

# Energy Research in CLARITY: Achieving Efficiency by Sensing Consumer Behaviour

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CLARITY: Centre for Sensor Web Technologies

# The CLARITY centre

- **The Adaptive Information Cluster (2003 – 2008)**
  - €5.6m (+€6m additional)
  - SPIN-OFF Changing Worlds – sold for 60M
  - Proved the ‘Sensor Web’ Proposition - key developments in wide range of crucial Sensor Web technologies
- **CLARITY: Centre for Sensor Web Technologies (2008 – 2013)**
  - UCD DCU and Tyndall
  - National, multi-site CSET - €12m+ SFI Funding, 5 Year Programme; Strong Industry Collaboration
  - Significant presence in Ireland’s research infrastructure, EPA, MI, IDA, EI & SFI



# Partners and Collaborations

## Social Collaborators include:



## Other Industrial Collaborators include:



# Energy research at UCD

Main Energy centre at UCD  
Directed by Prof Mark O'Malley

Energy distribution  
Smart Grid  
Alternative energy sources



CSET at UCD/DCU/Tyndall  
Directed by Prof Barry Smyth

Building energy management  
Individual carbon foot printing  
Energy recommendations



# Carbon Footprinting

*Contributing to meeting EU 2020 targets*

- **Measure to Improve**

- Off-the-shelf sensors provide the beginnings of a comprehensive approach to personal carbon footprinting.

- **Address 3 Key Areas**

- Electricity usage; waste & recycling; personal transport & health.

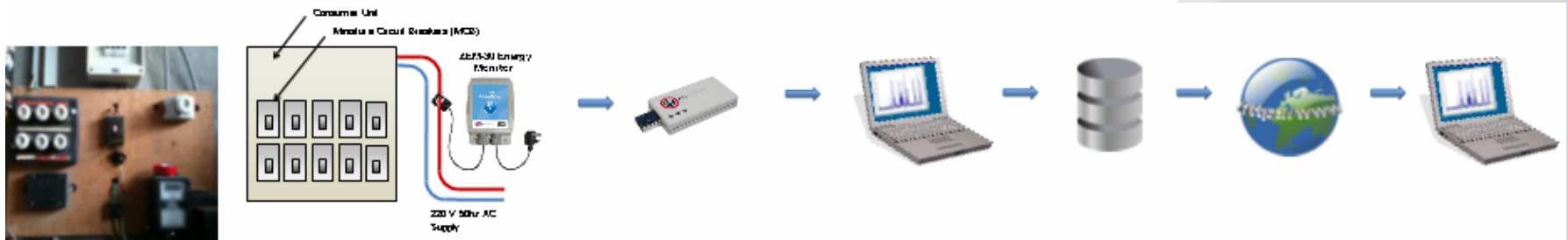
- **Focus on Communication & Education**

- Eventually leverage social media tools and recommender systems to engage individuals in their own carbon achievements.

# Hardware

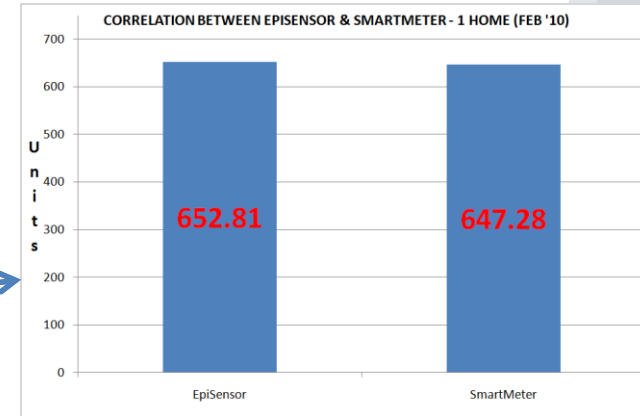
## ZEM-30 Energy Monitor

- Connected to positive line of mains supply
- Every minute records: RMS/Peak/SAG current/voltage, Watt hours, real/apparent power
- Communication via Zigbee network



# CLARITY Deployments

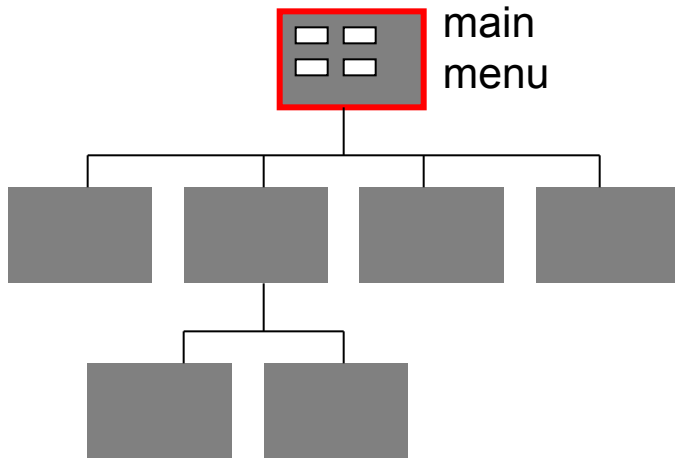
- 20 domestic participants, 2 lab settings
- 15,840 sensor readings per house per day!
- We're now gathering over 2 MILLION readings/week
- Data accurate to within 1% of Smart Meter
- Normal 5-7pm peak in electricity consumption



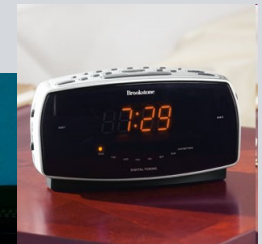
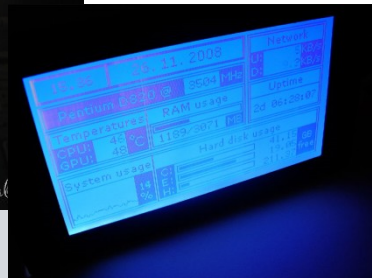
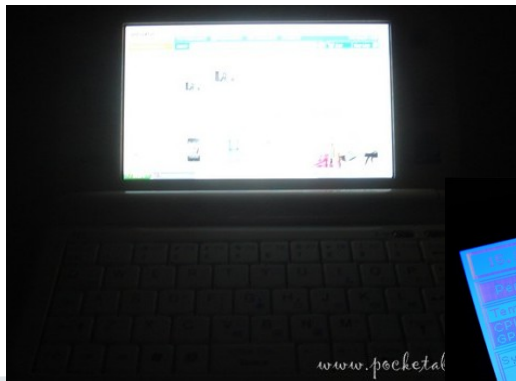
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Mon	23.30%	10.27%	2.29%	0.41%	1.70%	9.66%	17.55%	29.96%	38.69%	38.50%	39.92%	34.18%	36.60%	29.62%	32.49%	43.57%	51.69%	71.31%	91.22%	83.01%	71.93%	61.94%	54.76%	44.15%
Tue	29.29%	6.49%	0.50%	0.30%	4.10%	6.27%	10.33%	32.53%	36.70%	45.49%	42.51%	36.06%	33.77%	35.37%	41.86%	42.16%	52.22%	75.31%	100.00%	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%

# Visualisation

- No deep complex navigation
- Bright screen vs. dark screen

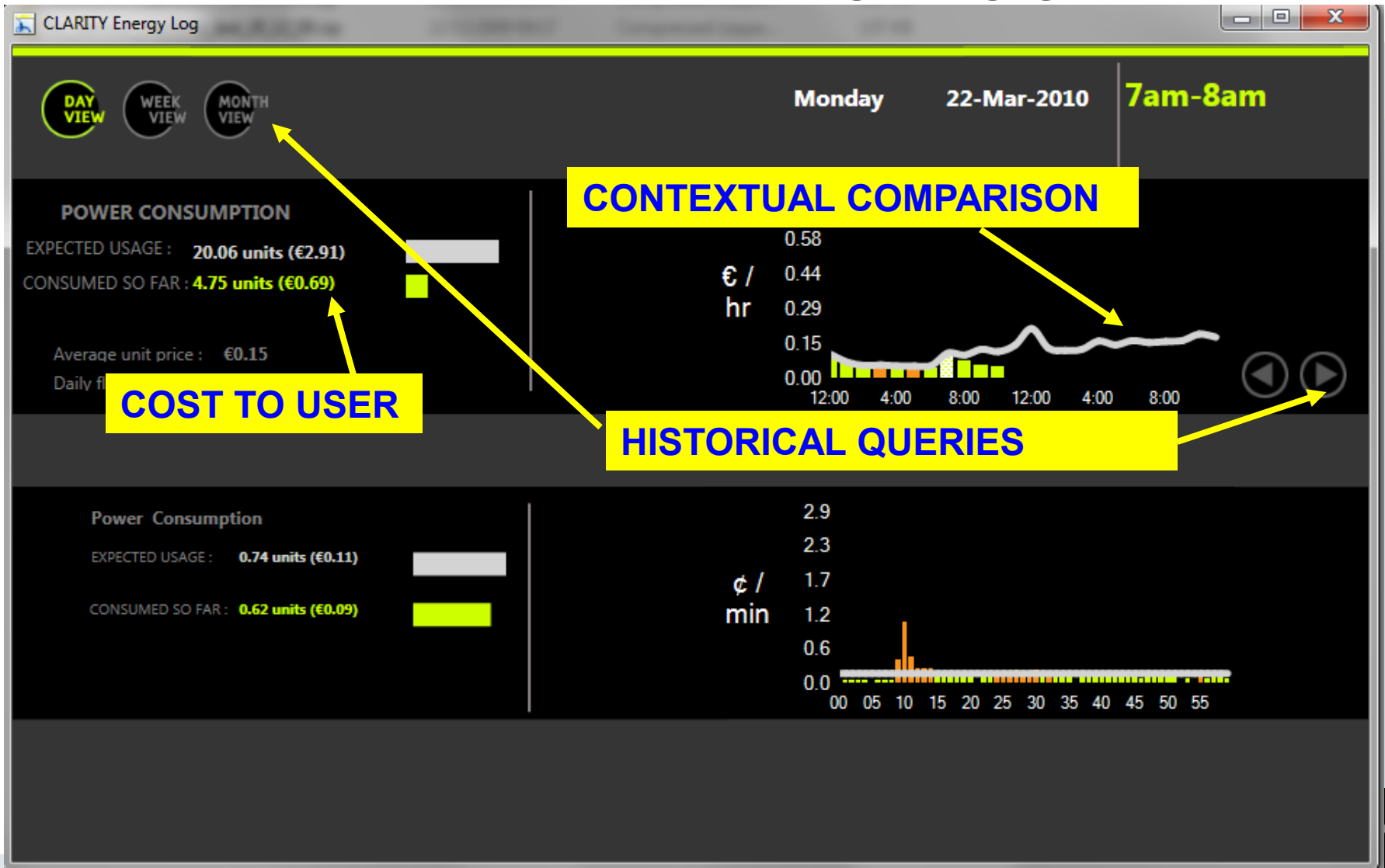


vs.



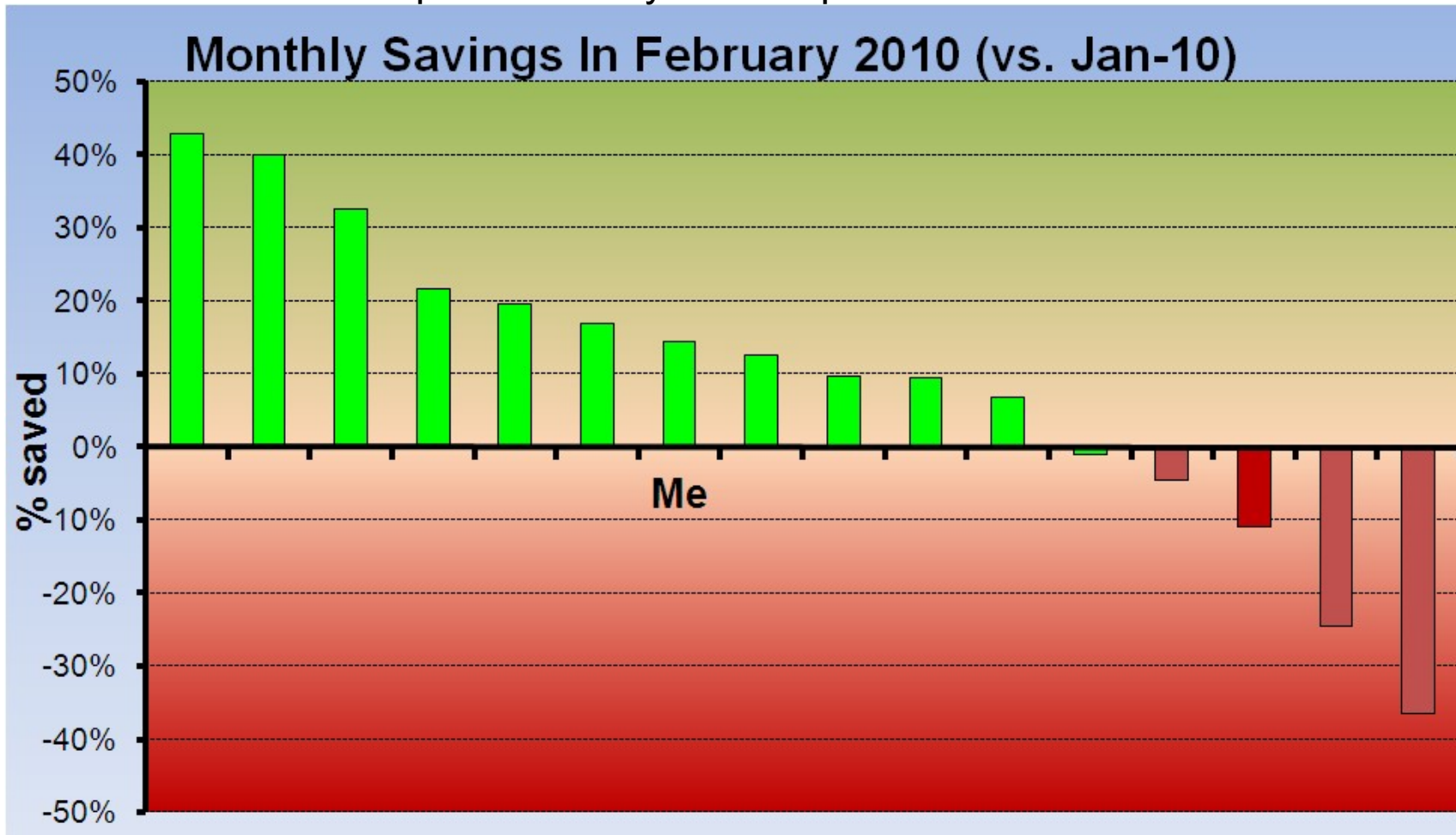


# IHD + Home Desktop App...



# Informing Users = Reduced Consumption?

As with other similar studies, even at this early stage we're already noticing the normal 5-15% drop in electricity consumption ...



# CO<sub>2</sub> > electricity only...

Figure 4 Primary Energy by Mode of Application

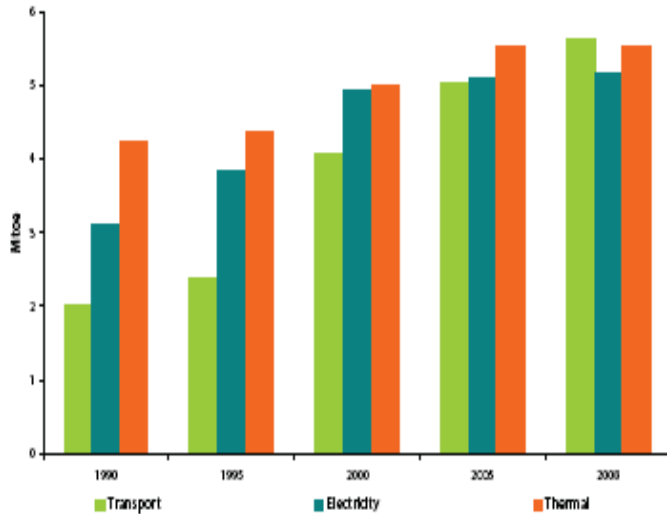
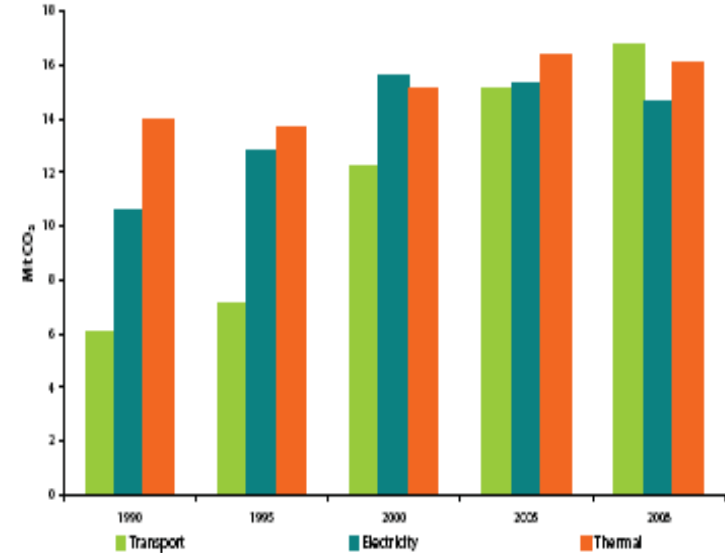


Figure 19 Energy-Related CO<sub>2</sub> Emissions by Mode of Energy Application



- ...Transport energy use grew by 177% over the period 1990 – 2008 (5.8% per annum) and consumes more than one third of all energy in Ireland... (page15, Energy in Ireland 1990-2008)

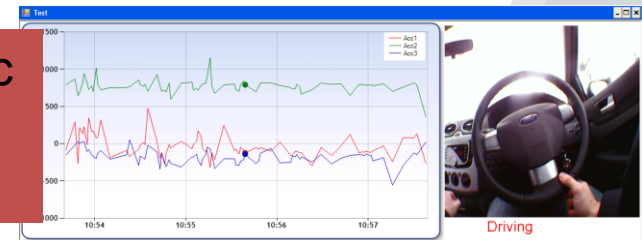
# Wearable Accelerometers

## Detecting Driving CO<sub>2</sub>

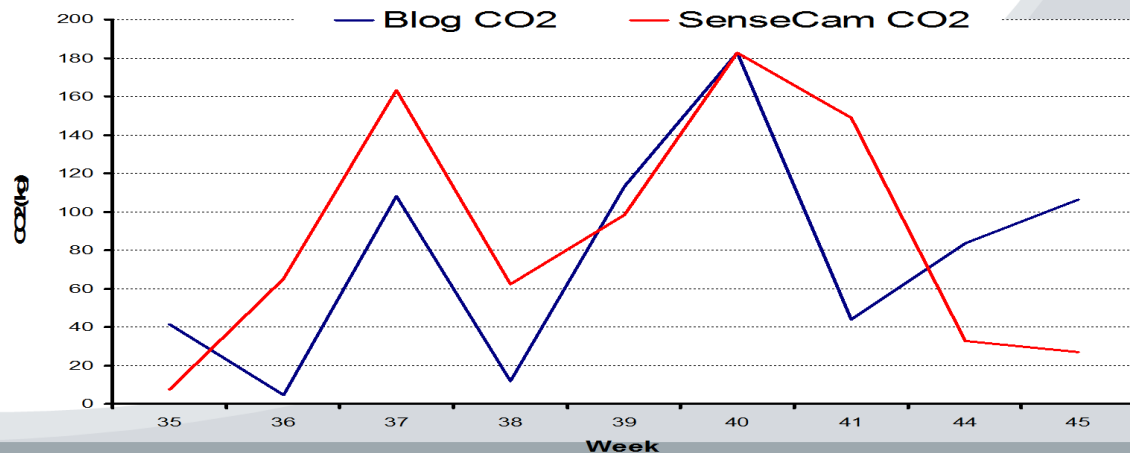
1. Keyring acc records x/y/z motion every second...



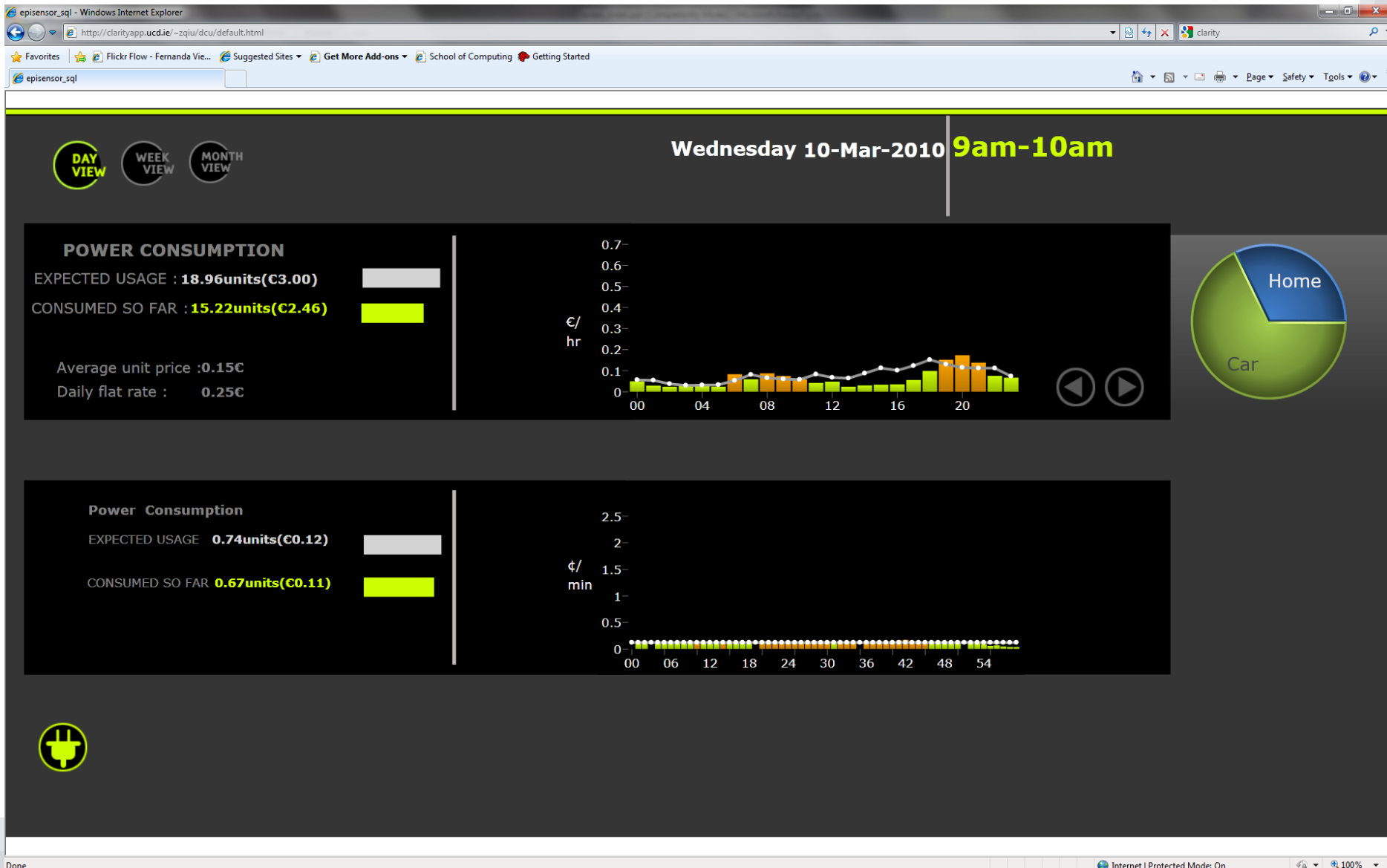
2. Using a range of classifiers: Logistic Regression, Naïve Bayes, J48, SVM, etc. to detect driving



3. Correlate driving duration with CO<sub>2</sub> emission...



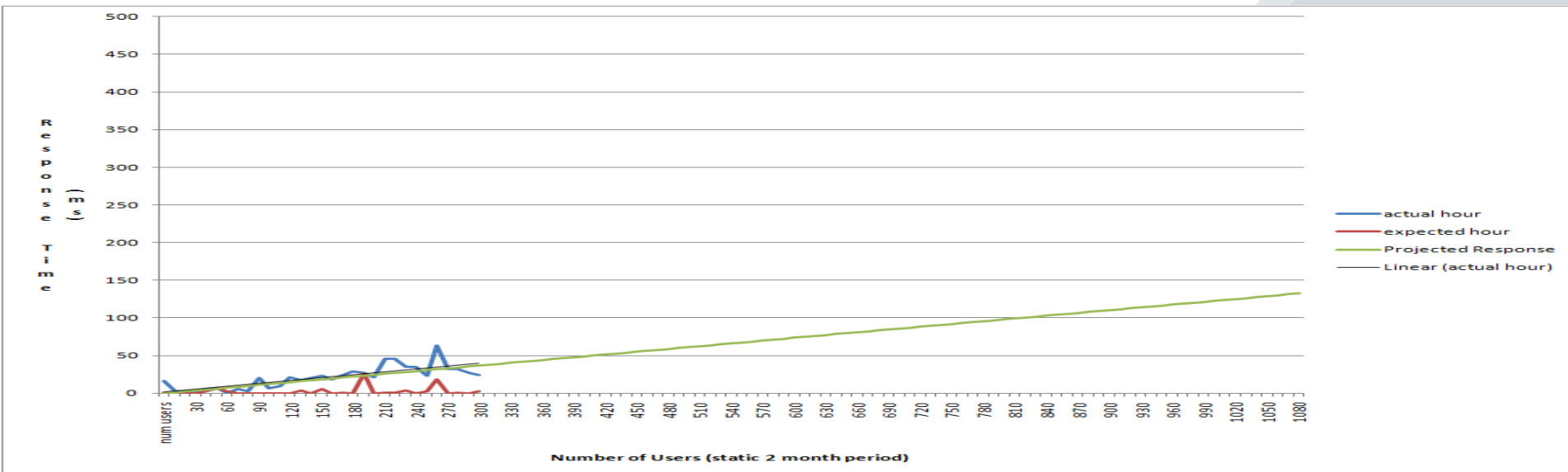
# Driving + Home CO<sub>2</sub> Web Page



# Can we scale?

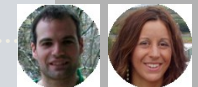
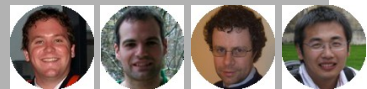
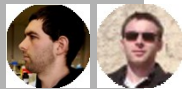
With a dated 5 year old PC we...

- Populated database with ~750 million records ... equivalent to 1 year's worth of data from 180 users
- Query response time should still be ok scaling up to ~800 users ... equivalent to ~250k users if only recording KW/h every 30 mins
- We're ready to trial our technologies with >>20 users, and are very open to collaborate with Irish Industry



ELECTRICITY

CLA



TRANSPORT

Home + Driving CO<sub>2</sub> for Mobile & TV



RARE + Appliance Detection

Processing Raw Data Streams

TinyOS Motes + Appliance Annotation

Wearable Accelerometer

CO Monitoring Car Park

Data Acquisition

Data Management

Applications

Episensor Web



Episensor Touchscreen



E3 Google Earth



Ambient Fabric



SMS Threshold Feedback

Social Networking



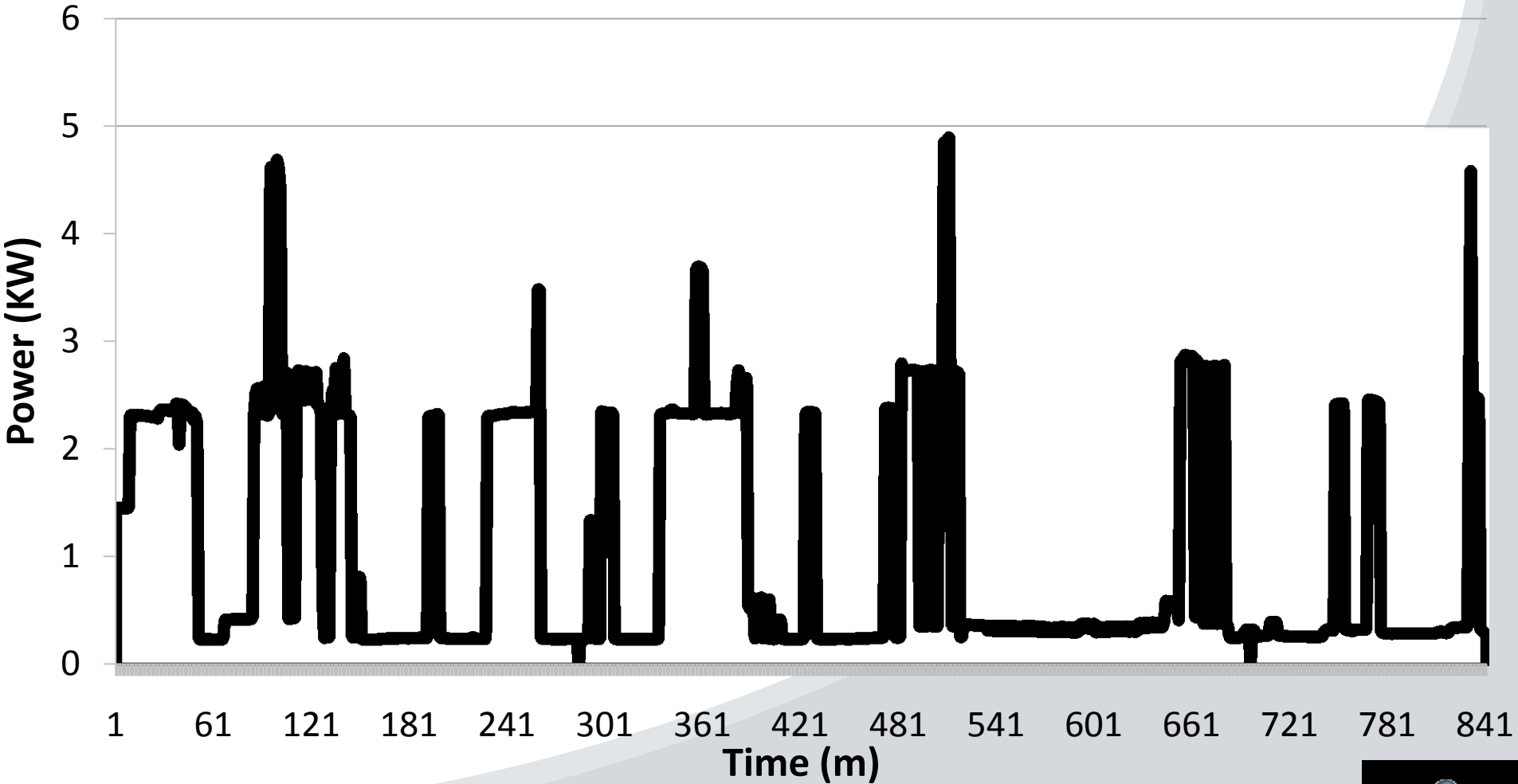
# Limits on Existing Energy Monitoring Systems

- **Home users hardly know how to:**
  - Make sense out of the data
  - How to properly interpret an energy graph
  - What actions to take to reduce the consumption
- **Information is not personalised to individual homes and user needs**

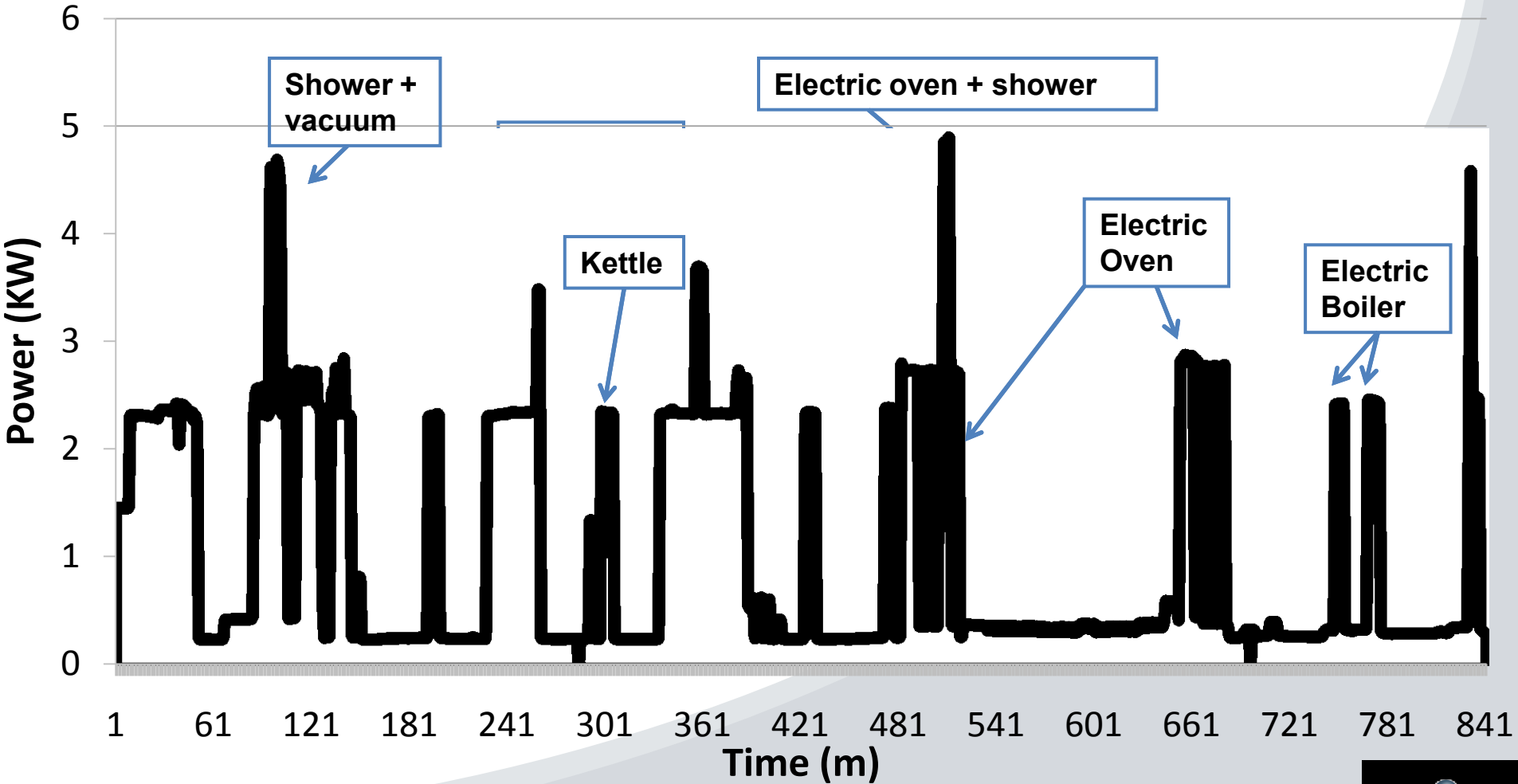




# Home Deployment



# Home Deployment



# The approach

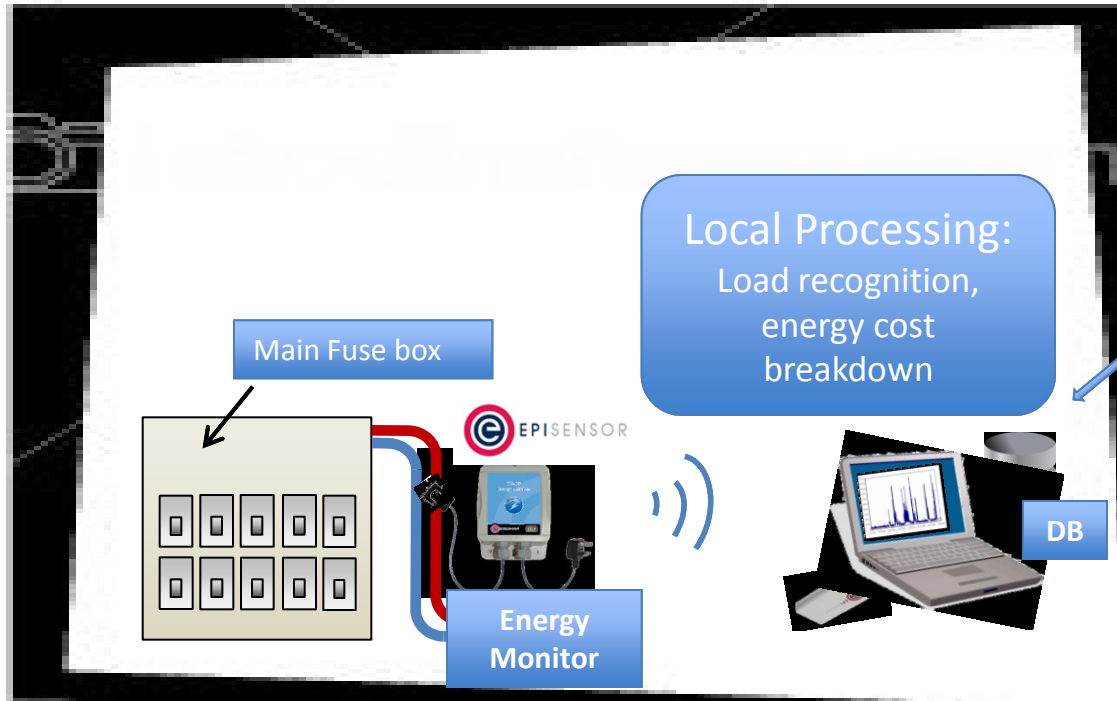
- **Traditional approach**
  - Retrofit the whole building with intelligent sockets

## Our approach

- Use a single plug-and-play electrical energy monitor connected to the main fuse box

# Architecture

Load descriptor database and  
Remote processing:  
Personalised recommendations, best tariff  
plan, load comparison



WWW



# Who will benefit

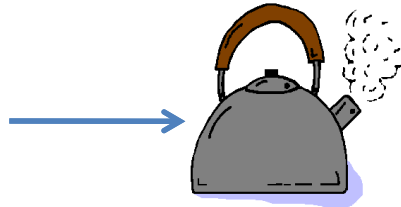
- **Consumer**
  - Empower home owners with consumption patterns to save money
- **Energy providers/distributors**
  - Enable peak consumption feedback /load balancing techniques
  - Allow better services on bills: Energy bill breakdown per appliance and personalised recommendations
- **Building manager**
  - Building energy profiling can greatly facilitate the management of the building

# Appliance Signature

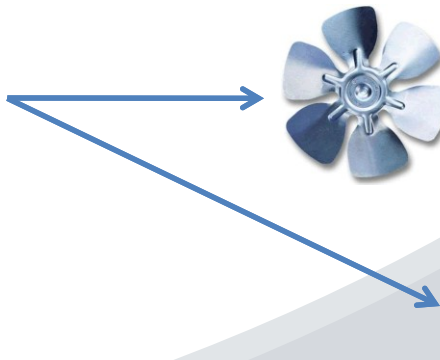
A blend of derived parameters constitute the

## Unique Appliance Signature

1. Real Power  $P$



2. Power Factor  $Pf$

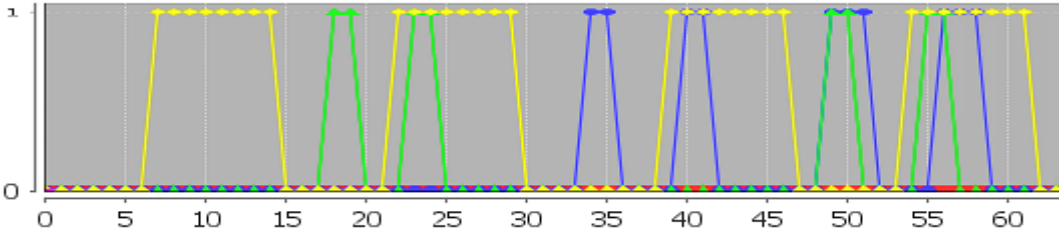


3. And so forth...

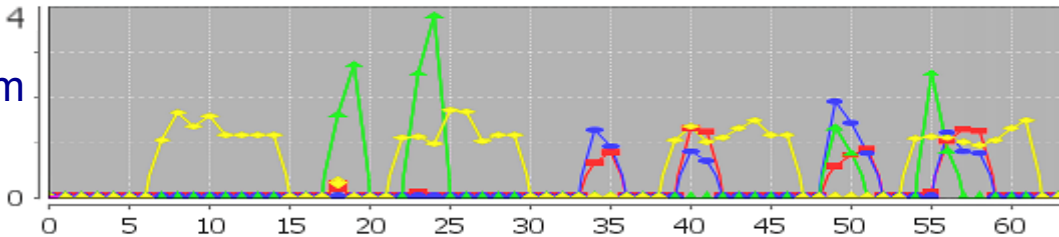
# RARE testing

Testing the efficiency of the machine learning technique

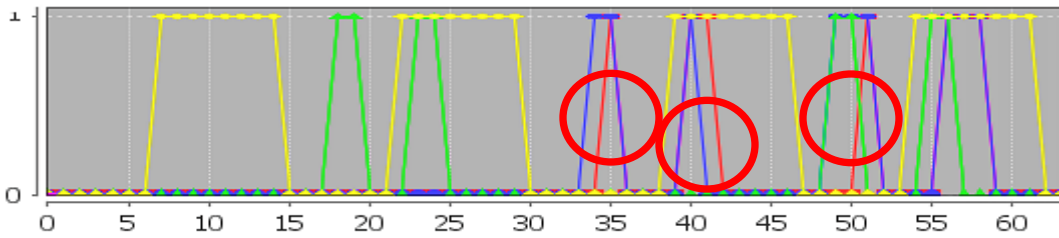
Appliance activity



Raw output:  
Direct output from RARE



Filter:  
Filtered output from RARE



>87%  
accuracy

Display of neural network data : Fridge Microwave Kettle Heater

# Pilots

## 1. UCD CLARITY (single phase)

1. Office spaces for appliances

## 2. Residential customers (single phase)

1. 20 homes in progress

## 3. Enterprise customers (3 phases)

1. Abbott Pharmaceuticals in progress
2. CSI building in progress
3. Insomnia coffee company



# Web Based Monitoring

# Basic functionalities

## Public website

Buy a supported energy monitor

Energy reduction incentives in your area

Who are our customers and their saving

Start saving

## Private web access to your energy space

Building Profiling

Trends

Providers

Marketing campaign

Planning

Ways to save

# Your account

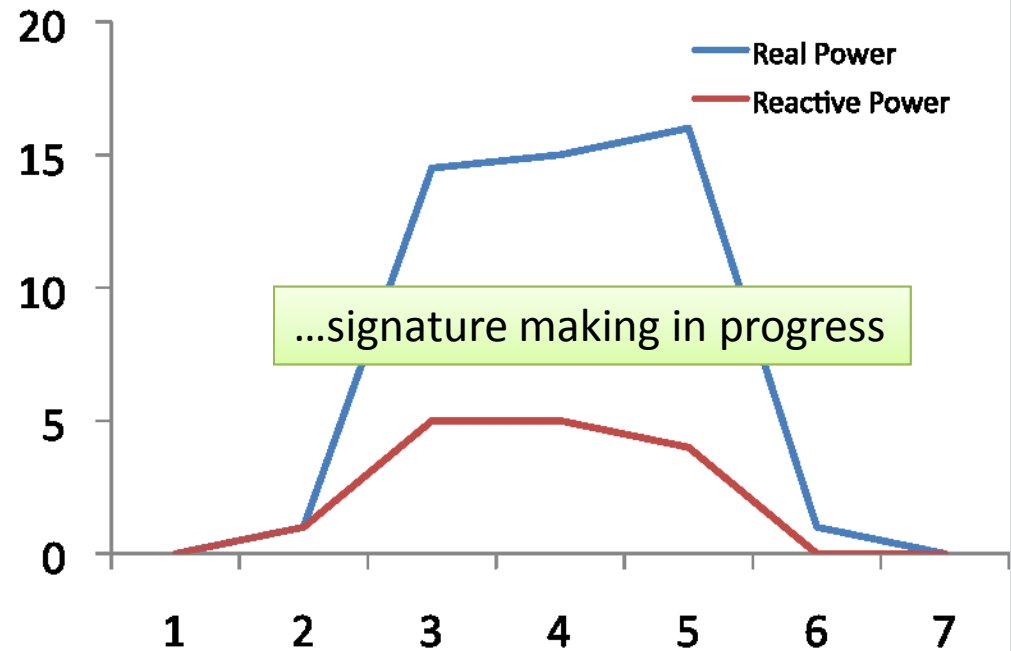
# Appliance Profiling

## Intuitive appliance profiling

Turn ON

Stand-by

Turn OFF

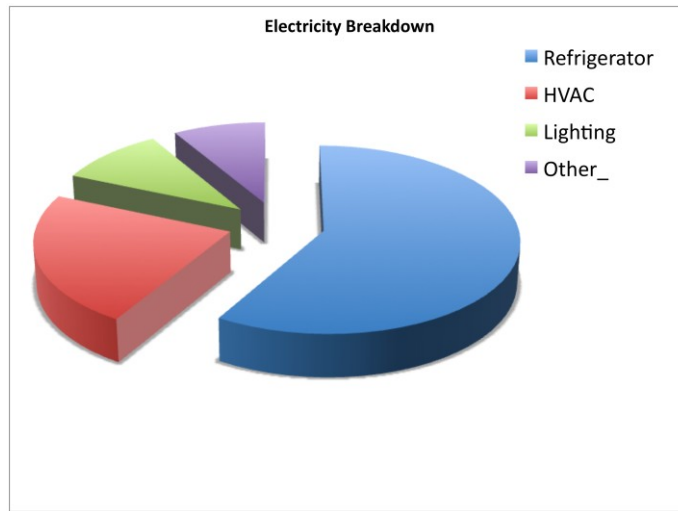


Name

Model:

# Spending Trends

## Electricity breakdown per device



Weekly

Monthly

### FULL LIST

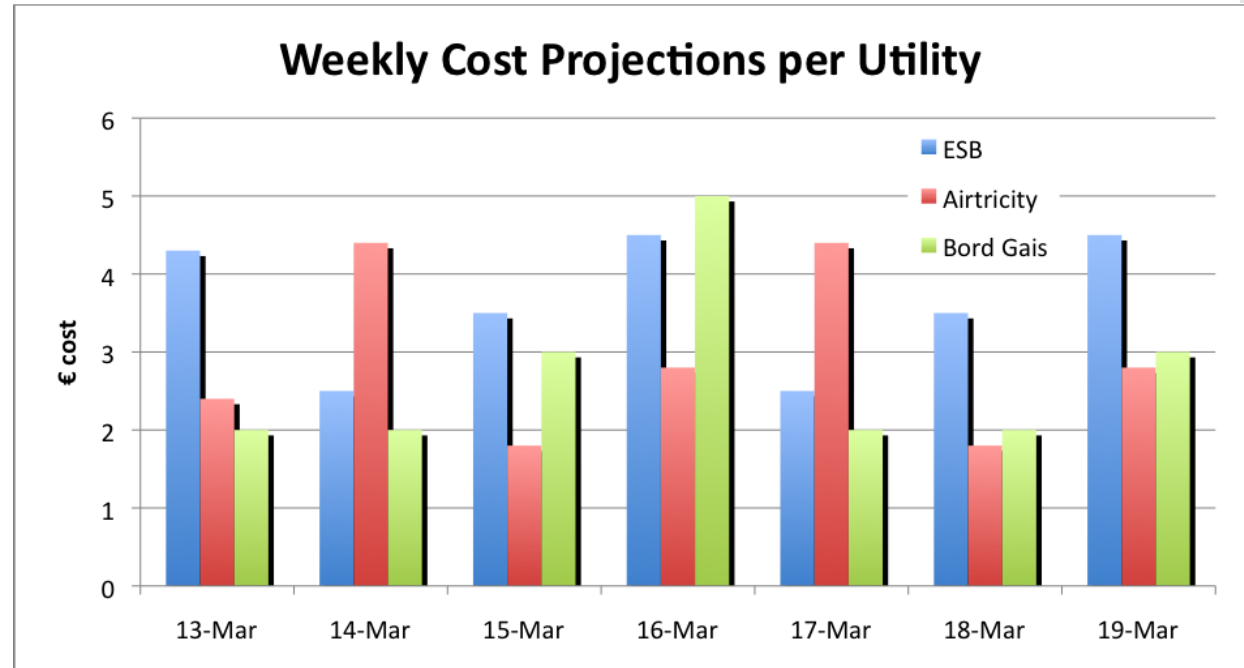
- 1.Refrigerator€ 135
- 2.HVAC €230
- 3.Lighting € 170
- 4.Dish washer€ 5
5. Coffee maker € 3
- 6.Electric heater € 2

...

**Click on the chart for recommendations how to save money**

# Provider/tariff Projections

- Weekly/monthly
  - Provider projections
  - Flat rate/night saver

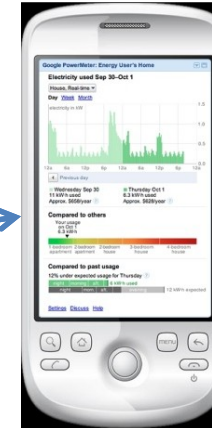


# Planning

## Alerts and energy predictions

### Sms/email

- Budget alert
- Periodical notification



### Saving predictions on

- Local Energy Providers
- More suitable electricity plans
- Alternative energy sources



Utilities

For info: [ruzzelli@ucd.ie](mailto:ruzzelli@ucd.ie)

...going forward, we are looking for strategic partners to help CLARITY bring this technology to market



questions

