UK Research and Innovation

Use case for the Data Infrastructure for National Infrastructure project (DINI)

Project Name: FORNET: DAFNI FORecasting Services for Energy NETworks

Authors

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1. Use case Report

1.1 Background and Context

Project Name: **FORNET**: DAFNI FORecasting Services for Energy NETworks

Stakeholders

- The **FORNET** project
- DAFNI Team
- The Principal-Investigator (P-I)
- The First Co-Investigators (Co-I 1)
- The second Co-Investigators (Co-I 2)
- and the Research Associate (RA)

the latter four as the per the following table:

P-I	Professor Konstantinos Nikolopoulos	Durham University	Institute for Hazard, Risk & Resilience Forecasting Laboratory (IHRR forLAB) & Durham University Business School
Co-I	Dr Yang Lu	York St John University	School of Science, Technology and Health
Co-I	Dr Haoran Zhang	Imperial College London	Centre of Environmental Policy (CEP), Imperial College London
RA	Dr Vasileios Bougioukos	Notre Dame London & Richmond American University of London	Vasileios Bougioukos | About| Faculty | Notre Dame London | University of Notre Dame

			Dr Vasileios Bougioukos - Richmond American University London

FORNET is a project within the Energy Sector following the DAFNI Energy Sandpit. The project focuses on Energy consumption at the consumer end. The specific challenge that our project addresses is the provision and integration of state-of-the-art forecasting methodologies to enhance the accuracy and robustness of energy demand forecasts on the DAFNI platform. Traditional energy forecasting methods often rely heavily on quantitative time series analysis, which, while powerful, may not fully capture the complexity of human behaviours and/or the impact of rare, extreme events like weather. Our project fills these gaps by incorporating events that drive behavioural change in consumption and treatments for extreme weather events into the forecasting process.

1.2 Description of Activities

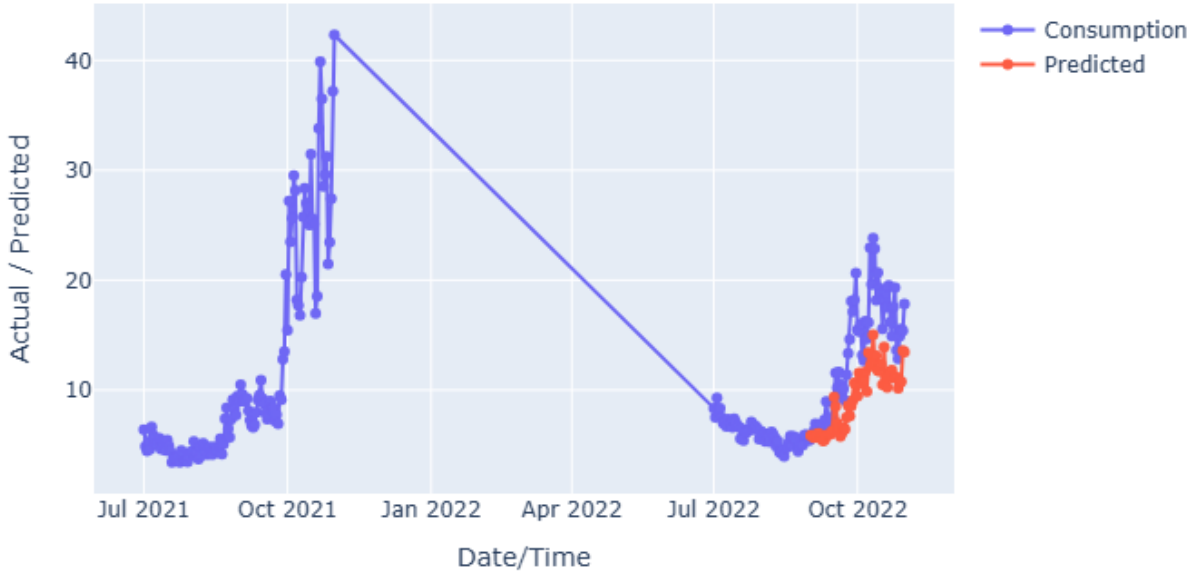
The project focused on using real data as well as simulated data for electricity consumption. We use real data for 36 properties in UK (public dataset available from Energy Catapult) and real data for weather and real events for the same chronological period.

We also based on these aforementioned data, created a simulated dataset for a larger population of 100 houses and respective daily electricity consumptions.

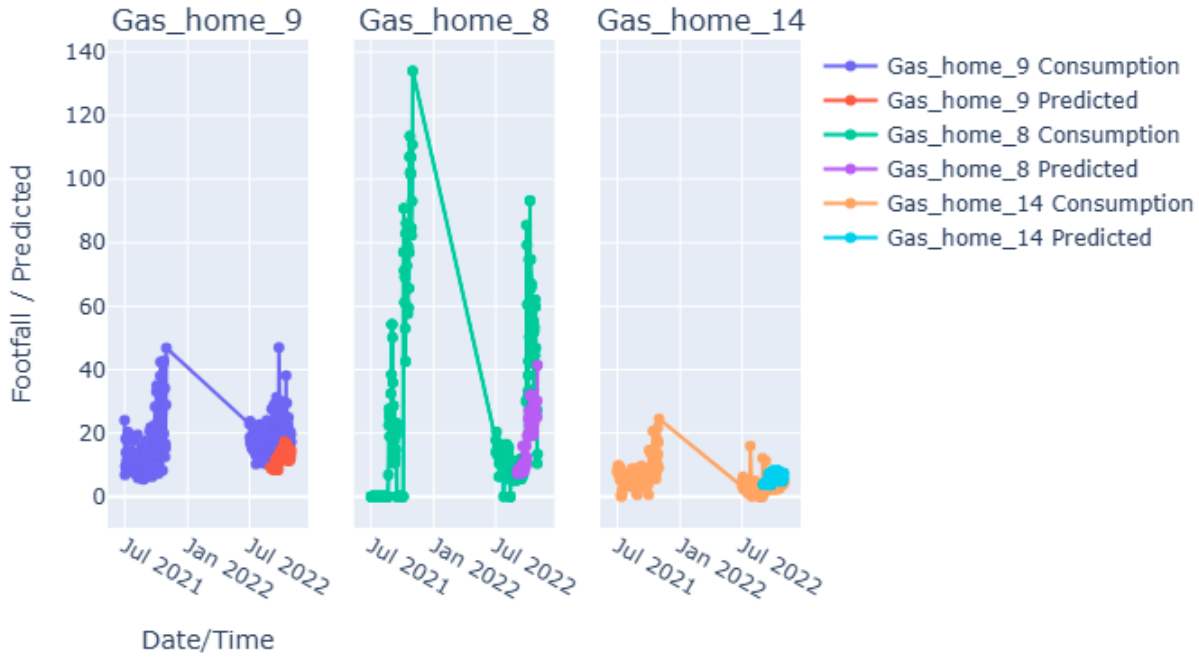
We used a state-of-the-art machine learning algorithm that can incorporate one or more of the following: historic demands, events, and weather and provide forecasts in real time on demand.

Indicative, some outputs from the workflow in the DAFNI platform. In the following figures we see extrapolations for the whole dataset, extrapolations per house, the actual errors of the forecasting methodology, and the features that proved to be more important in our analysis.

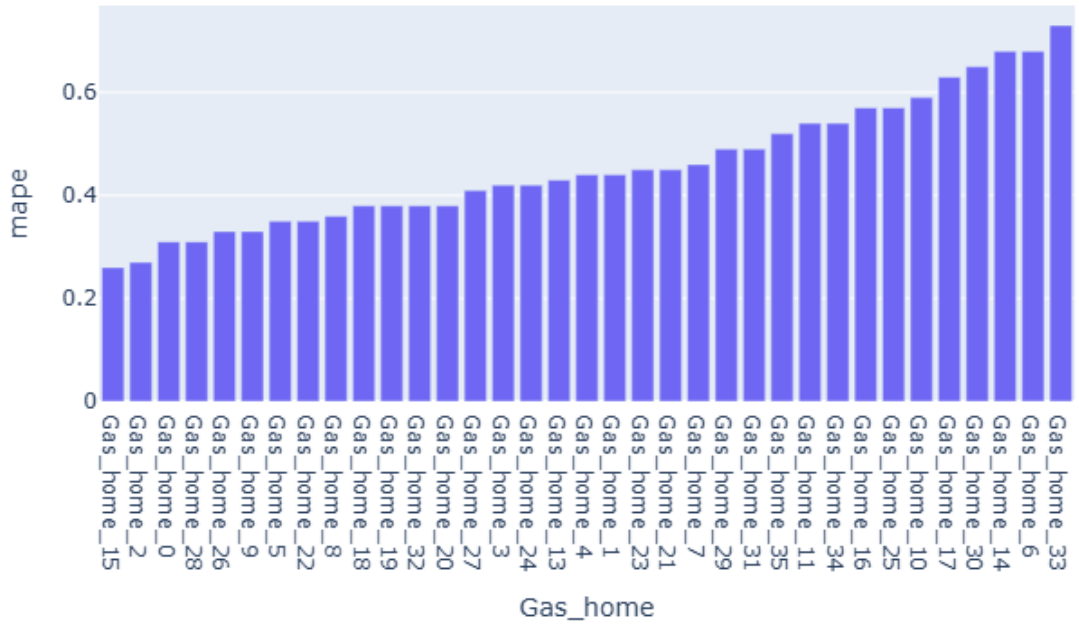
Consumption Actual vs Predicted



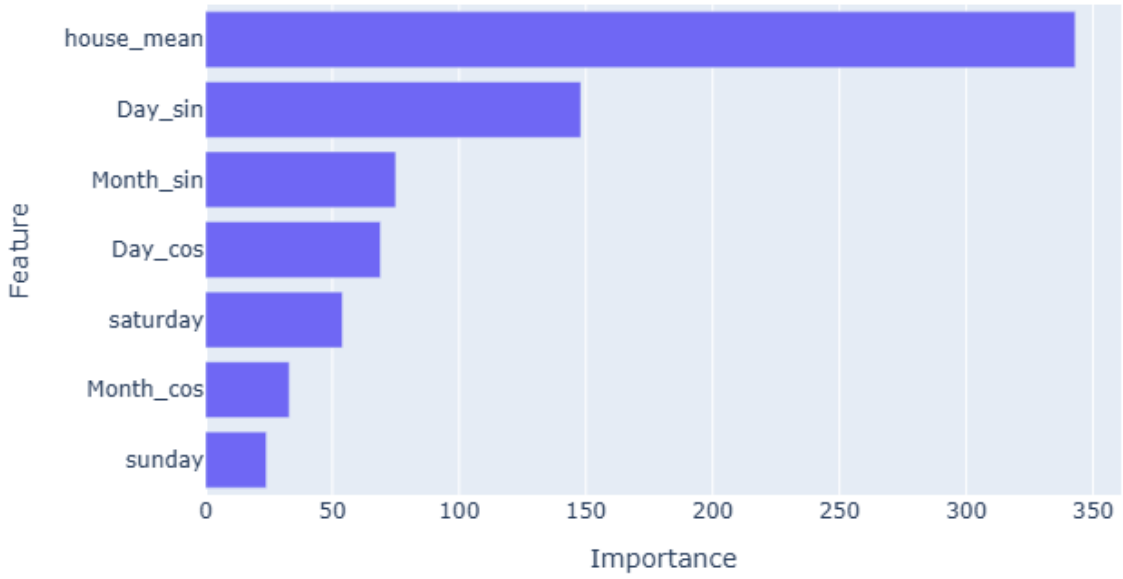
Comparison of Consumption vs Predicted for Selected Houses



MAPE per House



Feature Importance



1.3 Benefits of Data Sharing

There are great benefits from sharing the original data (original dataset at Energy catapult enhances with Events data by FORNET team) as well as the larger dataset of simulated data so academics and practitioners can evaluate the performance of their forecasting approaches versus the FORNET machine learning method that could act as a long-term benchmark.

The beneficiaries are: Students, Academics, Practitioners, Policy makers could benefit from these datasets.

The benefits arise from use of the datasets for research and experimentation purposes. So future researcher sand practitioners can run their electricity forecasting models in these data as well as benchmark their models versus the produced forecast from the models we provide as well.

1.4 Barriers for Data Sharing

The original data are available under specific licence that applies also to the enhanced datasets while the simulated dataset should be made by DAFNI freely available.

Thus, the original dataset can only be disseminated further under the specific licence of the original provider – Energy catapult; nevertheless, the restrictions are minimal.

On the contrary the simulation (and larger) dataset is free for any kind of research experimentation, benchmarking and further development and enhance with more descriptive variables if needed.

There was a clear lesson-learned in this phase of acquiring appropriate data: Data at individual consumer level are hard to acquire, and in future project companies like Octopus and OVO with smart meter data need to participate as well, possible the Grid too.

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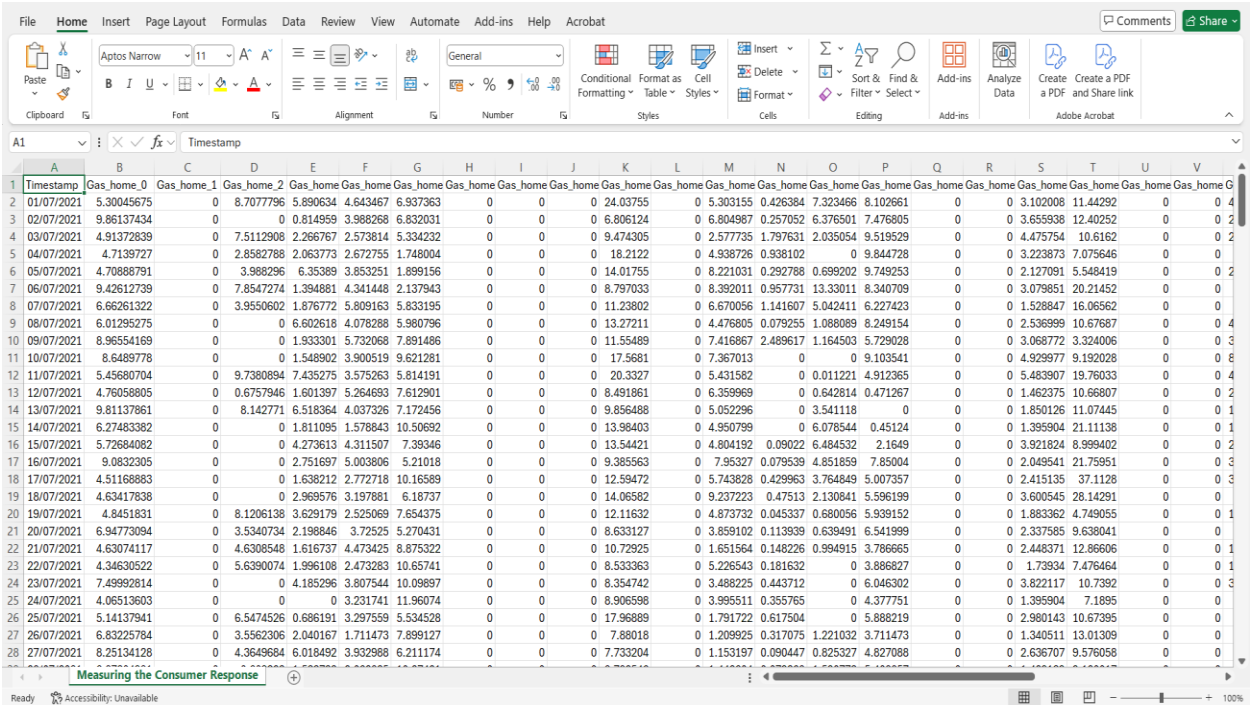
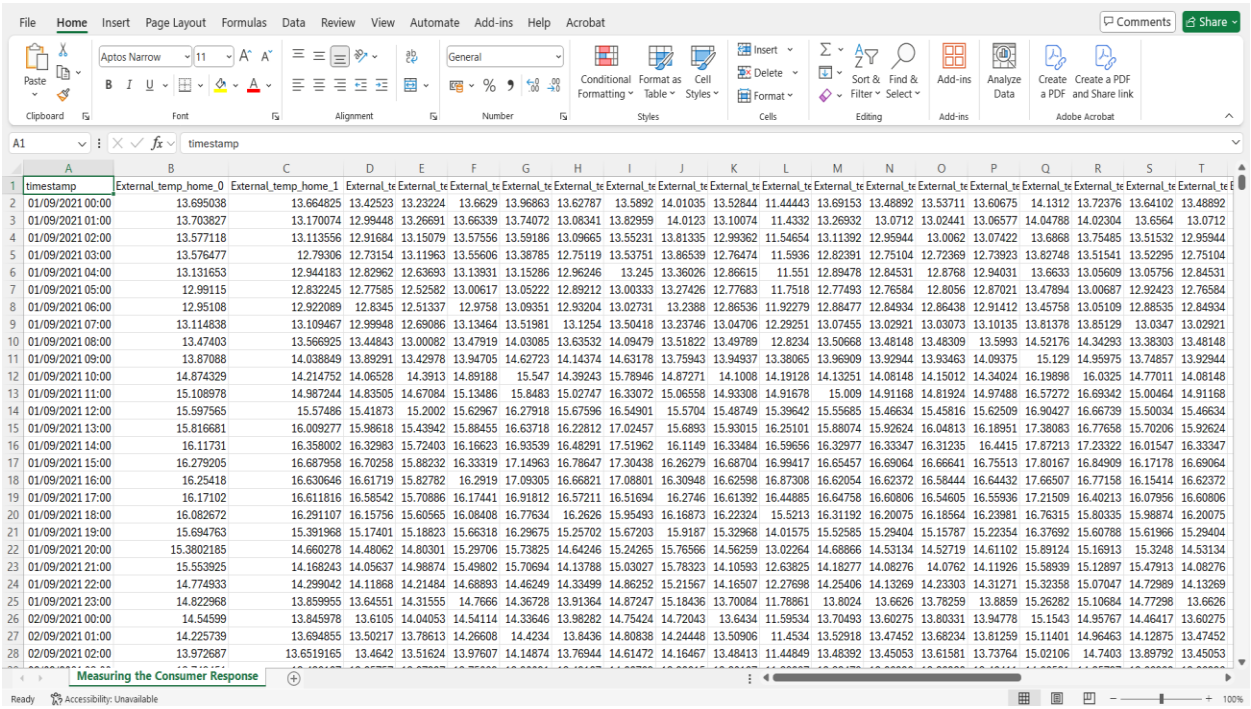
1.5 Sources of data – table

Data Source	Data Description	Purpose	Technical Details	
Name of data, URL if available *Data owner*	*Describe the data that the source provides*	*Describe why it is necessary and the benefit of accessing that data*	– *Data format* – *size* – *APIs metadata description* – *Ontologies* – *Use of Persistent Identifiers* – *Use of Standards*	*Giv* *da* *sh*
https://usmart.io/org/esc/discovery/discovery-view-detail/7b10af42-ca8c-4c81-8310-2efc6c352857 Measuring the Consumer Response to the Energy Crisis_Living_Lab_smart_meter_data Measuring the Consumer Response to the Energy Crisis_Copernicus_air_temperatures Reseampled_Simulated data	Gas daily consumption	Important to know, forecast and manage energy consumption	Csv / XLS 36 houses 2 years 4 months per year July Aug Sep Oct 2021 & 2022 Simulated data – same period – 100 houses Example Timestamp Gas_home_0 01/07/2021 5.300457	htt go Ac Sh



Timestamp	Gas_home_0	Gas_home_1	Gas_home_2	Gas_home	Gas_home	Gas_home	Gas_home	Gas_home	Gas_home	Gas_home	Gas_home	Gas_home	Gas_home	Gas_home	Gas_home	Gas_home	Gas_home	Gas_home	Gas_home	Gas_home	Gas_home	Gas_home
01/07/2021	5.30045675	0	8.7077796	5.890634	4.643467	6.937363	0	0	0	24.03755	0	5.303155	0.426384	7.323466	8.102661	0	0	3.102008	11.44292	0	0	4
02/07/2021	9.86137434	0	0	0.814959	3.988268	6.832031	0	0	0	6.806124	0	6.804987	0.257052	6.376501	7.476805	0	0	3.655938	12.40252	0	0	2
03/07/2021	4.91372839	0	7.5112908	2.266767	2.573814	5.334232	0	0	0	9.474305	0	2.577735	1.797631	2.035054	9.519529	0	0	4.475754	10.6162	0	0	2
04/07/2021	4.7139727	0	2.8582788	2.063773	2.672755	1.748004	0	0	0	18.2122	0	4.938726	0.938102	0	9.844728	0	0	3.223873	7.075646	0	0	
05/07/2021	4.70888791	0	3.988296	6.35389	3.853251	1.899156	0	0	0	14.01755	0	8.221031	0.292788	0.699202	9.749253	0	0	2.127091	5.548419	0	0	2
06/07/2021	9.42612739	0	7.8547274	1.394881	4.341448	2.137943	0	0	0	8.797033	0	8.392011	0.957731	13.33011	8.340709	0	0	3.079851	20.21452	0	0	
07/07/2021	6.66261322	0	3.9550602	1.876772	5.809163	5.833195	0	0	0	11.23802	0	6.670056	1.141607	5.042411	6.227423	0	0	1.528847	16.06562	0	0	
08/07/2021	6.01295275	0	0	6.602618	4.078288	5.980796	0	0	0	13.27211	0	4.476805	0.079255	1.088089	8.249154	0	0	2.536999	10.67687	0	0	4
09/07/2021	8.96554169	0	1.933301	5.732068	7.891486	0	0	0	0	11.55489	0	7.416867	2.489617	1.164503	5.729028	0	0	3.068772	3.324006	0	0	3
10/07/2021	8.6489778	0	0	1.548902	3.900519	9.621281	0	0	0	17.5681	0	7.367013	0	0	9.103541	0	0	4.929977	9.192028	0	0	8
11/07/2021	5.45680704	0	9.7380894	7.435275	3.575263	5.814191	0	0	0	20.3327	0	5.431582	0	0.011221	4.912365	0	0	5.483907	19.76033	0	0	4
12/07/2021	4.76058805	0	0.6757946	1.601397	5.264693	7.612901	0	0	0	8.491861	0	6.359969	0	0.642814	0.471267	0	0	1.462375	10.66807	0	0	2
13/07/2021	9.81137861	0	8.142771	6.518364	4.037326	7.172456	0	0	0	9.856488	0	5.052296	0	3.541118	0	0	0	1.850126	11.07445	0	0	1
14/07/2021	6.27483382	0	0	1.811095	1.578843	10.50692	0	0	0	13.98403	0	4.950799	0	6.078544	0.45124	0	0	1.395904	21.11138	0	0	1
15/07/2021	5.72684082	0	0	4.273613	4.311507	7.39346	0	0	0	13.54421	0	4.804192	0.09022	6.484532	2.1649	0	0	3.921824	8.999402	0	0	2
16/07/2021	9.0832305	0	0	2.751697	5.003806	5.21018	0	0	0	9.385563	0	7.95327	0.079539	4.851859	7.85004	0	0	2.049541	21.75951	0	0	3
17/07/2021	4.51168883	0	0	1.638212	2.772718	10.16589	0	0	0	12.59472	0	5.743828	0.429963	3.764849	5.007357	0	0	2.415135	37.1128	0	0	3
18/07/2021	4.63417838	0	0	2.969576	3.197881	6.18737	0	0	0	14.06582	0	9.237223	0.47513	2.130841	5.596199	0	0	3.600545	28.14291	0	0	
19/07/2021	4.8451831	0	8.1206138	3.629179	2.525069	7.654375	0	0	0	12.11632	0	4.873732	0.045337	0.680056	5.939152	0	0	1.883362	4.749055	0	0	1
20/07/2021	6.94773094	0	3.5340734	2.198846	3.72525	5.270431	0	0	0	8.633127	0	3.859102	0.113939	0.639491	6.541999	0	0	2.337585	9.638041	0	0	
21/07/2021	4.63074117	0	4.6308548	1.616737	4.473425	8.875322	0	0	0	10.72925	0	1.651564	0.148226	0.994915	3.786665	0	0	2.448371	12.86606	0	0	1
22/07/2021	4.34630522	0	5.6390074	1.996108	2.473283	10.65741	0	0	0	8.533363	0	5.226543	0.181632	0	3.886827	0	0	1.73934	7.476464	0	0	1
23/07/2021	7.49992814	0	0	4.185296	3.807544	10.09897	0	0	0	8.354742	0	3.488225	0.443712	0	6.046302	0	0	3.822117	10.7392	0	0	3
24/07/2021	4.06513603	0	0	0	3.231741	11.96074	0	0	0	8.906598	0	3.995511	0.355765	0	4.377751	0	0	1.395904	7.1895	0	0	
25/07/2021	5.14137941	0	6.5474526	0.686191	3.297559	5.534528	0	0	0	17.96889	0	1.791722	0.617504	0	5.888219	0	0	2.980143	10.67395	0	0	
26/07/2021	6.83225784	0	3.5562306	2.040167	1.711473	7.899127	0	0	0	7.88018	0	1.209925	0.317075	1.221032	3.711473	0	0	1.340511	13.01309	0	0	
27/07/2021	8.25134128	0	4.3649684	6.018492	3.932968	6.211174	0	0	0	7.733204	0	1.153197	0.090447	0.825327	4.827088	0	0	2.636707	9.576058	0	0	



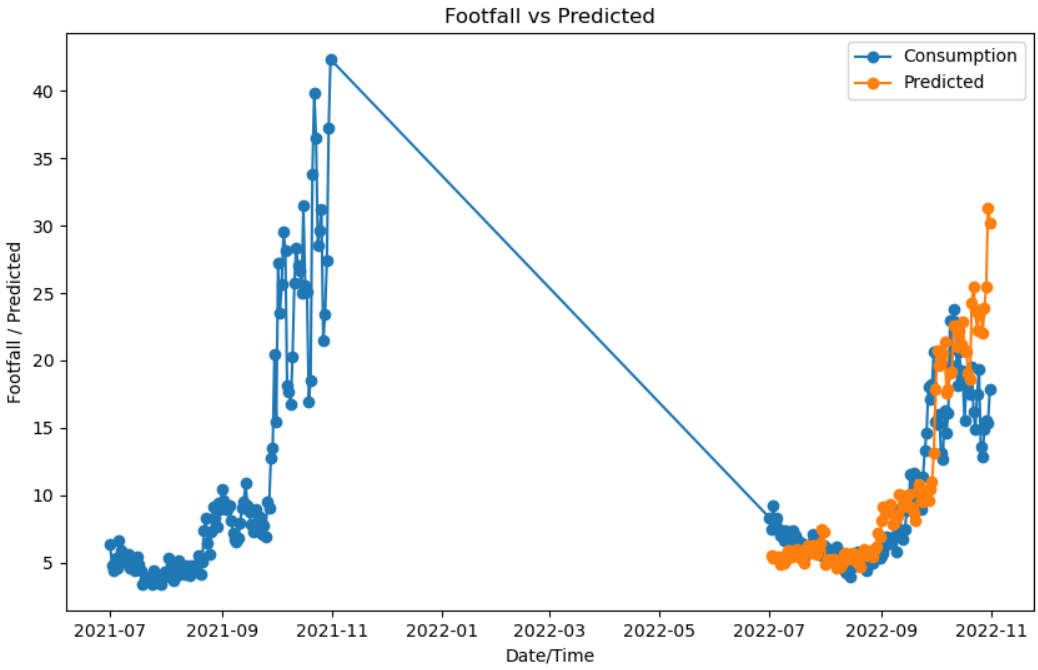
timestamp	External_temp_home_0	External_temp_home_1	External_te	External_te	External_te	External_te	External_te	External_te	External_te	External_te	External_te	External_te	External_te	External_te	External_te	External_te	External_te	External_te	External_te	External_te
01/09/2021 00:00	13.695038	13.664825	13.42523	13.23224	13.6629	13.96863	13.62787	13.5892	14.01035	13.52844	11.44443	13.69153	13.48892	13.53711	13.60675	14.1312	13.72376	13.64102	13.48892	
01/09/2021 01:00	13.703827	13.170074	12.99448	13.26691	13.66339	13.74072	13.08341	13.82959	14.0123	13.10074	11.4332	13.26932	13.0712	13.02441	13.06577	14.04788	14.02304	13.6564	13.0712	
01/09/2021 02:00	13.577118	13.113556	12.91684	13.15079	13.57556	13.59186	13.09665	13.55231	13.81335	12.99362	11.54654	13.11392	12.95944	13.0062	13.07422	13.6868	13.75485	13.51532	12.95944	
01/09/2021 03:00	13.576477	12.79306	12.73154	13.11963	13.55606	13.38785	12.75119	13.53751	13.86539	12.76474	11.5936	12.82391	12.75104	12.72369	12.73923	13.82748	13.51541	13.52295	12.75104	
01/09/2021 04:00	13.131653	12.944183	12.82962	12.63693	13.13931	13.15286	12.96246	13.245	13.36026	12.86615	11.551	12.89478	12.84531	12.8768	12.94031	13.6633	13.05609	13.05756	12.84531	
01/09/2021 05:00	12.99115	12.832245	12.77585	12.52582	13.00617	13.05222	12.89212	13.00333	13.27426	12.77683	11.7518	12.77493	12.76584	12.8056	12.87021	13.47894	13.00687	12.92423	12.76584	
01/09/2021 06:00	12.95108	12.922089	12.8345	12.51337	12.9758	13.09351	12.93204	13.02731	13.2388	12.86536	11.92279	12.88477	12.84934	12.86438	12.91412	13.45758	13.05109	12.88535	12.84934	
01/09/2021 07:00	13.114838	13.109467	12.99948	12.69086	13.13464	13.51981	13.1254	13.50418	13.23746	13.04706	12.29251	13.07455	13.02921	13.03073	13.10135	13.81378	13.85129	13.0347	13.02921	
01/09/2021 08:00	13.47403	13.566925	13.44843	13.00082	13.47919	14.03085	13.63532	14.09479	13.51822	13.49789	12.8234	13.50668	13.48148	13.48309	13.5993	14.52176	14.34293	13.38303	13.48148	
01/09/2021 09:00	13.87088	14.038849	13.89291	13.42978	13.94705	14.62723	14.14374	14.63178	13.75943	13.94937	13.38065	13.96909	13.92944	13.93463	14.09375	15.129	14.95975	13.74857	13.92944	
01/09/2021 10:00	14.874329	14.214752	14.06528	14.3913	14.89188	15.547	14.39243	15.78946	14.87271	14.1008	14.19128	14.13251	14.08148	14.15012	14.34024	16.19898	16.0325	14.77011	14.08148	
01/09/2021 11:00	15.108978	14.987244	14.83505	14.67084	15.13486	15.8483	15.02747	16.33072	15.06558	14.93308	14.91678	15.009	14.91168	14.81924	14.97488	16.57272	16.69342	15.00464	14.91168	
01/09/2021 12:00	15.597565	15.57486	15.41873	15.2002	15.62967	16.27918	15.67596	16.54901	15.5704	15.48749	15.39642	15.55685	15.46634	15.45816	15.62509	16.90427	16.66739	15.50034	15.46634	
01/09/2021 13:00	15.816681	16.009277	15.98618	15.43942	15.88455	16.63718	16.22812	17.02457	15.6893	15.93015	16.25101	15.88074	15.92624	16.04813	16.18951	17.38083	16.77658	15.70206	15.92624	
01/09/2021 14:00	16.11731	16.358002	16.32983	15.72403	16.16623	16.93539	16.48291	17.51962	16.1149	16.33484	16.59656	16.32977	16.33347	16.31235	16.4415	17.87213	17.23322	16.01547	16.33347	
01/09/2021 15:00	16.279205	16.687958	16.70258	15.88232	16.33319	17.14963	16.78647	17.30438	16.26279	16.68704	16.99417	16.65457	16.69064	16.66641	16.75513	17.80167	16.84909	16.17178	16.69064	
01/09/2021 16:00	16.25418	16.630646	16.61719	15.82782	16.2919	17.09305	16.66821	17.08801	16.30948	16.62598	16.87308	16.62054	16.62372	16.58444	16.64432	17.66507	16.77158	16.15414	16.62372	
01/09/2021 17:00	16.17102	16.611816	16.58542	15.70886	16.17441	16.91812	16.57211	16.51694	16.2746	16.61392	16.44885	16.64758	16.60806	16.54605	16.55936	17.21509	16.40213	16.07956	16.60806	
01/09/2021 18:00	16.082672	16.291107	16.15756	15.60565	16.08408	16.77634	16.2626	15.95493	16.16873	16.22324	15.5213	16.31192	16.20075	16.18564	16.23981	16.76315	15.80335	15.98874	16.20075	
01/09/2021 19:00	15.694763	15.391968	15.17401	15.18823	15.66318	16.29675	15.25702	15.67203	15.9187	15.32968	14.01575	15.52585	15.29404	15.15787	15.22354	16.37692	15.60788	15.61966	15.29404	
01/09/2021 20:00	15.3802185	14.660278	14.48062	14.80301	15.29706	15.73825	14.64246	15.24265	15.76566	14.56259	13.02264	14.68866	14.53134	14.52719	14.61102	15.89124	15.16913	15.3248	14.53134	
01/09/2021 21:00	15.553925	14.168243	14.05637	14.98874	15.49802	15.70694	14.13788	15.03027	15.78323	14.10593	12.63825	14.18277	14.08276	14.0762	14.11926	15.58939	15.12897	15.47913	14.08276	
01/09/2021 22:00	14.774933	14.299042	14.11868	14.21484	14.68893	14.46249	14.33499	14.86252	15.21567	14.16507	12.27698	14.25406	14.13269	14.23303	14.31271	15.32358	15.07047	14.72989	14.13269	
01/09/2021 23:00	14.822968	13.859955	13.64551	14.31555	14.7666	14.36728	13.91364	14.87247	15.18436	13.70084	11.78861	13.8024	13.6626	13.78259	13.8859	15.26282	15.10684	14.77298	13.6626	
02/09/2021 00:00	14.54599	13.845978	13.6105	14.04053	14.54114	14.33646	13.98282	14.75424	14.72043	13.6434	11.59534	13.70493	13.60275	13.80331	13.94778	15.1543	14.95767	14.46417	13.60275	
02/09/2021 01:00	14.225739	13.694855	13.50217	13.78613	14.26608	14.4234	13.8436	14.80838	14.24448	13.50906	11.4534	13.52918	13.47452	13.68234	13.81259	15.11401	14.96463	14.12875	13.47452	
02/09/2021 02:00	13.972687	13.6519165	13.4642	13.51624	13.97607	14.14874	13.76944	14.61472	14.16467	13.48413	11.44849	13.48392	13.45053	13.61581	13.73764	15.02106	14.7403	13.89792	13.45053	

1.6 Results Data

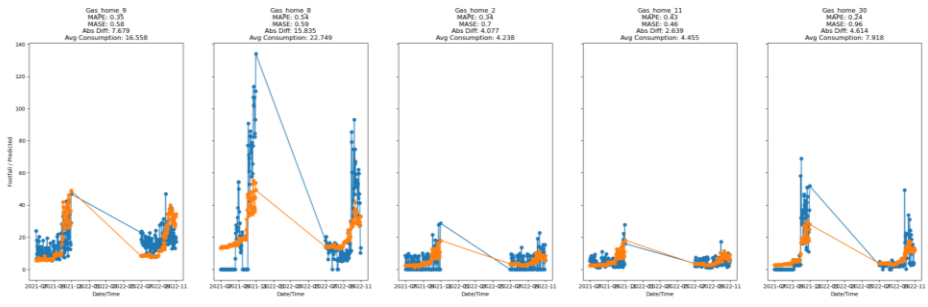
Two EXCEL XLA outputs, one for validation of best models WITHIN_SAMPLE, and one for Forecast extrapolation OUT_OF_SAMPLE

We do run three scenarios for validation and selection of best methods for: a) 2021 used for modelling and then forecasting 2022, b) 30 houses used to create models to forecast the remaining 6 houses, c) and 80-20 approach where 80% of the data are used for modelling and 20% for validation/evaluation.

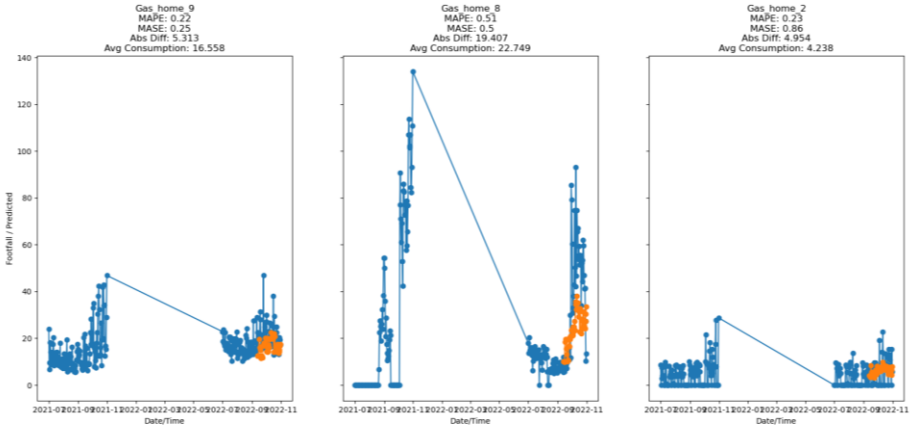
Four different methods do run in our workflow implementation in DAFNI: all methods use machine-learning, a LIGHT-GBMs with input only historical daily consumption, or that plus weather information, or all that plus events information, and all possible combinations of the above information.



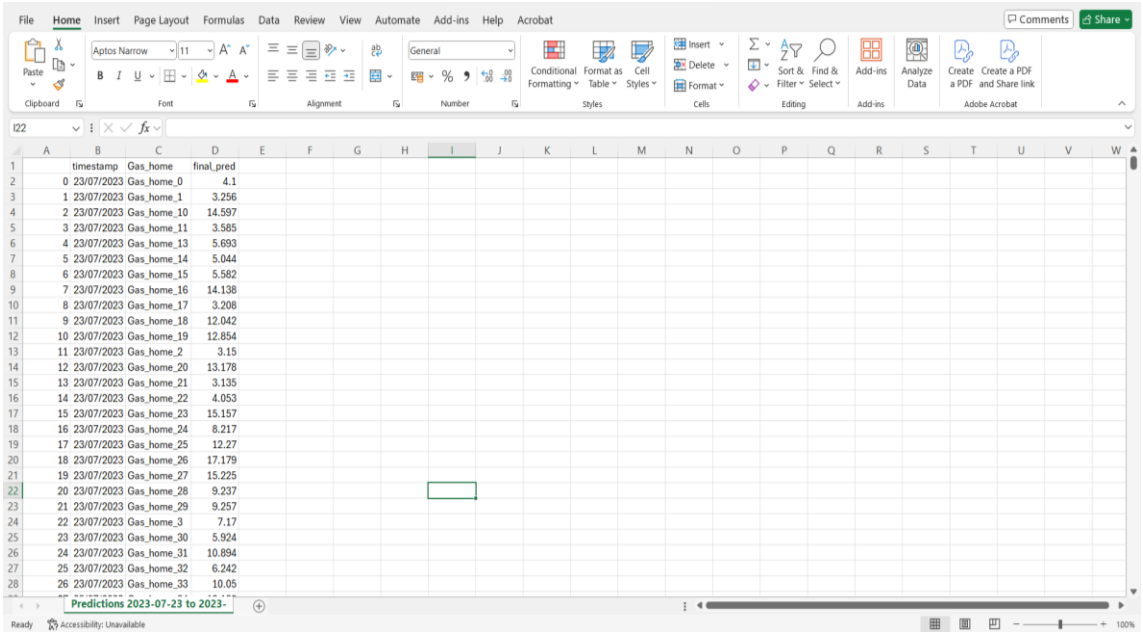
Scenario A: Forecasting a Year ahead



Scenario B: Forecasting for specific properties in the area



Scenario C: Forecasting for the last 20% of the available dates



	timestamp	Gas_home	final_pred
0	23/07/2023	Gas_home_0	4.1
1	23/07/2023	Gas_home_1	3.256
2	23/07/2023	Gas_home_10	14.597
3	23/07/2023	Gas_home_11	3.585
4	23/07/2023	Gas_home_13	5.693
5	23/07/2023	Gas_home_14	5.044
6	23/07/2023	Gas_home_15	5.582
7	23/07/2023	Gas_home_16	14.138
8	23/07/2023	Gas_home_17	3.208
9	23/07/2023	Gas_home_18	12.042
10	23/07/2023	Gas_home_19	12.854
11	23/07/2023	Gas_home_2	3.15
12	23/07/2023	Gas_home_20	13.178
13	23/07/2023	Gas_home_21	3.135
14	23/07/2023	Gas_home_22	4.053
15	23/07/2023	Gas_home_23	15.157
16	23/07/2023	Gas_home_24	8.217
17	23/07/2023	Gas_home_25	12.27
18	23/07/2023	Gas_home_26	17.179
19	23/07/2023	Gas_home_27	15.225
20	23/07/2023	Gas_home_28	9.237
21	23/07/2023	Gas_home_29	9.257
22	23/07/2023	Gas_home_3	7.17
23	23/07/2023	Gas_home_30	5.924
24	23/07/2023	Gas_home_31	10.894
25	23/07/2023	Gas_home_32	6.242
26	23/07/2023	Gas_home_33	10.05

OUT_OF_SAMPLE XLS file with daily forecasts for the future

1.7 Lessons Learnt and Recommendations

- *What works well at the moment?*
  Good validation of forecasting machine-learning models and fast out-of-sample forecasting.

- *Please provide some examples of effective data sharing.*
  Sharing of data will happen through the DAFNI platform at the end of the project.

- *What are the priorities identified for resolving any barriers?*
  Provide freely available simulated data on top of the licenced real data via the DAFNI platform.

- *If there was future funding, how would this project progress?*
  Work together with companies holding smart meters data, and the Grid and the Meteo office to create large databases (town and village size) and run the proposed models as well as other statistical benchmarks. Also, the supply-end could be analysed as well; and furthermore, scenarios with power generation per house via solar panels and other renewables. This will be attempted first thing after the project finishes with aiming for submission to a new call? Or EPSCR by September 2025.