# BIRD-WATTCHING: EXPLORING SONIFICATION OF HOME ELECTRICITY USE WITH BIRDSONG

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## ABSTRACT

This paper reports on work in progress to develop *Powerchord*, a near-real-time sonification system for electricity use data. Built around a common model of UK electricity monitor, Powerchord plays a variety of birdsong of different intensities in response to the instantaneous power readings from multiple household appliances, providing a form of ambient feedback intended to fit with the soundscapes of everyday domestic life while still enabling a deeper understanding of the energy use of appliances in the home.

We start by setting the context of the broader 'design for sustainable behaviour' and energy use feedback fields, noting the predominance of visual feedback displays. We then describe findings from a programme of design research with householders, which highlighted that energy's 'invisibility' is a barrier to behaviour change. Co-creation work with householders led to exploring the development of sonification of energy data, first in summary form, and then in near real-time. The affordances of birdsong are discussed, and future research possibilities outlined.

## 1. INTRODUCTION: THE CHALLENGES OF ENERGY BEHAVIOUR CHANGE

Design for behaviour change has grown significantly as a field of research in recent years [1]. It aims to reduce the undesirable social and environmental impacts of products and services, or increase the desired impacts, through design (in a broad sense) concentrating on *understanding* and *influencing* people's interactions with technology. It is inherently multidisciplinary, drawing on knowledge, perspectives and models from a number of fields relating to human behaviour.

'Interventions' largely take the form of redesign of products and services themselves, or the design of interfaces, usually digital—and usually visual—which give users information and feedback (and sometimes *feedforward* [2]) on use or the impacts of their actions. The digital approach builds on significant work in human-computer interaction (HCI) on *persuasive technology* [3] and on the effectiveness of behavioural feedback from other disciplinary perspectives. The field's growth parallels an increased policy focus on 'behaviour change' for social and environmental benefit, drawing on behavioural economics and 'choice architecture' [4] and addressing everything from encouraging exercise and healthy eating, to compliance with tax return procedures, as well as sustainability issues such as water and energy use, recycling, and transport choices.

A proliferation of taxonomies and models of behaviour change techniques, and practical guides for designers working on behaviour change [5,6,7], reflects this popularity: it is a fashionable field commercially as well as academically and politically.

However, while some techniques use multisensory approaches, the majority of feedback-based systems are primarily visual [8], and often assume a particular level of numeracy, or data literacy, on the part of the user. There is currently little work exploring the potential of non-visual interfaces in this context; sonification could enable ambient comprehension of many kinds of data relevant to behaviour change contexts [9].

### 1.1. Energy: a domain where most feedback is numerical

*Energy use* is one of the major issues on which design for behaviour change—more specifically, *design for sustainable behaviour*—has concentrated. Reducing our energy demand, and in turn our carbon dioxide ($CO_2$) impact, through influencing public behaviour, is a significant research topic across multiple intersecting technological and social science disciplines.

Aside from design work on technology or infrastructure change, such as retrofitting insulation to buildings (thus—

hopefully—leading to reductions in heating use), the majority of work on influencing energy use through behaviour change concentrates on numerical, visual feedback displays for electricity or gas use, in both domestic and commercial environments. There are numerous studies and meta-analyses looking at the effectiveness of different kinds of feedback (real-time, summary, normative, and so on) in this context, and the adoption of these kinds of displays within household life. As technology develops, the opportunities afforded by networked *smart meters*, which enable adaptive pricing changes (as well as providing energy utilities with much more detailed usage data) are also being explored, driven by legislation (e.g. in the UK, it is government policy for all homes and small businesses to have smart meters installed, with displays, by 2020 [31]).

While some influence on behaviour, leading to changes in energy use, has been found from feedback displays [e.g. 10], the situation is complex: simple numerical feedback may not take account of the realities of household life [11, 12, 13] or people's understanding of units and quantities [14], nor link people to wider comprehension of the energy system [15]. Most visual displays require the householder to look at the display—often a small LCD, or a web dashboard—regularly, and actually be able to act on it, for it to have any effect, assuming a model of individual householders as "micro-resource managers" [14], and while there have been some more ambient coloured light-based systems for displaying electricity use, such as DIY Kyoto's *Wattson* and Ambient Devices' *Orb*, and clever use of thermal imaging [16], these are exceptional.

As part of SusLabNWE, a European Living Lab project [17], we have taken a 'research through design' approach to exploring people's relationships with energy in everyday life. Initially, we worked with nine diverse households across London and the south-east, where possible integrating quantitative sensor data with qualitative insights. In this first phase of the project, we visited people at home, investigating stories of daily interactions with heating, lighting, appliances, and electricity monitors, and people's understanding of energy. This was followed with activities exploring themes including metaphors for energy, narrating everyday routines, and addressing 'What does energy look like?' through drawing exercises with members of the public, children, teenagers and energy experts [18].

### 1.2. Making the invisible audible

We ran a co-creation workshop with our householders, in which—working with designers—they created concepts for new kinds of interface or device which they felt would help them reduce their energy use. This was followed by a 'Home Energy Hackday' at the Science Museum's Dana Centre, bringing together designers, energy experts, and the Internet of Things community to explore new ways of understanding and engaging with energy, building on the ideas from householders.

One of the main themes that emerged was the general *invisibility* of energy in modern life, and its relation to behaviour. Householders' mental models of energy itself, and energy-using systems such as heating [19], together with the relative importance of different energy-using systems in the home, were partly determined by what was most salient—such as lighting—rather than 'hidden' uses such as heating and cooling (this aligns with other research, e.g. [20]).

By people's own admission, much of the energy 'wasted' at home through particular behaviours, such as leaving heating on when going out, or leaving lights on elsewhere in the house, was partly due to its invisibility from the perspective of where they were at the time. People questioned how they could change how they use energy when they can't easily see or feel it, or get a sense of the changing rate at which it is being used. There was confusion with units, for example between kilowatts as a measure of power and kilowatt-hours as a measure of energy. One householder told us:

> "I worked out that through gas and electricity every year, the average house gets the equivalent of a bit over three tons of coal delivered completely silently and without any mess.
> And go back a hundred years ago and everyone would have a really good quantitative understanding of how much energy they used because they had to physically shovel the stuff."

This issue suggested opportunities for visualisation beyond numbers, but also non-visually, for example *sonification* [21] of energy use. In the co-creation workshop with householders, one person suggested that being able to 'listen' to whether appliances were switched on or not, and what state they were in (e.g. listening to a washing machine will give a good idea as to where it is in its cycle), was potentially more useful for understanding how to reduce energy use than a visual display.

Another householder suggested—in response to discussion of smart metering and demand-based pricing changes—that being able to 'hear' the load on the grid (for example, a pleasant background hum could become discordant as the grid's frequency changes due to high demand, or the tick of a clock could become temporarily faster) would be less intrusive than, for example, a text message or a flashing light. There was discussion around the quality of the sound, for example whether a lower-pitched 'rumbling', like thunder, would be more appropriate for greater rate of energy use (i.e. power) than a higher pitch, and whether there could be a music system that somehow 'distorted' what it played when the house's energy use was higher than normal. The thunder-and-lightning theme had also come across in many drawings of 'What energy looks like' [18].

In general, the preference was also for displays which were disaggregated by appliance, or at least by 'function groups' of appliances, since this would enable actual behavioural responses, in terms of understanding where energy was being used, and then doing something about it. Similarly, the preference was for real-time displays rather than solely summaries, although these can also offer useful insights.

There are echoes here of early work in calm technology and ubiquitous computing, such as Natalie Jeremijenko's *Live Wire (Dangling String)* [22], or Anders Ernevi et al's Erratic Radio [23], in which the 'display' fits with the existing daily visual landscape and soundscapes of the office (or home). Sonification of energy use along these lines could enable *ambient comprehension* of energy use with multiple appliances, including pattern recognition and state changes [9].

Relating sound to energy use is not unknown. In explicit data sonification, Opower's 'Chicago in the Wintertime' [24] turns the city's residential electricity use over winter 2012-13 into piece of music; less directly, Foster et al's 'Power Ballads' [25] made use of aversive feedback based around popular UK chart music, automatically posted to the user's Facebook wall,

Figure 3: *Sound of the Office* audio file on SoundCloud: http://v.gd/officesound

based on high levels of electricity use. As part of our Home Energy Hackday, RCA student Ted Hunt demonstrated his ‘audio plug socket’, which uses a small MP3 player hidden within the socket to play provocative spoken word quotes around energy use and political issues such as fracking, when the socket is in use.

## 2. INITIAL EXPERIMENT: SOUND OF THE OFFICE

To explore energy sonification, we chose CurrentCost electricity monitors, as supplied to many utility customers in the UK, including some of our participating households. The CurrentCost ‘ecosystem’ includes a bridge connecting to a router and posting data to a website, and individual appliance monitors (IAMs) wirelessly connected to the base unit, enabling disaggregated data. CurrentCost has been used in a number of Internet of Things (IoT) academic studies [e.g. 26]. The system can also monitor gas use, if a household has a compatible meter.

An initial energy sonification *parameter-mapping* experiment was carried out in a university office. Three CurrentCost IAMs monitored electricity use of a kettle, a laser printer, and a gang socket for a row of desks, sending data to the CurrentCost website from where it was exported as a CSV file. Data for 12 hours—from midnight on a Sunday to midday Monday—were scaled [27] and manually converted into a three-track 30-second MIDI file using `csvmidi` and Aria Maestosa, with *lower* pitches representing *higher* power, and vice versa, and hourly drumbeat ‘ticks’ [21]. MIDI instruments represented appliances: a tenor sax is the kettle (up to 1.5kW in use); a synth brass is a Kyocera laser printer (background whine of 10W on standby, deepening to 300W-500W in use); and a polysynth is the gang socket, with laptops (15W-50W) plugged in during the day and a charger (1W) otherwise.

As the audio starts, over the printer’s whine, the kettle comes on as a security guard makes himself a 1.00am cup of tea. Then, early in the morning, the cleaners used the kettle—twice quickly (reboiling?) and then once again. Suddenly, at 9.30am, as staff arrive, the kettle goes on, laptops are plugged in, the printer starts printing and the energetic hubbub of office life appears.

The approach was conceptually similar to Hermann et al’s ‘auditory weather forecasts’ [28]—a summary ‘gist’, presented after the fact. We have subsequently also found Matthew Bay Kenney’s conceptually similar (but much more elegant) work at Penn State on sonifying the energy use of six office appliances over 20 hours [29].

Figure 2: Testing parsing of data from an intact CurrentCost, and triggering audio tracks.

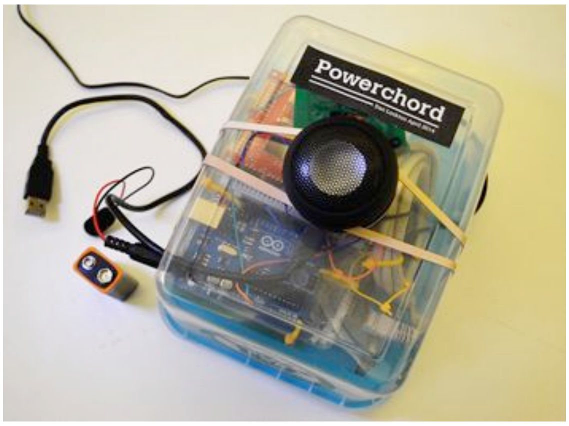


Figure 1: Working prototype of Powerchord.

While summary sonification provided an interesting auditory display of multiple appliance power use over a period—and provoked discussion in the office over the routines of the security guard and cleaners, otherwise ‘invisible’ characters in office life, it was clear that for the household context as explored in the co-creation workshop, (near-)real-time ‘closed loop’ feedback would offer many advantages. A family could use the sound to understand current power use, and change appliance use directly.

## 3. POWERCHORD (BIRDSONG EDITION)

To achieve near-real-time sonification of electricity use, it was decided to do processing locally rather than online. Building on others’ code [30] for extracting CurrentCost data output, we developed *Powerchord*, an Arduino-based system (Figs. 2, 3 and 4) which parses the CurrentCost’s XML output every 6s, extracting the IAM power figures for individual appliances, and mapping these figures to ranges defined in code. Three IAMs are used, though the system could support up to nine. While the initial proof-of-principle prototype retained the CurrentCost device intact, the next version involved dismantling it and using

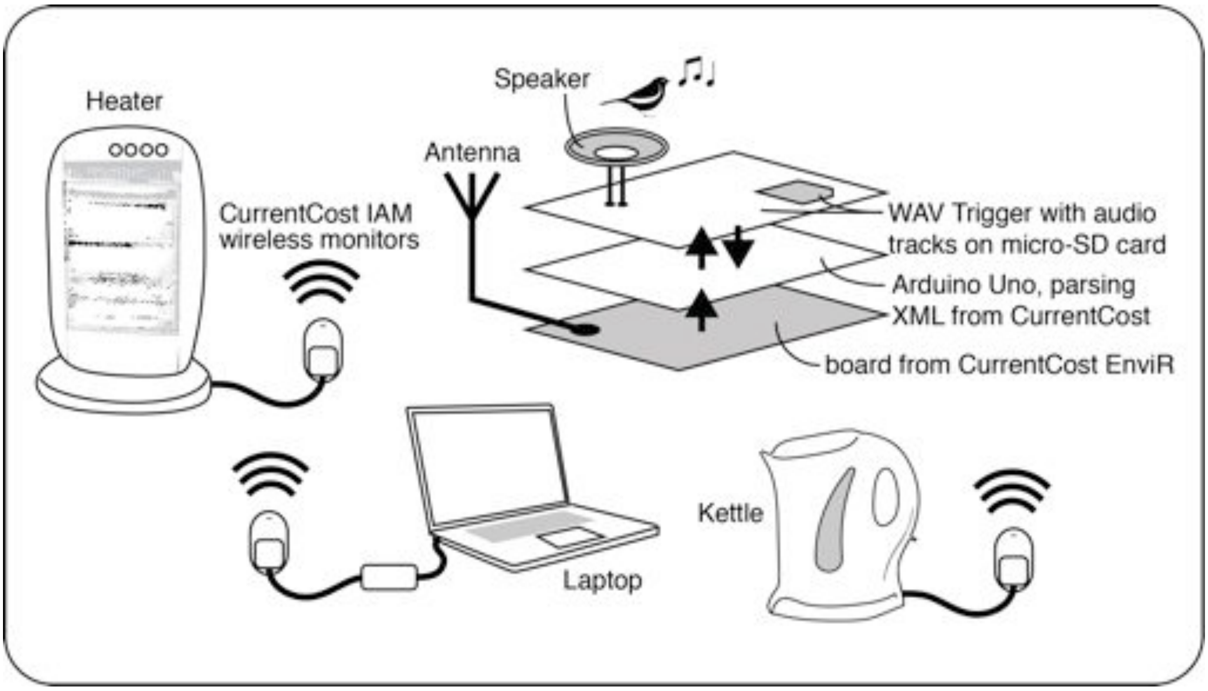


Figure 4: The components of the prototype Powerchord system, with three example appliances.

only the parts which were needed (meaning that the LCD was removed, for example).

Initially we worked with a GinSing synthesizer shield for the Arduino, producing different tones (with various effects) mapped to power ranges, but, lacking experience in composition and sound design, the results we were able to produce were aesthetically unattractive to say the least.

We decided instead to build on the idea from our co-creation work with householders around *fitting into the existing daily soundscapes of the home*—something more like the tick of a clock, or the sound of distant church bells, 'repurposing' them with extra energy information. This meant that recordings of these sounds, suitably modified, and triggered in appropriate circumstances, could be used, rather than tones being generated in real-time. As such, we linked the Arduino to a Robertsonics *WAV Trigger*, enabling polyphonic playback for multiple audio files simultaneously.

Power ranges were defined to match the typical ranges found in household appliances, from <10W for trickle charging, to >2kW for electric heaters. For each power range, for each appliance, the WAV Trigger plays a particular audio track stored on a memory card, and looped until the power range changes. Lower ranges can be set not to result in any sound; the prototype has both a loudspeaker and a headphone socket.

### 3.1. The affordances of birdsong

For the sounds themselves, the affordances and associations of *birdsong* and bird calls were identified as fitting the model of daily soundscapes, such that rather than being part of the "increasing clutter of beeps and bleeps" [9] of feedback people experience from the electronic devices around them, a natural, largely non-intrusive ambient set of sounds could serve to signify energy usage information.

On a somewhat reductionist level, the fact that we hear birds calling and singing every day—and notice when they are abnormally loud or agitated—yet are usually unable to understand what the sounds 'mean', suggests that birdsong represents an opportunity for this 'unused auditory bandwidth' to be exploited as a channel for information. More poetically, the subjective beauty of most bird vocalisation, such that even birds' alarm calls are usually considered pleasant (and very unlike the alarm sounds generated by most electronic devices), offers a different quality of experience to direct tone-mapped sonification. Connecting people better to the wider, complex systems around them, in which their behaviour plays a part—such as energy use—suggests that 'natural' metaphors may be particularly relevant [18]. One might equally imagine the sound of a river, waterfall, or the sea, or wind in the trees, as being appropriate in this context, or indeed other weather-based sound collections, such as taking further the thunder-and-lightning theme arising from householders' suggestions.

We selected common garden birds whose calls and song would likely already be familiar and potentially part of householders' daily soundscapes—blackbirds and house sparrows—and also, as a counterpoint, the distinctive calls of herring gulls, which potentially evoke seaside memories, but which are not 'tranquil' in the same way.

Using Xeno-Canto, a worldwide Creative Commons-licensed database of bird vocalisations, a number of clips of calls and song of blackbirds, house sparrows and herring gulls were edited in Audacity, such that that different intensities of

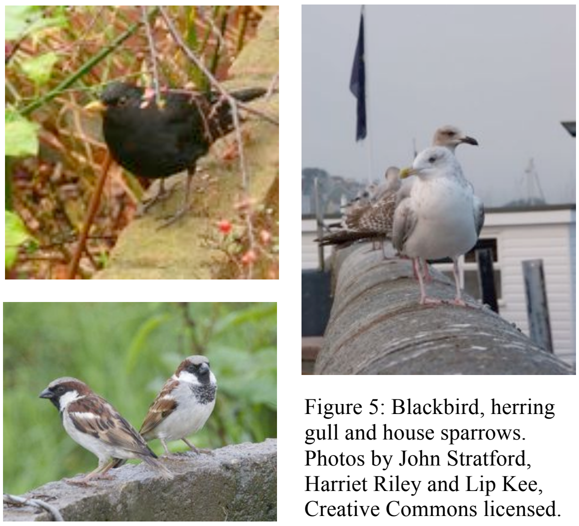

Figure 5: Blackbird, herring gull and house sparrows. Photos by John Stratford, Harriet Riley and Lip Kee, Creative Commons licensed.

call and song (number of birds, agitation level) could map to the power ranges, with different birds for each appliance (e.g. herring gulls for an electric kettle, since it is used intermittently rather than continuously, and the startling sound of the gulls is aligned with the sudden change in household energy use that switching on a kettle normally entails). A video is available—http://v.gd/powerchord

### 3.2. Testing

This paper reports on work very much in progress: at the time of writing, the prototype Powerchord, with blackbird, house sparrow and herring gull sounds loaded on its memory card, is currently being trialled in one of the authors' homes, to understand how, in practice, it might be used in everyday life, and to refine the design in the light of this—essentially, is it something a family can live with?

Questions under consideration include appropriate volume for the sound output, as well as what power levels ought to trigger particular outputs (should the 'background' electricity use of a house, such as the refrigerator, be monitored or ignored from the sonification perspective?), and whether they should do so continuously or only on edge triggers (e.g. at the point that the kettle or an electric heater is switched on, not all the time that it is switched on). Does the device lose its effect or its salience if it is continuously running?

Powerchord will be on display at the Victoria & Albert Museum's 'Digital Weekend' in September 2014, part of the London Design Festival, to garner further public reaction and suggestions, and improved prototypes will then be installed in three houses over autumn-winter 2014 which are also having their electricity use monitored separately, to understand how, in practice, householders with different lifestyles make use of Powerchord, whether their understanding of the energy system changes, and—although drawing on a very small sample size—whether it has any quantitative effect on electricity use through behaviour change. For example, if a 2kW electric fan heater results in the sound of a loud, angry group of herring gulls, while a smaller 400W heater leads to a subjectively more pleasant chattering of sparrows, does this make it more likely that a householder will choose to use the 400W over the 2kW heater?

The aim is to contribute, in an exploratory way, to energy use feedback work in the emerging 'design for sustainable behaviour' field, as outlined in section 1, through demonstrating the possibilities of sonification and non-visual feedback.

In terms of future research questions, if it is possible to develop Powerchord to the stage of being a relatively reliable platform for triggering particular sound files, polyphonically, in response to electricity (or gas) usage levels, in near-real-time, there are a number of possible avenues to explore, including linking sound to the load on the electricity grid (particularly where this may lead to different pricing per unit), applications in local or community microgrids where generation as well as consumption (and the balance between them) comes into consideration, and, as mentioned earlier, cases where edge triggers could be useful, e.g. to signal when a heating system thermostat switches a boiler on or off. We look forward to being able to report on future research on the project website, http://suslab.rca.ac.uk

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