Electric Acoustic: Exploring Energy Through Sonic & Vibration Displays

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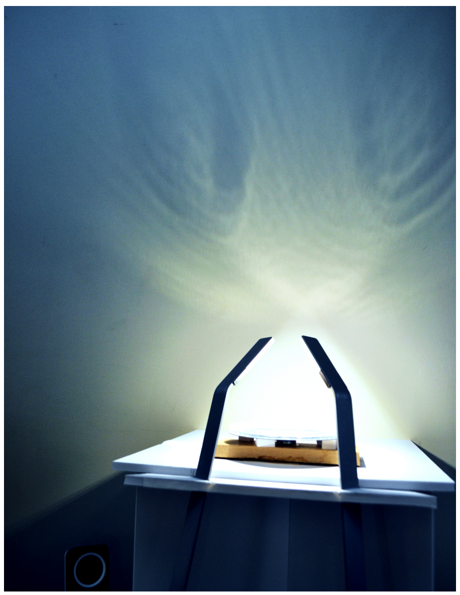

Figure 1: A dynamic reflection on the wall produced by the cymatic display—a mirrored dish of water vibrating with changes in the building's electricity use, synchronized with ambient sonification of the same data.

ABSTRACT

'Energy' is an abstract concept, invisible except through its effects, yet with vast geopolitical and environmental consequences—while driving many everyday practices. It is a curious 'material' to work with for designers, with experiential properties which are underexplored. In *Electric Acoustic*, we are exploring both sonification and vibration (cymatic displays) as media for experiencing energy, specifically electricity use. These materializations potentially enable deeper engagement with the invisible systems and infrastructures of everyday life. This short paper reports on our preliminary experiments and some of the issues and considerations arising during this initial exploration.

KEYWORDS

energy; sonification; interface design; qualitative interfaces and displays; cymatics; vibration.

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Figure 2: The faded spines of books kept on a windowsill are a form of summative solar 'energy' display: the integration of power over time produces an indexical visualization [15].

Energy vs power: dimensional analysis

Very often we experience energy as a flow, not as a stored quantity. We can't feel how much electricity is 'in' a battery by picking it up (though it is true that we can feel the weight of a can of gasoline). We could put the battery on our tongue [8] to experience the flow of energy (or, of course, actually connect it to something like a light bulb). We feel the flow of the wind, the 'flow' of sunlight. We are, technically, feeling *power* (the rate of change of energy) not energy.

A basic question for designers working with energy thus might be: are we working with energy or power? *(continued on next sidebar)*

INTRODUCTION: WHY ENERGY IS INTERESTING

This short paper describes *Electric Acoustic* (Figure 1), an experiment in designing a new kind of display for energy use through using sound and vibration. We are exploring the possibilities of considering energy's properties as something for designers to work with, rather than simply a source of quantified data to display.

'Energy' is an abstract concept, invisible except through its effects, yet with vast geopolitical and environmental consequences. We encounter it through everyday practices, plugging in appliances, charging devices that obsess us and structure our days, but at another level we fight wars and destroy wildlife habitats to extract a bit more energy from the compounded dead bodies of other species and plants buried in our earth. We learn at school about electricity, coal, oil, nuclear, wind, sunlight, and how energy can neither be created nor destroyed, but we are constantly warned about not wasting it. Sociotechnical imaginaries around energy can be highly politicized, from nuclear power [7] to climate change [20] and the emerging solarpunk genre. At the level of everyday interactions, energy's invisibility and essential 'mystery' leads to a whole variety of mental imagery and metaphors [2] and mental models of the systems of our homes and workplaces. While within the HCI community there have been innovative design attempts to 'materialize' energy [16], or even to treat it as a 'ghost' in the home to detect [1], the majority of HCI work on energy has been about testing the efficacy of displays to change people's behavior around their energy use, usually through quantification of individuals' actions, although group [10] and organizational [14] projects are also emerging. There is an opportunity for exploring this space further, through different kinds of interface and display for energy which address it at a more qualitative [11] level, which we seek to explore in *Electric Acoustic*.

DESIGN AND ENERGY

Designed interfaces and artifacts seeking to influence people's energy use have become common in HCI in recent years, framed as design for behavior change [19], often via visual displays giving users information and feedback (and sometimes feedforward) on use or costs of electricity or gas, or more rarely, the impacts of their actions. However, numerical feedback may not take account of the realities of household life [18], nor link people to wider comprehension of the energy system [4], and substantially disconnects the user from the properties of energy itself. As Pierce and Paulos [16] put it, 'We are unaware of energy largely because it does not have (and is not designed to have) a strong tangible presence in our lives'. Perhaps there is value in engaging people in understanding or experiencing energy rather than trying to change behavior directly; while there have been some more ambient colored light-based systems for displaying electricity use [6], use of thermal imaging [5], and engagement with wider aspects of our relationships with energy [12] these are exceptional. There is

Energy vs power: dimensional analysis *(continued)*

How does that affect our choices? Perhaps we are actually using a flow of energy as the 'input' but transforming it into a stored quantity, or otherwise integrating it with respect to time, to 'display' it?

For example, something showing accumulated sunlight-hours, whether an electronic display or a piece of dyed cloth or book spine that fades in the sun (Figure 2), is in effect integrating power over time to display a representation of a total amount of energy received or stored. And, vice versa, we might be working with a quantity of energy itself but turning it into a flow—power—to make it experiential or interpretable, or how it changes over time.

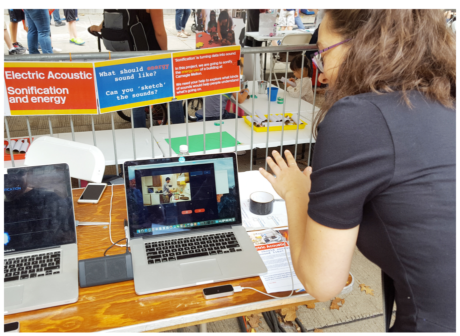


Figure 3: A Maker Faire visitor uses a Leap Motion to 'sketch' the sound of energy being used in a video of kitchen activities

less work exploring the 'materialization' of energy, making use of its properties while translating it from invisible to experiential.

What would it mean to think about designers working with energy's properties instead of only something to monitor and quantify? Do the different forms in which we encounter energy make a difference? There are no 'right' answers here, but these are interesting questions to consider. Energy enables things to perform actions. Is it a 'catalyst', or is that introducing a metaphor too far? Does energy have its own 'agency'? It can flow when not intended (with dangerous consequences, or wasteful if we are not making productive use of what it does). Its use or flow can be a signal (lights left on). Directly, we might imagine using electricity to burn marks on something, to electrolyze something, to create patterns (e.g. Lichtenberg figures in wood), or to shock a user [8], making 'electricity' visible or tangible. Our aim here has been to consider energy's properties as engaging rather than aversive: we are not trying to put people off using it, but to provide new ways of understanding or experiencing.

SONIFICATION (AND VIBRATION)

One underexplored property of energy is its ability to create sound. The 'electrical hum' or whine of power lines, transformers, motors/pumps, fluorescent lighting, and so on, provides an interesting starting point for more 'direct' *sonification*, but aside from literally amplifying this to make it more audible, some kind of translation or mapping is needed [17]. The first author has previously explored sonification of energy use in the *Powerchord* project [9], which used birdsong to provide real-time feedback on the electricity use of different appliances, but there is still relatively little work in this field. For example, Cowden and Dosiek [3] have built auditory displays of power grid voltage. There is no obvious 'right' set of dimensions for mapping energy to sound. Following the Powerchord work, in which complexity of sound, 'agitation' or 'arousedness' was mapped to power draw, we were curious to explore other kinds of mappings between power and sound. Our initial attempt, as a proof of concept, involved the simple mapping of power (in W) to frequency of a sine wave, where a higher measurement of power use produced a higher pitch, and vice versa. However, this mapping conflicted with a commonsense intuition about relative pitches, that larger objects (and animals) have larger resonant surfaces and cavities (and thus deeper pitches), and vice versa (see Maker Faire sidebar). A low wattage measurement from modest electricity use produced a low pitch that normally corresponds to larger (and perhaps more powerful) objects and phenomena—intuitively misleading. As a reviewer of this paper noted, there is perhaps a distinction between *higher* and *larger* amounts of power when considering psychoacoustic mapping, which makes sense experientially, but perhaps not when solely thinking in watts.

Sketching sound at the Maker Faire

We ran a booth at the Pittsburgh Maker Faire in October 2017 to get insights about how people perceived mappings between power and sound characteristics. After introductory questions about energy in the home, a series of fun challenges invited visitors to experiment with using Leap Motion sensors to sonify their hand movements, creating different sounds through hand position and speed of movement. Once 'trained' using the Leap Motion, participants watched videos of household appliances being used (e.g. a kitchen environment with someone cooking a meal using a microwave oven, opening the fridge, and using a hob), and asked them to 'sketch' (Figure 3) the sound (using a Leap Motion controlling pitch and volume) that they would expect to hear if they were listening to the energy being used. Do people maintain a kind of 'background hum' of energy use that varies when devices are switched on or off? Does the act of opening the fridge, or switching on a dryer, differ in how its energy use 'sounds' compared with the device being on continuously?

In the event, the exercise was probably too difficult for many participants just introduced to using the Leap Motion, but one pattern that emerged was that a change in (assumed) power draw (when an event occurred) was what often seemed notable to people—it was not so much the absolute level of power, but 'deltas' in it (up or down) which provoked people to signal with a temporary 'blip' in the sound they were producing with their hands. This suggested a potential route to explore for the next stage of the project.

Electric Acoustic installation

We were given access to electricity use data for a whole building at Carnegie Mellon University, and decided to use this as the basis for exploring ambient sonification. The dataset comprises measurements of the apparent power draw (in volt-amperes (VA), but practically equivalent to W), measured every 30s, for three months at the end of 2017 (more than 175,000 data points). The data shows periodicities, from the daily cycle of electricity usage from an ever-shifting multitude of parallel users, to distinct plateaus from central air conditioning. The opportunity arose for a small installation in a heavily-trafficked hallway of the building, and we decided to try to represent the dynamics of parallel, simultaneous electricity use by many users through both audio and visual media. In the event, a three-part installation was built, with the dataset feeding a sonified ambient soundtrack ('Electric Ensemble'), a sound-driven vibration display, and a dynamic visualization of the building (Figure 4).

Sonification: Electric Ensemble. Following experiments with direct mapping of power values to the pitch of an audible soundwave (see above), we explored mapping the power values to the frequency of a lowpass filter filtering white noise. High electricity usage caused the lowpass to include all higher frequencies, and low measurements cut out the high frequencies, leaving only the lower. This sounded much like ocean surf, or wind speed rising and falling, where high frequencies added an intensity and harshness, corresponding to increased electricity use. While the periodicity was very apparent at higher speeds, at speeds closer to real-time it became very difficult to discern changes. The sound's evocation of the wind perhaps risked mixing metaphors in this context—although could be highly appropriate in others, for example a wind turbine installation.

The measured electricity use in the building is an ever-changing summation of the electricity used by thousands of electronic devices and infrastructure. In order to capture that dynamic, an idealized sonification might produce one voice per electricity-draw-source—a charging phone, an automatic light, an elevator, etc. When a device begins drawing from the grid, the voice turns on, and when the device stops drawing electricity, the voice turns off. Higher electricity-draws such as building air conditioning produce deeper notes whereas lower electricity-draws such as charging phones produce higher notes, indicating their relative tininess. As the time resolution (30s) of the dataset is too sparse to pick up on every change in electricity-draw state, this idealized sonification can only be approximated. We built on an insight from the Maker Faire around *changes* in power draw and developed a sonification system looking at the delta from one datapoint to the next. If a device turns on or is plugged in, it creates a positive delta in the power draw, and when turned off or unplugged, it creates a negative delta. For each positive delta, the system turns on a note of a frequency inversely correlated with the delta's magnitude. The note is turned off when a negative delta of comparable magnitude arrives, presumably indicating that the device has turned off or disconnected.

Figure 4: Created in Processing, this visualization used the building's windows as a graphic equalizer-style bar chart, showing the contrast in hour-by-hour energy use on the hottest and the coldest day observed over three months, through blinking windows as the display cycled through each day. Columns depicted hours; rows showed power ranging from 96–280 kVA.

Notes on notes

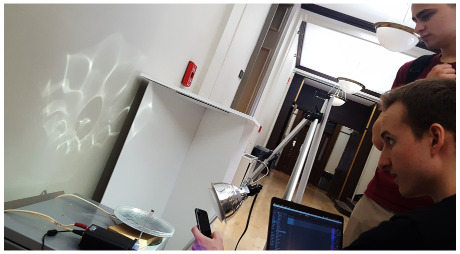
To be a pleasant (rather than aversive) ambient installation, the sonification needed to be harmonious. However, once all notes are constrained down to a harmonious subset, the fewer available notes reduce the granularity of the mapping. This sonification system uses a *Cmaj7add2* chord (the notes C D E G B). To avoid the muddiness present at lower registers, the lowest note was chosen to be C2 (65.41 Hz). To avoid the shrillness present at registers above 1 kHz, the highest note was chosen to be B5 (987.77 Hz). This leaves four octaves of five notes each. The range of deltas from the apparent power use dataset were from 0 VA to about 80,000 VA. Dividing this range into twenty equal sections leaves each note being triggered by a range of about 4,000 VA, or 20,000 VA per octave.

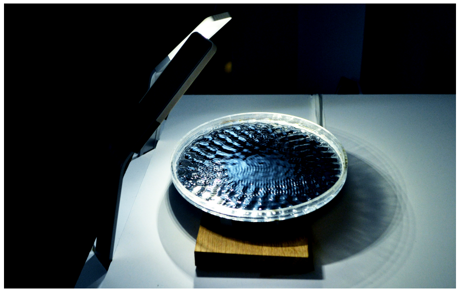
The sonification was processed in Max MSP, where 20 parallel sine wave oscillators tuned to four octaves of *Cmaj7add2* were individually triggered by their corresponding delta range. Heavy and long-term electrical draws like air conditioning are audible as low pitched drones whereas tiny, short term draws are audible as flickering, active, mid to high frequencies. While there are limitations in this implementation, it produced a pleasant, dynamic, ambient sound which visibly mapped to the cymatic display (next section), and could be operated at different speeds, allowing for real-time or high-speed playback (for perception of dynamics and periodicities in energy data that are normally too long and hidden to perceive).

Cymatic displays. While directly mapping power values to the pitch of an audible soundwave—with an unmoored speaker sitting on the desk and moving as it vibrated—we decided to explore further how this vibration might be used as a kind of display in itself, building on ideas around levels of 'directness' and indexical visualization [11, 15] but also the notion of energy itself as vibration, for example as visualized through alternating current waveforms. First, we placed a few drops of water on a plastic bag on top of the speaker and watched patterns emerge and vanish. While *Chladni figures* have been explored in artistic and scientific applications, often using powders to produce distinctive resonance patterns, *cymatic* displays in general have not received much attention in HCI. McGowan et al's *CymaSense* [13] offers an interactive cymatic visualization (generated in Unity) as a way of exploring music visually, and artist Ginger Leigh produces large interactive cymatics experiences, but the field has potential for development in an interface design context. The basic process we undertook in *Electric Acoustic* was to experiment (in Processing) mapping of power values in the dataset to audio values centered around multiples of 200 Hz, but which were played through a speaker with the cone removed and a mirrored dish of water substituted. Shining light onto the dish of water at an angle (Figure 5) produced varying reflection patterns changing with the power value. Open Sound Cont1rol (OSC) was then used to synchronize the sonification and the cymatic display, and the complete installation featured reflection patterns on the wall behind the water dish, ever-changing as the ambient sound cycled through the three-month dataset. In practice, the use of cymatics here was not necessarily about producing *distinctive* patterns which someone could read as a particular power value, but the potential for this does exist, with careful choice of frequencies.

FURTHER WORK

The project described here is a tentative exploration using sound and vibration to produce a new kind of display for energy use, inspired by properties of energy itself. There is clearly significant further development potential, and we aim to explore in particular the ways in which understanding and deeper engagement with invisible systems and infrastructures of everyday life (rather than hiding them away) could be enabled through these kinds of materializations.





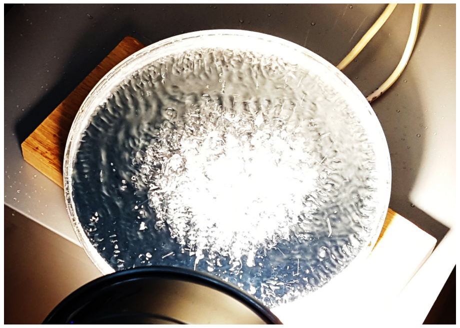


Figure 5: Developing the cymatic display.

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