Forecasting in Power Market

METU - IAM 750 – Energy Trading and Risk Management

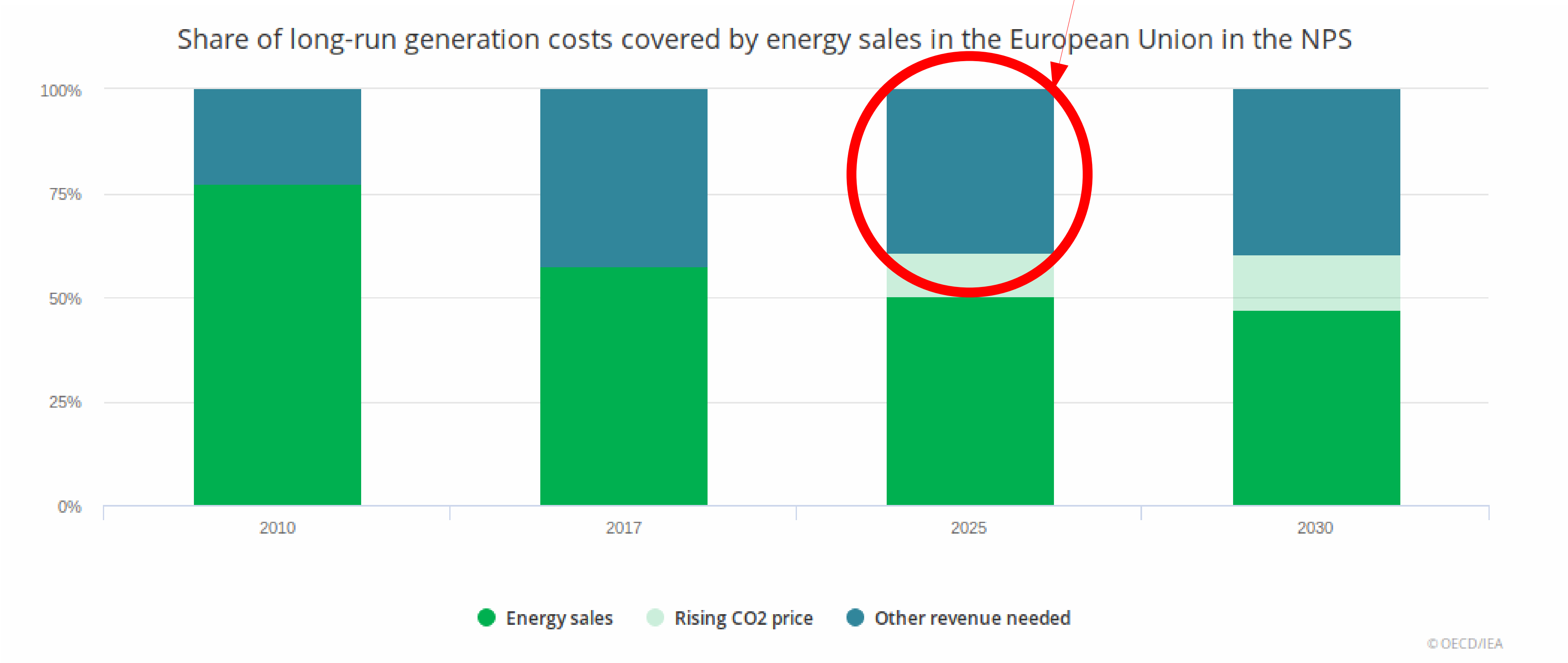
Barış Sanlı

Forecasting what?

- Past
  - Demand/Supply mix
- Present
  - +Price
- Future
  - +Renewables
  - +Distributed generation &
  - +Demand response effects

Non "energy sales" revenues?

How to forecast?



https://www.iea.org/weo2018/electricity/

Supply and demand

- Supply investment horizon
  - For heavy duty ones 5-7 years
  - Solar ~ 1 year
  - Storage ~ 6 months
- Demand
  - Population, economic growth, prices
  - Technology!!
    - Technologic progress faster on oil& gas than solar&battery

In algorithms they "used to" trust

- AI -> this is maybe the 5th wave of AI
  - Stanley Kubrick - 2001: Space Odyssey (1968)
- What has happened to

  IBM Watson?

  A Stat investigation later that year found Watson Health has struggled to learn about different cancer types, with a relatively small number of hospitals actually adopted its oncology system. Foreign providers have also complained that the supercomputer's recommendations favor American patients and treatment methods.

Health care: the killer app?

IBM Watson first wowed the public in 2011 with its triumphant performance on the game show "Jeopardy!" The AI owed its victory to its natural-language processing abilities, which enabled it to parse the show's complicated and pun-filled clues, then scan its vast library for the solution.

- Do you drive car by just looking at

  rear view?

https://spectrum.ieee.org/the-human-os/robotics/artificial-intelligence/layoffs-at-watson-health-reveal-ibms-problem-with-ai
https://www.healthcaredive.com/news/ibm-watson-health-paring-down-hospital-projects/526013/

Algorithms are inevitable

- Major question
  - Predictability
  - Explainability
- Advice: use both, trust none

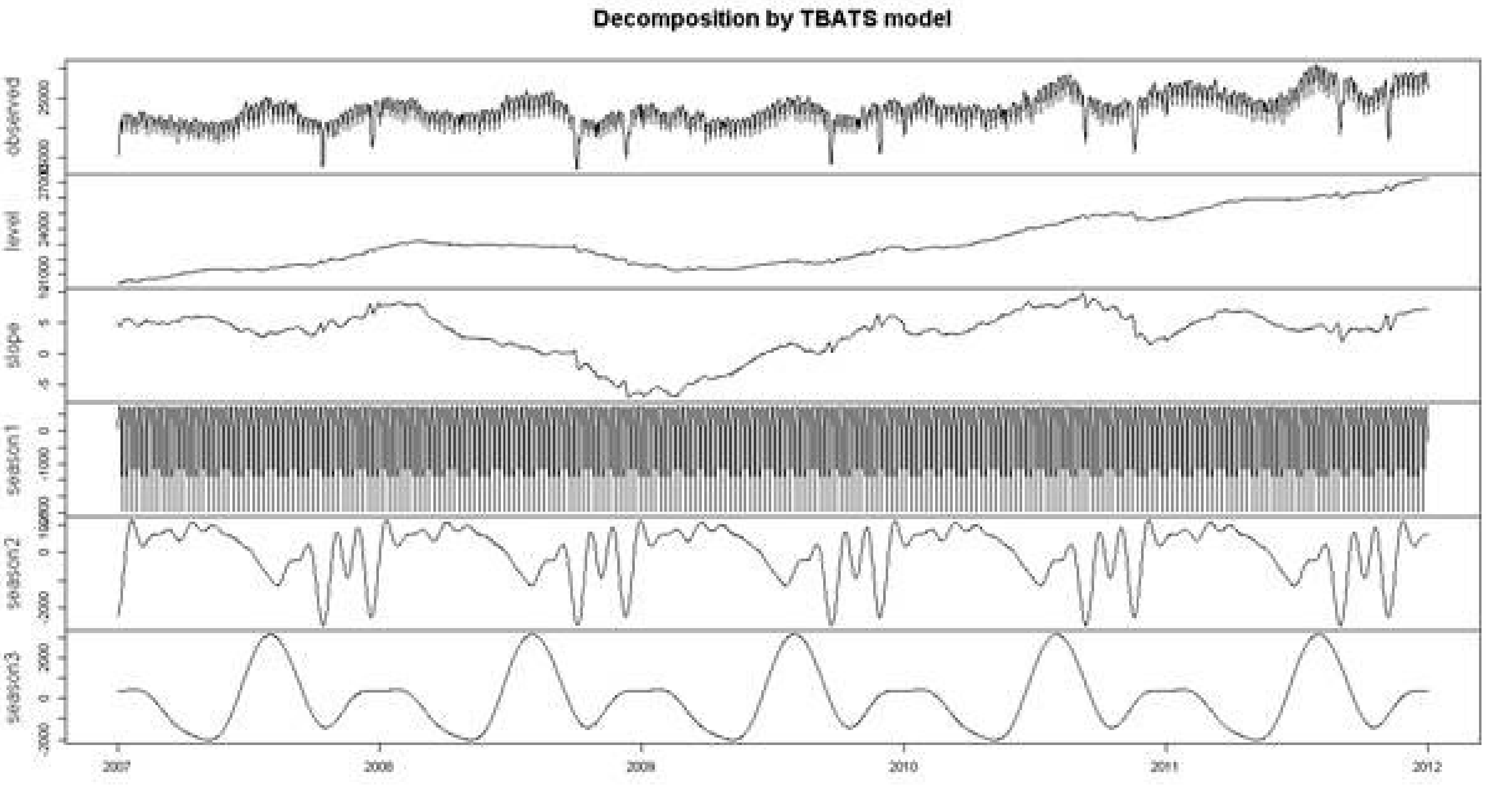
"Long-Term Capital Management, a hedge fund set up by, among others, the economists Myron Scholes and Robert Merton in 1994. With their work on derivatives, Scholes and Merton seemed to have hit on a formula that yielded a safe but lucrative trading strategy. In 1997 they were awarded the Nobel prize. A year later, Long-Term Capital Management lost $4.6bn (£3bn)in less than four months; a bailout was required to avert the threat to the global financial system. Markets, it seemed, didn't always behave like scientific models."

https://www.theguardian.com/commentisfree/2015/oct/11/nobel-prize-economics-not-science-hubris-disaster

http://www.barissanli.com/calismalar/2017/20170308-bsanli-bilkent.pdf

Using R

- Electricity demand has periods
  - Seasonal, moon calendar, solar calendar



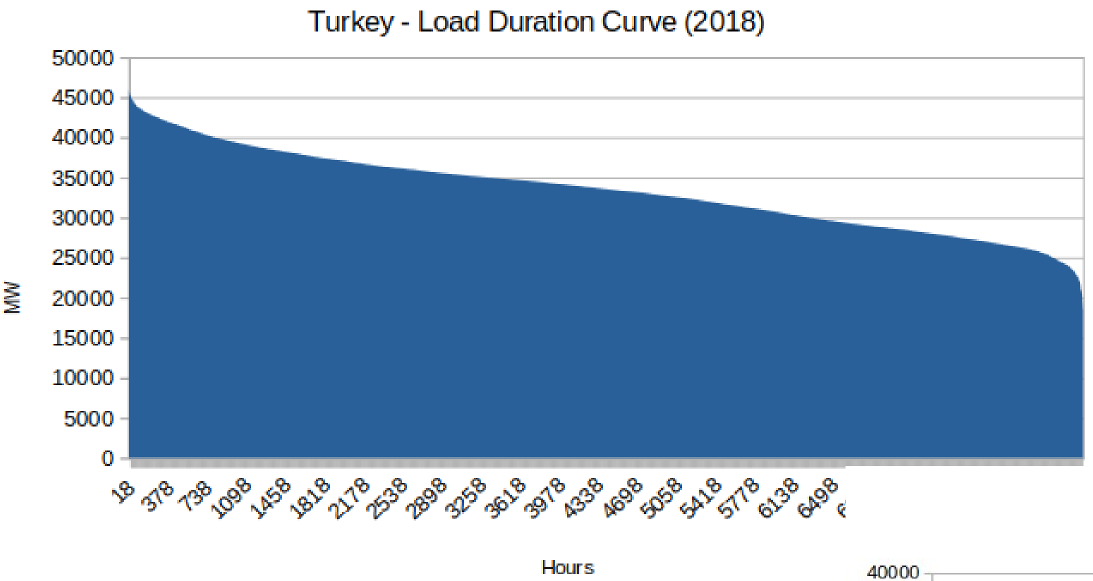
weekly

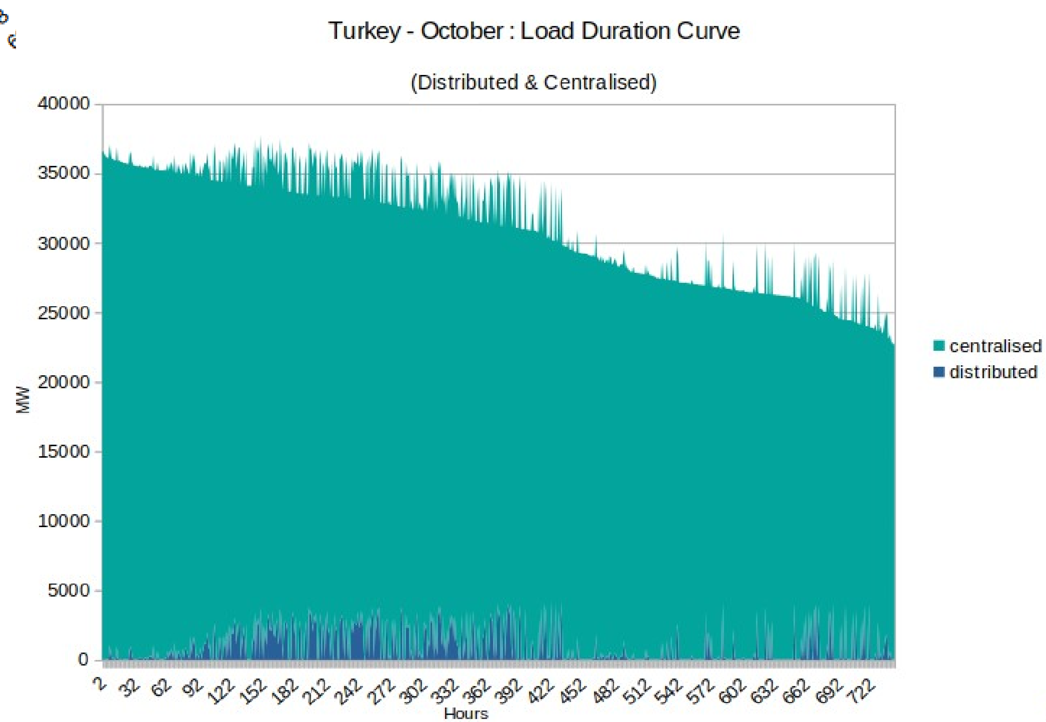
moon

solar

http://www.barissanli.com/calismalar/dersler/r/rders8.php

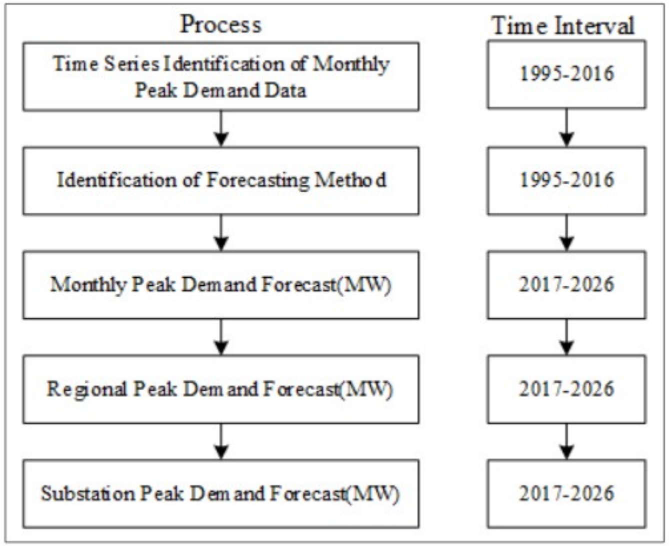
Load Duration Curve





Source: EPİAŞ

Recent study for Transmission Planning



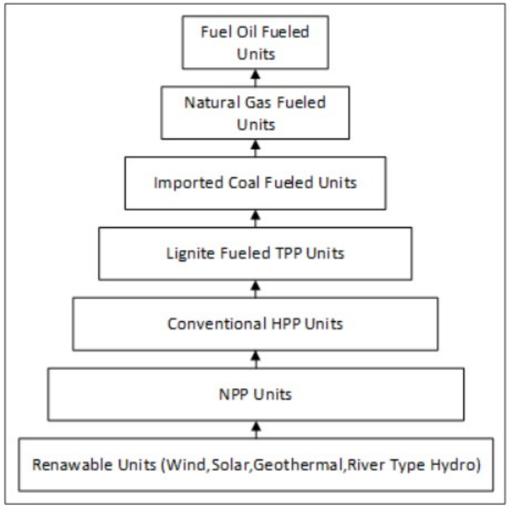


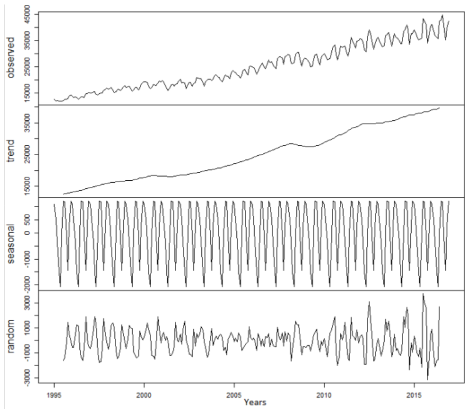
Figure 15. Generation Dispatch Procedure

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Nov.	Oct.	Dec.
2017	42500	40945	39415	38300	38190	42851	45542	46562	43606	37756	41975	44360
2018	44699	43074	41476	40309	40191	45039	47835	48892	45814	39722	44111	46589
2019	46939	45246	43581	42365	42240	47281	50186	51282	48081	41745	46309	48883
2020	49246	47485	45753	44488	44357	49596	52613	53750	50425	43839	48582	51256
2021	51632	49802	48003	46688	46552	51994	55125	56305	52854	46011	50939	53715
2022	54106	52206	50337	48970	48829	54480	57730	58954	55372	48266	53385	56266
2023	56671	54699	52759	51340	51192	57060	60431	61700	57985	50608	55922	58912
2024	59332	57286	55272	53799	53646	59735	63231	64547	60695	53039	58555	61656
2025	62092	59970	57880	56352	56193	62509	66134	67498	63504	55563	61285	64501
2026	64953	62753	60586	59001	58836	65386	69143	70556	66417	58182	64117	67451

1	İstanbul	Major	16	Mugla	Major	31	Coruh DISCO	Minor
2	İzmir	Major	17	Diyarbakir	Major	32	Baskent DISCO	Minor
3	Ankara	Major	18	K.maras	Major	33	Y.irmak DISCO	Minor
4	Bursa	Major	19	Denizli	Major	34	Aras DISCO	Minor
5	Antalya	Major	20	Kayseri	Major	35	Firat DISCO	Minor
6	Kocaeli	Major	21	Balikesir	Major	36	Çamlibel DISCO	Minor
7	Sanliurfa	Major	22	Canakkale	Major	37	Trakya DISCO	Minor
8	Adana	Major	23	Sakarya	Major	38	Vangolu DISCO	Minor
9	Konya	Major	24	Aydin	Major	39	Sakarya DISCO	Minor
10	Tekirdag	Major	25	Samsun	Major	40	Akdeniz DISCO	Minor
11	Hatay	Major	26	Eskisehir	Major	41	Akedas DISCO	Minor
12	Gaziantep	Major	27	Zonguldak	Major	42	Uludag DISCO	Minor
13	Mardin	Major	28	OS.gazi DISCO	Minor	43	Toroslar DISCO	Minor
14	Manisa	Major	29	Meram DISCO	Minor			
15	Mersin	Major	30	Dicle DISCO	Minor			

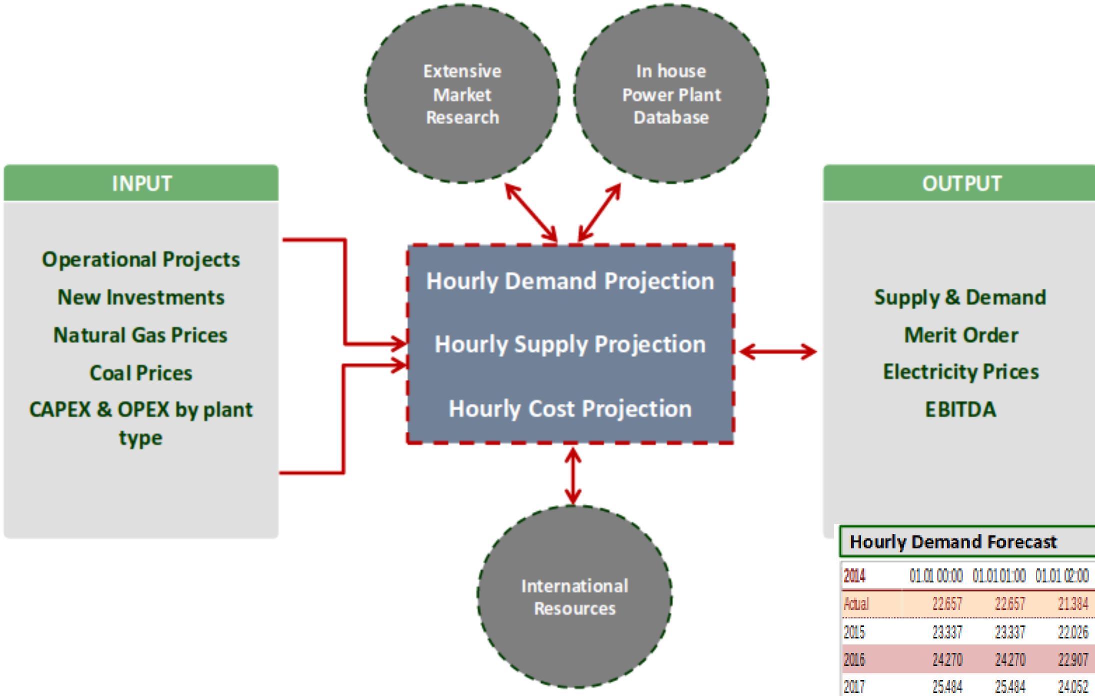
Table 5. Utilization Factors for Summer Peak and Spring Minimum Conditions

Power Plant Types	Summer Peak			Spring Minimum		
	Lower	Normal	Upper	Lower	Normal	Upper
ROR HPP Region I	19%	33%	47%	6%	31%	51%
ROR HPP Region II	22%	31%	45%	8%	45%	77%
ROR HPP Region III	31%	40%	60%	13%	49%	69%
ROR HPP Region IV	20%	24%	31%	9%	56%	79%
DAM HPP Region I	51%	64%	75%	7%	13%	22%
DAM HPP Region II	40%	51%	64%	3%	66%	89%
DAM HPP Region III	56%	68%	81%	4%	20%	30%
DAM HPP Region IV	55%	61%	68%	18%	27%	35%
Lignite Fueled TPP	47%	56%	65%	31%	37%	41%
Imp Coal Fueled TPP	86%	90%	95%	47%	53%	61%
Fuel oil fueled TPP	0%	0%	0%	0%	0%	0%
Nuclear Power Plants	0%	100%	100%	0%	100%	100%
Geothermal PPs	60%	72%	88%	66%	85%	91%
Biomass PPs	44%	51%	60%	44%	49%	55%
Wind Power Plants	27%	43%	56%	13%	23%	35%



Ali Haydar Güverçinci, http://etd.lib.metu.edu.tr/upload/12621200/index.pdf

An example model structure



Hourly Demand Forecast

2014	01.01 00:00	01.01 01:00	01.01 02:00	01.01 03:00	01.01 04:00	01.01 05:00	01.01 06:00
Actual	22.657	22.657	21.384	20.507	20.062	19.945	20.166
2015	23.337	23.337	22.026	21.122	20.664	20.543	20.771
2016	24.270	24.270	22.907	21.967	21.491	21.365	21.601
2017	25.484	25.484	24.052	23.065	22.565	22.433	22.681
2018	26.758	26.758	25.255	24.219	23.693	23.555	23.815
2019	28.096	28.096	26.518	25.430	24.878	24.733	25.006
2020	29.501	29.501	27.844	26.701	26.122	25.969	26.257
2021	30.976	30.976	29.236	28.036	27.428	27.268	27.569
2022	32.524	32.524	30.698	29.438	28.799	28.631	28.948
2023	34.151	34.151	32.232	30.910	30.239	30.063	30.395
2024	35.687	35.687	33.683	32.301	31.600	31.415	31.763
2025	37.115	37.115	35.030	33.593	32.864	32.672	33.034

Production Forecast per plant

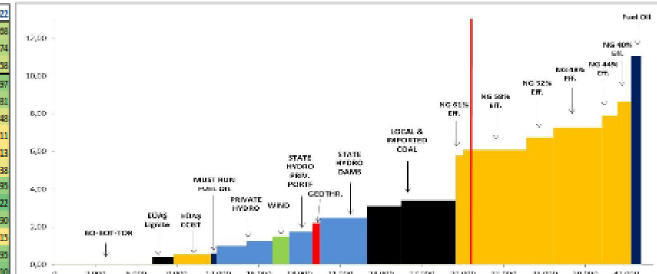
2015

#	2015 Merit Order	Cost	01.01 12:00	01.01 13:00	01.01 14:00	01.01 15:00	01.01 16:00	01.01 17:00	01.01 18:00
16	Ambarlı Natural Gas Plant B Section	0,55	675	675	675	675	675	675	675
17	Aliağa Natural Gas Plant - Motorin	0,55	140	140	140	140	140	140	140
18	Liquid Fuel (Must Run)	0,60	449	449	449	449	449	449	449
19	Solar (PV)	0,75	11	11	11	7	5	5	0
20	HEPP RoR (All Types)	1,00	1.478	1.478	1.478	1.478	1.478	1.478	1.478
21	HEPP Dam (Private+Autoproducer+TORA)	1,25	1.581	1.477	1.542	1.367	1.203	1.181	1.147
22	WEPP	1,50	994	994	994	994	994	994	994
23	HEPP Dam (EGC-PA+BOT)	1,75	1.677	1.402	1.412	1.705	1.430	1.317	1.156
24	JEPP	2,20	264	264	264	264	264	264	264
25	Biogas	2,25	212	212	212	212	212	212	212
26	HEPP Dam (EGC)	2,50	3.458	2.892	2.905	3.502	2.948	2.702	2.381
33	Local Coal (all types) (Private+Autoproducer)	4,19	426	426	426	426	426	426	426
34	Import Coal (Private+Autoproducer)	4,32	2.656	2.735	2.735	2.735	2.735	2.735	2.735
35	Natural Gas (D61)	6,22	0	0	0	0	0	0	0
36	Natural Gas (D58)	6,62	0	1.126	1.271	781	3.369	3.837	3.837

Hourly Electricity Price Forecast

Price Analysis	2015	2016	2017	2018	2019	2020	2021	2022
Base Load Elect. Price ($cent/kwh)	5,55	5,38	6,52	7,24	7,80	7,64	7,59	7,68
Mid Merit Electricity Price ($cent/kw	5,83	5,65	6,74	7,31	7,84	7,68	7,64	7,74
Night Elect. Price ($cent/kwh)	5,08	4,94	6,14	7,12	7,73	7,57	7,49	7,58
January Elect. Price ($cent/kwh)	5,88	5,80	6,85	7,30	8,04	7,94	7,89	7,97
February Elect. Price ($cent/kwh)	5,98	5,88	6,67	7,36	7,93	7,75	7,69	7,81
March Elect. Price ($cent/kwh)	5,32	5,23	6,20	6,97	7,66	7,42	7,35	7,48
April Elect. Price ($cent/kwh)	4,45	4,21	5,34	6,33	7,18	6,98	6,98	7,11
May Elect. Price ($cent/kwh)	4,61	4,42	5,49	6,37	7,21	7,01	7,00	7,13
June Elect. Price ($cent/kwh)	4,91	4,78	5,87	6,04	7,46	7,29	7,28	7,38
July Elect. Price ($cent/kwh)	5,84	5,65	6,98	7,69	8,04	7,94	7,90	7,95
August Elect. Price ($cent/kwh)	6,35	6,12	7,47	8,04	8,31	8,21	8,15	8,22
September Elect. Price ($cent/kwh)	5,93	5,72	7,03	7,63	8,06	7,91	7,83	7,90
October Elect. Price ($cent/kwh)	4,98	4,85	5,99	6,69	7,41	7,15	7,05	7,15
November Elect. Price ($cent/kwh)	5,90	5,76	6,97	7,09	8,09	7,98	7,88	7,95
December Elect. Price ($cent/kwh)	6,44	6,13	7,32	7,95	8,19	8,11	8,04	8,10

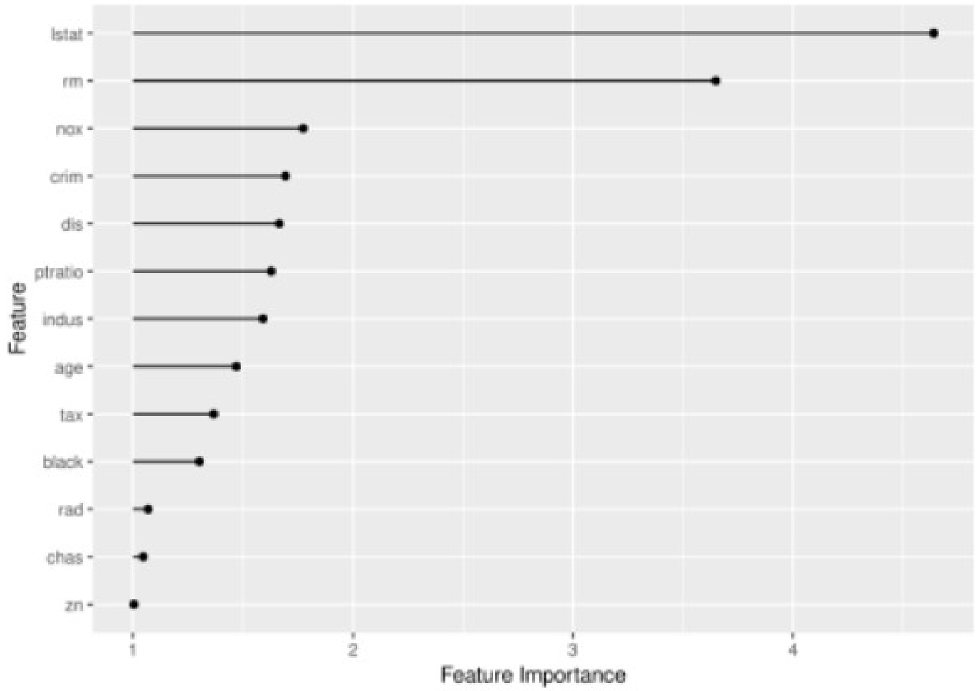
Merit Order

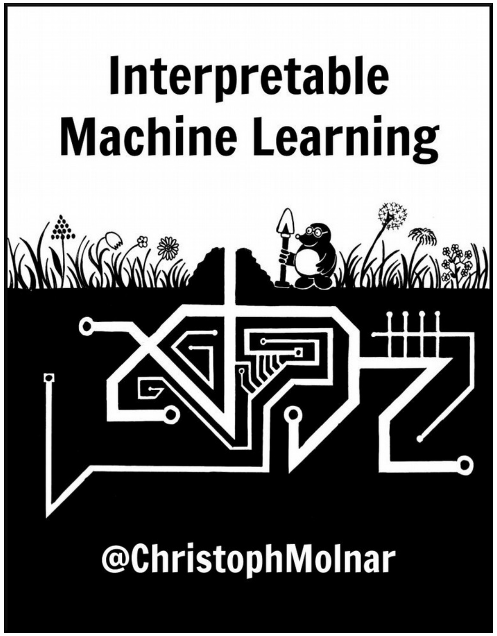


https://www.garantiinvestorrelations.com/en/images/pdf/2015-Electricity-Market-Report.pdf

Interpretable ML

```
imp = FeatureImp$new(predictor, loss = "mae")
plot(imp)
```





https://christophm.github.io/interpretable-ml-book/

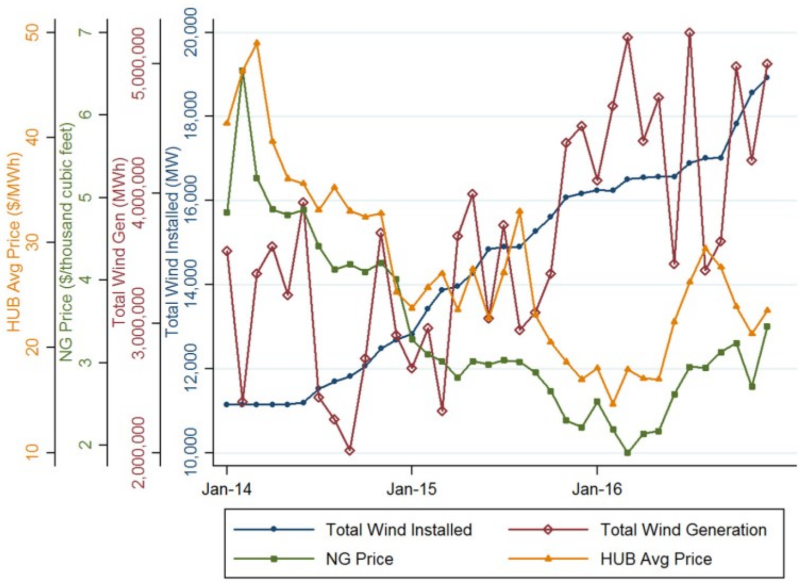
https://www.r-bloggers.com/interpretable-machine-learning-with-iml-and-mlr-2/

Renewables supressing prices

Energy Economics
Volume 76, October 2018, Pages 21-33

Effect of wind generation on ERCOT nodal prices ☆

Chen-Hao Tsai [a], Derya Eryilmaz [b]



. ERCOT installed wind capacity, monthly total wind generation, ng price and hub average energy price (2014 through 2016). Data sources: ERCOT for HUB energy price.

Every 1000 MW wind : Price decrease of $1.45/ MWh to $4.45/MWh for non-wind resources

Region	Reference	Price Data	Data Period	Data Frequency
Europe				
Germany	Cludius et al. (2014)	Day-Ahead	2008–2012	Hourly
	Dillig et al. (2016)	Day-Ahead	2011–2013	Hourly
Ireland	Denny et al. (2017)	4-day ex-post	2009	Hourly
Italy	Clò et al. (2015)	Day-Ahead	2009–2013	Daily
Netherlands	Mulder and Scholtens (2013)	Day-Ahead	2006–2011	Daily
Spain	Gelabert et al. (2011)	Day-Ahead	2005–2009	Daily
	Gil et al. (2012)	Day-Ahead	2007–2010	Hourly
United States				
CAISO	Woo et al. (2016)	Day-Ahead Zonal Real-Time Zonal	2012–2015	Hourly
ERCOT	Woo et al. (2011)	Real-Time Zonal	2007–2010	15 min
Pacific Northwest	Woo et al. (2013)	Day-Ahead (Hub)	2006–2012	Hourly
PJM	Gil and Lin (2013)	Day-Ahead (Hub)	2010	Hourly

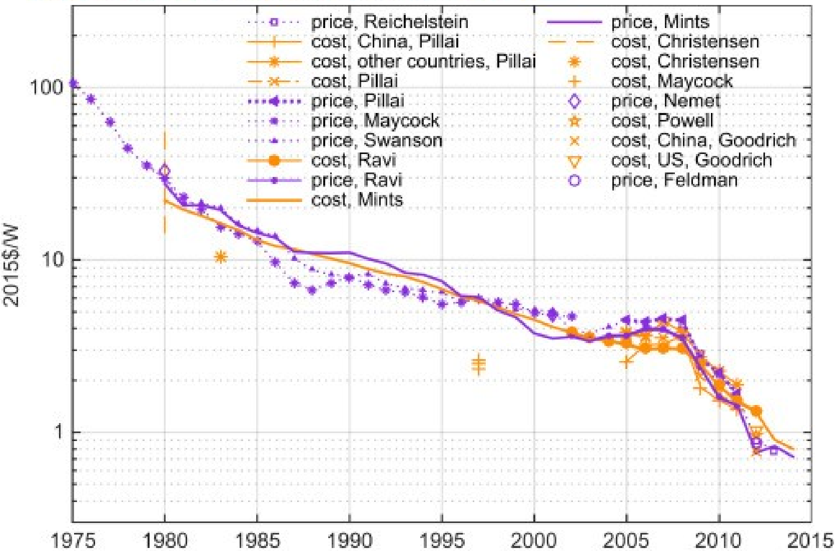
https://www.sciencedirect.com/science/article/pii/S0140988318303931?via%3Dihub

Forecast of technology- lessons learned

Energy Policy
Volume 123, December 2018, Pages 700-710

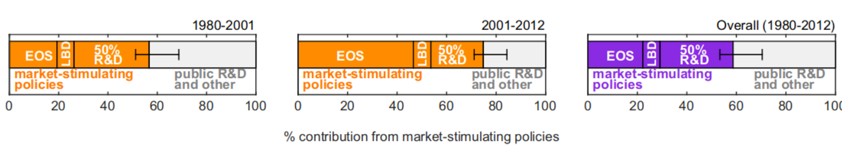
Evaluating the causes of cost reduction in photovoltaic modules

Goksin Kavlak [a], James McNerney [a], Jessika E. Trancik [a, b]



Cost components in 1980, 2001, and 2012. Costs are in 2015 US dollars.

Cost component	1980		2001		2012	
	$/W	%	$/W	%	$/W	%
Silicon cost	10.88	37%	0.55	13%	0.15	14%
Non-silicon materials cost	9.17	32%	1.21	30%	0.56	51%
Plant size-dependent cost	9.01	31%	2.33	57%	0.38	35%
Total module cost	29.07	100%	4.08	100%	1.08	100%



Crystalline PV

- Low level factors
  - Variables of cost model(wafer area)
- High level
  - R&D, learning-by-doing, and scale economies

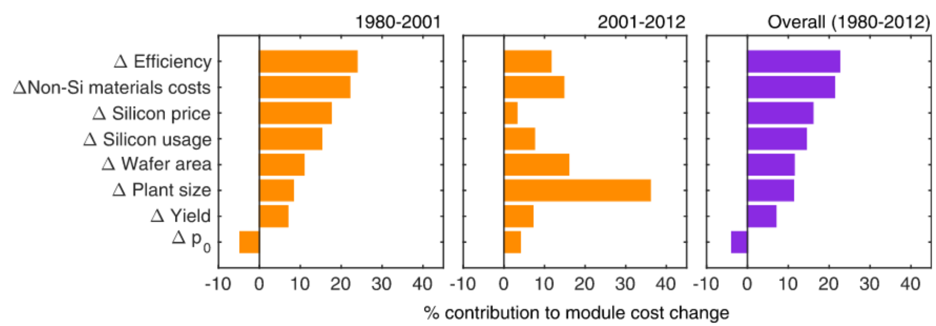


Fig. 3. Contribution of the low-level mechanisms to module cost decline in 1980–2001 (left), 2001–2012 (middle), and 1980–2012 (right). Mechanisms are listed in the order of decreasing contribution for the 1980–2001 period.

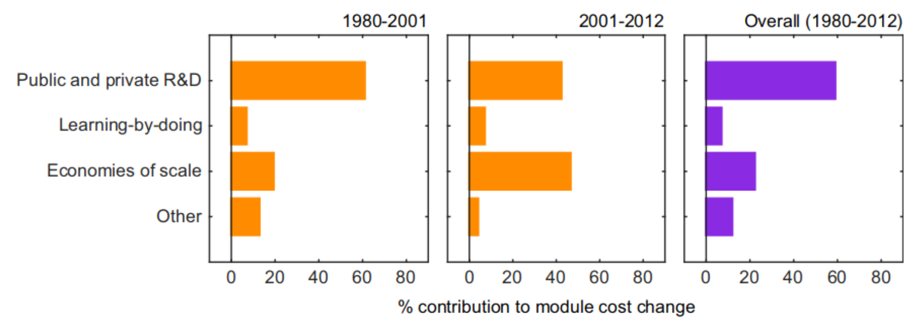


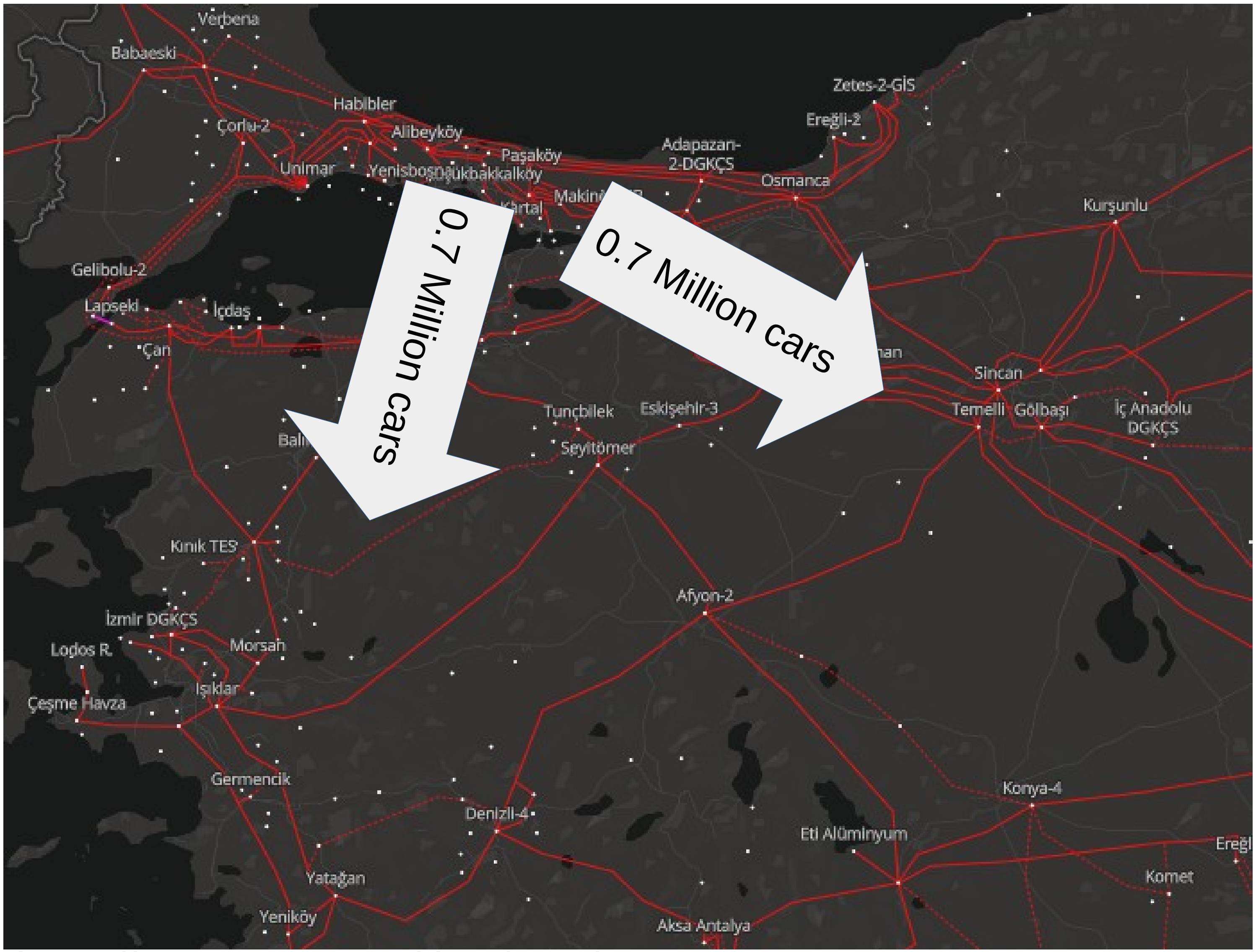
Fig. 4. Contribution of the high-level mechanisms to module cost decline in 1980–2001 (left), 2001–2012 (middle), and 1980–2012 (right). We categorize the changes that require a lab setting or a nonroutine production activity (e.g. experimental production line) as being caused by research and development (Pisano, 1996, Rosenberg, 1982). We consider an improvement to have been made by learning-by-doing if it was achieved as a result of repeated routine manufacturing activity and

https://www.sciencedirect.com/science/article/pii/S0301421518305196

Forecasting new actors

- Demand elasticity
- EV & Distributed generation
- Bots
- Algorithmic traders
- New financial instruments
- Aggregators
- Prosumers

Great Migration of Tribes 2030 (Bayram Trafiği)



Every car
+ 20kW charge

0.7 mCars:
~ 4000 MW

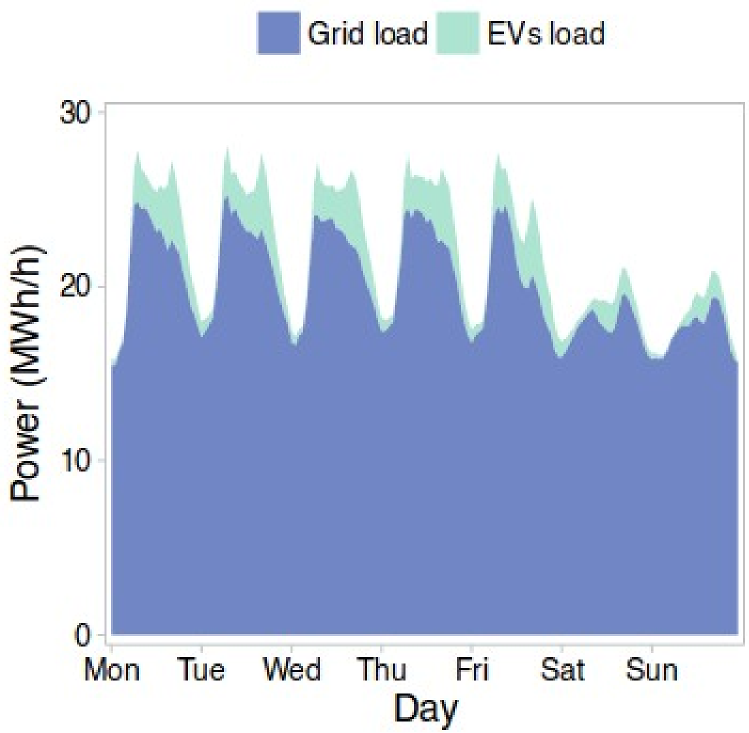
2018 Peak demand:
~ 49000 MW

A change in:
- demand
- topology of grid

https://www.entsoe.eu/data/map/

http://www.hurriyet.com.tr/ekonomi/bayramda-15-5-milyon-arac-yollardaydi-40574570

EV&PV: Winter problem



January

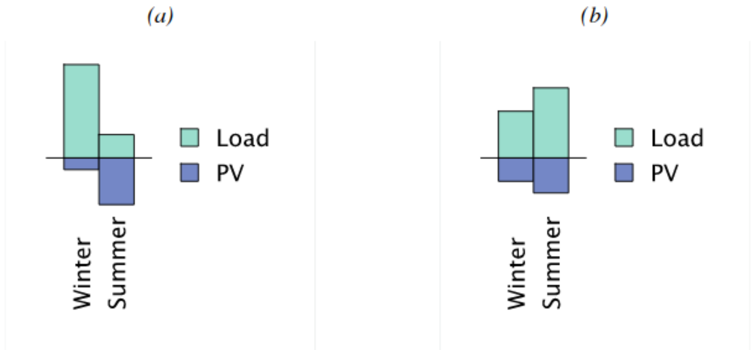


Figure 4.3. Example of two hypothetical seasonal profiles of PV and load. (a) Corresponds to a location with high winter load and low summer load, while (b) corresponds to a more balanced load profile in both seasons, yet, slightly higher in summer. Both (a) and (b) have the same load and PV percentage penetration, i.e., the areas are equal in the two subplots.

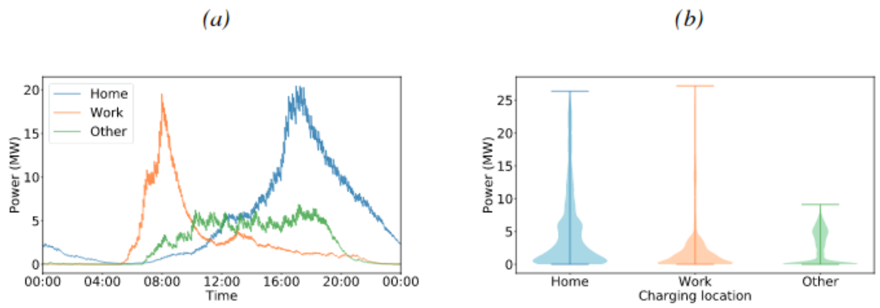


Figure 4.5. (a) The three charging profiles of an average day for the 100% EV penetration everywhere charging using 6.9 kW chargers. (b) Violin plot for the load values during the whole month of simulation.

http://www.diva-portal.org/smash/get/diva2:1244542/FULLTEXT01.pdf

Short term PV forecasts

Contents lists available at ScienceDirect

Applied Energy

journal homepage: www.elsevier.com/locate/apenergy

Prediction of short-term PV power output and uncertainty analysis

Luyao Liu[a], Yi Zhao[a], Dongliang Chang[b], Jiyang Xie[b], Zhanyu Ma[b,*], Qie Sun[a,*], Hongyi Yin[a,*], Ronald Wennersten[a]

Correlation between PV power output and meteorological factors.

Meteorological factor	Correlation coefficient
Solar irradiance	0.9840
Air temperature	0.7615
Cloud type	−0.4847
Dew point	0.6386
Relative humidity	−0.4918
Precipitable water	0.3409
Wind direction	0.1263
Wind speed	0.1970
Air pressure	0.0815

Four partitions according to the index k_d

Data types	Weather conditions	k_d range
Type 1	Rainy day	$0.75 < k_d \leq 1$
Type 2	Overcast day	$0.45 < k_d \leq 0.75$
Type 3	Partially cloudy day	$0.15 < k_d \leq 0.45$
Type 4	Sunny day	$k_d \leq 0.15$

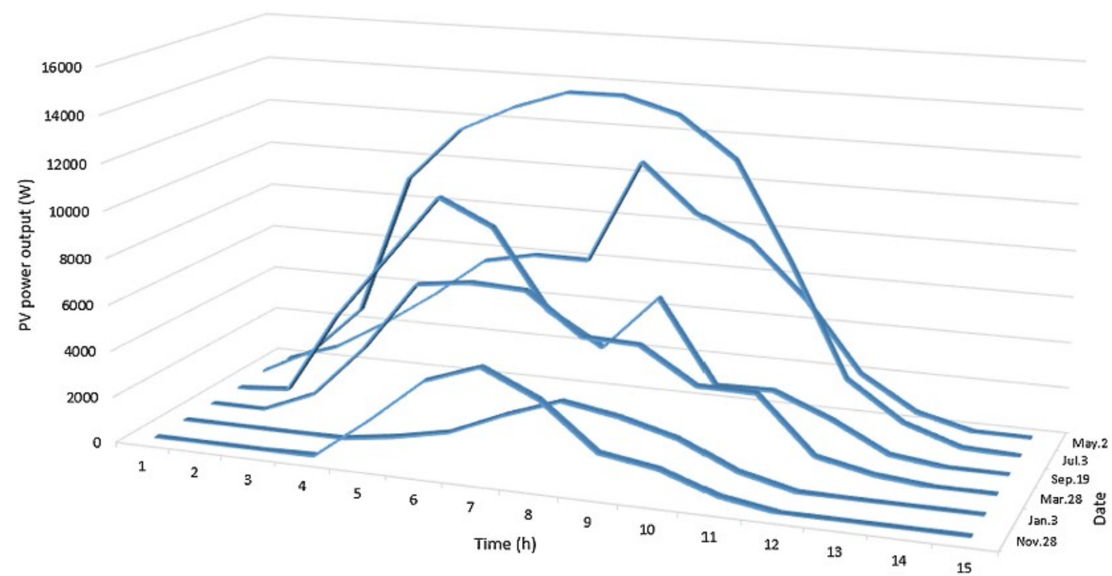


Fig. 2. Examples of PV power outputs.

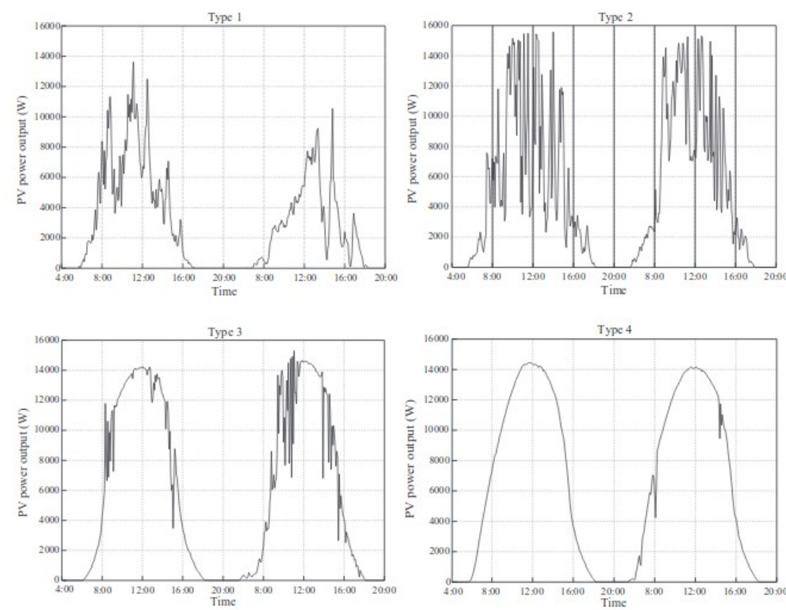
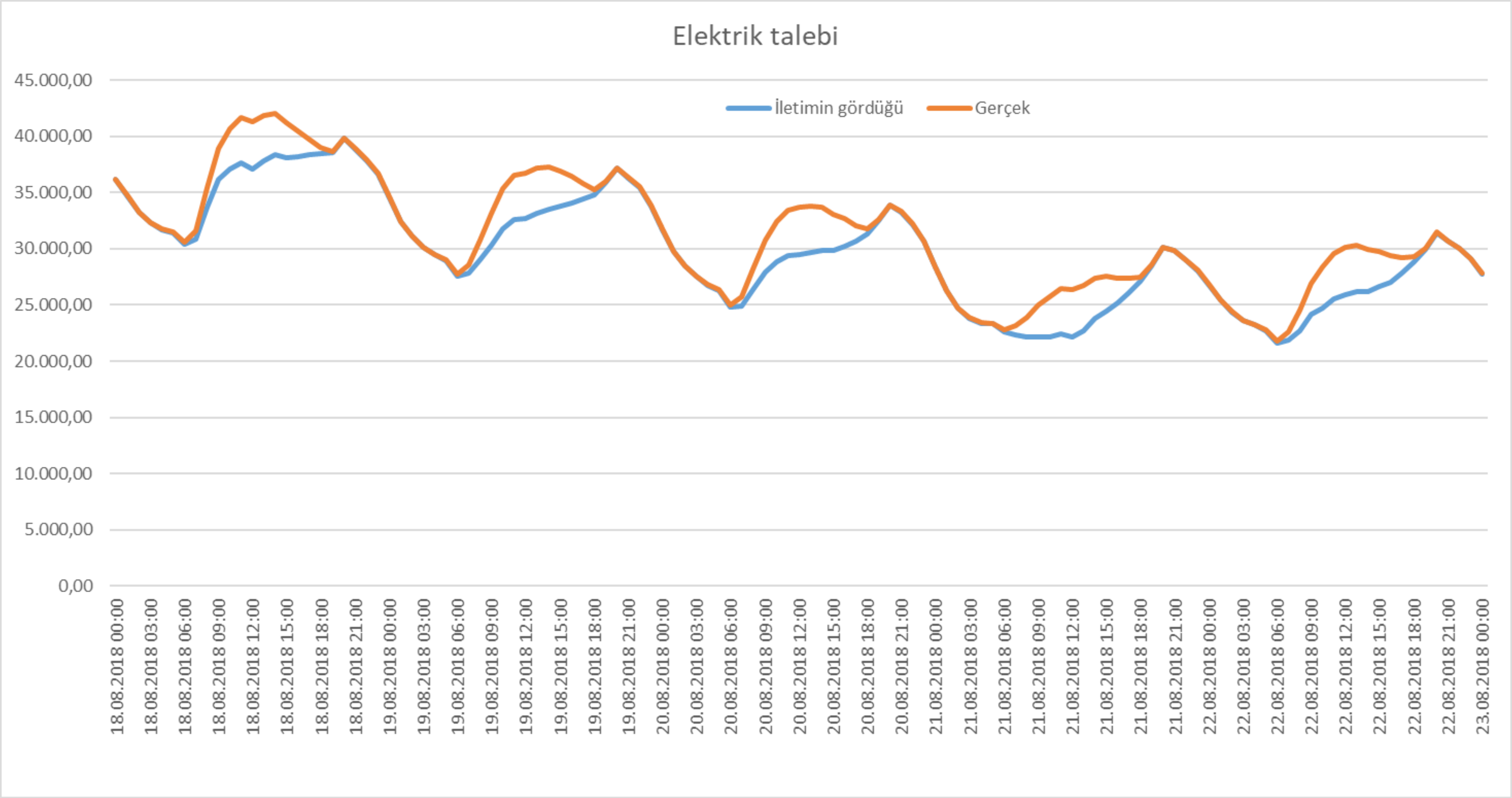


Fig. 3. Data categories of different weather conditions obtained from weather clustering analysis.

https://www.researchgate.net/profile/Luyao_Liu6/publication/326323669_Prediction_of_short-term_PV_power_output_and_uncertainty_analysis/links/5bfd0428299bf10737f9bbfe/Prediction-of-short-term-PV-power-output-and-uncertainty-analysis.pdf

PV effect – Real & perceived by transmission



Questions?

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