USING DESIGN DRIVEN INNOVATION AS A VEHICLE OF 'ECO' SUSTAINABILITY IN MEDIUM COMPLEXITY PRODUCTS — THE CASE OF DOMESTIC WHITE-GOOD APPLIANCES

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Using the author's past research of 1.5 years into design innovation for sustainability in medium complexity devices, this paper tracks the development of medium complexity products towards fulfilling the challenges of sustainability. 'Sustainable, Green, or Eco' Design in the product scale could be broadly defined as the philosophy of Designing with environmental or ecological sensitivities in mind. Design has responded to the demands of sustainability at various levels, but this paper concentrates on the adaptation which electro domestic appliances or white goods have undergone in the recent years up until the post-crisis scenario, not only in terms of industrial design but also in the area of interaction design.

Devices have evolved from just incorporating material substitutions to innovating completely new product architectures. This development not only changes the manner in which such devices and appliances are conceptualized but also used by the consumer. When standard and accepted product archetypes suddenly change due to 'disruptive innovations' associated with design, then the challenge of product-user interaction becomes the central issue, and this holds true for 'Eco' Design also [1, 2].

Keywords: Design innovation, Product archetypes, Product — User Interaction, Sustainability.

1. INTRODUCTION — THE RISE OF SUSTAINABILITY

Sustainability is a complex agenda in the Design industry with implications both in the *Services* scale and *Industrial* scale. But even before this bifurcation there is a semantic issue to be addressed. Addressing sustainability from a service scale usually means approaching from the point of view of 'social' innovation. Dealing in the industrial scale entails approaching the issue from the 'technology' innovation point of view. While in the Service industry scale sustainability has dealt with subjects such as green energy, '0' emissions, sustainable communities, ethical food etc. in other words mostly in the social scale, the author in this paper will deal within the Industrial scale and thus look into the realms of product design, product interaction, technology innovation, 'eco' design with a special focus into medium complexity products i.e. domestic 'white good' appliances. Henceforth this paper will address sustainability for medium complexity appliances as 'Eco' Design or Design for eco efficiency.

Focusing on the product scale, the electro domestic appliances have undergone various innovations to respond to today's energy challenges. These innovations are very distinct from what other segments in the product design industry have spawned. 'Eco' appliances today form a very important segment in the white goods industry and are increasingly regarded as the hallmark of highly engineered and technological products. It has emerged during the author's PhD research into electro domestic

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appliances that product-user interaction plays a direct role in the future innovations of industrial design for 'eco' appliances.

1.1. Sustainability + Innovation

It has been widely observed that to meet the demands and challenges which eco design presents to the design industry, designers and engineers have to be innovative in their approach, whether it be in the aspects of material selection, product typology, technology application or even in the basic architecture of the product itself. But perhaps the opposite is also true, that being innovative in the design industry in the contemporary scenario also means to foster eco design practices or issues directly related to it.

Indeed using the lens of design driven innovation to filter through the flood of 'eco' appliances coming into the market allows for a more scientific and systematic approach in identifying truly worthy 'eco' products, as this distinction is a bit vague at the moment.

During the course of author's research it became quite apparent that the attributes which are regarded as meritorious when classifying a product as 'eco' are very subjective and quite debatable. Some manufacturers deem it sufficient to install a highly efficient motor in their washing machines, while others might look into eliminating certain poisonous compounds from their machines, still others adopt a design based approach such as incorporating a detergent tank within the machine so that the appliance automatically draws detergent from it (Hotpoint Ariston), hence eliminating the wastage which users routinely commit by adding too much detergent manually for each cycle.

1.2. Levers of innovation

There are 3 kinds of levers effecting innovations which the author benchmarked in recent product development. A lever can be described as the starting point of creativity [3], which ultimately has the greatest bearing on how design driven innovation was applied to product development:

Technology: This lever is probably the most scientific as it relates to requirements defined by a certain production methodology but also opportunities which are afforded by the designer to the user by virtue of application of a certain technology.

Mode of use: This lever relates to how the user interprets the products and dictates the modification or creation of product-user interaction. This would also relate to the emotional connection that a user establishes with a product upon seeing it.

Form: This is possibly the most subjective of the 3 levers, which relates to the external morphological form of a product. This lever is possibly the strongest and most applied of the 3 and relates to both the visceral aspect when dealing with the aesthetic & 'Formal' aspects of product but also connected to the emotional & cognitive aspects which relates to how the product communicates with the user but also how the user perceives it, and would thus vary from user to user [4, 11].

1.3. Evolution of eco design in medium complexity products

When studying the propagation of green ideas and practices in the general medium complexity product paradigm, it is quite clear that the second generation of green products are widely being developed. Often the first generation of 'eco' products were viewed upon as crude technology driven products, with very little design input applied. Such products were not widely accepted, but, perhaps they were never intended for the mass market because their appeal was indeed very limited. Largely unfinished as far as design was concerned, such products & devices mostly concentrated upon application of new materials to existing product typologies, or explored mostly new energy saving technologies such as solar cells, perpetual motion, down-cycling etc. Such products very often worked with the supposition that just the inclusion of technological or a material application was sufficient to justify a product as eco efficient, without due consideration to its other core aspects such as design, usability, & interaction [2, 13].

The second generation of 'eco' products were largely design driven products & devices. These products sought go beyond the existing typologies and archetypes, in other words they were utilizing design driven innovation to achieve eco-efficiency. Such products were largely characterized by using new production technologies, utilizing and integrating digital technology into their common functioning, seamlessly integrating design with the other aspects of the product, in other words leveraging one of the levers of design driven innovation to arrive at product solutions.

2. THE CASE OF 'WHITE GOODS'

In electro domestic appliance industry sustainability has no such stark generations to differentiate. Instead there is a linear and gradual evolution of 'eco' appliances. When talking of sustainability with respect to electro-domestic appliances, there is a clear trend toward embracing and incorporating more and more technology. Appliances are no more 'static' machines but rather 'adaptive' and 'responsive' with a lot of intelligence built inside them [1, 6, 7].

As a result of this Designers are also turning to '*interaction*' design to control and deliver all this intelligence thus contributing directly to develop a whole range of design driven innovations that are evolving and shaping the future of this industry. During the course of the author's PhD thesis in collaboration with Whirlpool Global Consumer Design (GCD) in Milan, it became quite clear that the electro-domestic appliance industry has not undergone any significant change or innovation since the late 60's when the current architecture of most of these machines was developed. Indeed it is thanks to the agenda of eco design and the consequent development of eco efficient appliances that this industry is innovating again and producing completely new kind of product architectures and concepts. It thus becomes clear that eco efficiency and 'innovation' have become complimentary.

The below figure maps the segmentation in the electro domestic appliance industry. The Y-axis corresponds to Design, so top left quadrant are design driven mainstream appliances. These devices are more attractive on a visceral level [11]. The X-axis maps Eco-efficiency, or appliances which are otherwise seeking to address sustainability in some capacity. Therefore the bottom right quadrant is 'eco' products and the bottom left quadrant would be the mainstream domestic appliances. The upper

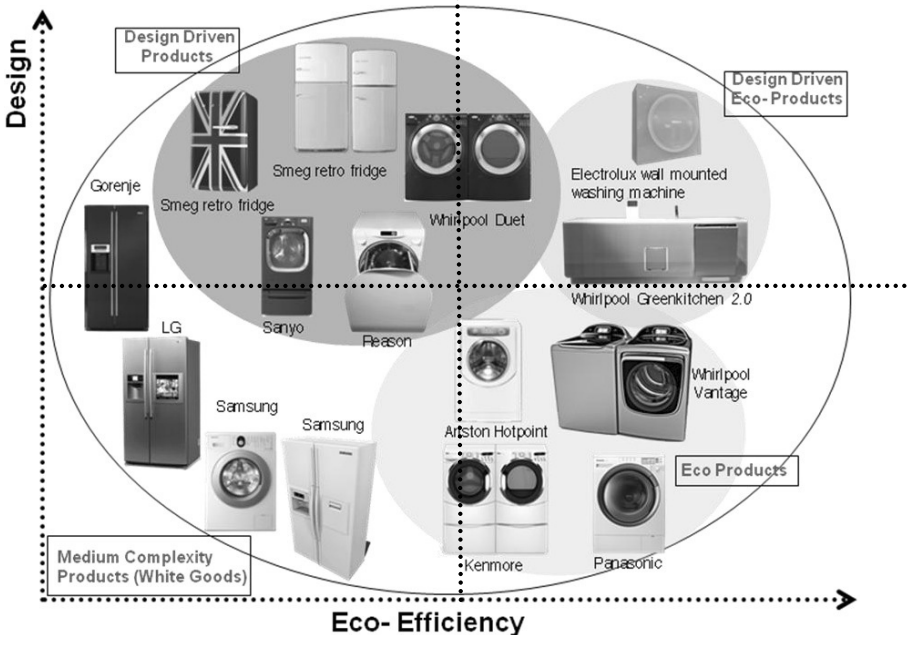

Figure 1. Benchmarking electro domestic appliances.

right quadrant is the design driven 'eco' appliances category, these are appliances which are innovation inspired and use one or more of the innovation levers of technology, mode of use, or form effectively in addition to the considerations of eco efficiency.

The top right quadrant products are indeed the exception in the over-all picture, and it is the goal of the entire industry to transcend from the 'eco' quadrant into the 'design driven eco' products quadrant [12]. This quadrant is also a bridge between mainstream design innovation and technology innovations taking place in the 'eco' segment.

Some important conclusions can be made about the above study which are unique to electro-domestic appliance industry are:

1. Externally the 'eco' appliance category & the mainstream appliances appear undifferentiated, In other words there is no design driven distinction between the 2 product categories.
2. This means that most of the innovation which addresses sustainability is technology inspired in the white goods industry.
3. The design driven 'eco' appliance category is presently a new niche which is still sparsely populated but this is where the industry as a whole must move towards to address the challenge of sustainability in domestic appliances.

2.1. Benchmarking 'eco' features in electro-domestic appliances

Understanding the application of eco efficiency in white goods led the author to benchmark how many of 'eco' features are implemented through technological incorporations and how many are executed through design. A shortlist of features in 4 major appliance categories of *washing machine, dishwasher, dryer & fridge*, which were selected after undertaking an extensive market study of major white goods manufacturers across Europe, US, and Japan, was prepared. This list was also indicative of the direction in which major appliance manufacturers were moving to incorporate sustainability into their products. Most major appliance manufacturers have indeed developed a dedicated lineup of 'eco' appliances which address any one or most of the 'eco' features widely regarded as energy and resource saving. With regard to washing machines, the features ranged from detergent saving, low temperature cycle, higher spin speed, foam control, leakage detection, centrifuge speed management & a steam cycle to eliminate need for ironing. Most of these features are incorporated by integrating sensors of various kinds into the machine. The result being the machine is optimized to function in a pre-programmed manner which is set by the manufacturer. But externally there is very little to distinguish these machines from a design standpoint as 'eco' machines. From a *Design* standpoint, mostly manufacturers just badge these machines with a special 'green logo' badge, which is an in-house designation developed by each appliance manufacturer. Of course from a *manufacturing* standpoint they try to adhere to the European production protocols such as RoHS, WEEE, EuP. As an example, in the case of Whirlpool Europe (Cassinetta) they enact various eco efficient protocols in the form of supplier code of ethics, installing a co-generation system that employs natural gas to generate electricity during production, & a nanoceramic procedure which reduces chemicals in waste-water during the product painting process (Whirlpool sustainability report, 2009) [10]. The net difference being that the 'eco' appliances have a lot more technology built into them, thus making them very expensive, and therefore only targeted at the premium user.

Table 1 shows most of the 'eco' features are implemented through technology. It highlights the importance of interaction systems for such machines, since the interface acts as the window to all this inbuilt technology making it comprehensible to the user.

2.2. Interface design as a trigger for design driven innovation in white goods

As was illustrated in the previous section, most innovations in white goods are implemented through a sensor. All this built in technology has to communicate with the users of such products. This is where the interface of such machines plays an important role, and is witnessing a lot of innovation lately.

Table 1. Benchmarking 'eco' features in washing machines across major brands.

Washing Machine	Brand	By Sensor	By Usage	Saves water	Saves energy	Saves chemicals
Low temperature cycle	gorenje Electrolux Panasonic	30 deg. wash cycles instead of 40 deg. 15 deg. eco wash cycle.	20 min. quick wash program at 30 deg.	■	■ ■ ■	
Steam wash	MAYTAG SAMSUNG Electrolux gorenje	Steam injected at desired temp to dry clothes and reduce ironing.			■ ■ ■ ■	
Detergent management	Hotpoint ARISTON gorenje	Detergent is managed by external tank below drum.		■ ■		■ ■
Foam control	gorenje Panasonic	Amount of foam buildup s controlled through water volume.			■ ■	■
Clothes Cleaning feature	Kenmore SAMSUNG SAMSUNG	Silver particles to kill bacteria. micro bubbles shake dirt off.	Cold Clean Cycle using special drum movements			■ ■ ■
Inclined drum	Panasonic	Lesser water consumption.		■		
Leakage protection	Panasonic Electrolux	Sensor detects water leakage & shuts off supply.		■ ■		

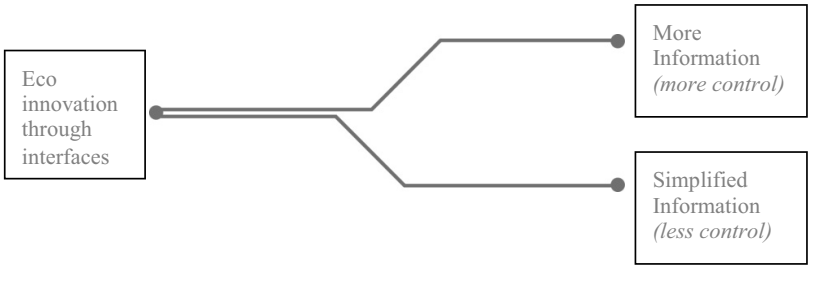

Figure 2. Trends in interface design for white goods.

Broadly it is through the interface that the manufacturers control how much intelligence they chose to expose to the user and how much self-automation the machines impose upon their functionality. There are 2 clear trends in interface design of white goods being illustrated below (Fig. 2).

As far as interface design leading to new product innovation is concerned it leads to 2 possible outcomes:

- New information typology which is being displayed to the end user.
- New user interactions and behavior which these interfaces encourage.

The combined outcome of these 2 factors will be to give rise to a new segment of smart 'eco' appliances. These appliances will reinvent the archetypes of existing white goods. Indeed this is inevitable, as all the existing product forms and typologies were formed before the rise of digital technology and information platforms.

Hence this is an effort on the part of the manufacturers and designers to change how users perceive home appliances and what is the role these products play in the contemporary domestic scenario. Through quality of information being communicated to the users, these devices are actually educating

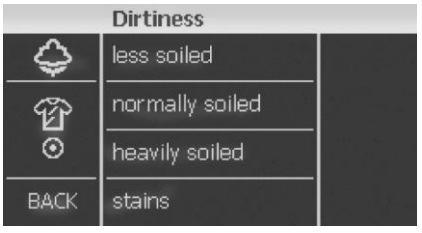

Figure 3. Simplified interface.

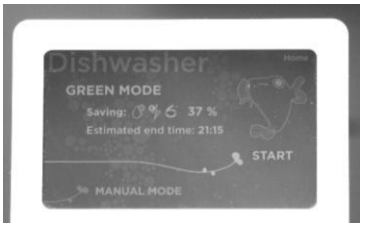

Figure 4. Touch sensitive detailed interface.

the users in aspects of saving energy, and 'green' behavior. Thus far these were abstract notions in everybody's lives but now the white goods industry is actively trying to incorporate these changes into the everyday lives of users and promoting them as an aspect of contemporary living.

Previously pilot studies have been carried out where home energy displays terminals have attempted to educate the consumers about their energy consumption pattern (Ueno T., R. Inada, and O. Saeki. 2005) [5, 8]. But their motive was to study the phenomenon of observing change in the user's behavior once s/he understood energy consumption in more tangible terms and units which were easier to relate to and also the fact that being able to constantly monitor energy also helped to curtail wastage. More recently design driven visually rich display devices — which simplified complex information such as kWh into USD — have proliferated. The display background changed from green (for low energy consumption) to red (for high consumption). The second generation devices such as the Intel home energy panel (Fig. 6) are actually full-fledged tablet devices, which are also the complete control surface for all the domestic appliances thus eliminating all their knobs with a single integrated touch panel. Such a device is actually an extension of the appliance(s) it is controlling and can potentially have profound implications on how such future appliances will be designed now that they can be remotely controlled and share a common control panel. Further such an advanced device is not merely a control panel but a complete home energy monitoring system with a sophisticated layered display architecture but intuitively designed, which is totally integrated with the upcoming smartgrids [8] thus optimizing the energy footprint of the whole household across the board. Letting the user understand how s/he is positively contributing is an important step in the overall acceptance of 'eco' appliances.

Figure 5. *HomeJoule* energy meter.

Figure 6. *Intel Smart Home Energy* panel.

3. THE WHIRLPOOL GREEN KITCHEN 2.0

The Integrated Green Kitchen 2.0 concept, developed in collaboration with Whirlpool Europe & their Global Consumer Design (GCD) studio based in Cassinetta, Italy, during the course of the author's PhD forms a case study on 'eco' innovation where interface design and industrial design play an integral part to form an innovative kitchen architecture.

It is important to note that this project serves to highlight the linear pattern of development in the 'eco' white goods. The 3 steps of innovation are as follows:

1. Technology driven trends which were pointed out extensively in the benchmarking studies dictate appliance functioning & construction.
2. Interface driven trends which are now being implemented as a direct follow through to the technology driven trends are second stage of development.
3. The third stage represents design driven trends. In this phase is when the overall design and architecture will radically evolve to reflect the development in the interface & technology driven trends and finally result in perfect integration of digital communication and mechanical functions to seamlessly address eco efficiency. At the moment just the implementation of screens in existing appliances is the rudimentary initial manifestation of this phase. Eventually the form factors will evolve to address these screens more completely [1]. Greenkitchen 2.0 reflects the development of this 3rd step in the development of 'eco' appliances.

This project is an important benchmark in 3 aspects of the author's research:

1. The GreenKitchen 2.0 is an attempt to explore the application of eco efficiency not only from a technology standpoint, but also through a design standpoint.
2. This project illustrates the challenges which designers face while communicating the 'eco' aspects of a radically innovative product to the end users.
3. GreenKitchen 2.0 is an example to show how interface design can play a central role in modifying user perception of existing product typologies, and help toward the acceptance of a completely new product architecture.

3.1. Radical innovation to achieve eco efficiency

GreenKitchen 2.0 is a concept for appliance architecture which seeks to merge several different white goods categories under 1 unified product architecture. The aim being to fully integrate: refrigerator, washing machine, oven, hob, H20 cooker, dishwasher, & dryer as one integrated platform which operate in a closed energy loop & all are controlled by a single 9" tablet. Thus no energy is wasted in the functioning of this device. For example the heat from the refrigerator compressor is captured and used to heat the water for the dishwasher, as such all energy is reutilized and in the process the physical architecture of all these appliances underwent a radical innovation. In addition an integrated solar panel which is mounted outside the house can be dynamically controlled by the user to power any appliance s/he wishes in the Green Kitchen 2.0.

Figure 7. The GreenKitchen 2.0 with the 9" Touch screen interface.

3.2. The Interface & communicating new information

The appliances integrated into this kitchen were conceptualized to break the traditional archetypes surrounding their functioning thus far. The biggest challenge in this project was to communicate the innovation in a language which the end user could understand. There is an extreme amount of information built into this device, but unlike the traditional eco design approach, all this technology was hidden and it was up to the interface to deliver a smooth, simple, and extremely seamless user experience to the user.

The interface, designed by the author, was based on a portable 9" touch screen. The quality of information that was displayed was completely new and relatively untested for white goods [9]. Information such as real-time tracking of energy consumption by the user, mapping user appliance usage habits graphically, appliance operation prioritization for automatically staggering operation times, water and electricity consumption for each appliance, real time running cost of each device etc. were all tracked visually and very intuitively by this interface. In addition this kitchen is connected to a smart energy grid so it automatically delays wash cycles according to cheapest tariffs of the day. A lot of research went into using simple iconography and metrics to communicate the energy and resource consumption of devices in order to encourage users to participate more actively.

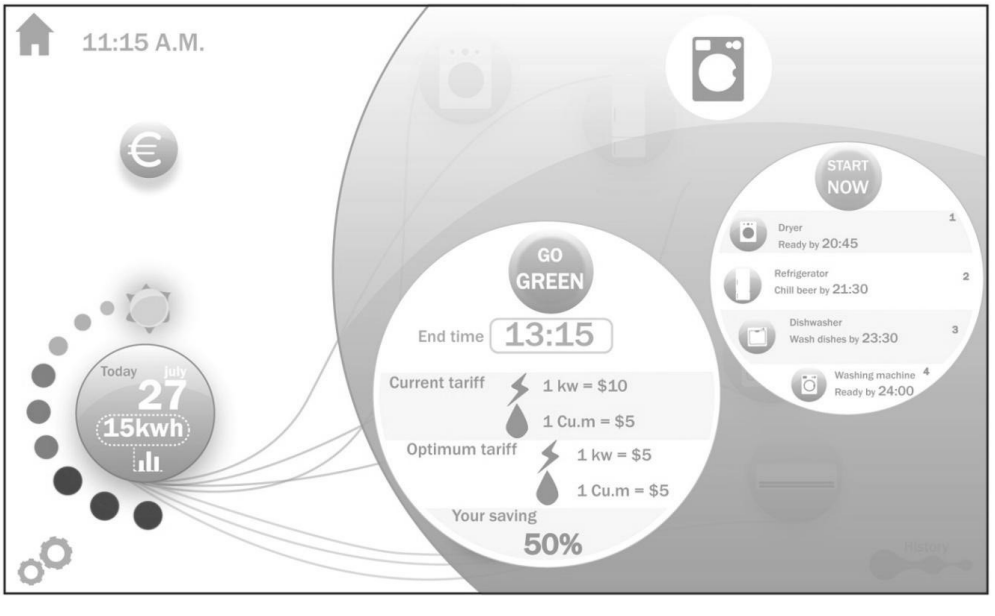

Figure 8. Appliance control home-screen.

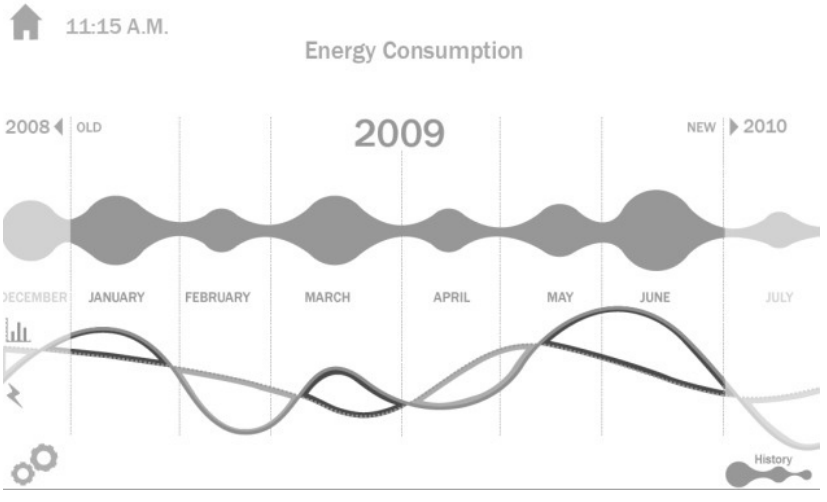

Figure 9. User real time energy consumption map.

4. CONCLUSIONS & THE FUTURE DEVELOPMENT OF '*SMART ECO*' APPLIANCES

The main point to be made here is that technology is indeed a very strong lever of design driven innovation for sustainability, but its real application can be improved many fold if it is combined with the application of mode of use lever (ie: usage and interaction). Indeed in the Greenkitchen 2.0 is an innovation on 3 levels: technology, usage & interaction, and form. Of-course exploring new concepts such as controlling all the appliances wirelessly through a tablet, and integrating all the appliances as one, have the over-all result of enticing a lot of interest from the users who then associate product eco efficiency with innovation. This project was showcased in the 2010 International Milan Design Week (*Salone del Mobile*), it received an over whelming response from consumers thus making a clear connection between design innovation and eco efficiency in the consumers' minds.

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