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Let's Make our Buildings as Smart as our Cars

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Zerofootprint is an organization dedicated to a mass reduction in global environmental impact. We provide software and services to individuals, governments, universities, and corporations that measures and manages carbon footprint and engages employees and citizens worldwide in combating climate change.

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SMART BUILDINGS FOR A LOW CARBON WORLD

When you look at the world today and how we are going about tackling climate change, you have to question some of our priorities. We tend to focus on certain things, such as the carbon emissions of SUVs, when there are far bigger carbon villains in our midst. If you take our cities, it is buildings that are the biggest polluters. Seventy-nine percent of carbon emissions in New York come from its buildings, while the average for buildings in North American cities as a whole is 40 percent.

The situation is just as bad elsewhere. Buildings account for 60 percent of London's carbon. Meanwhile, figures revealed by the British government in December 2008 showed that public premises in England and Wales, including ministerial offices, police stations, museums and art galleries, pump out 11 million tonnes of carbon dioxide a year – more than Kenya's entire carbon footprint.

Buildings require cooling in the summer and heating in the winter, consuming huge amounts of energy. Their lighting, hot water systems and elevators soak up energy too. And they are filled with appliances – computers, printers, photocopiers, fridges, coffee machines – all of which guzzle electricity.

Most of our buildings simply big inert structures – they have little or no intelligence built into them. Compare the average building to a modern car, say a Honda Civic. The car has more sensors, more microprocessors and more mathematics governing its operation that almost any building. The car is aware of its environment and its internal conditions. It knows if you are in the vehicle and will remind you to put your seat belt on if you haven't and to close the door properly. The car monitors and reports on its operation, letting you know its speed, the revs of its engine, its fuel consumption and distance travelled. As you drive, various algorithms help optimise its performance, from the fuel mix to its braking. And it warns you of potential problems, such as fuel or oil running low or the engine overheating.

If we go back in time 30 years, the Honda Civic was a relatively simple machine, without the microprocessors or the optimisation. It also produced a large amount of emissions. In fact, it was 100 times more polluting than the Honda Civic of today. How did we get from that basic functional vehicle, to the smart, aware, self-optimising car of today? We used technology and mathematics, and now our cars are clever and very much cleaner. We need to do the same with our buildings. We have the technology. We know how to do the math. We need to use these to make our buildings as smart as our cars.

Through intelligent use of technology and optimisation we will be able to make significant reductions in carbon footprint. Cutting the emissions of buildings in North America by just 10 percent would do more for the planet that taking all the SUVs off the road. (SUVs are responsible for 3 percent of emissions in North America.) Just as car manufacturers have done, we need to employ sensors and microprocessors to make our buildings self-aware and to report to us what is going on. And we need to use mathematics to make buildings more energy efficient.

Making the Invisible Visible

The first challenge in making our buildings smart is to make the invisible visible. The problem with carbon emissions is that we can't see them. It is not just that carbon dioxide is a colourless gas. Most emissions are elsewhere, out of sight – certainly, when it comes to electricity. Unless you live in view of a power station and can see the plumes of smoke rising out of their stacks, you won't see the emissions produced by the generation of the electricity you consume as you feel breeze of your air-conditioning system while you work at your computer.

Our cars are way ahead on this. We don't need to watch the exhaust pipe of our cars to know that we are consuming fuel and creating carbon. We simply need to look at the dashboard. The dashboard is where the car feeds back to us information about its operation. It gives us a clear, continuously-updated summary of the car's speed, revs, fuel consumption, etc. This is what we need for our buildings – simple visual representations of their internal conditions and performance.

Walk into any building in London or New York today and you won't find a dashboard. But the idea is coming. In Masdar, the zero carbon city under construction in Abu Dhabi, they are planning dashboards to visualise their greenhouse gas sustainability performance. They are making the invisible visible.

Measuring So We Can Manage

The second challenge in making our buildings more energy efficient is measuring activity and performance. We can only manage what we can measure, so we have to measure what is going on everywhere within a building. Some of this we do already, but it is not easily accessible. The electricity meter is hidden away in some basement cupboard, and only looked at once a quarter by someone from the power company. And the meter just gives a gross reading – it does not tell us anything about where the consumption is happening or why.

Meanwhile, all the systems and appliances within the building operate in isolation. The heating, ventilation and air-conditioning (HVAC) systems, lighting, water heating, elevators and so on are standalone – they don't talk to each other and, in some cases, they don't report their performance anywhere. Let's look more closely at the HVACs – the biggest energy hogs.

Say it is a fine spring day that starts out comfortable but then starts to heat up. Most of the buildings in the city have their thermostats set around the same temperature, and when that threshold is reached they all switch on their HVAC. That causes a spike in electricity demand, which can have big consequences in terms of carbon emissions. The spike means another power station has to come online, and at peak times that usually means the least efficient, highest polluting plant.

Now if the HVACs could talk to the internet and report what they were doing, and if there was some central intelligence, some mathematical program that monitored and analysed these reports and calculated an optimal strategy and could send instructions back to the HVACs, it would be possible control the response of the cooling systems in such a way as to avoid the spike. Heating and cooling systems consume most energy when they first fire up, as they work to drive the temperature up or down to the required level. After that, their consumption falls to the level required to maintain the temperature. A smart optimisation program could schedule a staggered firing up of the HVACs, possibly adjusting their target temperatures too, in order to avoid the spike. This smoothing of electricity demand can take a huge load off the system, and prevent a dirty coal-fired station coming online.

This Isn't Science Fiction

We already have the technology to do this today. There are wireless controllers that attach to HVACs and connect to the internet to report performance and receive instructions. If every HVAC were to have such a controller attached we could use smart algorithms to shave off peaks in electricity demand and make substantial energy and carbon savings.

Now what if we extend the idea to all appliances in a building – to the hot water system, and all the computers, printers, photocopiers, fridges, kettles, etc. – and connected them all to the internet so they could report on performance and receive instructions? And what if we applied price incentives as well as smart algorithms? They tried this in an experiment in the residential area of Olympic Peninsula across the Puget Sound from Seattle in 2006. The Pacific Northwest National Laboratory of the US Department of Energy installed smart technology, including intelligent electric meters, thermostats, water heaters and clothes dryers, in 112 volunteer households.

The appliances communicated with internet-based software that allowed the householders to set their preferences as regards not only the temperature of their homes, but also the economic performance of their appliances. During the experiment, electricity supplied to the homes was variably priced according to demand on the grid, with the price rising during peaks.

By adopting strategies such as programming their clothes dryers to take advantage of cheaper off-peak rates, and thermostats and water heating elements to automatically turn down when the electricity price rose, the householders saved on average 10 percent on their electricity bills. More important from a climate change point of view, the experiment showed that a combination of this kind of intelligent appliance response to the state of the grid, along with distributed generation, could reduce peak loads by 50 percent. The Pacific Northwest National Laboratory concluded: "If all customers were engaged in reducing peak loads at this level, peak electricity prices would be substantially reduced, and construction of about $70 billion (over a 20 year period) of new generation, transmission and distribution systems could be avoided."

If the same technology were applied to Ontario, Canada, it would have an enormous effect on carbon emissions. Ontario's primary power generation is nuclear and hydro. This is always on and covers what is called the base load. During peaks, Ontario switches on more expensive and far more polluting coal-fired stations. Cutting peak demand in Ontario by 50 percent would have a dramatic impact on the region's carbon emissions. This is part of the thinking behind Ontario's smart meter program, where utilities are replacing traditional meters in homes with devices that they can read hour by hour, and introducing variable pricing to encourage householders to use electricity at off-peak times.

The Benefits of Smart

Smart meters can be part of a wider project to make our energy generation and distribution systems smarter and reduce their carbon footprint. As *IBM* chairman and *chief executive officer* Sam Palmisano pointed out in his remarks to the US Council on Foreign Relations in November 2008, the lack of intelligence and control in national grid systems means that we lose up to 70 percent of generated electrical energy. And it is not just our grids. Traffic systems, product supply chains, water systems, healthcare and other facilities and processes could all become much more efficient, and thereby less polluting, by infusing them with a mixture of technology and mathematics, said Palmisano.

"New computing models can handle the proliferation of end-user devices, sensors and actuators and connect them with back-end systems," said Palmisano. "Combined with advanced analytics, those supercomputers can turn mountains of data into intelligence that can be translated into action, making our systems, processes and infrastructures more efficient, more productive and responsive—in a word, *smarter*."

As an example of this intelligence in action, Palmisano cited Stockholm's smart traffic system, which through a combination of measures, including better monitoring and economic incentives, has resulted in 20 percent less traffic, a 12 percent drop in emissions and a reported 40,000 additional daily users of public transport.

Smart Building Pioneers

We have the technology and know-how today to make our buildings smart. Where building owners are taking approach, they are making significant reductions in carbon footprint, and reaping many other rewards besides. Ave Maria University, Florida, which opened in 2007, is an early pioneer. Right at the design phase, the university decided that its buildings would be as smart and efficient as possible. The first task was to ensure that all systems within the buildings – 23 in total, including heating and cooling, fire, security, lighting and communication – could talk to a Web-based network. This network is overseen by a master control system that manages the facilities centrally, with as much automation as possible. Cameras and sensors monitor the buildings' activities, with the control system and facilities staff optimising the operation and performance of the cooling, lighting and other systems. Lights, air conditioning and air flow are activated where students are present, and turned off where they are not.

The payback on this smart integration was both immediate and ongoing. Upfront, the university saved $1.5 million by connecting everything to a Web-based network and avoiding redundant cabling. With the built-in automation and optimisation, and the detailed information feedback (accessible by any device that can connect to the Web, including smart cell phones), the university is making annual savings of $350,000 because the facilities can be run with a third of the staff normally required for the size of institution. Furthermore, the university is saving $600,000 a year in utility bills because it is able to optimise the use of HVACs, lighting and other facilities and avoid energy waste. The carbon savings from this avoided power generation are ongoing. Buildings last on average 50-100 years, so reducing their carbon footprint has a lasting environmentally beneficial legacy.

Much of the success of project like Ave Maria University is about giving people more information about their energy consumption – making the invisible visible. The same applies to the Olympic Peninsula experiment, where participants said that knowing the cost of electricity and the performance of their appliances enabled them to make intelligent choices that were both to their economic benefit and to the general good of the grid. The dashboard is one of the most effective mechanisms we have found of making the invisible visible when it comes to our machines and facilities. The quick visual summary of conditions and performance in our cars enables us to make better decisions when we drive. Dashboards in buildings could help us make more intelligent decisions about how we operate them as well.

Dashboards and Benchmarks

A dashboard that can be displayed on the screen of all the desk or cell phones is a feature of the smart system that Gruppo RETI, a technology services company based outside Milan, installed in its new headquarters. Like Ave Maria University, the Gruppo RETI building integrates all its facilities managements and services on a Web-based network, including smart lighting, HVACs, security systems and telephones. Staff can control their own personal environment via the dashboard, including window blinds, lighting and air conditioning, or set their general preferences using a 'scenario management' facility, which will automatically create their favoured environment when the system detects their presence. The system monitors and optimises energy consumption, for example turning off lights when no one is present, and the energy savings achieved so far are promising, says the company.

Buildings like the Gruppo RETI headquarters and Ave Maria University are setting benchmarks for building intelligence and efficient energy use. (Note that there is not degradation of conditions and the occupants' comfort is optimised at the same time as the energy savings are achieved.) We need these kind of building benchmarks in every city and town. We need to be able to look at the dashboard of a building and know not only how it is performing in its own terms, but how this compares with other similar buildings in the same area. Benchmarks provide goals we can aim towards. Eventually, we might set benchmarks with specific carbon footprint targets, in the same way as we set speed limits for cars at present. These building 'carbon speed limits' might fluctuate during the day to manage energy demand and avoid spikes and overloading the grid.

But it is not just new buildings that we can make smart. These technologies – temperature and lighting sensors, Web-based communication networks and optimisation mathematics – can be retrofitted to older buildings too. At the same time, those in charge of buildings need to be better educated about energy management. The British government report revealed that the poor energy performance of its buildings was the result not only of inefficient equipment, but also of ignorance among officials and poor energy management.

Creating Incentives

Benchmarks provide measures that can be used as goals, but to maximise the carbon reductions that we can achieve with the new tools and technologies we need to fully engage the managers and occupants of buildings. This can be done in a variety of ways. One is to simply mandate it. This is what electronics giant Panasonic has done with its manufacturing plants. The company has set strict carbon emissions targets for its 294 sites, and included these in the bonus criteria for the both the plant managers and workers.

Panasonic is installing monitoring devices at its manufacturing sites, and its new regime is part of a plan to reduce its global carbon emissions by 300,000 tons to 3.68 million tons by March 2010. The target is voluntary, and the company sees it not only as an act of corporate responsibility, but also as a way to demonstrate its technologies and competitiveness. But as an indication of how seriously Panasonic is taking the issue, from now on it will count carbon elimination as one of its main management indicators along with sales, inventory, operating profit and return on capital.

This mandatory approach to carbon reduction is not possible or appropriate for many office workers, students, households and other building occupants, so different methods are required. Persuasion, disclosure, disapproval and encouragement of positive actions have all been tried by environmental activists over the years. However, psychologists warn that a simplistic approach can be counter-productive.

In a recent experiment, researchers from California State University monitored the energy consumption of 300 volunteer households and gave them various forms of feedback. Some were told only what the average consumption was. Others had an 'emoticon', a happy or sad face, placed next to their consumption figures based on whether they were higher or lower than the average. They then measured the householder's energy consumption over the following months, with interesting results.

Encouragingly, once householders received information that they were over the average they tended to reduce their consumption. Unfortunately, the information had the opposite effect on those who discovered they were under the average – they tended to increase their consumption to the norm. But this negative 'boomerang' effect was avoided in the case of those householders whose under-consumption was accompanied by a smiley face. This simple indication of approval was enough to encourage these households to maintain their energy frugal ways.

The results suggest unless information about carbon footprint is accompanied by some form of approval for responsible behaviour it can have the opposite of the intended effect. But it does also show that once we have information about our energy use, and we can put it into context with the social norms and approved behaviour around us, we tend to respond quickly and responsibly. Carried out in the right way, feedback to building users could have a significant impact on their emissions.

Conclusion

A concerted effort to make out buildings as smart as our cars, and to give building users information and incentives in relation to their emissions, could have a significant impact on global carbon output and climate change.