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Sensor Data Streams from Smart Metering

Alan Smeaton
CLARITY: Centre for Sensor Web Technologies and
School of Computing
Dublin City University

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CLARITY Overview

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UCD / DCU / TNI

130+ (PhD/PD) Researchers

Diverse Expertise

Health / Environment / Media

Strong Industry Focus

Award-Winning Research & Commercialization

Core Team

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Prof. Barry Smyth
CLARITY Director
RS4

Personalization, Recommender Systems, User Modeling

Prof. Alan Smeaton
Deputy Director
RS4

Information retrieval, multimedia Information, video retrieval,…

Dr. Donnacha O' Driscoll
Centre Manager

Prof. Dermot Diamond
RS1

Materials science, novel sensor Technologies, wearables.

Prof. Greg O' Hare
RS2

Middleware, agent oriented computing, mobile computing.

Prof. Noel O' Connor
RS3 Leader

Signal processing, audio/video processing, data analysis.

Dr. Brian Caulfield
RS2/Sports

Physiotherapy, Human motion, Body sensing technologies,…

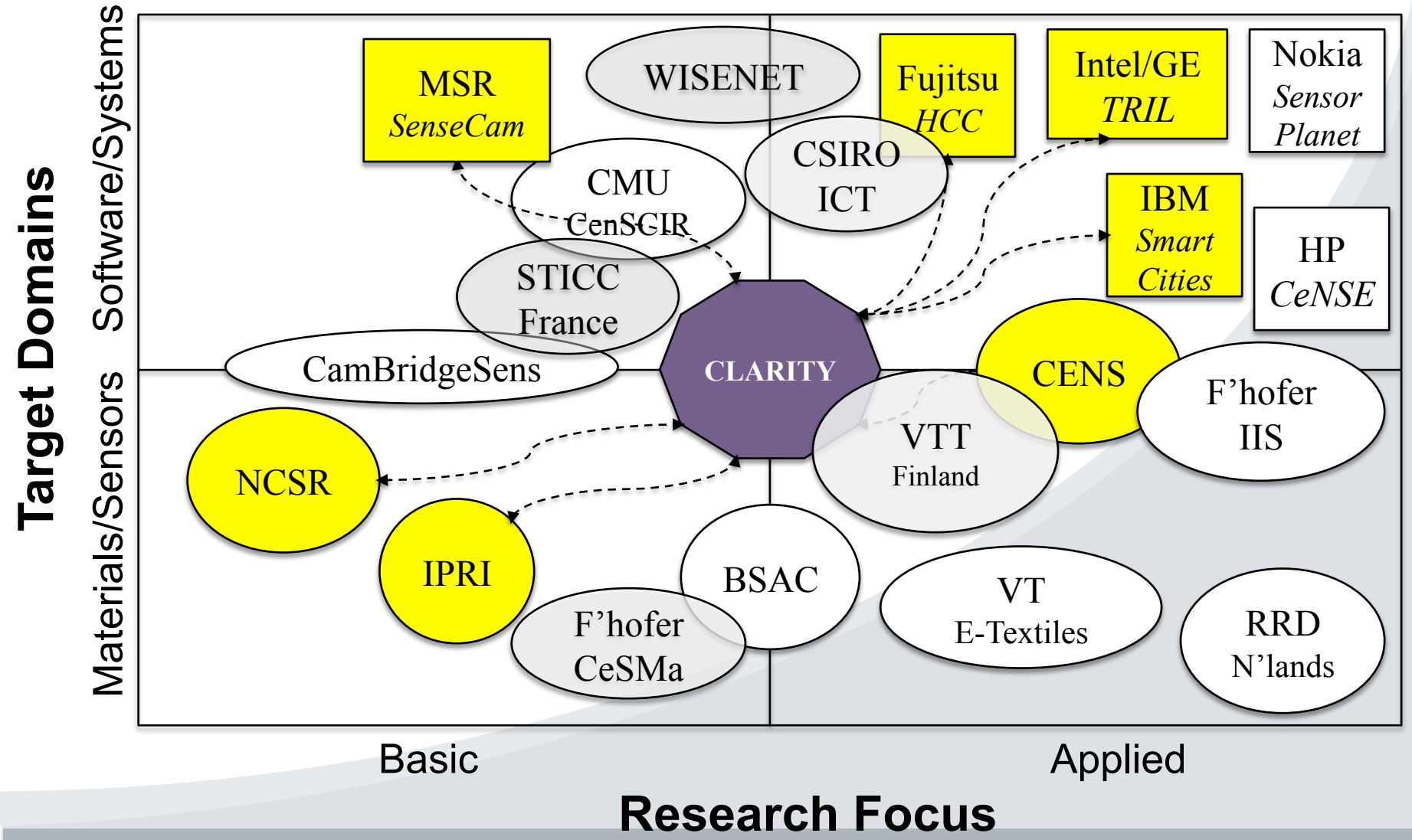
Prof. Niall Moyna
Sports

Sports science, human Performance, ….

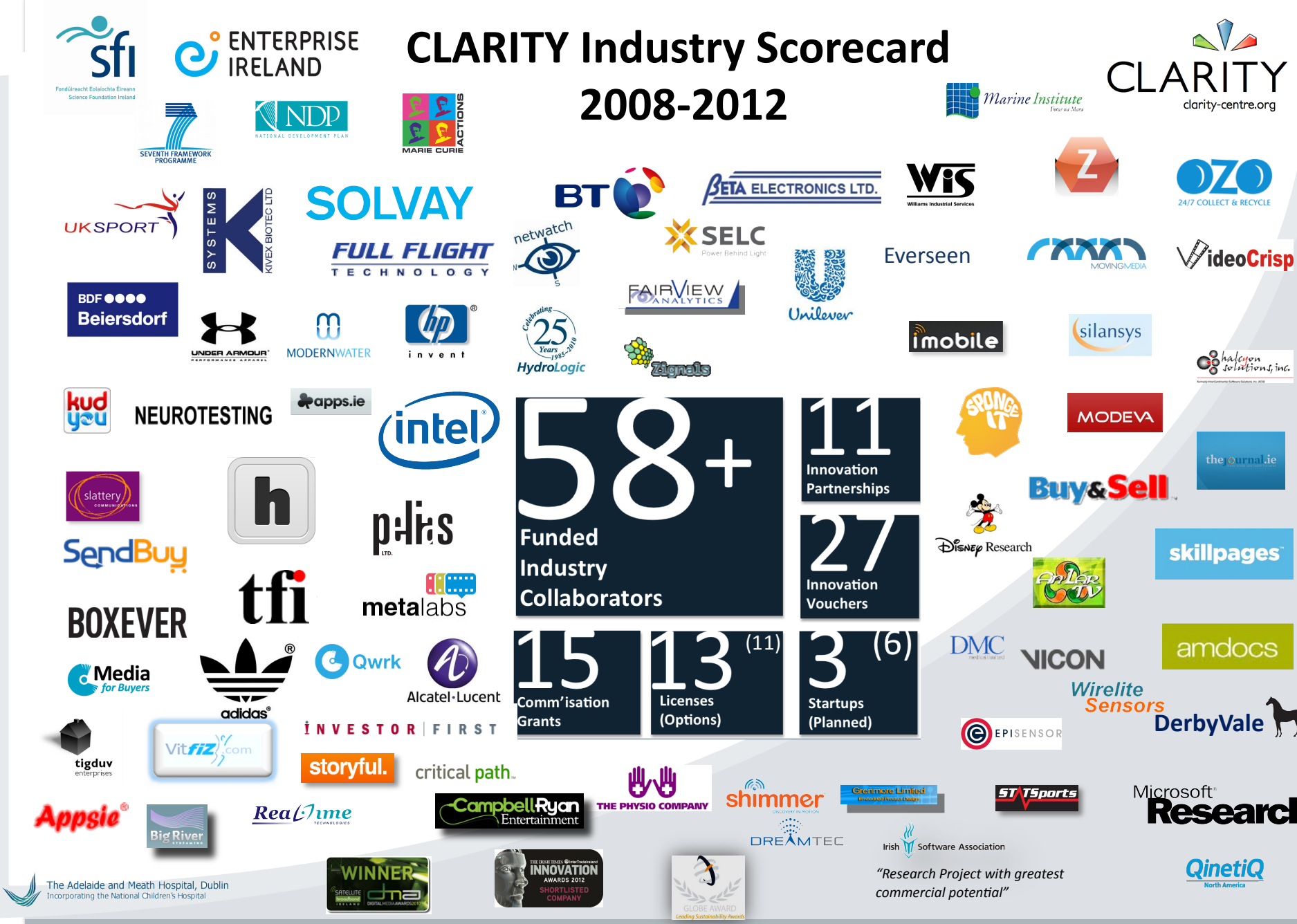
Dr. Cian O' Mathuna
RS2

Sensor platforms and hardware, Power management, …

CLARITY Landscape



CLARITY Industry Scorecard 2008-2012



CLARITY Demonstrators

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Personal Health & Sports

Energy & the Environment

Ambient Assisted Living

Sensing the Real-Time Web

Domestic Energy

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- **Many smart energy metering trials**
- **Ireland's CER ran an 8,000-home customer behaviour trial, technology trials, cost-benefit analysis**
- **Motivations are the usual combination of**
  - Better Customer Information and Choice
  - Lower Energy Bills – time of use tariffs
  - Greater Energy Efficiency and Reduced Costs
  - Reduced CO_2 emissions

Domestic Energy

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- **Many smart energy cost-benefit analysis trials**

Status of CBA in CEER countries	Electricity	Gas
Countries have conducted a CBA	11[1]	6[2]
Positive result of CBA	7[3]	5[4]
Countries plan (or ongoing) to conduct a CBA (in some cases for the 2nd time – France, Hungary, Poland, Portugal)	12[5]	14[6]
Countries do not plan a CBA	2[7]	5[8]
Countries with no CBA, but no longer relevant (yes/no of roll-out already decided)	3[9]	0

1: Austria, Denmark, France, Hungary, the Netherlands, Norway, Poland, Portugal, Slovenia, Sweden, United Kingdom
2: Austria, France, Hungary, Italy, the Netherlands, United Kingdom
3: Austria, France, the Netherlands, Norway, Poland, Portugal, United Kingdom (Poland – study was TSO, not gov't authority. In Sweden, although result was negative, roll-out for electricity proceeded.)
4: Austria, France, the Netherlands, Italy, United Kingdom
5: Belgium, Czech Republic, Germany, France, Greece, Hungary, Ireland, Luxembourg, Latvia, Poland, Portugal, Romania (Belgium - each region conducting its own, no federal one planned) (Portugal - to be decided by gov't)
6: Belgium, Czech Republic, Germany, Spain, Finland, Greece, Hungary, Ireland, Latvia, Luxemburg, Lithuania, Portugal, Slovenia, Sweden (Portugal - to be decided by gov't)
7: Lithuania, Slovak Republic
8: Denmark, Norway, Poland, Romania, Slovak Republic (Norway has no gas)
9: Spain, Finland, Italy

Domestic Energy

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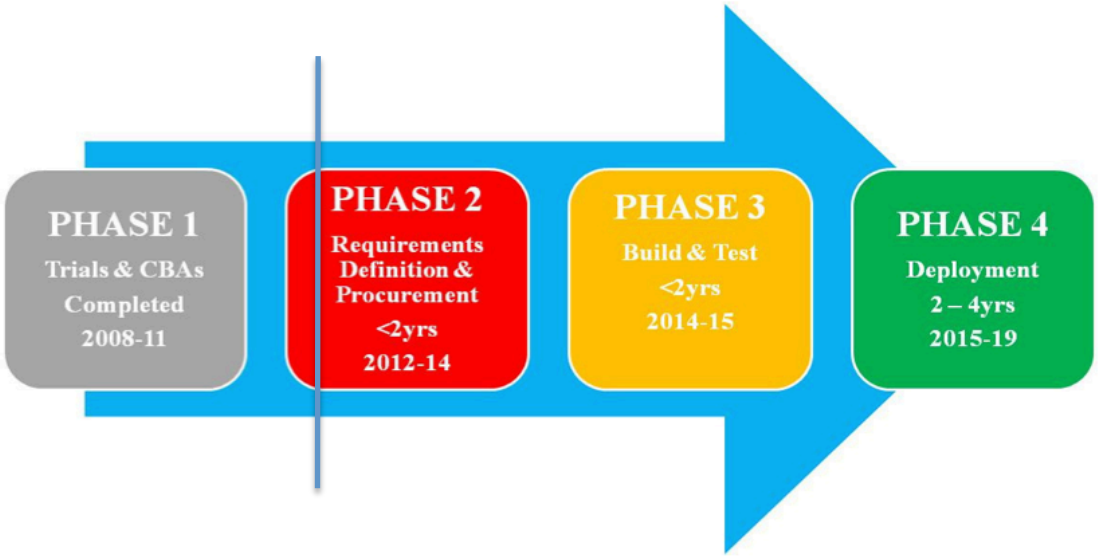
- **CER has decided to proceed and include**
  - *In-home Display device*
  - *Smart Bills*
  - *Time-of-Use Pricing*
  - *Pre-payment services*



Smart meters = sensors

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- From the HAN, we regard smart meters as generating sensor data, which is what CLARITY is interested in;
- Working with Episensor, we deployed our own in-home smart metering to 2 dozen homes, over years
- Monitor the electrical consumption within the home, on a per-minute basis

Smart meters = sensors

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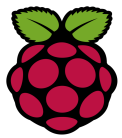
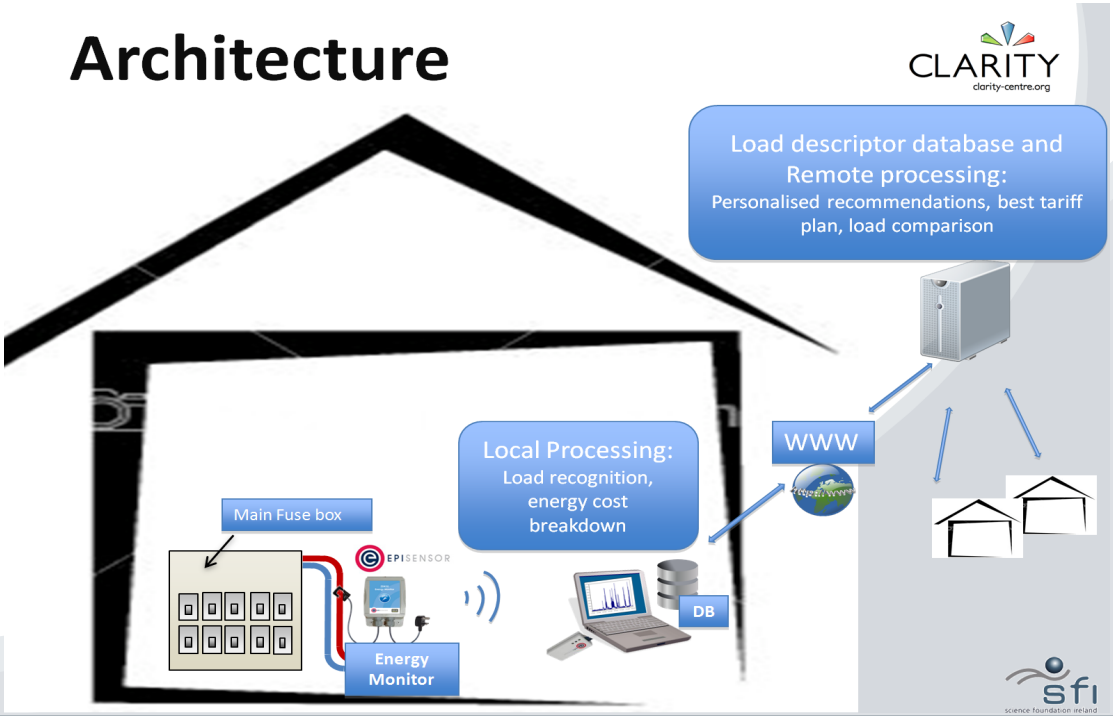
- **Components …**
  - Cuff, mains power, Zigbee, local DB on PC, broadband to cloud, web apps
  - Now plugPC and Raspberry Pi



Architecture



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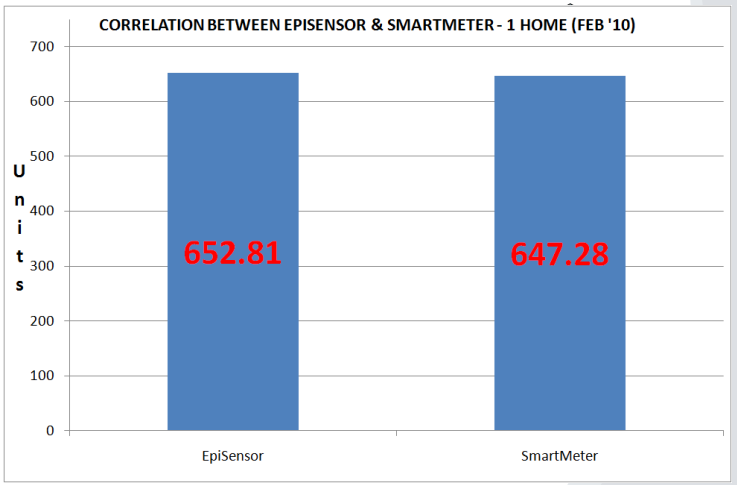

ZEM-30 Energy Monitor

- Reports multiple power/current/voltage
- 15,840 sensor readings per house per day !
- Normal 5-7PM peak in electricity consumption

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Mon	23.30%	10.27%	2.29%	0.41%	1.70%	9.66%	17.55%	29.96%	38.69%	38.50%	39.92%	34.18%	36.60%	29.62%	32.49%	43.57%	51.69%	71.31%	91.22%	83.01%	71.93%	61.94%	54.76%	44.15%
Tue	29.29%	6.49%	0.50%	0.30%	4.10%	6.27%	10.33%	32.53%	36.70%	45.49%	42.51%	36.06%	33.77%	35.37%	41.86%	42.16%	52.22%	75.31%	100.0...	77.10%	71.93%	73.14%	60.81%	44.28%
Wed	20.00%	7.48%	0.01%	0.00%	3.66%	8.78%	15.70%	29.18%	43.00%	39.66%	37.49%	34.90%	30.08%	27.72%	34.92%	34.47%	50.77%	68.57%	99.50%	91.12%	76.78%	60.16%	53.13%	40.88%
Thu	21.24%	5.30%	1.93%	1.41%	3.92%	7.47%	16.15%	43.85%	44.76%	45.73%	43.50%	41.94%	47.68%	35.01%	50.02%	53.48%	69.46%	86.10%	98.74%	95.09%	70.76%	55.37%	49.95%	39.99%
Fri	21.27%	9.18%	4.50%	1.90%	2.00%	7.33%	14.02%	29.99%	45.46%	40.45%	35.79%	28.99%	27.58%	37.63%	43.37%	38.67%	47.61%	58.54%	76.15%	75.50%	74.42%	65.59%	52.69%	41.93%
Sat	28.16%	18.36%	6.12%	3.75%	3.07%	9.19%	6.31%	7.59%	22.78%	41.62%	48.43%	45.68%	49.70%	53.88%	60.18%	47.98%	55.20%	75.86%	84.03%	70.21%	61.38%	51.15%	45.15%	42.90%
Sun	27.93%	18.69%	9.97%	10.04%	4.21%	12.08%	7.45%	7.73%	20.35%	32.55%	53.73%	63.35%	57.50%	49.85%	49.29%	59.99%	68.39%	76.22%	93.03%	82.27%	80.68%	67.26%	61.48%	37.75%

Sensing The Home

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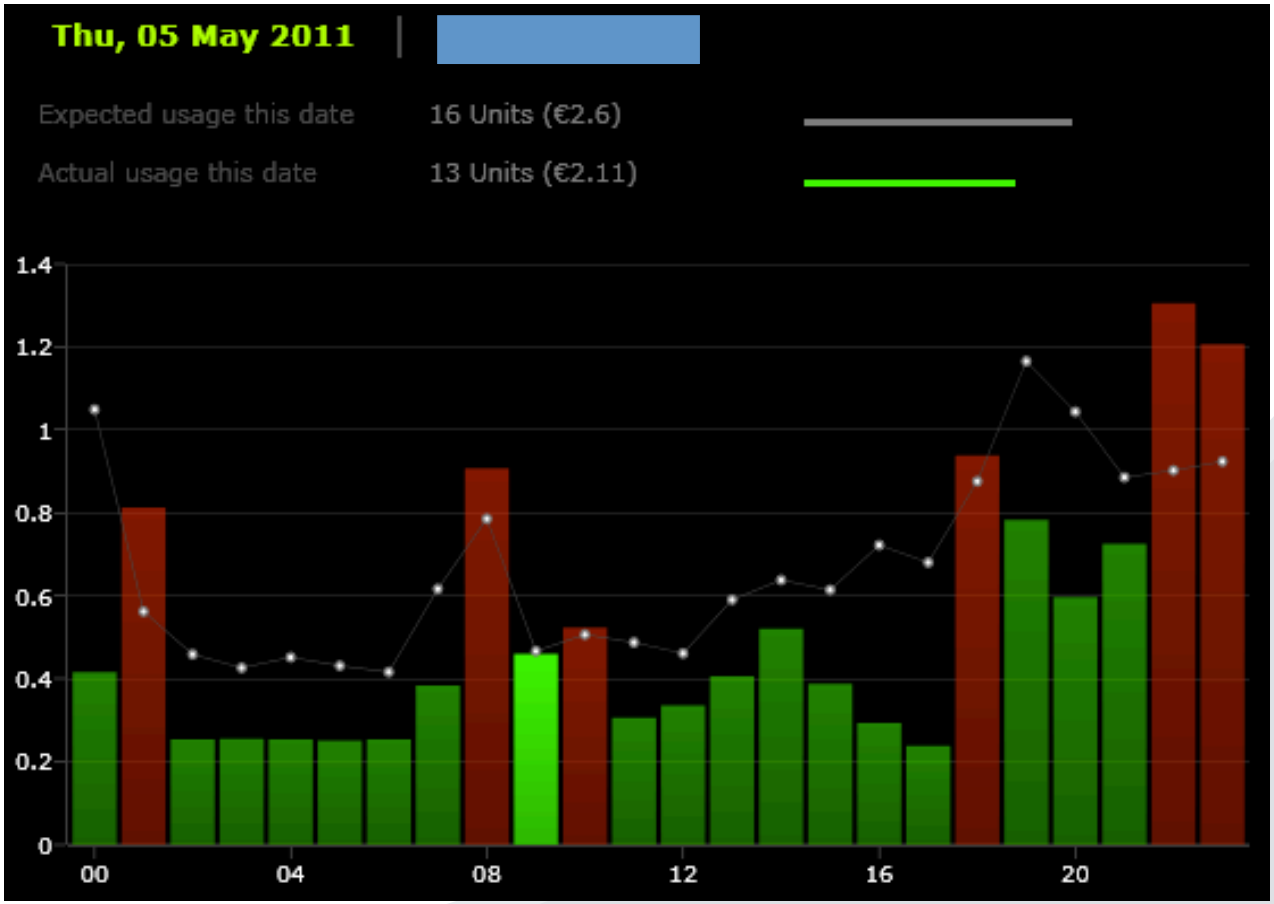

Web-based interface

So what ?

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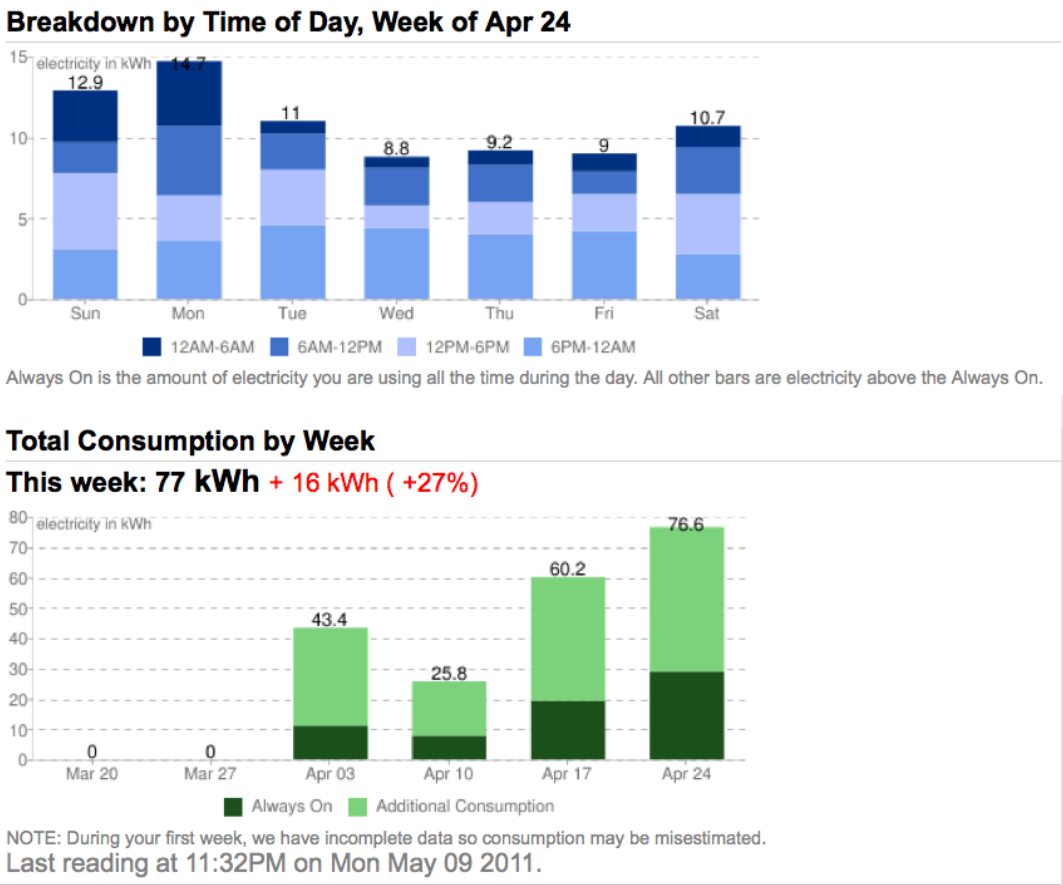
- **Personal feedback reduces demand ?**
  - Olympic Peninsula Project
  - Darby Review Paper
  - ENEL 27 million smart meters
  - Microsoft Holm & Google power meter
  - Irish Commission for Energy Regulation behavioural trials
  - … and many others
- **We are interested in different kinds of intervention based on fine-grained usage sensing, not IHD, but more**

Intervention 1

- Weekly email … Google Powermeter did this also … but with comparisons against others



Intervention 2

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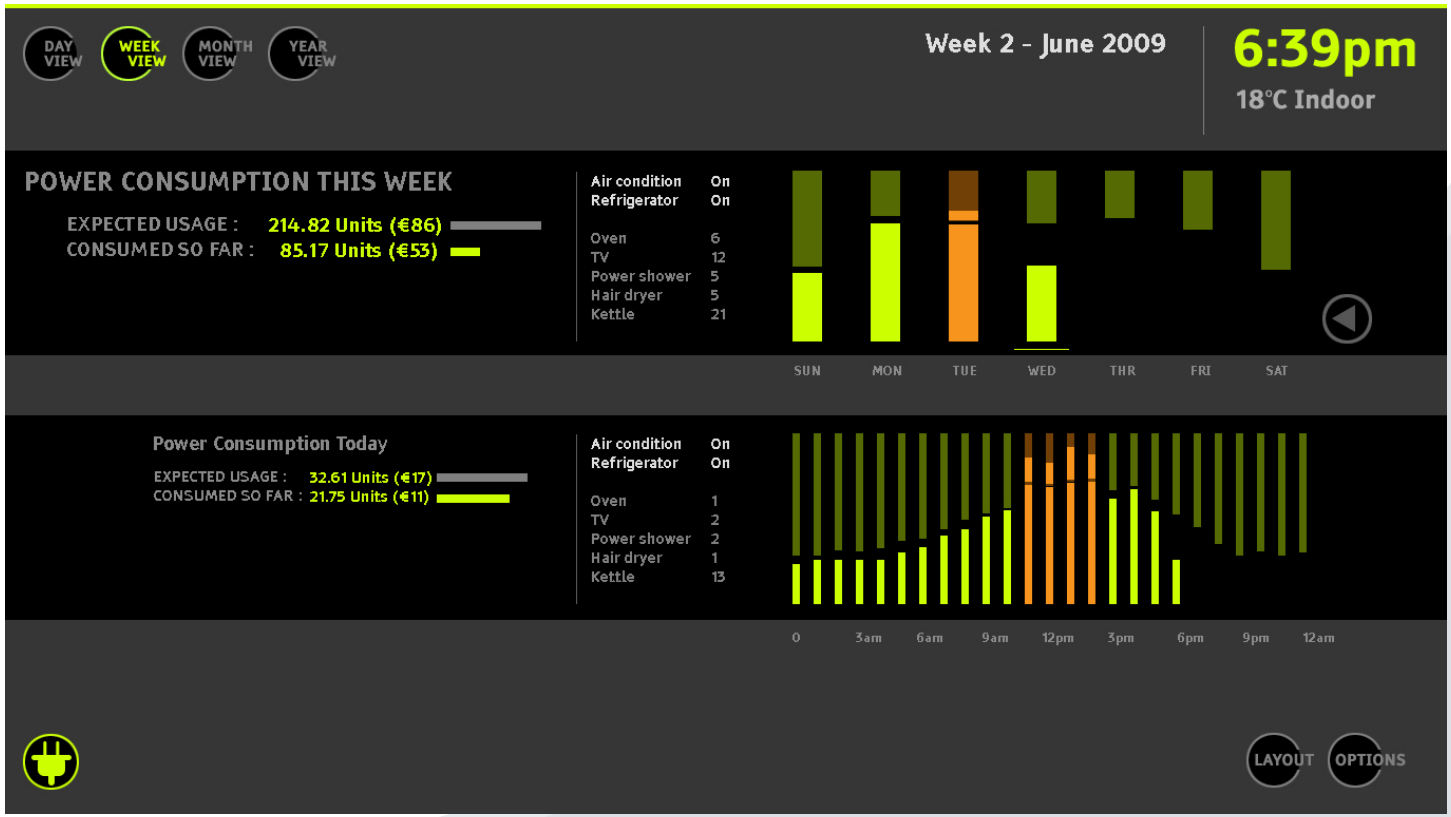
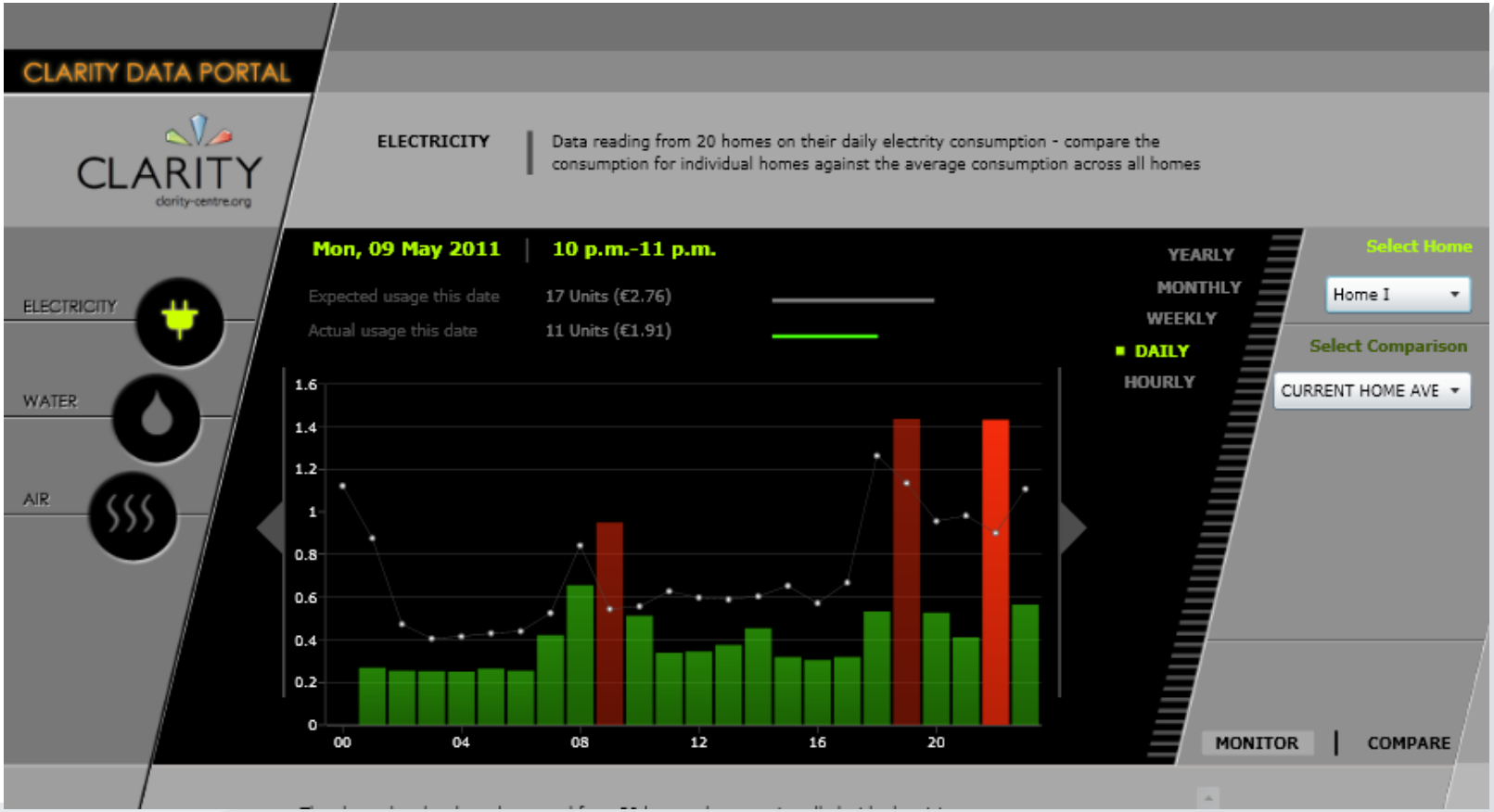
- Touchscreen display



Intervention 3

- Web portal



Intervention 4

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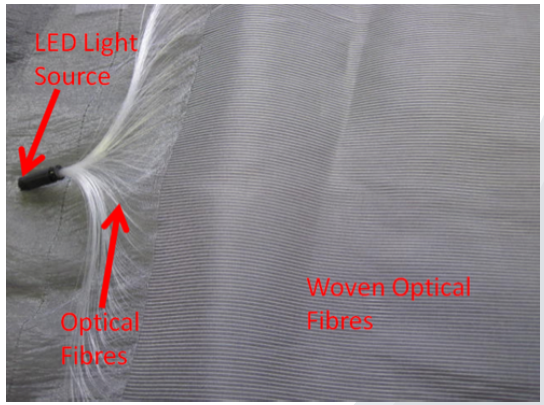
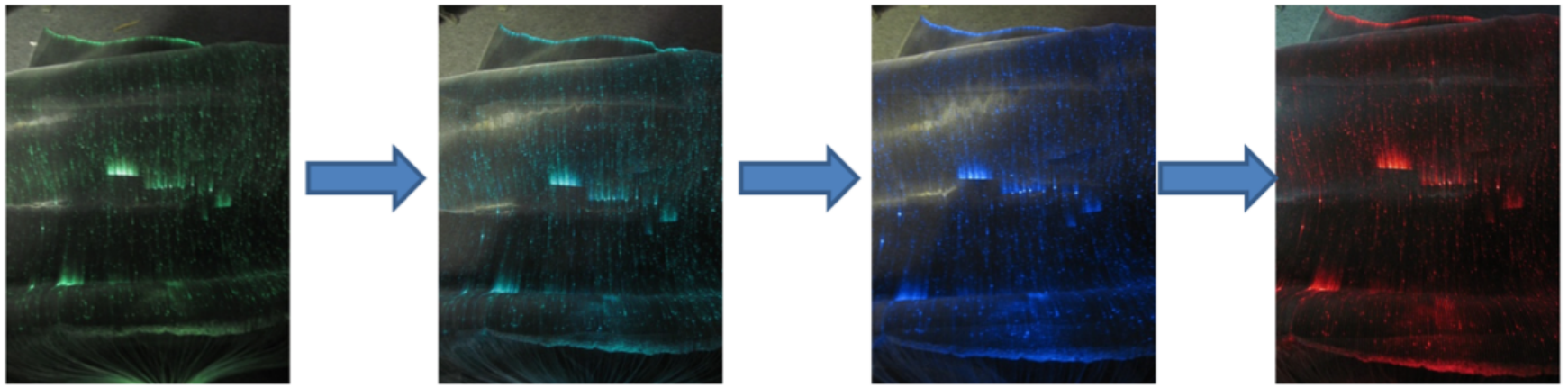
- Colour-changing soft furnishings
- Tablecloth, cushions, etc. - where colour changes ambiently reflect the +/- energy usage vs. typical historical norm for that day/time





Interventions ?

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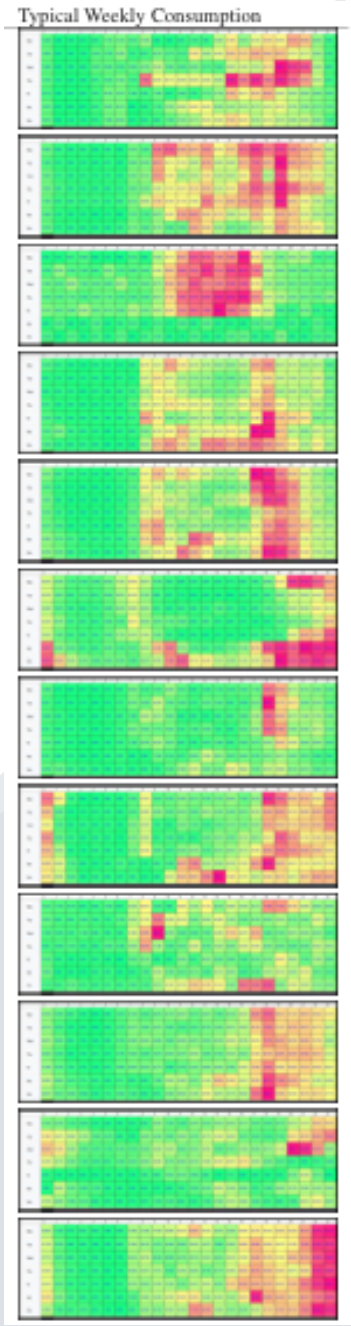
- Guess what ? We found the same as everyone else … initial enthusiasm gives way to bad habits - need to continuously inform
- Real role for persuasive technologies … captology

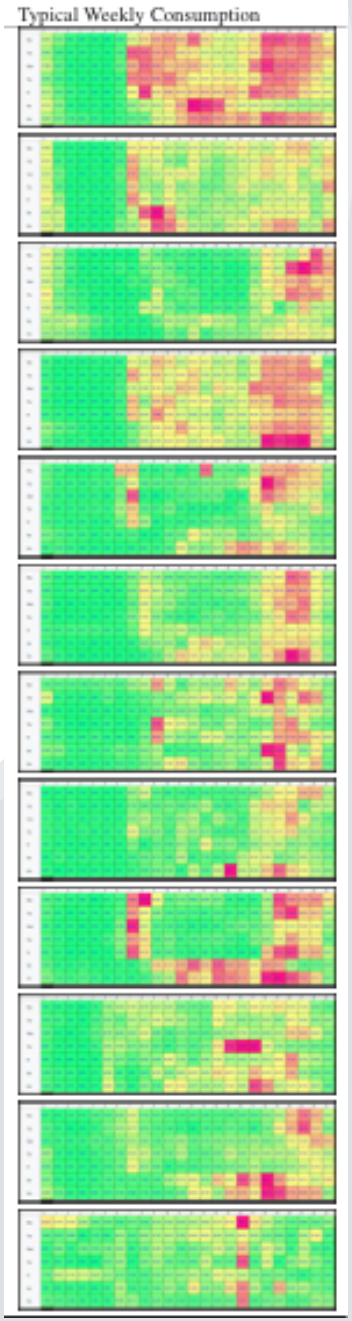
Strange outcome

- A strange outcome was the interest in the heatmaps as a tool to summarise lifestyles;
- One ambient, cheap sensor tells a lot about living patterns;
- Subsequently working with ethnographers and geriatricians on monitoring the lifestyles of people;
- All from a cheap €100 option



Strange Outcome

- This will be even cheaper with rollout of smart meters, where this can be done for free … direct interface to the meter
- Could allow easy inter-user comparisons, comparison across peers, long-term deviation detection
- And that was very interesting, but …



Sensing The Home

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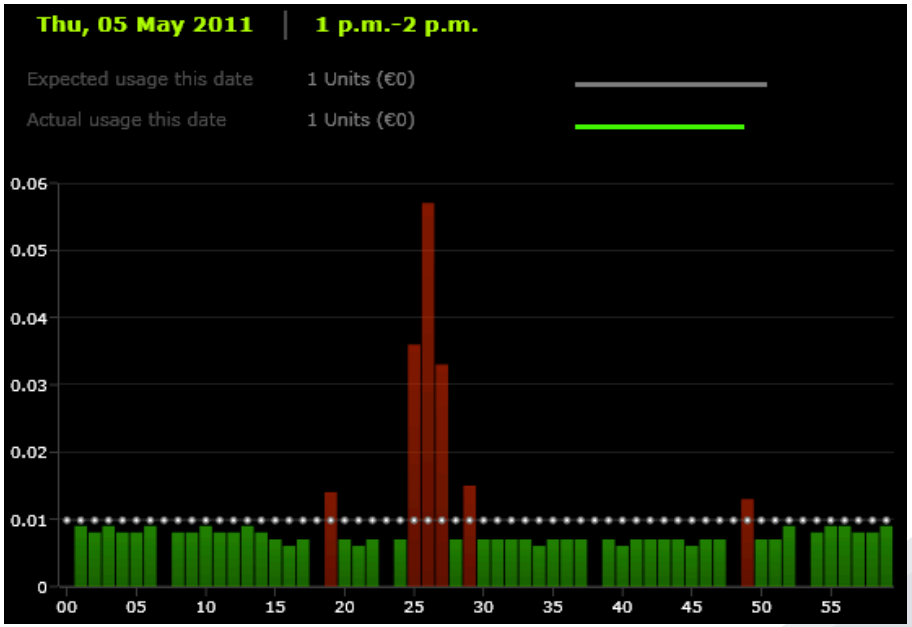

- This is total energy usage in a home, covering all appliances.
- But, we have gone a step further …

Home Deployment

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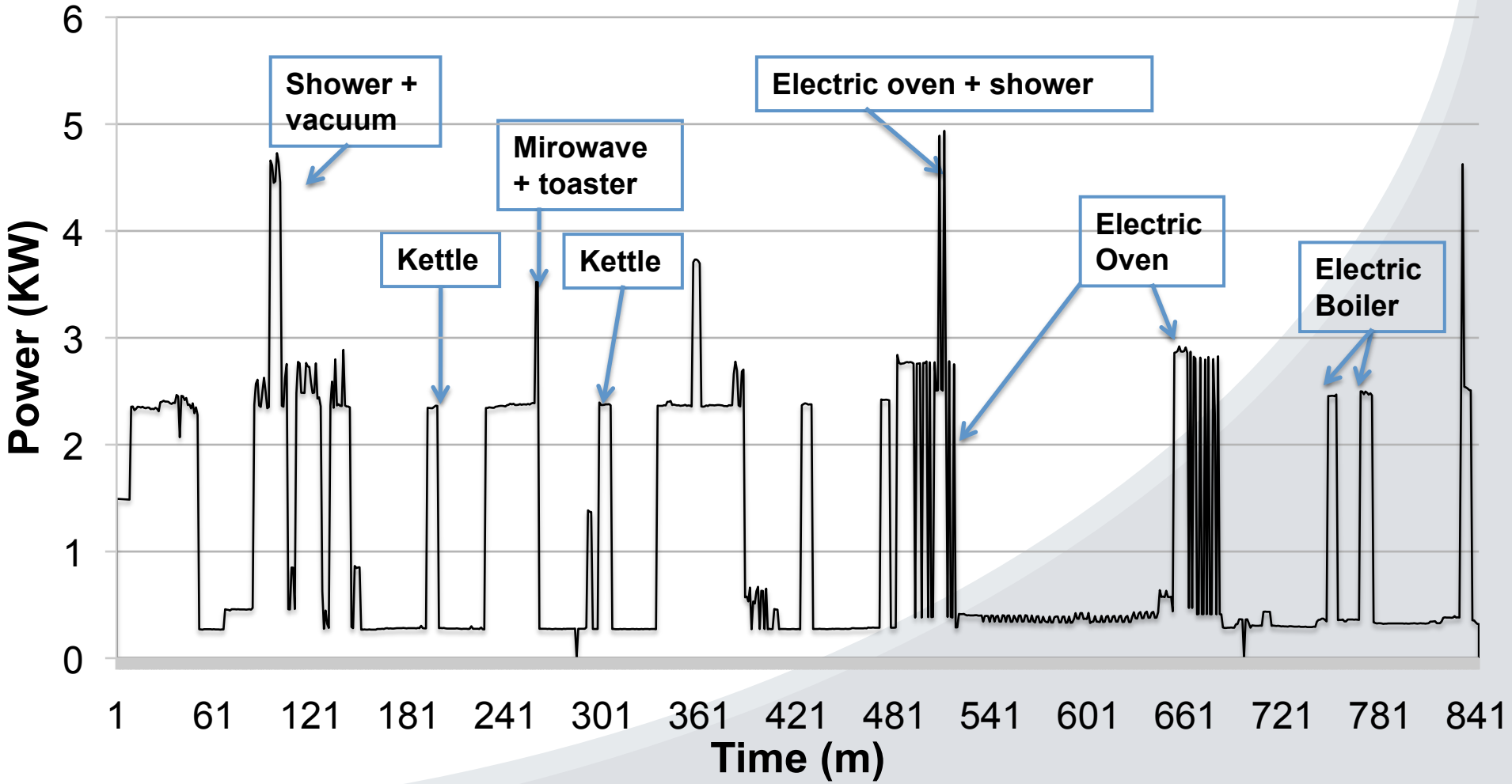

Sensing the Home

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- Analysis of the electrical power usage of a home provides appliance signatures.
- This enables identification of different types of household appliance usage.
- We gathered groundtruth and used machine learning (SVM) to build classifiers for devices
- Assessed accuracy at 95% precision/recall
- Use this in smart bills, and behaviour analysis

E.g. Electric Kettle

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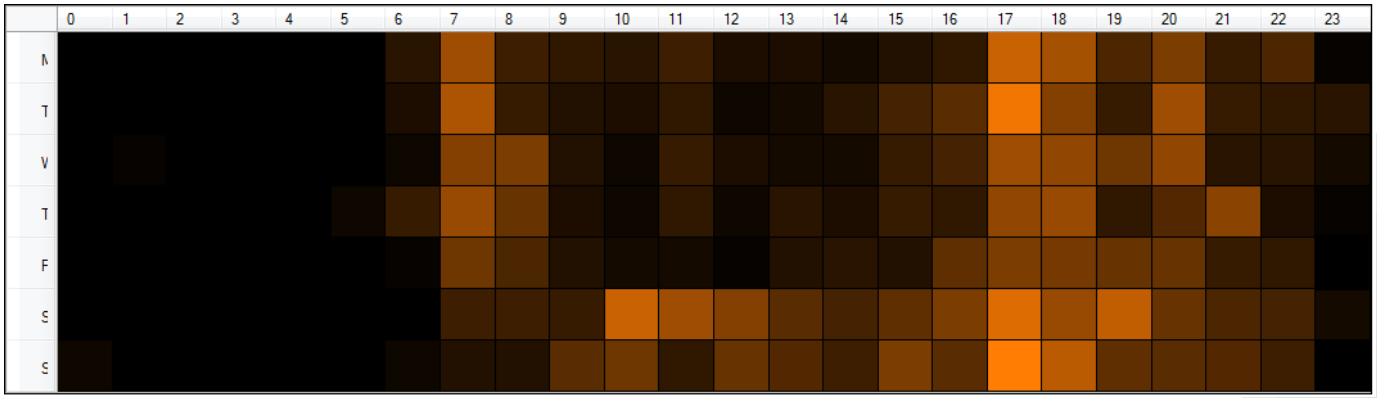
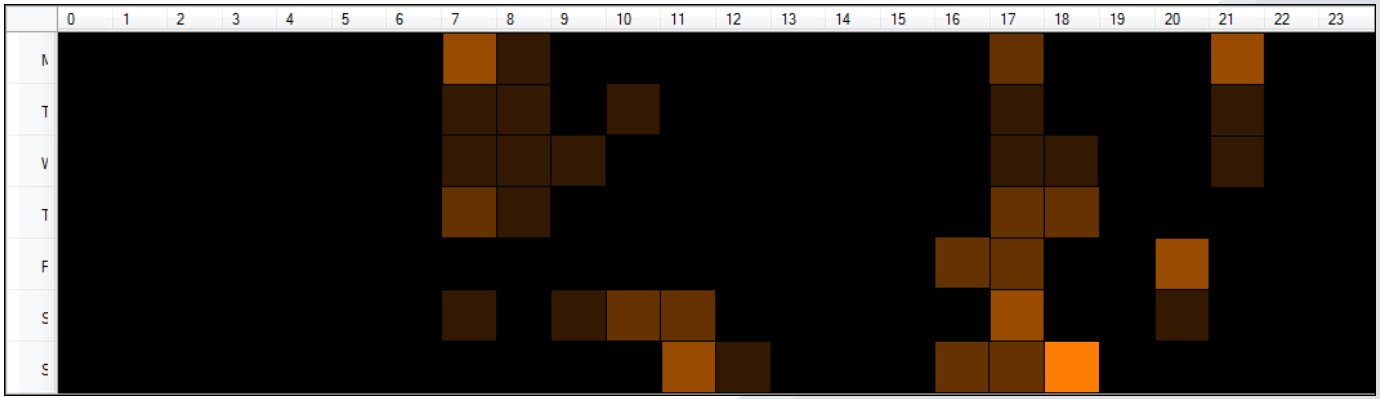
- 1 year



- June only



- This tells what is happening in my home
- Better when combined with other appliances and sensors, a cheap ambient sensor

E.g. Electric Shower

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	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Mon	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	9.15%	26.14%	53.59%	49.02%	75.16%	66.67%	54.90%	33.99%	25.49%	0.00%	10.46%	1.96%	4.58%	7.19%	11.76%	0.00%	0.00%	2.61%
Tue	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	7.19%	50.33%	100.0...	64.71%	37.91%	57.52%	0.00%	37.25%	5.88%	6.54%	6.54%	1.96%	5.88%	0.00%	0.00%	3.27%	11.11%	0.00%
Wed	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	9.15%	61.44%	79.08%	52.29%	49.67%	38.56%	31.37%	18.30%	6.54%	11.76%	2.61%	9.15%	11.11%	7.19%	0.00%	0.00%	3.92%	0.00%
Thu	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	3.27%	77.12%	60.78%	96.73%	56.21%	58.17%	19.61%	33.33%	22.22%	9.15%	14.38%	0.00%	0.00%	13.07%	7.19%	8.50%	3.27%	0.00%
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Morning Showers

Appliance Detection

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- **Other ways to capture appliance usage … contact sensors, circuit-based or appliance-specific sensing**
  - We show its not actually necessary
- **We don't focus on dynamic machine learning, we post-process**
  - who would need to know ?

Conclusion

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- **Monitoring home energy usage has great potential**
  - IHD and billing as the sole user intervention doesn't maximise potential impact
  - Autonomous appliance management is better
  - Can be much more than just energy saving
- **Can enable other uses when smart metering architecture permits user access to own data**
- **It shows the richness of good data and is an ICT challenge !**