A Consumer Bill of Rights for Energy Conservation

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***Abstract*—Sustainable energy supply and demand can partially be solved by the conservation of energy, which is a personal and self-driven action. However, energy conservation currently requires the purchase of third-party products. The upfront cost of purchasing these products to monitor energy consumption in a home is a barrier that further cements the divide of those that have and those that have not. Detailed appliance power consumption reporting should be made available for free as part of the home's smart meter. Governments and power utilities must improve and expand policies that promote a socio-economic balance allowing everyone to participate in energy conservation regardless of their economic situation in a sustained way. We critically look at what economics and government polices exist and need to exist. We also demonstrate the computational means to achieve this – nonintrusive load monitoring (NILM) – and discuss how manufacturing and standards organizations need to work together to provide the essential information that describes how appliances consume energy. This paper proposes a Consumer Bill of Rights for Energy Conservation.**

***Index Terms*—energy policy, energy economics, smart meter, NILM, load disaggregation, appliance manufactures, standards**

I. Introduction

It is apparent that issues of sustainable energy production are solvable through the use of alternative energy supplies and energy conservation efforts. However, energy conservation is a personal and self-driven action that requires solutions tailored to individual occupant preferences. Increases in energy demand have driven the price of electricity to (in some cases) extreme highs (e.g. over $2/kWh). Products can be purchased that help occupants understand how energy is consumed within their homes, if the occupants have the financial means. Occupants on low or fixed income will need to conserve more, as prices rise, to stay within their budgetary means. In order for them to conserve, they need energy monitoring products that could inform them of what appliances consume the most energy and when. These products have a high cost. Here lies the socio-economic imbalance that would see the cruel paradox: *spending money to save money*. This upfront cost is a barrier that further cements the divide of those that have and those that have not. Detailed appliance power consumption reporting should be made available for free as part of the home's smart meter. Governments and power utilities must create policies that foster a socio-economic balance allowing everyone to participate in energy conservation regardless of their economic situation. This is the only way time-of-use rates and demand response initiatives can be implemented fairly. We propose a *consumer bill of rights* that would guide power utilities to provide the conditions that enable everyone to participate in energy conservation. We also demonstrate the computational means to achieve this – nonintrusive load monitoring (NILM) – and discuss how this technological advance can promote customer autonomy and individual action if appropriate legal and institutional safeguards are established.

We critically look at the economical and political environment to identify the barriers and opportunities for having everyone participate in energy conservation (Section II). We explain what is needed for everyone to participate in energy conservation (Section III). We then look at how manufacturers can participate and how standards organizations can enforce compliance for providing the necessary information (Section IV). We conclude with our proposed Consumer Bill of Rights and a final remark (Section V).

II. The State of Policy & Economics

Population growth and increasing standards of living for many people in developing countries will cause strong growth in energy demand. The World Energy Outlook 2013 [1] reported that from 2000 to 2010 total world primary energy demand grew by 26%, and under current policy scenarios, it is projected to grow by 45% by 2035. When looking specifically at electricity demand, from 1990 to 2011 demand almost doubled and is projected to grow 81% by 2035. Increased demand is most dramatic in Asia: over 70% of the increased energy demand is from developing countries, led by China and India.

Global collaboration on energy technology, including improved energy efficiency is crucial to secure future energy supplies and mitigate their environmental impact. As demand grows, conservation and efficiency continue to be the best and lowest cost resource option. According to the International Energy Agency (IEA) [1], a renewed focus on energy efficiency is being observed globally. Diverse policies have been introduced over the past year including: measures for efficiency improvements in buildings in Europe and Japan, in motor vehicles in North America and in air conditioners in parts of the Middle East.

A. Energy Pricing Reform

Energy pricing reforms have been implemented in various jurisdictions including China and India. Raising electricity

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prices has an effect in reducing consumption; however, it also has a dramatic negative impact in the wellbeing of individuals suffering from energy poverty. There are various definitions of energy poverty; for the purposes of this paper, it could be understood as when a household must spend 10% or more of its after-tax income on home energy [2], [3].

The potential for energy efficiency is still far from exhausted: two-thirds of the economic potential of energy efficiency appear to remain untapped, according with the one policy scenario modelled by the IEA [1]. Action is needed to break down the various barriers to investment in energy efficiency, including the development of accessible options for low-income households.

B. The Example of British Columbia

In British Columbia, a 10-year plan for annual increase (cost per kWh) was announced in late 2013, initiating by 9% increase on April 1, 2014 – about $8 a month for the average residential customer [4]. To provide specific examples of energy conservation and efficiency policies and programs focused on low-income households, we will use the case of British Columbia (BC). Over a 70 year period (1942–2012) BC's residential sector annual electricity use grew by more than ten times [5]. Causation of the growth is a complex question to answer. However, studies point to the effects of appliance proliferation (frost-free refrigerators, electric space heaters, computers, large TVs, set-top boxes, and energy efficient furnace fans) combined with over 10 years of increases in basement suite penetration (i.e. more families per home) particularly in new homes, and declining prices in real terms compared to the 1980s [5].

BC's population is expected to rise from 4.6 million in 2011 to 5.8 million in 2031. Utilities in BC forecast that provincial electricity demand will increase by approximately 40% over the next 20 years [6]. It is anticipated that the majority of the demand growth will come from the industrial sector, mostly from activity in oil and gas and in mining. This estimation does not account for savings that may be achieved through energy efficiency and conservation measures that play a crucial role in meeting expected demand. BC has set ambitious targets including: meeting 66% of all new electricity demand through conservation and 20% reduction in energy consumed in houses by 2020. Three pieces of legislation are driving energy conservation and efficiency efforts:

1) The Clean Energy Act sets out British Columbia's energy objectives including: achieve electricity self-sufficiency by 2016, and generate at least 93% of the electricity in the province from clean or renewable resources [7]. It also provides for the establishment of energy efficiency measures.
2) The Energy Efficiency Act [8] sets energy performance standards for devices that use, control or affect the use of energy such as: household appliances, heating and cooling systems, and lighting.
3) The Demand Side Management Regulation [9].

BC has been engaged in energy conservation since the early 1980's and it has been recognized as a leader in promoting conservation and efficiency. Examples of specific programs operating in BC are:

1) LiveSmart BC [10] that offers home owners various incentives and rebates for energy saving improvements and equipment. The program is administered by the Province of BC in partnership with BC Hydro and FortisBC. However, as reported in 2012 only 5% of eligible B.C. homes have done a LiveSmart BC retrofit.
2) Power Smart, a BC Hydro owned program that provides capital incentives to motivate customers to invest in conservation and efficiency. Some authors [11] believe that Power Smart has a low degree of cost-effectiveness and that it will not decrease demand in the residential sectors to the extent required for BC to become electricity self-sufficient by 2016.
3) FortisBC PowerSense [12] program that provides financial incentives and advice on energy efficient technologies and practises.

Unfortunately, the above programs are often not accessible for customers who have limited disposable incomes. Energy Poverty affects approximately 17% (297,000) of British Columbia homes [2]. Energy Poverty forces vulnerable British Columbians to choose between daily necessities, such as foregoing heat so that they can afford groceries.

Although energy conservation programs are an essential part of the Province's overall energy conservation strategy, they may actually deepen the Energy Poverty of low-income households. For example, the costs for utility–demand side management (DSM) incentive programs are recovered through utility rates paid by all ratepayers, including low-income households that may end up subsidizing the energy efficiency upgrades of their higher-income counterparts [13].

C. Energy Poverty

To address the issue of energy poverty, governments across the planet have developed different programs. In the United States, for example, the federal and state governments tend to collaborate in framing and financing low-income energy efficiency programs to alleviate Energy Poverty, while public/private utilities plan and deliver them, often in partnership with local non-profit organizations and community action agencies. Although these programs have existed in the USA for decades, they are more recent in both Canada and BC [13].

In 2009, BC introduced the Energy Conservation Assistance Program (ECAP) [14] as a separate program to assist qualifying low-income electricity residential customers free of charge. ECAP provides a home energy evaluation, the installation of energy saving products, and personalized energy efficiency advice. To qualify for this program, households require a moderate to high electricity consumption (more than 8,000 kWh/yr, which is approximately an electricity bill exceeding $600 per year) and a combined income below the Low-Income Cut-Off (LICO) as published by Statistics Canada [15]. The program is offered province-wide but service is limited in rural or remote areas depending on accessibility and minimum participation levels. The program is available for renters; however, low-income households are only eligible to receive the program assistance once every 10 years [16].

There are not yet publicly available results of the performance of ECAP. Apparently it has received support and good advertisement in some municipalities in BC (e.g. Tofino, Sanich, New Westminster and others) ; however, low-income consumers still face a number of obstacles to participate in this and other conventional household energy efficiency programs, including, for example:

- Even when programs offer free products and services, low-income families may have trouble getting information about them, either because they may confront a language or literacy barrier, or they may not have access to typical communications media [13].
- Low-income families likely have more pressing needs to manage, such as food, clothing, and shelter.
- Even when they are informed about energy efficiency measures and interested in adopting them, they may be prevented by: (a) their greater likelihood of being renters; (b) their lack of time to investigate; and (c) their tendency to move more often [13].

These barriers need to be taken into account when designing energy efficiency solutions for low-income families.

III. Understanding Appliance Consumption

Power utility companies around the world are replacing old electromechanical meters with new smart meters. However, smart meters are not actually *smart*. They are simply digital power meters with enhanced communications capabilities. The smart meter can be enhanced to provide the communication of rich information, such as lists of appliances running. For example, this lists shows what appliances are running, how much energy they have consumed, and the current rate at which they are consuming. Makonin et al. recently defined a *smarter* smart meter [17] that contains an algorithm (only on the home area network side to alleviate privacy concerns) that determines what loads/appliances are running and then communicates this rich data to informative displays (see Figure 1) so that occupants can make smart energy conservation decisions. We feel this is essential for supporting such initiatives as time-of-day usage charges (peak charges) and demand response (DR).

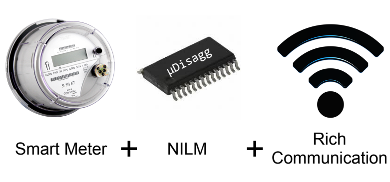

Fig. 1. The *smarter* smart meter equation.

A. Nonintrusive Load Monitoring

Nonintrusive (appliance) load monitoring (NILM or NIALM) is the process of determining what loads or appliances are running in a house from analyzing the power signal of the whole-house power meter. NILM, which is sometimes called load disaggregation, can be used in systems to inform occupants about how energy is used within a home without the need of purchasing additional power monitoring sensors. Once occupants are informed about what appliances are running, and how much power these appliances consume, they can then make informed decisions about conserving power, whether motivated by economic or ecological concerns (or both).

NILM research first began with a call in 1989 from Electric Power Research Institute (EPRI) [18]. Shortly after, Sultanem [19] and then Hart [20] published their research results. A typical NILM algorithm has four general steps (see Figure 2): a way to measure the main power of the house, a way to detect when appliances turn ON and OFF and when they change operational states, a way to extract different features of measurements (e.g. current spikes, steady-state durations), and finally using the previous steps to classify what appliances are on (and in what state) and to determine how much energy they have consumed.

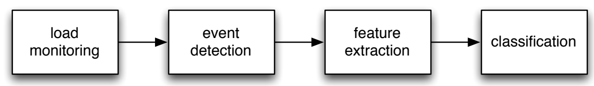

Fig. 2. Block diagram of a topical NILM algorithm.

Having NILM in a smart meter will provide the necessary information that occupants can use to understand how their home consumes energy. A recent study [21] shows that 80% of participants want to have access to NILM data (i.e. knowing how their appliances consume energy) and believe that every one should have access to this information. The study also shows when NILM information is made available to occupants, those occupants can reduce their energy consumption by an average of 14%. In fact, more research is showing that in order for occupants to reduce (on average) their energy consumption by more the 9.2%, real-time appliance specific consumption information is needed [22], [23]. Figure 3 is an example of a simple breakdown of NILM results that occupants need. This information shows the HVAC system (the heat pump and the furnace) is the largest consumer of energy and that there is a high degree of accuracy (61.5% estimated *vs* 61.3% actual) when determining this using NILM. The heating and cooling of a home is an action that is deferrable. Deferrable actions are actions that can be postponed (most of the time) and in situations where the rate per kWh may fluctuate we now have a tool that informs us about opportunities to conserve energy and save money.

B. Informative Displays

While NILM would determine what appliances are running and how much they are consuming, there still needs to be a mechanism to convey such information in a home. We cannot rely on low-income households to have access to a computer and the Internet at home. So, we must provide *informative displays* that can convey NILM data to occupants. Although

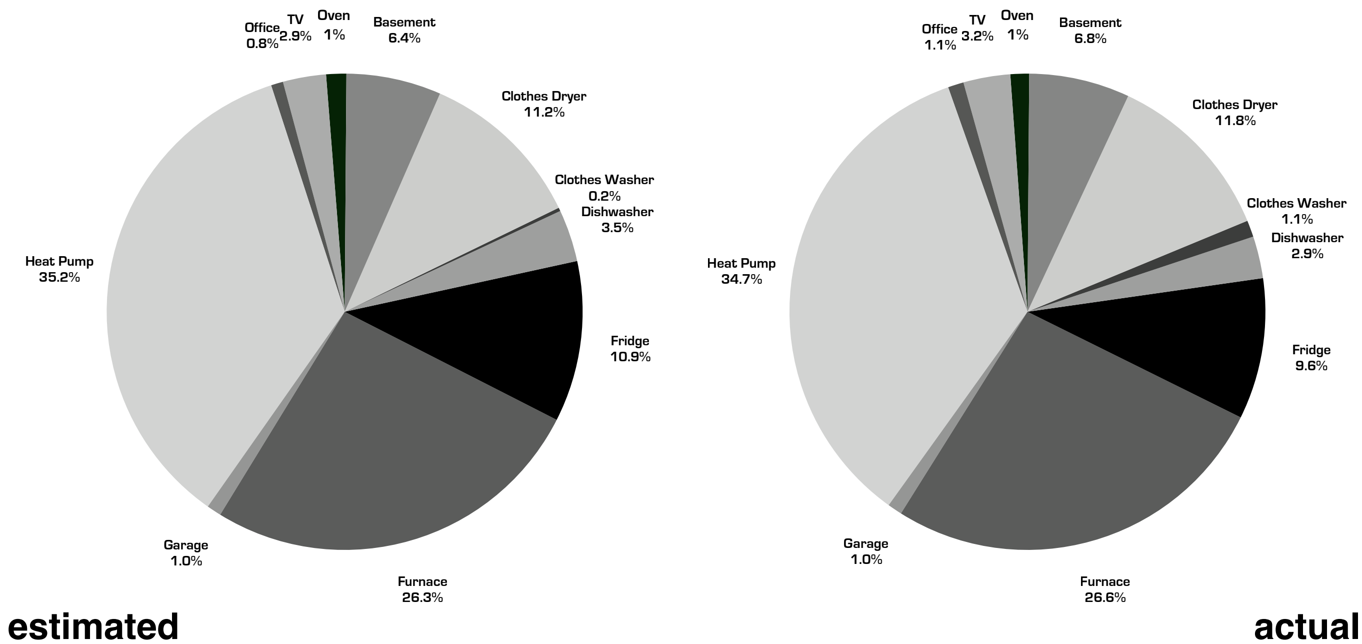

Fig. 3. The consumption estimation results of 11 loads over a period of 1 year using the AMPds dataset [24]. Results from our NILM algorithm, using a hidden Markov models [25].

most researchers agree that energy use information can positively affect consumption behaviour [26], there are huge challenges in determining how informative displays should be designed and placed with a home, and what type on information is needed. Researchers in human-computer interaction (HCI), visualization, environmental psychology [26], [27], and architecture study how occupants engage with a home ("occupant intelligence" [28]) and how this should influence the design and deployment of informative displays. However, informative displays need to provide timely information and must be placed conveniently within a home. Critical to this is contextually appropriate information in real-time – what is using energy, when and how.

Information presented in a timely manner is more than just meeting a near real-time requirement [29]. This means having the informative display provide feedback that matches the pattern of consumption as it happens. Lags in the consumption-to-feedback function can lead to a misunderstanding of what appliance is consuming power and when. Timely access to the right information is critical in motivating occupant engagement [26]. If informative displays are difficult to use, cumbersome, or not easily accessible then this results in the display either being recycled, thrown into the garbage, or boxed up and forgotten – a barrier to occupant engagement and create what DiSalvo et al. [30] called a wasteful rapid obsolescence cycle

Convenience means the informative display is placed in a home in high traffic areas. Research has found that occupants considered the kitchen and the living/family room as two of the most convenient locations to place an informative display [31], [32] based on lifestyle factors [33].

IV. Providing Better Appliance Information

In order to understand how energy is consumed within their home without having to buy expensive products, as part of the homeowner's smart meter, detailed power consumption information must be available in order to make NILM possible. To motivate manufacturers to supply this information in a consistent and accurate manner, the government and Natural Resources Canada (NRCan) would need to introduce policies stating that manufacturers must provide detailed power consumption publicly to consumers and the Canadian Standards Association (CSA) would promote this. Manufacturers who want to evaluate their products and apply the CSA mark to their product would have to meet these standards. The type of detailed power consumption information in question would include average power usage, an explanation of the appliance's operational states, power usage in each state and the duration of each state. Only with this information can it be possible to correctly and consistently identify what appliance is running and when it is running using NILM. In this section we explore what information is necessary to be provided to the public, how manufacturers can participate and how standards organizations such as the Canadian Standards Association (CSA) can enforce compliance by the manufacturers for providing the necessary information.

A. Standards Organizations

Standards organizations play the role of encouraging manufacturers to comply with certain policies in order to be certified under certain globally recognized standards like those of the International Organization for Standardization (ISO). They help ensure peace of mind to retailers and consumers about the products they are purchasing. On a smaller scale, for example, in Canada the CSA is the official agency for all electrical equipment intended for sale or installation in Canada and its mark is currently applied on products globally. The CSA is internationally accredited as a member of the ISO and conduct verification for ENERGY STAR requirements from the Environmental Protection Agency (EPA) [34]. In order for manufacturers to apply the CSA mark to their product, they must meet the requirements for the appliance as stated in the applicable standard. If a standard were written with requirements for manufacturers to provide detailed power consumption information to the consumers, manufacturers would be forced to provide this information if they wish to use the CSA mark on their product.

The National Resources Canada (NRCan) has two brands that help to make it easier for consumers to understand their power consumption: EnerGuide and Energy Star [35]. The Energy Star label informs customers that the product meets or exceeds the standards for energy efficiency. The EnerGuide label helps consumers compare the appliance's energy efficiency with other appliances in the same class and is mandatory on certain appliances as per Canada's Energy Efficiency Regulations [35]. By introducing a new brand that would be universal to all household appliances and would indicate compliance with the government's policy to provide detailed power consumption information, NRCan would encourage manufacturers to comply by providing this information.

B. Better Appliance Information

Some appliances do not operate in simple on and off states. Appliances with different operational modes (multi-state) have complex power signatures and are harder to identify from the aggregate power measurement of the smart meter. In order for NILM to be highly accurate, appliance manufacturers would need to comply with a CSA standard to provide all necessary information about the appliance's power signature to the public. To effectively identify the appliance's share of the overall household load, besides the average power usage information that is already provided on the EnerGuide [36] labels, the power usage must be known in more detail, including power usage of all the operational states that the appliance runs at (if applicable) and the expected or average duration of each operational state.

In order to receive CSA/ISO approval, appliance manufacturers must provide better information on how their appliances run. This can be done in two ways: online and label. For online, appliance information must be uploaded to a government run database. This would allow consumers to download the power signature information and integrate it with their smart metering system in order to be able to detect when that specific appliance is being used and how long it is being used for. The most ideal way of storing this information would be through an online database where standards organizations could provide access to this open database of power signatures. An alternate solution (for low-income households) would be the appliance manual, or a sticker on the appliance, to contain a label that lists all this information (see Figure 4 for an example) and the user would be required to enter this information into the load monitoring system.

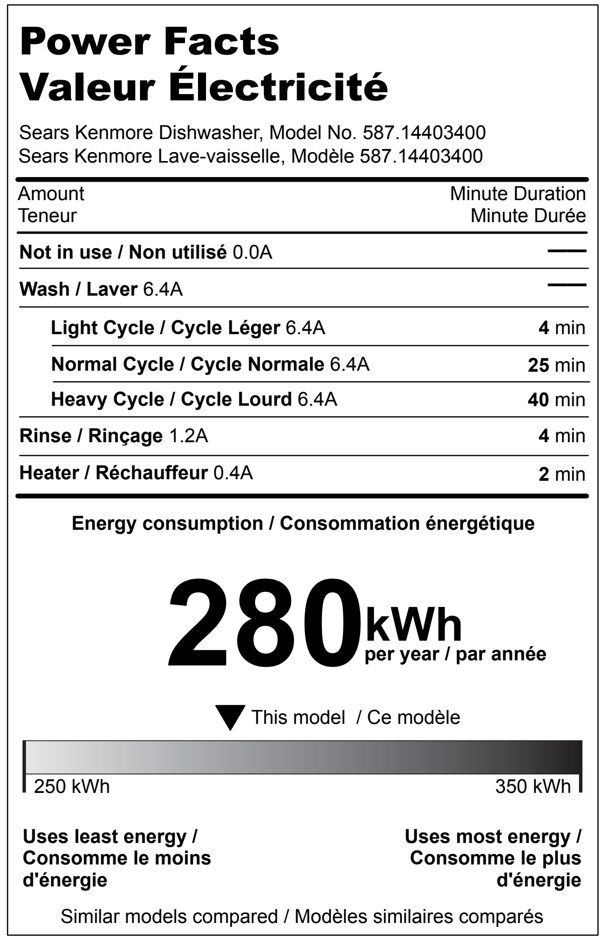

Fig. 4. Example power facts label that would appear on an appliance which would provide the necessary information for NILM to disaggregate this appliance from the whole-house power meter reading. This label can be seen as an extension of the existing EnerGuide label.

V. The Consumer Bill of Rights for Energy Conservation

Access to rich information about appliance consumption no matter the socio-economic situation of a household is paramount for everyone to participate in energy conservation activities. Our proposed Consumer Bill of Rights enshrines this belief.

Article I: Access The consumer has the right to know the power demands and signatures of each appliance, including the average, peak, and multiple-state power consumption. Access to this information must be made available via an informative display that would communicate directly to the smart meter, and not rely on the consumer having a computer or access to the Internet.

Article II: Privacy The consumer's detailed appliance use information, or disaggregated data, belongs solely to the consumer. The consumer and producer jointly own aggregate power usage data, and shall not be distributed to third parties except in anonymized and aggregated form, and with the consumer's express written consent.

Article III: Security The consumer has the right to expect that data is sent from the smart meter to the power utility and/or to devices in the home over a secure communication network.

Article IV: Equality The consumer has the right, no matter the socio-economic situation, to equal opportunity to participate in energy conservation activities.

Article V: Comfort The consumer has the right to use energy to support basic comforts without shame or penalization.

Article VI: Re-entry The consumer has the right to re-enter into programs that promote general energy conservation retrofitting. Programs must allow for staged completions in recognition of change of residence and budget constraints.

Article VII: Maximization The enumeration of the foregoing rights shall not be construed to deny or disparage others retained by the consumer.

Because of the dynamic nature of homes and occupants, we cannot begin to predict nor understand what type of energy conservation strategies different homes would use. We need only provide rich information about appliances and let the occupants make their own decisions based on their needs, opportunities and comfort.

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