Energy Management Systems for Italy and Austria

Andrea Monacchi, Dominik Egarter, Tamer Khatib, Wilfried Elmenreich

ALPEN-ADRIA UNIVERSITÄT
KLAGENFURT | WIEN GRAZ

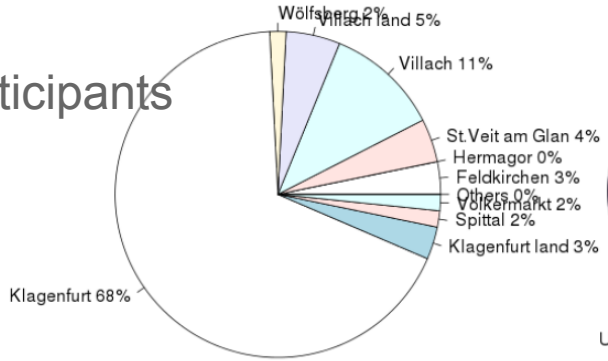
Lakeside Labs
SELF-ORGANIZING NETWORKED SYSTEMS

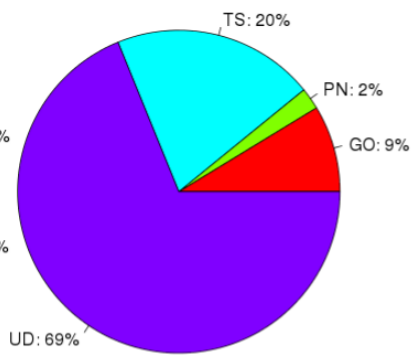
Motivation

- Recent years
  - Energy transition towards sustainable supply
  - Massive installation of RE & electrical loads (e.g. vehicles)
- Demand response & HEMS
  - Monitoring and rationalization of local energy
  - User in the loop VS autonomous operation
- Management strategies should consider regional differences
  - Consumption scenarios (area specific)
  - Consumption behavior (user specific)

Web based survey study

- Targeted to residents of CAR and FVG older than 18
- 43 questions grouped in 5 sections
  - Household information
  - Use of electrical devices
  - Sensitivity towards consumption and renewable energy
  - Sensitivity towards technology
  - Demographic information
- 340 full responses out of 397 participants
  - CAR: 186 (96F, 90M)
  - FVG: 139 (63F, 76M)





Consumption scenarios

- Smart metering available in FVG
  - Higher feedback resolution
  - Time-of-use tariffs promote device shifting
- Greater amount of greedy electrical devices in CAR
  - Water and space heating, cooking
- More developed gas network in FVG
- Low exploitation of renewable energy, mostly PV, higher in FVG
- Still scarce knowledge of home automation systems
- Willingness to exploit dynamic pricing and interfaces high in both regions

A. Monacchi, W. Elmenreich, S. D'Alessandro, A. M. Tonello. Strategies for Domestic Energy Conservation in Carinthia and Friuli-Venezia Giulia. In Proceedings of the 39th Annual Conference of the IEEE Industrial Electronics Society (IECON), Vienna, Austria, 2013.

T. Khatib, A. Monacchi, W. Elmenreich, D. Egarter, S. D'Alessandro, A. M. Tonello. European end-user's level of energy consumption and attitude toward smart homes: A case study of residential sectors in Austria and Italy. Energy Technology & Policy, Taylor & Francis. 2014.

GREEND = GREEND Electrical ENergy Dataset

Consumption behavior

- GREEND dataset
  - P @ 1Hz in 8 selected households in AT and IT for 1 year

A. Monacchi, D. Egarter, W. Elmenreich, S. D'Alessandro, and A.M. Tonello. GREEND: an energy consumption dataset of households in Italy and Austria. in *Proc. of IEEE Int. Conf. on Smart Grid Communications (SmartGridComm)*, Venice, Italy, Nov 2014.

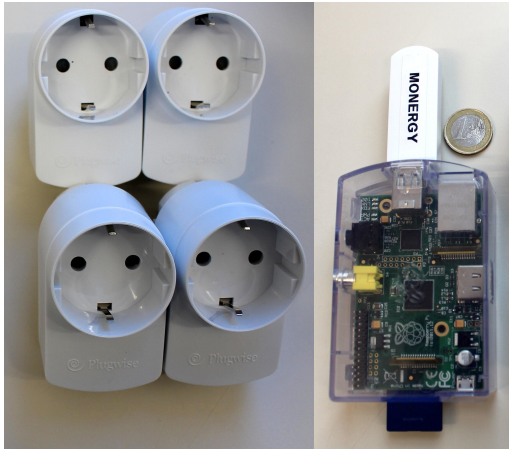
- Features:
  - minimal requirements given by NILM

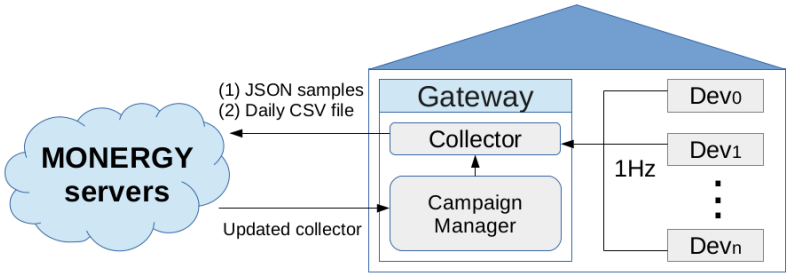
Zeifman, M. Disaggregation of home energy display data using probabilistic approach. *IEEE Transactions on Consumer Electronics*, vol.58, no.1, pp.23-31, February 2012.

- Scenario selection:
  - greedy common devices (survey study in CAR & FVG)
  - aim at diversity in dwelling and residents characteristics

The measurement platform

1. Plugwise smart plugs
2. ARM-based gateway
3. Gateway dæmon
   - Periodic remote update
   - Best-effort round-robin collection
   - 4 storage modalities





Codebase freely available at: http://sourceforge.net/projects/monergy/

Energy consumption datasets

- Few households, very short campaign, very high resolution
  - ➢ Interesting for load disaggregation community
- Few households, long-term campaign, very low resolution
  - ➢ necessary for energy consumption modeling & forecast
- Many households, medium length, low resolution
  - ➢ Necessary for statistical significance
- Many devices, no household association, low duration & resolution
  - ➢ Source of device power profiles to extract signatures

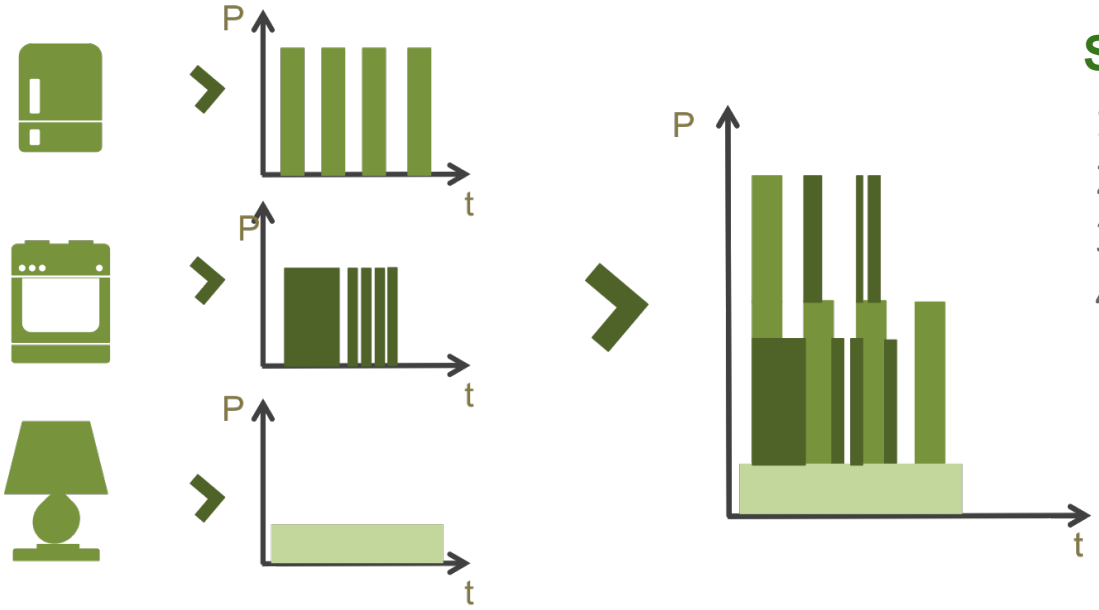
Dataset	Location	Duration	Houses	Sensors	Features	Resolution
BLUED	Pennsylvania	8 days	1	Agg.	I, V, switch events	12 KHz
REDD	Boston	3-19 days	6	9-24	V + Q (Agg), P (Sub)	15 KHz
UK-DALE	UK	499 days	4	5 - 53 (house 1)	P (Agg), P (Sub)	16 KHz, 6 KHz
AMPds	Vancouver	1 year	1	19	I, V, pf, f, P, Q, S	1 min
iHEPCDS	France	4 years	1	3 circuits	I, V, P, Q	1 min
HES	UK	1 month	251	13-51	P	2 min
OCTES	FI, IS, Scot.	4-13 months	33	Agg.	P, energy price	7 secs
ACS-F1	Switzerland	1 hour session	N/A	100 (10 types)	I, V, Q, f,Φ	10 secs
Tracebase	Germany	N/A	N/A	158 (43 types)	P	1 - 10 secs
iAWE	India	73 days	1	33 (10 dev. level)	I, V, f, P, S, E, Φ	1 Hz
Sample	Texas	7 days	10	12	S	1 min
Smart*	Massachusetts	3 months	1 sub + 2 (sub & agg)	25 circuits, 29 device monitors	P + S (circuits), P (submetered)	1 Hz
GREEND	Austria, Italy	1 year	8	9	P	1 Hz

Deployments

House	Residents	Place	Deployment
0	retired couple (2 p)	Spittal / Drau (AT)	Coffee machine, washing machine, radio, water kettle, fridge w/ freezer, dishwasher, kitchen lamp, TV, vacuum cleaner
1	young couple (2 p)	Klagenfurt (AT)	Fridge, dishwasher, microwave, water kettle, washing machine, radio w/ amplifier, drier, kitchenware (mixer and fruit juicer), bedside light
2	mature couple with adult son (3 p)	Spittal / Drau (AT)	TV, NAS, washing machine, drier, dishwasher, notebook, kitchenware, coffee machine, bread machine
3	mature couple with 2 young kids (4 p)	Klagenfurt (AT)	Entrance outlet, Dishwasher, water kettle, fridge w/o freezer, washing machine, hair drier, computer, coffee machine, TV
4	young couple (2 p)	Udine (IT)	Total outlets, total lights, kitchen TV, living room TV, fridge w/ freezer, electric oven, computer w/ scanner and printer, washing machine, hood
5	mature couple with adult son (3 p)	Colloredo di Prato (IT)	Plasma TV, lamp, toaster, stove, iron, computer w/ scanner and printer, LCD TV, washing machine, fridge w/ freezer
6	mature couple with 2 young kids (4 p)	Udine (IT)	Total ground and first floor (including lights and outlets, with whitegoods, air conditioner and TV), total garden and shelter, total third floor.
7	retired couple (2 p)	Basiliano (IT)	TV w/ decoder, electric oven, dishwasher, hood, fridge w/ freezer, kitchen TV, ADSL modem, freezer, laptop w/ scanner and printer

Applications

Non-intrusive load monitoring

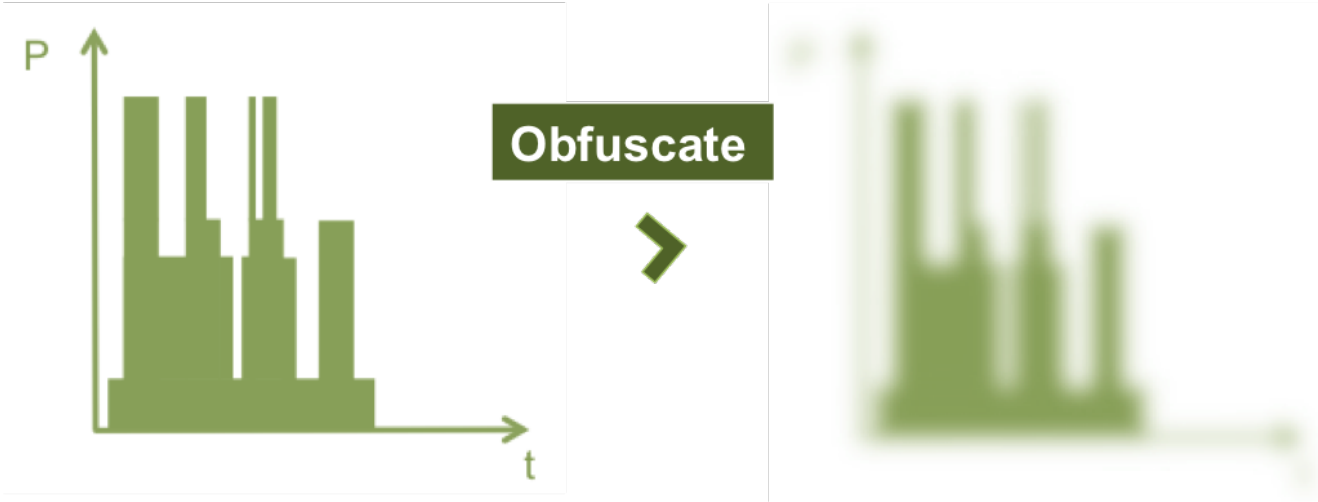


STEPS:

1. Preprocessing
2. Feature extraction
3. Appliance model creation
4. Appliance classification

D. Egarter, V. P. Bhuvana, and W. Elmenreich. PALDi: Online load disaggregation via particle filtering. IEEE Transactions on Instrumentation and Measurement. 2014. no.99, pp.1,1.

Load Based Load Hiding

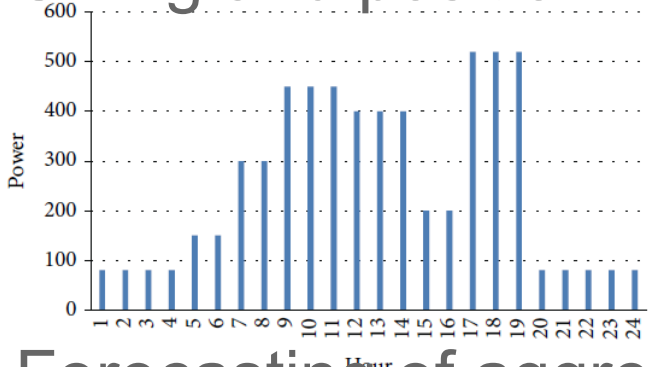


- Battery-load hiding (control of rechargeable batteries)
- Load-based load hiding (control of water boiler)

D. Egarter, C. Prokop and W. Elmenreich: Load Hiding of Households. In *Proc. of IEEE Int. Conf. on Smart Grid Communications (SmartGridComm)*, Venice, Italy, Nov 2014.

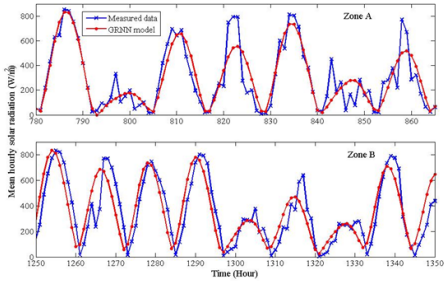
Design of smart microgrids

- Sizing and positioning of PV-based microgrids



T. Khatib and W. Elmenreich. Optimum availability of standalone photovoltaic power systems for remote housing electrification. *International Journal of Photoenergy*, 2014.

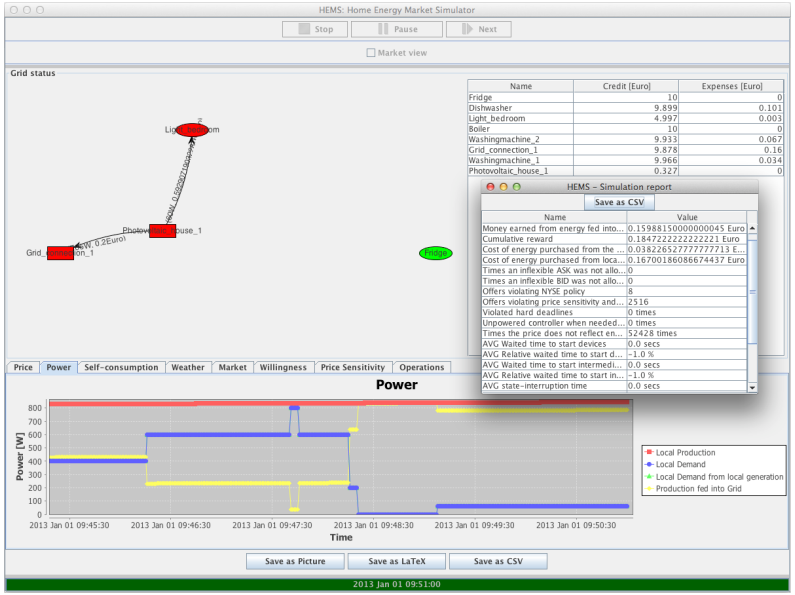
- Forecasting of aggregated demand and supply



T. Khatib and W. Elmenreich. An improved location dependent model for hourly solar irradiance data generation from daily solar irradiance data using generalized regression artificial neural network. Submitted to *Energy*, 2014.

Energy management

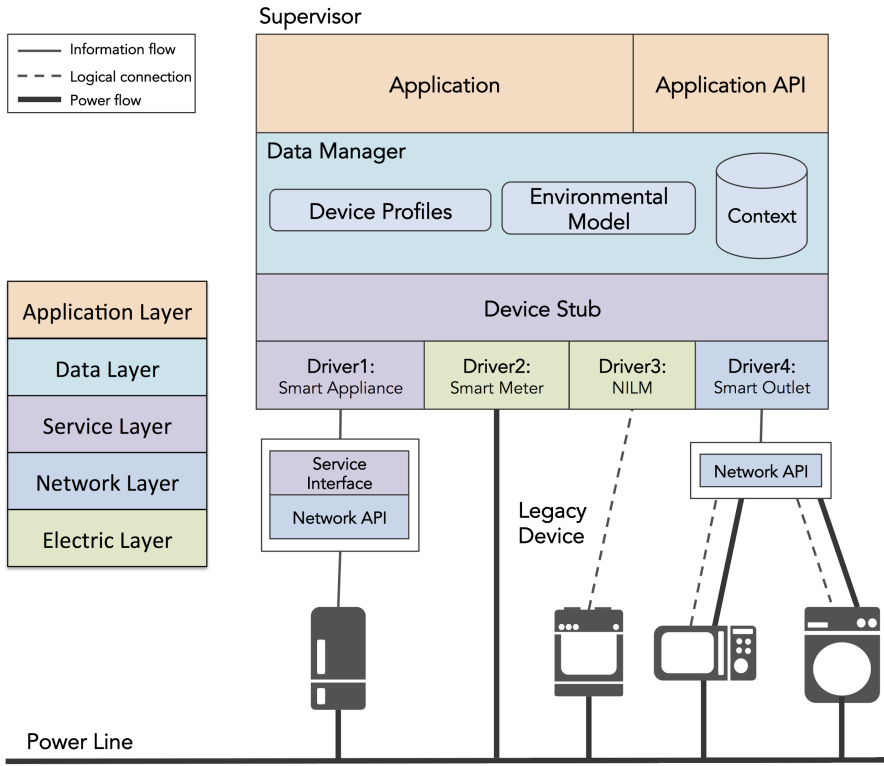
- Simulation of energy market
- Design of energy traders



A. Monacchi, S. Zhevzhyk. W.Elmenreich. HEMS: A Home Energy Market Simulator. Computer Science - Research and Development. Springer, 2014.

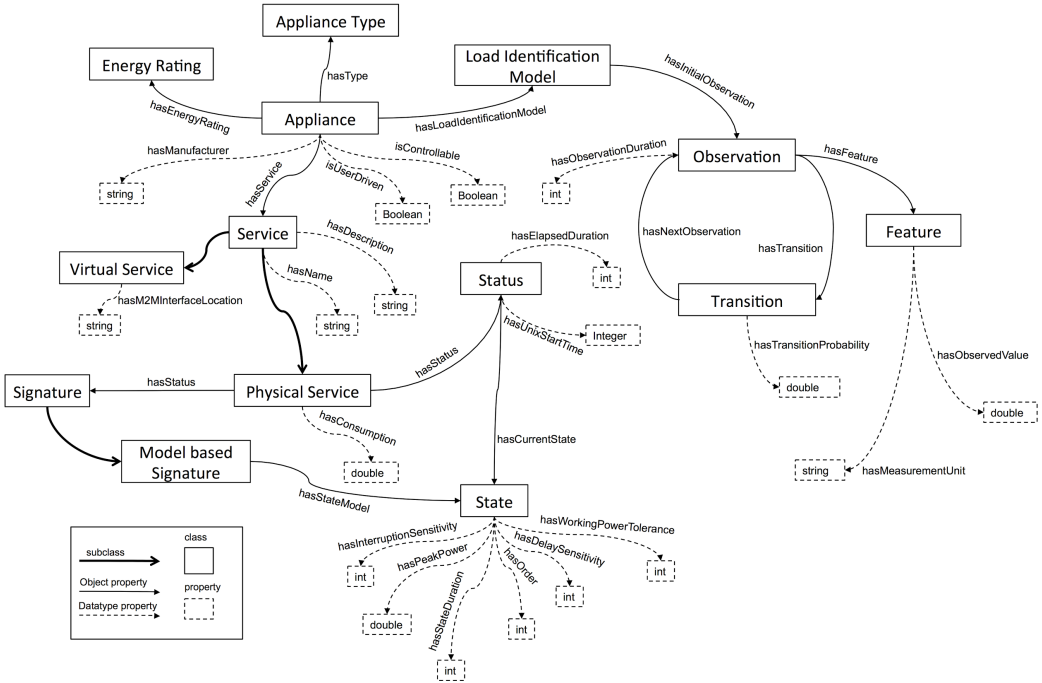
Interoperability in HEMS

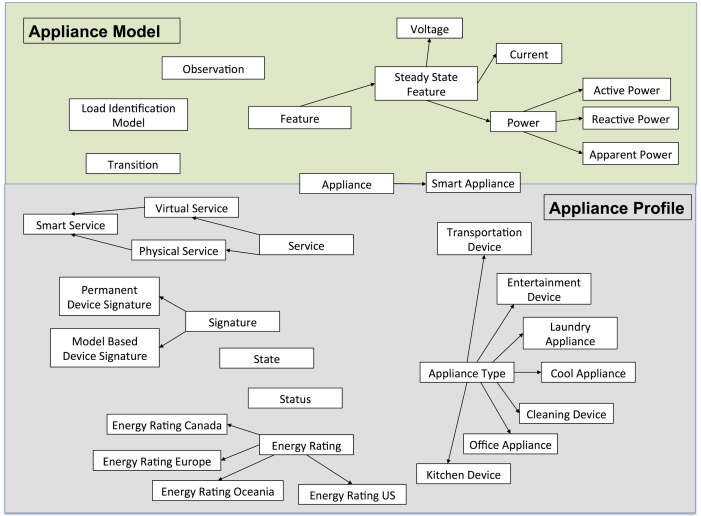
- Seamless integration of smart and legacy devices
- On line detection and annotation of devices
- Homogeneous data representation for applications



Interoperability in HEMS

- Ontology describing device operation



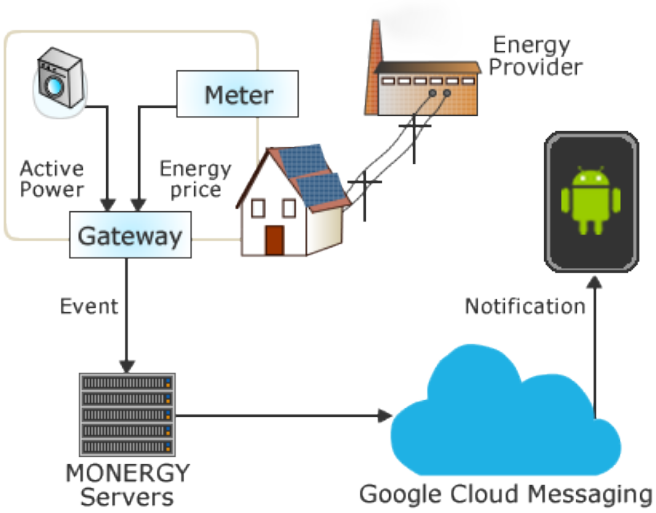


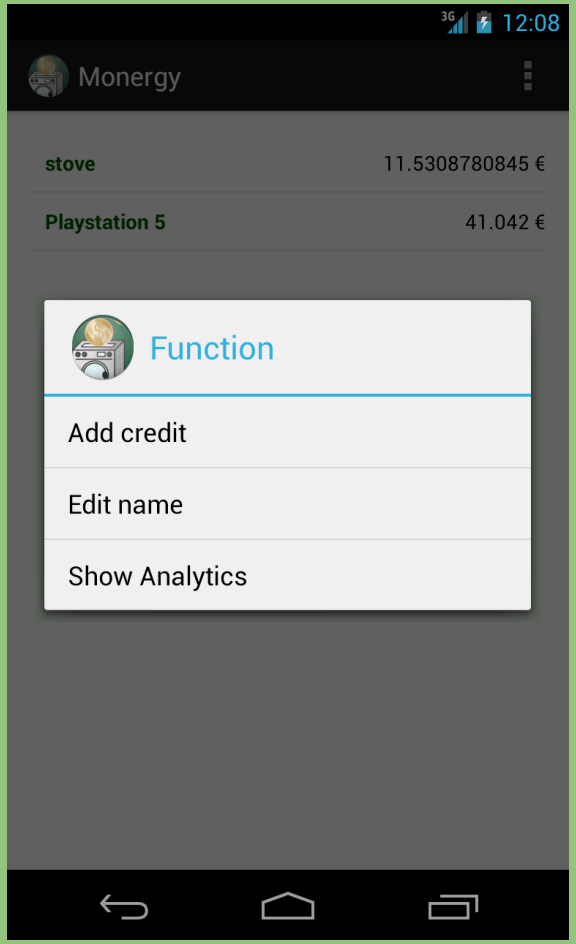
http://www.monergy-project.eu/ontologies/appliances.owl

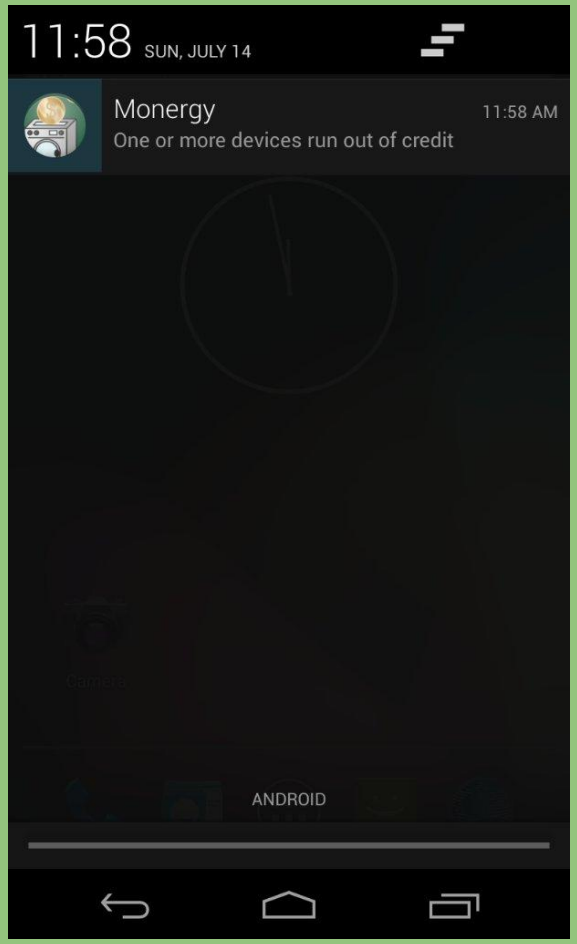
Demonstrators

Pay-as-you-go devices

- Prepaid billing (11%) + Appliance-level information (12%) = ?
- Classification of devices
  - Credit proportional to importance
- Classification of users
  - Appliance login to identify users
  - Hard vs Soft policy
  - Different privileges




12:08
Monergy
stove
11.5308780845 €
Playstation 5
41.042 €
Function
Add credit
Edit name
Show Analytics


11:58
SUN, JULY 14
Monergy
11:58 AM
One or more devices run out of credit
ANDROID

Mjölnir: the open source energy advisor

Mjölnir

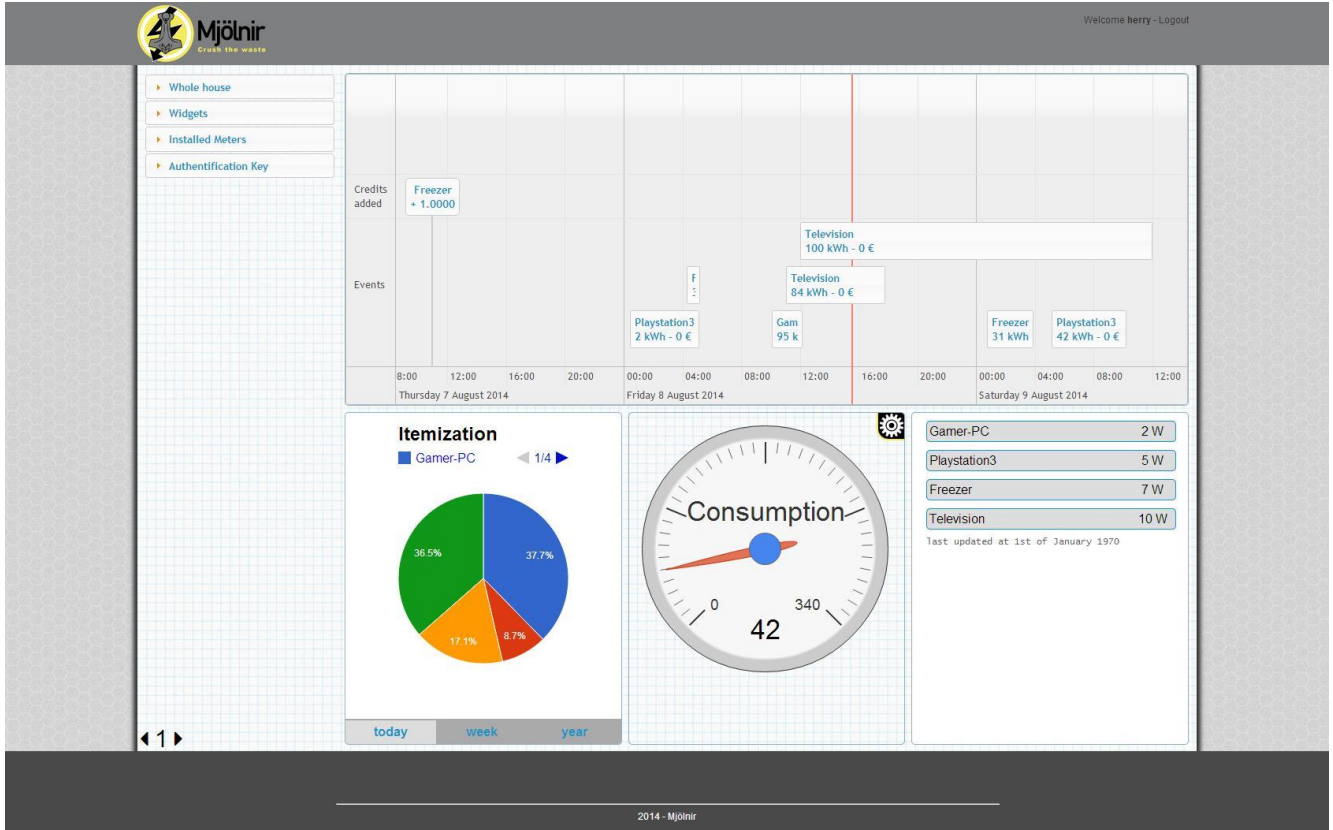
Crush the waste

- http://mjoelnir.sourceforge.net
- Compatible with:
  - MONERGY App
  - OpenEnergy Monitor, Plugwise kit

Versions:

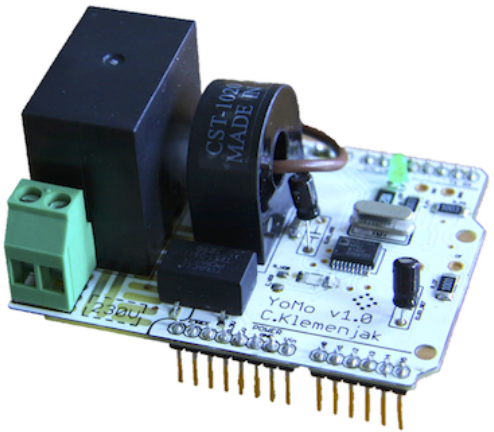
- **0.0.1** (alpha) July 31st 2014
- **0.1.1** (beta) February 1st 2015
- **0.2.0** Planned

Mjölnir: the open source energy advisor



YOMO smart meter

- Arduino shield for energy monitoring and control
- Open-source & open-hardware
  - No licence fees
  - Extendable
- Low cost
  - Overall parts 30 €
  - Production costs with assembly 90 €



C. Klemenjak, D. Egarter, and W. Elmenreich: YOMO - The Arduino based Smart Metering Board, in *Journal of Computer Science - Research and Development*. Springer. to appear.

Andrea Monacchi, Dominik Egarter,
Tamer Khatib, Wilfried Elmenreich

Smart Grid group
Institute of Networked and Embedded Systems
Alpen-Adria Universität Klagenfurt

Questions?