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Fraunhofer Institute for Algorithms and Scientific Computing SCAI

Satellite session of CCS 2023

Mehrnaz Anvari

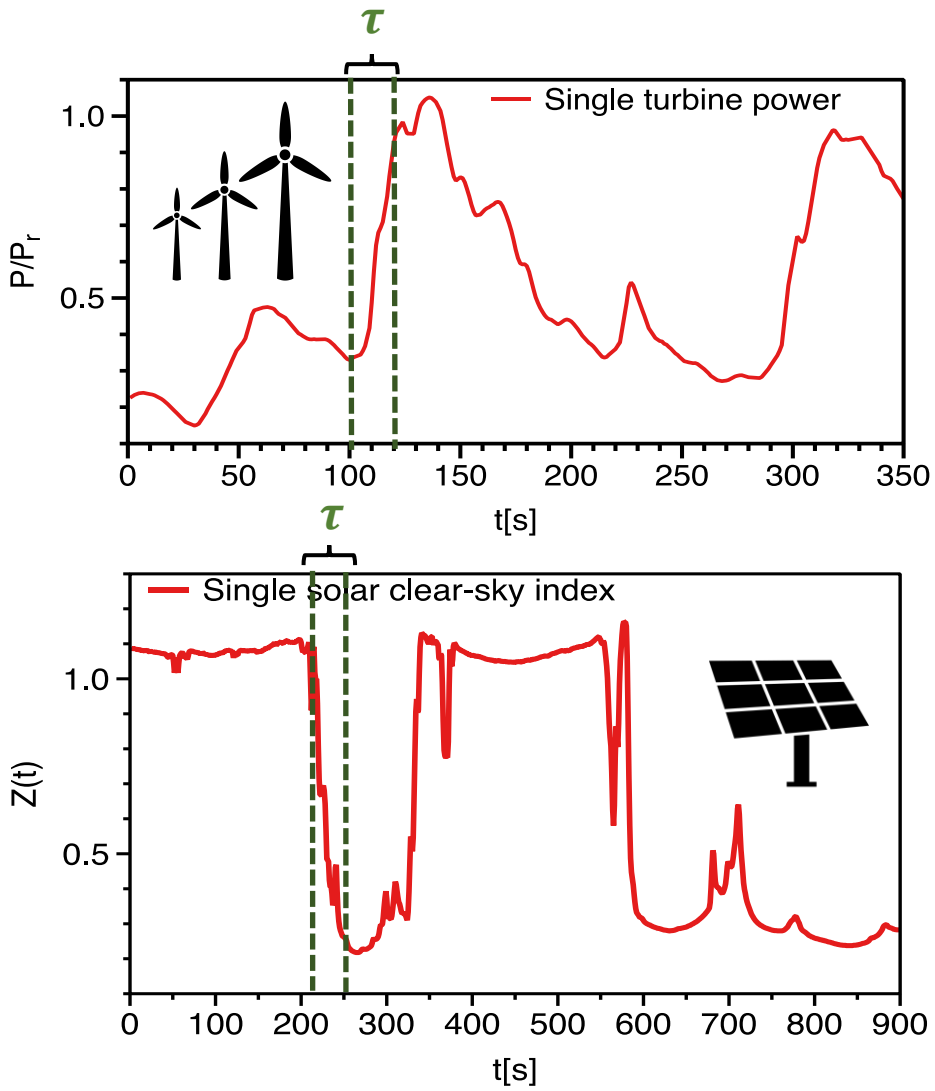
Oct. 19, 2023

Data-Driven Load Profiles and the Dynamics of Residential Electric Power Consumption

Extreme (Weather) Events

➢ Short-time scales extreme events

- Physical Review Letters 110(13), 138701 (2013)
- The European Physical Journal SpecialTopics 223, 2637–2644 (2014)
- New Journal of Physics 18(6), 063027 (2016)
- Solar Energy 157, 735–743 (2017)



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- Environmental Research Letters 17, 044018 (2022)

California Department of Water Resources in January 2014 Image credit: Paul Hames

Dunkelflaute, www.helmholtz-klima.de/aktuelles

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Affect the energy sources availability

California Department of Water Resources in January 2014 Image credit: Paul Hames

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  - arXiv:2301.13793 (accepted in Nature Energy, 2023)
  - The Eleventh International Conference on SmartGrids, Green Communications and IT Energy-aware Technologies (2021)
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Hurricane Laura 2020
https://dailyenergyinsider.com/

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Damage to the power grid infrastructures

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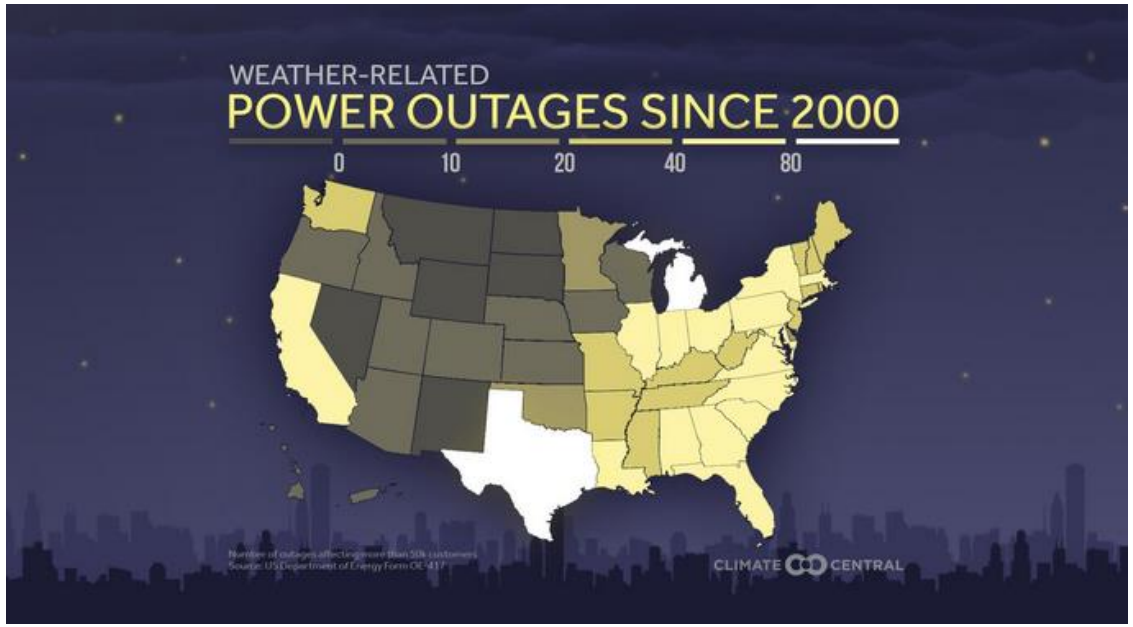

https://www.climatecentral.org/climate-matters/power-outages

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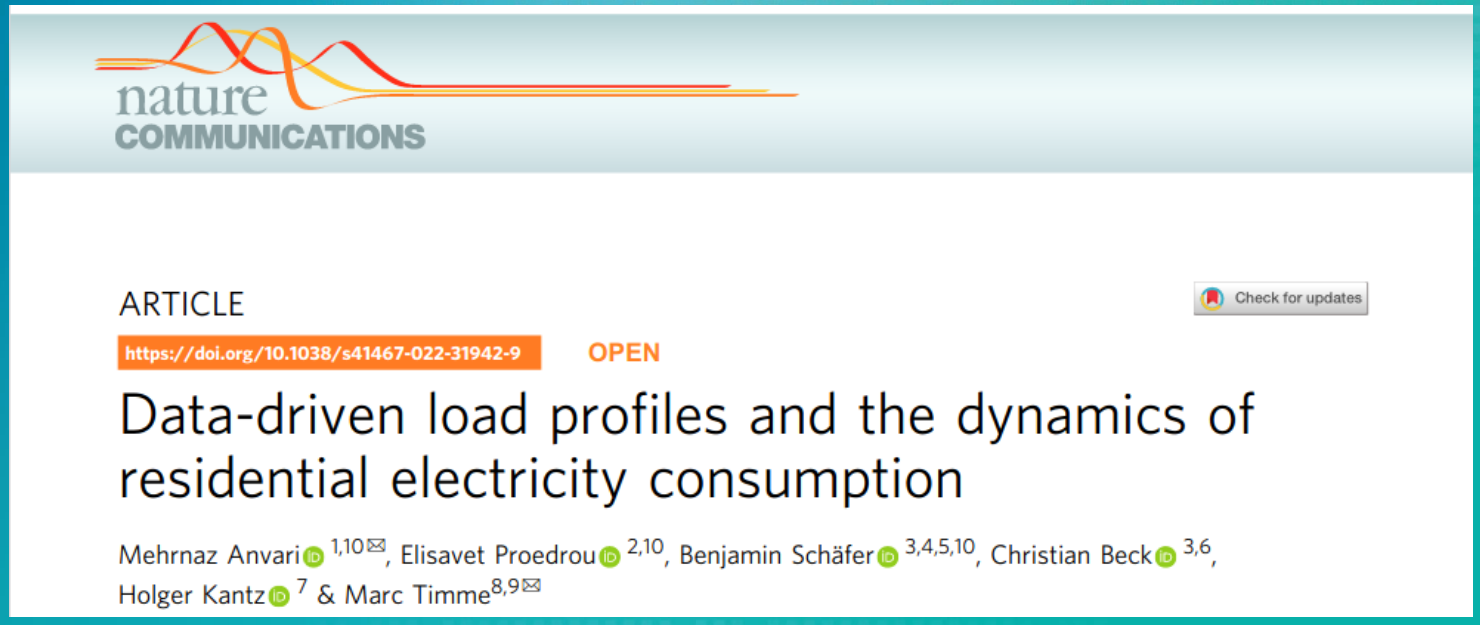


nature COMMUNICATIONS

ARTICLE

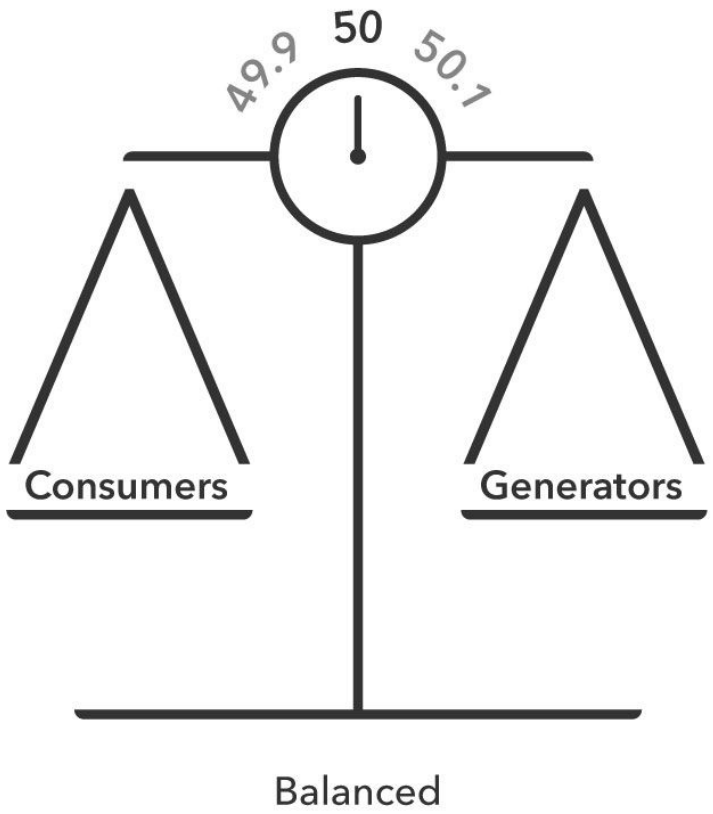
Check for updates

https://doi.org/10.1038/s41467-022-31942-9 OPEN

Data-driven load profiles and the dynamics of residential electricity consumption

Mehrnaz Anvari[1,10✉], Elisavet Proedrou[2,10], Benjamin Schäfer[3,4,5,10], Christian Beck[3,6], Holger Kantz[7] & Marc Timme[8,9✉]

Energy Balance



https://www.next-kraftwerke.com/

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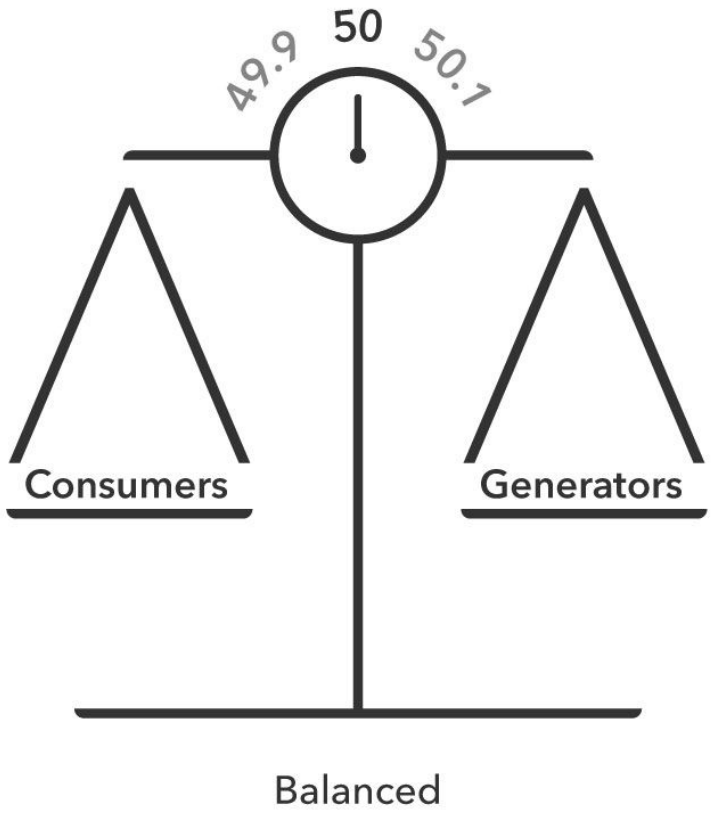

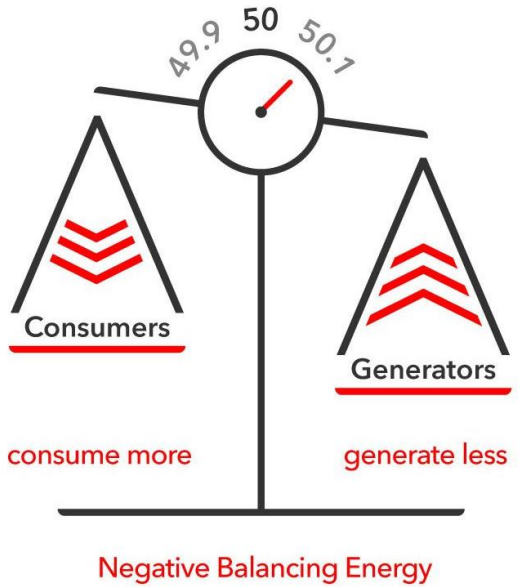

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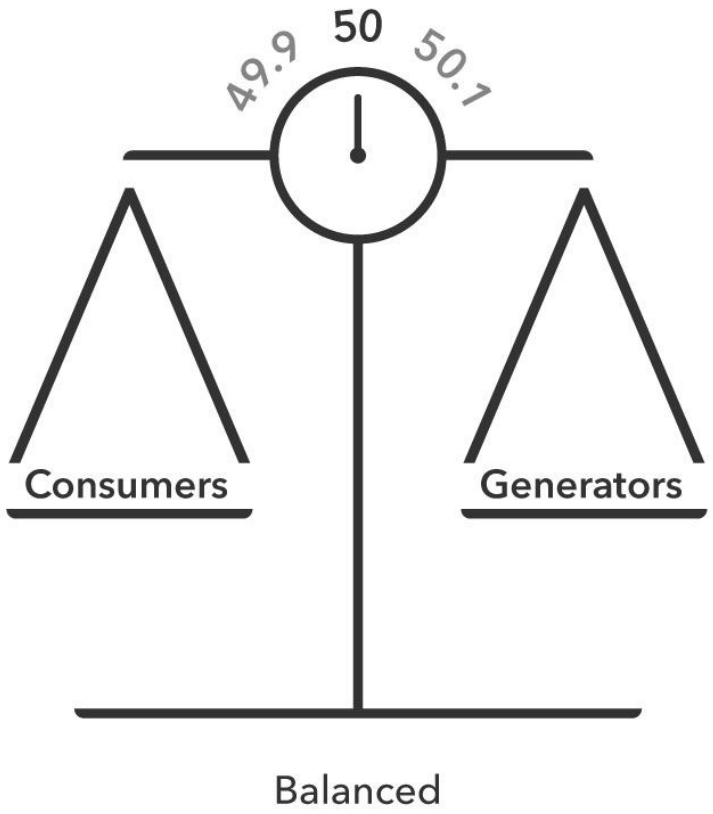

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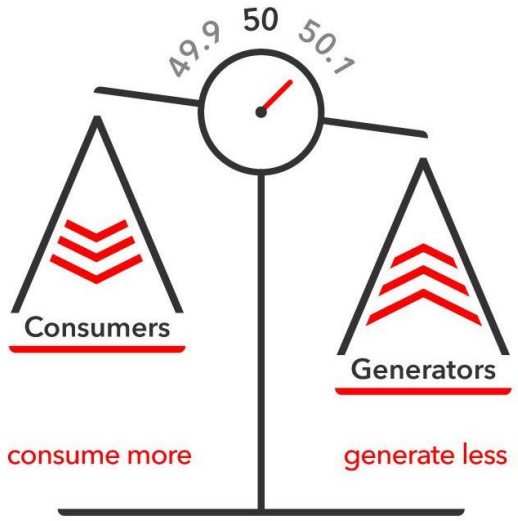
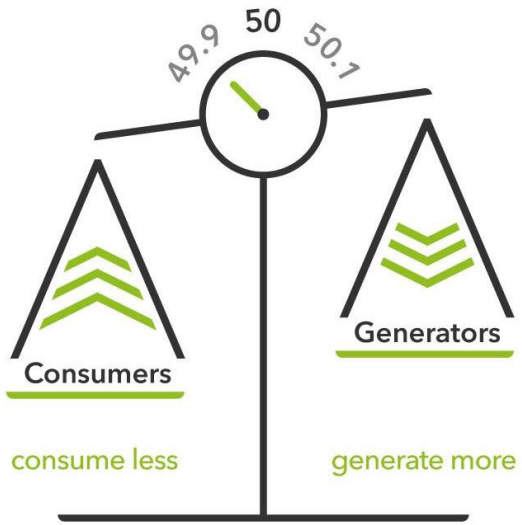
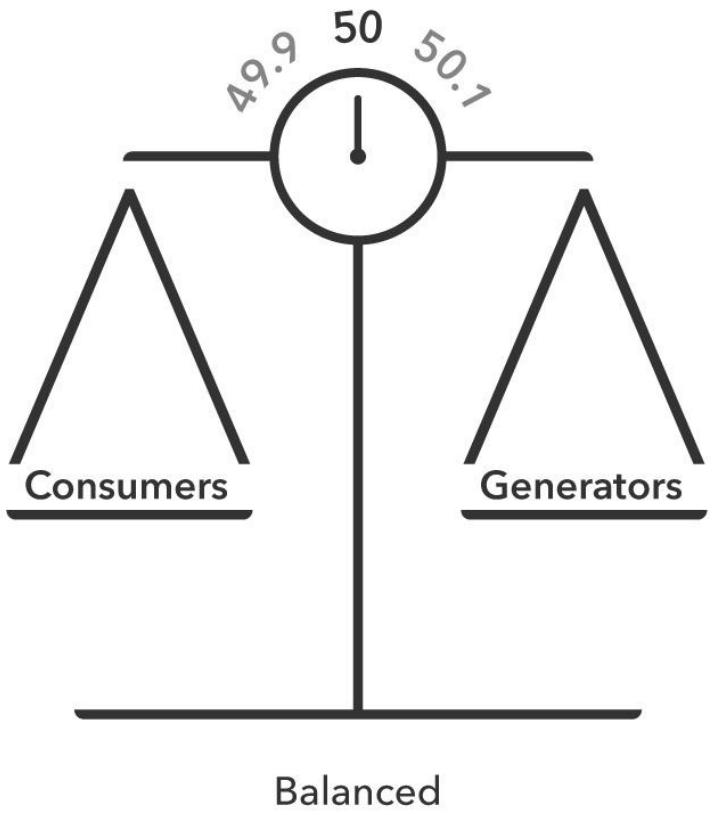


Negative Balancing Energy



Positive Balancing Energy

The Frequency Dynamics



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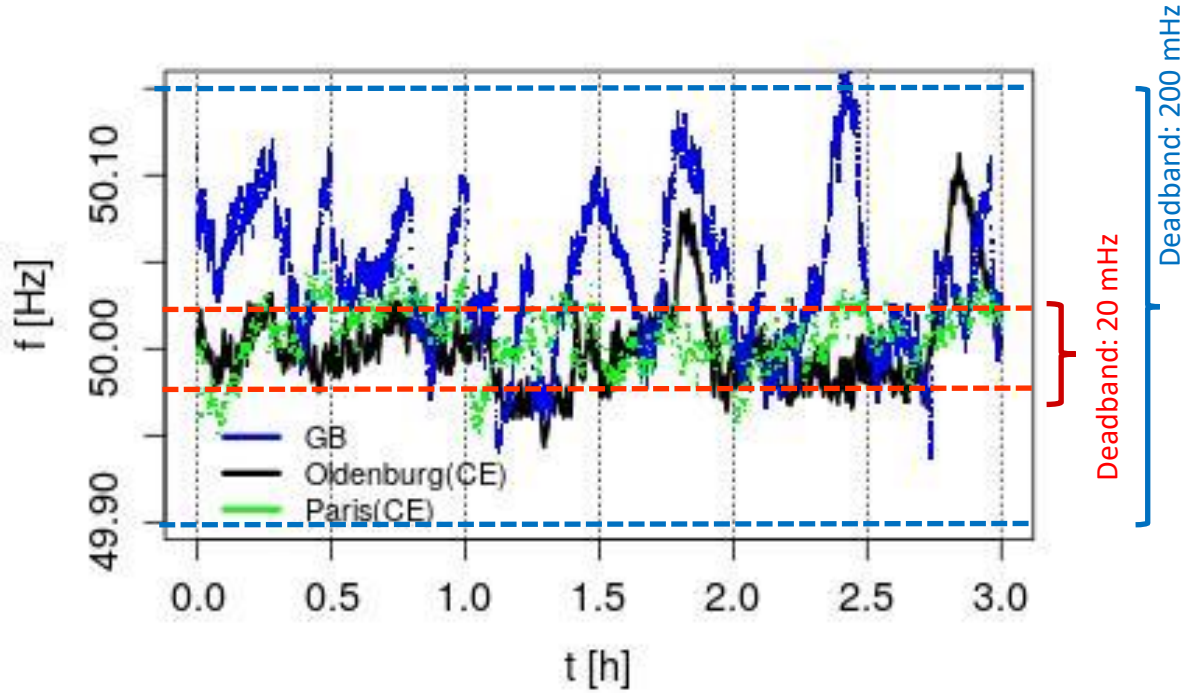
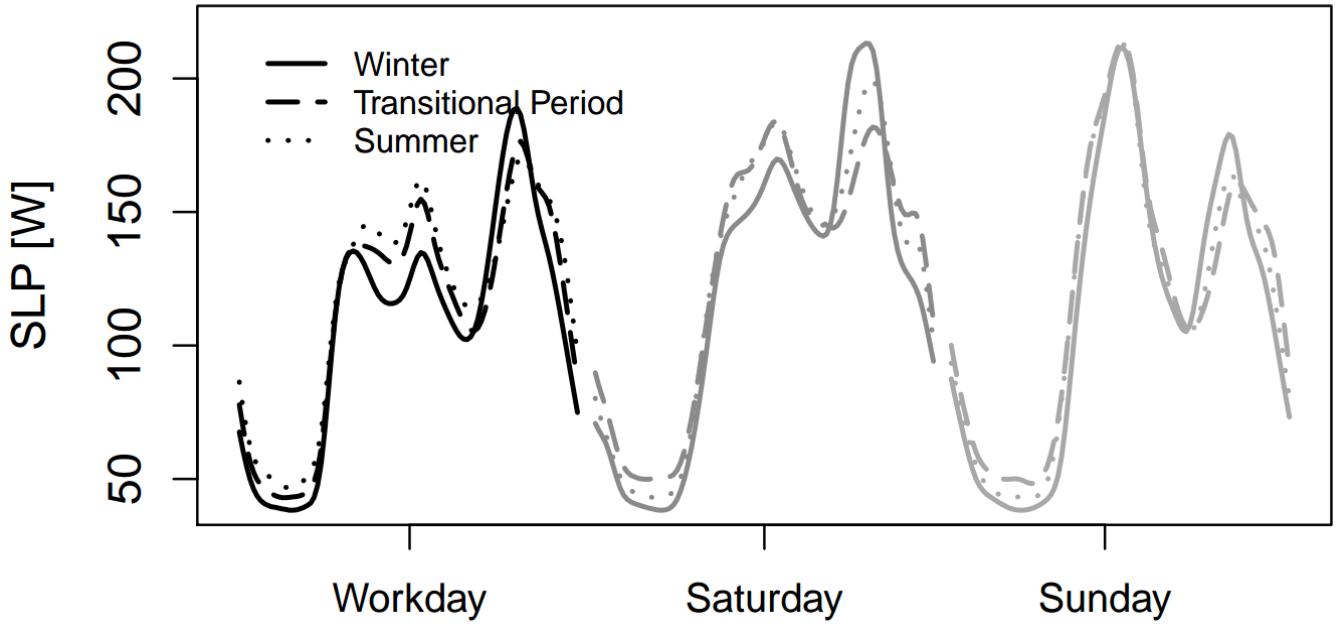


Phys. Rev. Research 2, 013339 (2020)

Power outages/Blackout

https://www.shutterstock.com/video/

Standard Load Profile



Source: BDEW Standard Load Profile

Standard Load Profile

Standard/Classical models

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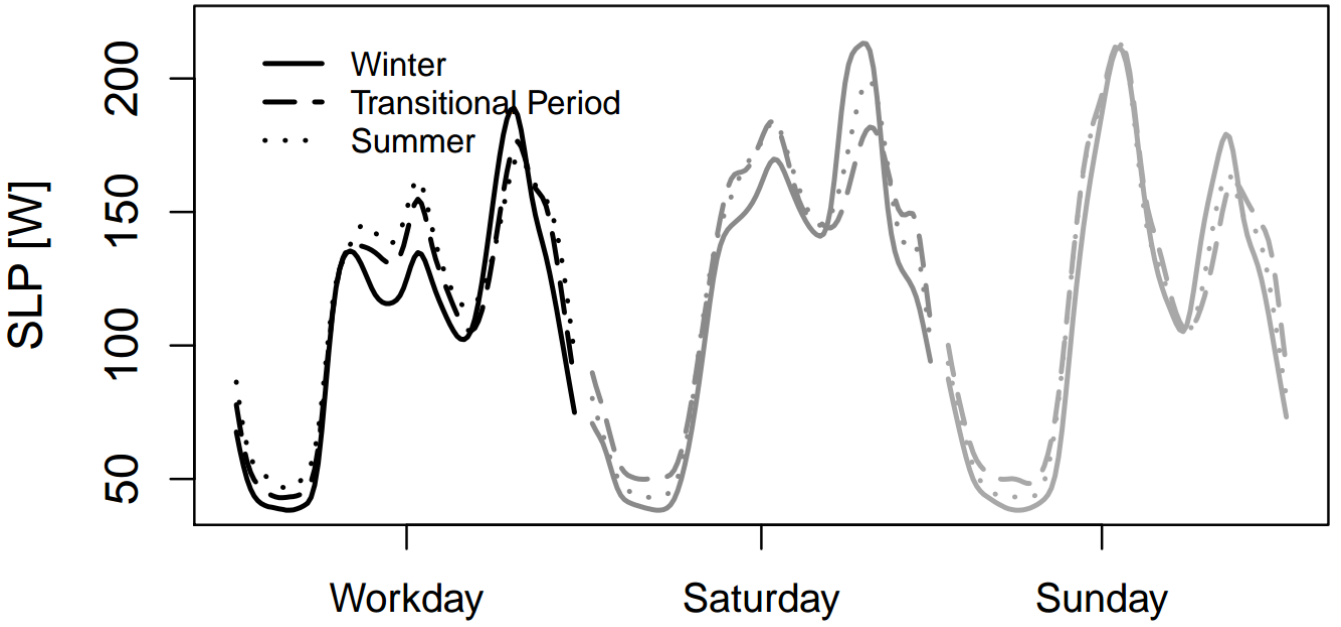
  - total electricity consumption of multiple households
  - and macro-variables



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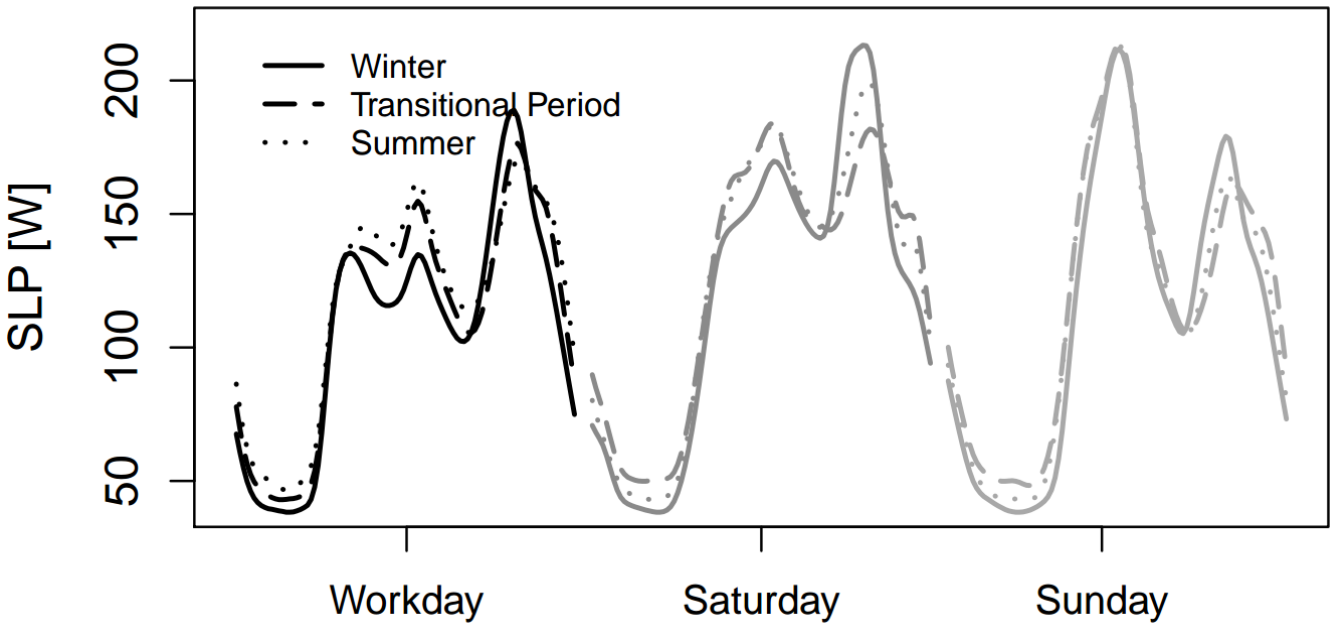

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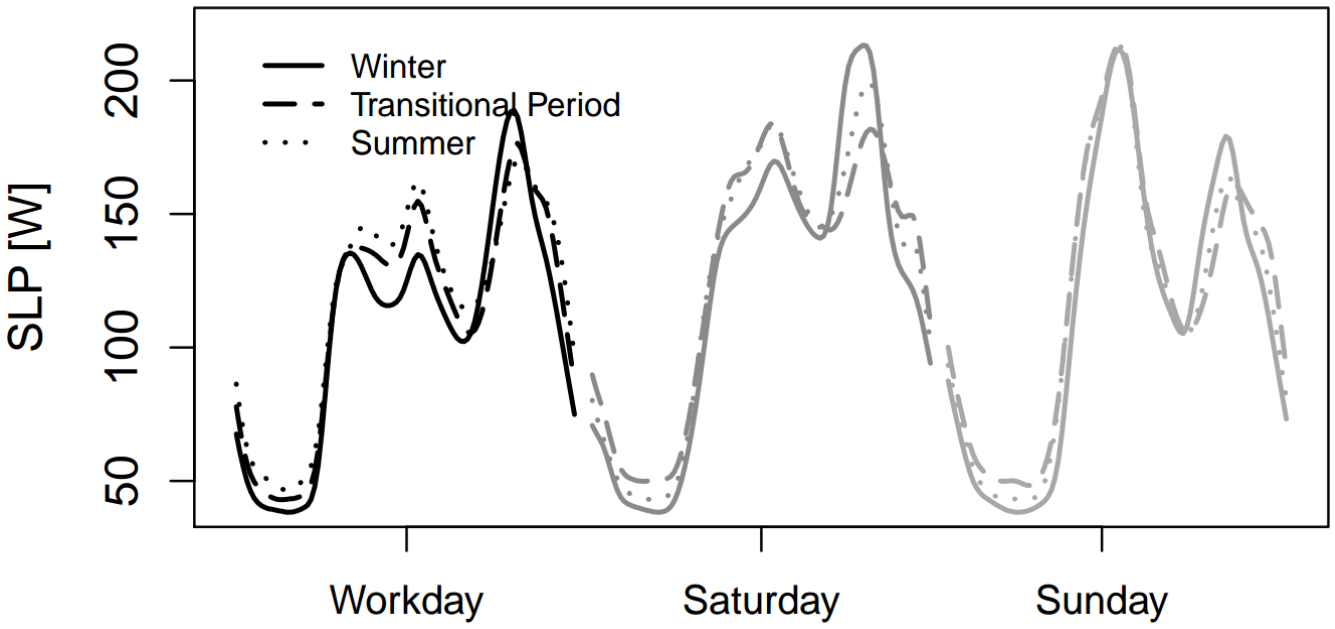

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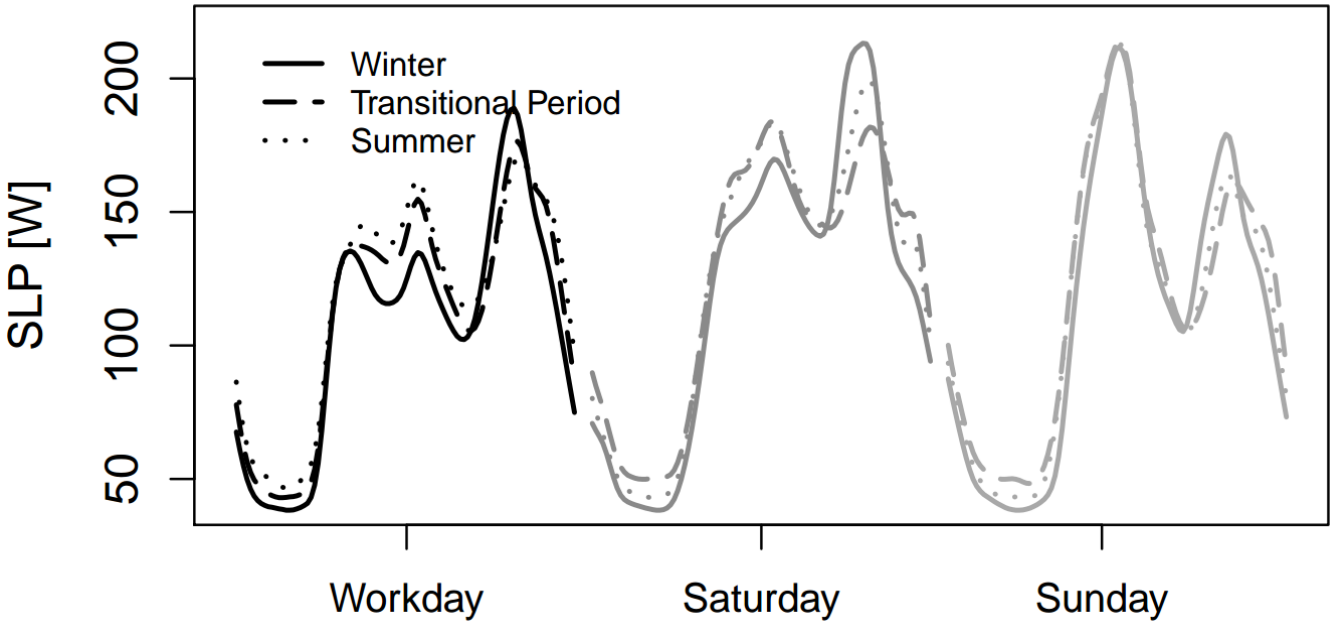
H0 Standard Load Profile

German Standard Load Profile:
Bundesverband der Energie- und Wasserwirtschaft (BDEW) e.V.

- Puplished in 1990
- The data recorded before 1970
- After filtering the data of 332 houses are available
- All data was upsampled to 15 minutes



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https://www.allgaeunetz.com/download/vdewm022000lastprofilverfahrenzurbelieferungun.pdf

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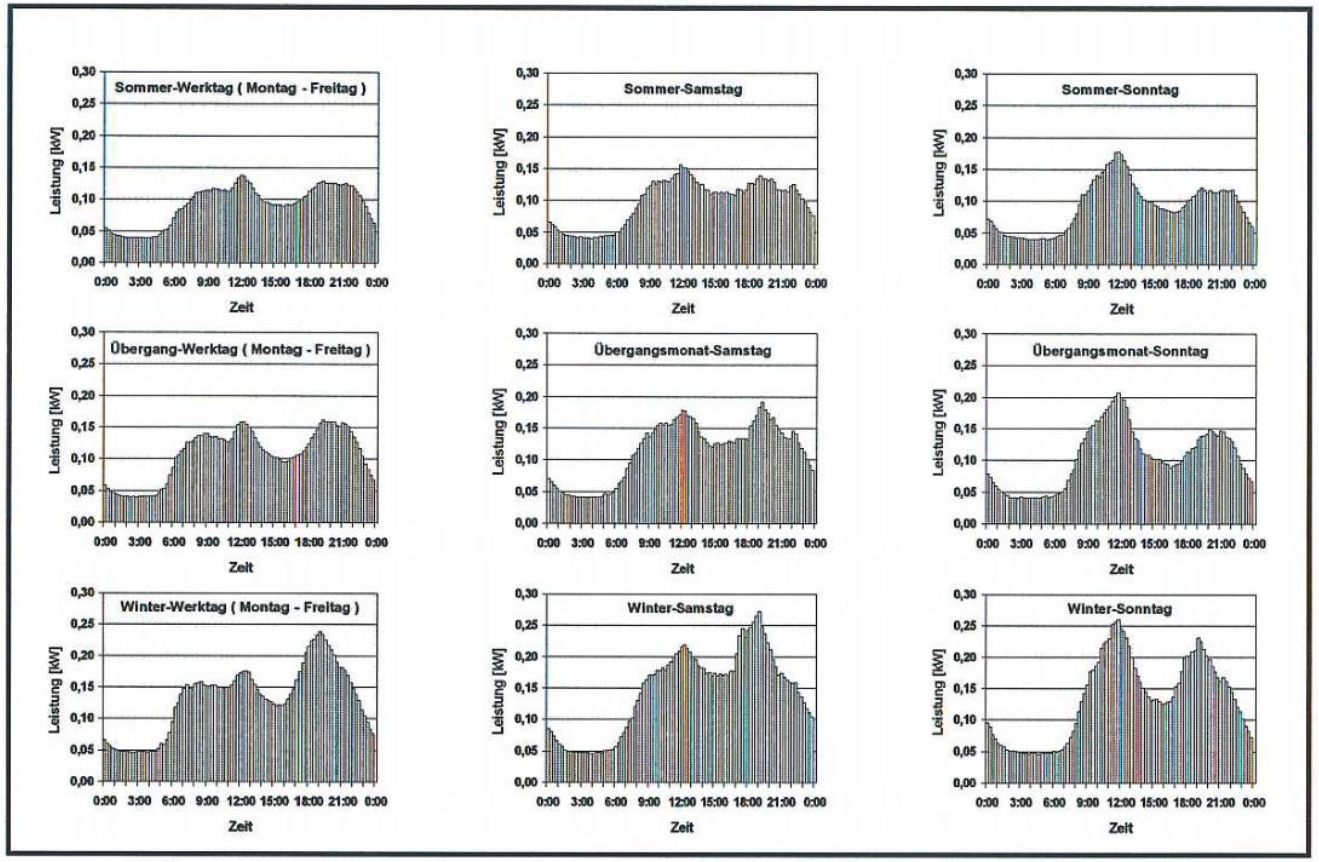

Bild 5.1: Normlastprofile (nicht dynamisiert) für Haushaltskunden (Beispiel abweichend von BTU-Haushaltslastprofilen)

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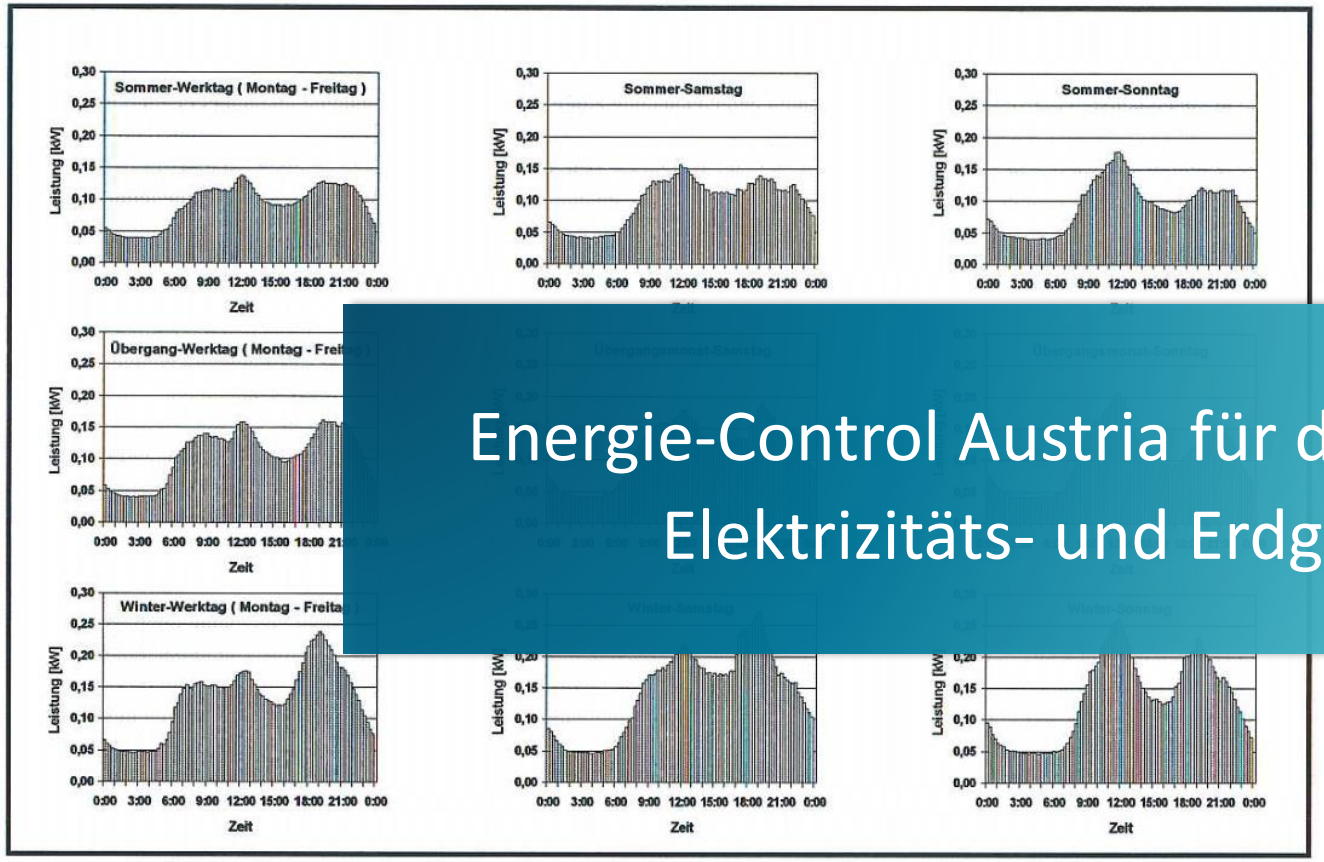

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Energie-Control Austria für die Regulierung der Elektrizitäts- und Erdgaswirtschaft

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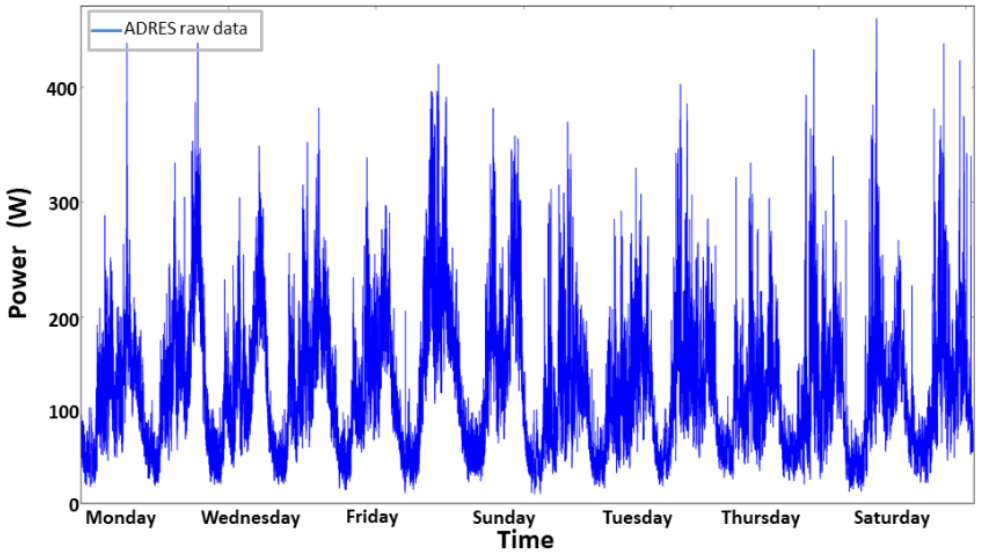

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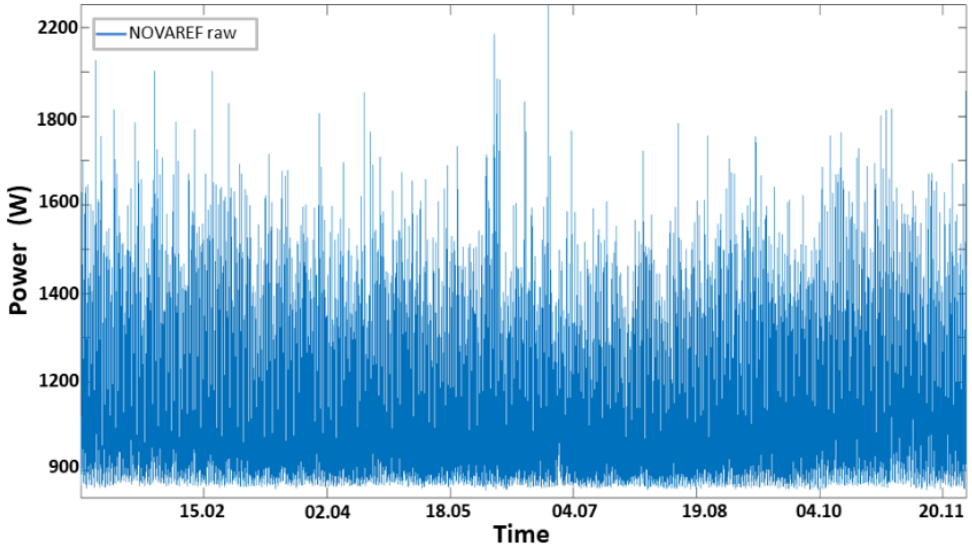

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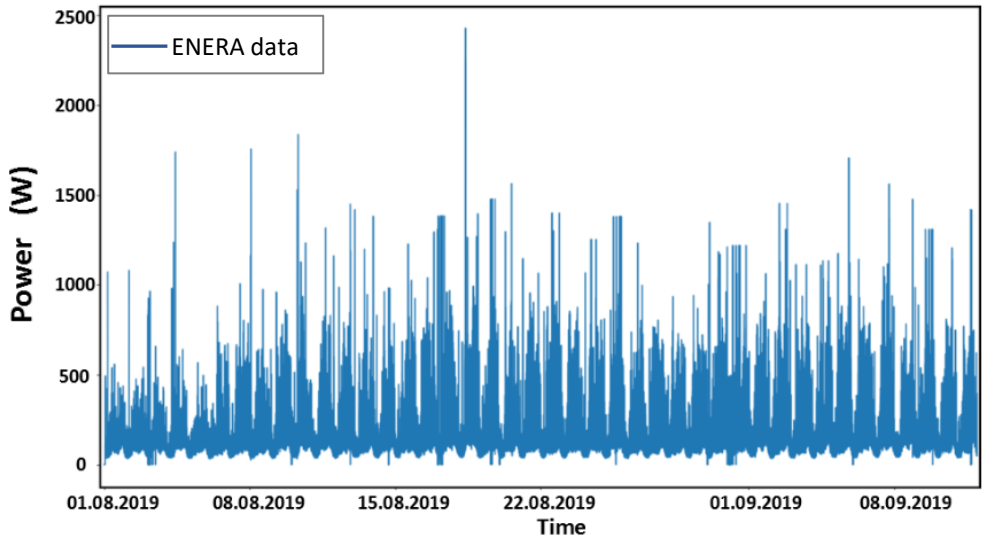

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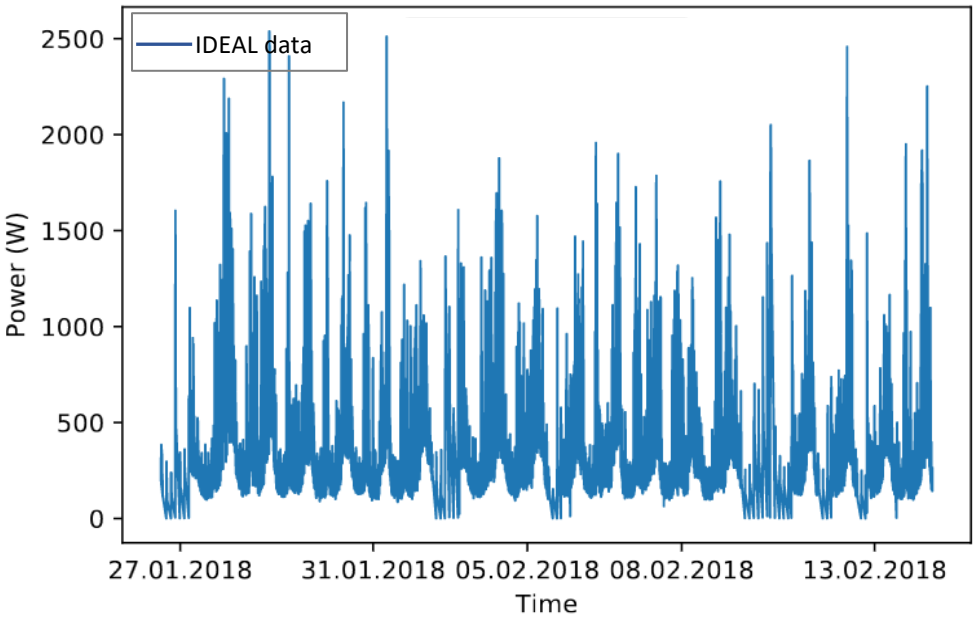
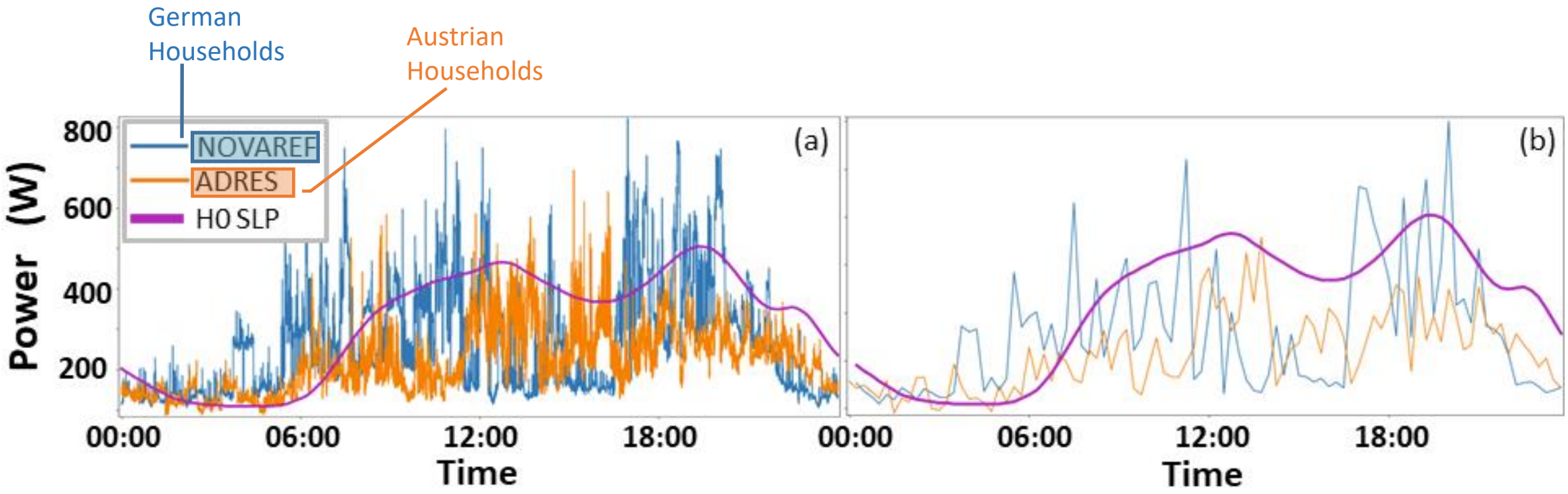
- **IDEAL project:** collected by two EPSRC-funded projects, 255 households in UK, Sampling rate: 1Hz



Comparison with H0 SLP



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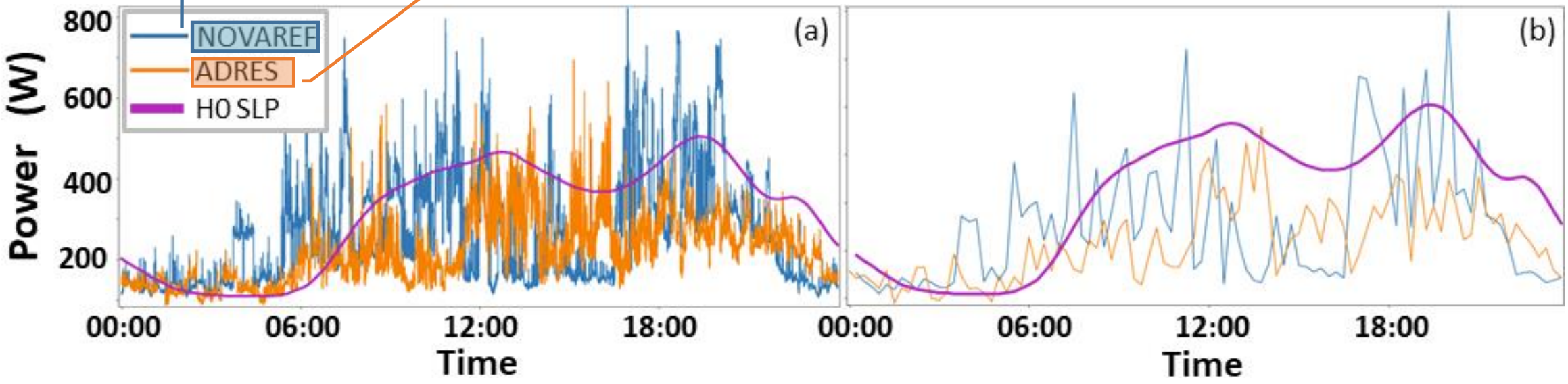
German Households

Austrian Households



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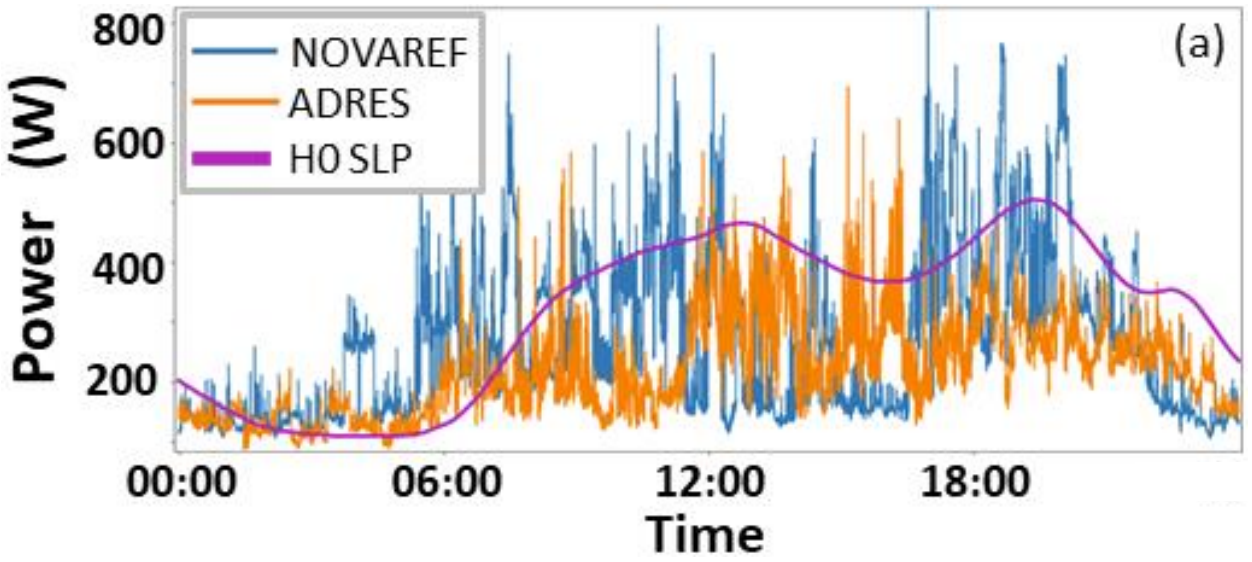
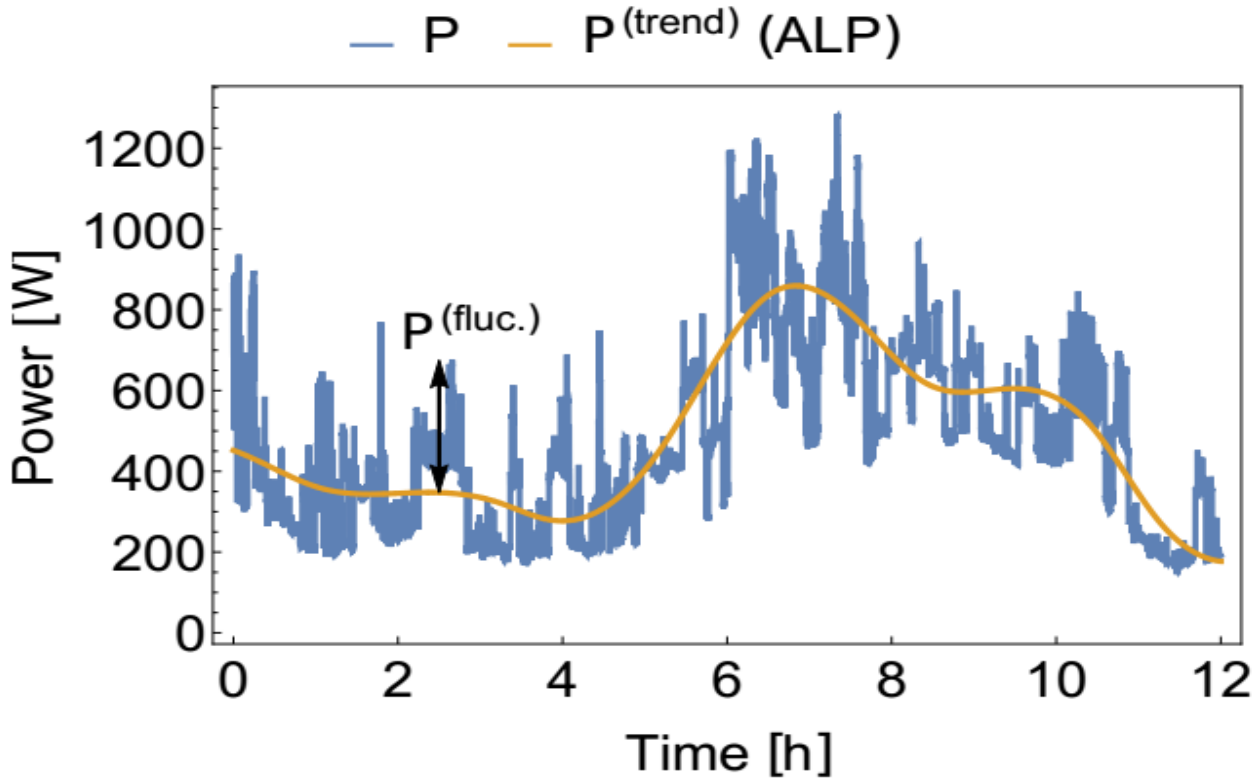
- Data-driven load profile



Data-driven Load Profile (DLP)

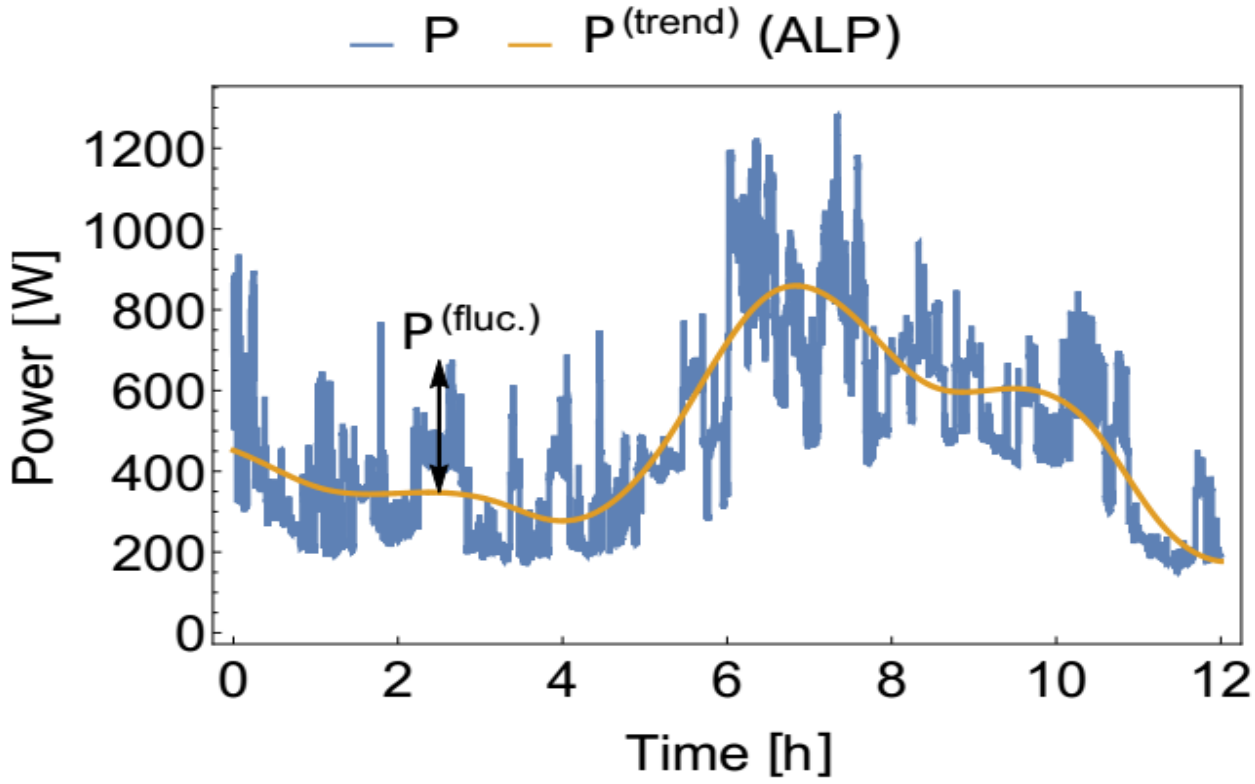
+ --> Date-driven Load Profile (DLP)



Data-driven Load Profile (DLP)

Average Load Profile (ALP) +

--> Date-driven Load Profile (DLP)



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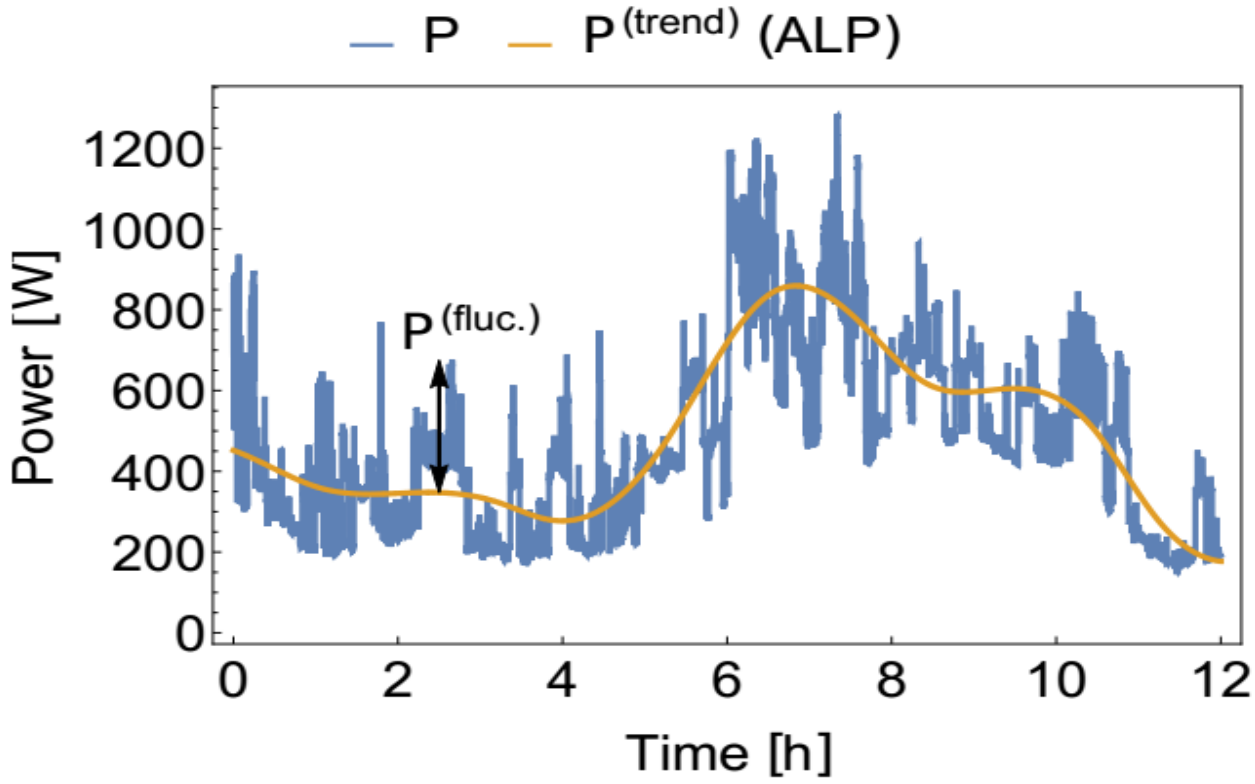
Data-driven Load Profile (DLP)

Average Load Profile (ALP) + Stochastic Fluctuation Profile (SFP) --> **Date-driven Load Profile (DLP)**



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Average Load Profile (ALP)

Empirical Mode Decomposition (EMD)

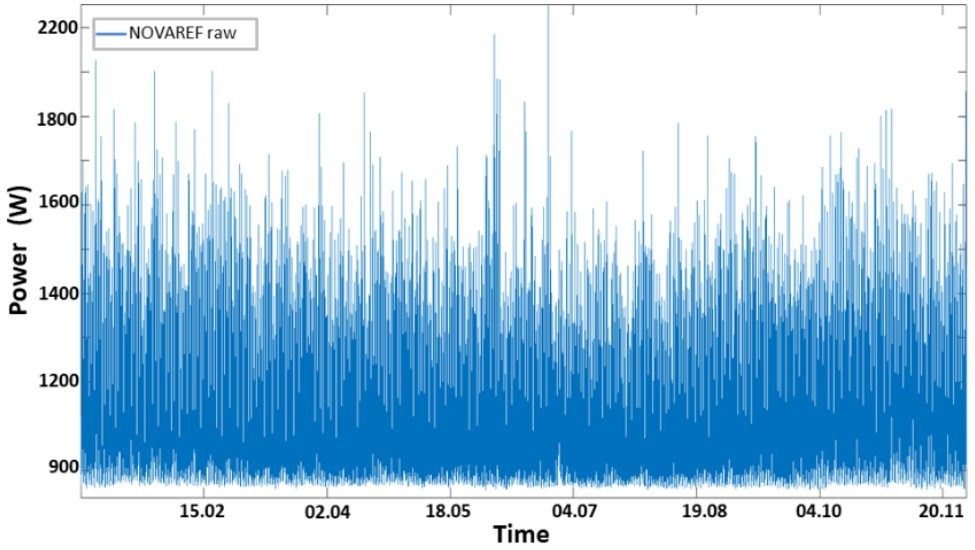
$$X(t) = \sum_{i=1}^{n} c_i + r_n$$

$X(t) \equiv$ Time series

$c_i \equiv$ Intrinsic Mode Function (IMF)

$r_n \equiv$ Residual Function

Advances in Adaptive Data Analysis 01, 1–41 (2009)



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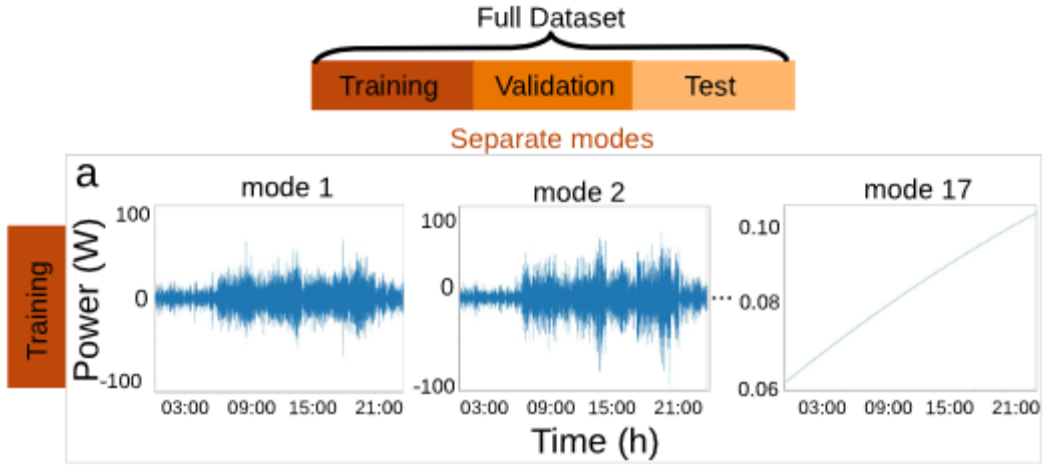
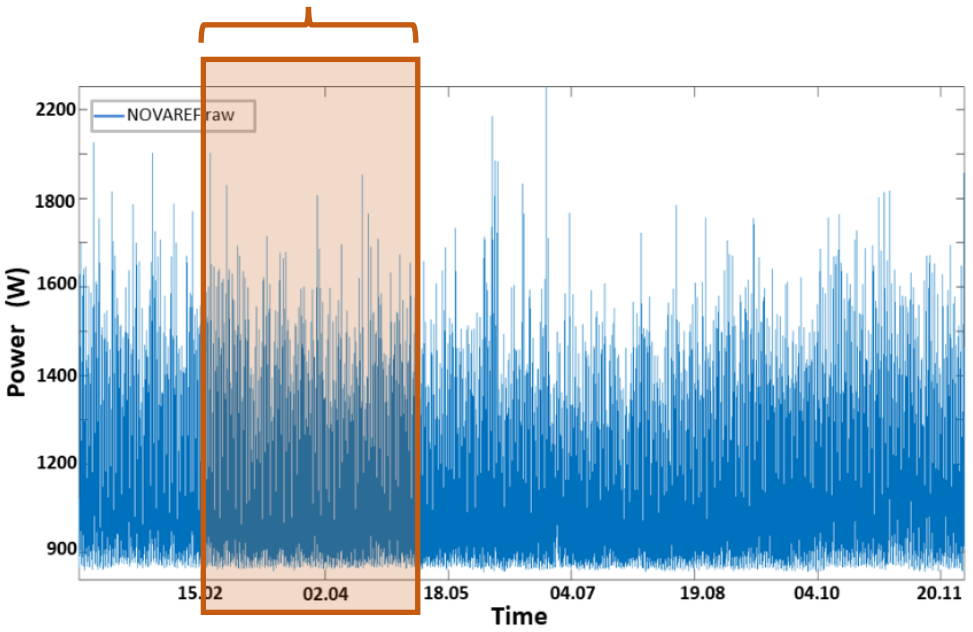
$$ALP = \sum_{i=1}^{N} M_{i+s}$$

For NOVAREF s = 9 & N = 8

Advances in Adaptive Data Analysis 01, 1–41 (2009)



four chronologically consecutive weeks



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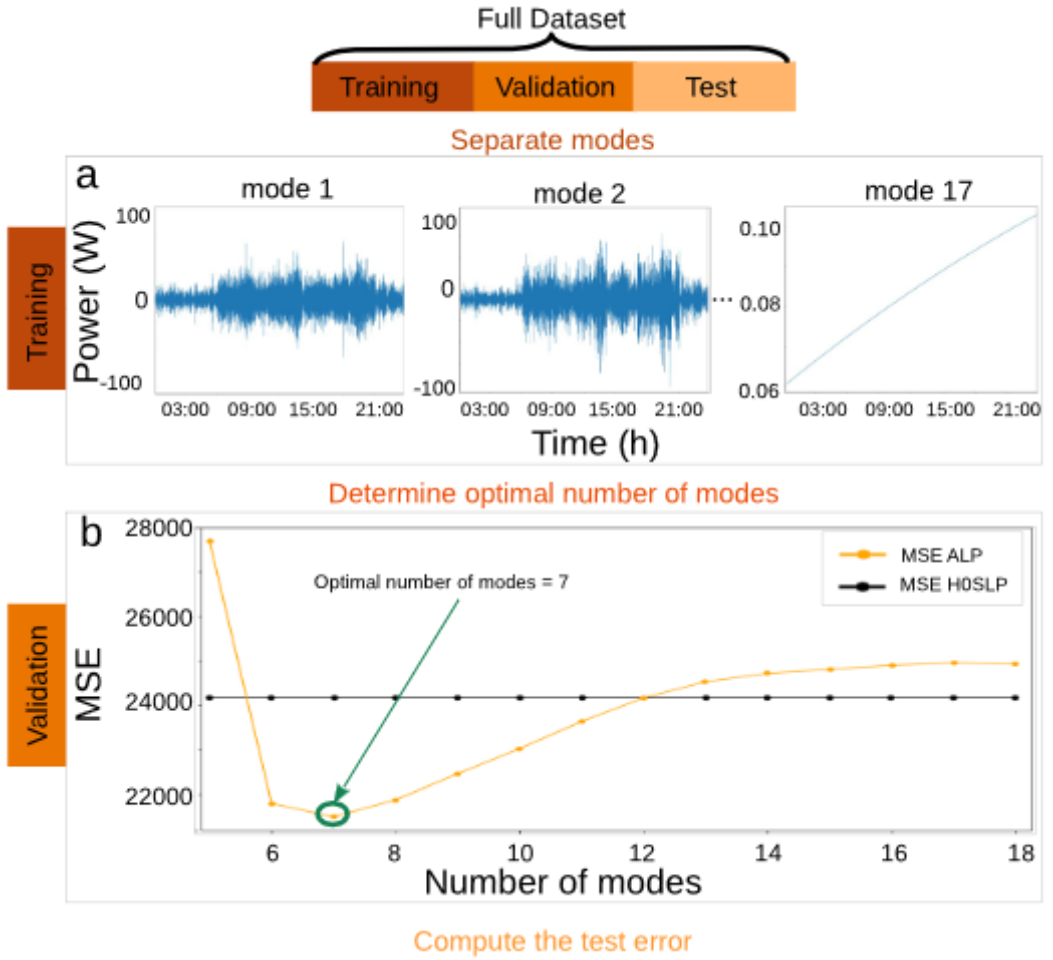

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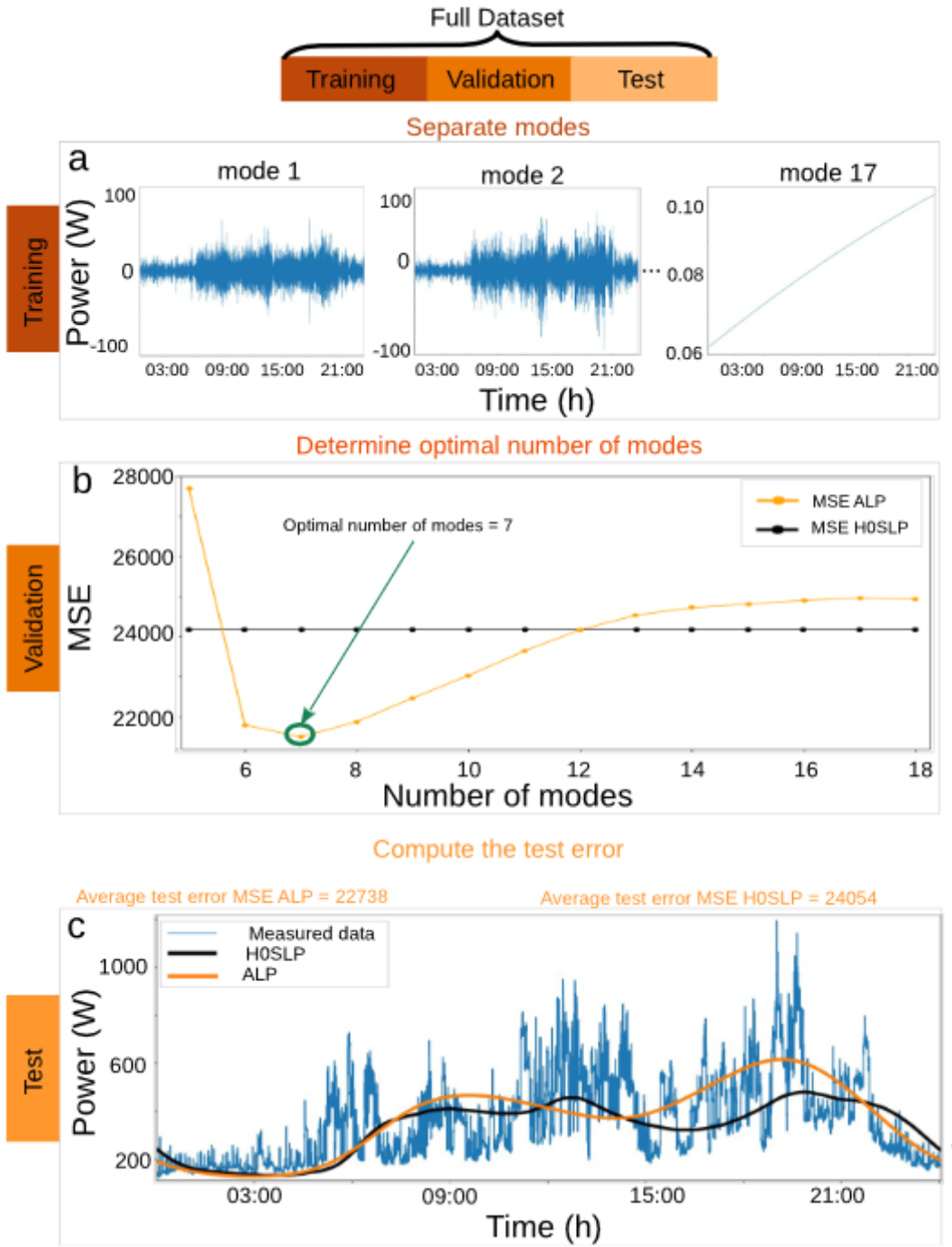
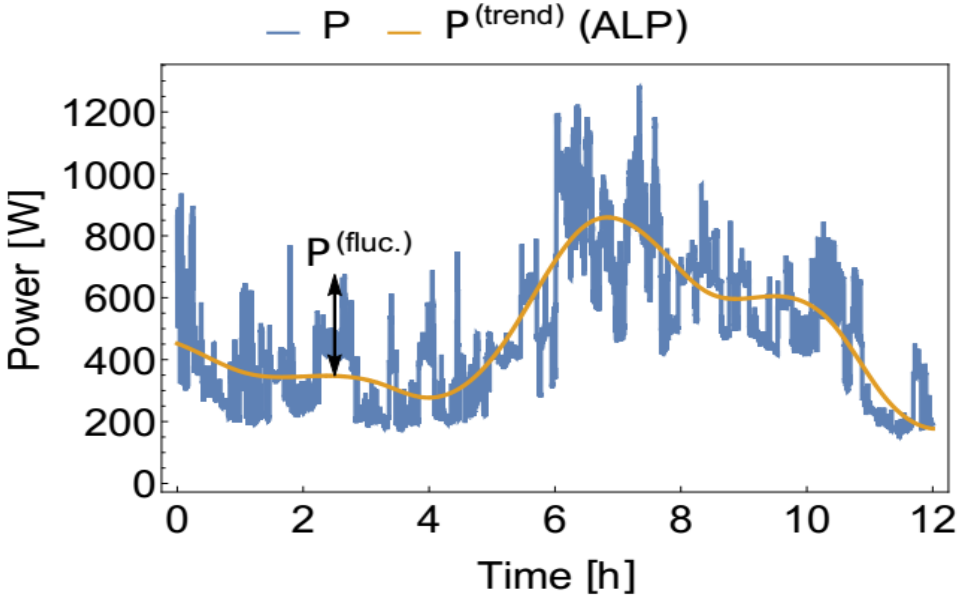


Stochastic Fluctuations Profile (SFP)

Superstatistics methods

$$P^{(fluc)}(t) = P(t) - P^{trend/(ALP)}(t)$$



Physica A: Stat. Mechan. Appl. 322, 267–275 (2003)
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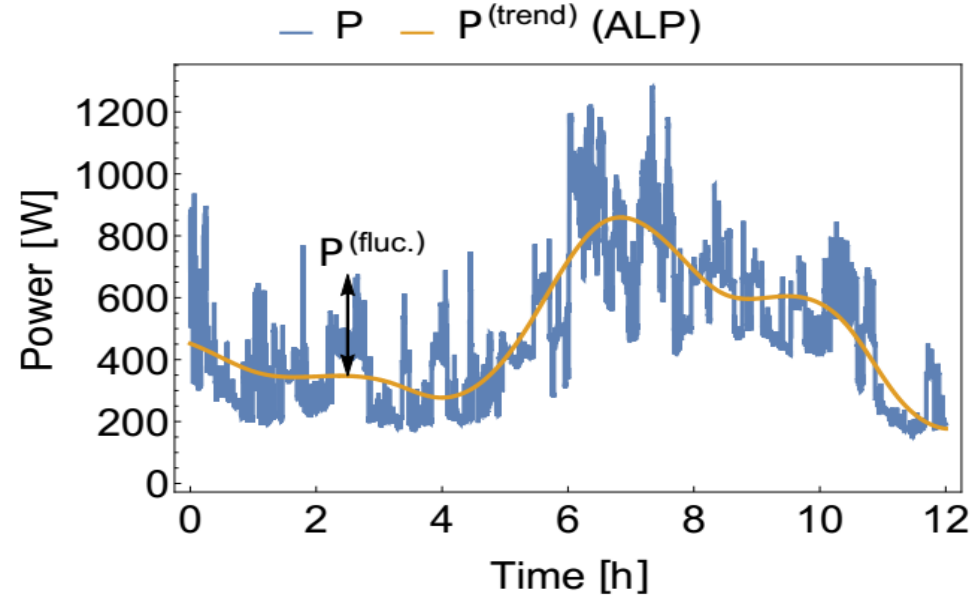

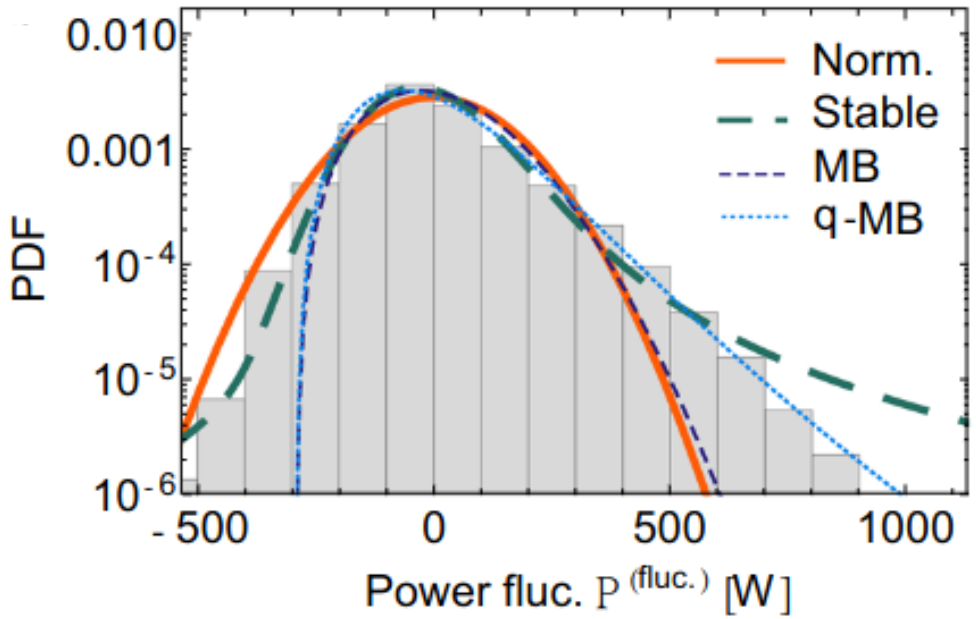

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Superstatistics methods

$$\boldsymbol{P^{(fluc)}}(t) = P(t) - P^{trend/(ALP)}(t)$$

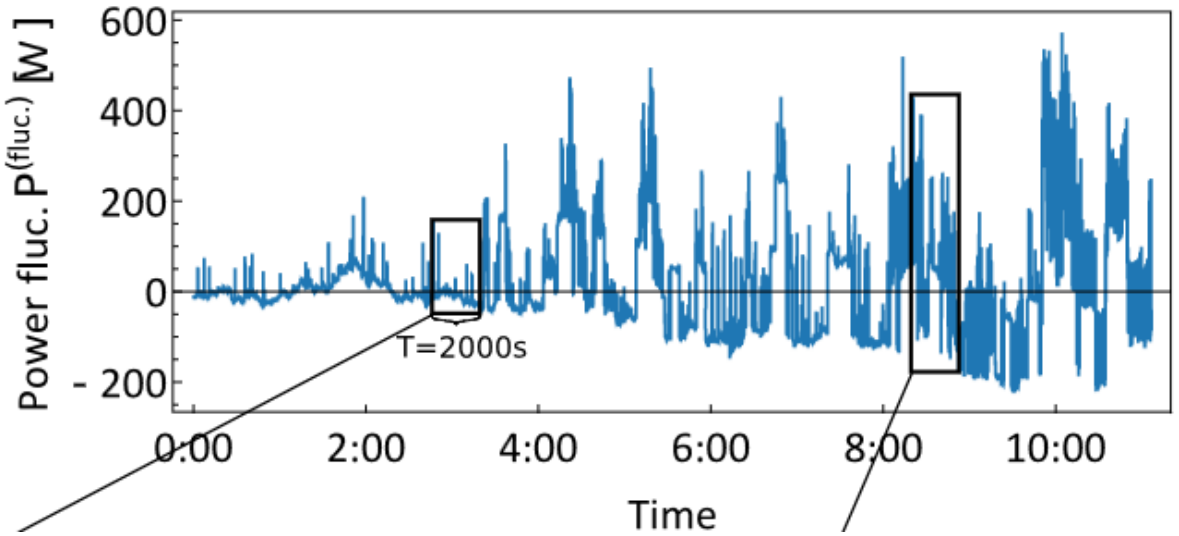
Local Maxwell-Boltzmann distribution

$$P^{(fluc)}(t) = \sqrt{(x_1(t))^2 + \ldots + (x_J(t))^2} + \mu_{MB}$$

$$dx_i(t) = -\gamma x_i(t) + \epsilon dW$$

$$p(P^{(fluc)}) = \frac{1}{\sigma_{MB}^3}\sqrt{\frac{2}{\pi}}(P^{(fluc)} - \mu_{MB})^2 \times$$

$$exp(-\frac{(P^{(fluc)} - \mu_{MB})^2}{2\sigma_{MB}^2})$$



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Stochastic Fluctuations Profile (SFP)

Superstatistics methods

$$\boldsymbol{P^{(fluc)}}(t) = P(t) - P^{trend/(ALP)}(t)$$

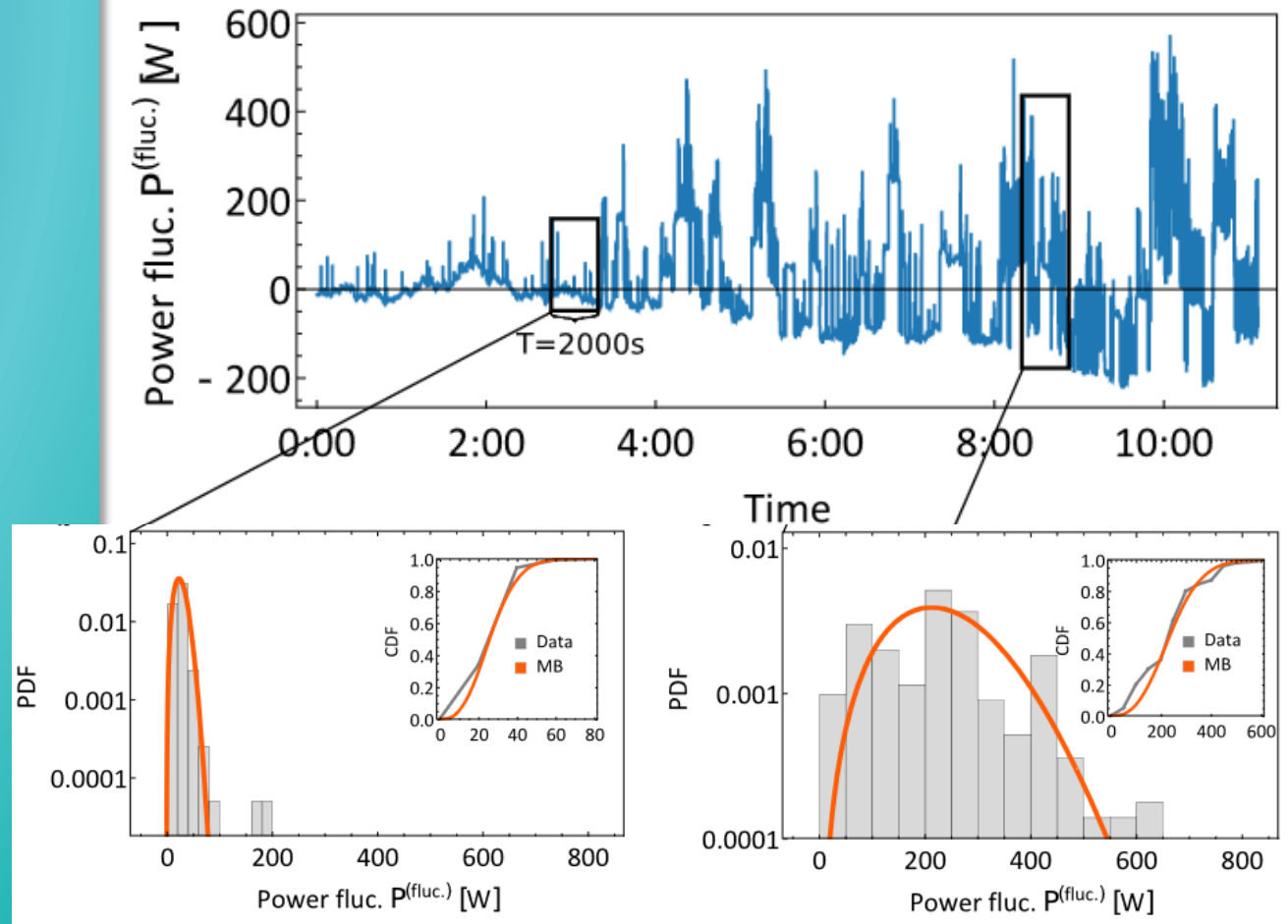
Local Maxwell-Boltzmann distribution

$$P^{(fluc)}(t) = \sqrt{(x_1(t))^2 + \ldots + (x_J(t))^2} + \mu_{MB}$$

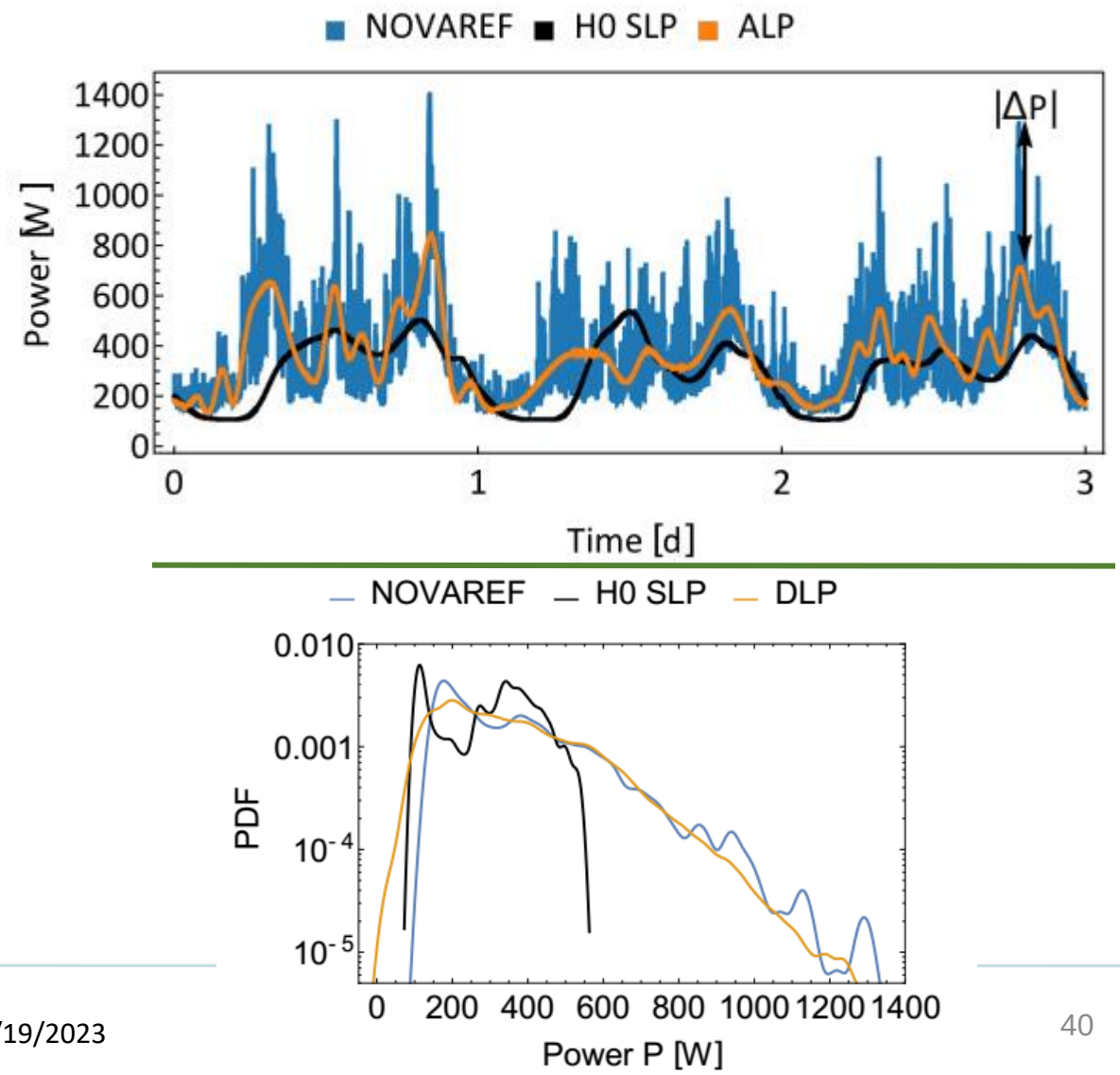
$$dx_i(t) = -\gamma x_i(t) + \epsilon dW$$

$$p(P^{(fluc)}) = \frac{1}{\sigma_{MB}^3}\sqrt{\frac{2}{\pi}}(P^{(fluc)} - \mu_{MB})^2 \times$$

$$exp(-\frac{(P^{(fluc)} - \mu_{MB})^2}{2\sigma_{MB}^2})$$



Data-driven Load Profile (DLP)



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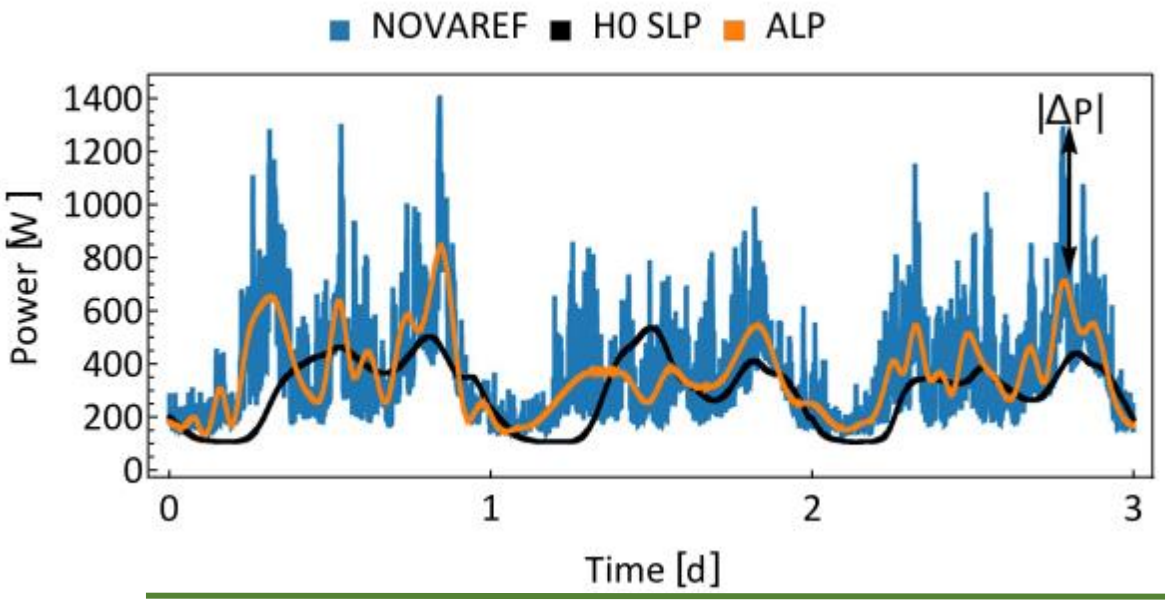
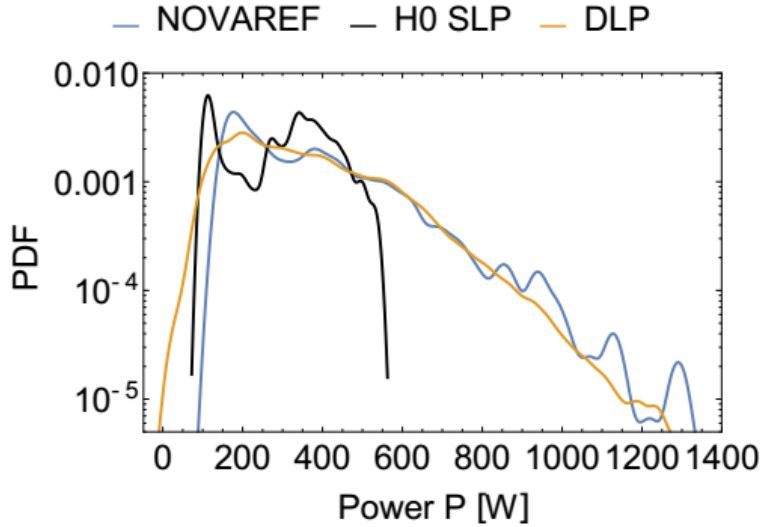
Data-driven Load Profile (DLP)





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Mehrnaz Anvari[1,10✉], Elisavet Proedrou[2,10], Benjamin Schäfer[3,4,5,10], Christian Beck[3,6], Holger Kantz[7] & Marc Timme[8,9✉]

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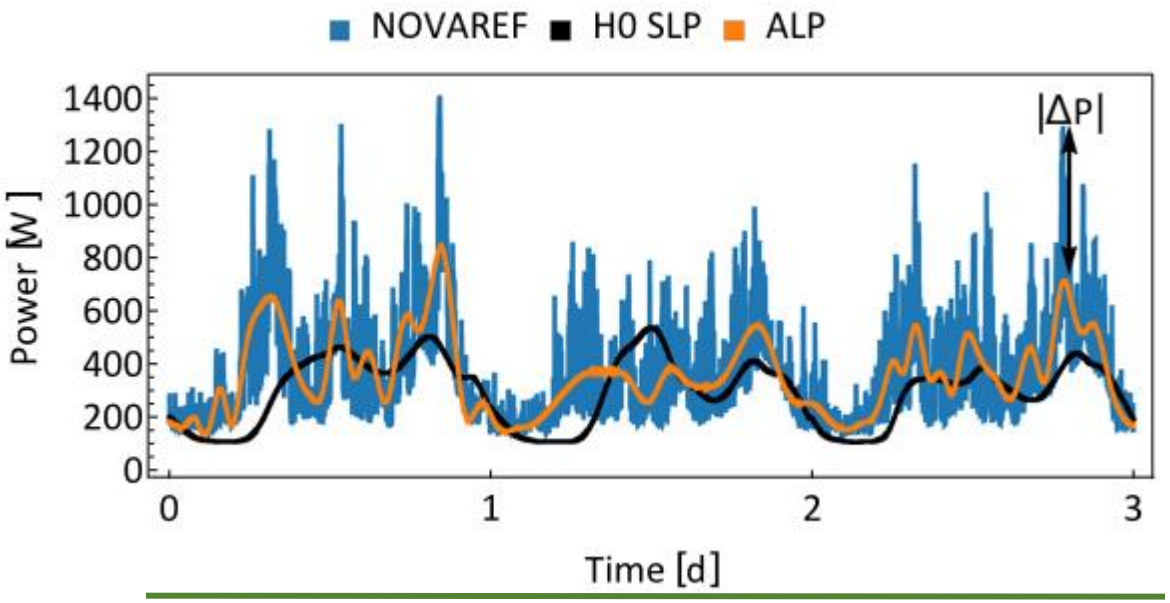

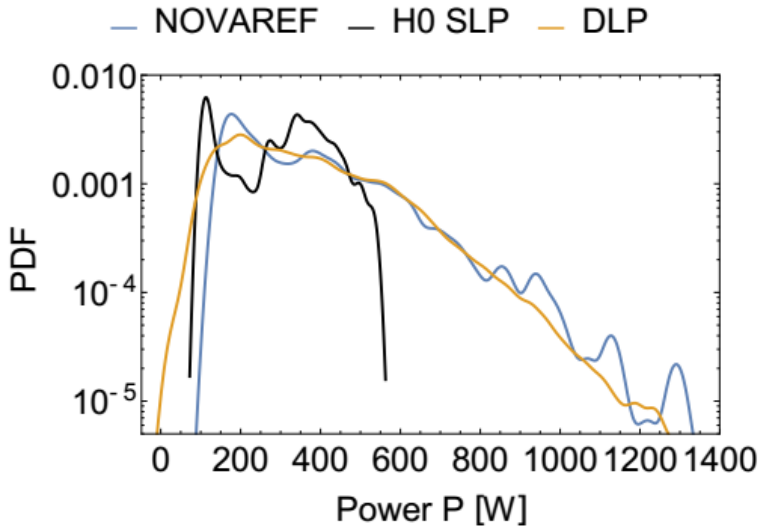

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Supplementary Information accompanying the manuscript
Data-driven load profiles and the dynamics of residential electricity consumption

Mehrnaz Anvari,[1,*] Elisavet Proedrou,[2,*] Benjamin Schäfer,[3,4,5,*]
Christian Beck,[3,6] Holger Kantz,[7] and Marc Timme[8]

[1] *Potsdam Institute for Climate Impact Research (PIK), Member of the Leibniz Association, P.O. Box 60 12 03, D-14412 Potsdam, Germany*
[2] *DLR Institute for Networked Energy Systems, Oldenburg, Germany*
[3] *School of Mathematical Sciences, Queen Mary University of London, United Kingdom*
[4] *Faculty of Science and Technology, Norwegian University of Life Sciences, 1432 s, Norway*
[5] *Institute for Automation and Applied Informatics, Karlsruhe Institute for Technology, Germany*
[6] *The Alan Turing Institute, London, United Kingdom*
[7] *Max Planck Institute for the Physics of Complex Systems, D-01187 Dresden, Germany*
[8] *Chair for Network Dynamics, Center for Advancing Electronics Dresden (cfaed) and Institute for Theoretical Physics, Technical University of Dresden, 01062 Dresden, Germany*

Within this Supplementary Information, we provide additional evidence and material supporting the narrative and conclusions of the main text. In particular, we provide details on the data used, explain the detrending in more detail and provide in-depth analysis complementing the fluctuation analysis from the main text.

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Contact

Dr. Mehrnaz Anvari

Business unit Network Evaluation Technologies

Tel. +49 22 4114-4067

Fax +49 22 4114-4442

mehrnaz.anvari@scai.fraunhofer.de

https://www.scai.fraunhofer.de/de/geschaeftsfelder/network-evaluation-technologies.html

Fraunhofer SCAI
Schloss Birlinghoven
53757 Sankt Augustin
https://www.scai.fraunhofer.de/

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