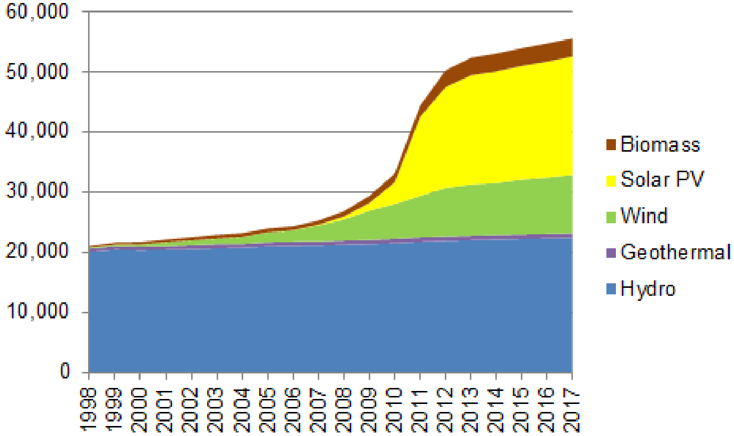
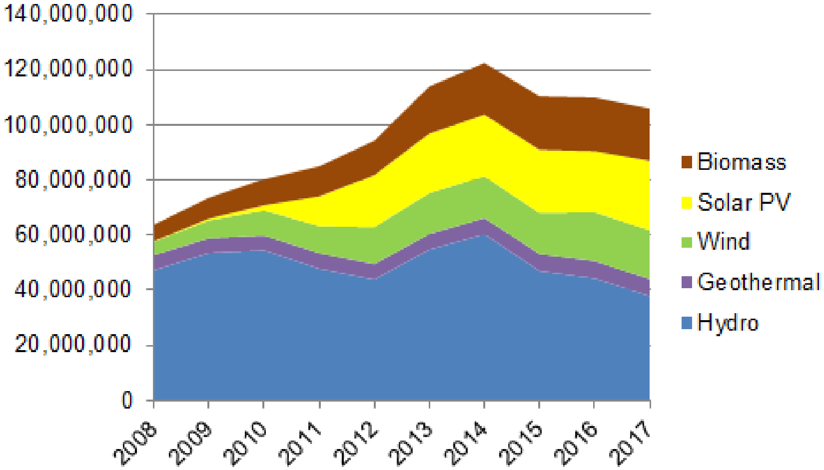
Increasing penetration of VER: recent trends in Italy

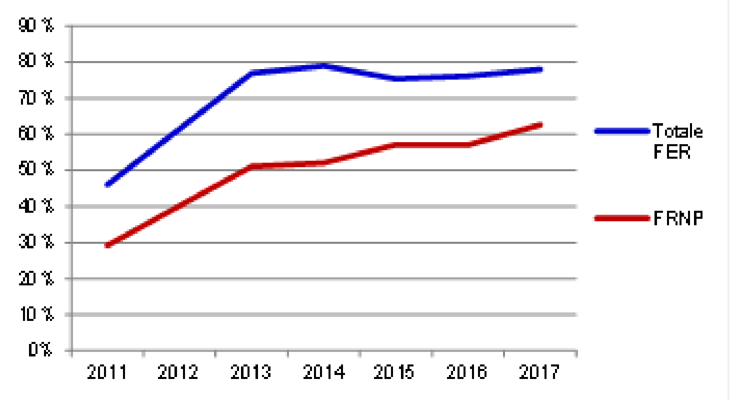
RES installed capacity - Italy 1998-2017



RES electricity generation – Italy 2008-2017



Max penetration RES and VER (as % of demand)



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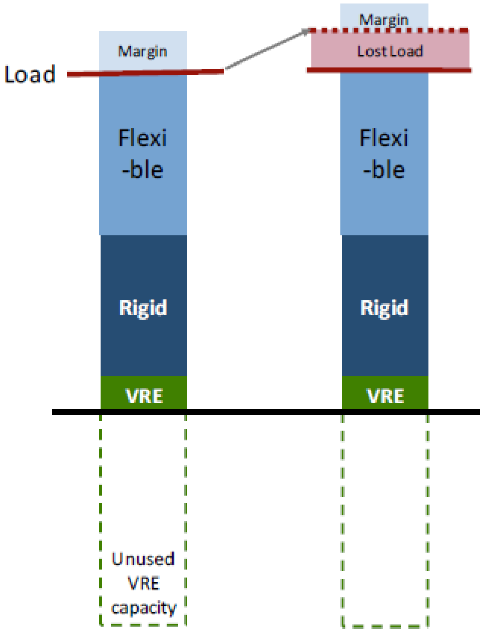
Adequacy : theory and insights from recent trends

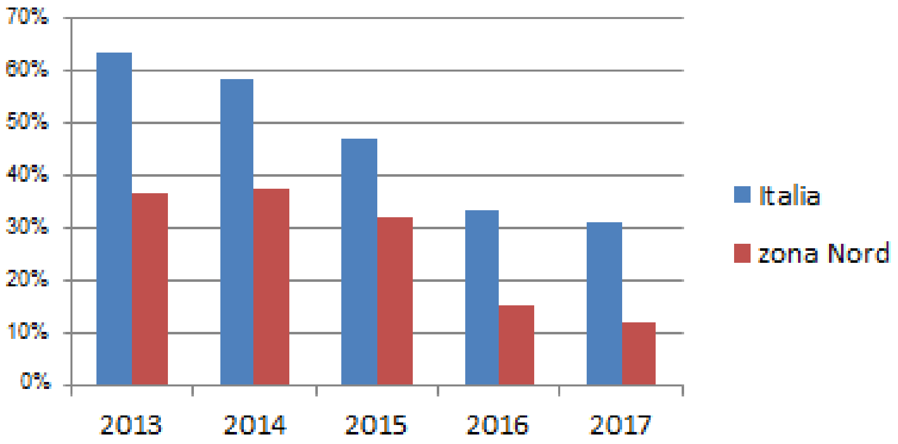
- Peak load adequacy during hours with high demand and low renewable input; contribution of variable renewables to peak demand can be low: low capacity credit of wind / solar
- Enough dispatchable capacity is needed to meet peak demand (incl. generation capacity, storage and demand response) BUT low capacity factors

Peak load adequacy



Baritaud, 2012

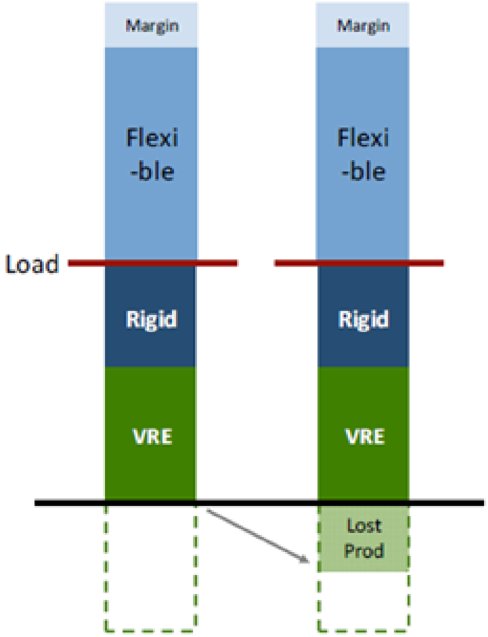
Capacity margin Italy 2013-2017



Adequacy and flexibility: theory and and insights from recent trends

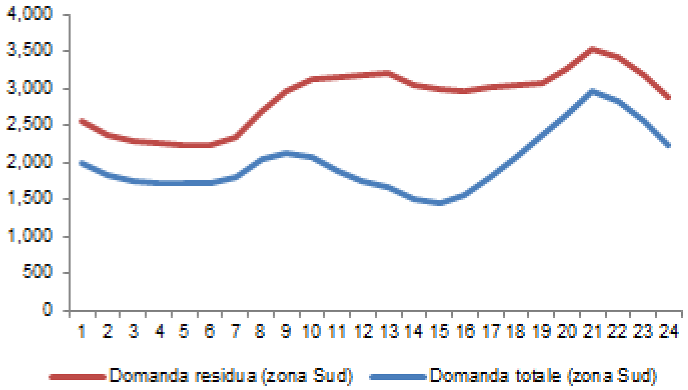
- Minimum load balancing: need to maintain generation equal to the load during hours with low demand and high RES input; minimum residual load
- Hours of excess VRE output (negative residual load)

Risk of curtailment



Baritaud, 2012

2011



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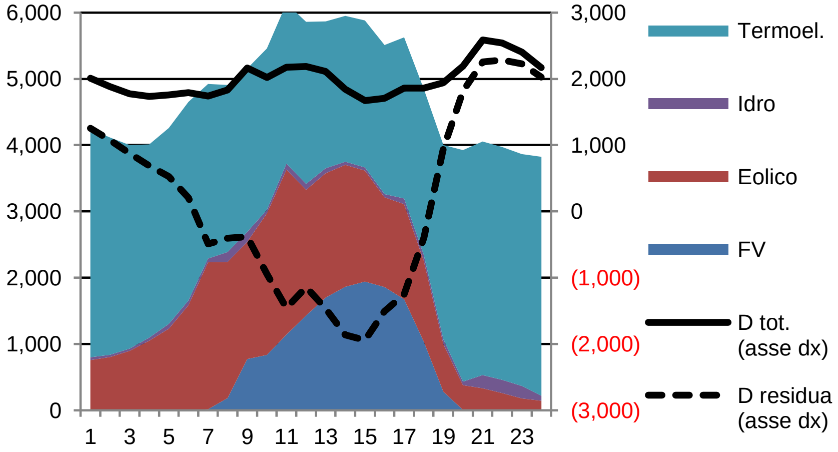
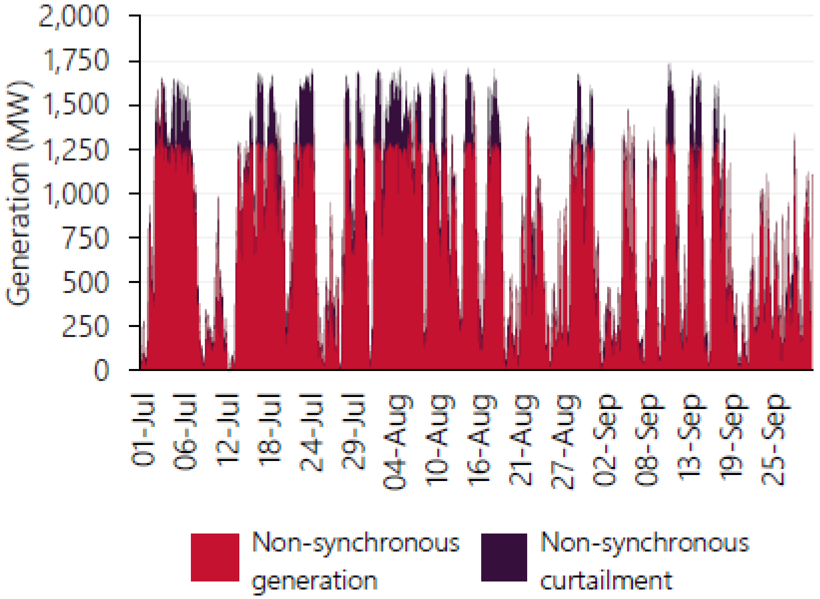


Increasing curtailment of VER

South Australia

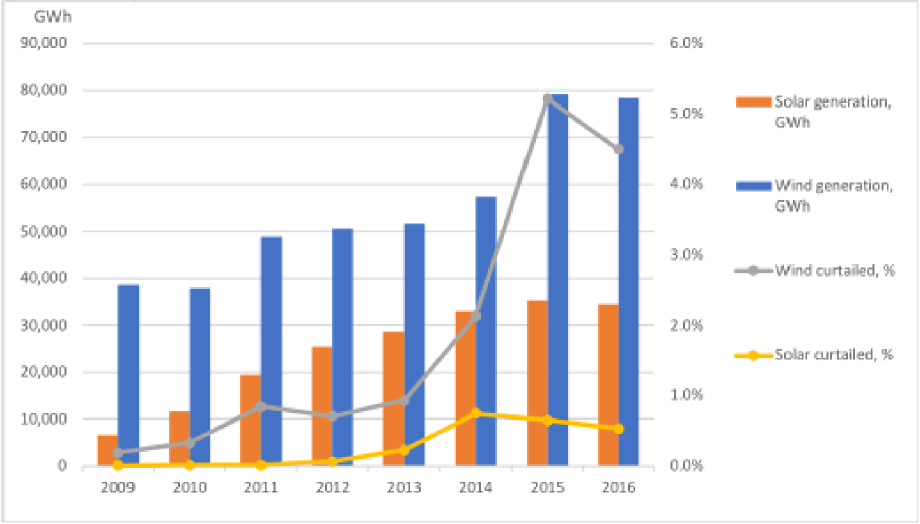
Figure 6 Generation and curtailment of non-synchronous units in South Australia



- Q3 2018, total curtailments of non-synchronous generation increased to around 150 GWh (or 10% of South Australian non-sync. gen.) curtailment 26% of the time during the quarter, highest amount on record
- Key drivers were record high wind generation and insufficient synchronous generators being available to meet system strength requirements.

Germany

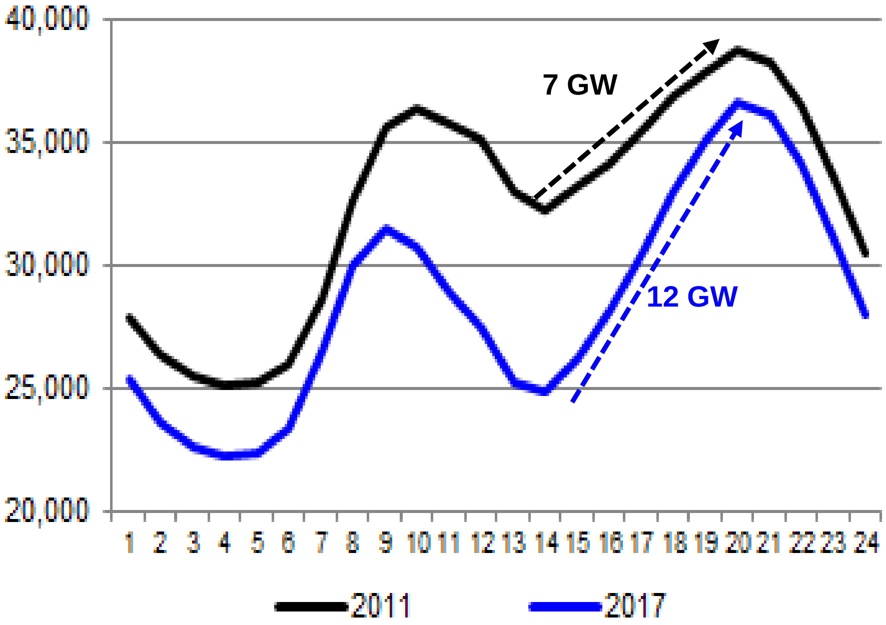
Figure 11: Wind & Solar Generation (GWh) and Curtailment (as a percentage of generation)



Power-Industry Transition, Here and Now
Wind and Solar Won't Break the Grid: Nine Case Studies
February 2018
Gerard Wynn, Energy Finance Consultant

Increasing ramp rates

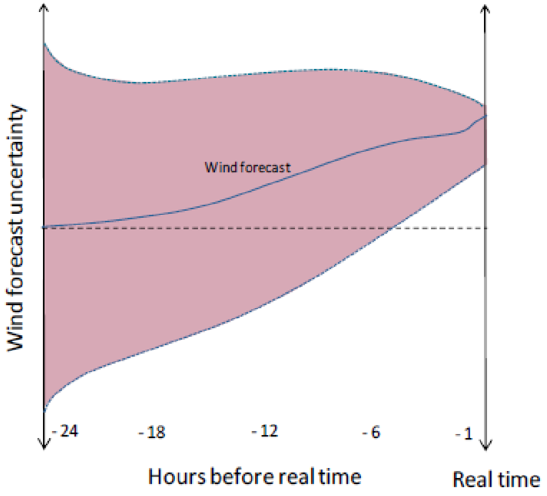
- Ramp rates of residual demand when renewable output decreases and demand increases simultanously: shape of the residual demand curve that needs to be followed by conventional generation plants; flexibility of conventional plants more frequently and intensively called upon
- Ensuring network reliability under such conditions will require a series of actions, including relying on storage and demand response. Interconnections will be particularly valuable for the aggregation of loads in different countries and to smooth wind output variations



Increasing hourly variation of electricity production

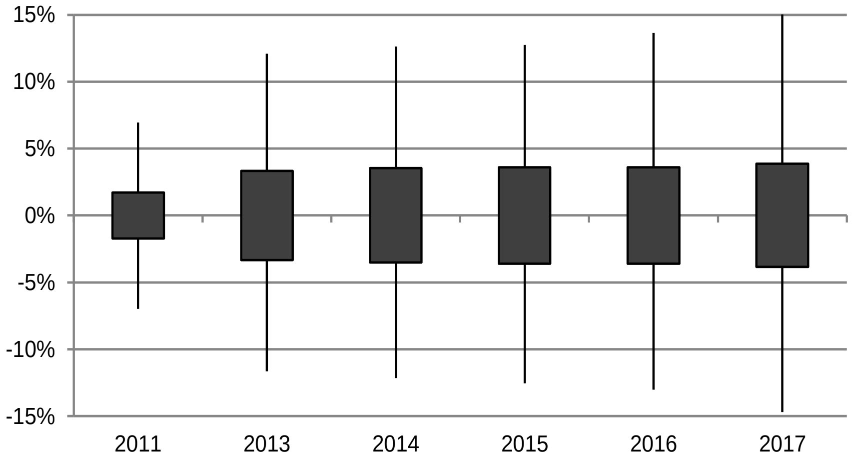
- Predictability of VRE: whereas demand uncertainty on a day-ahead time-scale is typically in the range of 1-2% of load, the mean absolute error for wind is 15%, 24 hours before real time
- Uncertain wind and solar generation forecasts increase the need for flexibility closer to real time. As a result, wind uncertainty may yield a need to redefine the amount of reserves required to maintain the standard of power system security

Figure 19 • **The evolution of wind forecast uncertainty 24 hours before real time** (illustrative)



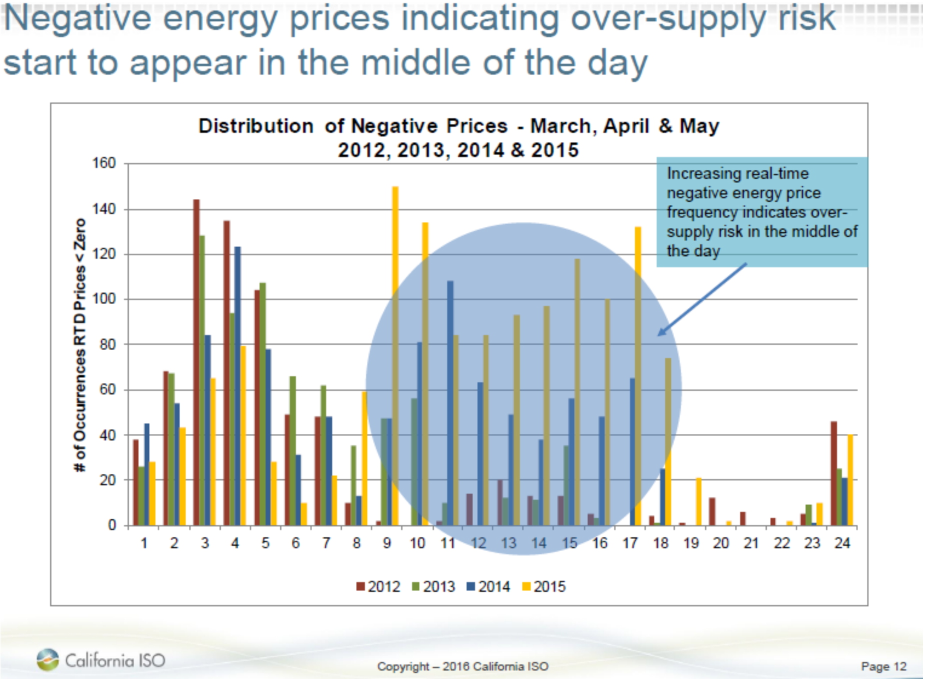
Baritaud, 2012

Hourly variation VER (as % of demand)



Increased frequency of low/negative prices

- ➢ VER shift the supply curve of conventional electricity virtually out of the market temporarily very low market prices close to zero
- ➢ Negative prices can occur if wind has to be dispatched and conventional load are running at their minimal technical level and want to avoid shut down for economic reasons or must be kept online for system security reason



Negative energy prices indicating over-supply risk start to appear in the middle of the day

Distribution of Negative Prices - March, April & May 2012, 2013, 2014 & 2015

Increasing real-time negative energy price frequency indicates over-supply risk in the middle of the day

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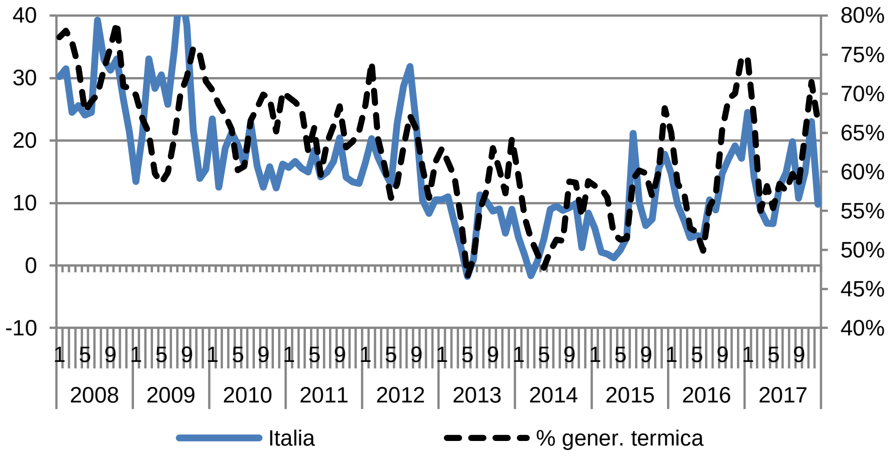
Spark spread Italy 2008-2017 and % thermal generation

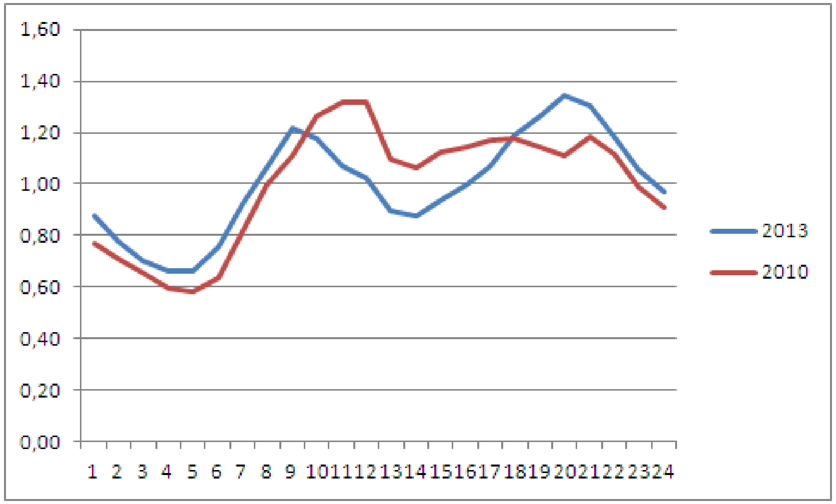


Integrating variable energy resources at the California ISO
Presented to the Air & Waste Management Association Mother Lode Chapter
March 22, 2016, Delphine Hou

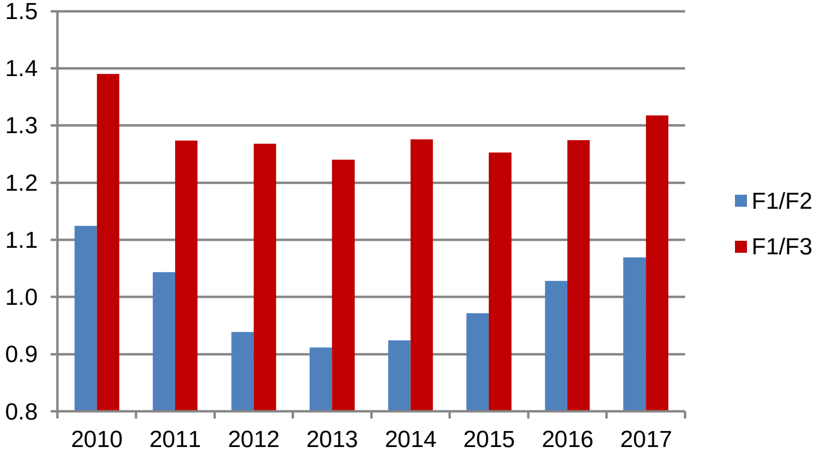
New relationship between electricity prices and demand

- Indirect impact of PV and wind on the costs at which fossil capacities are offered at times when renewable energy sources are scarce.
- Major effects: higher price volatility from hour-to-hour and day-to-day; high prices do not necessarily appear at peak demand times but at times with low availability of electricity from RES; low price level will be associated with high production from RES; growth of balancing markets

Ratio hourly price / avg price



Ratio between prices different hours



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Feasibility of 100% electricity system

- Heard Brook, Wigley, Bradshawd, *Burden of proof: A comprehensive review of the feasibility of 100% renewable-electricity systems*, Renewable and Sustainable Energy Reviews, 76 (2017) 1122–1133
- “While many modelled scenarios have been published claiming to show that a 100% renewable electricity system is achievable, there is no empirical or historical evidence that demonstrates that such systems are in fact feasible”
- “None of the 24 studies provides convincing evidence that basic feasibility criteria can be met ”

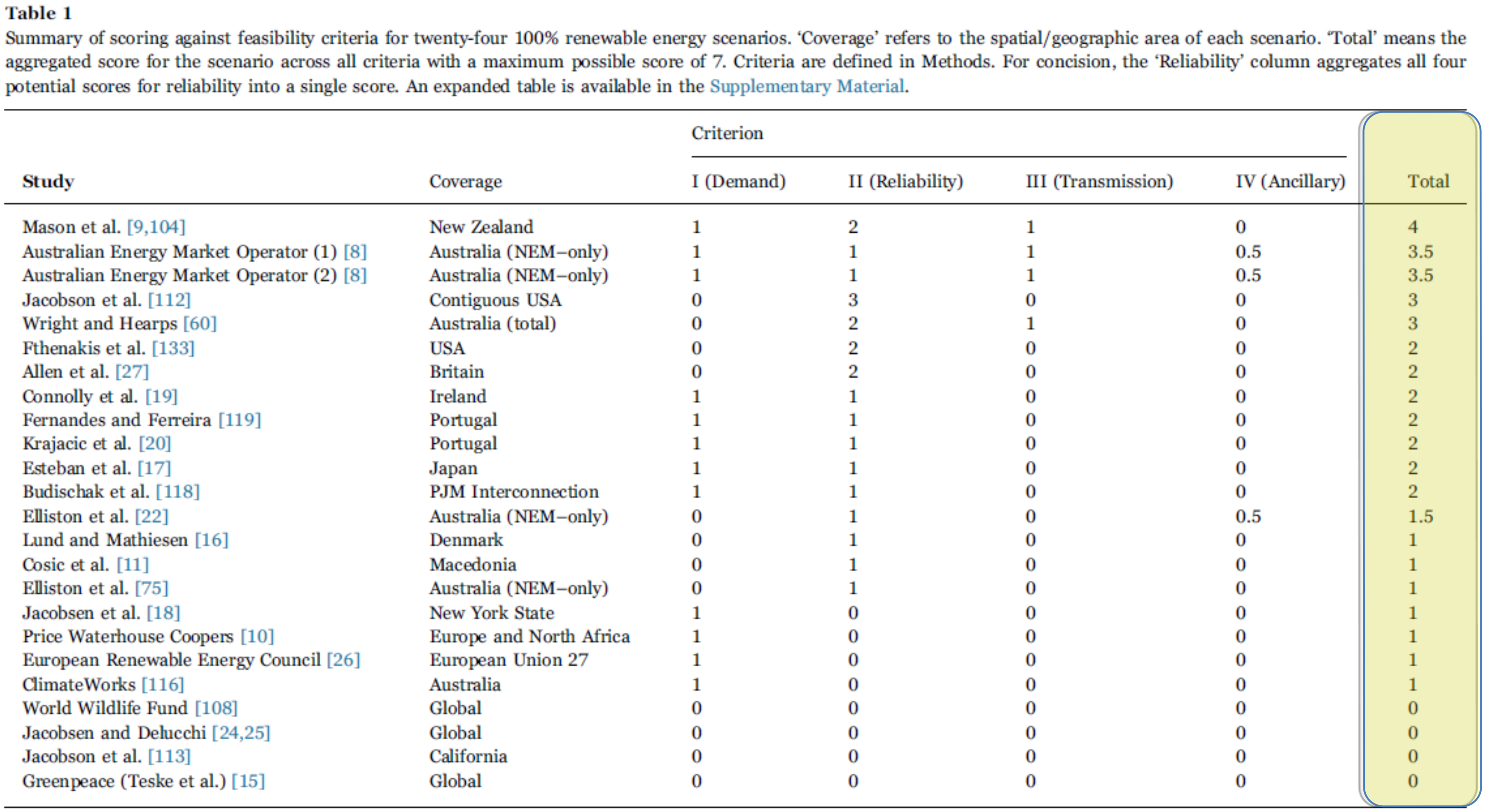


Table 1

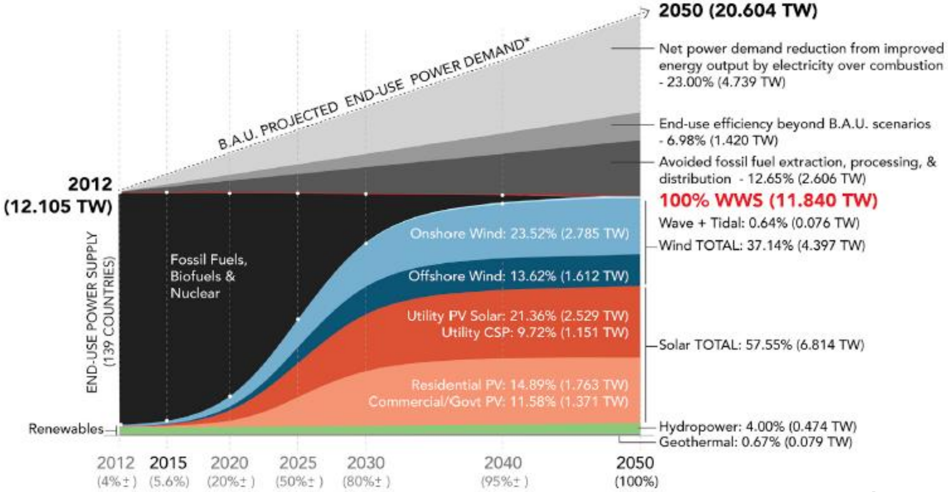
Summary of scoring against feasibility criteria for twenty-four 100% renewable energy scenarios. ‘Coverage’ refers to the spatial/geographic area of each scenario. ‘Total’ means the aggregated score for the scenario across all criteria with a maximum possible score of 7. Criteria are defined in Methods. For concision, the ‘Reliability’ column aggregates all four potential scores for reliability into a single score. An expanded table is available in the Supplementary Material.

		Criterion				
Study	Coverage	I (Demand)	II (Reliability)	III (Transmission)	IV (Ancillary)	Total
Mason et al. [9,104]	New Zealand	1	2	1	0	4
Australian Energy Market Operator (1) [8]	Australia (NEM–only)	1	1	1	0.5	3.5
Australian Energy Market Operator (2) [8]	Australia (NEM–only)	1	1	1	0.5	3.5
Jacobson et al. [112]	Contiguous USA	0	3	0	0	3
Wright and Hearps [60]	Australia (total)	0	2	1	0	3
Fthenakis et al. [133]	USA	0	2	0	0	2
Allen et al. [27]	Britain	0	2	0	0	2
Connolly et al. [19]	Ireland	1	1	0	0	2
Fernandes and Ferreira [119]	Portugal	1	1	0	0	2
Krajacic et al. [20]	Portugal	1	1	0	0	2
Esteban et al. [17]	Japan	1	1	0	0	2
Budischak et al. [118]	PJM Interconnection	1	1	0	0	2
Elliston et al. [22]	Australia (NEM–only)	0	1	0	0.5	1.5
Lund and Mathiesen [16]	Denmark	0	1	0	0	1
Cosic et al. [11]	Macedonia	0	1	0	0	1
Elliston et al. [75]	Australia (NEM–only)	0	1	0	0	1
Jacobsen et al. [18]	New York State	1	0	0	0	1
Price Waterhouse Coopers [10]	Europe and North Africa	1	0	0	0	1
European Renewable Energy Council [26]	European Union 27	1	0	0	0	1
ClimateWorks [116]	Australia	1	0	0	0	1
World Wildlife Fund [108]	Global	0	0	0	0	0
Jacobsen and Delucchi [24,25]	Global	0	0	0	0	0
Jacobson et al. [113]	California	0	0	0	0	0
Greenpeace (Teske et al.) [15]	Global	0	0	0	0	0

Feasibility of 100% electricity system and (neglected) trade-offs

- A number of challenges were not addressed at the time of the 2009 climate and energy package. (…) The management challenges linked to the introduction of renewables (…) were also not fully considered and the impact of a large number of national support schemes for renewables on market integration was underestimated
- The Third Energy package (…) did not address the issue of whether the market offered the necessary incentives to invest in generation, distribution and transmission, and storage capacity in a system with greater shares of renewables
- The current climate and energy targets were designed to be mutually supporting and there are indeed interactions between them. (…) There are obvious synergies but there are also potential trade-offs

(COM(2013) 169 final)



Projected Power Supply & Demand, 139 Countries

*ENERGY FOR ALL USES INCLUDING ELECTRICTY, HEATING, TRANSPORTATION, INDUSTRY

Jacobson et al, 2017

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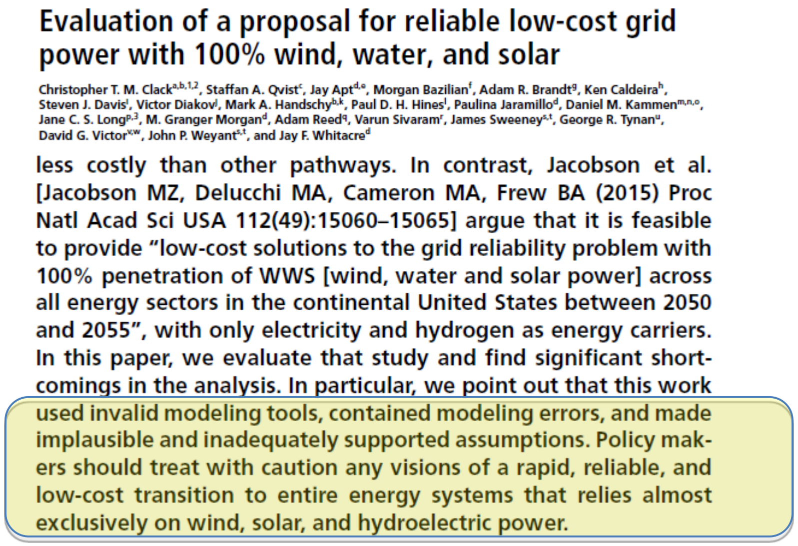

Evaluation of a proposal for reliable low-cost grid power with 100% wind, water, and solar

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less costly than other pathways. In contrast, Jacobson et al. [Jacobson MZ, Delucchi MA, Cameron MA, Frew BA (2015) Proc Natl Acad Sci USA 112(49):15060–15065] argue that it is feasible to provide "low-cost solutions to the grid reliability problem with 100% penetration of WWS [wind, water and solar power] across all energy sectors in the continental United States between 2050 and 2055", with only electricity and hydrogen as energy carriers. In this paper, we evaluate that study and find significant shortcomings in the analysis. In particular, we point out that this work used invalid modeling tools, contained modeling errors, and made implausible and inadequately supported assumptions. Policy makers should treat with caution any visions of a rapid, reliable, and low-cost transition to entire energy systems that relies almost exclusively on wind, solar, and hydroelectric power.

Renewables Intermittency in Energy System Model

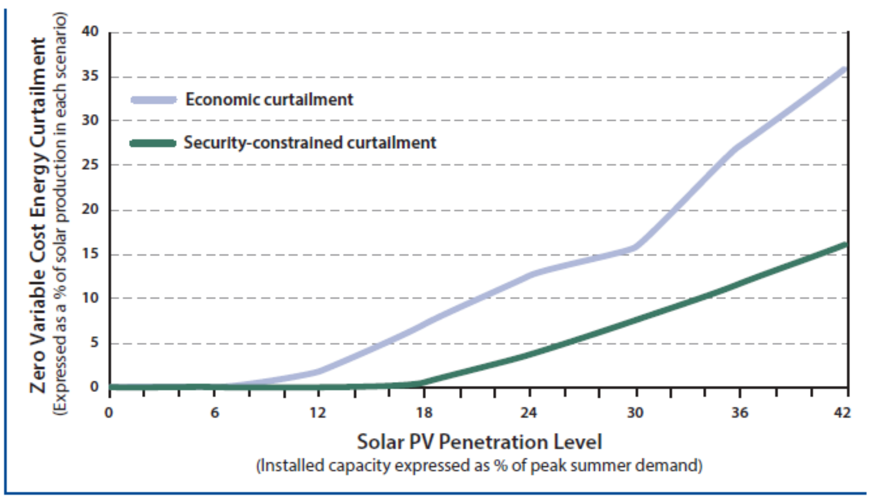
- *"The current share of these renewable energy sources (RES) can still more or less be handled by existing systems and flexibility, benefiting from remaining excess capacity of dispatchable (backup) generation and links to other grids that can balance the intermittency.*
- *However, often higher levels of intermittent RES are envisaged for the future, posing significant challenges on system operation and planning. In assessing possible energy futures, long-term energy system models are typically used. The representation of RES in such models needs careful attention, as intermittent RES come with a number of specific characteristics, making them different from conventional dispatchable generation."*

Erik Delarue, Jennifer Morris,
Renewables Intermittency: Operational Limits and Implications for Long-Term Energy System Models
MIT Joint Program on the Science and Policy of Global Change, 2015

Implications of increasing share of RES/VER

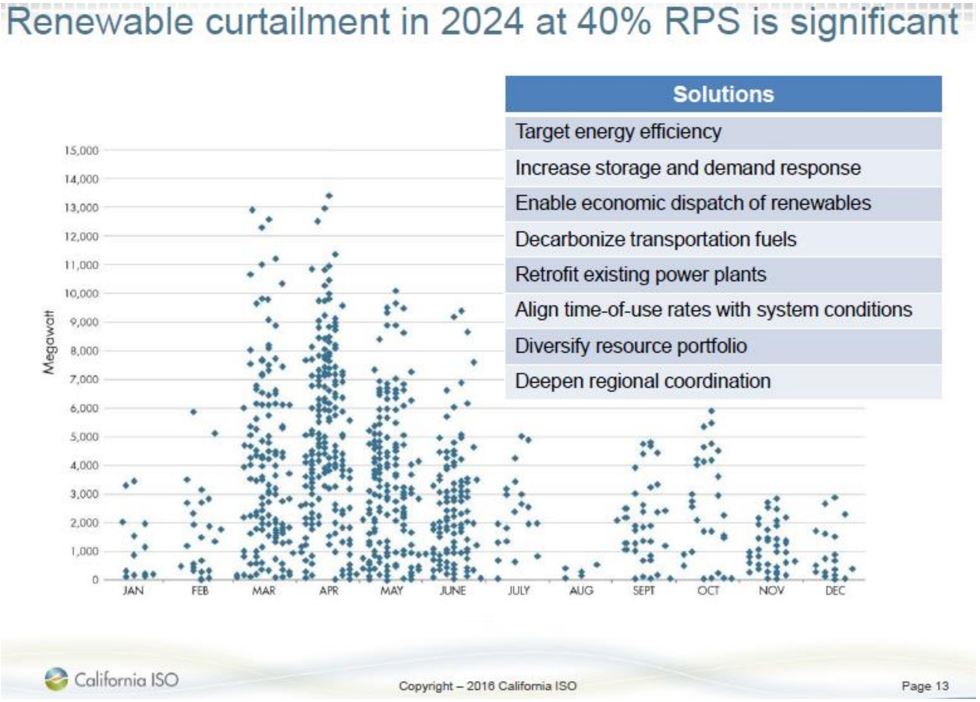
- Economic and/or *security* constained curtailment increases with Solar PV penetration

Figure 8.5 Economic Curtailment of Zero-Variable-Cost Energy



MIT, The future of solar, 2015

- California ISO: Estimation of curtailement in California 2024



Renewable curtailment in 2024 at 40% RPS is significant

Solutions
Target energy efficiency
Increase storage and demand response
Enable economic dispatch of renewables
Decarbonize transportation fuels
Retrofit existing power plants
Align time-of-use rates with system conditions
Diversify resource portfolio
Deepen regional coordination

California ISO

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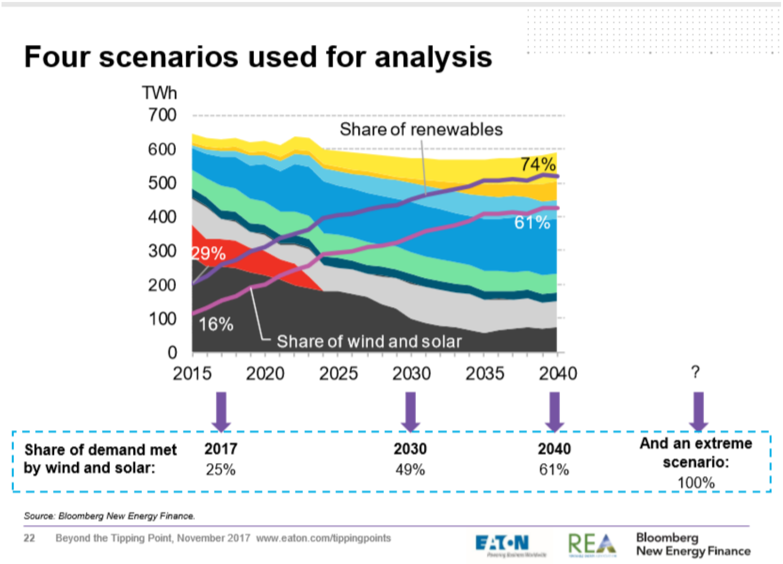
Implications of increasing share of RES/VER: Germany 2040 (BNEF)

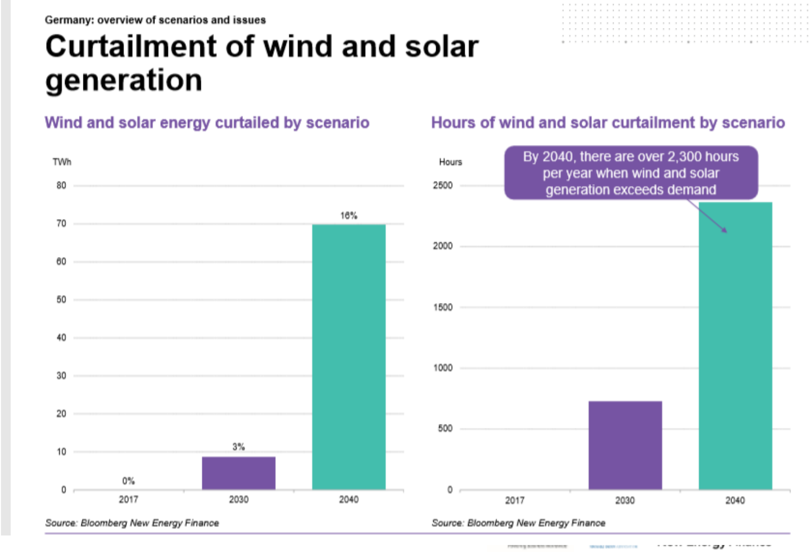


Four scenarios used for analysis

Share of demand met by wind and solar:	2017	2030	2040	And an extreme scenario:
	25%	49%	61%	100%

Source: Bloomberg New Energy Finance.

22 Beyond the Tipping Point, November 2017 www.eaton.com/tippingpoints



Germany: overview of scenarios and issues

Curtailment of wind and solar generation

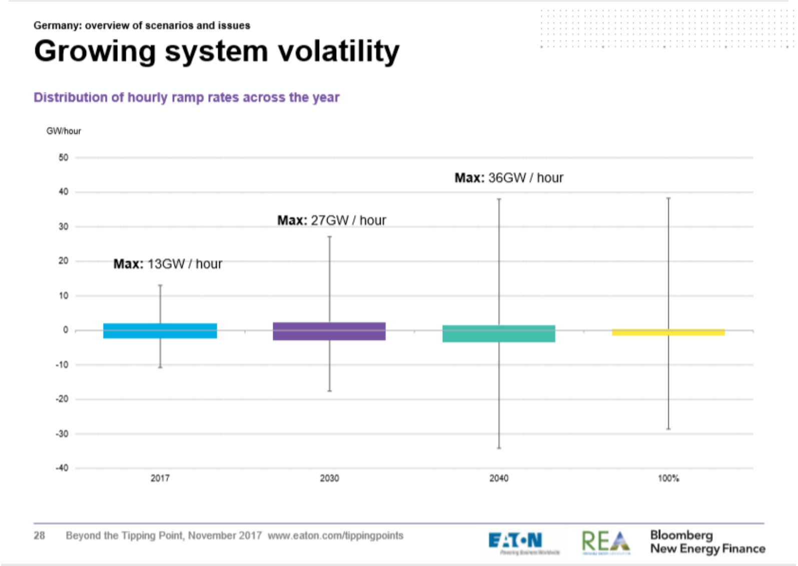
Wind and solar energy curtailed by scenario

Source: Bloomberg New Energy Finance

Hours of wind and solar curtailment by scenario

By 2040, there are over 2,300 hours per year when wind and solar generation exceeds demand

Source: Bloomberg New Energy Finance



Germany: overview of scenarios and issues

Growing system volatility

Distribution of hourly ramp rates across the year

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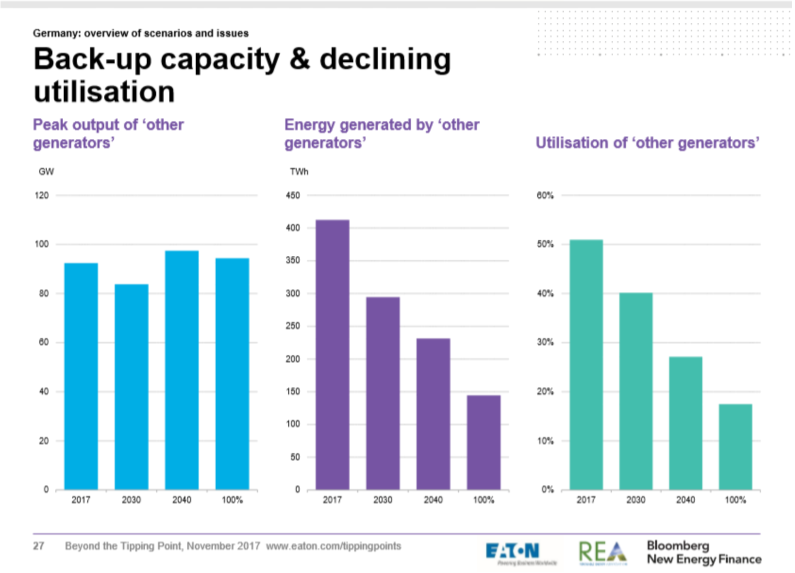

Germany: overview of scenarios and issues

Back-up capacity & declining utilisation

Peak output of 'other generators'

Energy generated by 'other generators'

Utilisation of 'other generators'

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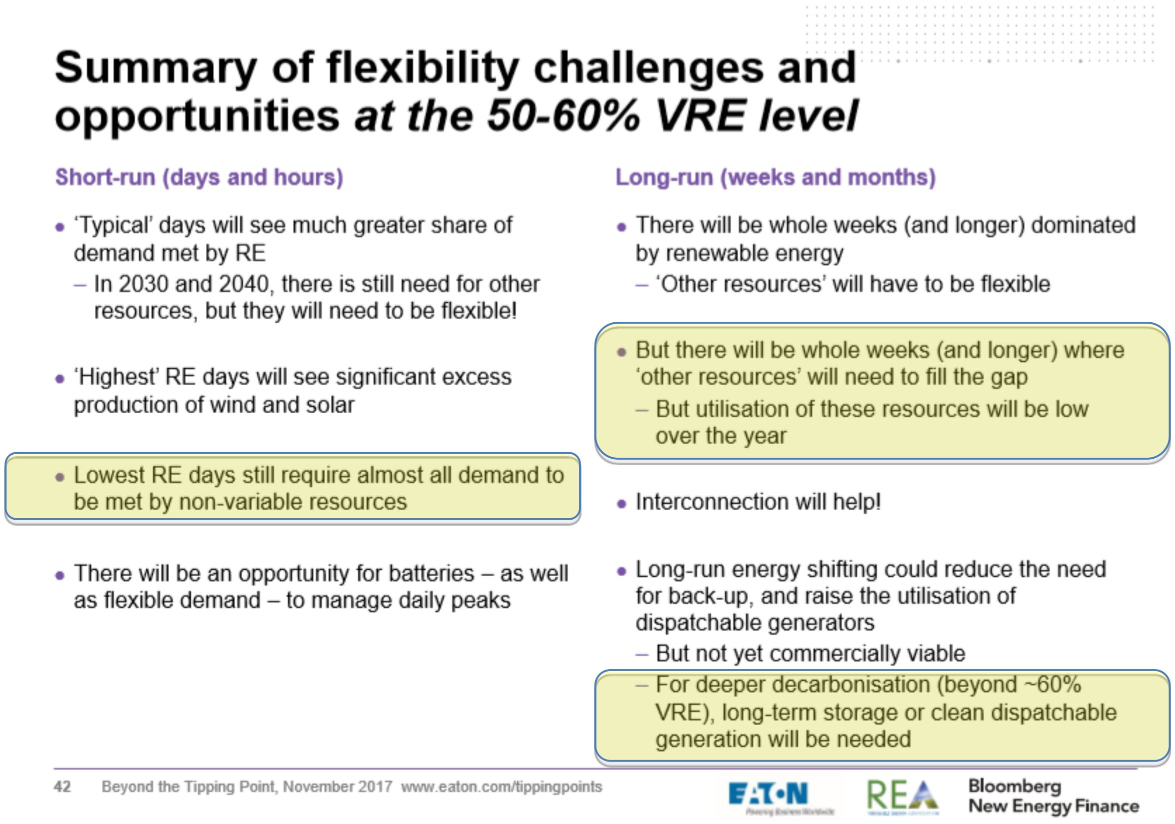
Beyond the Tipping Point. Flexibility gaps in future high-renewable energy systems in the U.K., Germany and Nordics
A Bloomberg New Energy Finance study commissioned by Eaton in partnership with the Renewable Energy Association
Presentation for CEER, March 1, 2018

Implications of increasing share of RES/VER: Germany 2040 (BNEF)



Summary of flexibility challenges and opportunities *at the 50-60% VRE level*

Short-run (days and hours)

- ‘Typical’ days will see much greater share of demand met by RE
  - In 2030 and 2040, there is still need for other resources, but they will need to be flexible!
- ‘Highest’ RE days will see significant excess production of wind and solar
- Lowest RE days still require almost all demand to be met by non-variable resources
- There will be an opportunity for batteries – as well as flexible demand – to manage daily peaks

Long-run (weeks and months)

- There will be whole weeks (and longer) dominated by renewable energy
  - ‘Other resources’ will have to be flexible
- But there will be whole weeks (and longer) where ‘other resources’ will need to fill the gap
  - But utilisation of these resources will be low over the year
- Interconnection will help!
- Long-run energy shifting could reduce the need for back-up, and raise the utilisation of dispatchable generators
  - But not yet commercially viable
  - For deeper decarbonisation (beyond ~60% VRE), long-term storage or clean dispatchable generation will be needed

Bloomberg
New Energy Finance

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Implications of increasing share of RES/VER: whole EU 2030 (EC)

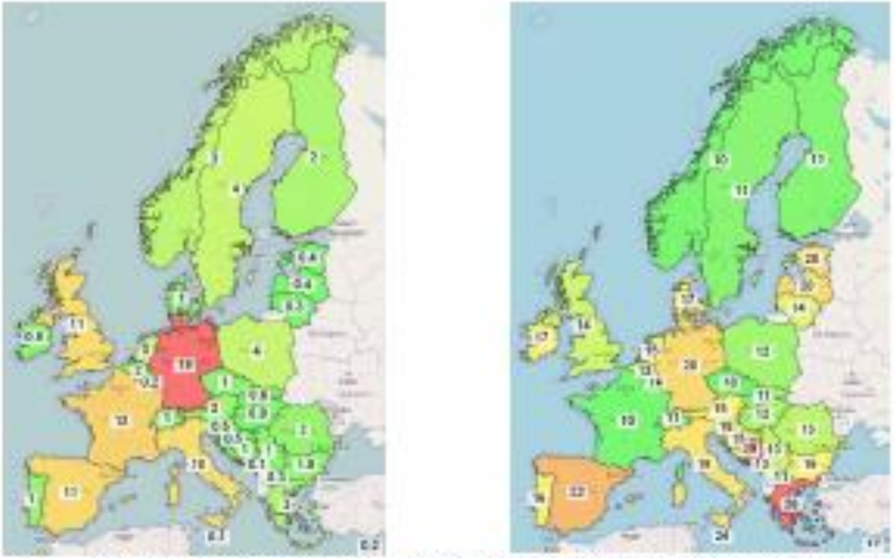


Figure 11 – Maximum hourly ramp rates across Europe fo
as share of peak load (in

- Ramp rates substantially steeper: maximum hourly ramp rates in Germany = 1/3 of national load
- Relatively important levels of curtailment in Spain, almost negligible elsewhere

METIS Studies. Study S11
Effect of high shares of renewables on power systems

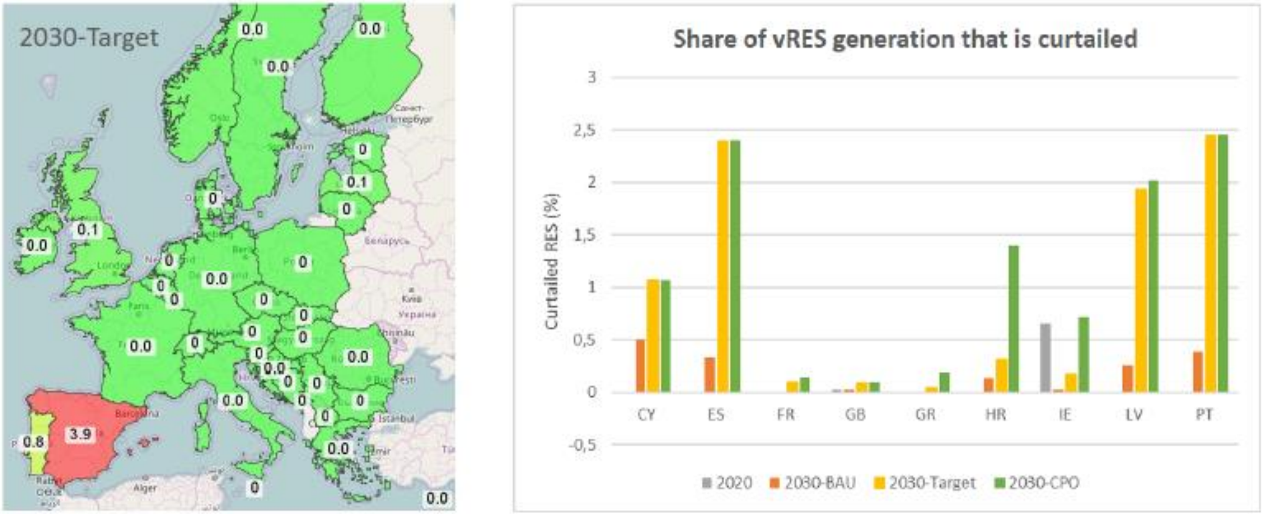
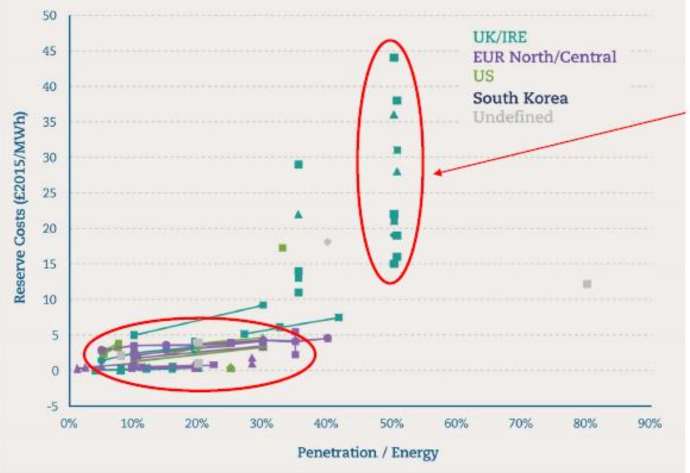


Figure 18 - Curtailment across Europe in absolute (left) in relative terms (right)

Implications of increasing share of RES/VER: evidence based approach (UKERC)

Short term system balancing – reserve costs

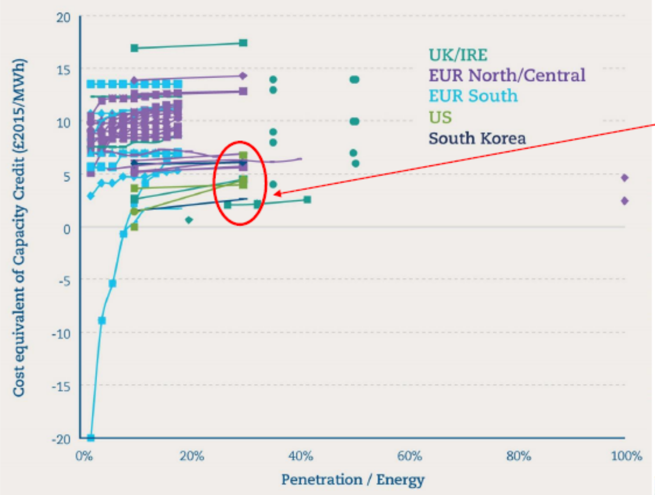


At 50% penetration level, costs range between £15 and £45/MWh

Up to a 30% penetration level, majority of results are £5/MWh or less

UKERC

Reliably meeting peak demand – capacity costs

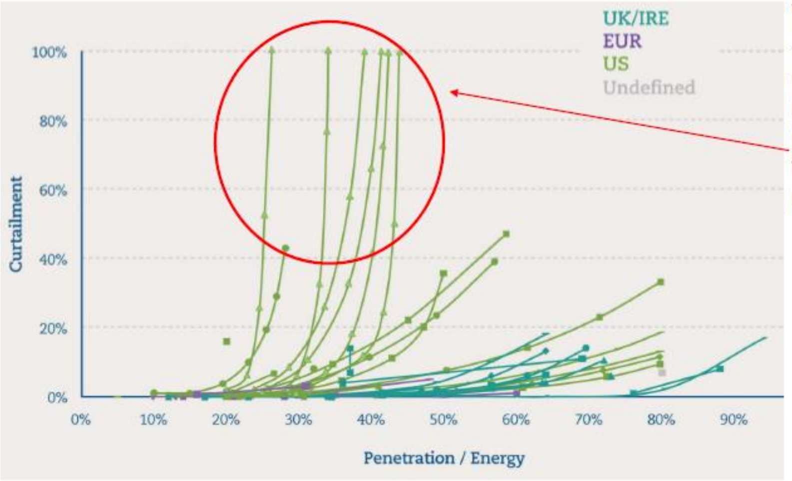


At a 30% penetration level (where wind analyses dominate) most results are £4-7/MWh

UKERC

Implications of increasing share of RES/VER: evidence based approach (UKERC)

Curtailment



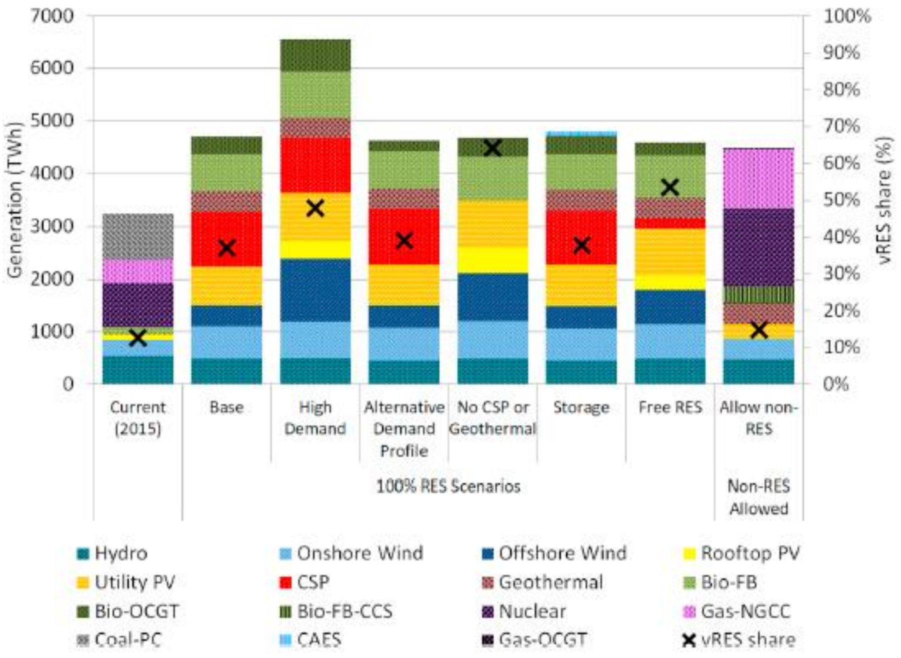
What not to do - extreme outliers can result from boundary-testing model runs

Other impacts/issues

- **Transmission and network costs**: up to 30% penetration level, evidence suggests that costs are in the range of £5–£20/MWh
  - But transmission reinforcement benefits the whole system, not just renewables
- **Thermal plant efficiency reduction**: very small at low penetration levels, but can increase as penetration levels rise
  - Imposes costs on remaining conventional generators
- **System inertia**: focus is on the technical challenges rather than costs, likely to only become significant at very high instantaneous penetrations
  - Particular issue for island systems with no/poor interconnection
- **Electricity markets**: significant reduction of the load factors of the remaining thermal plant on the system, and the economic value of output from intermittent generators declines as penetration levels rise

- Trade-offs of conventional plants to back up v-RES: effect of partloading on efficiency – and hence emissions – often neglected. CCGT efficiency drops as low as 35% when its load is reduced to 50% or less of the rated power output – an efficiency reduction of 20 percentage points

Some (uncertain) conclusions:
Requirements of a 100% EU renewable power system by 2050



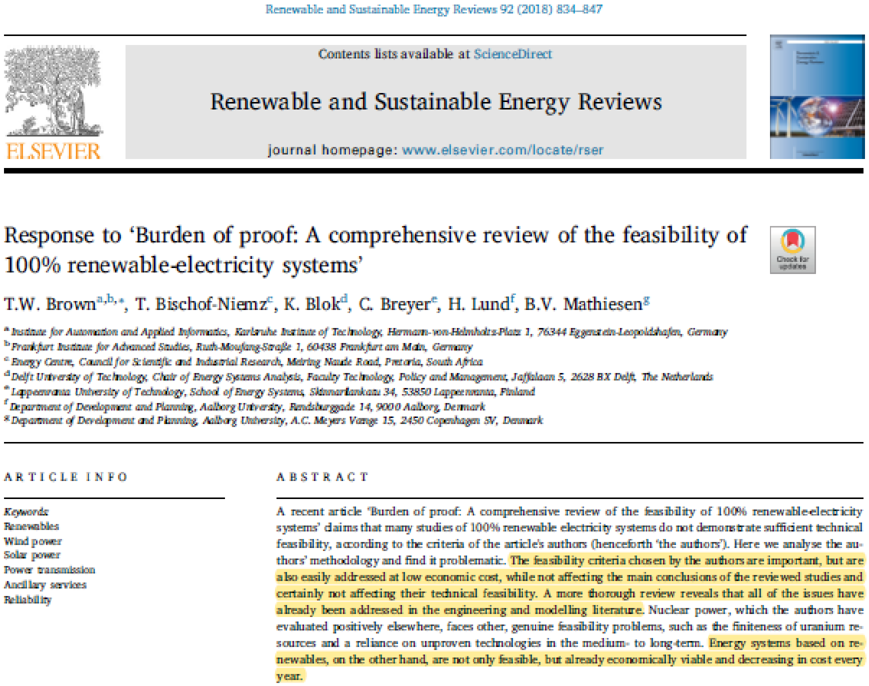
Source: Zappa et al., Is a a 100% renewable…, Applied Energy, 2019

- ➢ expanding **generation** capacity to at least 1.9 TW (1 TW today)
- ➢ expanding cross-border **transmission** capacity by at least ~140GW (current levels 60 GW),
- ➢ well-managed integration of **heat pumps** and EV, to reduce peak demand
- ➢ energy **efficiency** to prevent massive increase in electricity demand (and for biomass)
- ➢ large-scale mobilisation of Europe's **biomass** resources (power sector use at least x4.5)
- ➢ increasing solid biomass and biogas capacity deployment to at least 4GWy−1 and 6GWy−1 every year until 2050
- ➢ wind **deployment levels** of at least 7.5GWy−1 to be maintained (currently 10.6GWy−1) PV deployment to increase to at least 15GWy−1 (currently 10.6GWy−1) until 2050
- ➢ additional **costs**, at least 530 €bn y−1, approximately 30% higher than for a system with nuclear or CCS

Some (uncertain) conclusions

- *After some threshold, decreasing relationship between RES capacity and its marginal contribution to generation; therefore, even with perfect backup,* ***a technical limit exists on achievable RES shares****. In the absence of system flexibility, substantial backup is required to ensure reliable electricity*
- ***Costs of intermittency****: trade-off decarbonization/cost of energy*
- *50-60% VER is already a challenging power system.* ***Still a role role for dispatchable generation*** *(Biomass? Gas low efficiency?)*
- *Even a 100% renewable power system would require significant flexible zero-carbon* ***firm capacity*** *to balance VER. This could be hydropower, CSP, geothermal, biomass, or seasonal storage,* ***yet none of these technologies are currently being deployed at the level necessary*** *to support a 100% renewable power system by 2050.*

However:



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Response to 'Burden of proof: A comprehensive review of the feasibility of 100% renewable-electricity systems'

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ABSTRACT

A recent article 'Burden of proof: A comprehensive review of the feasibility of 100% renewable-electricity systems' claims that many studies of 100% renewable electricity systems do not demonstrate sufficient technical feasibility, according to the criteria of the article's authors (henceforth 'the authors'). Here we analyse the authors' methodology and find it problematic. The feasibility criteria chosen by the authors are important, but are also easily addressed at low economic cost, while not affecting the main conclusions of the reviewed studies and certainly not affecting their technical feasibility. A more thorough review reveals that all of the issues have already been addressed in the engineering and modelling literature. Nuclear power, which the authors have evaluated positively elsewhere, faces other, genuine feasibility problems, such as the finiteness of uranium resources and a reliance on unproven technologies in the medium- to long-term. Energy systems based on renewables, on the other hand, are not only feasible, but already economically viable and decreasing in cost every year.

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