Sustainability by Design?: from micro-studies to macro-action

Oliver Bates, Vanessa Thomas,
Adrian Friday, Mike Hazas
School of Computing and
Communications
Lancaster University Lancaster,
UK, LA1 4YW
{o.bates,v.thomas1,a.friday,m.hazas}@lancaster.ac.uk

Abstract
Our recent work has taken a multidisciplinary and mixed-methods approach to studying energy use in the home, the energy impacts of daily food practice, and domestic thermal comfort. We're now engaged with attempting to catalyse innovation around energy reduction on our University campus to put our findings into action via an institution-wide 'living lab'. In this paper we draw design patterns and anti-patterns from our work, and particularly highlight the need for holistic studies to shape design, recognising the needs of stakeholders and organisational decision making in catalysing sustainable action.

Author Keywords
Design patterns; Sustainability; Methodology

ACM Classification Keywords
H.5.2 [Information interfaces and presentation (e.g., HCI)]: Miscellaneous.

Introduction
Our recent work has taken a multidisciplinary and mixed-methods approach involving the gathering of primary quantitative and qualitative field data. We have studied energy use in the home [1]; the direct and embodied impacts of food practice [4]; and attempted to understand and manipulate practices around achieving thermal comfort using

less energy [3]. We're now attempting to catalyse innovation around energy reduction and sustainability in research, teaching and operations on our University campus by creating an integrative data platform to support an institution-wide 'living lab'. In this paper we draw design patterns and anti-patterns from our hard won experience, and provide observations about the limitations of our studies of value to other researchers and practitioners in sustainable HCI.

Reflecting on micro-enquiries of everyday life

Focusing on the small, linking to the big

In the UK, food production, distribution and consumption accounts for 27% of total direct greenhouse gas (GHG) emissions. Changing from an 'average' diet to a plant-based one, could save 22% (26% for a dairy free vegan diet). This is over 40 Mt CO_2e per year [2]. Our 'micro-account' of four shared university dormitory kitchens over twenty-one days [4] captured participants' food preparation activity, quantified the GHG emissions and direct energy used to cook, and unpacked participants food practices.

Detailed studies of this kind are illuminating, despite the small number of participants: we were able to connect energy, efficiency and energy waste of foods cooked—there certainly were instances of profligate energy waste due to long-pre and post heat cycles, and 'overcooking'. But more importantly, when balanced against the majority of cooking cycles, we see this was a relatively small component of the overall direct energy involved with cooking. The diet we observed, while repetitive and not necessarily that healthy, was actually fast and convenient. This context is a critical as we see that embodied GHG in the foods' production and transport accounted for over 70% of the GHG footprint of the foods we observed, i.e. focusing interventions around dietary change is potentially much more significant.

- **Pattern**: reshaping food technology and encouraging sharing addresses 15% of direct energy impacts; 'big' HCI design needs to address competence, expectations and meaning around 'proper' and 'normal' food to make a sustainable diet convenient.
- **Anti-pattern**: a focus around direct energy in the home will limit the view to the appliance (pre- post- heating was only 2%), and not take into consideration how food fits with practices enacted in the home.

The need for a holistic view

IT consumption in the UK more than doubled between 2000 and 2009, and now comprises about 25% of domestic electricity demand [8]. A holistic account based on device inventories, fine energy measurements, and estimated embodied GHG puts energy use into context and help explains the 'why' of energy use. We showed that the yearly CO_2 emissions from IT's direct energy use is a small fraction of the emissions arising from manufacturing and transport ($<$20%) [1]; and that radically different impacts derive from remarkably similar sets of IT-supported practices, albeit at vastly different capabilities and qualities in service provision. Watching TV, surfing and writing essays on a laptop; versus the same practices carried out using a desktop connected to two monitors, for example. More complex *constellations* of linked devices set up for e.g. gaming, led to *exceptional* durations of energy use stretching well beyond the practices they were intended to support: constellations resulted in about one-third of the total media and IT impacts in our study (42% of the direct impacts, and 16.5% of the embodied emissions).

Compared to this, personal and wearable devices such as phones and tablets had very small embodied emissions (2%), and a vanishingly small direct energy demand. However, holistically, such devices have upstream impacts, and are increasingly seen to migrate and augment existing practices which increases the energy demand and data intensity of these practices [7].

- **Pattern**: Understanding the environmental impacts of digital technology and ICT reveals its holistic impacts; Understanding the complex interconnection of our digital technologies in 'constellations' have high data and energy demand.
- **Anti-pattern**: decreasing environmental impacts of digital technologies by increasing user awareness surrounding the impacts of digital technology; care in what we make convenient: 'media rich' forms of communication and sharing by default.

The need to reshape practice
Heating and cooling of indoor environments is resource-intensive and accounts for a large proportion of energy demand (estimated at 24% in the UK, and 18% in the US). The thermal environment can be hard to control, overheated, and contribute to expectations that indoor temperatures do not vary with the seasons or require appropriate seasonal dress [5]. We replaced the heating control system in 8 university campus rooms for fifty days from January-March 2013 [3], with the goal of finding new ways to control mechanical heating with less energy; but more significantly, promoting the 'active pursuit' of thermal comfort [6]—here, building occupants make themselves comfortable by other means (e.g. moving around, blankets, hot drinks, clothing layers, and adjustment of shading and ventilation).

During our study, room temperatures were more variable with median room temperature lower in all but one case. Heat input decreased by 19.2%–76.4% (mean 42.2%), i.e. there was significant energy savings potential. But to design adaptive thermal comfort into existing buildings, is to try to change the existing expectations and norms around indoor heating—unsurprisingly, we did not get this right first time. Our system was not comfortable nor acceptable for all of our participants: some participants found it difficult to incorporate into their lives. All of our participants adapted, and their thermal comfort practices necessarily transitioned to account for more local and short-lived access to mechanical heat, including using radiators, windows and doors less and wearing extra layers of clothing.

- **Pattern**: engage reflection on thermal experiences; facilitate encounters with low-energy, dynamic adaptation (such as clothing and hot drinks).
- **Anti-pattern**: maintain 'the normal' practice and expectations indoor temperatures at a specific setpoint temperatures, based on generalising assumptions of what people wear indoors.

Sustainability and melting glaciers
By studying practices rather than devices, we could come to understand the motivation for energy use of many devices and appliances to perform a practice. Methodologically, our mixed-methods enquiries have provided rich and nuanced insights into our participants' lives: fine-grained quantitive data, linked out holistically to energy demands upstream, and embodied GHG have allowed us to put direct energy use into perspective: critical for focusing future HCI design. Exploratory plots of the quantitative data has proved a valuable tool for exploring the role of energy and technology jointly with our participants, leading us to unpack the norms and expectations that drive energy use in the first place.

We need to play the long game. We are helping push for the establishment of a sustainability 'living lab' to encourage more promotion of sustainable action on campus. This is part of a concerted effort to turn our theoretical findings into practice. Despite strong institutional backing from senior decision makers, actually getting our ideas into practice has been challenging. Sustainable HCI is used to thinking of sustainability as a cross-cutting concern, but we found that this means it also cross-cuts organisational decision making processes and responsibilities—sustainability decisions impact research, teaching, finance—and certainly require backing at the highest level: we recognise that only by changing both infrastructure, and the norms and expectations throughout the organisation can we hope to bring about substantial change. But who has the remit to make decisions about this? We have had to lobby to get this responsibility recognised.

Can sustainability be 'core business' of the institution? We are still making the case to stakeholders to dedicate their staff time to the project. We have had to make a credible financial case that the system will pay for itself and demonstrate additional benefits to our institution. A particular innovation in making our case, has been splitting the work into a zero cost proof of concept phase with clearly defined success criteria, including projected cost savings for one building from our estate given demonstrable overheating, and demonstrable demand for our data using testimony from surveyed stakeholders. We continue to fight to free up the developers from their 'day jobs'. This has highlighted to us the importance *identify the stakeholders you need to engage with your project; be mindful of the remit of decision markers and consider how to make the case to them in terms they can understand.*

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