# Implicitly Human-Powered Devices

**David Verweij**
Open Lab
Newcastle University
Newcastle upon Tyne
d.verweij2@ncl.ac.uk

**Karim Ladha**
Open Lab
Newcastle University
Newcastle upon Tyne
karim.ladha@ncl.ac.uk

**Dan Jackson**
Open Lab
Newcastle University
Newcastle upon Tyne
dan.jackson@ncl.ac.uk

**David Kirk**
Open Lab
Newcastle University
Newcastle upon Tyne
david.kirk@ncl.ac.uk

## Abstract
This paper explores how we can harvest energy from human interaction with digital devices in an implicit way. Primarily useful for batteryless devices and sporadic interactions, we conceptualized several implementations where no additional energy-generating interactions are needed. Instead, we generate energy from human exertions (already) required to interface with the device. Using six sketched concepts, we show how this can be achieved using existing interactions, or intuitive alternatives. Here, the energy generation is rather 'hidden' and in some cases can enhance the interaction experience. Energy harvesting thereby follows form, rather than form follows energy harvesting.



## Author Keywords
Energy Harvesting; Human-powered; Interaction Design;

## CSS Concepts
• Human-centered computing~Human computer interaction (HCI)~Interaction Devices;
• Hardware~Power and energy~Energy generation and storage

## Introduction and Background
To incorporate energy harvesting in consumer electronics, we can use a variety of 'natural' energy sources, including kinetic (e.g. wind), thermal (e.g. waste heat) and solar – each with their own power density and efficiency [3]. However, on-device energy harvesting for multifunctional devices, such as smartphones or smart thermostats, will often not suffice as the sole energy source. In the case of human-powered energy harvesting, this might even lead to dissatisfactory user experiences [16]. Instead, self-sustainability seems more promising for emergency scenarios [16] (e.g. power outages) or single-purpose devices such as (ambient) sensors. Even still, the expectations of (near) real-time data logging, combined with excessive battery lives (e.g. ~2 years for a temperature and door sensor [8]) makes arguing for on-device energy harvesting difficult.

Except, batteryless devices do have their potential. Not only do they combat the environmental harm of (lithium) batteries [11], they can also lower production costs, scalability and simplify functionality. In particular, human-powered single-purpose devices can offer on-demand functionality with digital services, without requiring any maintenance. To demonstrate, we have (re)designed 6 products that are batteryless and human-powered. Rather than introducing additional mechanisms and interactions to generate the required energy, we embedded the energy harvesting within the core interaction. As such, we allow for an implicit (and intuitive) human-powered interaction. These designs exemplify how energy harvesting can be suitably integrated and contribute to the development of future self-sustainable devices.

## Human-Powered

A familiar human-powered device is the dyno torch, where a crank or squeeze mechanism will charge a battery to fuel a torch, battery bank or other battery-equipped device. This implementation is a good example of *active* and *human-powered microgeneration* as elaborated on by Pierce and Paulos in [16]. Most human-powered microgeneration implementations require additional interactions (e.g. to build up a charge), which often differ from the actual interaction with the device. This is evident in most existing human-powered equipment, such as these dyno torches, but also more novel prototypes such as a squeezable mobile phone [16]. Instead, we identify opportunities where the microgeneration is embedded in the interaction with the device for cases where this small and sporadic amount of energy suffices.

[1] Assuming a required energy of ~5 mJ/cm2 and a 5.5” (100 cm2) screen, combined with a geared up generator or alternative mechanism such as [20].

## (Re)Designs

The overarching theme in our redesigns lies within services that produce digital output upon direct interaction. This means that without any interaction, and due to the lack of battery, no output is produced – ever. In addition, the required energy for these services needs to be low – in the order of milli-Watts. Put together, these fed into our following batteryless (re)designs.

*Page-Turner*

We imagine a simplified e-reader (see Figure 1) that houses a 5.5” e-ink display. The reader has enough non-volatile memory to store a single e-book. At the bottom of the device, an ergonomically shaped handle allows itself to be pivoted around its centre. When the user rotates the handle anti- or clockwise by 180 degrees, enough energy[1] is generated to load the previous or next page respectively. The bistability of e-ink displays enables the loaded page to stay in view without any supplied power. Permanent magnets ensure a ‘snappy’ and non-linear interaction with the handle, similar to turning a physical book page, as well as keep the handle horizontally in place when not in use. Its batteryless design offers no wireless connectivity, and as such requires the user to upload an e-book using their phone (equipped with NFC), or via a regular USB cable.

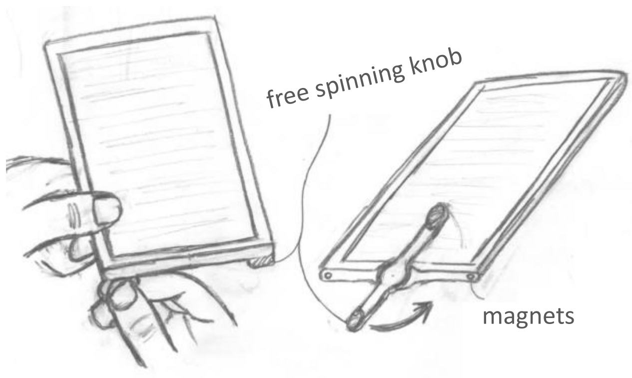


**Figure 1**: An E-book that only stores one digital book. Rotating the handle 180 degrees will generate the energy to 'flip' to the new page, and thereby acts as an input.

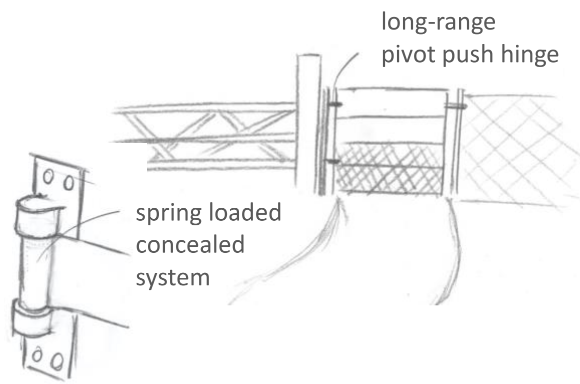


**Figure 2**: A remote gate equipped with Pivot Push. Any energy harvested from pivoting, such as opening and closing the gate, sends a single push notification to the central home unit for further processing.

*Pivot Push*

Particularly useful for remote letterboxes or garden gates, the Pivot Pish is an inconspicuous mechanism embedded in a hinge (see Figure 2). This mechanism generates energy from a person opening and (optionally automatically) closing it, just enough to connect and send a notification to a centralized unit wirelessly. For letterbox designs, the small amount of generated energy (around 3 mW based on [7]) required this design to be placed within 10-20 meters of the central unit. It then utilizes the common low-power Zigbee wireless protocol to send its message. For larger designs, such as a garden gate, a larger amount of energy (~1W based on [14]) allows the use of the Long Range (LoRa) wireless protocol (possible with ~10 mW [5]) to reach distances of up to 2-3 km. This implementation can be put to use for security monitoring or measuring traffic at remote locations such as on remote hiking trails.

*Snappy Sensors*

Similar to the Pivot Push, Snappy Sensors (see Figure 3) generate energy by opening and closing doors, windows, and alike. Replacing existing magnetic catches, the embedded microcontroller draws energy upon opening or closing the object. This energy (~5 mW based on [9]) allows a single wireless Zigbee message to reach the central home unit. Snappy Sensors can act as security alarms if installed on windows, or offer a low-impact method for monitoring relatives in-home care.

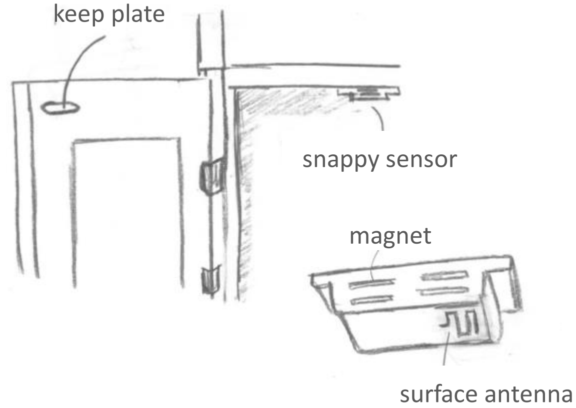


**Figure 3**: Using snappy sensors on kitchen cabinets introduced digital services to everyday interactions at home.

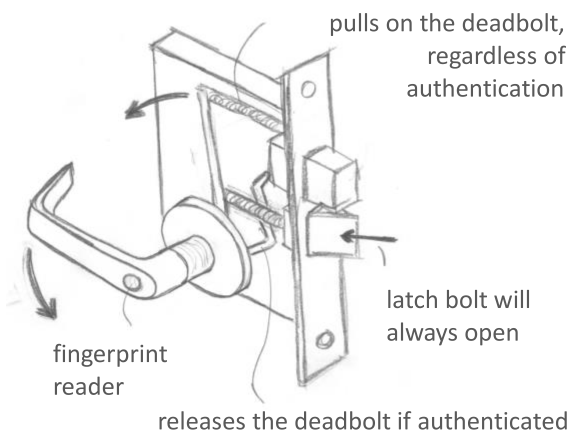


**Figure 4**: Mimicking commercial fingerprint reading door handles, this Security Door Handler is powered by a single (semi) rotation of a normal looking door handle.

*Security Door Handler*
By increasing the gear ratio from the page-turner mechanism, this door handle (see Figure 4) will verify the thumb fingerprint from the hand that turns it. Upon rotating the Security Door Handler by 60 degrees, authentication using the 10 locally stored fingerprints is performed. At the same time, a spring is pulled to – when authenticated - retract the locking deadbolt. A keyhole provides backup entry using a master key. Managing fingerprint authentication is done via a regular USB cable and provided computer software. The Security Door Handler is particularly useful to retrofit inhouse or remote doors that multiple people need access to.

*Cold Casting Coat*
By combining textiles with (flexible) Peltier elements (similar to [1]), we imagine a light-emitting coat (see Figure 5). This coat takes body heat to directly power a small number of LED lights on the back and arms of this coat. In more extreme movements, such as cycling, or with colder temperatures in winter or at night, the intensity of the lights will increase. A simple timer circuit will ensure a noticeable light pattern as well as reduced energy usage of the embedded lights. This coat augments any lights already in use (as their low brightness cannot replace them) and increases visibility towards fellow road users.

*The Paralyzed Digital Photo Frame*
Stretching the definition of what is human-powered, as well as implicit, we imagine the use of a mobile phone as interface *and* power source through the concept of the Paralyzed Digital Photo Frame (see Figure 6). Inspired by Dementyev's NFC-powered companion display [6], this frame is powerless in the sense of no

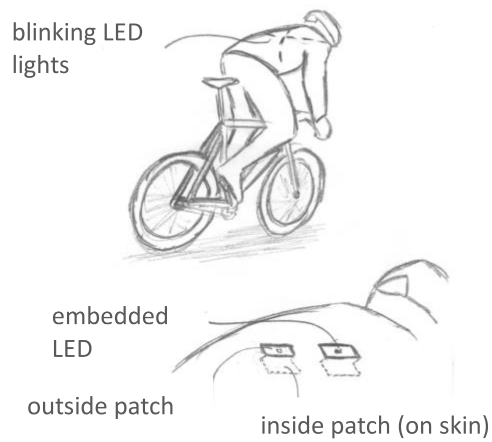


**Figure 5**: Using the temperature difference between the inside and outside of a jacket, embedded LED lights are thermoelectrically powered to increase its wearer visibility.

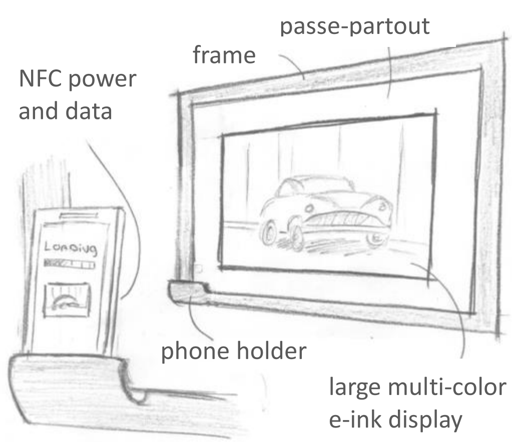


**Figure 6:** A barebone 'paralyzed' photo frame offers an efficient single purpose and aesthetically pleasing way to display various pictures. With the help of a smartphone, this product offers additional digital services only when needed.

battery, as well as its computational thinking. It embeds a large e-ink display, showing a single picture indefinitely until its owner chooses to replace it. When a phone is placed into the embedded phone holder, the hidden NFC tag prompts an application on the phone. The user is then able to select a single picture to be displayed on the frame – for which power (and data) is transferred via NFC (identical to [6]). The slow, but evident, degradation of the screen's bistability - and thereby the sharpness of the image – motivates the owner to update the photo frame every month or so.

## Towards Implicitly Human-Powered

The presented concepts show how human-powered energy harvesting can be embedded in an intended interaction with the device, hidden, and potentially unconsciously performed. We thereby aimed to intrinsically link minimal and familiar interaction with their energy harvesting needs, such that energy harvesting follows form (within the constraints of energy harvesting mechanics), rather than form follows energy harvesting. In addition, the introduced load-inducing mechanisms have the potential to enrich the interaction with carefully designed tactile feedback. This contrast jarring, potentially unintuitive (and dissatisfactory [16]) user experiences from adding separate crank or squeeze mechanisms to generate power.

### *Simply Single Purpose*

In our design exploration, we experienced that implicitly embedding energy harvesting is difficult – if not impossible - in most devices and services we use nowadays, such as sensors and remote controls. Yet, equally, this exploration resulted in novel use cases for human-powered and potentially intuitive and natural interactions. It led to simple, energy independent and human-initiated services: a clear commonality amongst our concepts. This contrasts most consumer electronics that aim to provide a constant (or regular) connection to inform their status (e.g. temperature sensors) or offer multiple features. Instead, we argue our 'simple' conceptual products offer serenity in an age of always-on, and on-demand access – permitted they fulfil their owners need in the presented edge cases. Considerations around privacy and security are hereby potentially simplified. Though we admit, this would require some refinement, particularly in products that do need to connect with cloud services.

*Context of Energy Use*

The benefits of (human-powered) harvested energy seem most valuable in its direct context of use, as argued by Loh and colleagues' [12]. We further expand this notion to harvest energy **through** use, which would contribute to the relationship with energy as a more interactive rather than background technology [15, 16]. We found, and drew inspiration from, existing work that closely relates to this notion, including consumer products (such as the dyno torch) and academic work that equally contribute to our train of thought. For example, Strothmann's bike lights [13] are solely powered on the magnetism from the rotating bike wheels, where Philips' Hue tap switch [18] is powered on the kinetic energy from the button press. Adding to this batteryless approach are solutions such as a (patent for a) squeezable fuelless cigarette lighter [4], and the academically explored remote controls from Villar and Hodges [19] and Badshah and colleagues [2] where the power generative movement doubles as an input. Using printed media, Karagozler and colleagues have shown how interaction with interactive printed media can be used to power these interactions using 'paper generators' [10].

The context of energy use in our redesigns varied, ranging from changing the content on the device itself to notifying external services about the presence of unaware passersby during a hike. We imagine this range is easily expanded by adapting, for example, the snappy sensors to enable smart home automation (e.g. turning on the light upon entering your home). We might then consider the context of use for their generated energy decoupled, which could potentially weaken users' sense of the devices energy harvesting nature [12]. Instead, designing these services through an implicit human-powered lens resulted in products with the security and peacefulness of a never-on-unless-used architecture. Similarly, their human-powered need ensured 'on-demand' functionality, whilst aiding in the mitigation of the information overload of our continuous everyday data collection.

## Future developments

With more developments in wireless connectivity and charging (such as power over Wi-Fi [17]), people might argue against batteryless designs. On the contrary! As we have hopefully shown, human-powered designs offer more, alternative, and potentially preferable experiences than just environmentally friendly, energy-independence and self-sustainability. These experiences can also be applied to non human-powered devices, using other energy sources based on human interaction. This is demonstrated by the Paralyzed Digital Photo Frame concept. Our next steps are to further discuss our proposal with like-minded researchers and designers. In particular, we seek to refine the concept of implicitly human-poweredness, and further investigate its usability implications such as user expectation and operation reliability.

## References


[1] Allison, L.K. and Andrew, T.L. 2019. A Wearable All-Fabric Thermoelectric Generator. *Advanced Materials Technologies*. 4, 5 (2019), 1800615. DOI:https://doi.org/10.1002/admt.201800615.

[2] Badshah, A., Gupta, S., Cohn, G., Villar, N., Hodges, S. and Patel, S.N. 2011. Interactive generator: a self-powered haptic feedback device. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Vancouver, BC, Canada, May 2011), 2051–2054.

[3] Bai, Y., Jantunen, H. and Juuti, J. 2018. Energy Harvesting Research: The Road from Single Source to Multisource. *Advanced Materials*. 30, 34 (2018), 1707271. DOI:https://doi.org/10.1002/adma.201707271.

[4] Barthelemy, P.A. and Desmet, C.L. 2012. Fuelless Lifelong Cigarette Lighter. US20120138591A1. Jun. 7, 2012.

[5] Delgado, C., Sanz, J.M. and Famaey, J. 2019. On the Feasibility of Battery-Less LoRaWAN Communications using Energy Harvesting. *IEEE Global Communications Conference (IEEE GLOBECOM)* (Waikoloa, HI, USA, Dec. 2019).

[6] Dementyev, A., Gummeson, J., Thrasher, D., Parks, A., Ganesan, D., Smith, J.R. and Sample, A.P. 2013. Wirelessly powered bistable display tags. *Proceedings of the 2013 ACM international joint conference on Pervasive and ubiquitous computing* (Zurich, Switzerland, Sep. 2013), 383–386.

[7] Dinulovic, D., Brooks, M., Haug, M. and Petrovic, T. 2015. Rotational Electromagnetic Energy Harvesting System. *Physics Procedia*. 75, (Jan. 2015), 1244–1251. DOI:https://doi.org/10.1016/j.phpro.2015.12.137.

[8] FIBARO Door Window Sensor: *https://www.fibaro.com/en/products/door-window-sensor/*. Accessed: 2020-01-29.

[9] Kaleta, J., Mech, R. and Wiewiórski, P. 2019. Energy Harvester Based on Magnetomechanical Effect as a Power Source for Multi-node Wireless Network. *A Guide to Small-Scale Energy Harvesting Techniques*. (May 2019). DOI:https://doi.org/10.5772/intechopen.85987.

[10] Karagozler, M.E., Poupyrev, I., Fedder, G.K. and Suzuki, Y. 2013. Paper generators: harvesting energy from touching, rubbing and sliding. *Proceedings of the 26th annual ACM symposium on User interface software and technology* (St. Andrews, Scotland, United Kingdom, Oct. 2013), 23–30.

[11] Katwala, A. 2018. The spiralling environmental cost of our lithium battery addiction. *Wired UK*.

[12] Loh, Z., Lee, J.-J. and Song, K.H. 2017. Long Live the Sensor! Designing with Energy Harvesting. *Proceedings of the 2017 ACM SIGCHI Conference on Creativity and Cognition* (Singapore, Singapore, Jun. 2017), 323–335.

[13] Magnic Innovations: *https://www.magniclight.com/en/*. Accessed: 2020-01-22.

[14] Partridge, J.S. and Bucknall, R.W.G. 2018. Potential for harvesting electrical energy from swing and revolving door use. *Cogent Engineering*. 5, 1 (Jan. 2018), 1458435. DOI:https://doi.org/10.1080/23311916.2018.1458435.

[15] Pierce, J. and Paulos, E. 2011. A phenomenology of human-electricity relations. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Vancouver, BC, Canada, May 2011), 2405–2408.
[16] Pierce, J. and Paulos, E. 2012. Designing everyday technologies with human-power and interactive microgeneration. *Proceedings of the Designing Interactive Systems Conference* (Newcastle Upon Tyne, United Kingdom, Jun. 2012), 602–611.
[17] Talla, V., Kellogg, B., Ransford, B., Naderiparizi, S., Gollakota, S. and Smith, J.R. 2015. Powering the next billion devices with wi-fi. *Proceedings of the 11th ACM Conference on Emerging Networking Experiments and Technologies* (Heidelberg, Germany, Dec. 2015), 1–13.
[18] Tap switch: *https://www2.meethue.com/en-gb/p/hue-tap-switch/8718696743133*. Accessed: 2020-02-03.
[19] Villar, N. and Hodges, S. 2010. The peppermill: a human-powered user interface device. *Proceedings of the fourth international conference on Tangible, embedded, and embodied interaction* (Cambridge, Massachusetts, USA, Jan. 2010), 29–32.
[20] Xie, Z., Xiong, J., Zhang, D., Wang, T., Shao, Y. and Huang, W. 2018. Design and Experimental Investigation of a Piezoelectric Rotation Energy Harvester Using Bistable and Frequency Up-Conversion Mechanisms. *Applied Sciences*. 8, 9 (Sep. 2018), 1418. DOI:https://doi.org/10.3390/app8091418.