Energy Research in CLARITY: Achieving Efficiency by Sensing Consumer Behaviour

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CLARITY: Centre for Sensor Web Technologies
The CLARITY centre

- €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

- 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:

- Marine Institute
- EPA
- Irish Hockey
- Tennis Ireland
- The Alzheimer Society of Ireland
- National Museum of Ireland

Other Industrial Collaborators include:

- Disney
- Amdocs
- Tyndall National Institute
- QinetiQ
- DCU
- UCD Dublin
- IBM
- Critical Path
- CR MUSIC & ENTERTAINMENT
- TSMC
- Wirelite Sensors
- Fairview Analytics
- ESL Electromagnetic Solutions
- FX PAL
- ESA
- Grenmore Limited
- Microsoft Research
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 footprinting
- Energy recommendations
Carbon Footprinting

Contribute 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.
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
Visualisation

- No deep complex navigation
- Bright screen vs. dark screen
IHD + Home Desktop App...

CONTEXTUAL COMPARISON

COST TO USER

HISTORICAL QUERIES
As with other similar studies, even at this early stage we’re already noticing the normal 5-15% drop in electricity consumption …
CO₂ > electricity only...

- 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$_2$

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$_2$ emission…
Driving + Home CO₂ Web Page

**Power Consumption**

**Expected Usage:** 18.96 units (C3.00)

**Consumed So Far:** 15.22 units (C2.46)

Average unit price: 0.15¢
Daily flat rate: 0.25¢

**Power Consumption**

**Expected Usage:** 0.74 units (C0.12)

**Consumed So Far:** 0.67 units (C0.11)

Wednesday 10-Mar-2010 9am-10am
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
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

Power (KW) vs Time (m)
Home Deployment

- Shower + vacuum
- Electric oven + shower
- Kettle
- Electric Oven
- Electric Boiler
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

Local Processing:
Load recognition, energy cost breakdown

Main Fuse box
Energy Monitor
WWW
DB
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 $P_f$

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

Display of neural network data: Fridge, Microwave, Kettle, Heater

>87% accuracy
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

...signature making in progress

Name: 
Model:  
Spending Trends

Click on the chart for recommendations how to save money

- Pie charts
- Timeline
- Merchants

Electricity breakdown per device

- Refrigerator: €135
- HVAC: €230
- Lighting: €170
- Dish washer: €5
- Coffee maker: €3
- Electric heater: €2

FULL LIST

1. Refrigerator: €135
2. HVAC: €230
3. Lighting: €170
4. Dish washer: €5
5. Coffee maker: €3
6. Electric heater: €2
...
Provider/tariff Projections

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

[Bar chart showing weekly cost projections per utility for different dates]
Planning

Alerts and energy predictions

Sms/email
- Budget alert
- Periodical notification

Saving predictions on
- Local Energy Providers
- More suitable electricity plans
- Alternative energy sources
...going forward, we are looking for strategic partners to help CLARITY bring this technology to market

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questions