The Green Switch: Designing for Sustainability in Mobile Computing

Galit Zadok me@galit.co.uk **Riikka Puustinen** riikka@frostblossom.com

Abstract

Growth of mobile users is projected to reach 6 billion by 2013, with 80% of users in the developing world where the mobile phone is their primary communication and computing device. At the same time, sales of energy-intensive Smart Phones have grown 15% last year with all mobile phones to be Smart by 2015. The increased consumption means an average replacement rate of 18 months, accounting for 500 million handsets replaced last year in Europe alone. This makes the mobile phone the consumer electronic device with the highest replacement rate in history.

These parallel and growing trends make sustainability in mobile computing an urgent problem to address. In addressing sustainability, solutions with a significant impact that actively reduce emissions are required. Such efforts within the mobile industry are underway in the manufacturing and disposal phases. However, sustainability efforts in the product use-phase have been limited. Efforts have largely focused on the ecological appeal, neglecting to address the human or user appeal that is required to instigate behavioural change on a mass-market level. To redress this issue, this position paper outlines a product and service design methodology called *The Green Switch*. The methodology is structured as a human and ecological check-list that creates a framework by which one can assess the likely mass-market take-up and therefore the positive environmental impact of a mobile product or service. In addition, the paper introduces an early-stage design concept called the *Green Mode App,* as an example of a mobile product which adheres to The Green Switch methodology.

1. Mobile and Sustainability

The first section covers mobile telecommunication and current sustainability efforts.

1.1. The Growth of Mobile Technology

Since its commercial launch 30 years ago, mobile telecommunications has substantially grown and currently accounts for 4.6 billion users with a billion mobile internet users.[1] The total user base is estimated to reach 6 billion by 2013. 75% of all global users are in the developing world where mobile phones provide people access to telecommunications for the very first time.[2] A recent digital-divide study by Tomi Ahonen, a mobile industry thought leader, concluded that the mobile phone is the only technology which reaches half the population of the developing world.[3] For that reason, Jeffrey Sachs, a development expert at Columbia University's Earth Institute, considers mobile technology "the single most transformative tool for development."

The popularity of the mobile phone also reflects adaptive, *Always-On* digital lifestyles, where the user is the most vital part. A study by ITU supports this view and shows that between 1998 and 2008, mobile usage growth outpaced PC Internet usage growth by 65%.[4]

1.2. The Smart Phone Phenomenon

As a reflection of lifestyle needs, the mobile phone is evolving into a mobile computing device that encompasses advanced PC-like functionality. The demand for these *Smart Phones* with processors, abundant memory, and large screens has been high and by some estimates almost all handsets sold will be Smart by 2015.[5]

As well as voice and SMS, the advanced features on a Smart Phone now include audio, video, gaming, internet browsing, email, camera, productivity applications, bespoke applications, and GPS (enabling location-based services and navigation). This wide range of features on a standard Smart Phone has departed from the 11-feature Nokia 1100[6], the best selling mobile phone of all times.[7] In comparison, the Nokia N900 has a product specification of 132 bullet-point features[8] whilst the iPhone 3GS has 87 features[9]. This emerging trend of the-more-the-better in mobile computing risks mimicking PC computing, with its software bloat, feature creep, additional hardware resource needs, and greater energy consumption.

1.3. Consumption Trends

The mobile phone is the consumer electronic device with the highest replacement rate in history. In Europe, nearly 800 million mobile phone users replace their phones on average every 18 months. That is 500 million handsets a year. Considering the current average handset is designed for a lifecycle of 3.5 years, this trend of rapid replacement is attributed by the mobile industry to the tendency of consumers to want a device with more applications.[10] However, qualitative research by Mo-

torola Labs and the University of Toronto has found that the majority of users replace their phones because of contract length and incentive programs[11].

With the decrease in the value of voice and SMS revenues, mobile operators have shifted emphasis to increasing data and value-added services revenues. Therefore, their drive to increase users' adoption of Smart Phones and their usage of data services is a great financial motivator for encouraging users to rapidly replace their handsets. The UK regulator shows that 70% of consumers choose not to upgrade their mobile phone when financial subsidies are not offered by mobile operators.[12] The majority of old handsets either go to a home landfill, which is a desk or dresser drawer, or passed on to friends or family.[13] In turn, these devices eventually wind up at the landfill or at collection services that transport them to the developing world.

1.3. Current Sustainability Efforts within Mobile Computing

These parallel and growing trends make sustainability in mobile computing an urgent problem to address. In addressing sustainability as a whole, the UK's Tyndall Centre for Climate Change Research advocates solutions with a significant impact that will sharply reduce demand-led energy consumption.[14] However, a 2009 study by Ofcom[15] (the UK broadcast and telecoms regulator) has concluded that a fundamental balance must be struck between the increasing environmental impacts as systems and services grow, as technology and markets develop, and the social, economic and commercial benefits delivered by such systems and services. This tension is considered to be a key challenge for the communications industry going forward.

That study also highlights that consumer equipment, where devices have small individual impacts, often have very substantial impacts overall due to the large volumes involved and shorter product life compared to infrastructure systems.

1.4.1. Manufacturing-Phase Efforts

The EU has the most comprehensive regulations in place, with targets viewed as worth meeting globally by the most proactive handset vendors such as Nokia, Samsung, and Sony Ericsson.

However, the process of manufacturing green handsets is still more costly than conventional manufacturing. Handset makers not only have to redesign handsets with green materials and establish recycling processes, but they now have to document their "greenness" and comply with increasing number of regulations. Creating a verifiably green handset can mean revamping the whole supply chain and retooling the production process.

The incentive for handset markets is a survey of 1000 adults which found that 40% would choose a green handset over a conventional model if they were the same price and offered the same functionality. 7% said they would be willing to pay more for a green handset.[16] Responding to consumer sentiment, Samsung has been leading the eco-friendly handset trend with the Samsung *Reclaim* and the Samsung *Blue Earth*. Like the Reclaim, Blue Earth's shell is made from recycled water bottles but goes further with solar panels on its rear face.

1.4.2. Disposal Phase Efforts

In July 2007, a new European law known as the WEEE Regulations (Waste Electrical and Electronic Equipment) came into force. Producers of electronic and electrical goods now have the financial responsibility for the collection, treatment and recycling of their WEEE. A 2008 global recycling survey by Nokia highlighted that only 3% of handsets are recycled and that one of the main reasons why so few people recycle is because they simply don't know that it is possible to do so.[17] In response to legislation and lack of recycling awareness by mobile phone users, handset manufactures have started promoting free-of-charge take-back programs.

1.4.3. Use-Phase Efforts

In the use-phase, efforts have largely been focused on reducing energy consumption in the supporting mobile infrastructure. The major innovation for reduced power consumption come from developing countries that lack a ubiquitous national power grid, and therefore must rely on renewable energy sources such a wind and solar-power. Much of the efficiency enhancements from infrastructure manufacturers are driven by this need to deploy cellular networks in regions were electricity must be generated on site. Developed countries will therefore benefit from these advances, especially for new deployments and upgrades.[18] Regulators are also exploring reducing energy consumption by encouraging network sharing. ARCEP, the French regulator, has asked the industry to come up with a network sharing plan, or the regulator is likely to mandate one. It is also consulting on spectrum licensing decisions and related energy use.[19]

The 2009 Ofcom study highlights that 3G services are expected to greatly increase network resources as localised high-capacity deployments require higher data throughput which results in an increase in cell power consumption. Thus growing demand by subscribers for the enhanced services of 3G will put pressure on deploying more network resources and hence increasing energy consumption.

The consumer use-phase efforts have mainly focused on reducing energy consumption of chargers in no-load power consumption mode. The no-load mode refers to the state when chargers are not actively used to charge the handset and thus are of no practical use. Regulation is encouraging manufacturers to make reductions in no-load energy demands[20], and handset manufacturers are responding. By 2008 Sony Ericsson reduced the average no-load power consumption by more than 90%[21], whilst Nokia has achieved 80% reduction[22].

To further spur the industry into action, in October 2009, the ITU has given its stamp of approval to an energy-efficient one-charger-fits-all new mobile phone solution. The new Universal Charging Solution (UCS) enables the same charger to be used for all future handsets, regardless of make and model. In addition to dramatically cutting the number of chargers produced, shipped and subsequently discarded as new models become available, the new standard will reduce the energy consumed by the charger. The new UCS standard was based on input from the GSMA, which predicts elimination of 51,000 tonnes of redundant chargers, and a subsequent reduction of 13.6 million tonnes in greenhouse gas emissions each year.[23]

1.4.4. Energy Consumption of the Handset while in Use

To date, little effort has been focused on the actual energy consumption by the users and data has been unclear and inconsistent. This is an area that clearly needs further study and definitive data. Nevertheless, indications that consumer usage of 3G services impact energy consumption are starting to become apparent, as seen in Table 1-1.

Phone Model	**Talk-time Battery Life** (hours)
iPhone 3G (3G on)	4.95
iPhone 3G (3G off)	8.75
iPhone 3GS (3G on)	5.36
iPhone 3GS (3G off)	13.40

Table 1-1 CNET iPhone battery life reviews

The table data, taken from independent CNET reviews[24] of the battery life of the Apple iPhone shows that 3G services greatly reduce battery time, by 43% for the iPhone 3G and 60% for the iPhone 3GS. As the iPhone leads the trend for other handset manufacturers to follow, it is likely that other Smart Phones will have similar energy consumption trends.

Addressing sustainability and energy reduction at the consumer use-phase is becoming urgent. As the mobile phone is transitioning from a voice device to a sophisticated computing device, much money, development effort and design focus is deployed by both the mobile and computer industries.

This is a great opportunity. Hardware and application designers can address sustainability at the fundamental and critical design level. The positive impact from such efforts will not only result in reduction of energy consumption by the handset itself, but also on the network infrastructure that supports 3G services.

2. Design Methodology & Rationale

Following the need to address sustainability at the mobile design level, we recognised the need for a method to do so. Our aim was to create a simple and memorable methodology which assesses whether a *green* design idea is likely to be adopted by many people and hence substantially reduce energy consumption as a whole.

2.1. *The Green Switch* Design Methodology

The aim of the methodology is for mobile products or services to be designed to reduce use-phase energy consumption. The Green Switch design methodology is a design approach where a product or service is designed to fulfil **both** human and ecological needs. It is distilled to a checklist of five attributes which are **all** to be fulfilled, in order to achieve the aim of the methodology.

The Green Switch checklist is divided in two main sections: *Mass-Market Appeal* and *Green Appeal*.

Green Switch Checklist		Y	N
Human- Centric	**Mass-Market Appeal**		
	Beneficial		
	Convenient		
	Good value		
	Socially acceptable		
Ecology-centric	**Green Appeal**		
	Reduction in energy consumption		

Table 2-1: Green Switch Methodology

(Aim: ✓(Y) in all the boxes)

Mass Market Appeal

Mass-Market Appeal highlights qualities that make products or services more appealing for mass adoption. The four attributes of the Mass-Market Appeal are all *Human-Centric*, by which we mean a focus on human attributes. These are user-centred design (UCD) principles in which the needs, wants, and limitations of end users are given extensive attention.

A mass-market product should be:

1) **Beneficial**: it answers *is it beneficial and relevant for the user?*

The product/service should provide a tangible benefit. The benefit can be a factor such as overall design or performance. One of the most obvious benefits of mobile devices is *location independence*, which is enabled by form, features, capabilities, user interface and proliferation of similar devices. Just like a Swiss Army Knife, these devices are portable multi-purpose tools.[25] In other words, mobile devices offers a platform where it is possible to either install new applications or access online services to match the user's changing and emerging needs.

Mobile products are *contextual*, following the user's interactions with the content and the surrounding world over time. Context-aware products fit better to the user's routine and take into account time and location, user's needs and interests. If the user's activity can be understood, it can be translated into a design solution that is *relevant* for the user. Ultimately, the most appropriate information can be delivered most effectively by allowing the user to focus less on the technology and more on the situation they are in[26]. Hence for the mobile product or service to be beneficial it should also ensure the relevance to the user in the appropriate context.

2) **Convenient**: it answers *is it convenient to use?*

The product/service should contribute to effortless use by being *reliable* and *easy to use*. A mobile device is *identifiable* and *personal*, as it belongs to a single user. Mobile products are *interruptible* because of inconsistent connectivity and various situations that demand the user's immediate attention. They are generally designed to *allow distractions*, and to *support easy recovery* whenever the user returns to the interrupted task. Simple design practices can contribute to the product convenience, for example by using familiar interaction patterns consistently.

3) **Good value**: it answers *is it good value?*

The product/service should give advantage or monetary worth compared to the price paid for it. *Quality* is weighed against *the cost* of using the product or service and resources used in the product. Cost can be a monetary value but also can encompass a psychological cost. For example, a free product that causes extreme usage frustration cannot be considered as good value, if there is a frustration-free alternative available with a nominal cost.

4) **Socially acceptable**: it answers *is it socially acceptable, even desirable?*

The product/service should at the very least conform to norms and *follow the rules of target society*, but it may be also helpful for a product to support *ideal self-image,* which helps the users view themselves as better people (whether or not they are looking to feel different). Mobile devices *extend social interaction* with help of communication features that make their users constantly available to be connected with their social circles. Mobile products and services can be also an item of *fashion* that indicates their owner's actual or desired place in the social structure.

Green Appeal

Green Appeal is the fifth *Ecology-centric* attribute, by which we mean a focus on Earth environment. Since climate change patterns associated largely with energy supply are the dominant environmental problem, this attribute is solely focused on reducing energy consumption by the user. This helps conserve natural resources and decrease demand for electricity plants, hence reducing carbon emissions.

5) **Reduction in energy consumption**: it answers *Does it reduce energy consumption?*

A sustainable product should reduce the need for electric power. Possible technical areas to focus on a mobile device are system processes, idle and call state, network connections, Central Processing Unit, screen status, screen brightness, SD Card and Media players.

A recent study by Northwestern University[27] looking at user activity and power optimization for mobile architectures highlights the integral relationship between user behaviour and power consumption. It concludes that the hardware components that dominate power consumption vary drastically depending upon the workload of a mobile architecture and that on a mobile architecture, the end user *is* the workload. The researchers, by analyzing the user logs, found that the power breakdown of a device is highly dependent upon the individual user, but that the screen and the CPU tend to dominate the active power consumption. Active power consumption accounted for 50.7% of all system power.

Furthermore, at the end of the above user study, the users were asked whether they would turn a combination of power optimization schemes on if they had a tool to control them and knew they would save about 10% of their battery life. Out of the 20 users, 15 said that they would use these optimizations, 1 was apathetic, and 4 of the users would not use the optimiza-

tions. Out of the 15 that responded with a yes, 5 of them expressed a desire for application-dependent optimization.

Practical User Experience design considerations can range from *User Interface* solutions to *Interaction Design* solutions streamlining the sequence in which the user travels through a service. For example, colour choices on the operating system level can affect the battery life. Both Apple iPhone and Google Android devices use black and dark tones predominantly on their user interfaces, hence extending battery life.

Products or services using The Green Switch design methodology must appeal to a majority of consumers by instigating usage that in turn makes a positive ecological impact. Ecological products and services should be at least equivalent in quality and value to other mainstream products of the same category, with the added value of environmental responsibility. *Green* products should be personally relevant and beneficial for the user, while being also convenient, socially acceptable and of good value.[28] The retail price of *Green* products and services should be competitive, though if the user is willing to pay a premium, they must still perceive the product or service to be of a good value, regardless of its premium cost.

Designers should seek for opportunities to reduce energy consumption of products, either through hardware or software solutions, ideally both. Even though this methodology focuses on the use-phase of a device, a full product life cycle must be considered to ensure that no environmental burdens are shifted to other life phases, i.e. improvements in one part of the life cycle (e.g. production) lead to even higher impacts in other parts of the same life cycle (e.g. the product use), and vice versa.

2.2. Rationale of Methodology

The single most important reason for this design methodology is the need for an impact. Sustainable design solutions can have an impact only if the solution is widespread and thus adopted by mass consumers. The Green Switch design methodology is focused on maximising the service or product adoption, whilst minimising the environmental impact. The Green Switch Checklist (Table 2-1) can be used as an evaluation tool for assessing the appeal of a sustainable mobile product or service.

Our working assumption is that a design practice can make a change, if it is clearly focussed and addresses sustainability issues. The key to successful designs is users feeling good about themselves – no need to scare or preach. In addition, design solutions can encourage more sustainable consumption by addressing the need for a behavioural change. BJ Fogg's behavioural studies[29] suggest that a change in behaviour can happen when three elements converge at the same moment: Motivation, Ability, and Trigger. When behavioural change does not occur, at least one of those three elements is missing. The core motivators for behaviour change are Pleasure/Pain, Hope/Fear, and Social acceptance/Rejection. It is more likely that the new behaviour occurs if the conditions and context make it simple for the person to uptake the new behaviour. For example they have sufficient time in their hands, or the task is effortless.[30]

Indeed, the most effective persuasive design solutions are very simple and do not require too much effort from the end user. It is best to ask users to take easy actions, which then may open up doors to more complicated actions.

Dr. BJ Fogg has identified three different triggers for behaviour change.

1. First is *Spark*, which is required when the user lacks motivation to perform a target behaviour but has a high ability to do so.
2. Second type of trigger, *Facilitator*, can be used when the user has high motivation but lack ability.
3. Third trigger type is *Signal*, which serves as a reminder for people who have both the ability and motivation for a behavioural change.

For example Ford has implemented a dashboard on their hybrid cars that shows a vine growing on it when the driver has green driving habits.[31] This type of trigger simply indicates when the target behaviour is appropriate, and gives feedback for the driver when they have been successful. For eco-conscious drivers this may be a good enough reward to further their green habits.

All of the abovementioned triggers educate users through simple actions. When users become aware of the energy consumption patterns of electronic devices, they may take up other habits such as switching off lights at home or unplugging chargers to conserve energy. The Green Switch Design Methodology looks into positive motivators that encourage behavioural change, so that sustainable products can offer pleasure, hope and social acceptance in equal measures. We believe that adoption of sustainable products could be very high if they were beneficial, convenient, good value and socially acceptable. These product qualities are likely to initiate behavioural change in buying habits by offering all the same conveniences as mass-market products but with the added ecological benefits.

2.3. Challenges

Recent studies show that values are shifting at a deep level: the majority of consumers now prefer brands that are environmentally and socially responsible.[32] However, current challenges for green designs are cost-effective manufacturing processes and lack of global sustainability standards. The issue of standards has been a long-term challenge for international organizations, because it means that there are no compulsory and universally agreed methods for measuring and enforcing sustainability of products. Therefore, for example, Greenpeace uses their own ranking criteria for greener electronics.[33]

What cannot be measured cannot be managed. At the moment corporations can seek ecological recognition for their products through various ISO standards, which is optional unless products are marketed through their environmental claims. Nevertheless, advanced procedures exist locally: in Europe products must meet the minimum requirements of Life Cycle Assessment (LCA) by European Commission.[34]

In designing for sustainability in mobile computing, and in addressing the aforementioned challenges, we are interested in further developing The Green Switch methodology. Our specific interest is in further researching how each of five attributes can be clearly measured, possibly extending it from a Y/N mechanism to a scale of, for example, 1-10. Whilst the four human-centric attributes can be challenging to measure due to their social and behavioural nature, the fifth attribute, the reduction of energy consumption, should be easier.

Our hope is that a mobile product or service using The Green Switch methodology will not only be able to ascertain, at the design stage, that it can make an ecological impact, but furthermore, determine **How Much** of a positive impact can be attained.

3. The Green Mode App

This section gives an early-stage design concept idea, the *Green Mode*, which adheres to the methodology.

3.1 Design Concept: Green Mode App

The Green Mode is an app concept for a Smart Phone that explores the idea of switching off active functions and apps when the user does not need them.

Key features of the Green Mode app are:

- ***Green* vs. *Fat* Mode:** Identification by the user of their primary, or most frequently used functions and applications. All primary functions and applications are then marked as *Green* Mode. The full functionality of the Smart Phone is the *Fat* Mode.
- **Green Mode Status:** An icon on the main information bar to alert the user that they are in the Green Mode. See Figure 3-1 as example of a green leaf icon to indicate that the Green Mode is on.
- **Toggle:** The user can toggle between Green Mode and Fat Mode according to their needs and enable their full-featured handset. See Figure 3-2 as example of choosing Green or Fat modes.
- **Auto-Green Mode:** The device can automatically enter *Green* Mode when being idle for a period of time and the users can simply enable the full-featured or *Fat* Mode when necessary.
- **Customisation:** The Green Mode app does not stipulate or force the user which applications or functions are considered Fat, and which are considered Green. Each individual user has individual preferences on frequently used functions or applications, and hence a Green Mode is customisable to address changing needs by the user. See Figure 3-3 as example of selecting functions and applications to be grouped as Green Mode.

3.2 Rationale

Longer Battery Life: Mobile phones consume power on active background functions, which are often irrelevant for the users when the device is idle. Our current assumption is that through this design solution the user could gain control over functionalities of their Smart Phones. Extending battery life results in reducing the times a user charges their handset, thus reducing overall electricity consumption for the life of the handset.

Reclaimed Autonomy by the User: Green Mode app allows the user to choose when to be Always-On. John Thackara, a design thought leader, points out that "The benefits of mobile technologies cannot be disputed, however we are in danger of losing autonomy as technology renders us, through its devices, Always-On."[35]

3.3. Adherence to methodology

The Green Mode app adheres to the five attributes:

Beneficial: Allows better performance of a Smart Phone through increased speed of use and longer battery life. Less frequent recharging required. Ease of regulating time spent Always-On.

Convenient: A quick and easy switch between Green and Fat modes ensures that the users are aware of the app and thus more likely to use it.

Good value: Helps save energy on a full-featured Smart Phone. Thus the user get the full benefits of the

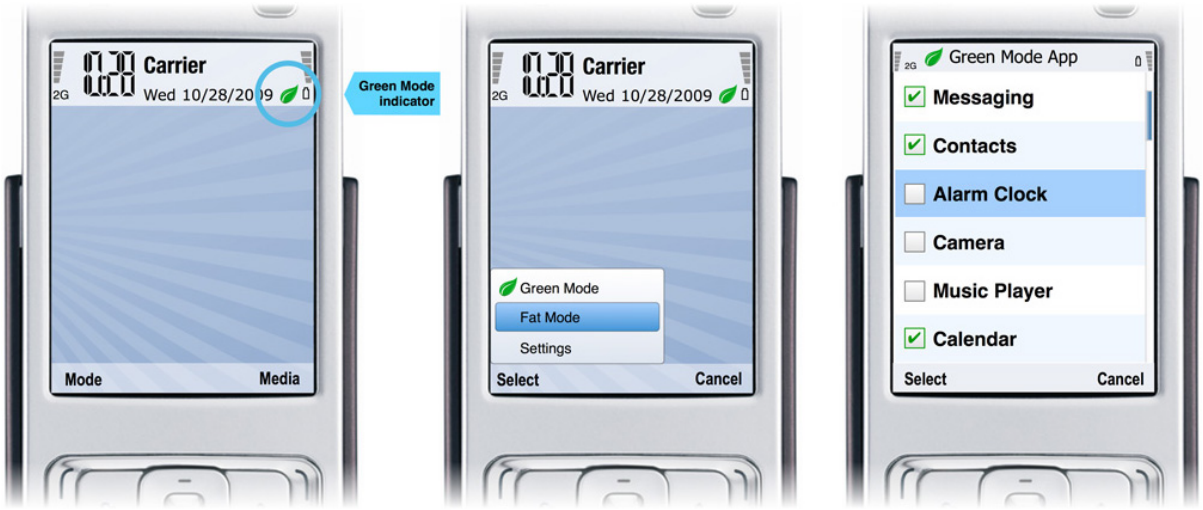

Figure 3-1: Green Mode status indicator

Figure 3-2: Choosing Green or Fat modes

Figure 3-3: Selecting Green Modes functions

Smart Phone, but with less effort in recharging the battery and less money spent in electricity consumption.

Socially acceptable: Socially acceptable app, as it addresses the user's personal impact on the environment.

Reduction in energy consumption: Battery life increase through usage of Green Mode, through a reduction in the need to recharge Smart Phone frequently. Results in reduced energy consumption by the handset.

4. Conclusion and Future Work

The global growth of mobile usage, uptake of energy-intensive Smart Phones, and high replacement rate of mobile devices make sustainability in mobile computing an urgent problem to address. Although the reduction of energy consumption is being embraced by the mobile industry, these concurrent trends risk aggravating the ecological impact of mobile - drastically and suddenly. A "perfect sustainability storm" might be brewing if designing energy efficiency and energy reduction into mobile products and services is ignored.

This position paper has three contributions. Firstly, it outlines the sustainability challenge in mobile computing and its growing significance. Secondly, we propose a design methodology The Green Switch, which can help assess the likelihood a *green* design will be adopted by many people and hence reduce energy consumption. Thirdly, we propose an early-stage design concept, the Green Mode app which adheres to The Green Switch methodology.

There are several directions for extending this work. Further research is required regarding use-phase energy consumption of the Smart Phone and the impact of functions and applications on energy consumption increase. Specific Smart Phone functions and applications with higher energy consumption should be made more energy efficient, and could result in the introduction of efficiency ratings for functions and applications. Another measurement can include a power output rating, measured in Watts and visible per function or application on a Smart Phone. This could allow extended functionality for the Green Mode app, by giving the user visibility of cumulative energy consumption in Kilowatt-hours in the Fat and the Green mode.

We aim to examine the possibility of extending the framework of The Green Switch methodology by further researching how each of the five attributes can be clearly measured. Whilst the four human-centric attributes can be more challenging to measure, the fifth attribute, the reduction of energy consumption, should be relatively straightforward.

Finally, we propose that the broad thinking behind The Green Switch methodology — namely that ecological and human appeal must be satisfied in order to achieve the positive environmental impact — could be applied not only to mobile computing but to other computing systems such as workstations and servers.

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