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Regression-based electricity load profiles of 32 industrial and commercial subsectors in Germany

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Key-Words:

- Long term electric load forecasting
- Multiple Regression analysis
- Subsector load profiles
- Standard load profiles
- Industrial and commercial loads

Abstract: This dataset holds the subsector specific electricity load profiles (German: Branchenlastprofile) of 32 industrial and commercial subsectors in Germany. As a result of the research project DemandRegio, the subsector load profiles are derived from a large number of metered load data using a multiple regression method. The validation of subsector load profiles can be demonstrated within the modelling tool “disaggregator” on GitHub, a Python implementation of the overall results of the research project DemandRegio. Using subsector load profiles in the disaggregator-tool, the accuracy of the model was significantly improved in comparison to the utilization of standard load profiles.

This dataset holds the subsector specific electricity load profiles (German: *Branchenlastprofile* (BLP)) of 32 industrial and commercial subsectors in Germany. As a result of the research project DemandRegio [1], the subsector load profiles (BLP) are derived from more than 1,100 metered load curves using a multiple regression method. BLP can be used to replace partially outdated VDEW standard load profiles (SLP) [2] as well as input profiles for various energy system models [3], [4]. Moreover, the BLP fill important data gaps [5] and transform personal and therefore sensitive load data into open, anonymized, averaged and usable data [4]. In addition, BLP provide a basis to develop more detailed demand models, e.g. with regard to underlying energy consuming applications. This increased level of detail allows to assess the technical potential of demand side response measures for specific subsectors. While demand side response constitutes a relevant source for necessary flexibility in a system of high renewable energy penetration [6], its potentials are still under-explored particularly in the commercial sector [7].

Both internal and external studies [8], [9], [10] suggest that the use of current VDEW SLP is associated with structural deviations between predicted and actual load. These discrepancies can be shown using time series of electricity distribution network operators, which record the deviations of predicted load from actual load of SLP consumers (German: *Differenzbilanzkreiszeitreihe*) [8]. Using newly developed BLP, we provide a possibility to reduce these deviations and depict a more differentiated and accurate mapping of electricity consumption. This can be shown on a subsector level as well as an aggregated level. On a subsector level, Figure 1 illustrates the increased capacity of differentiation and accuracy in

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a direct comparison of the VDEW G1-SLP[1] and the subsector load profile for offices (WZ64-71) with real office load data (RLD). In contrast to the BLP, the SLP tends to significantly overestimate the load during the day, while significantly underestimating the load at night time. Looking for comparable subsector load profiles from the UK [11], the De Montfort Profile exhibits similar structures as the BLP – and deviates significantly from the SLP. These and similar SLP deviations are partially carried forward to the aggregated level. The heatmap in Figure 2 demonstrates the increased accuracy when using all 32 BLP to predict the ENTSO-E load. Here, the deviation of time-series between the predicted and actual ENTSO-E load of the year 2019 is displayed. Figure 2 shows that using SLP (left figure), the residuals are significantly higher compared to using 32 BLP, where applicable (right figure). This corresponds with significant improvements of prediction accuracy measures for the ENTSO-E load as well as several Distribution System Operator (DSO) loads, which are displayed in Table 1 and Table 2 (Appendix A). Hence, the BLP of this dataset close several data gaps and can be seen as an updated extension of partially outdated SLP.

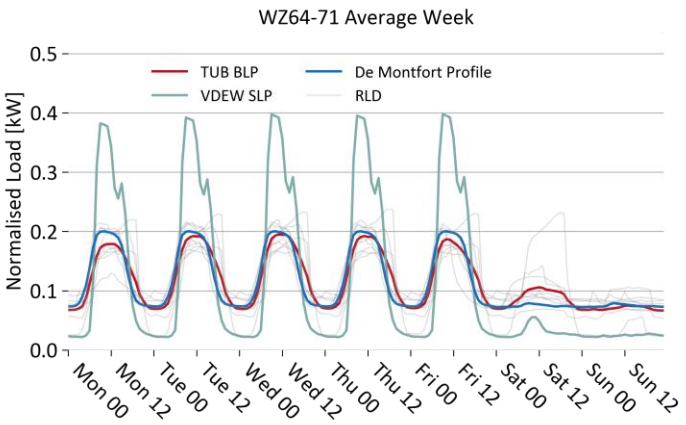

Figure 1: Comparison of 13 real office load profiles (RLD, grey) with the VDEW G1-SLP, the corresponding BLP and the De Montfort Profile

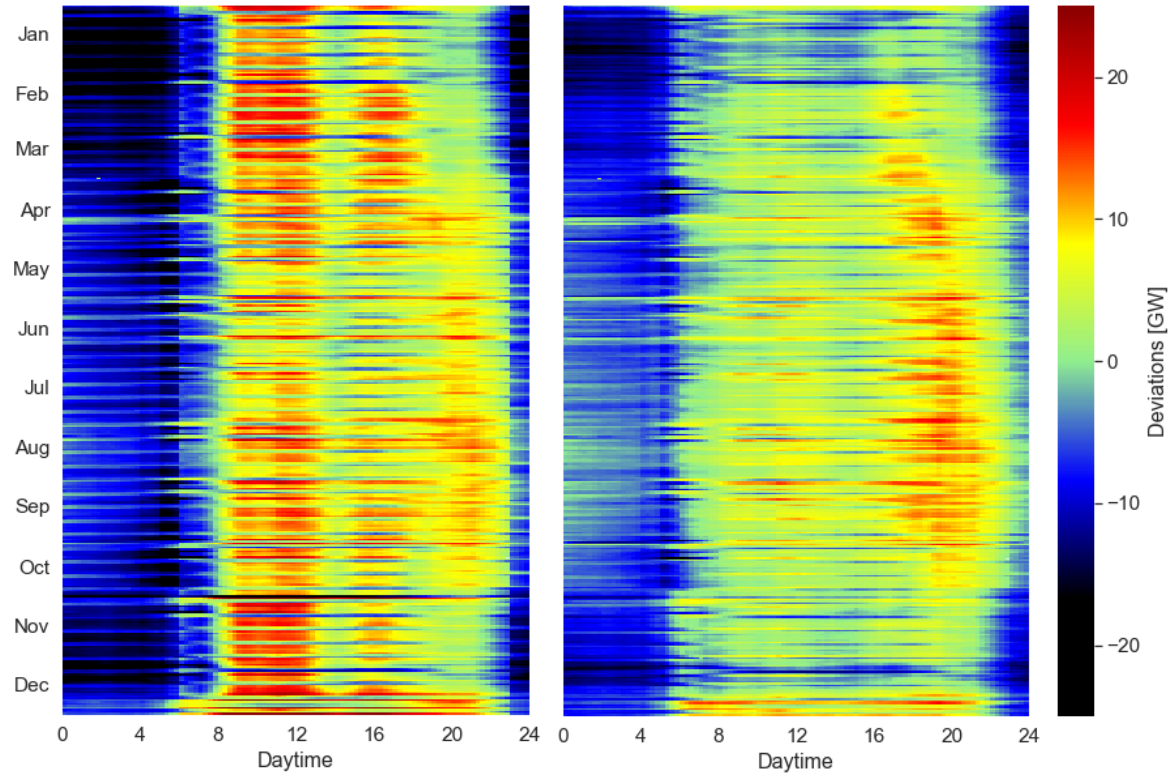

Figure 2: Residuals of the DemandRegio disaggregator tool forecasting the ENSTO-E load of 2019, using SLP (left) and subsector laod profiles (BLP) (right).

As depicted in Appendix A, using BLP instead of the prediction accuracy improved on average by ΔR^2 = 2,2% and ΔMAPE = 3,8% for DSO loads applicable for comparison. In a similar validation with ENTSO-

[1] The G1-SLP depicts commercial companies which predominantly consume electricity from 8 am to 6 pm on working days. The electricity consumption of office companies is represented by the G1-SLP [2].

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E loads in the years 2015 – 2019, the prediction accuracy improved even more, by ΔR^2 = 2,9% and ΔMAPE = 5,0%. Due to updated BLP and a different smoothing approach, the above validation figures slightly deviate from the validation figures presented in [1].

The above validation of BLP can be demonstrated within the modelling tool "disaggregator", a Python implementation of the overall results of the research project DemandRegio. The modeling toolkit is publicly available under an open source licence and can be accessed via GitHub [3]. Using subsector load profiles in the disaggregator-tool, we significantly improved model accuracy in comparison to the utilization of standard load profiles (Figure 2). The input data sets can be accessed as open data [12]. Subsector load profiles can also be found here [13]. Regionally specific subsector load profiles for all 401 counties (German: *Landkreise*) can be either generated with the toolkit, accessed on the DemandRegio database (hosted by Ffe) [12] via REST-API or provided on request. The context, methodology and validation of subsector load profiles is documented in the final report of the research project DemandRegio [1] (in German, chapters 4.5, 5.4, 5.6.3). A publication in English will follow.

This dataset shows the average load profiles of the following 32 industrial and commercial subsectors[2] in Germany for the years 2009 – 2018, subsectors as defined by Destatis [14]:

- WZ10: Manufacture of food products
- WZ11: Manufacture of beverages
- WZ12: Manufacture of tobacco products
- WZ17: Manufacture of paper
- WZ21: Manufacture of pharmaceuticals
- WZ22: Manufacture of rubber and plastics
- WZ26: Manufacture of computer, electronic and optical products
- WZ28: Manufacture of machinery
- WZ29: Manufacture of motor vehicles
- WZ32: Other manufacturing
- WZ37: Sewerage
- WZ38: Waste collection, treatment and disposal
- WZ41: Construction of buildings
- WZ46: Wholesale trade
- WZ47: Retail trade
- WZ52: Warehousing and support activities for transportation
- WZ55: Accommodation
- WZ62: Computer programming, consultancy
- WZ63: Information service activities
- WZ64-71: Offices
- WZ72: Research and Development
- WZ77: Rental and leasing activities
- WZ82: Office administrative and support activities
- WZ84: Public administration
- WZ85: Education
- WZ86: Human health activities
- WZ87: Residential care activities
- WZ88: Social work activities
- WZ90: Creative, arts and entertainment activities
- WZ91: Libraries, museums and other cultural activities
- WZ93: Sports activities, amusement and recreation activities
- WZ94: Activities of membership organisations

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[2] see Appendix B for subsector names in German language

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Appendix A: Validation and quality parameters of model approaches

Table 1: Quality parameters of both model approaches compared to the total load of selected DSOs using SLP and BLP

Validation basis	County	Year	Disaggregator SLP		Disaggregator BLP	
			R^2 [%]	MAPE [%]	R^2 [%]	MAPE [%]
SÜC Energie und H2O GmbH Coburg	DE243	2017	*63,8*	*22,2*	*73,2*	*13,8*
Stadtwerke Straubing	DE223	2017	*58,1*	*18,9*	*61,2*	*15,5*
		2018	*73,5*	*15,0*	*80,5*	*10,8*
Netz Lübeck GmbH	DEF03	2017	*86,7*	*14,3*	*87,7*	*10,1*
		2019	*83,2*	*15,2*	*87,5*	*10,2*
SWB Bielefeld	DEA41	2017	*77,4*	*14,0*	*80,9*	*11,4*
		2018	*76,0*	*14,5*	*79,5*	*11,5*
Stadtwerke Bochum	DEA51	2018	*78,0*	*13,1*	*79,3*	*9,7*
		2019	*78,8*	*13,2*	*80,7*	*9,3*
DO-Netze Dortmund	DEA52	2017	*76,3*	*16,2*	*77,7*	*10,7*
		2019	*77,2*	*16,2*	*78,8*	*10,4*
EVB Eisenach	DEG0N	2017	*82,5*	*14,2*	*86,3*	*10,8*
		2019	*81,5*	*13,8*	*85,0*	*10,5*
SWE Netz Erfurt	DEG01	2017	*38,1*	*27,3*	*34,6*	*20,6*
		2019	*32,2*	*28,2*	*29,7*	*21,9*
KNS/TWL Ludwigshafen am Rhein	DEB34	2017	*83,3*	*21,6*	*83,3*	*22,6*
		2019	*84,0*	*19,7*	*85,5*	*20,7*
WSW Wuppertal	DEA1A	2017	*74,2*	*14,3*	*74,8*	*11,7*
		2019	*75,6*	*14,1*	*76,2*	*11,4*
	Average value		***72,6%***	***17,2%***	***74,9%***	***13,3%***

Table 2: Quality parameters of both model approaches compared to the total load of ENTSO-E using SLP and BLP

Validation basis	Year	Disaggregator SLP		Disaggregator BLP	
		R^2 [%]	MAPE [%]	R^2 [%]	MAPE [%]
ENTSO-E load	2015	*80,3*	*14,0*	*83,2*	*8,9*
	2016	*79,3*	*14,1*	*82,4*	*8,8*
	2017	*77,9*	*14,0*	*80,5*	*9,2*
	2018	*78,8*	*14,1*	*81,7*	*9,2*
	2019	*76,8*	*14,4*	*79,9*	*9,5*
Average value		***78,6%***	***14,1%***	***81,5%***	***9,1%***

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Appendix B: German names of modelled subsectors according to the classification WZ 2008

- WZ10: Nahrungsmittelherstellung
- WZ11: Getränkeherstellung
- WZ12: Tabakverarbeitung
- WZ17: Papierherstellung
- WZ21: Pharmazeutische Erzeugnisse
- WZ22: Gummi- und Kunststoffwaren
- WZ26: Datenverarbeitungsgeräte
- WZ28: Maschinenbau
- WZ29: Kraftwagen und Kraftwagenteile
- WZ32: Herstellung sonstiger Waren
- WZ37: Abwasserentsorgung
- WZ38: Abfallentsorgung
- WZ41: Hochbau
- WZ46: Großhandel
- WZ47: Einzelhandel
- WZ52: Lagerei u. sonstige Verkehrsdienstleistungen
- WZ55: Beherbergung
- WZ62: IT-Dienstleistungen
- WZ63: Informationsdienstleistungen
- WZ64-71: Büroähnliche Betriebe
- WZ72: Forschung und Entwicklung
- WZ77: Vermietung beweglicher Sachen
- WZ82: Dienstleistungen für Unternehmen und Privatpersonen
- WZ84: Öffentliche Verwaltung
- WZ85: Erziehung und Unterricht
- WZ86: Gesundheitswesen
- WZ87: Heime
- WZ88: Sozialwesen
- WZ90: Kreative, künstlerische und unterhaltende Tätigkeiten
- WZ91: Bibliotheken, Museen und zoologische Gärten
- WZ93: Sport, Unterhaltung und Erholung
- WZ94: Interessenvertretungen, Vereine

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