Sensitivity of residual load variability to renewables’ siting and demand response

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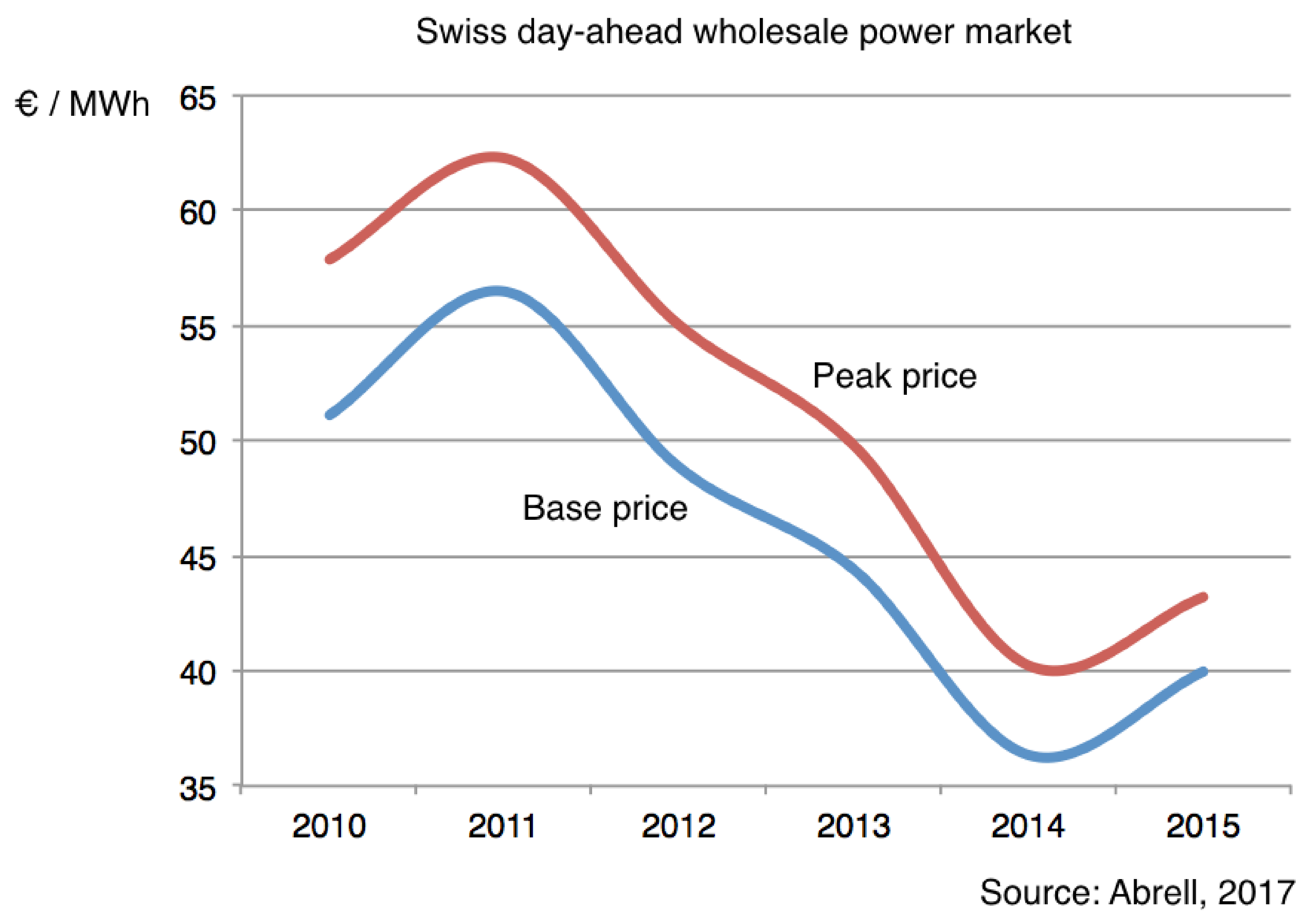
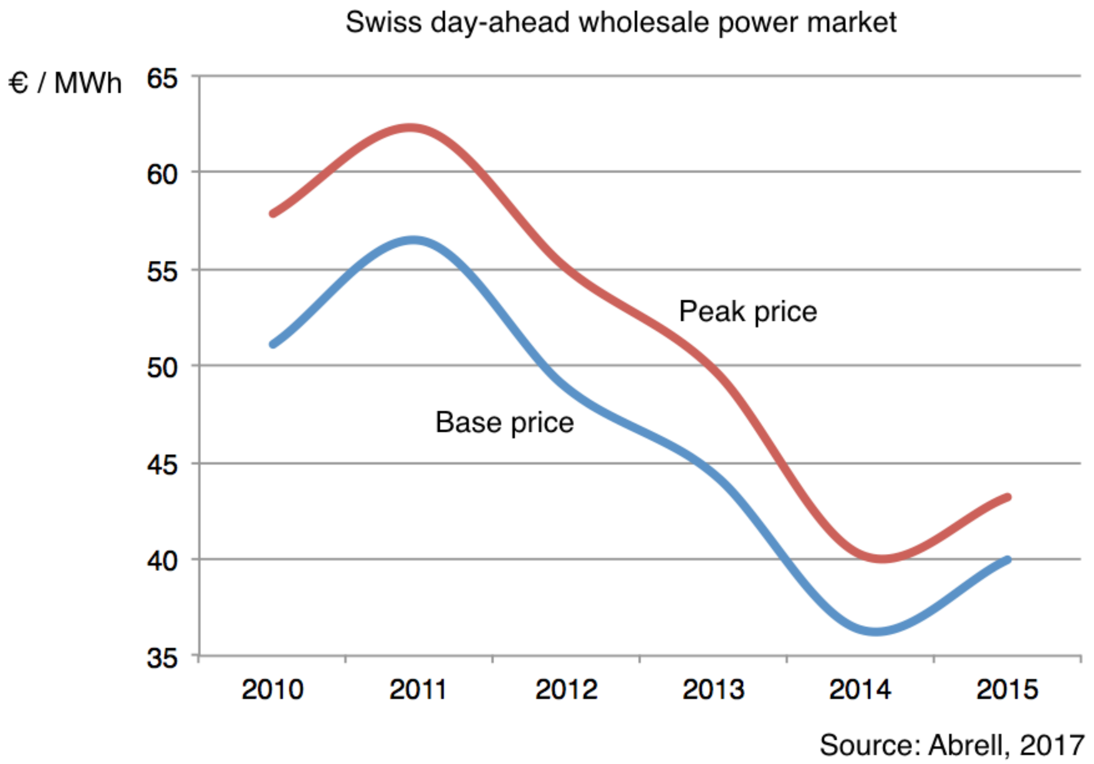


- Trend towards falling wholesale power prices
- A narrowing of the gap between base and peak prices

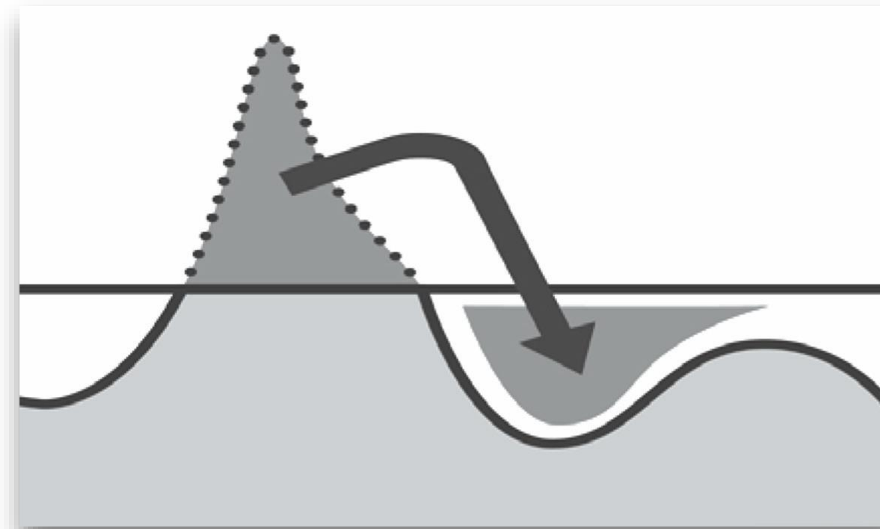


- Storage dams and pumped storage offer dispatchable load; deep geothermal and run-of-river hydro offer base load.
- They are all costly compared to new wind and solar in terms of their levelized cost per MWh, so the critical question is the value of the flexibility and security that they offer.
- Battery storage is becoming viable for short time scales, but not for longer-term with fewer cycles per year
- To understand the value of flexibility and security, we need to look at the remainder of the power system, in Switzerland and neighbouring countries

Build-out and siting of wind and solar

Electromobility

Demand-response



- Construct a set of political scenarios that cover the range of possible variance on these factors
- Model the effects on the power system of these factors, across the scenarios, using a high-resolution energy system model
- Use a market model to understand the conditions under which the value of flexibility and reliability is high

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The potential and usefulness of demand response to provide electricity system services

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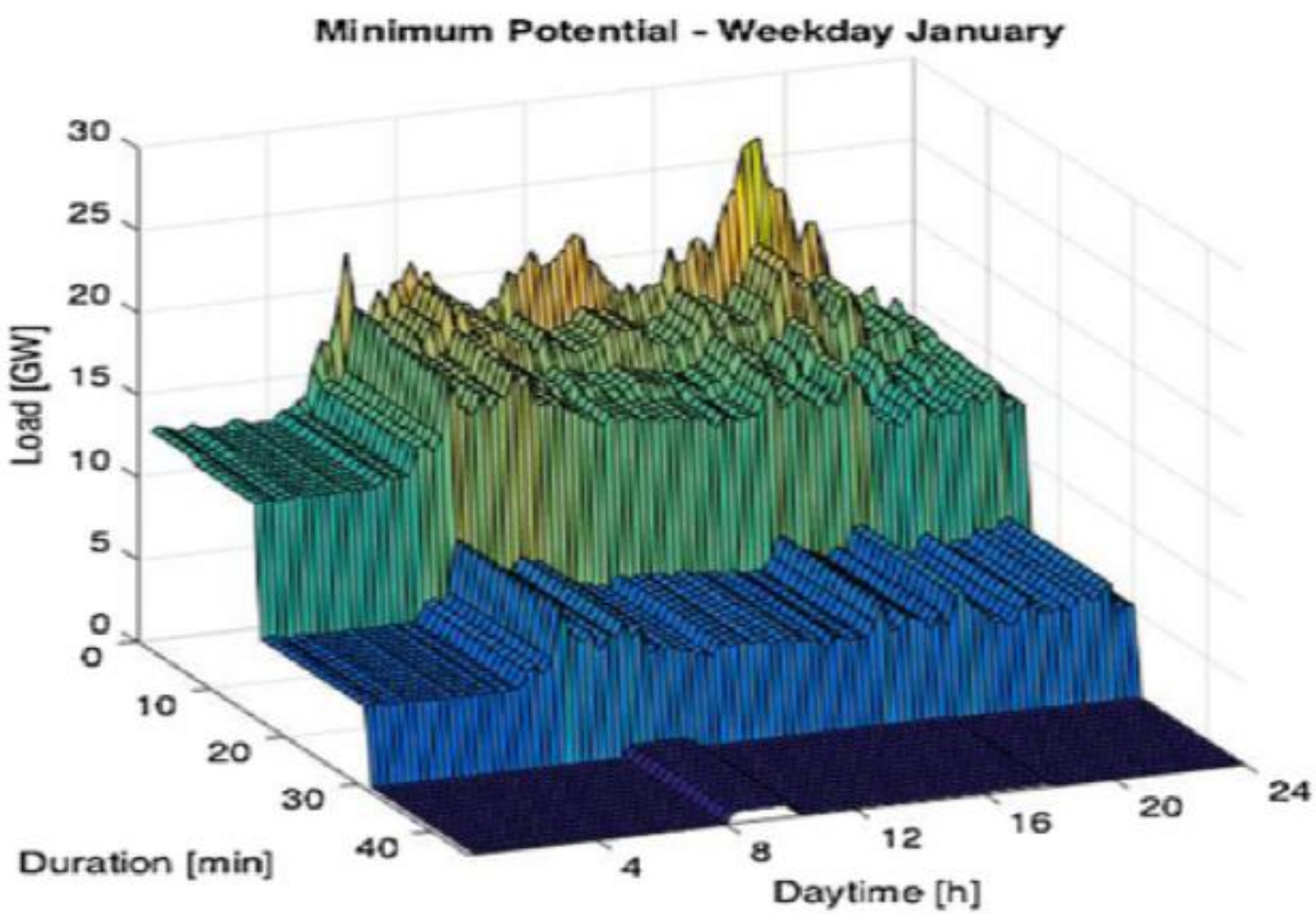
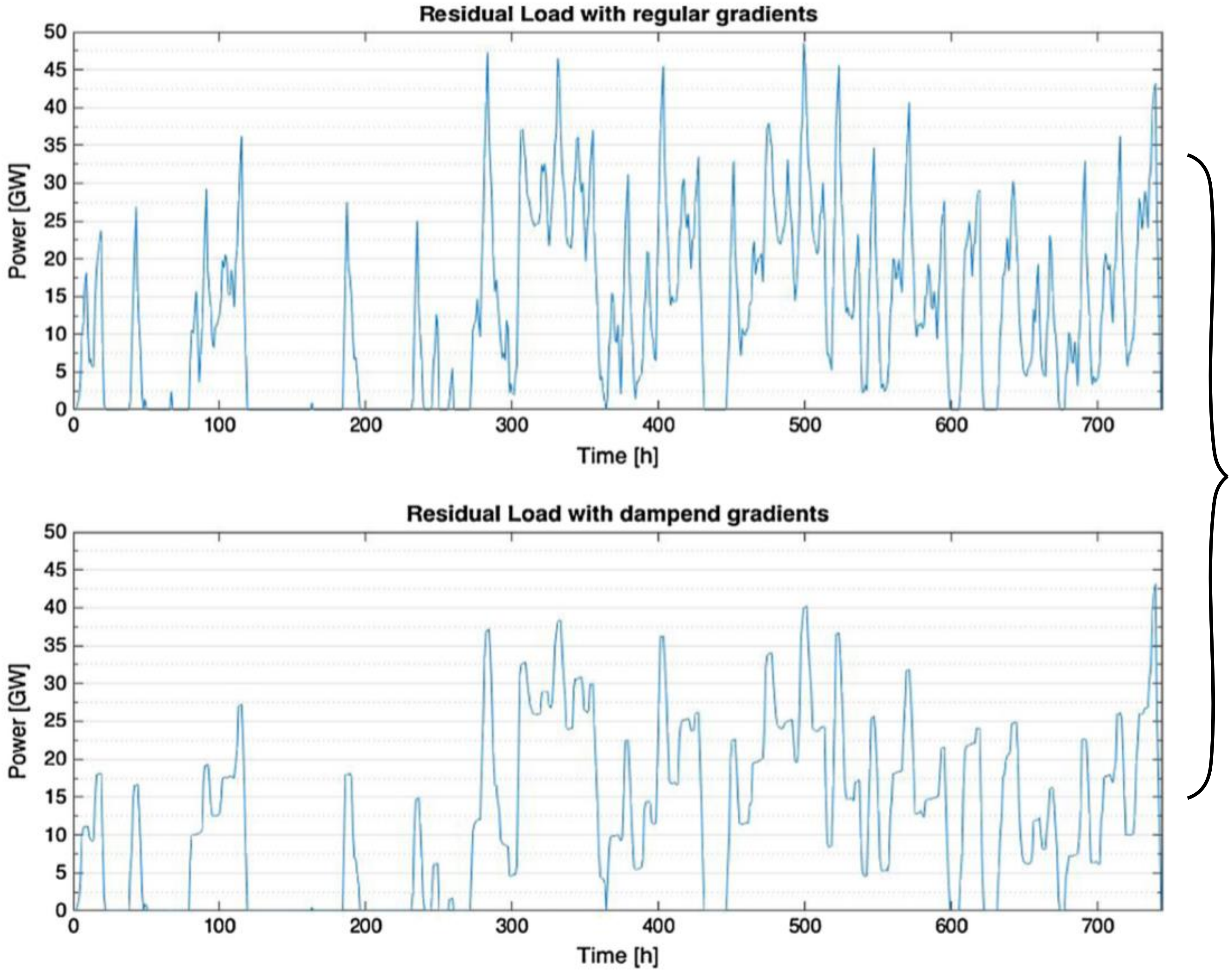
Sector	Process	Total cons. [TWh/year] $E_{x,\ target}$	Cons. share of total sector c_x	Share shiftable s_x	Max. shift duration	
					Immediate	Announced
Household	a Washing machine	6	4%	94%	6 min	[*]
	b Tumble dryer	4.5	3%	94%	10 min	[*]
	c Dishwasher	6	4%	93%	6 min	[*]
	d Oven/stove	16.4	11%	90%[1]	1 min	1 min
	e Refrigerator	14.9	10%	97%	30 min	30 min
	f Freezer	13.4	9%	97%	30 min	30 min
	g Water heater	14.1	9.5%	90%	30 min	[*]
	h El. direct heating	4.5	3%	93%	15 min	15 min
	i El. storage heating	20.9	14%	93%	15 min	[*]
	j Circulation pump	10.6	7.1%	93%[2]	15 min	15 min
Commercial	k Process cooling	7.4	8.2%	100%	30 min	30 min
	l Climate cooling	3	3.3%	70%	15 min	15 min
	m Mechanic force	2.6	2.9%	75%	15 min	15 min
	n Hot water	3.4	3.8%	25%	45 min	2 h
	o Room heating	4.2	4.7%	100%	15 min	8 h
Industry	p Chlor-alkali	5.3	1.9%	40%	0	2 h
	q Air separation	5	1.8%	30%	0	4 h
	r Aluminum	7.8	2.8%	25%	0	4 h
	s Copper/zinc	1.1	0.4%	25%	0	4 h
	t Paper	20.8	7.4%	100%	0	1.5 h
	u Steel	5.3	1.9%	100%	0	0.5 h
	v Cement	2.2	0.8%	100%	0	3 h

Reproduced annual load profiles with a bottom-up model of power sector demand, based on actual processes, including all with some potential for demand response

Made use of survey data on users' willingness to delay consumption


Minimum Potential - Weekday January
Load [GW]
30
25
20
15
10
5
0
Duration [min]
0
10
20
30
40
Daytime [h]
4
8
12
16
20
24



We can shave something like 20% off of short load peaks, but can have little effect on variability at longer time scales

nature climate change

LETTERS

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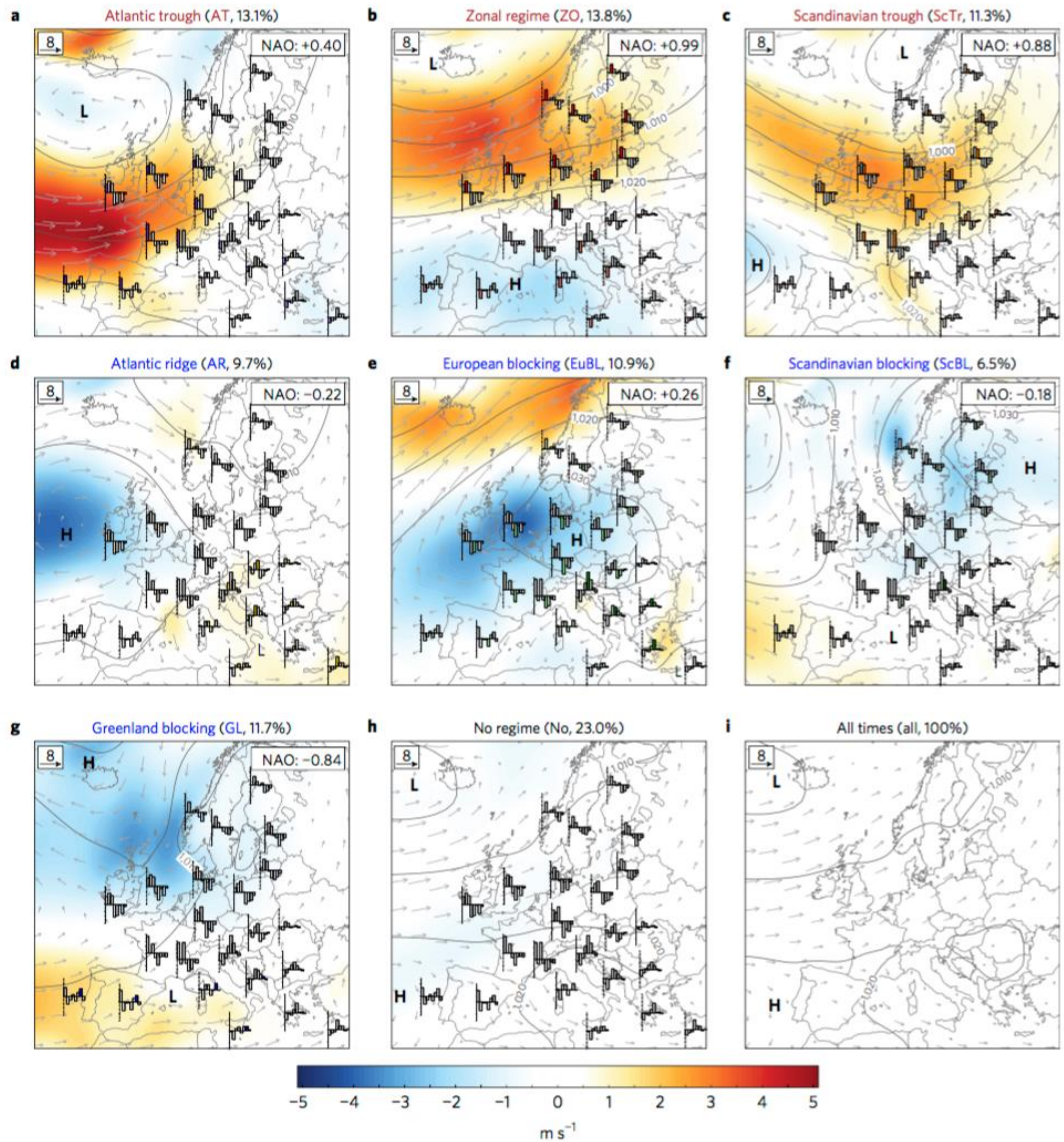
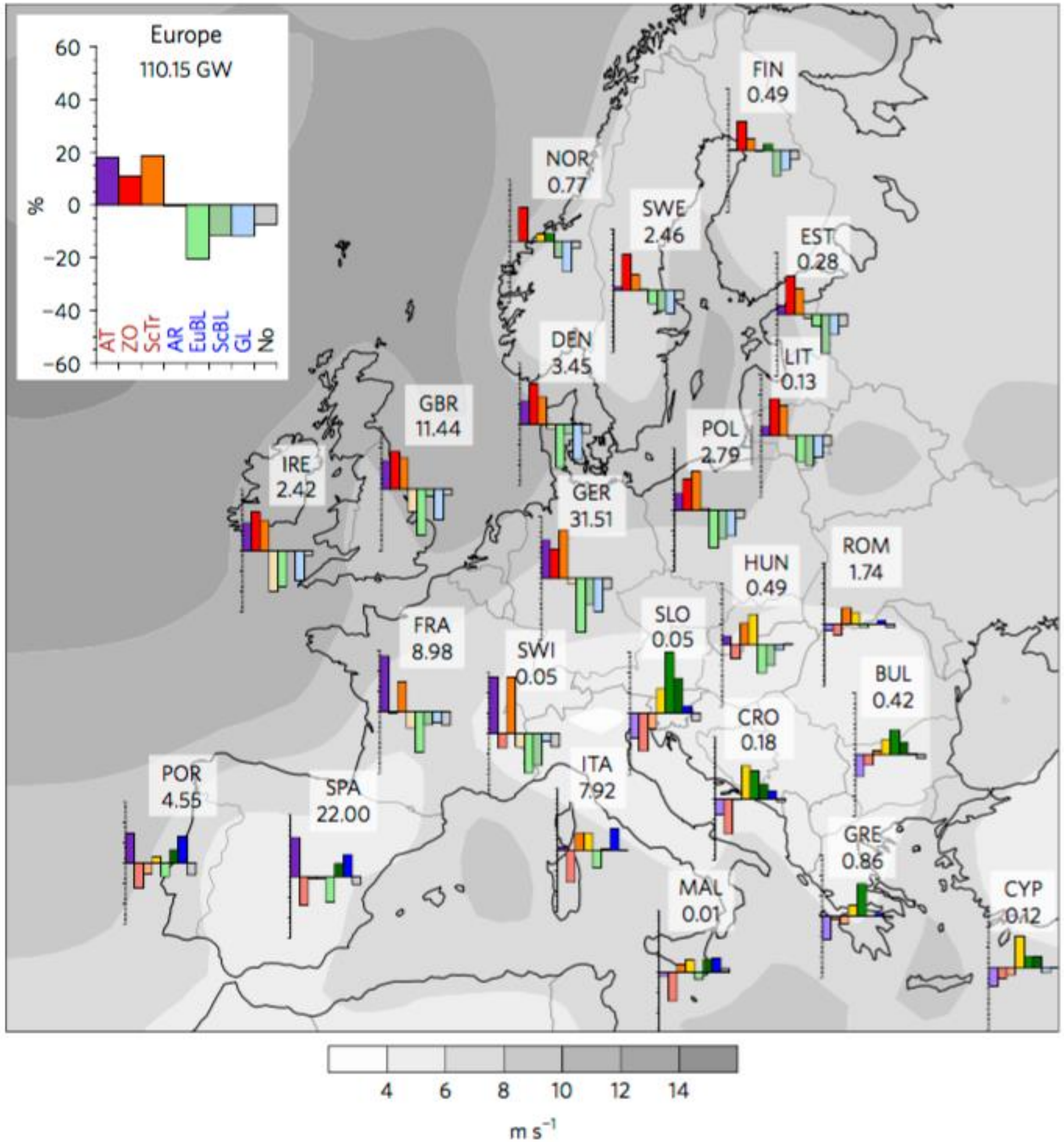
Balancing Europe's wind-power output through spatial deployment informed by weather regimes

Christian M. Grams[1]*, Remo Beerli[1], Stefan Pfenninger[2], Iain Staffell[3] and Heini Wernli[1]*

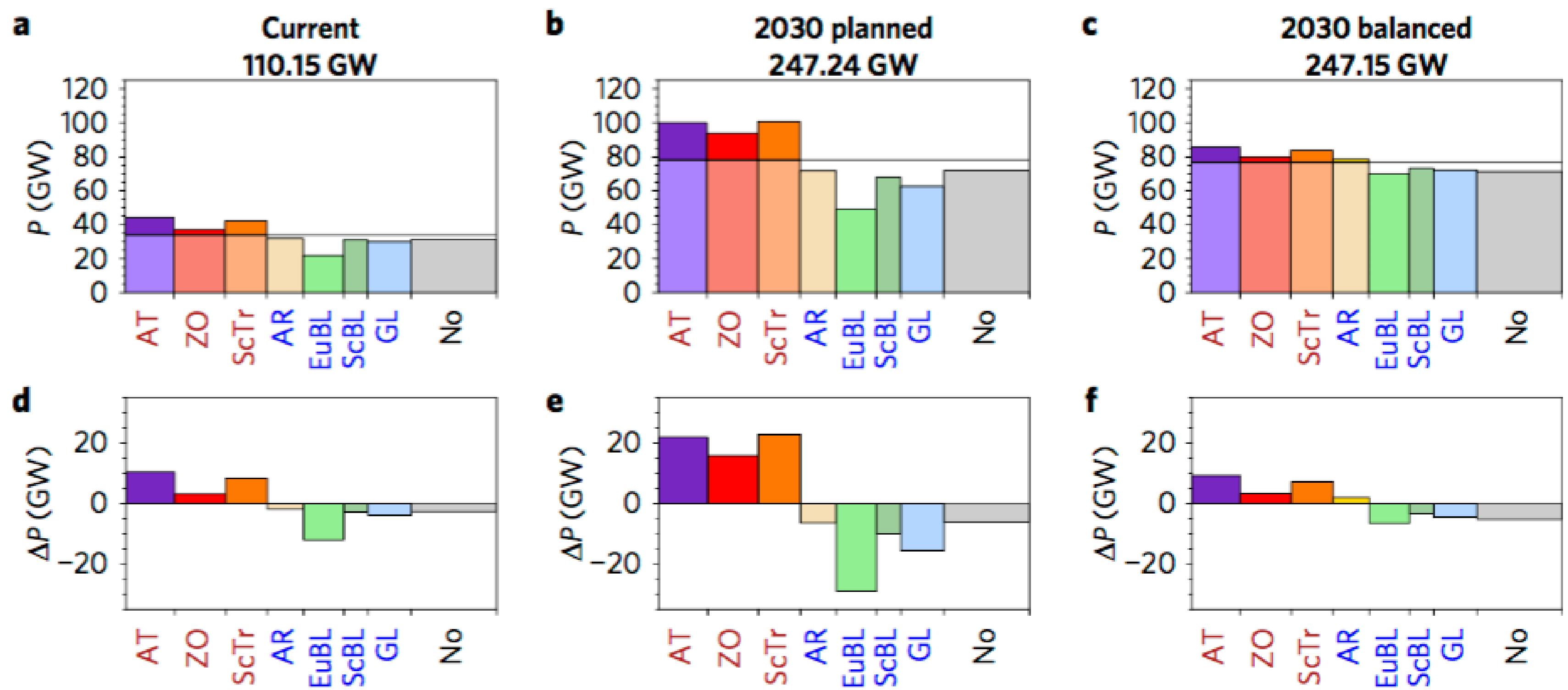
Linked a set of eight European weather regimes to localised wind-speed anomalies

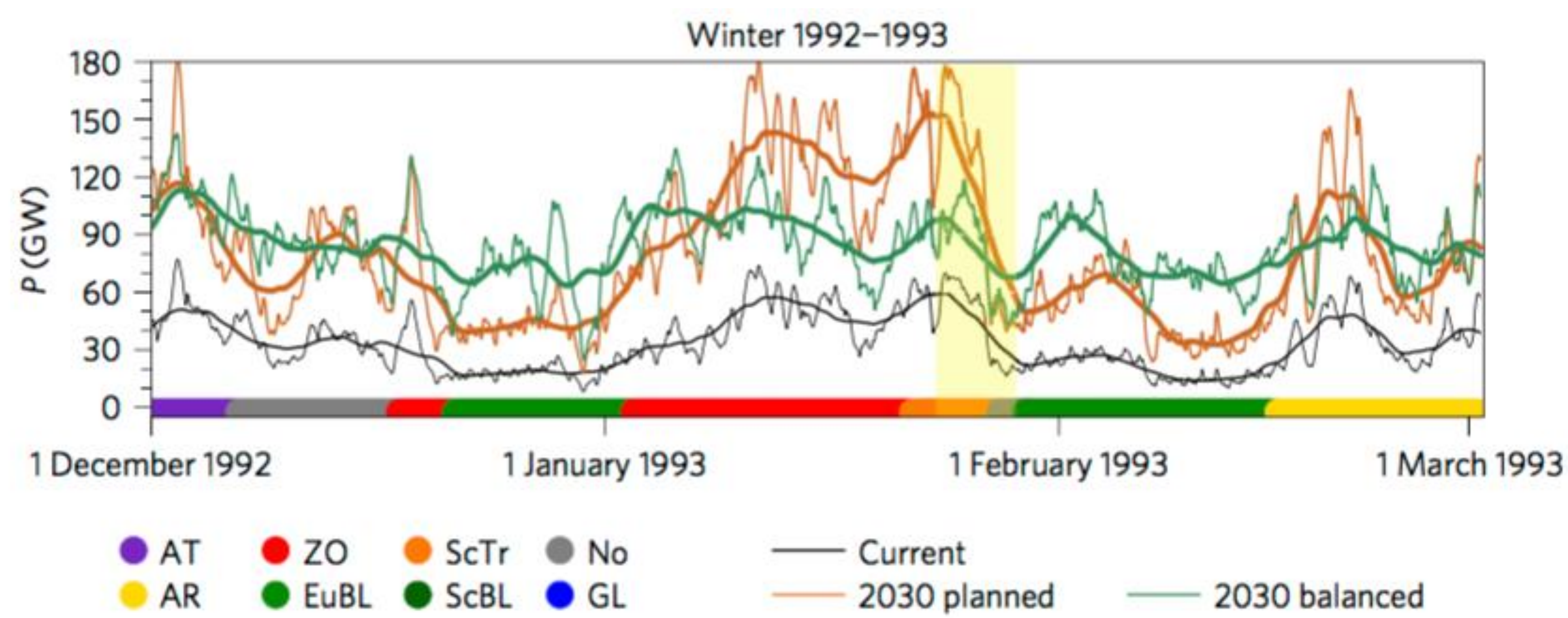


Using wind generation models, mapped the influence of weather regimes onto national load profiles



Examined the effects of planned wind capacity expansion, compared to a hypothetical expansion more balanced across regions





Where is this going?

- Ongoing: we are conducting expert interviews and document analysis to further define a realistic but broad set of political scenarios.
- Coming Soon: We can integrate results such as I have shown into these scenarios, using first a high-resolution energy system model, and then an energy market model.
- Ultimately: we will be able to provide insights into the political developments that will be more or less advantageous for new hydro and geothermal projects in Switzerland.

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