Mathematics, physics and astronomy for the home

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International Conference on Excellence in the Home
Sustainable Living Professional Approaches to Housework
March 17-18, 2011
The Grocers Hall, London

Abstract

Energy saving at home requires measurement. Parents and children are not normally able to estimate the cost of household appliances' consumption and the economics of their personal behaviour. There is a need for a scientific approach to home life, in order to live better, spend less and preserve the environment. Teachers in primary schools should consider this approach.

Keywords

Energy saving, measurement, ecology, education

Scenario

From time to time we read articles on magazines and newspapers about the importance of switching off household electric appliances in order to save money: the sleep mode – standby – is not advisable because it uselessly consumes energy. Obviously there is a trade off in deciding what to switch off completely: a computer takes much more time to boot from its power off state, and the same thing now happens to many digital TV sets because they actually are computers. But the experts inform us that we can save hundreds of € or $ or £ every year if we switch them off completely when we do not use them.

There is also a positive pressure, often with legal enforcement, on changing incandescent light bulbs with low energy fluorescent lamps. But who is really able to calculate the savings in his or her home? Is it better to wait until the old bulbs burn out or to change them immediately? It is a typical "what if" analysis, relatively easy to manage with any spreadsheet.

Bijker [1997] writes that 'General Electric had a long tradition of specifically addressing women in their advertising campaigns. Here, in a 1925 advertisement, the implicit message is "The cost of electrical technology is so small that its price is irrelevant when compared with the value of children" [Nye 1985]'. The author refers to messages that accused women who dedicated too much time to washing and cleaning, stealing it from time for their children: they should instead buy the latest washing machine and vacuum cleaner. In this case the balance is between time and money: which criteria should you use to choose? First of all you have to know which are the costs involved with the new appliance: not only purchasing costs but also running costs (energy, maintenance, consumables, etc.) which sum up to the total cost of ownership. If you don't calculate it you will not be able to weigh it opposite the time saved in doing housework.

How many architects are able to tell where is North just by watching the sky at day or at night? Do they know which are the typical winds of a region and the temperature and humidity associated with them? I have the answer based on my personal statistics: fewer than what you expect. If they don't realize that at noon the sun is always southward and its elevation depends on the latitude and the time of the year, most probably when they plan a building they do not care too much to where the windows are faced. And you are perfectly aware of what happens in winter when the bedroom is on the north side of the house where the sun never shows: it is cold, while maybe the living room in the afternoon is too hot in summer if it is on the opposite side. Of course, things are different in the different countries. Watching the way medieval towns were built in the southern Mediterranean area you realize that they were using natural ventilation and protection from the sun to stay more comfortable during the hot season [Butera, 2007]. Studying how the typical Trulli in Apulia are built shows a careful traditional design to preserve heat in winter and cold in summer. In many places there are examples of how the Arabs were masters in cooling down homes with water fountains. With the introduction of artificial warming and cooling, apparently you need not care about the external environment, but this approach has a high cost for society: it means money from you, pollution for everybody, and an excess of CO_2 in the air. How can we make *green* homes if we don't know the physics of the atmosphere? But you are not compelled to become a specialist in eco-architecture: it is sufficient to rely on some basic scientific knowledge and a lot of common sense.

In Italy we always have roll-up shutters outside the windows at home. Internal curtains, typical of northern countries are not sufficient to shield from the strong lighting and the heat of a summer day. The habit of keeping them half opened is widespread among women, just in case the sun shines and destroys the furniture because the UV rays damage colours and textiles: this is a good physics knowledge. But very few of them realize that it is useless not to open them completely if the sun never reaches the window because of its orientation. The effect is that the room is dim and they need to switch on the light, wasting energy. A simple understanding of astronomy would avoid the cost.

Mediterranean's love open air, that's why they open the windows very often, to refresh, or forget them opened after a meeting. The temperature lowers in winter and an extra cost of heating is required. They are not able to say how long they should keep them open in order to introduce the necessary oxygen.

We generally say that a lower humidity is better when the temperature is high, but are we able to calculate the heat index or to determine the acceptable humidity at a given temperature? If we have the means for calculating these values we can discover that in some situations cooling is not necessary: dehumidification is sufficient with a much lower energy cost.

Everybody knows that if the thermometer shows that my body temperature is 44 °C, there is something wrong with it or, as I used to play when I was a child, someone placed it on the light bulb (the thermometer usually broke, exploding, and I would play with the dangerous mercury drops). It means that the knowledge of the body temperature range is part of our education. It is not the same for other ranges: which is the best water temperature for a shower? We often produce very hot water and later mix it with cold one to have a comfortable washing experience: do we really need to store it at 70 °C? And how much water do I need for filling the bath? Less or more than a five minutes shower?

Another field of better understanding is the thermostat. If in the living room it is set to 32 °C on a cold winter day, very few people notice it or act consequently. They surely do not want to reach that temperature in the house, but the general opinion is that placing it at a high temperature will give heat faster. The normal result of this behaviour is overheating and ends up with opening the window for cooling down. They do not understand the switching role of the thermostat: the heating will stop only when the room reaches the displayed temperature but the heating speed does not change if it is set at 32 instead of the desired 22 °C.

Proposal

Knowing how things work is the first step. The second is measuring consumption. Sometimes you can realize that there is a leak in the water pipes before a flooding disaster occurs if you notice that you are wasting more than normally on a standard day. If you don't know what is your daily intake of water you will not be able to compare it with an abnormal consumption.

The task is getting easier now with simple and relatively inexpensive gauges and monitors to measure instant and average expenditure of the single appliance or at global level. There are also wider approaches: a U.S. company distributes a measuring software to develop a Home Energy

Reporting program. The main idea is showing household consumptions compared with the neighbourhood’s. They call it normative social influence because they leverage on the awareness of doing better than the average of other families who have almost the same needs: it is a psychological process. I’m not surprised that the founder of the company is a former owner of an educational software company: the power of education is strong.

Browsing the web I found an interesting 36 hour course in the American River College of Sacramento, California named *Mathematics for the Home and Workplace* with the aim of using ‘a variety of realistic consumer-oriented applications to refresh, reinforce, and extend students’ mastery of basic mathematics concepts. The applications will include earned wages, buying and maintaining a car, working with food, budgeting, banking, and other consumer and job related activities’. This is a proper way of teaching math, applying it to real family life.

Another good attempt to explain physics applied to everyday situations is a book about the physics of a 5” heel [Marelli 2009]. Girls and ladies are scientifically and amusingly introduced to many of the daily phenomena regarding the life of a woman at home, at work and at leisure.

We need primary school teachers to introduce pupils in understanding home behaviours using a scientific approach. I’m not saying that they should teach Bayesian analysis: it is much more useful and effective to learn rules of thumb or heuristics [Gigerenzer 2008]. Children are now called “digital natives” [Prensky 2010] and are able to solve difficult problems and manage themselves in complicated situations while playing videogames. If their teachers succeed in transforming a one-way lesson in a participated experience with the goal of producing savings at home, the pupils will be amused and their parents happy. It will be a win-win situation with a professional approach to housework.

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AN EXAMPLE OF SIMPLE MATHEMATICS

COST COMPARISON FOR DIFFERENT TYPES OF LIGHT BULBS
in order to decide whether to change from one type to another

The table below shows typical data for equivalent lighting with very simple formulas.

LED bulbs are sometimes declared to last from 25,000 to 45,000 hours and compact fluorescent bulbs from 8,000 to 10,000 hours. The differences are not negligible and influence the convenience ratio.

The buying cost is multiplied to reach the lifespan of the LED bulb, but no cost for replacement (maintenance) is included, while it may be significant if the bulb is in a difficult-to-reach location. The maximum number of switch on-off before burn-out is not important because for the three types of bulbs it now exceeds any normal behaviour.

power cost €/KWh *0,15* *hours in a year* *8760*

First scenario

	power	lifespan	lifespan if always on	buying cost for one item	replacements for the LED lifespan	total buying cost	consumption cost for the LED lifespan	**total cost for the LED lifespan**
Type of lamp	*Watt*	*hours*	*years*	€	*number*	€	€	**€**
incandescent bulb	40	1000	0.1	1.00	25.0	25.00	150.00	**175.00**
compact fluorescent	10	8000	0.9	3.00	3.1	9.38	37.50	**46.88**
LED	7	25000	2.9	35.00	1.0	35.00	26.25	**61.25**

Second scenario

incandescent bulb	40	1000	0.1	1.00	45.0	45.00	270.00	**315.00**
compact fluorescent	10	10000	1.1	3.00	4.5	13.50	67.50	**81.00**
LED	7	45000	5.1	35.00	1.0	35.00	47.25	**82.25**

- power*: the power of different light bulbs with the same intensity of lighting*
- lifespan*: the average duration of the bulbs, which may vary according to the brand and the quality*
- lifespan if always on*: how many years the bulb lasts if it is on 24 hours a day*
- buying cost for one item*: typical selling price in a shop*
- replacements for the LED lifespan*: how many times you need to replace the bulb after its lifespan before reaching the duration of the LED bulb*
- total buying cost*: the buying cost multiplied for the replacement number*
- consumption cost for the LED lifespan*: the power cost during the lifespan of the LED bulb*
- total cost for the LED lifespan*: the sum of all the costs during the lifespan of the LED bulb*

The analysis shows that it is surely convenient to dismiss incandescent bulbs while there is not a definite saving to use LED lighting, so far, with current buying costs. The comparison can be adapted for lamps which are not on 24 hours a day. In that case, the LED becomes convenient only if the lamp requires a costly effort to reach the site where it is located.

In a real scenario the comparison should include the actual costs for the type of bulb required, with their declared lifespan, and the local power supplier's cost.

More arguments should be considered, such as the color, the time to reach the full brightness and the shape of the bulb: in fact, the three types have relevant differences.