The European Commission's science and knowledge service

Joint Research Centre

Future residential electric load profiles and the need for interoperability

Heinz Wilkening
Christoph Troyer

Acknowledgement

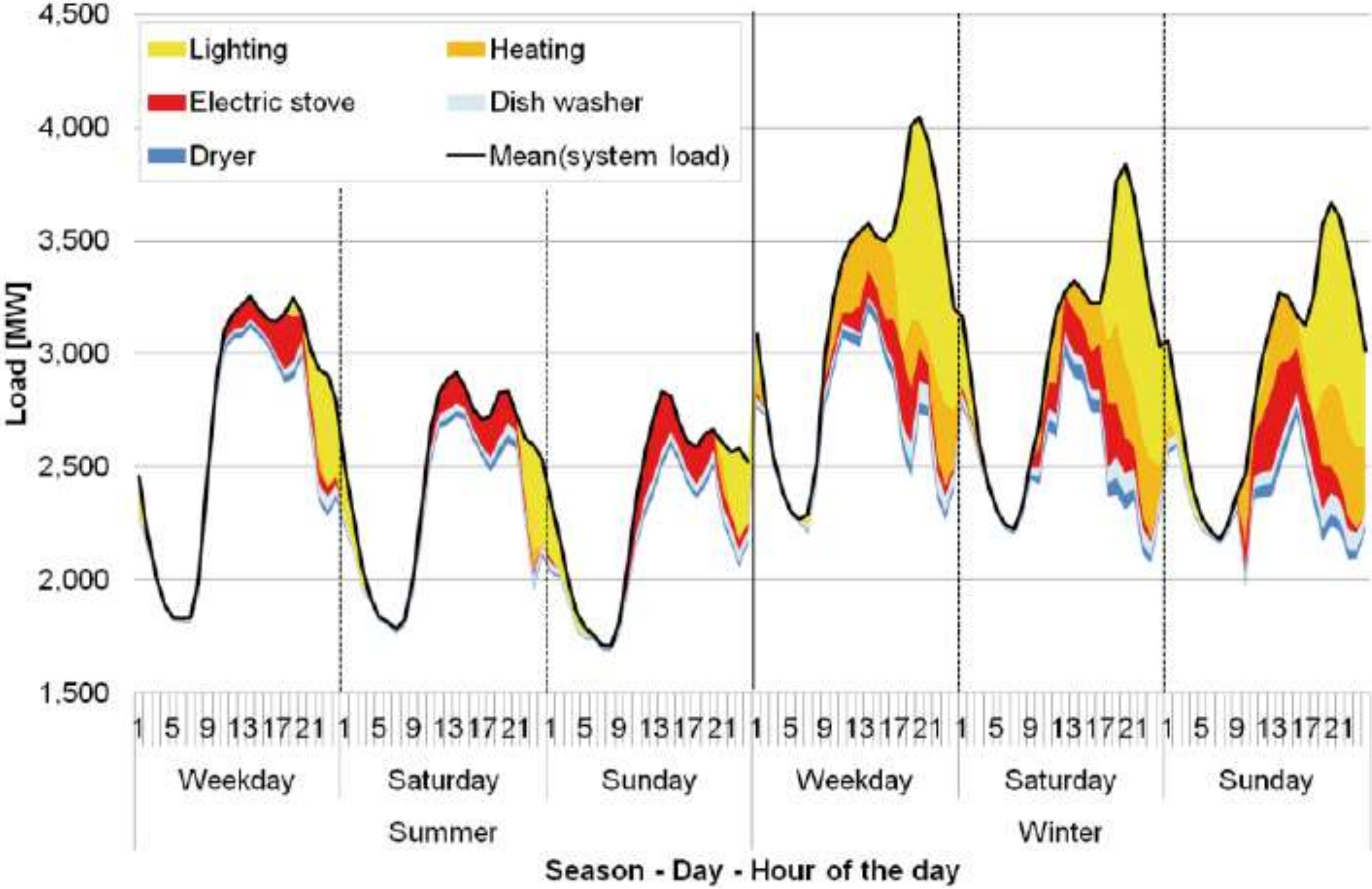
This work wouldn't have been possible without Christoph Troyer, who did most of the programming in a very clever way.

I also like to thank my colleague Thomas Huld, who helped my with the solar data. And many others like Dr. Selma Lossau (NetzeBW), Tim Bierschwalle (enercity Hannover), Erwin Mulder (Vortech), Thomas Wolski (ppc), Tobias Boßmann (Fraunhofer ISI now Artelys) and Danny Klaar (Tennet)

European Commission

From Light Bulb to LED

Typical Electric Load Profile



Daily load profile of system load and end-uses in Ireland in 2011

Source:BOSSMANN ET AL. 1112 ECEEE 2015

European Commission

From the conventional car to the electric vehicles

European Commission

Herausforderung für den Netzbetreiber

Lastbetrachtung für normale Haushalte

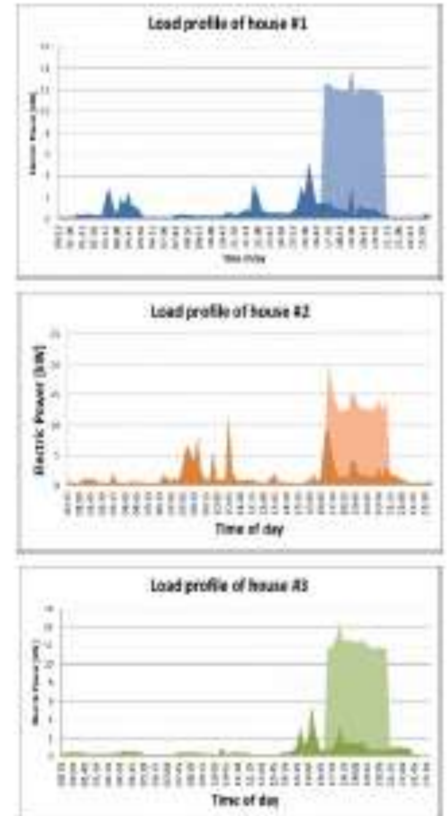
- Sehr individuelle Lastprofile
- Kurze Spitzenlasten ~14 kW

Das Netz ist nicht auf das theoretische Maximum ausgelegt

→Planung geht von realistischer Gleichzeitigkeit aus

Herausforderung für den Netzbetreiber

Einfluss von E-Fahrzeugen auf das Stromnetz

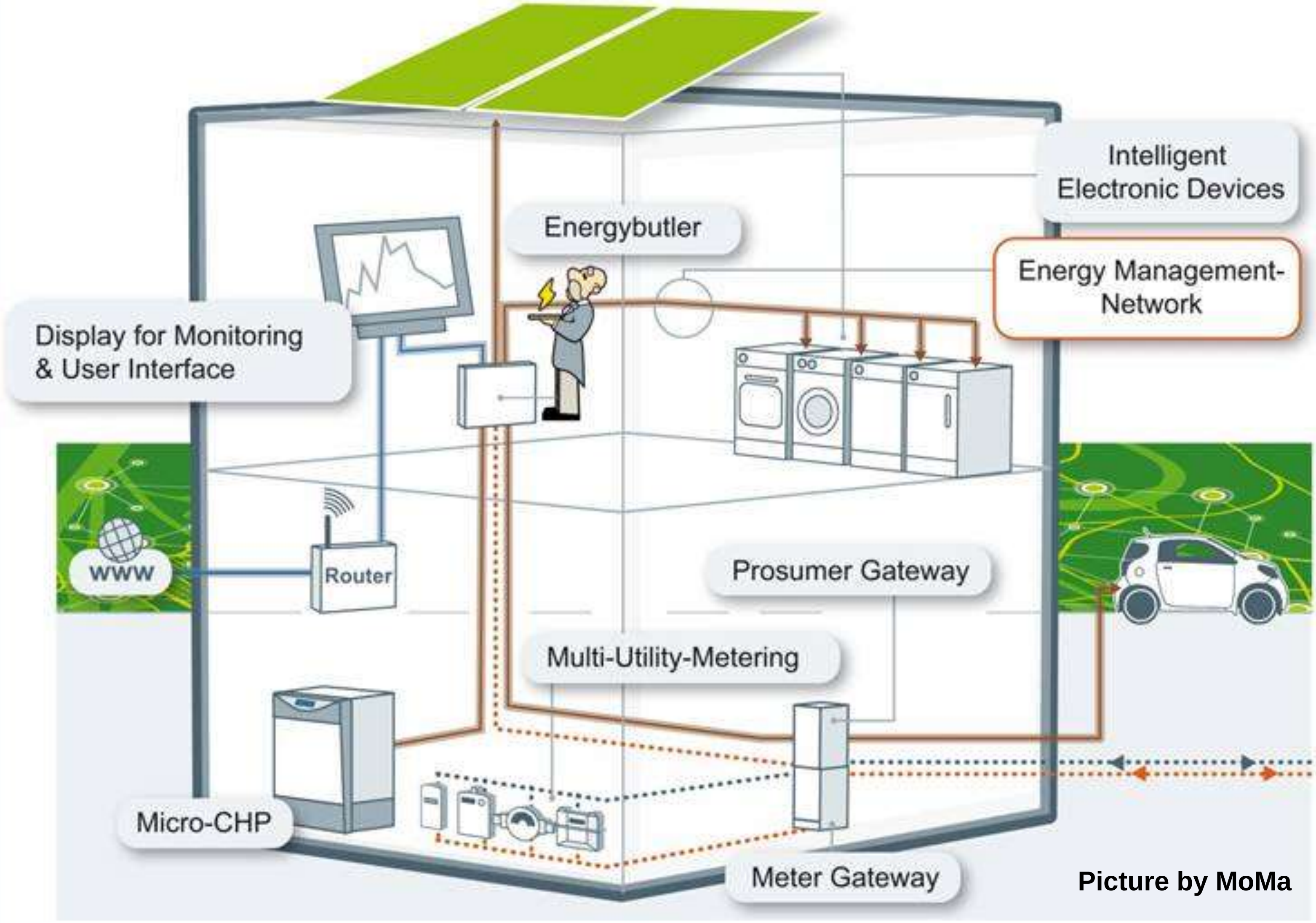


- Deutlicher Lastzuwachs
- Relativ lange Ladedauer

Ein Fahrzeug verändert die Situation nicht… aber viele Fahrzeuge in einer Nachbarschaft erfordern Netzanpassungen

Part 1
resLoadSIM

The Idea of an Energy-Gateway
Energy-Butler



Picture by MoMa

The resLoadSIM Program

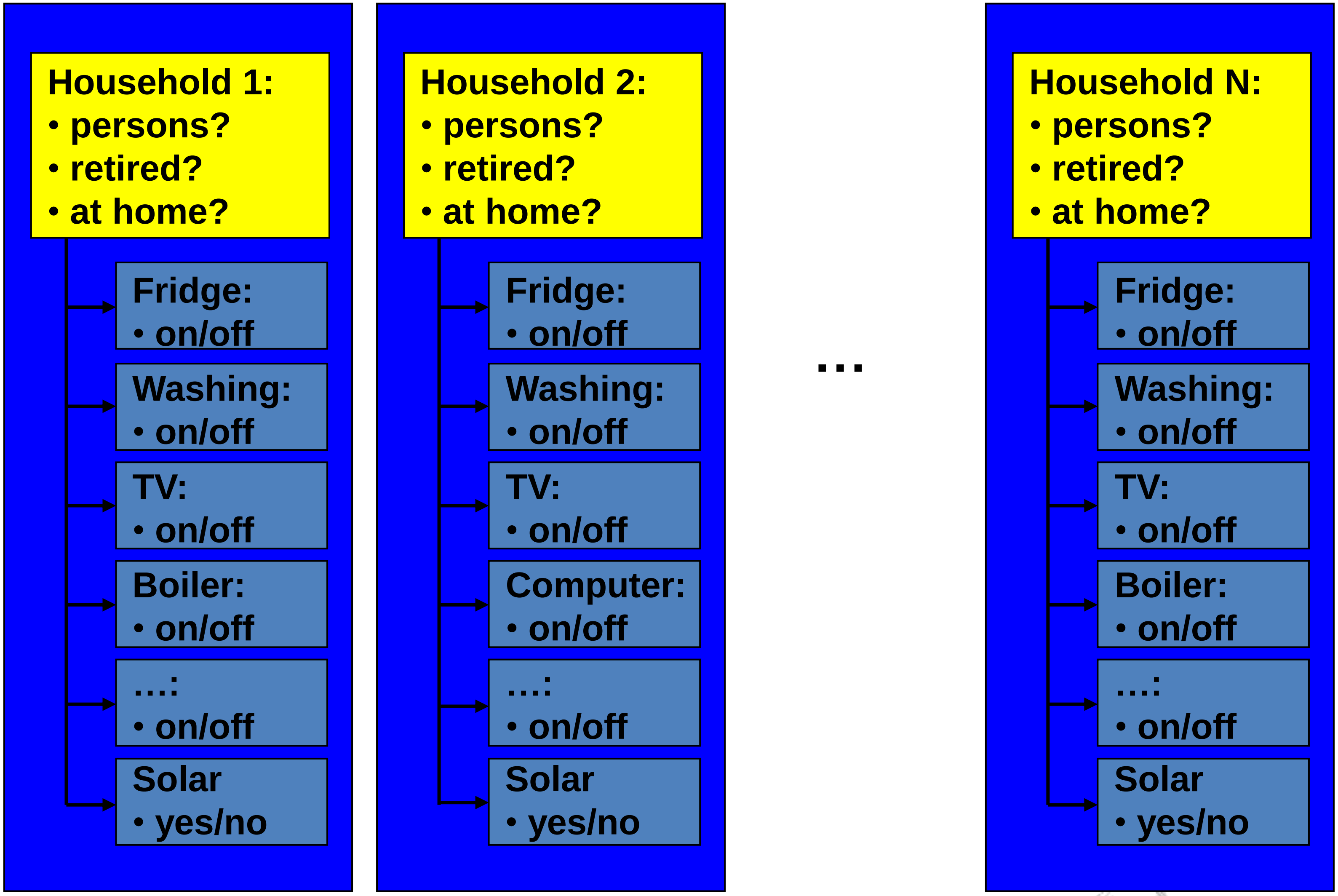
resLoadSIM simulates load profiles of individual households by predicting the switching on/off of each appliances (electric loads) in the household using an probabilistic/random approach.

Advantages of resLoadSIM:
- **is very flexible**
- **allows realistic control of certain appliances (load shifting)**

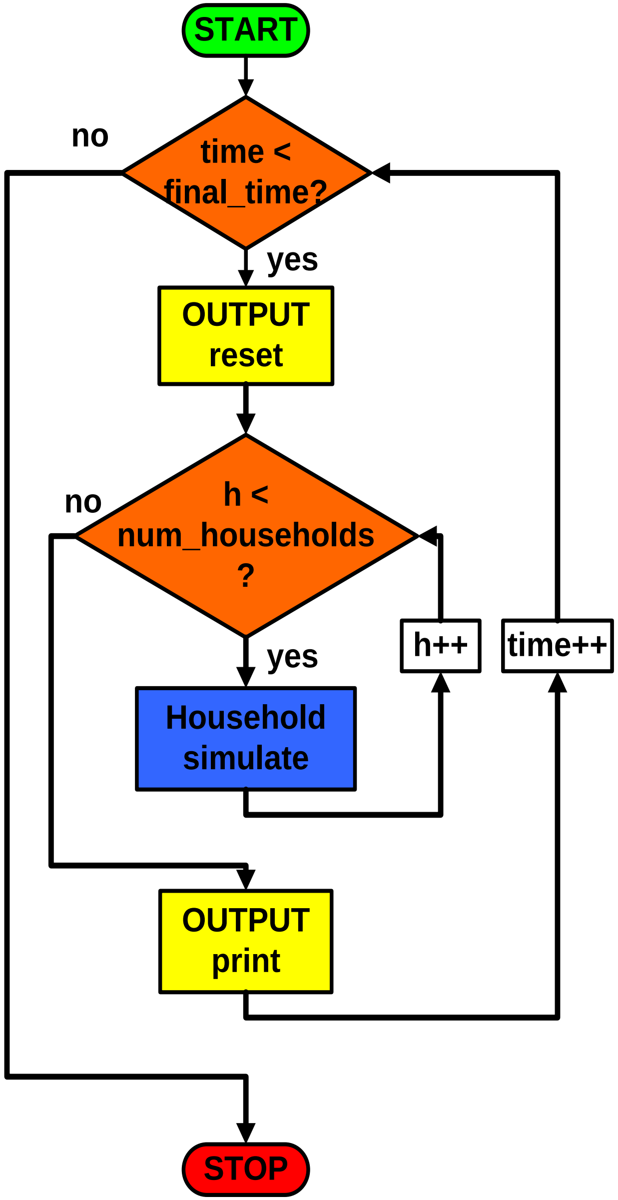
Disadvantages of resLoadSIM:
- **is difficult to validate**
- **only active and constant power of appliances**
- **due to the random nature of the method, results are not reproducible and sometimes difficult to compare**

Best alternative to resLoadSIM:
- **None??? Even real experimental data cannot be used as flexible, because these cannot be influenced due to historic nature of the data**

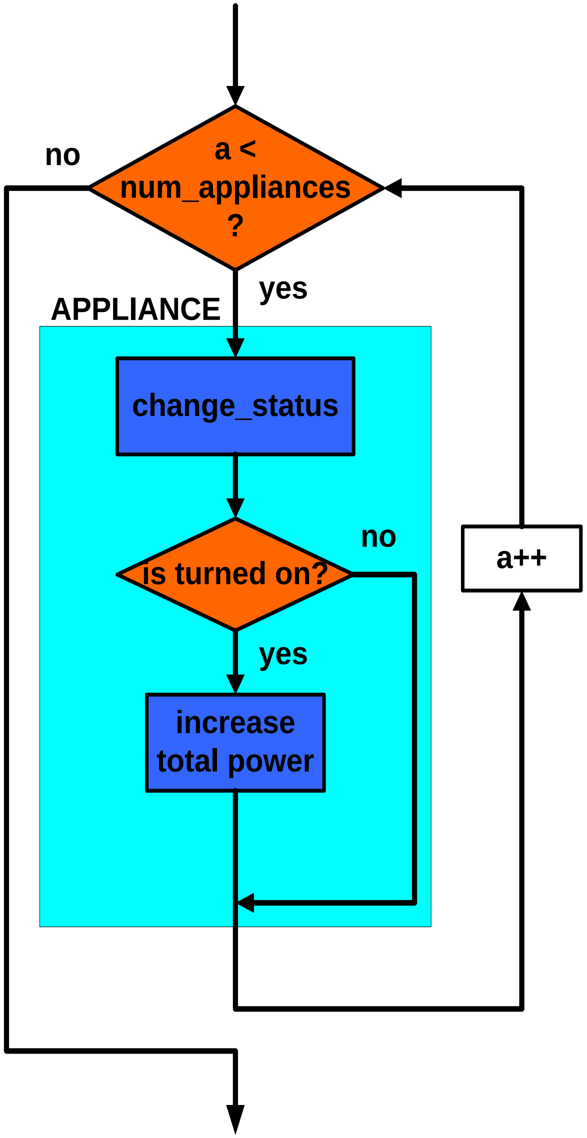
Electric Energy Consumption in Private Households as it is today



European Commission

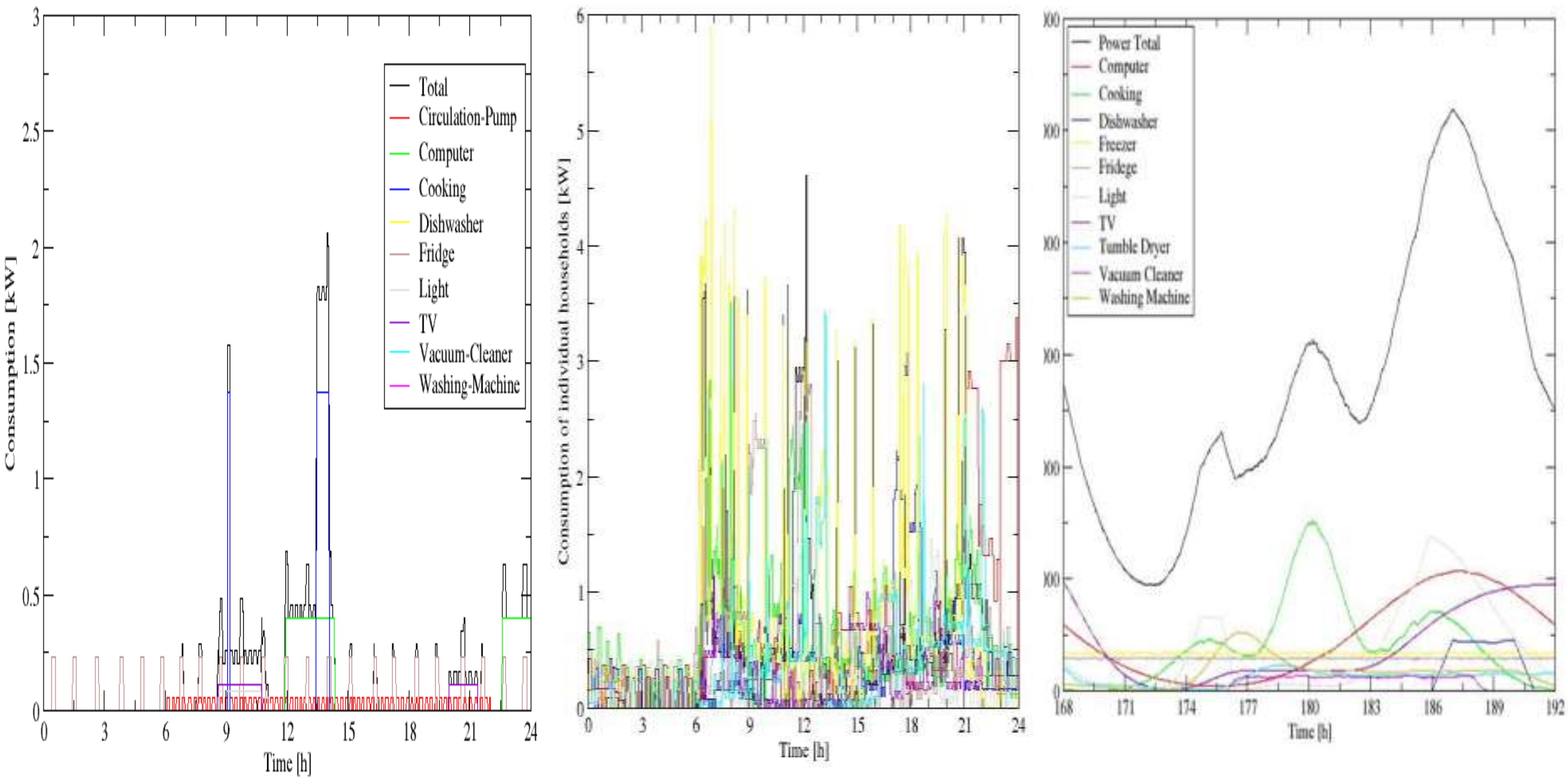


Modelling a large number of individual households



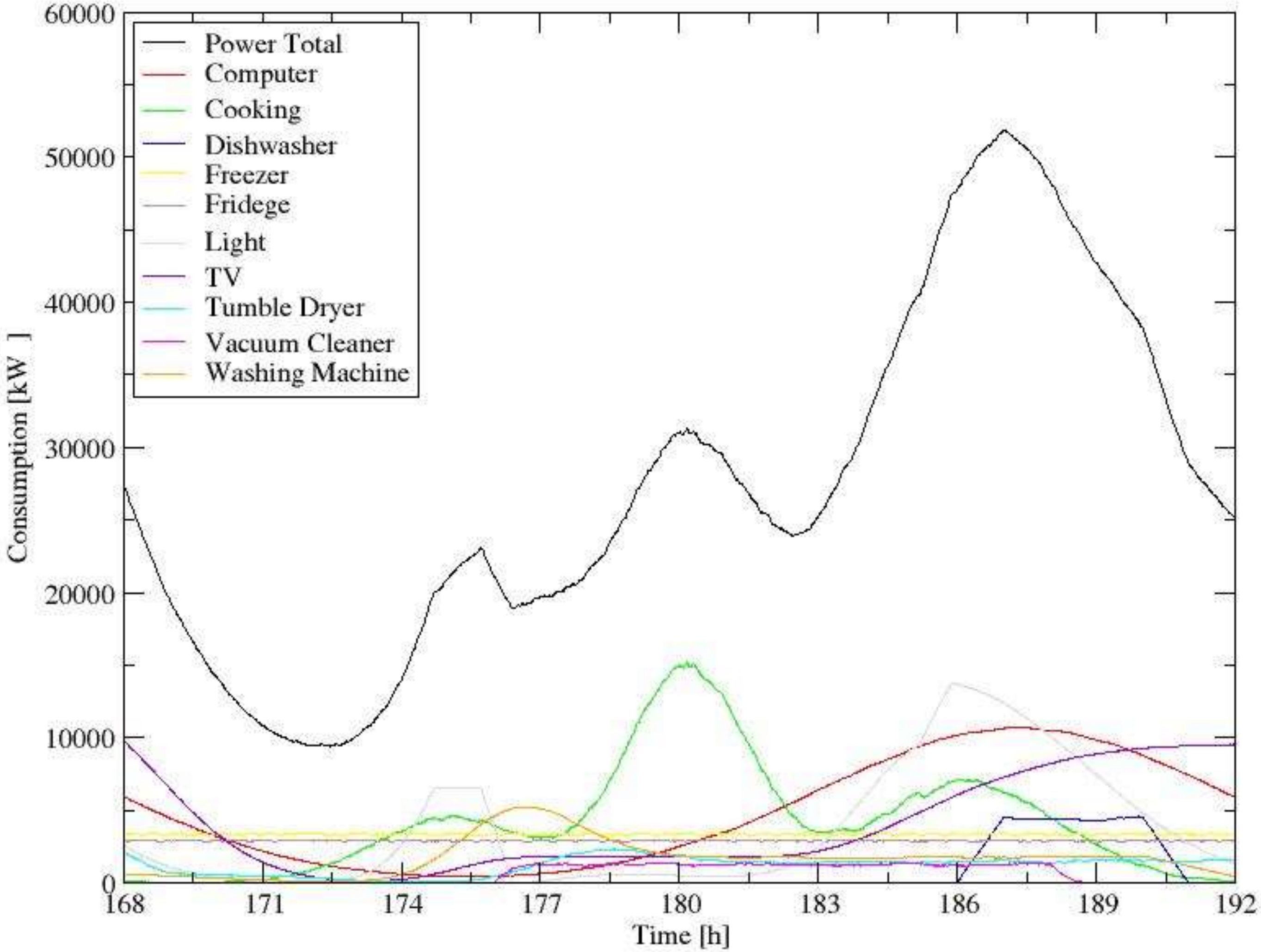
Within each household model all appliances

resLoadSIM: from single households appliances towards aggregating multiple households

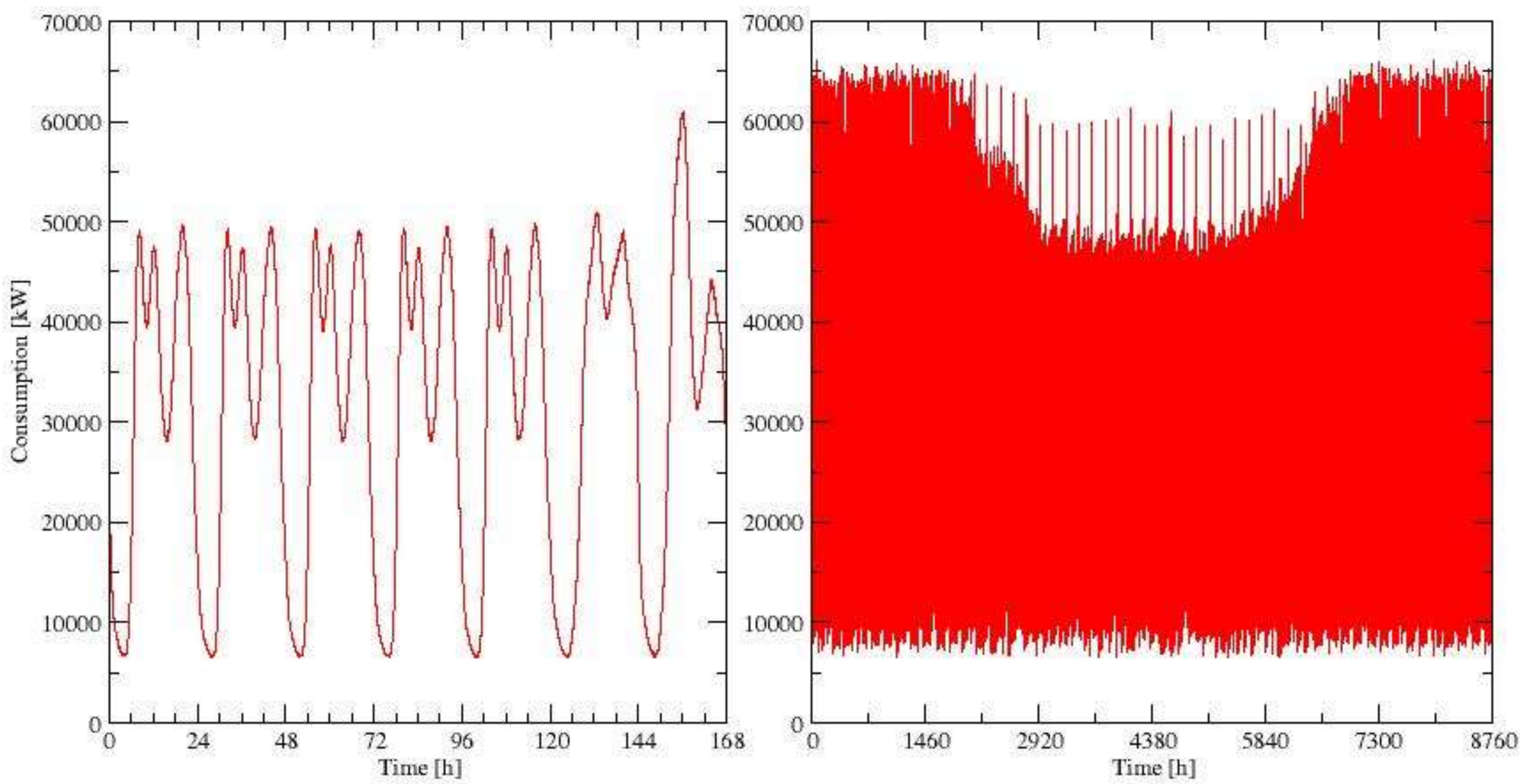


European Commission

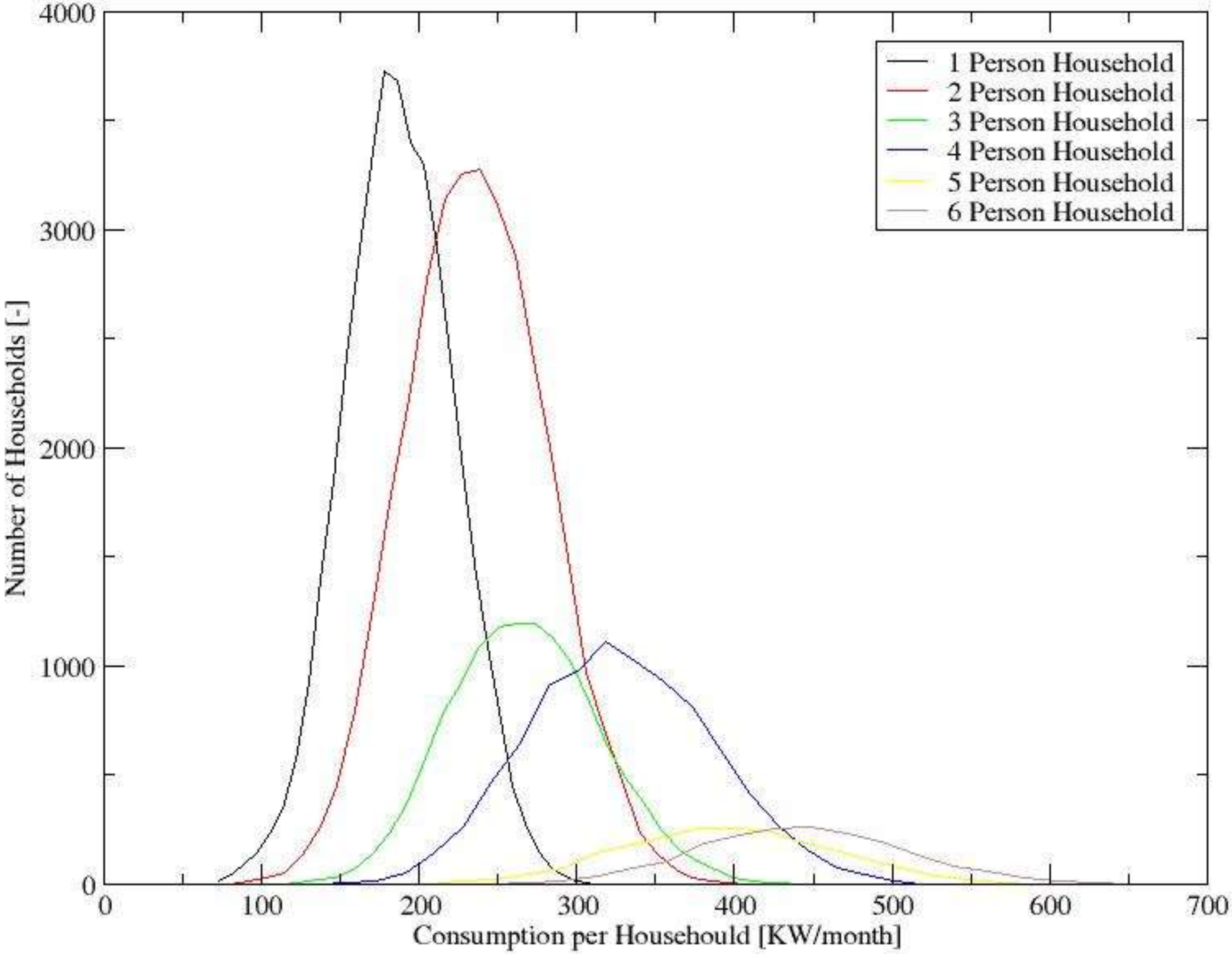
Load Profile 100000 Households



Weekly and Annual Load Variation



Load Distribution



Validation Reference 1

EnergieAgentur.NRW

Was verbraucht wie viel?

Verbrauchswerte der Bereiche nach Haushaltsgrößen
mit und ohne elektrische Warmwasserbereitung (WWB)

Rang	Verbrauchsbereich	Verbrauchswerte verschiedener Haushaltsgrößen mit und ohne elektrische WWB [kWh/a]					
		1-Pers.	2-Pers.	3-Pers.	4-Pers.	5-Pers.	6-Pers.
1	Büro	346,7	419,1	531,3	608,7	703,3	826,6
2	TV / Audio	290,6	407,6	542,8	568,6	630,4	729,1
3	Warmwasser	316,1	428,6	516,0	544,2	632,1	708,8
4	Kühlen	337,3	393,0	430,7	454,4	472,7	521,0
5	Licht	228,8	296,7	375,2	474,1	637,7	642,9
6	Kochen	177,8	334,4	392,5	467,6	509,2	552,6
7	Diverses	163,4	218,1	293,6	348,4	481,1	481,0
8	Trocknen	55,9	152,8	282,8	409,6	524,7	595,2
9	Umwälzpumpe	139,8	170,9	253,1	320,5	382,3	386,3
10	Spülen	55,7	142,2	225,3	307,8	372,5	415,2
11	Waschen	88,9	137,5	202,2	258,8	330,4	379,7
12	Gefrieren	54,8	147,5	200,0	246,6	293,0	340,9
Summe (gerundet)		**2.256**	**3.248**	**4.246**	**5.009**	**5.969**	**6.579**
Anzahl Datensätze: 380.370		72.693	143.699	72.139	67.605	18.988	5.246

Quelle: EnergieAgentur.NRW (04/2011)

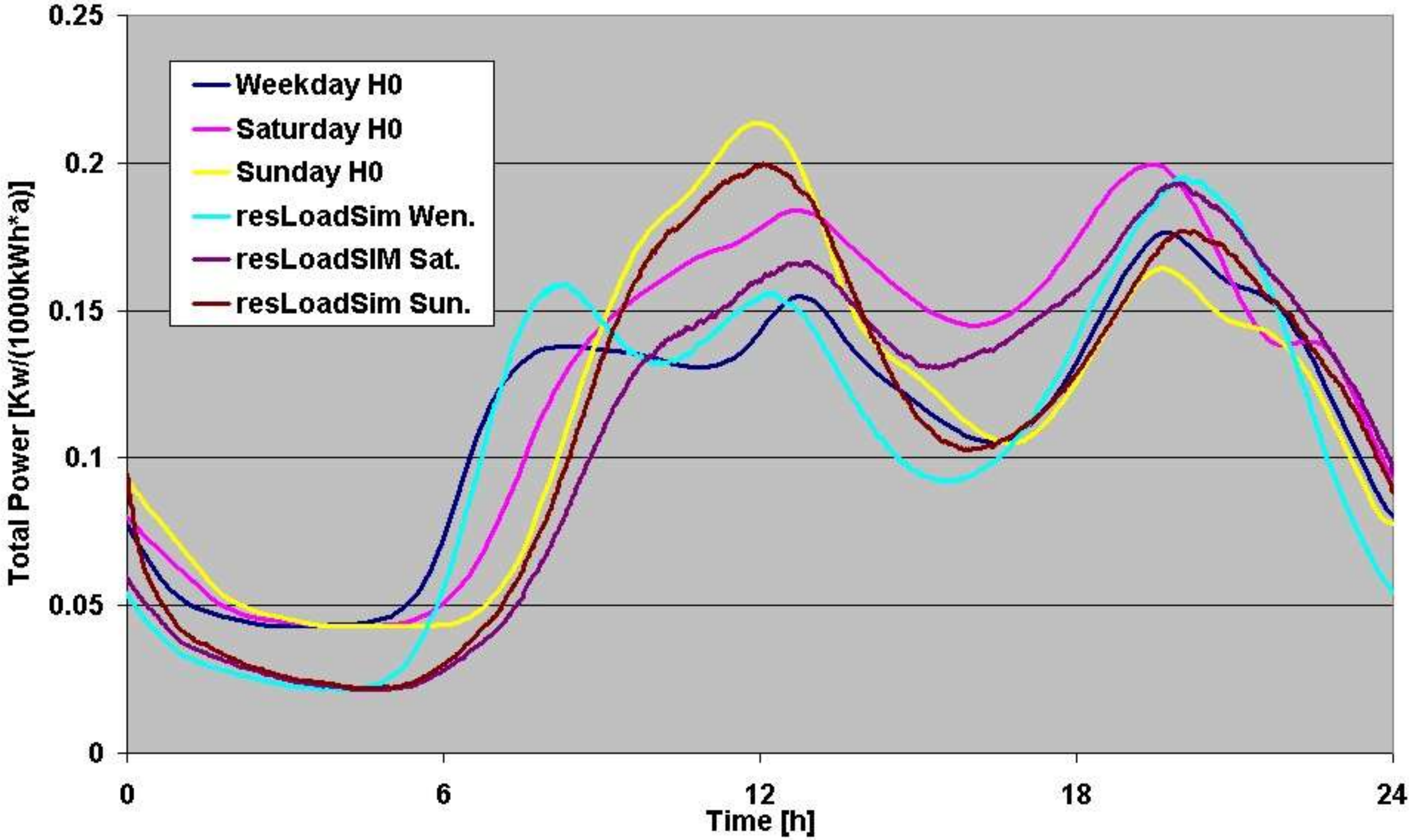
European Commission

Validation has been done against German data provided by EnergieAgentur.NRW for typical German households

```
Person in Household                 1     2      3      4      5      6
-------------------------------------------------------------------------


……

Fridge
 ResLoadSIM [kWh]                 345.   391.   431.   450.   470.   507.
 EnergieAgentur.NRW [kWh]         337.   393.   430.   454.   472.   521.
……


Total
=========================================================================
 ResLoadSIM [kWh]                2152.  3116.  4069.  4801.  5725.  6251.
 EnergieAgentur.NRW [kWh]        2256.  3248.  4246.  5009.  5969.  6579.
```

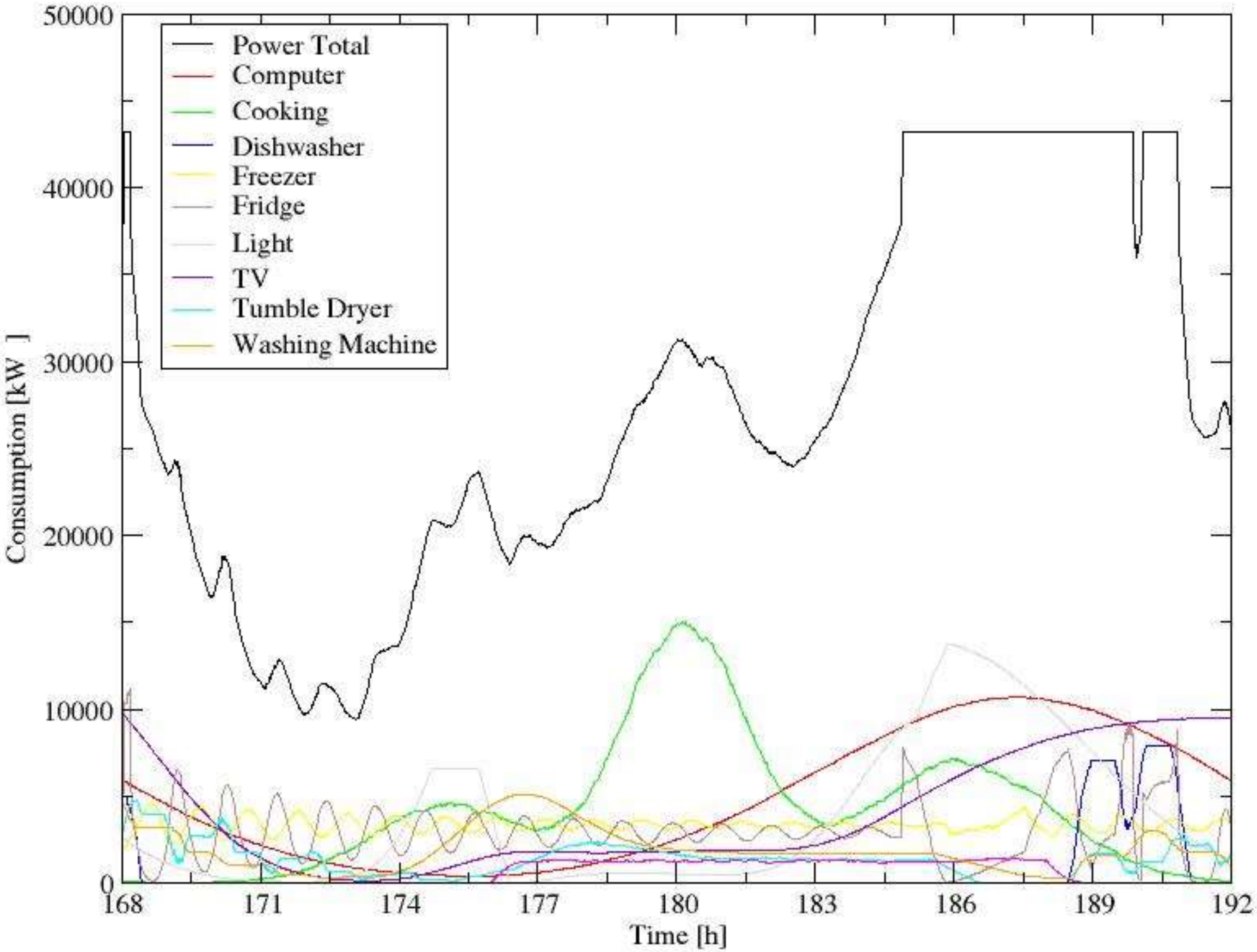

European Commission

Comparison with standard load profiles, validation reference 2



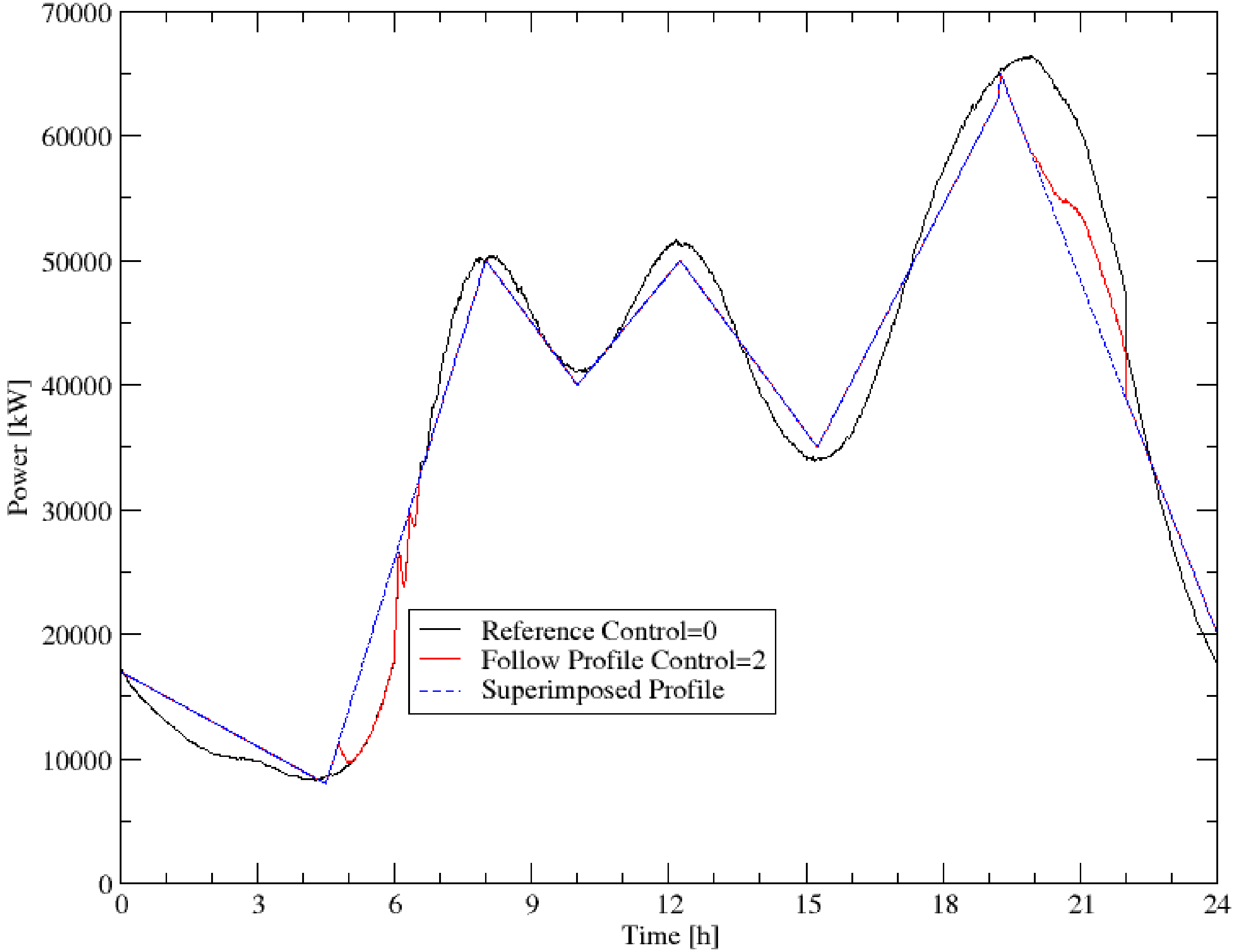
Comparison standard profiles for households transition period versus resLoadSIM

100000 Households with Peak Shaving at 85% nominal Load



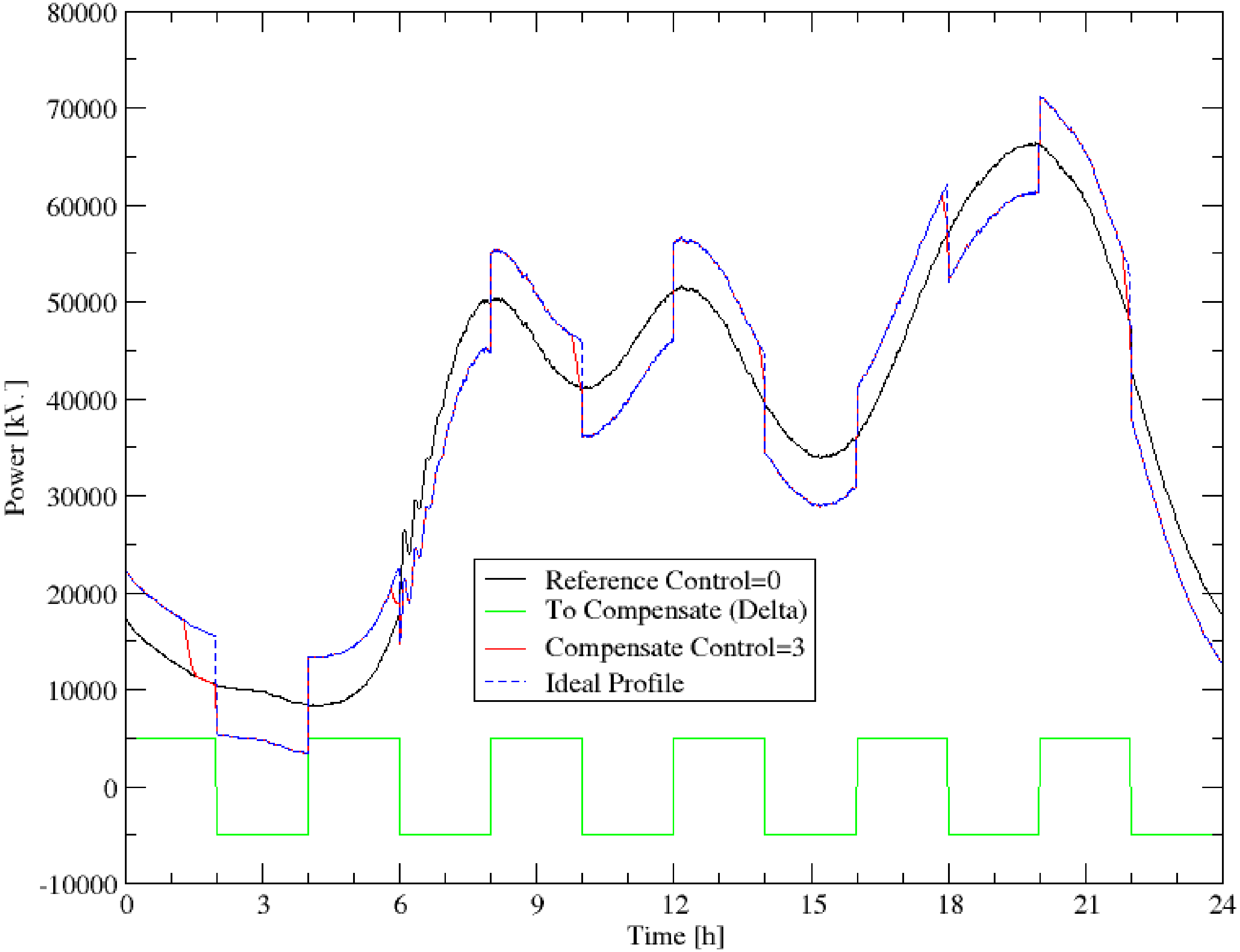
European Commission

100000 Households following a given load profile



European Commission

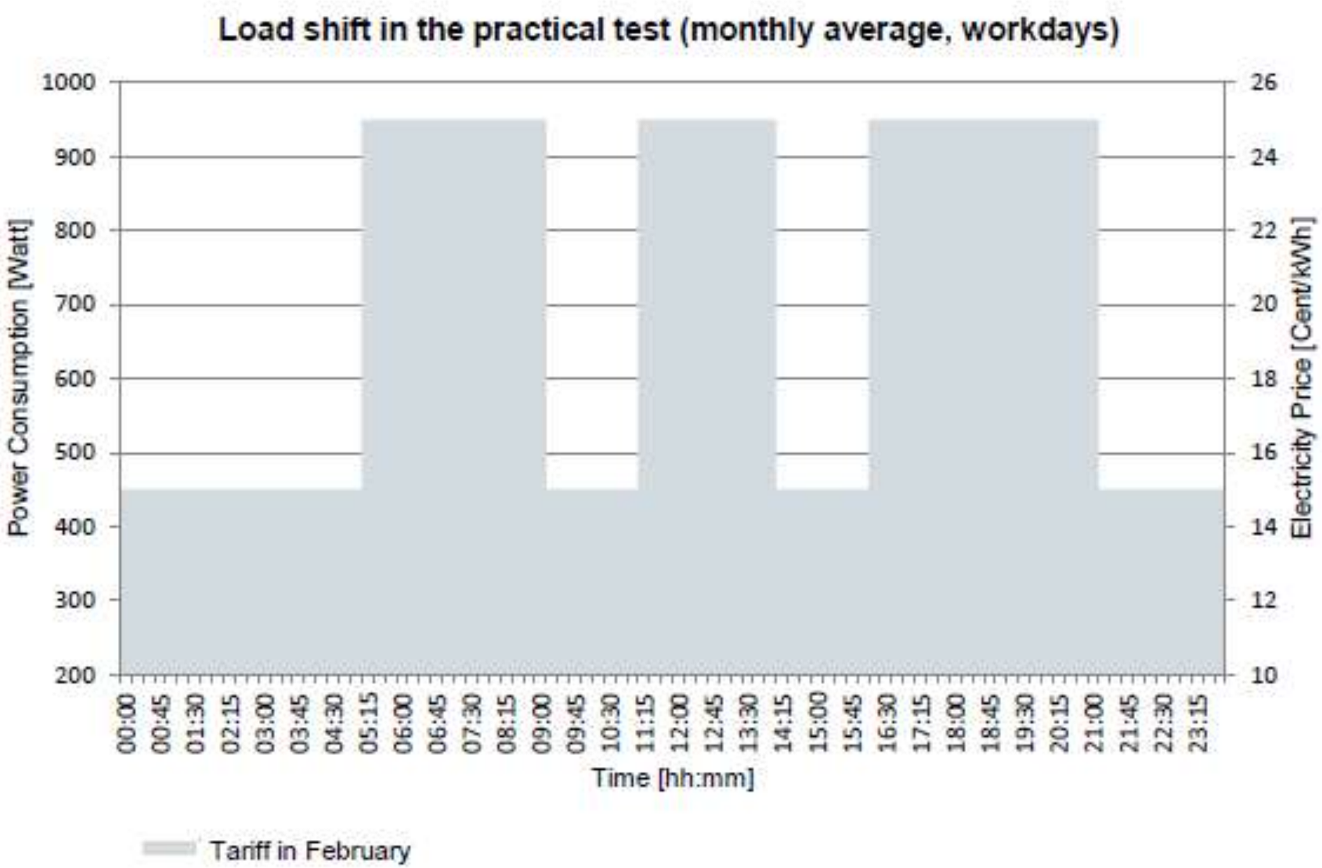
100000 Households Compensate a Given Delta-Profile



European Commission

Interim Results - Load Shift

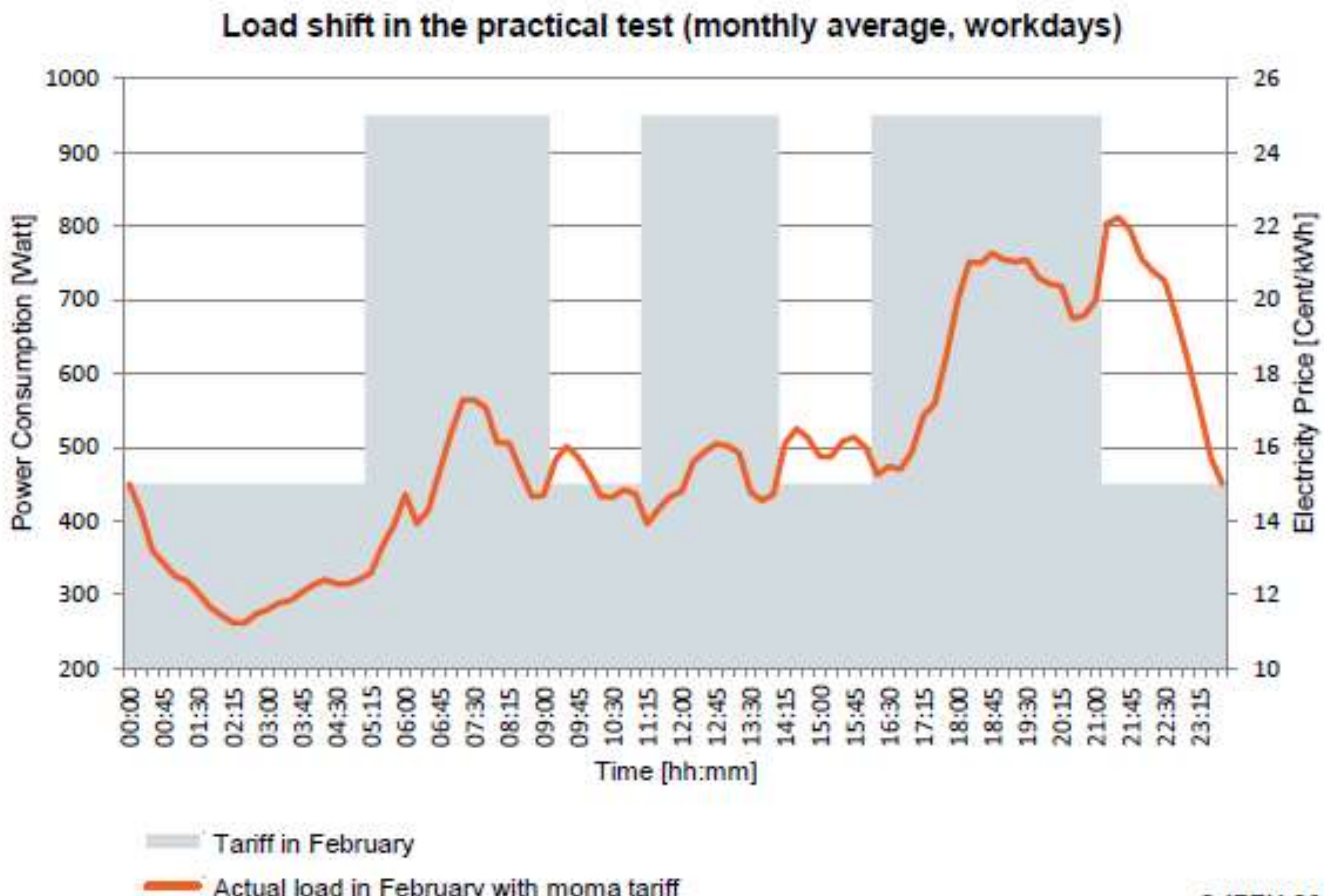
Modellstadt Mannheim



Gefördert durch das Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit

Interim Results - Load Shift

Modellstadt Mannheim



Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit

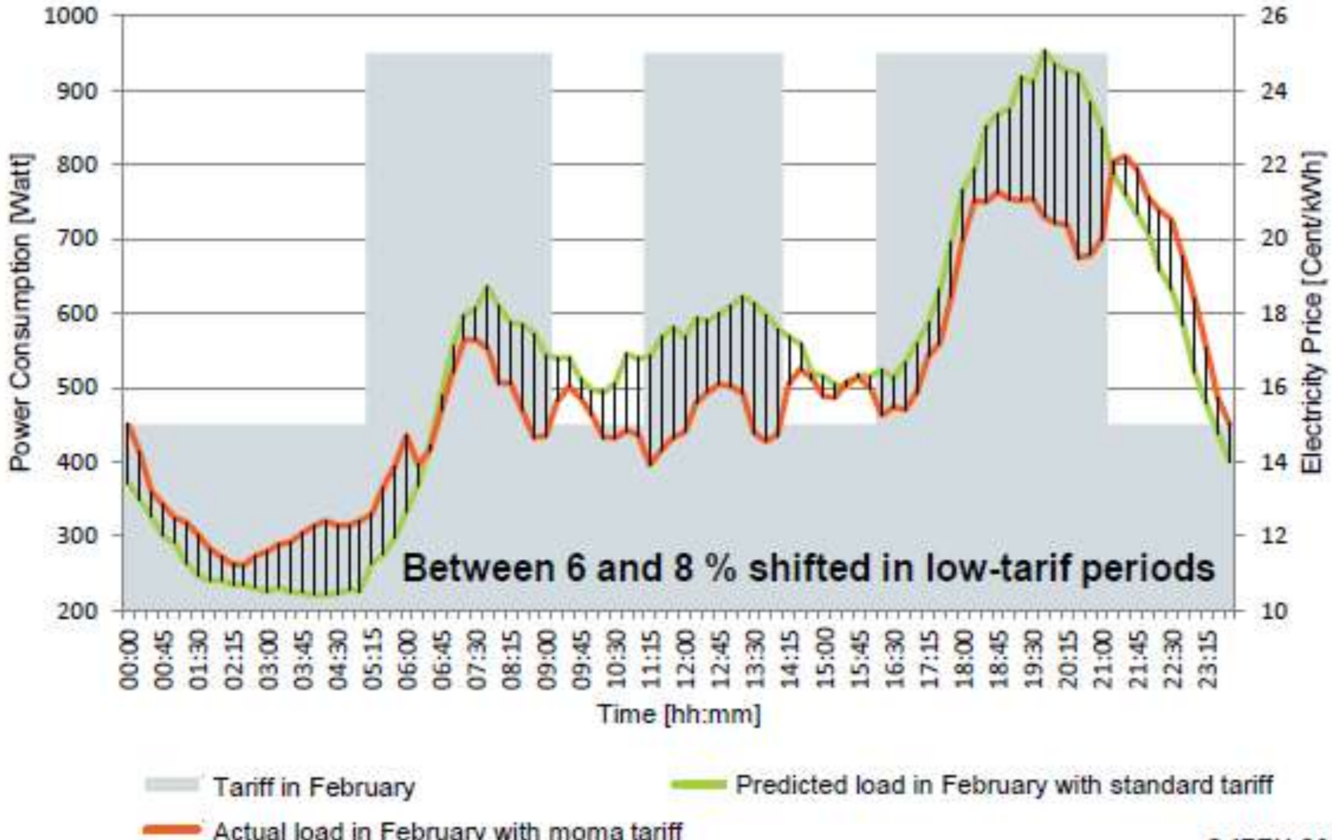
EENERGY

Interim Results - Load Shift

moma
Modellstadt Mannheim

- **Shift of electricity consumption:** In low tariff periods the electricity consumption rises and falls in high tariff periods

Load shift in the practical test (monthly average, workdays)



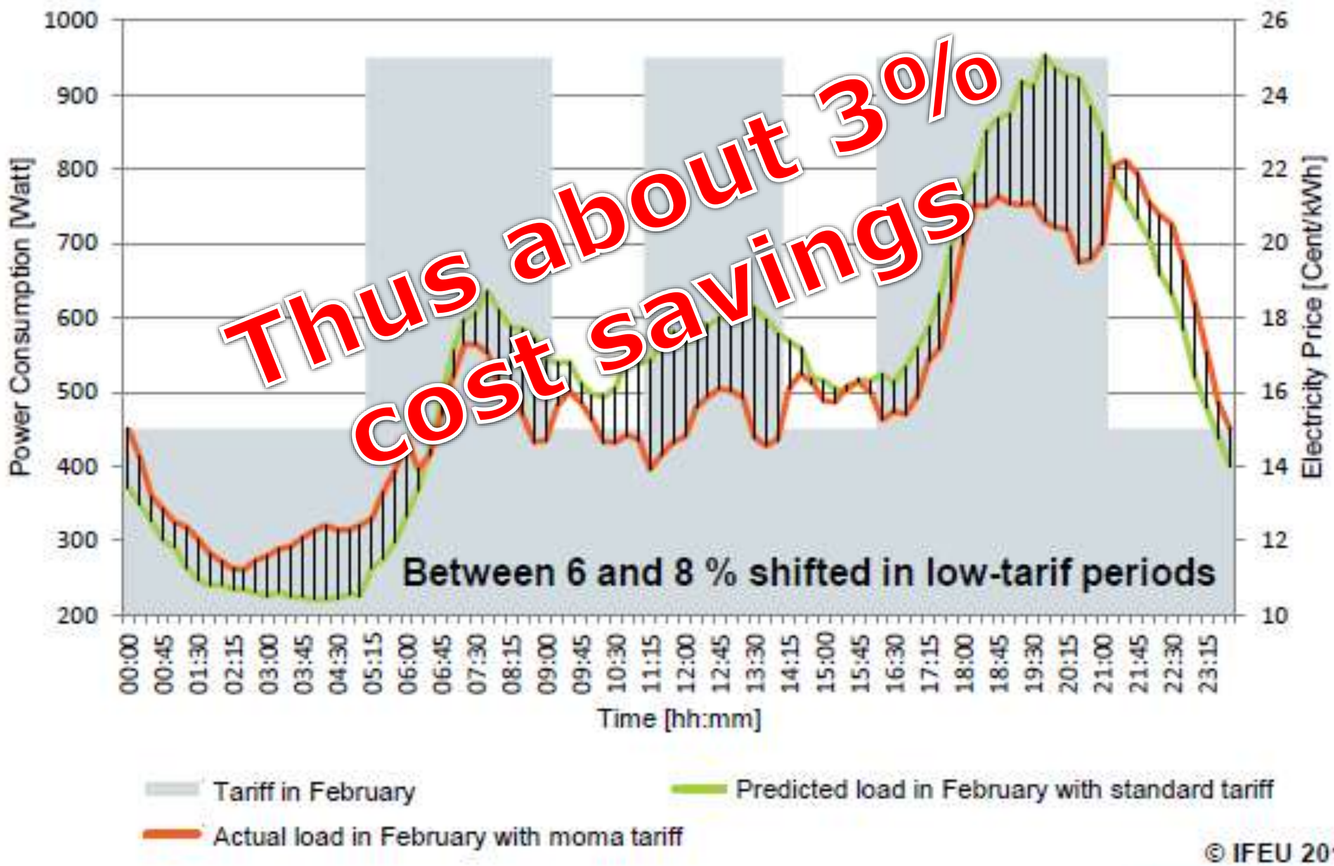
Gefördert durch das Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit

E-ENERGY

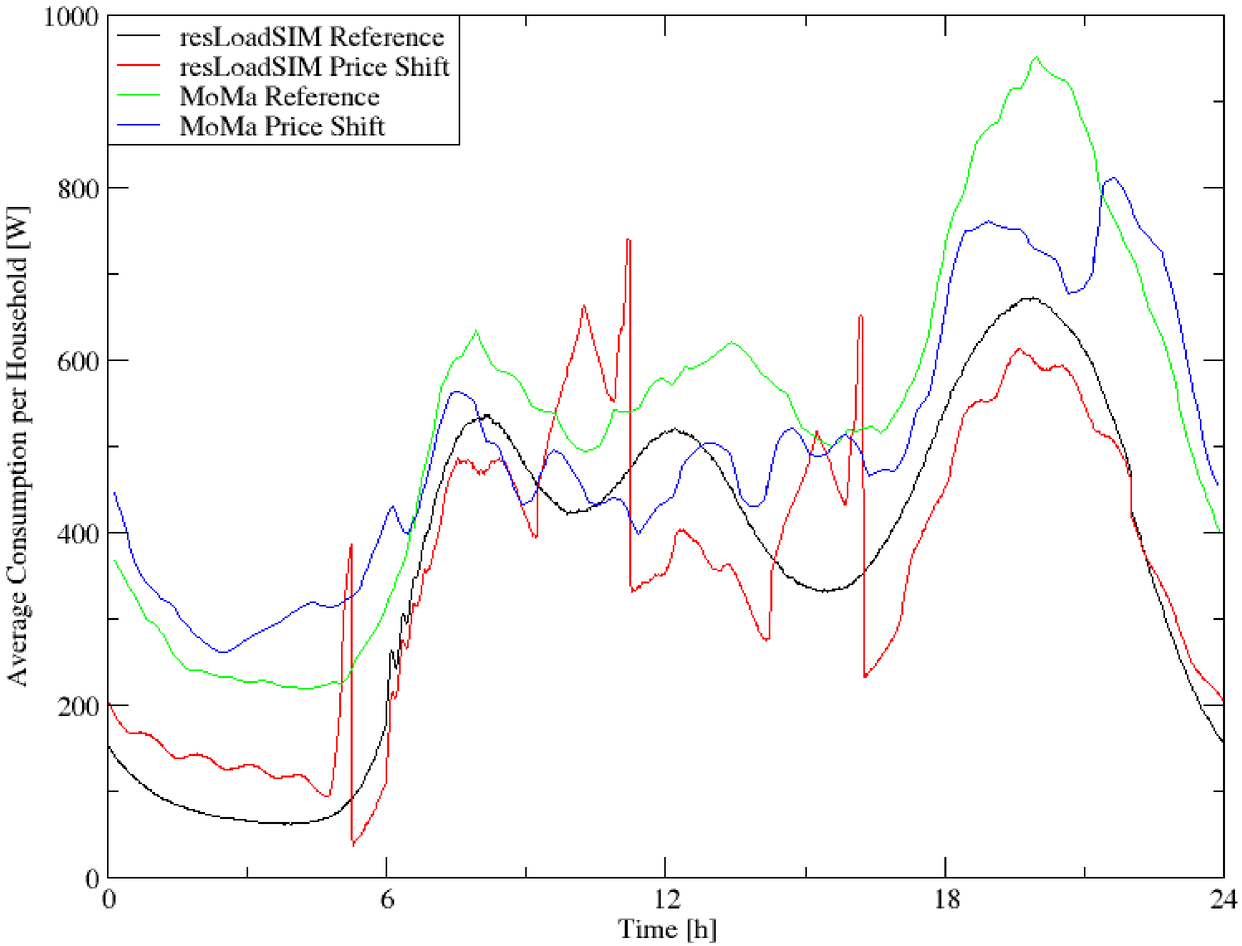
Interim Results - Load Shift

- **Shift of electricity consumption:** In low tariff periods the electricity consumption rises and falls in high tariff periods

Load shift in the practical test (monthly average, workdays)



Comparison resLoadSIM with MoMa when using flexible prices for DSM, validation reference 3



Loads are generally under-predicted compared to MoMa,. This could be the results of different boundary conditions, which are not know in detail for MoMa, e.g. the percentage of households with electric hot water generation. The load shift due to price signal can be seen clearly also in resLoadSIM.

European Commission

Consumption and costs, comparing reference and price shifting for resLoadSIM

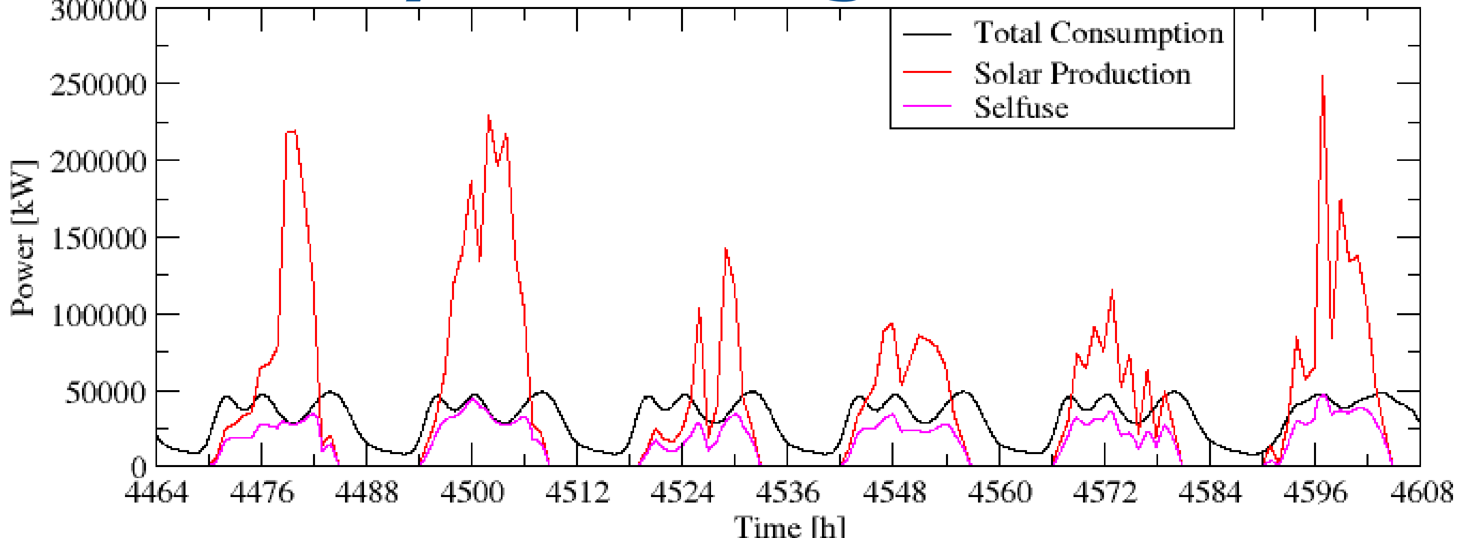
Cat.	Number	Mean Consumption	Mean Costs
1	41302	2110.907 kWh	453.91 €
2	33782	3061.091 kWh	654.92 €
3	12968	4003.204 kWh	851.59 €
4	8943	4716.520 kWh	1002.48 €
5	1996	5617.220 kWh	1190.27 €
6	1009	6214.629 kWh	1317.26 €
All	100000	3021.704 kWh	645.85 €

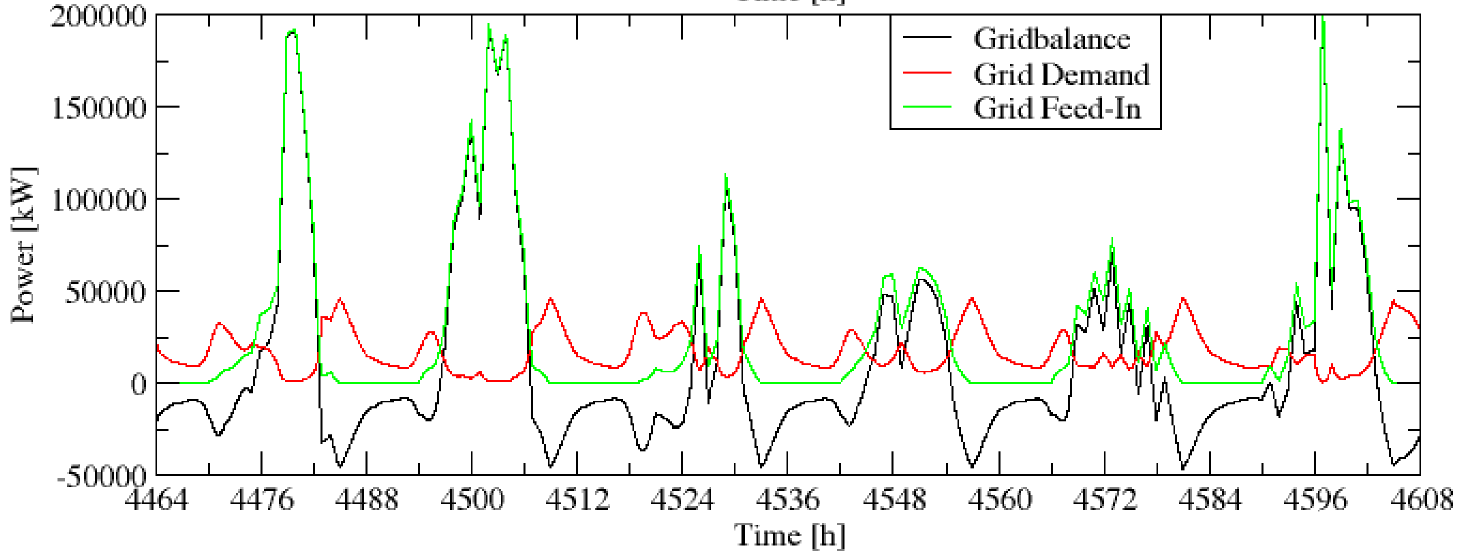
Cat.	Number	Mean Consumption	Mean Costs
1	41302	2106.796 kWh	435.74 €
2	33782	3045.802 kWh	618.35 €
3	12968	3974.653 kWh	795.51 €
4	8943	4665.840 kWh	924.80 €
5	1996	5547.540 kWh	1095.66 €
6	1009	6127.465 kWh	1204.55 €
All	100000	3004.336 kWh	608.75 €

About 10% load is shifted due to price signal. This is somewhat higher than was observed in MoMa. We therefore consider to introduce an `ignore_price` flag for some appliances to be set randomly, to represent those who really want the service now, e.g. starting the washing machine immediately.
Second remark, the cost savings are only limited, about 6% or less than € 40,- in average.

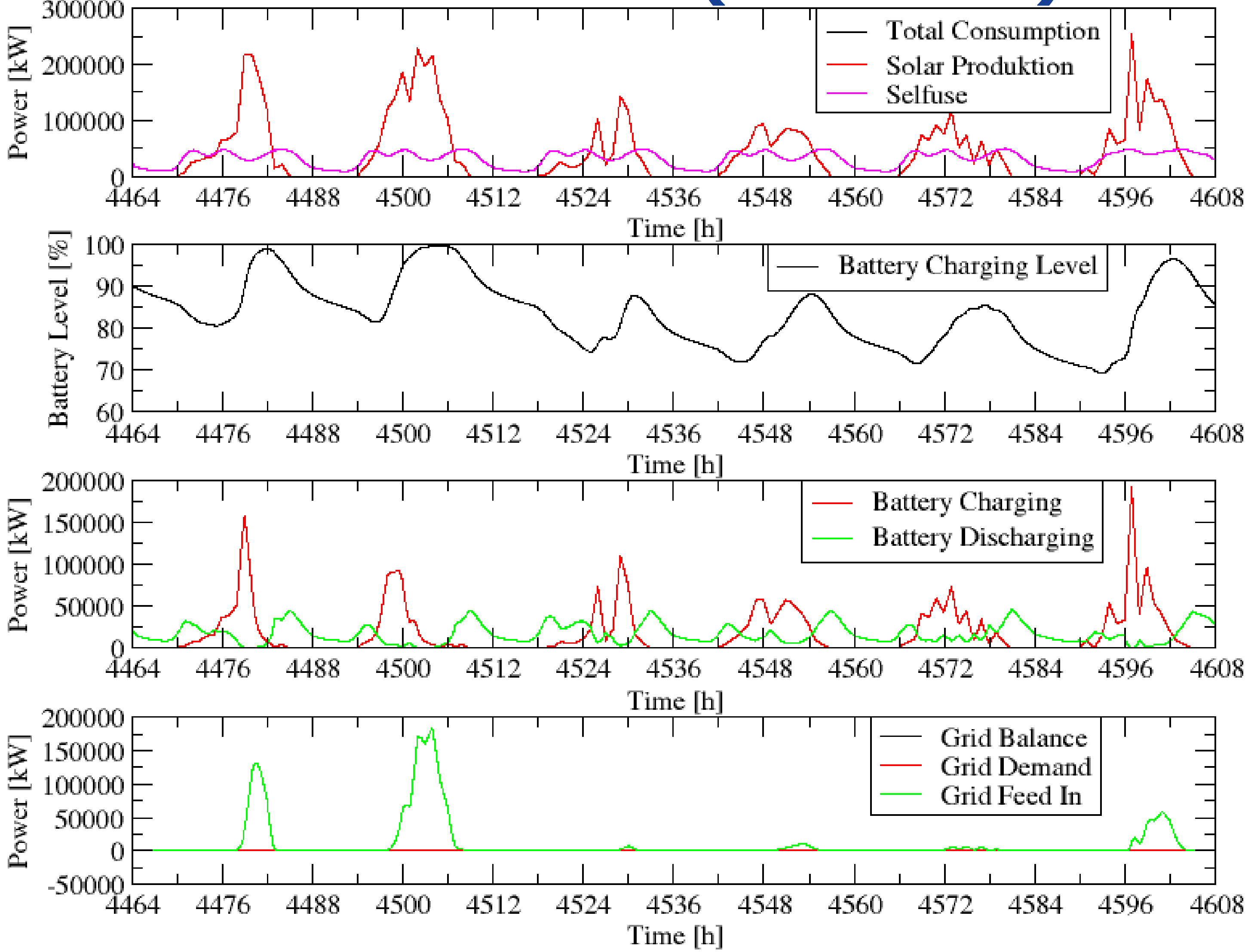
European Commission

Households can become Energy-Prosumers by Installing Photovoltaic



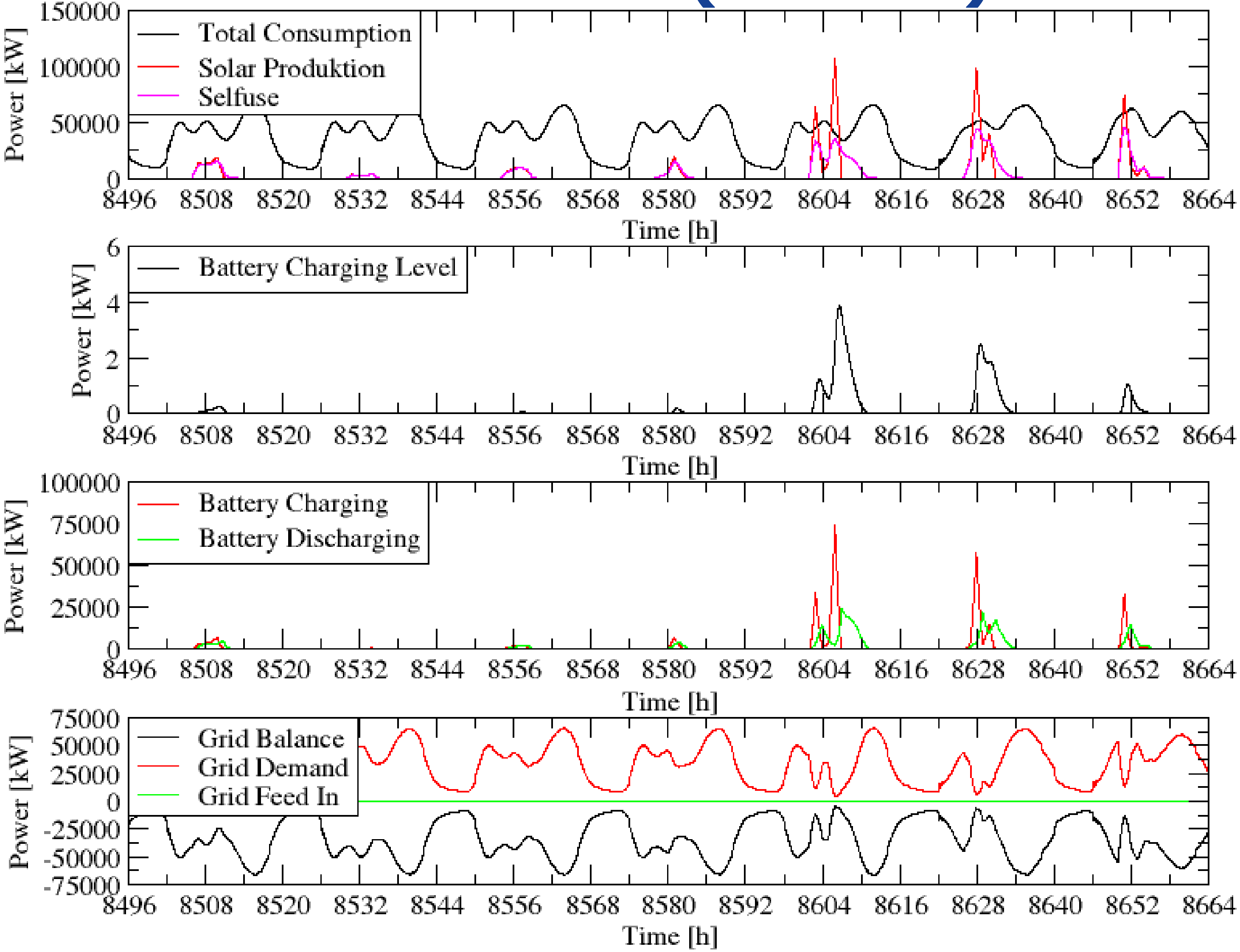


The Effect of combining Photovoltaic with Batteries (Summer)



European Commission

The Effect of combining Photovoltaic with Batteries (Winter)



European Commission

zero:e park - Zero emission settlement Passive Houses in Hannover-Wettbergen, validation reference 4

Aerial and side view

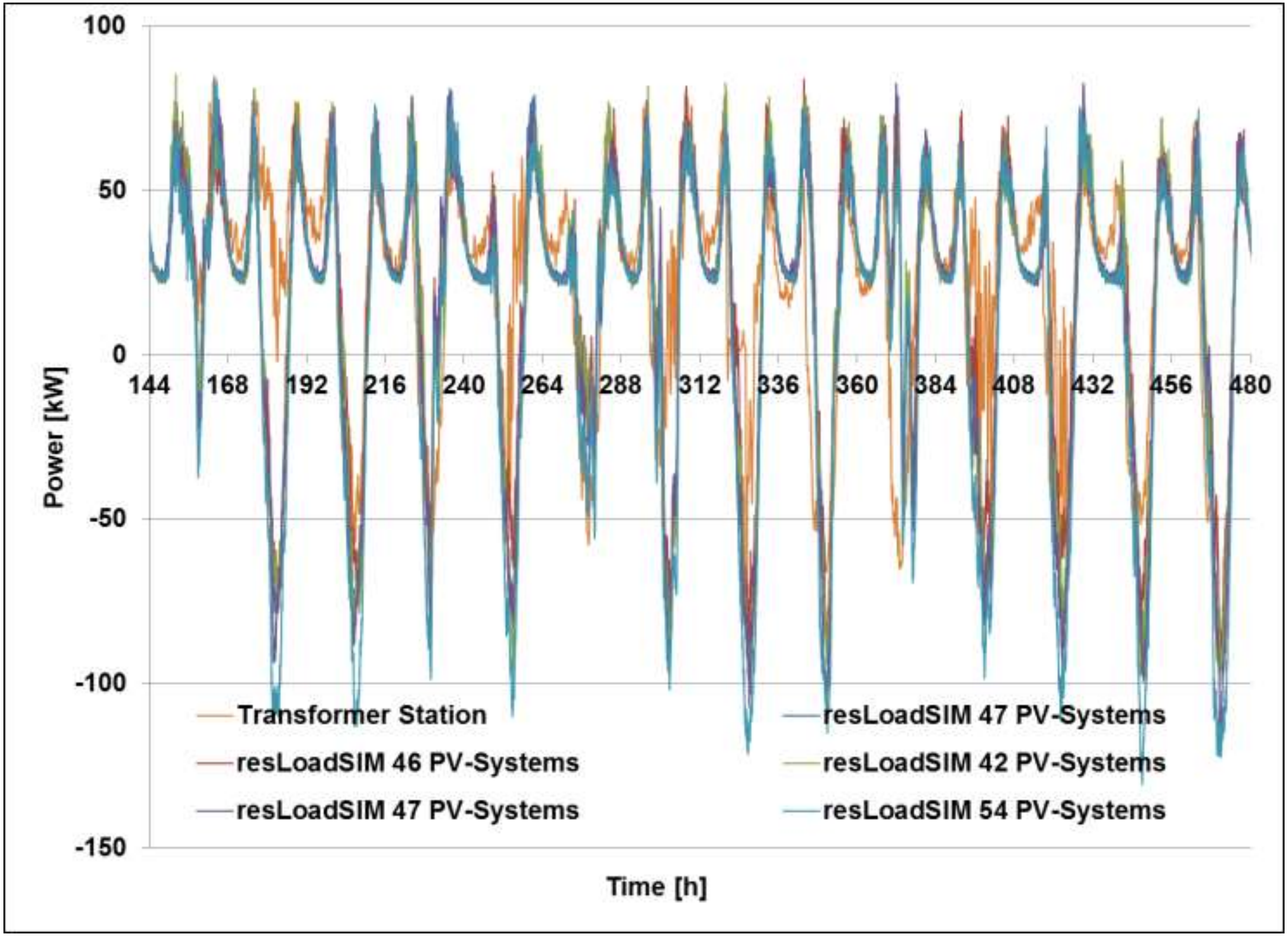
Source: www.zero-e-park.de

European Commission

Assumptions

- **126 households with an average of 190m2 with passive house standard**
- **Highly efficient devices 10, 35, 35 and 20% in the best four Energy Efficiency Classes.**
- **40% have pv installations of 5.4 kWp**
- **5, 10, 35, 30, 15 and 5% of 1, 2, 3, 4, 5 and 6 residents per household**
- **Solar data from pv-gis with an weighted average of 15, 20, 30, 20 and 15% for East 20, South 28, South 38, South 48 and West 20 deg orientation of the Solar panels.**

Comparison with 5 resLoadSIM runs



European Commission

resLoadSIM demonstration

Conclusion 1: resLoadSIM

A new method for simulating residential load profiles was presented. It was shown, that the method is valid and can generate interesting insight for the potential of demand side management as well others such as self-consumption or energy-efficiency.

Just to mention, resLoadSIM underwent an external software review, which was positive!
Second, we currently develop a web interface for resLoadSIM, which will allow external parties and interested people to use resLaodSIM.

Future Load Profiles

In the future we can expect an increased amount of renewable generation via photovoltaic on the residential scale. At the same time there will be new electrical consuming “devices” at home, mainly heat pumps and e-vehicles. Also there is a trend by housing companies to replace combined hot-water and heating system by electrical boilers.

This is increasing the loads on the Distribution-Grid, with the potential to congestions e.g. over- or under-voltages.

Are there strategies, which could prevent this congestions even if there is an increased load?

Part 2
Combining resLoadSIM with a distribution grid simulation tool

Volkskrant 18th July 2016

Huizen in de straten Velduil en Sneeuwuil in Bedum, Groningen. De zonnepanelen produceren zoveel stroom, dat het netwerk de spanning niet aankan. Foto Harry Cock / de Volkskrant

Na bevingen nu haperende zonnestroom

Er zijn zoveel zonnepanelen aangebracht op Groningse woningen die zijn beschadigd door de gasboringen, dat de stoppen doorslaan. Dat kost de bewoners geld.

Van onze verslaggever
Jeroen Trommelen

AMSTERDAM Soms slaan de hoofdstoppen door en juist als de zon volop schijnt, schakelen de zonnepanelen zichzelf uit omdat ze hun stroom niet kwijt kunnen. In diverse Groningse gemeenten hebben gedupeerden van bevingschade door de gasproductie nu óók last van een haperende groene energievoorziening. De zonnepanelen die ze na de reparatie van hun huizen als extraatje mochten laten aanleggen, produceren zoveel stroom dat het netwerk de spanning niet aankan.

Het probleem speelt ondermeer in plaatsen als Bedum en Stedum waar massaal gebruik is gemaakt van de speciale regeling van gasproducent NAM. Daarmee konden gedupeerden 4.000 euro krijgen voor 'waardevermeerdering van de woning', te besteden aan energiebesparende of energieopwekkende maatregelen. Huiseigenaren van negen gemeenten konden profiteren van de regeling, waarvoor ruim 37 duizend aanvragen zijn gedaan.

Dat was het begin van nieuwe problemen, zegt Wim de Haan in Bedum, die drie jaar geleden al op eigen initiatief zonnepanelen op het dak liet plaatsen. Tot onlangs leverde dat nooit storingen op bij teruglevering aan het energienet. 'Maar nu bijna de hele straat ze heeft, staat mijn omvormer tussen twaalf en drie uur 's middags geregeld op nul en brandt er een rood lampje. Dan is het net overbelast en schakelt de installatie zichzelf uit.'

Dat betekent nieuwe tegenslag voor ondermeer de straat Velduil, waar bijna alle, vrijwel nieuwe woningen beschadigd raakten door de aardgasbevingen. Bij familie De Haan bedroeg de schade 14 duizend euro. Bij buurman Hokse ontstonden grote scheuren in binnen- en buitenmuren en knapten de tegels in de badkamer doormidden. Dat is prima gerepareerd op kosten van de NAM, zegt Henk Hokse, die ook tevreden was met het cadeautje van 4.000 euro waarmee hij zijn dak vol met panelen liet leggen.

Juist op momenten dat de zon schijnt en de installatie stroom kan terugleveren, slaat hij af

Maar ook deze panelen doen het dus vaak niet, juist op momenten dat de zon flink schijnt en de installatie stroom aan het openbare net zou kunnen terugleveren. Dat kost hem geld en frustreert de productie van groene stroom. 'Netbeheerder Enexis heeft een monteur gestuurd die het capaciteitsprobleem bevestigt. Ook in andere plaatsen speelt het, maar we horen er niets over en het lijkt alsof het probleem wordt verzwegen.'

Volgens Enexis, netbeheerder in Zuid-, Oost- en Noord-Nederland, wordt er niets verzwegen en zijn de problemen 'hooguit een incident'. Vorig jaar heeft het probleem van overbelasting zich voorgedaan in een aantal Groningse gemeenten zoals Loppersum, zegt woordvoerder Loek de Lange. 'Maar dat is inmiddels achterhaald. We hebben contact gezocht met de installatiebranche om erachter te komen waar capaciteitsproblemen zijn. Dat is naar volle tevredenheid geregeld.'

In het bevinggebied is het aantal zonnepanelen in korte tijd met 30 procent gestegen, zegt hij. 'Dat is een uitzonderlijke situatie waardoor ongeveer 70 klanten iets langer hebben moeten wachten voordat ze hun stroom volledig konden terugleveren. Daarvoor hebben we het vermogen van transformatoren verhoogd en het kabelnet verzwaard. We investeren jaarlijks voor 700 miljoen euro en dit soort aanpassingen zijn geen probleem.'

Problemen bestaan echter nog steeds, zegt ook Rolf van der Tuuk, zonnespecialist bij installatiebedrijf Vaatstra in Bedum. 'Niet alleen bij ons maar ook in Winsum staat regelmatig een te hoge spanning op het net waardoor omvormers zichzelf uitschakelen. We monitoren veel van die installaties op afstand en zien dat ze zichzelf soms honderden keren per dag uit- en aanzetten. In een straat in Stedum met allemaal daken op het zuiden, vlogen zelfs de hoofdstoppen eruit.'

Vergelijkbare problemen elders in Nederland zijn niet bekend, zegt de woordvoerder van Netbeheer Nederland waarin alle beheerders van energienetten zijn verenigd. 'Maar het is zeker een dilemma dat zich in de toekomst vaker kan voordoen.'

In Groningen NAM has offered 4000,- Euro to those how suffered from this small earth-quakes due to natural gas exploration. This money should be used increasing the value of their houses and most people put solar panels on their roofs.
These new installations are causing over-potentials in the distribution grid and as a consequence solar inverters to switch off. Sometimes this happens hundreds of times a day and even some main fuses reacted.

European Commission

Replace PYPower by PFLOW

We discovered that PYPower is extremely slow compared to MATPOWER. Nevertheless we found an even better program called PFLOW.

Advantages of PFLOW:

- **Is very fast as it is written in C.**
- **Is flexible to use, as we have the source code at hand.**
- **Is based on the free numerical library PetSC from ANL.**
- **As PetSC is parallel also PFLOW is HPC compatible .**
- **There is already an hydraulic example (water pipes) using PetSC, which would be an advantage is we consider:**
  - **Gas Distribution grid**
  - **District heating**

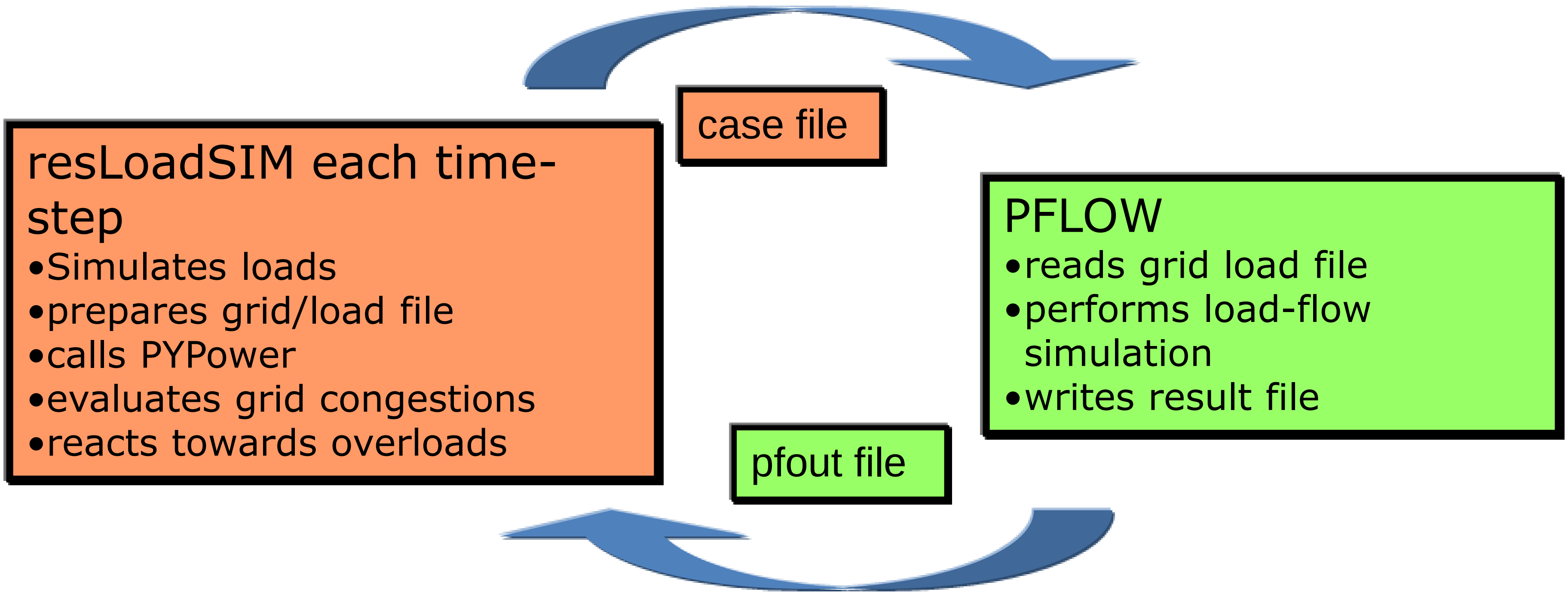
Disadvantages of PFLOW:

- **3-phase balanced simulation only, no asymmetric single-phase loads**

Best alternative to PFLOW:

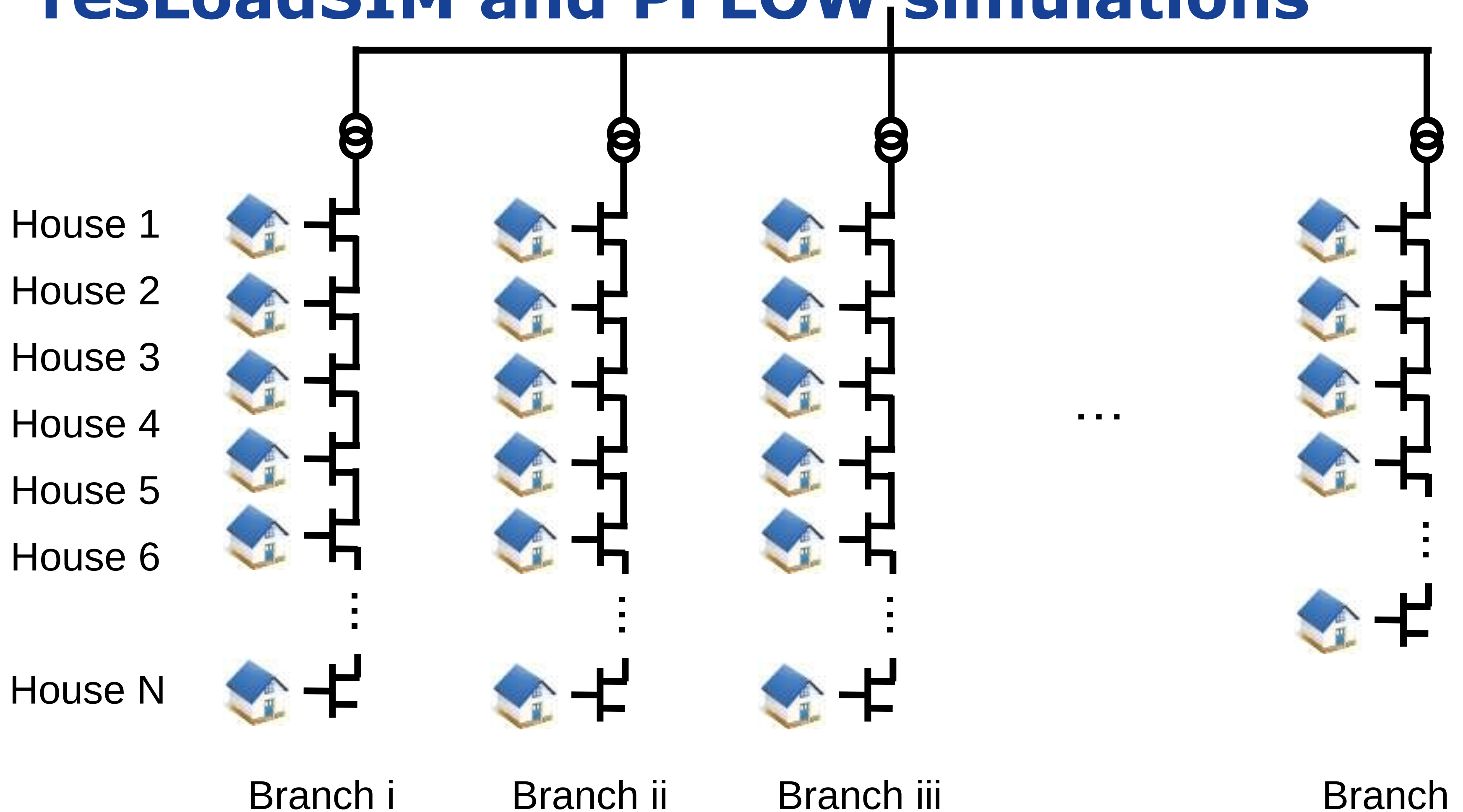
- **??? We are looking at the possibility with TU-Delft to develop an unbalanced/ asymmetric single phase solver**

A first step linking resLoadSIM and PYPower using simple ad-hoc communication via files



Ad-hoc communication scheme between resLoadSIM and PFLOW. As there is no change in the source code of PFLOW needed.

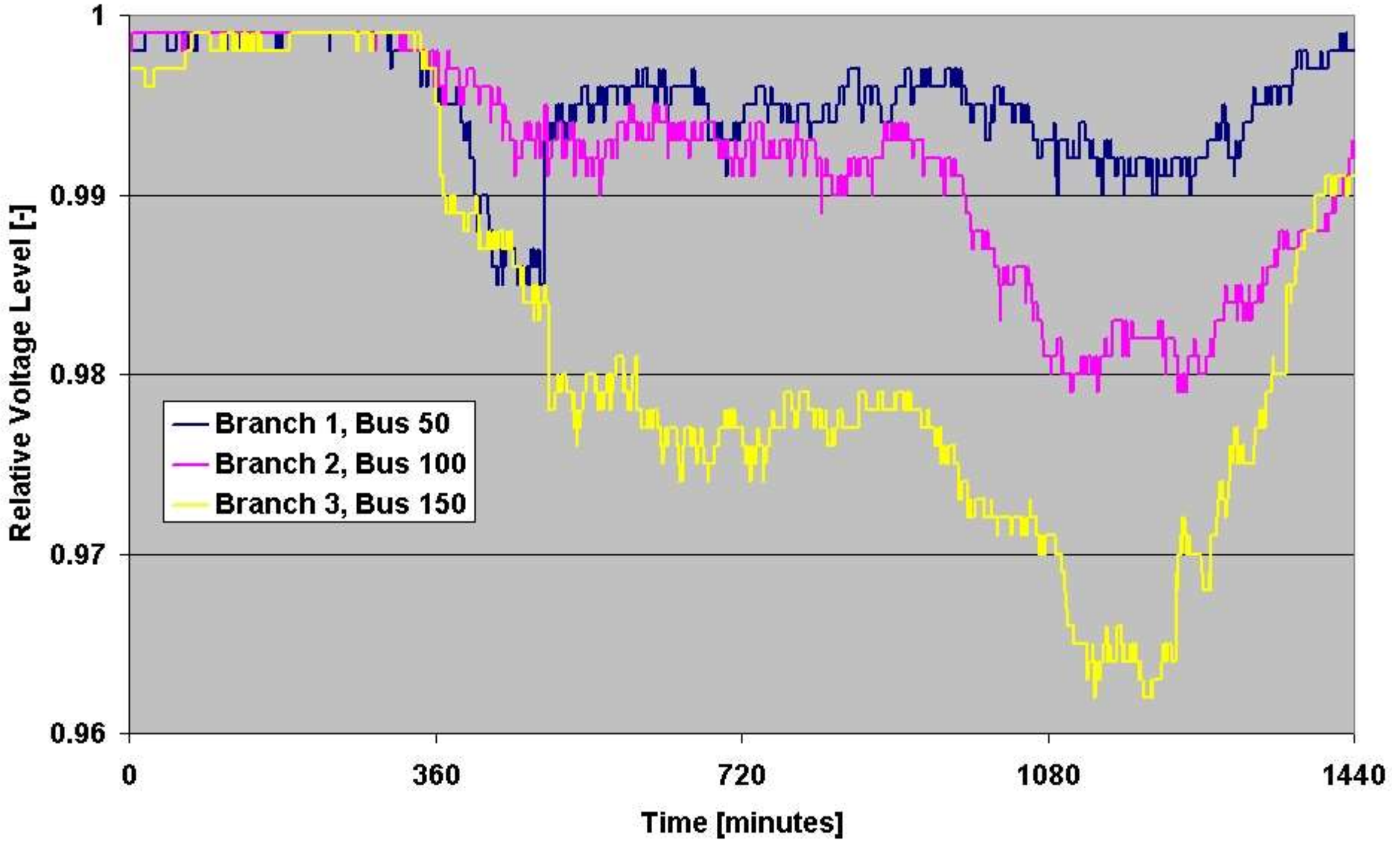
The reference grid to be considered for the prototype for combined resLoadSIM and PFLOW simulations



Step 1, one way information flow

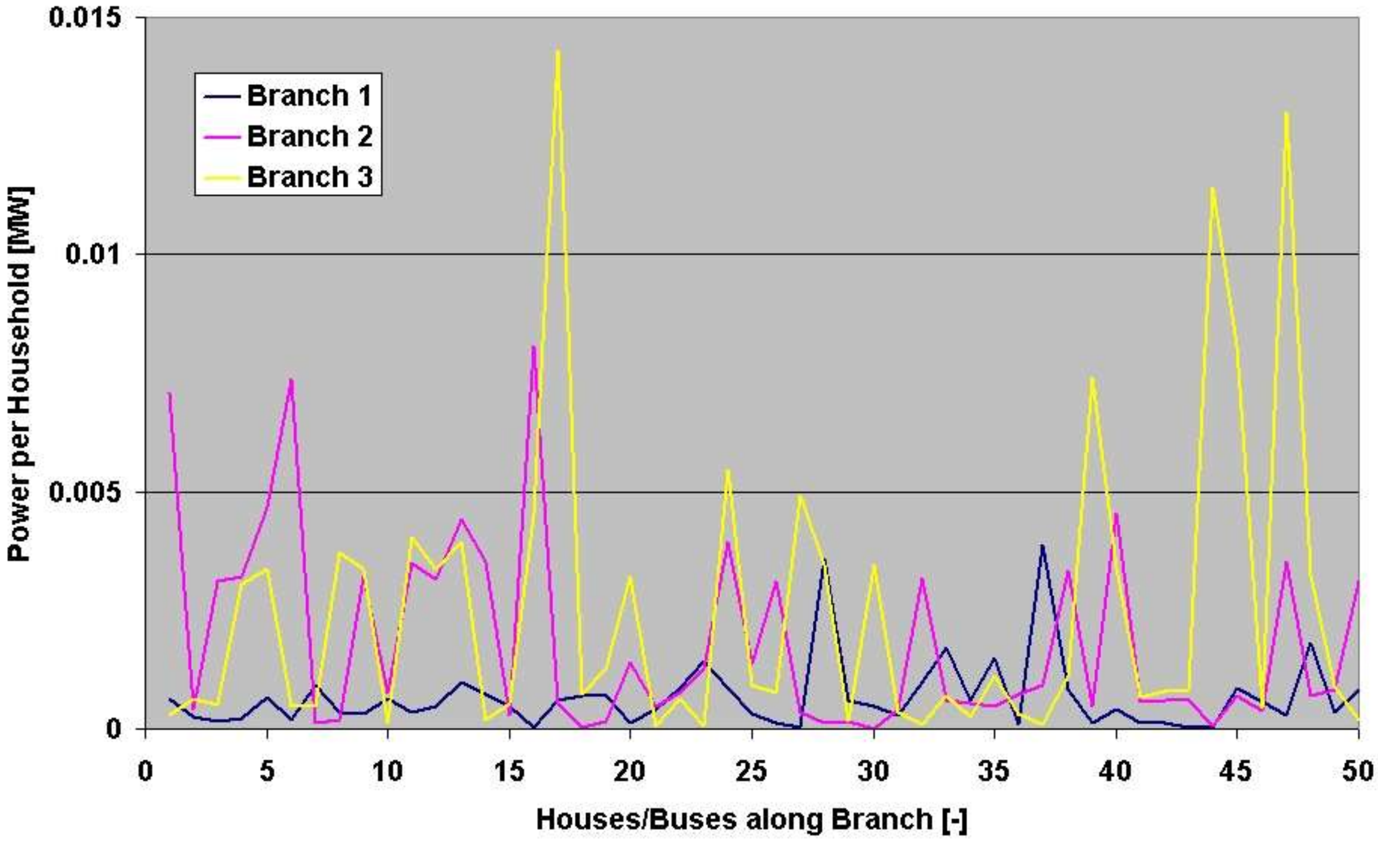
- 3 branches of each 50 households are simulated
- only loads are considered and provided to PYPower by resLoadSIM
- to increase load 15% of households have electric heating and 40% have E-Vehicles
- there is no feedback from PYPower to resLoadSIM (one-way coupling)

Relative Voltage Level



Voltage level of branch 3 drops considerably at the end of line

Loads along the branches at 1220 minutes

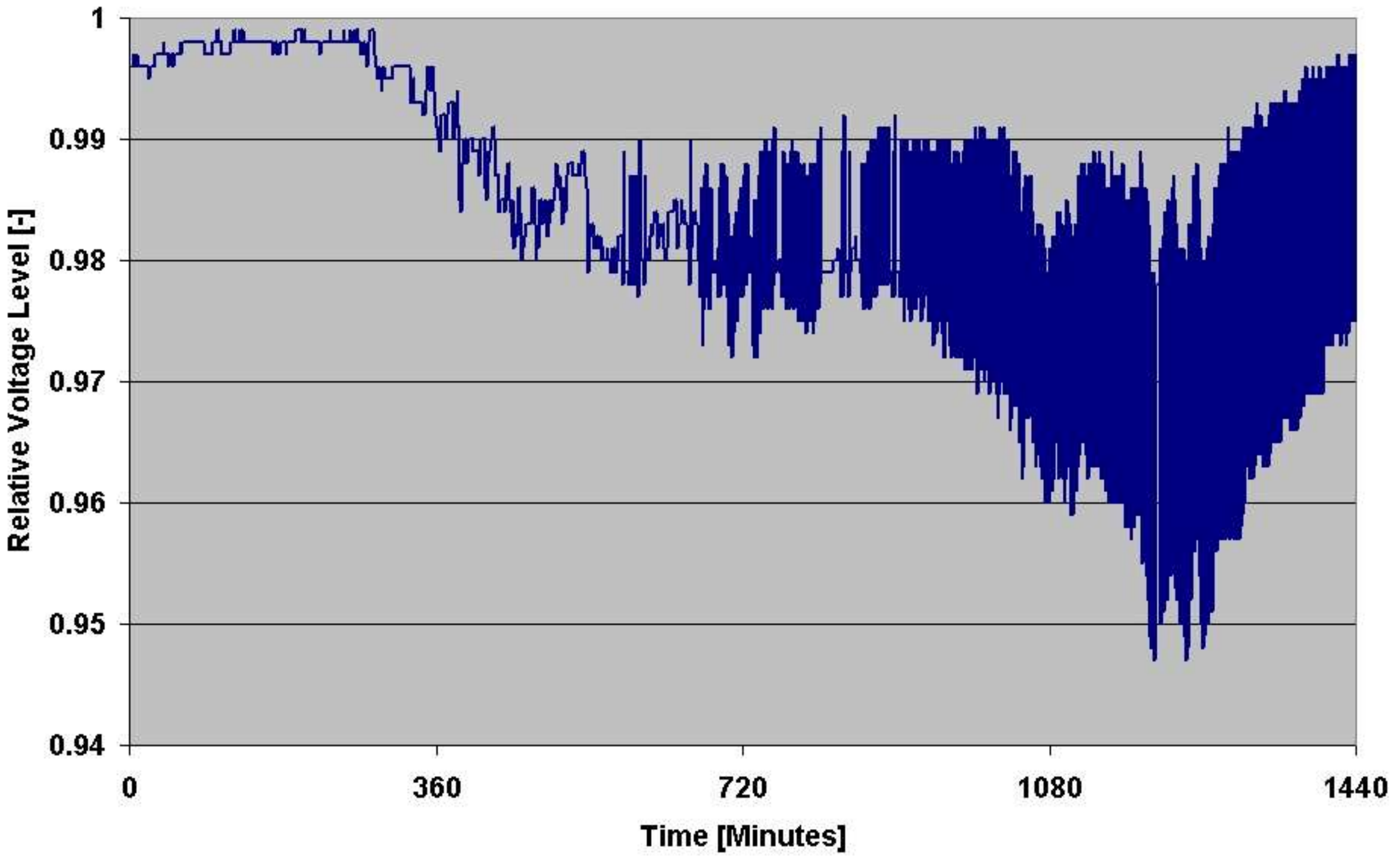


Power level of branch 3 is considerable higher compared to branch 1 and 2

Step 3, two way information flow and heavy loads are reconnected (case 12)

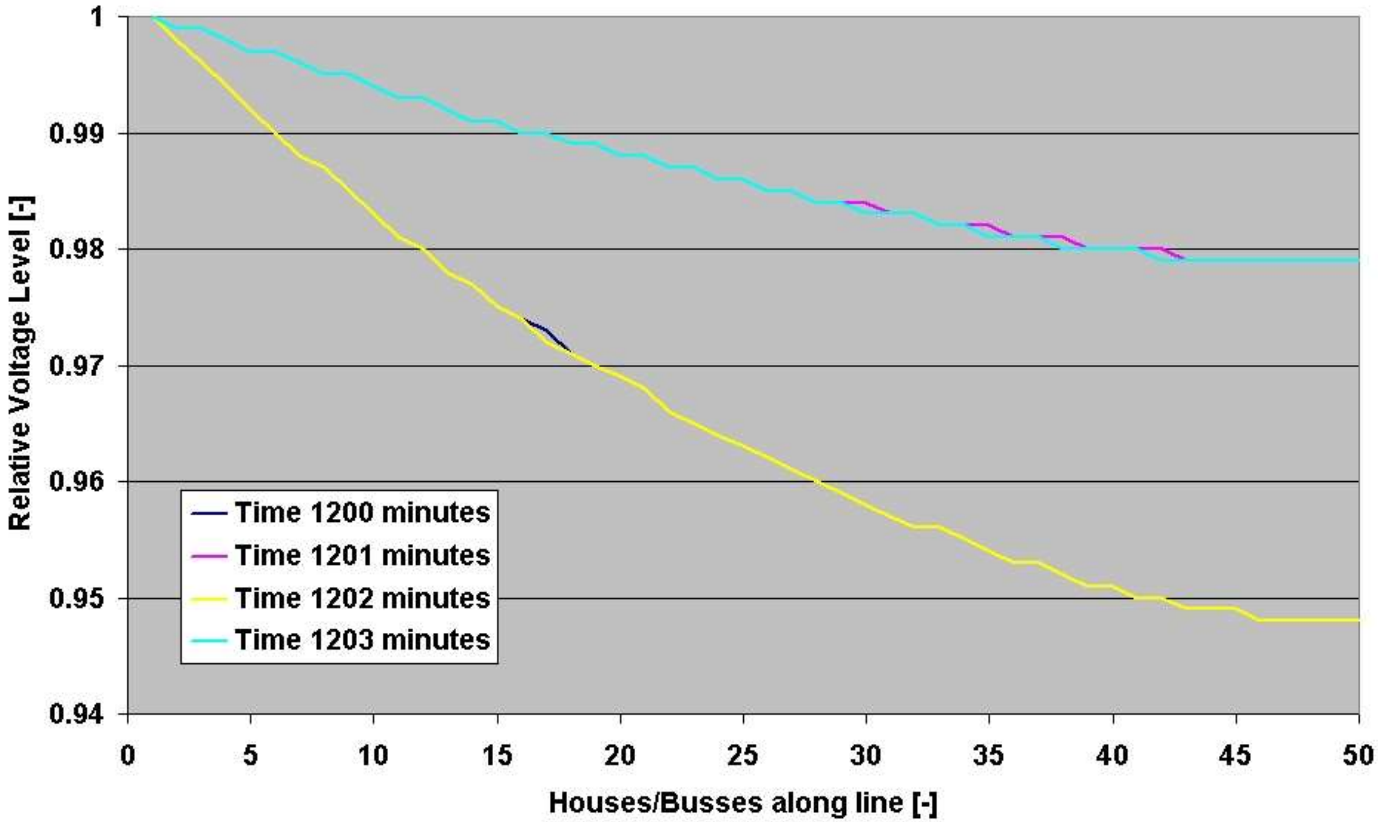
- 1 branch of 50 households are simulated
- only loads are considered and provided to PYPower by resLoadSIM
- to increase load 15% of households have electric heating and 40% have E-Vehicles
- in case of an under-potential (<225 V), electric heating and E-Vehicles charging is dropped
- electric heating and E-Vehicles charging is reinitiated, as soon as voltage levels are acceptable again

Relative voltage level at the end of the line



Voltage level drops below threshold and increases afterwards, but drops again below threshold

Relative voltage level along the line



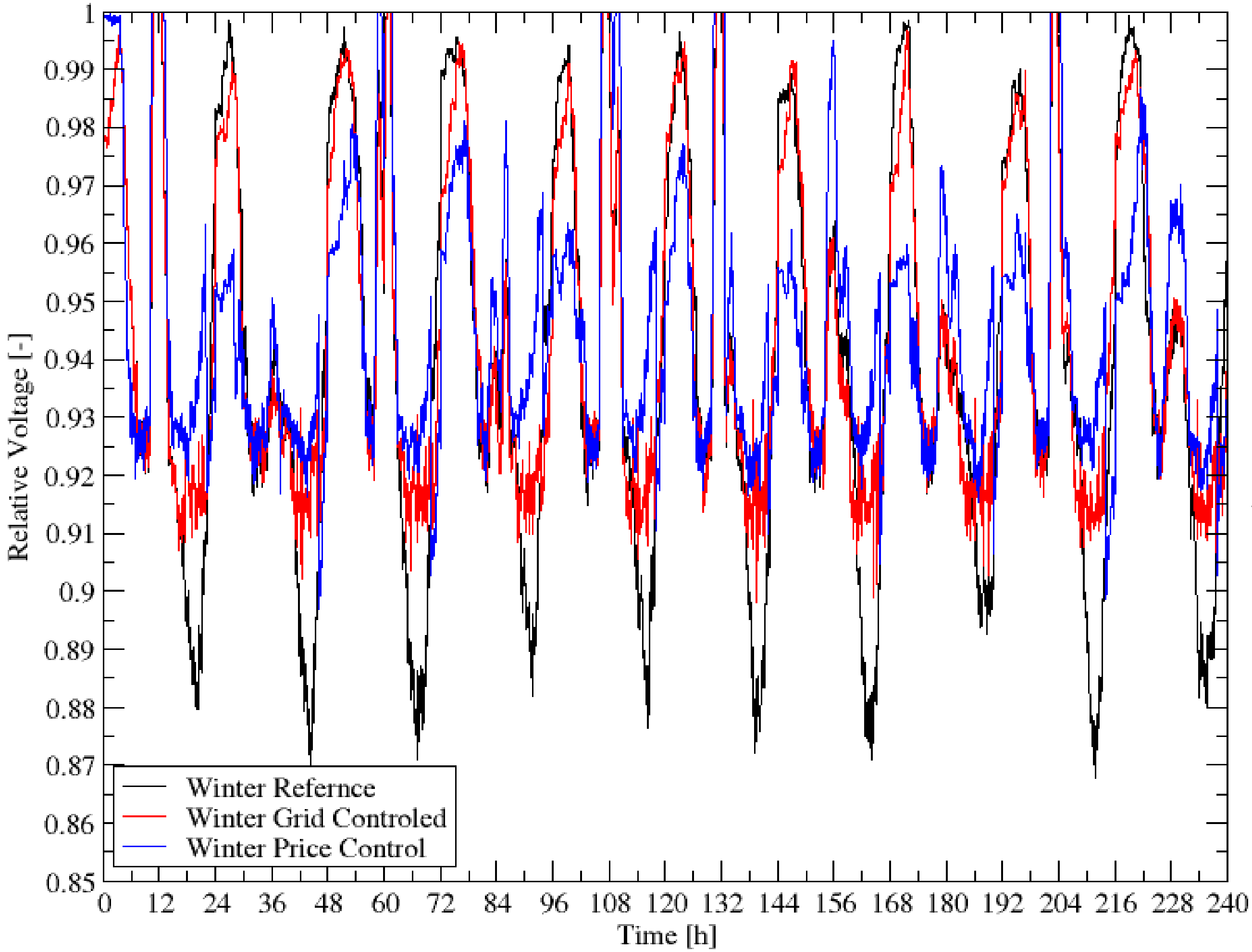
Voltage level increase immediately (next time-step), after heavy loads are dropped, but decrease again immediately as heavy loads are reconnected again, which is a hysteresis effect

European Commission

Step 4, two way information flow and heavy loads are dispatched in a smart way

- 3 branch of 50 households are simulated
- loads and photovoltaic generation is considered and provided to PFLOW by resLoadSIM
- to increase load 50% of households have electric heating and 50% have E-Vehicles
- 50% of households have solar panels with a production ratio of 1.5
- in case of congestion (-10 % of nominal voltage), E-Vehicles charging and heating is shifted in steps of 10%.
- electric heating and E-Vehicles charging is reinitiated, as soon as voltage levels are acceptable again (hysteresis):
  - UNDERVOLTAGE_LOWER_THRESHOLD 0.91
  - UNDERVOLTAGE_UPPER_THRESHOLD 0.925
  - OVERVOLTAGE_UPPER_THRESHOLD 1.09
  - OVERVOLTAGE_LOWER_THRESHOLD 1.075

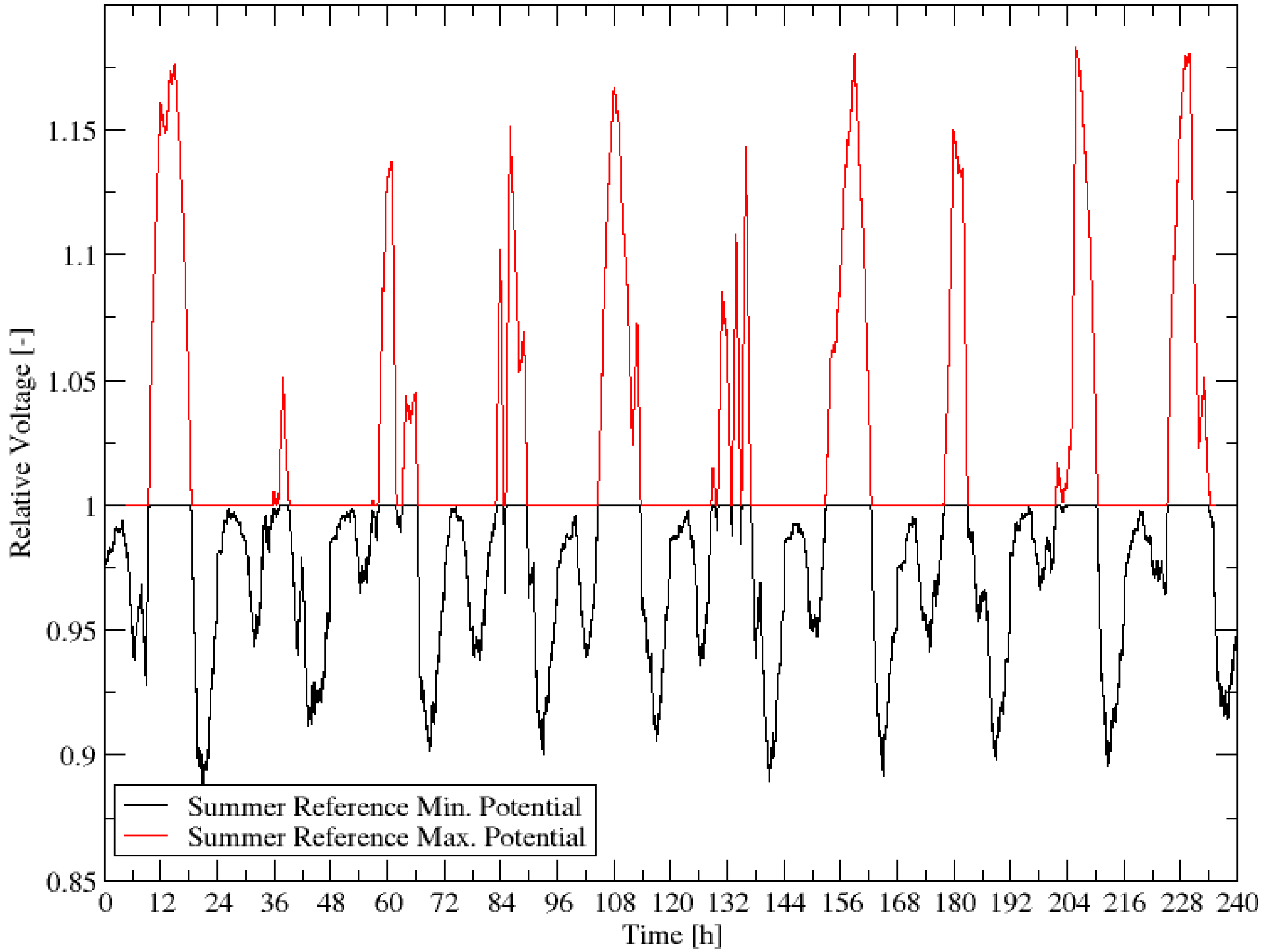
Relative voltage levels at the end of the line



In a typical Winter situation load control as well as price signals can reduce the load in such a way that severe under-voltage in the grid can be avoided.

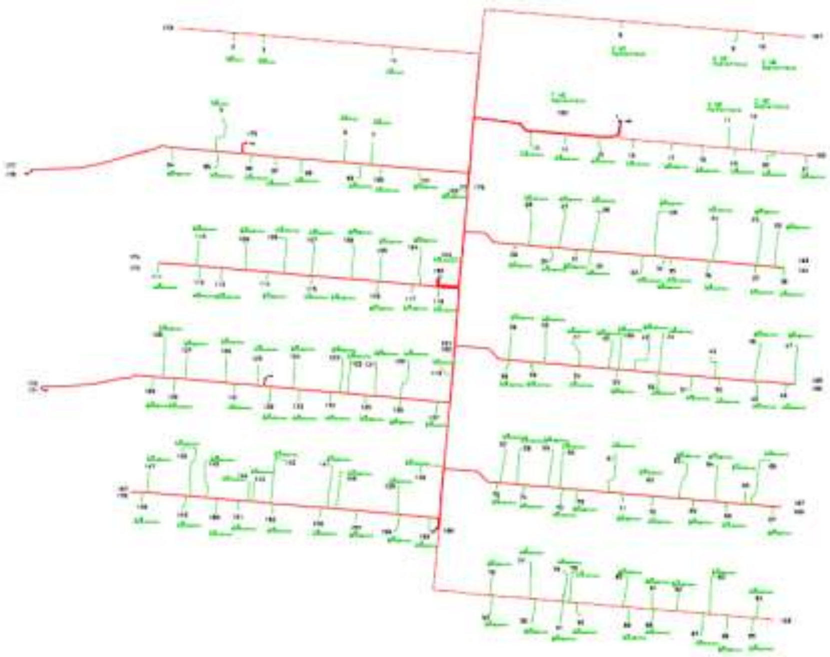
European Commission

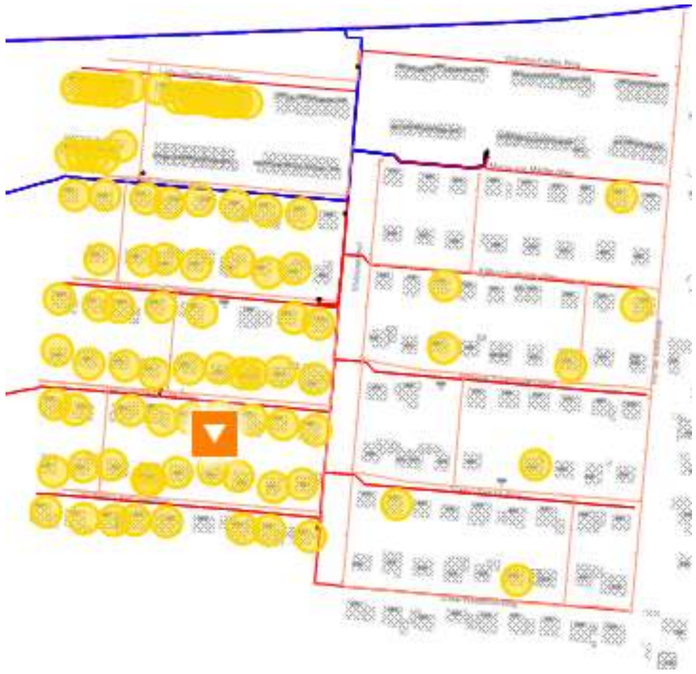
Relative voltage levels



In a typical summer situation load control (DMS) cannot increase the load in such a way that severe over-potentials due to photovoltaic feed in can be avoided. Storage is also only of little help, maybe with feed-in during night.

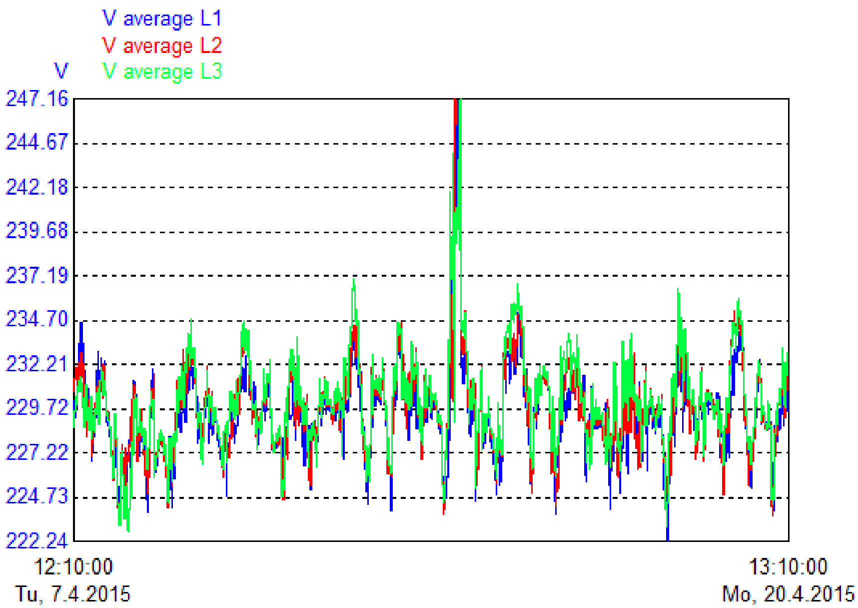
LV Distribution Grid Z-E Park

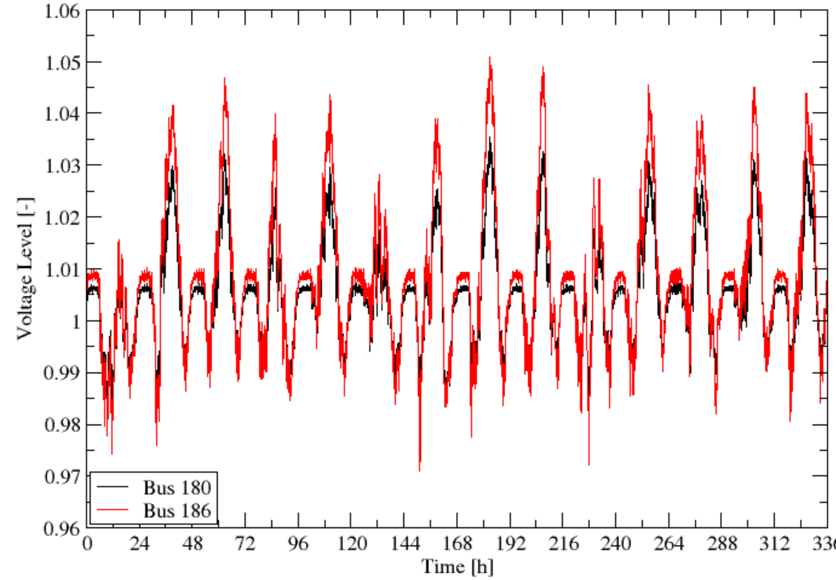




Details LV distribution grid (left) and yellow houses connected in 2015 others in 2016 (right)

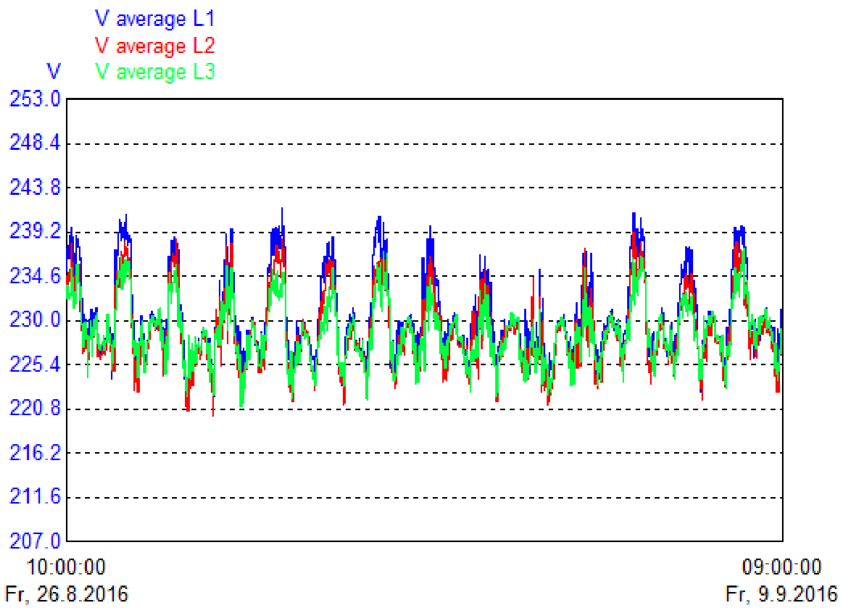
Voltage comparison Bus 186 in 2015

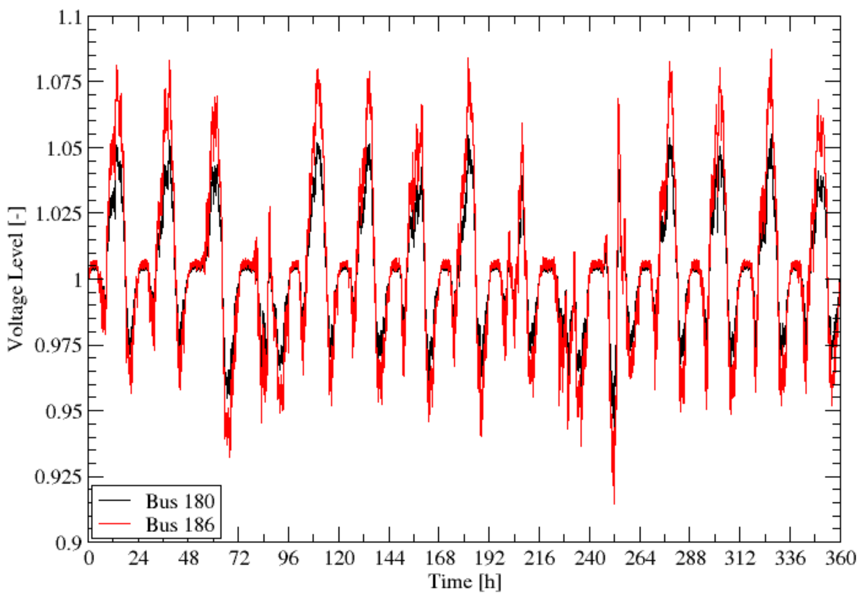




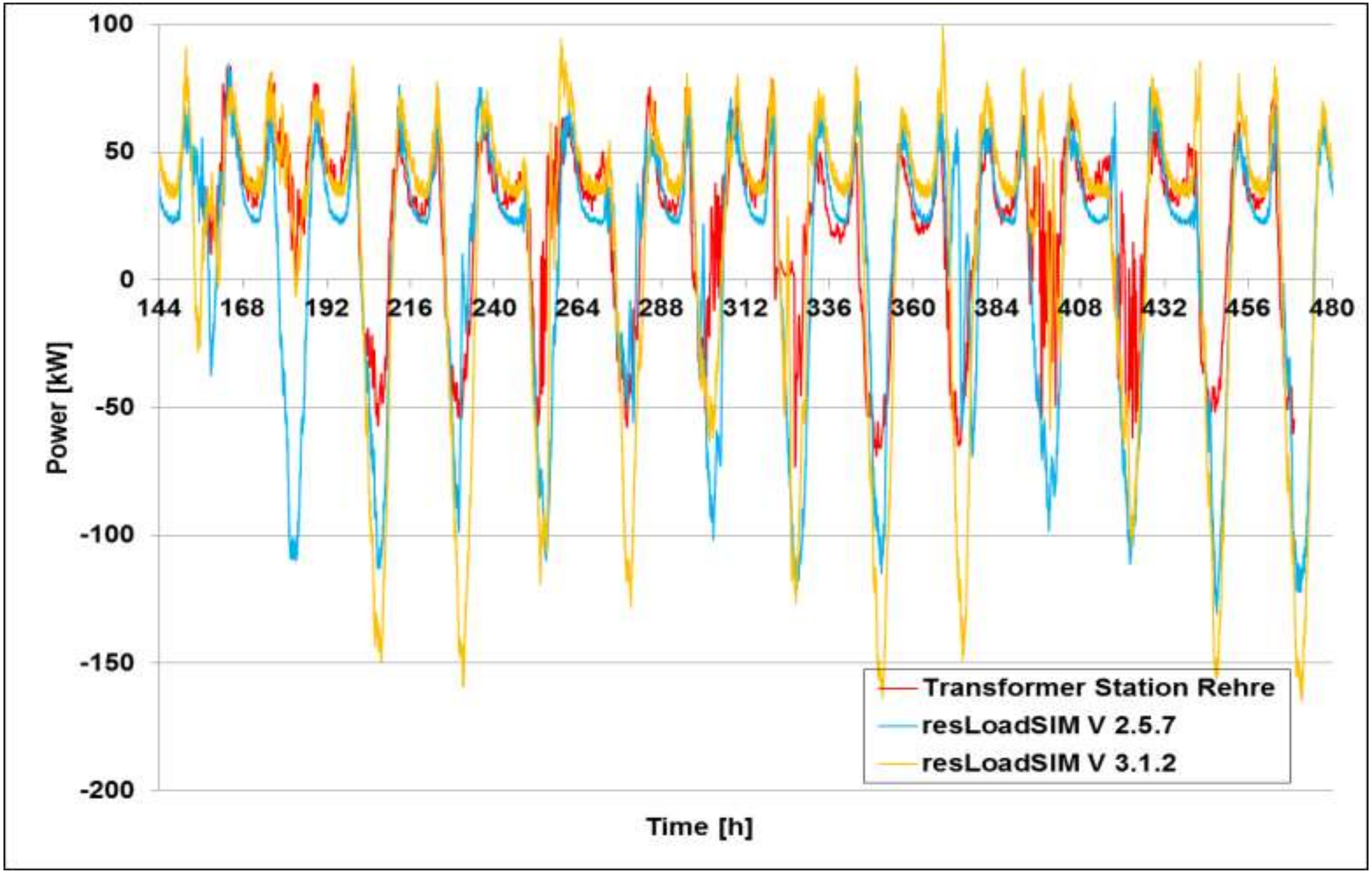
European Commission

Voltage comparison Bus 186 in 2016





Comparison resLoadSIM V 2.5.7 and 3.1.2



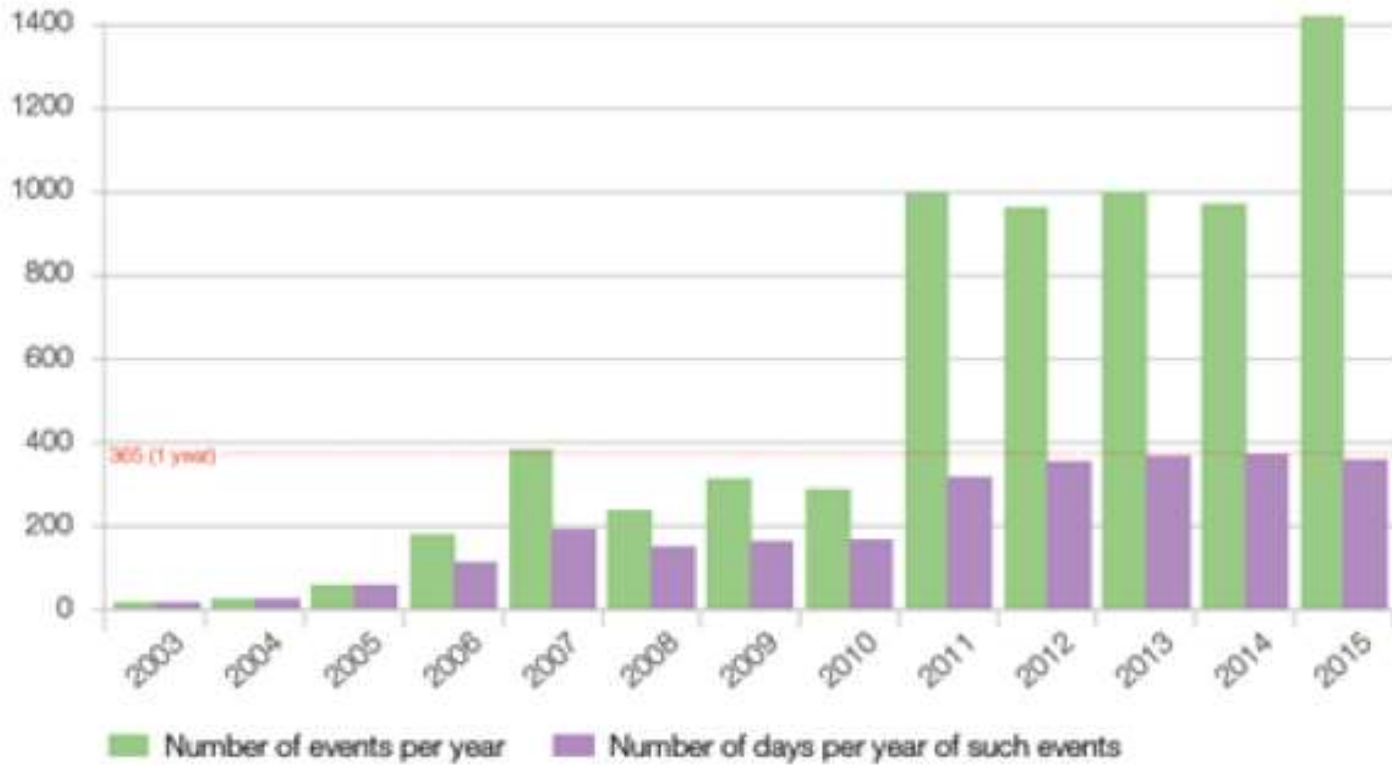
Conclusion 2: Combining resLoadSIM with PFLOW

When combining resLoadSIM with a distribution grid simulation tool we were able to identify situations, which in the future could lead to congestions. We were also able to demonstrate strategies, which would resolve these congestions such as demand side management (DSM) at residential scale.

Demand side management requires interoperability of all equipment involved.

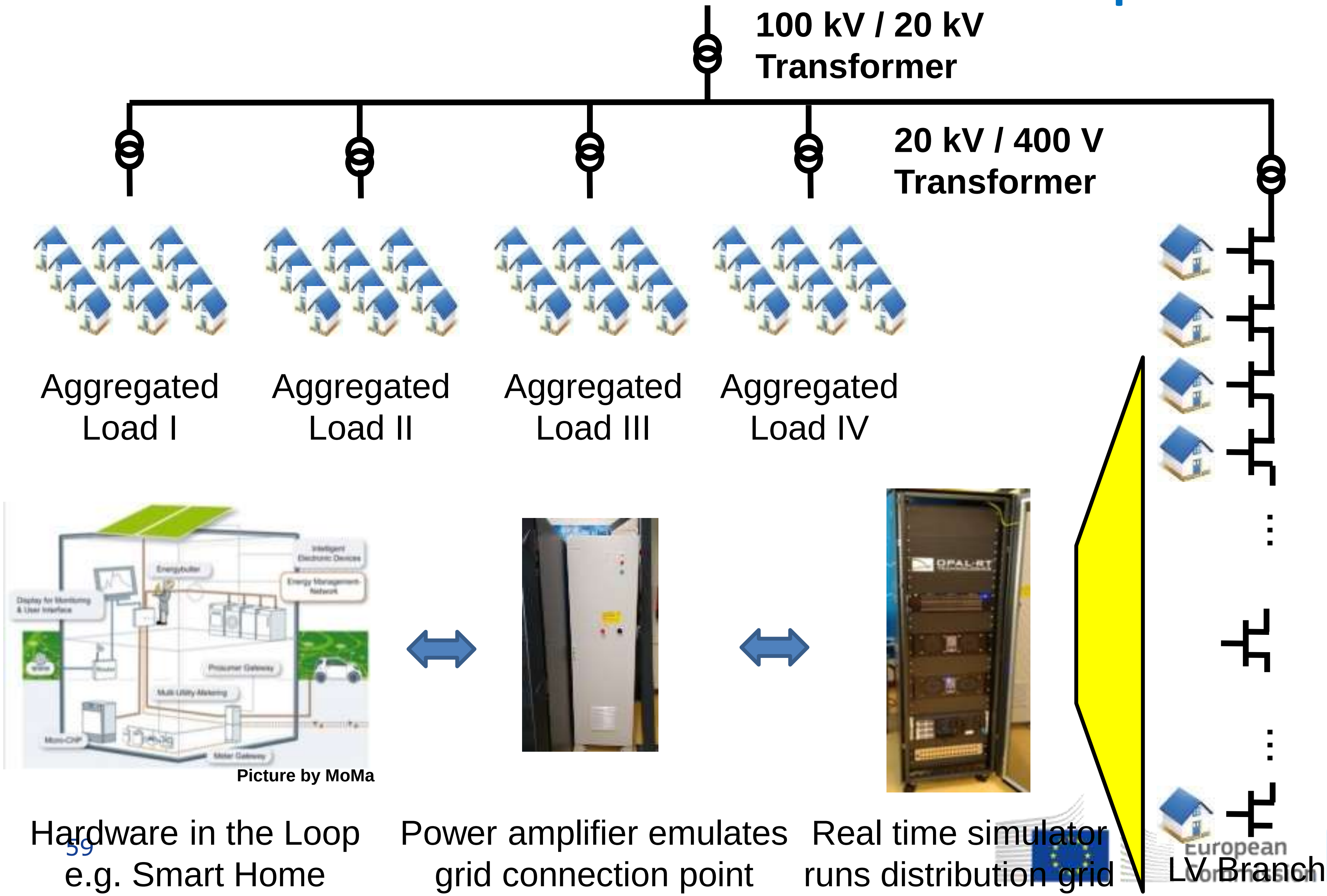
Redispatch at TenneT Germany

(within its own control area)

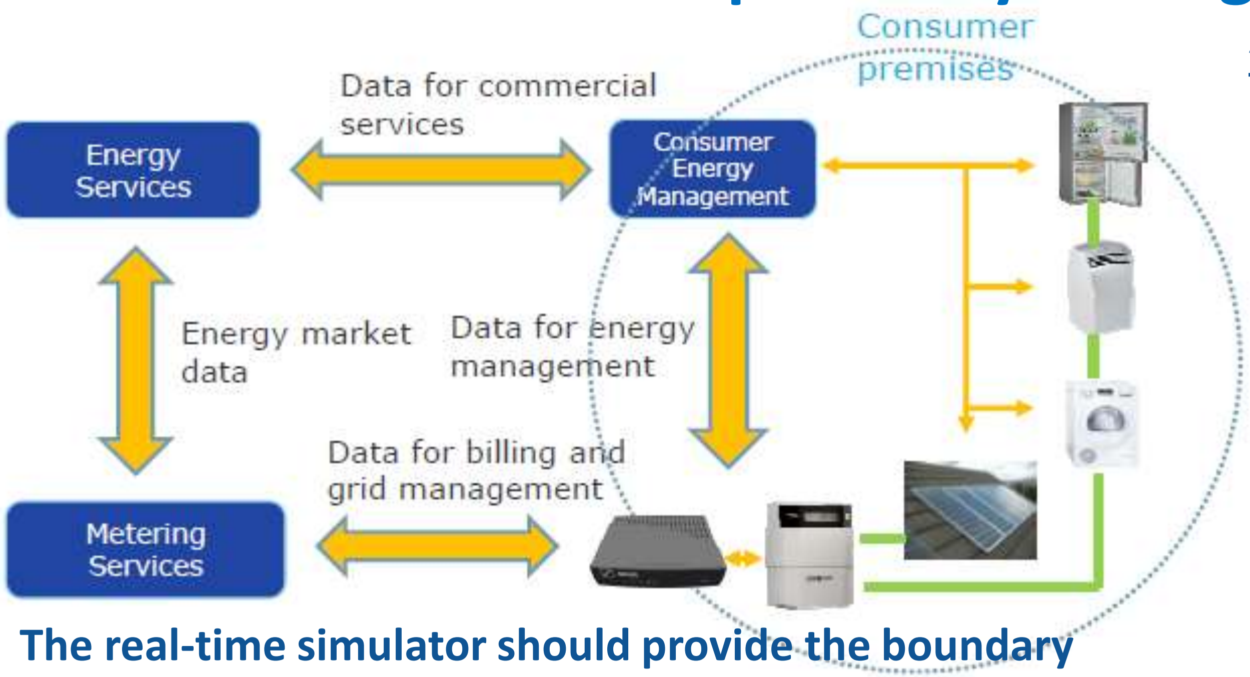


European Commission

The distribution grid to be considered in the real time simulation and the hardware in the loop



The real-time simulator as part of our Lab for interoperability testing



An example for the future: The Four interfaces of the DSF infrastructure, as indicated by Figure, starting from the left, upper side: (i) between Energy Services and Consumer Energy Management (CEM); (ii) between CEM and smart appliances, e.g., refrigerator, air conditioner, washing machine and solar panels; (iii) between smart meter (gateway) and CEM; and (iv) between smart meter (gateway) and in-home display

from Interoperability for Demand Side Flexibility (DNV-GL, TNO, ESMIG)

- **The real-time simulator should provide the boundary conditions within the smart-home interoperability testbed (hardware and controller in loop testing).**
- **In a first step a rather simple general model will be developed, that can be considered as basis for further developments with more specific application in the interoperability field e.g. demand side flexibility and/or real time pricing.**

"Things should be made as simple as possible, but not any simpler"
Albert Einstein

Unbalanced Load Flow Solver with PETSc

Delft University of Technology

- D.J.P. Lahaye (TU Delft)
- Jonathan A. Cedeño (TU Delft)
- Heinz Wilkening (JRC Petten)

European Commission
Joint Research Centre
Institute for Energy and Transport

TU Delft — Delft University of Technology

Distributed Power Flow Modelling

- D.J.P. Lahaye (TU Delft)
- Milos Cvetkovic (TU Delft)
- Silvia Vitiello (JRC Ispra)
- Stefano G. Rinaldo (JRC Ispra – PoliMi)
- Andrea Ceresoli (PoliMi)
- Heinz Wilkening (JRC Petten)

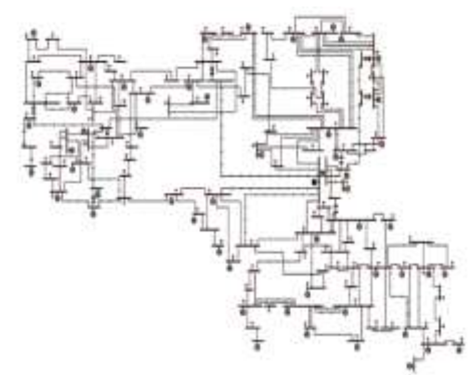
POLITECNICO MILANO 1863

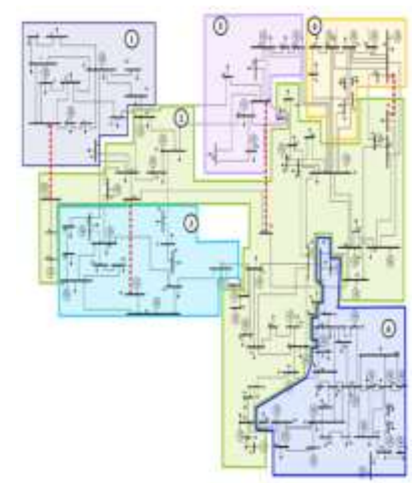
European Commission
Joint Research Centre
Institute for Energy and Transport

Distributed Power Flow in PETSc – Overview

How does it work Distributed PF?

- Split into n sub-networks and assign to different machines
- Compute solution on each sub-network by means of an
  iterative approach
- Solution at interface converges during computations
- Eventually same solution compared to classical global power flow approach





Why Distributed PF is interesting?

- Reasonable times for getting solution
- Interface flows within sub-networks are an output
- The parallel run can also be executed from different geographical locations
- Privacy of information, real-time coupled simulations

European Commission

Distributed Power Flow in PETSc – *Workflow of the code*

PETSc

- Portable, Extensible Toolkit for Scientific Computation
- Fast code executions in compiled languages: C, C++, Fortran
- Developed by Argonne National Laboratory
- Communications managed by MPI protocol

Input
- Read MATPOWER test case
- Current work: make a distributed import of data to achieve full privacy of information

Create the Network
- DMNetwork routines create the network object in PETSc

Distribute the Network
- Split the network respecting the ownership among different entities
- The user specifies the ownership of branches at input

Solve AC Problem
- Parallel solution provided by fast-converging iterative methods already implemented in PETSc
- Message Passing Interface (MPI) manages the exchange of information among machines

Print Distributed Output
- Voltage magnitude and phase angle
- Active and Reactive power over the branches
- Output printed only about the owned branches

Distribution Network Models (DiNeMo)

- Carlos Mateoa (IIT Comillas Madrid)
- Giuseppe Prettico (JRC Ispra)
- Tomás Gómez (IIT Comillas Madrid)
- Rafael Cossent (IIT Comillas Madrid)
- Flavia Gangale (JRC Ispra)
- Pablo Frías (IIT Comillas Madrid)
- Gianluca Fulli (JRC Ispra)

UNIVERSIDAD PONTIFICIA ICAI ICADE COMILLAS MADRID

European Commission
Joint Research Centre
Institute for Energy and Transport

European Commission

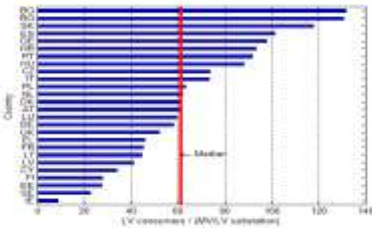
DiNeMo Core Module

USER INPUTS

Map from OpensStreetMap

Other Technical Data

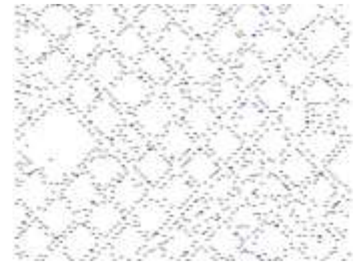
UT data (2014-2015)	instrument	BJD (2457000+)	R (K)	t_{exp} (s)	S/N
Dec 20	ESPaDOnS	11.8699	65	2800	170
Dec 21	ESPaDOnS	12.8692	65	2800	170
Dec 22	ESPaDOnS	13.9010	65	2800	180
Dec 28	ESPaDOnS	20.0190	65	2800	140
Dec 29	ESPaDOnS	20.0759	65	2800	180
Dec 30	ESPaDOnS	21.0154	65	2800	180
Jan 07	ESPaDOnS	29.8689	65	2800	170
Jan 08	ESPaDOnS	30.8817	65	2800	180
Jan 09	ESPaDOnS	31.8181	65	2800	170
Jan 10	ESPaDOnS	32.8186	65	2800	150
Jan 11	ESPaDOnS	33.8889	65	2800	180
Jan 12	ESPaDOnS	34.7815	65	2800	170
Jan 13	ESPaDOnS	35.7150	65	2800	180
Jan 14	ESPaDOnS	36.7141	65	2800	170
Jan 15	ESPaDOnS	37.8043	65	2800	170



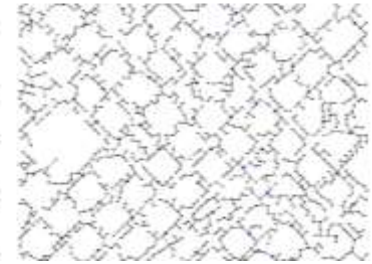
DSOs Observatory Data

Based on the **input data** provided by the user (map, population figures as density and peak demand and others if known) the module can provide the **representative distribution network models** built on the input data. Several files are given as output: **GIS shapefiles**, **matpower scripts**, **excel files** and many more

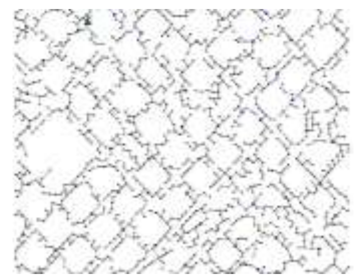
Consumers identification



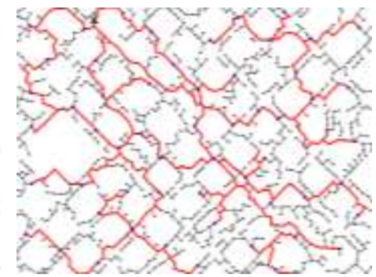
LV calculation/connection

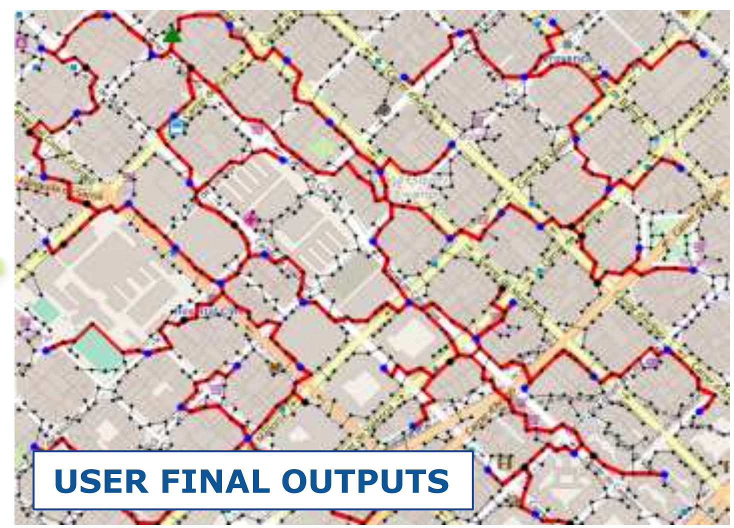


MV calculation/connection



HV/MV connection





USER FINAL OUTPUTS

Thank You

Stay in touch

E-Mail: ***Heinz.Wilkening@ec.europa.eu***

SESI webpage: ***https://ses.jrc.ec.europa.eu***

EU Science Hub: ***ec.europa.eu/jrc***

Twitter: ***@EU_ScienceHub***

Facebook: ***EU Science Hub - Joint Research Centre***

LinkedIn: ***Joint Research Centre***

YouTube: ***EU Science Hub***

European Commission