International Journal of Electrical and Electronic Engineering & Telecommunications

ISSN 2319 – 2518 www.ijeetc.com
Vol. 3, No. 3, July 2014

Research Paper

CONVERGENCE OF GREEN AND SMART BUILDINGS BASED ON GREEN COMPUTING

M Vishnu Kumar[1]*, J Jayapriya[1], S Nirmala Devi[1] and N Dhanalakshmi[2]

*Corresponding Author: M Vishnu Kumar, ✉ vishnunaline.cse@gmail.com

Green and intelligent buildings have been getting increasing attention in and around world due to their potential to reduce building energy costs, mitigate greenhouse gas emissions, reduce water consumption, and add value to the buildings given the savings and the positive effects on occupant safety, comfort, and satisfaction. This research introduces the concept of improved intelligence to make buildings greener and smarter, provides an analysis of the current state of existing and emerging technologies in the building automation space, and outlines products and processes, as well as trends, which supported by the concept of Green Computing.

Keywords: BMS, ICT, EnerGuide, Flushometers, HVAC

INTRODUCTION

Smarter buildings that emerge from a holistic point of view involve collaboration between facilities and IT organizations at new levels and require new transformational skills in organizations or businesses. The term 'smart buildings' describes a suite of technologies used to make the design, construction and operation of buildings more efficient, applicable to both existing and new-build properties. These might include Building Management Systems (BMS) based on green computing that run heating and cooling systems according to occupants'needs or software that switches off all PCs and monitors after everyone has gone home. BMS data can be used to identify additional opportunities for efficiency improvements. A host of BMSs already exist and as Information and Communications Technology (ICT) applications become more sophisticated, the range of BMS functions will expand. One of the much discussed, but yet to be realized, dreams for architects, engineers and progressive developers is the idea of the zero-waste, zero-energy building – one which, when in use, has zero net energy consumption and zero carbon emissions. As operation accounts

1 Department of Computer Science and Engineering, PTR College of Engineering and Technology, Madurai, Tamilnadu, India.
2 Department of Information Technology, NPR College of Engineering and Technology, Dindigul, Tamilnadu, India.

for 85% of the total whole-life energy consumption of a building and buildings account for the majority of global CO_2 emissions, this would be an enormous step forward. Alongside the design of an office, home or factory, and the materials used in its construction, a key part of the process is to create 'intelligent' buildings – ones which adopt low- and high-tech methods to ensure optimum management of resources.

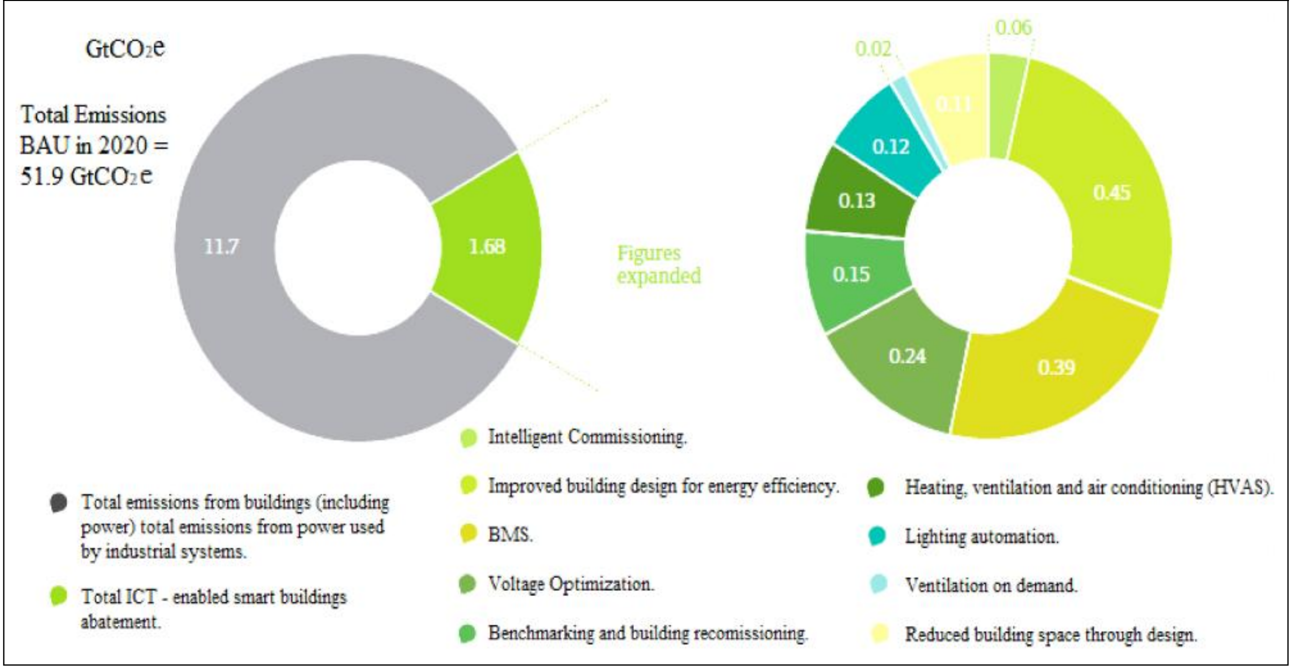
BACKGROUND

Today's buildings and workplaces are major generators—and consumers—of data. Where once buildings were simply physical infrastructures composed of concrete, wires and steel, buildings now also include a huge variety of connected sensors and systems that constantly generate volumes of data about the building. But they think is how do you leverage this data to better manage your facility? How do you deliver more value to your organization by increasing operational effectiveness and improving both financial and environmental performance?

THE GLOBAL IMPACTS OF SMART BUILDINGS

Global building emissions were 8% of total emissions in 2002 (3.36 GtCO2e). These figures exclude the energy used to run the buildings. If this is taken into account, the sector would emit 11.7 GtCO2e in 2020. ICT offers a major opportunity to reduce emissions from this sector, by 15% in 2020, by the options set out in Figure 1. Emissions from buildings in emerging economies, such as India and China, are expected to grow as their populations become increasingly urbanized. In spite of increased attention to energy wasted in buildings, construction is taking place the world over with little consideration of the implementation of best practice energy efficiency measures. Several national

Figure 1: Smart Buildings: The Global Impact 2020



schemes have been set up to establish and promote these best practice standards in efficiency. These include: EnerGuide for Houses (energy retrofits and upgrades) and New Houses (new construction) (Canada); Green Building Council/House Energy Rating (Australia); DGNB (Germany); BREEAM (UK); CASBEE (Japan); and, perhaps best known, Leadership in Energy and Environmental Design (LEED) (USA).

Yet, while these initiatives guide proactive architects, designers and builders in their quest for 'green' building, until this currently niche market becomes mainstream, with mandatory standards and smart building regulations, the full positive impact of ICT on the building sector will not be felt. In addition, because buildings are major sites for electricity consumption, there is a strong proposition to link them with "smart grid" initiatives and even transport. Project Better Place is currently piloting plug-in vehicles, which draw electricity from the home or electric filling stations, to see whether there are negative impacts on grid stability—an initiative that relies on ICT to make it work.

Hurdles to Adoption

There are a number of barriers to the adoption of the technology and realizing the full emissions savings opportunities. These include:

- The buildings sector is slow to adopt new technology—a 20-25-year cycle for residential units and a 15-year cycle for commercial buildings is typical.
- A lack of skilled technicians to handle complex BMS—most buildings of less than 10,000 sq ft (930 sq meters) do not have trained operating staff.
- As each building is designed and built as unique, it is difficult to apply common standards for efficiency and operations.
- Lack of incentives for architects, builders, developers and owners to invest in smart building technology from which they will not benefit.
- Lack of incentives for energy companies to sell less energy and encourage efficiency among customers.

Overcoming Methods for These Hurdles

A number of solutions could be implemented to overcome these barriers:

- Develop open standards to enable interoperability of BMS.
- Develop new business models to overcome the misalignment in incentives that currently exists, such as performance contracting and tax credits.
- Develop new financial mechanisms for builders that support investment in energy efficiency, such as mortgages that fund energy efficiency or carbon credits.
- Develop green building valuation tools.
- Provide better training to building operators and information to users by simple devices such as visual smart meters or interfaces to influence behavioral change.

The National Science and Technology Council in the United States estimates that commercial and residential buildings consume a third of the world's energy. For example, In North America, it translates to 72% of the electricity generation, 12% of the water use, and 60% of non-industrial waste. Consider another fact. If worldwide energy-use trends continue, buildings will become the largest consumer of global energy by 2020—more than the transportation and industrial sectors combined. And waste as much as half of the electricity and water that they use. Smart buildings: Making living and working spaces more energy-efficient could save 1.7 GtCO2e from building energy use in 2020, worth $340.8 bn.

NEW AND DEVELOPING BRIGHT GREEN TECHNOLOGIES

Buildings consume up to 42% of all energy worldwide. By 2020, buildings will likely be the largest consumers of energy—and the largest emitters of greenhouse gases—on the planet. Even worse, about 30% of a building's total operating cost goes for energy. So, as the cost of energy goes up, the need to reduce both consumption and overall building expenses takes on new urgency. Creating smarter cities starts with making buildings smarter which is The best way for a building to become smarter is by empowering owners and managers to collect energy and operational metrics into a single, centralized location and apply enterprise-wide analytical and optimization capabilities to gain insights from that information. The following technologies are used to reduce the carbon emissions in their own way.

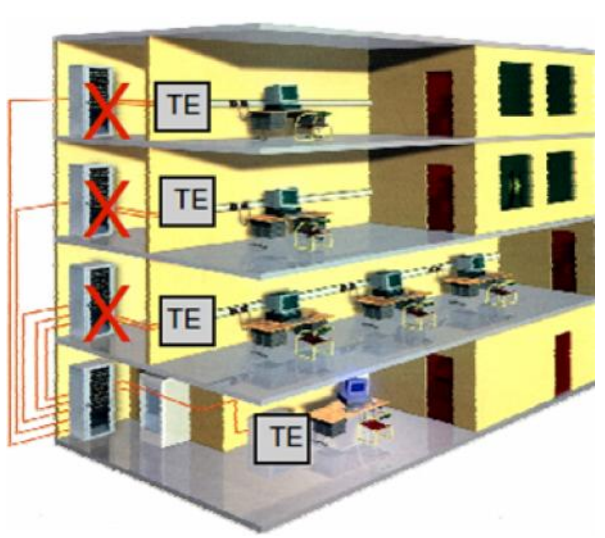
Water Conservation Technologies

Water shortages are expected to be an ever-present challenge, and offers tremendous market potential for water conservation technologies and products. One such option that has been displaying growing potential is the application of integrated monitoring and control of water use. By networking sensor operated faucets and flushometers in conjunction with supplemental water meters and sensors, facilities managers are able to monitor the entire restroom environment. Total realistic life cycle costs of the restroom are, for the first time, within the grasp of owners and developers. This new level of integration will help companies establish a single source of water knowledge while increasing both the overall sustainability of the restroom space and positive experience for the end-user.

Fiber-to-The-Telecom-Enclosure (FTTE) or Zone Cabling

With commercial industry relying heavily on solutions provided by information technology, the network infrastructure is more critical than ever. The cost to business for installation and maintenance is a large investment. Users seeking data communications architectures that support a wide range of network applications can use a Telecommunication Industry Association (TIA) standards based

Figure 2: Zone Cabling



solution: Fiber-to-The-Telecom-Enclosure (FTTE) or Zone cabling as Figure 2. The FTTE architecture extends the fiber optic backbone to telecom enclosure closer to workstations throughout a building. The telecom enclosure can then distribute a flexible topology of mixed media and power to the devices using copper category cable, fiber optics, coaxial cable, and A/V cable.

As a result, buildings can benefit from more useable real estate due to the removal or consolidation of the telecommunications room on each floor. Also, there is a 20-30% cost reduction on cabling due to consolidation and removal of proprietary networks, improved network performance, single contractor/ integrator vs. several specialists for disparate systems, and a substantial reduction in cost and disruption to staff when making changes within work areas.

Electrical Architecture

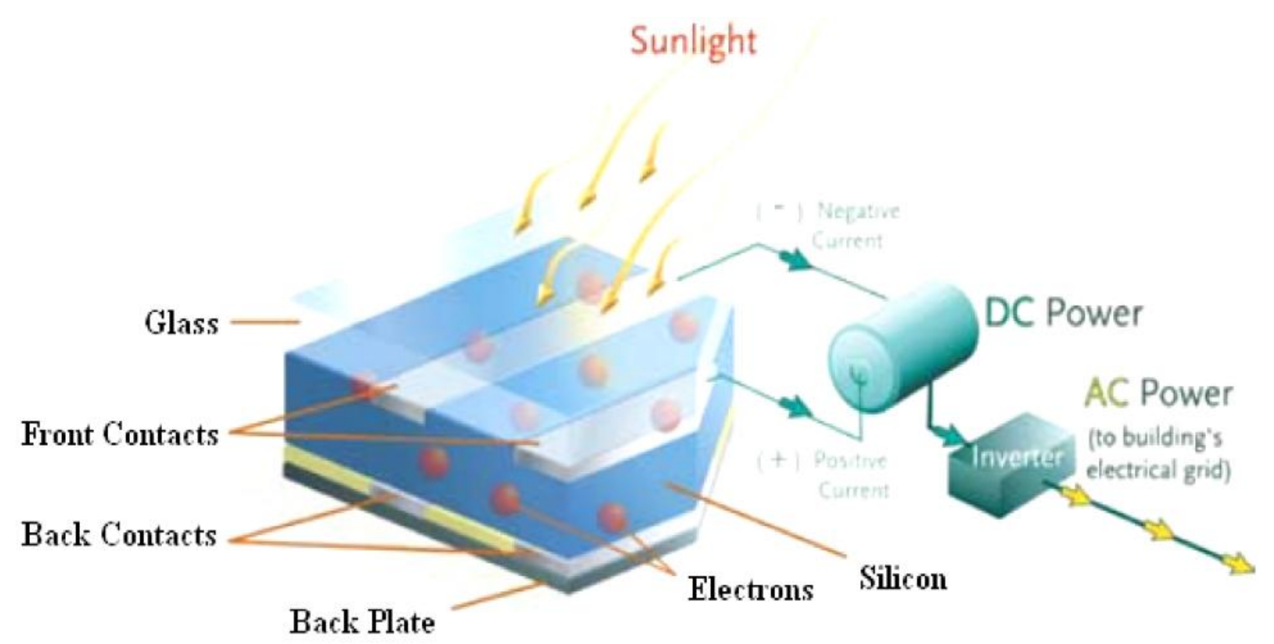
To meet the needs of flexible and integrated infrastructures, electrical infrastructures are flexible, adaptable, and are able to serve as the integrated center for lighting, energy, and control systems. This new programmable environment combines a new electrical infrastructure that replaces the traditional pipe and wire electrical systems with embedded lighting controls that are connected together through nodes on a network. This technology can address the following three major needs of building owners and tenant: 1) facilitate people using the building to become active agents in the utilization, creation, and evolution of spaces that support their activities; 2) preserve and improve the investment and ROI for the building owners and managers; and 3) reduce the impact on the environment by the building, from its initial construction stage through its life cycle. Labor costs can be reduced by 40-60% over the life of the building as it requires less labor during the initial installation and requires less labor to maintain the building. The ability to save money also extends to energy savings, as it can reduce the energy costs in a building by making it more energy efficient whereby recouping 20-60% energy savings that would otherwise have been lost by traditional electrical infrastructure.

Electricity from Renewable Sources

Battery Park City's green guidelines also require that buildings use on-site renewable methods to generate 5% of their base electrical loads. To meet this requirement, all green residential buildings in Battery Park City use photovoltaic panels, which generate power from sunlight as shown in Figure 3. In one of these buildings, panels will maximize the power produced by tracking the path of the sun. By doing this, the system will be 5-10% more efficient than standard photovoltaic.

Developers have also investigated using wind power in Battery Park City. Unfortunately, given the wind speeds at the site and the life cycle costs of the current generation of wind turbines, the power generated would cost about four times that of a photovoltaic system. While wind power isn't practical in Battery Park City, there are ways it can be used to achieve LEED credits for buildings located there. When NYMEX retrofitted its building to be green, it purchased renewable energy credits to cover the electricity needs of its entire building using wind energy generated elsewhere. At the time the purchase was made, it represented the largest purchase of

Figure 3: Sunlight is Converted into Electricity via Photovoltaic Cells, Providing 5% of Each New Residential Building's Common Load



these credits for a single building in New York City. Newer green buildings in Battery Park City employ cogeneration equipment. These micro turbines and a planned fuel cell use natural gas to create electricity within the building thereby minimizing energy loss that is usual when bringing electricity in from an electric plant. The equipment emits significantly less CO2, NOX and SOX. As an added bonus, the heat from these systems will be used to create hot water for the building.

Smart Meters

A critical element in all of this is the role of smart meters which will be introduced across many parts of the developed world over the next decade. In the EU, smart meters are seen as pivotal to meeting the energy consumption targets that have been agreed for 2020. Wirelessly connected to both utility suppliers and home management systems these will not only measure instantaneous energy and water consumption but also be able to provide pricing information to help building owners and occupants tailor supply and demand. With their 'bi-directional communication capability' that will enable utility companies to undertake better demand side management, these smart meters also open the door to the idea of smart grid where energy is sent to, from and between different locations. With each building effectively acting as an active node in a grid, local energy production and storage can become far more efficient and consumption peaks and troughs can be smoothed. Taken in conjunction with more distributed sources of renewable energy supply such as wind, solar and biomass, the smart grid and intelligent buildings can really make a difference in energy consumption and sustainable living.

On top of the functional side, many architects and engineers are also very keen that future intelligent buildings are also better places to live and work in: they should be 'safe and secure' but also 'comfortable and make us feel happy and valued'. The regulatory actions already undertaken will ensure that, in many markets, the capability is there for more of the infrastructure to become increasingly 'intelligent' in the way that utilities, communications and access are managed. The challenge will be for us as individuals to both change our consumption behaviors, many of which conflict with improved efficiency, while at the same time preserving—and ideally enhancing—our ability to get the most out of our buildings. The average building is around for sixty years so whole-scale change to the zero-energy ambition will take far longer than the ten years currently under discussion but, through a combination of retrofit and new-build, over the next decade, many people are positive about progress in developed and developing markets. Indeed, some suggest that, linked to the rollout of high-speed broadband; developing countries could use intelligent buildings as another opportunity to leapfrog over the developed economies which have more of a legacy of infrastructure to deal with.

How ICT Can Help

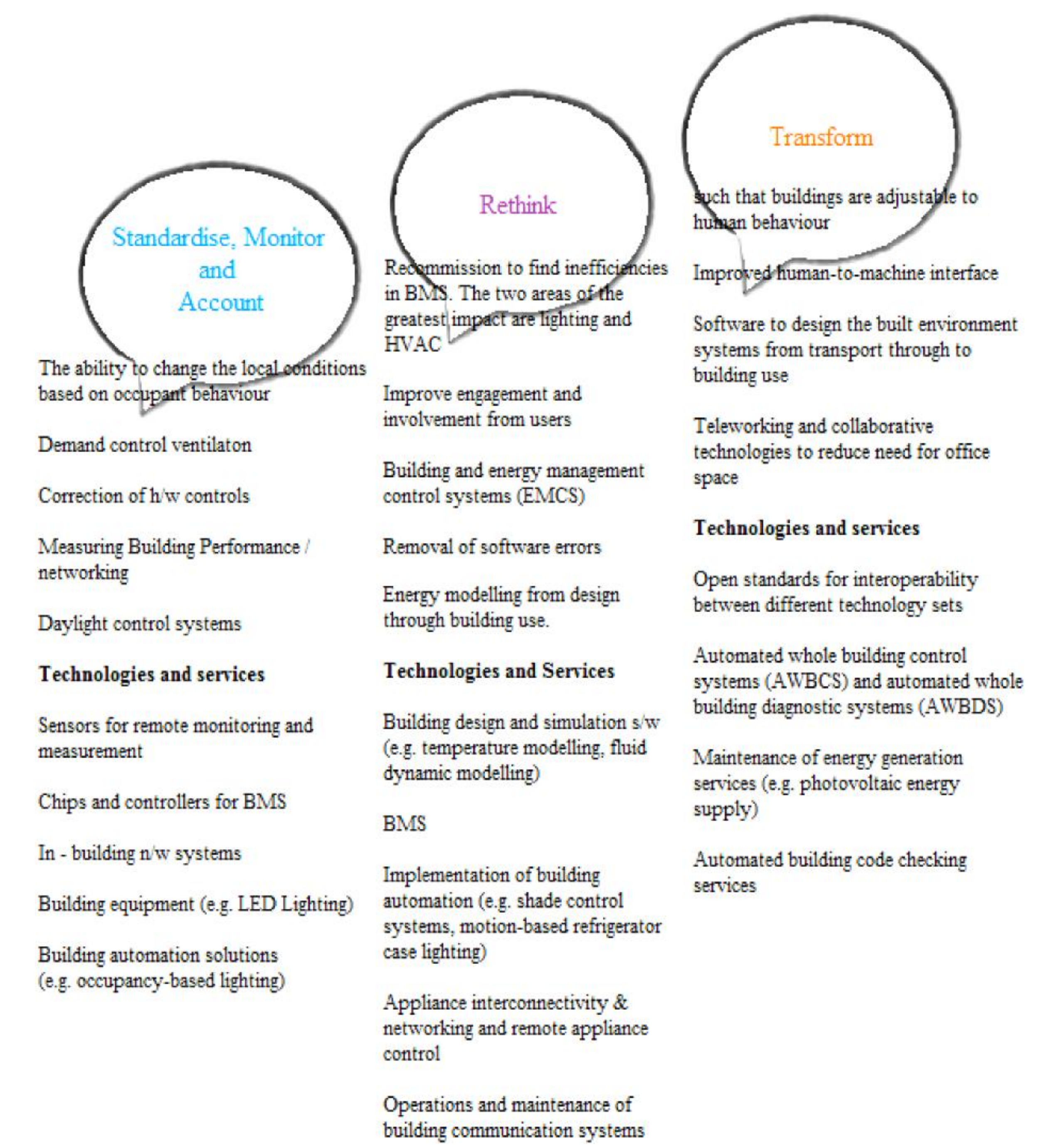
Energy consumption in buildings is driven by two factors.

1. Energy intensity
2. Surface area

ICT-based monitoring, feedback and optimization tools can be used to reduce both at every stage of a building's life cycle, from design and construction to use and demolition. Buildings are often poorly designed at the outset, with little consideration for how their uses may change over time. Even if energy efficiency has been incorporated at the start, a building's actual energy performance can be impaired if builders deviate from the plans or if occupants do not operate the BMS according to plans or specifications. Assuming the building has been designed and built to specification, poor commissioning (ensuring the building's systems function as specified), constant change of use and poor maintenance can significantly reduce the effectiveness of any BMS. This means that buildings differ dramatically in the energy they consume and as a result the same technology applications can have very different impacts.

There are various smart buildings technologies available today that can help reduce emissions at each stage of a building's lifecycle. Energy modeling software can help architects determine how design influences energy use. Builders can use software to compare energy models with actual construction. Once the building is complete, ICT can measure and benchmark its performance and compare actual to predicted energy efficiency. Occupants can install a BMS to automate building functions such as lighting and heating and cooling and if a building undergoes a change of use, ICT can be used to redesign its energy model and measure the impacts of this change. Figure 4 shows how ICT can identify energy consumption, optimize for reduction in energy and emissions and transform current ways of designing and using the built environment. The US and Canada are home to some of the most exciting and ambitious innovations in smart building technology.

Figure 4: Smart Buildings: The Role of ICT



Smart Living

More than 65% of the electricity consumed by buildings in the United States is used for the operation of heating, ventilation and cooling (HVAC) systems. In cities the size of New York City, that number jumps to 95%. HVAC systems in New York City buildings are responsible for 79% of CO_2 emissions. The Solaire building in New York was the US's first "green" residential tower and was inspired by the Battery Park City

Authority's initiatives. As well as other sustainability features, it contains a comprehensive BMS to control the entire building.

This was built into the plans at the design stage, is continuously updated and undergoes an annual re-commission. The BMS provides real time monitoring and reacts to external stimuli, such as the weather. Winner of several awards and recipient of the LEED Gold rating, the Solaire is 35% more energy efficient than building code requirements and uses 67% less energy than other similarly sized buildings in peak hours. Since opening in 2002, energy consumption has decreased by 16% and, as a result of its green credentials; the developers have been able to charge a rental premium of 10%.

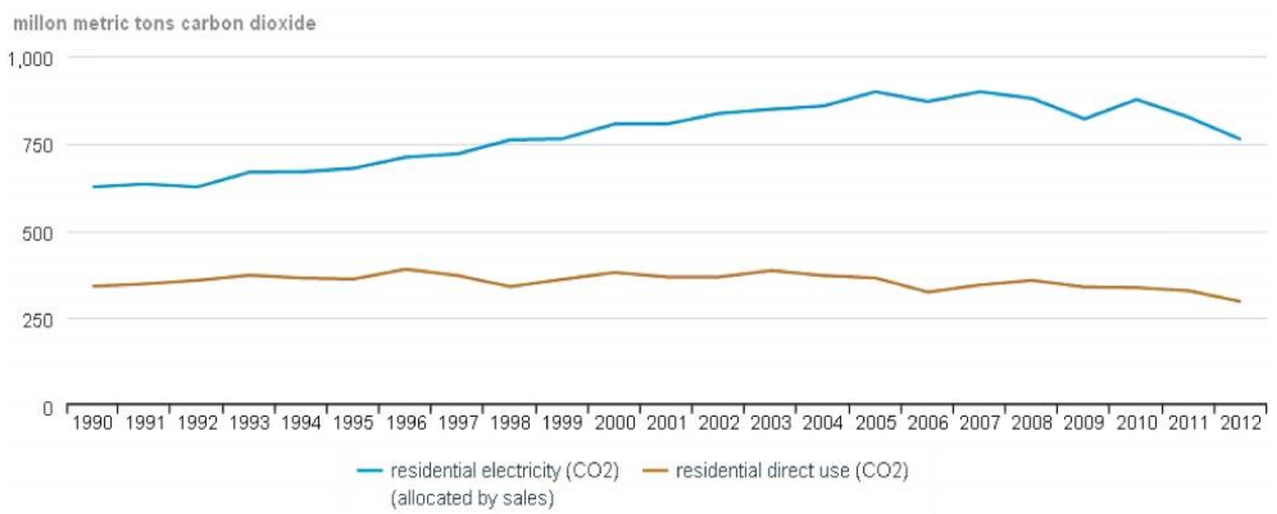
LOWER RESIDENTIAL DEMAND FOR ELECTRICITY ALSO HELPED EMISSIONS DECLINE

Residential sector electricity consumption was lower in 2012 as compared to 2011 and this also helped to lower emissions as electricity-related emissions have been the principle source of residential sector emissions since 1965.

- Although cooling degree days (CDD) were slightly higher for the year compared to 2011 (and 10% above the 10-year average), for the summer cooling season they were down 4% compared to 2011.
- In addition to residential electricity consumption declining by 3.4%, electricity system losses declined even further (4.8%) implying an efficiency increase in electricity generation, transmission, and distribution of over 1%.
- Since 2007, residential sector electricity-related carbon dioxide emissions have declined to levels last seen in the late-1990s and direct use emissions (total minus electricity-related) are below 1990 levels.

Cooling Degree-Days (CDD): A measure of how warm a location is over a period of time

Figure 5: Residential Carbon Dioxide Emissions from Electricity and Direct Use of Fuels, 1990-2012



Source: US Energy Information Administration, Monthly Energy Review, Table 12.2 (September 2013) relative to a base temperature, most commonly specified as 65 degrees Fahrenheit. The measure is computed for each day by subtracting the base temperature (65 degrees) from the average of the day's high and low temperatures, with negative values set equal to zero. Each day's cooling degree days are summed to create a cooling degree day measure for a specified reference period. Cooling degree days are used in energy analysis as an indicator of air conditioning energy requirements or use.

CONCLUSION

Currently, buildings need to exhibit higher operational efficiency and lower cost with respect to factors such as energy consumption and operational costs, life cycle benefits, management of resources, and legislative requirements. Ongoing operating costs typically represent 50-80% of a building's total life cycle costs over an estimated 40-year life span. From all over this research provides documented evidence to educate and influence end-users, building owners, architects, and contractors that a "greener building" can be achieved using intelligent technology and that this "greening" will provide a tangible and enable buildings to meet core objectives of sustainability (Energy, Water, and CO_2).

REFERENCES

1. Aditya Mishra, David Irwin and Prashant Shenoy (2013), "Green Charge: Managing Renewable Energy in Smart Buildings".
2. Commercial Buildings Energy Consumption Survey, Energy Information Administration, December 2006.
3. Granderson *et al.* (2010), "Building Energy Information Systems: User Case Studies", Springerlink.
4. http://newyork.thecityatlas.org/lifestyle/greener-buildings-brings-green-bank-accounts/
5. http://www.batteryparkcity.org/pdf_n/GreenBook_Chapter04.pdf
6. http://www.green-buildings.com/content/782019-carbon-footprints-green-construction-it-common-practice-india.
7. http://www.ibm.com/smarterplanet/us/en/greenbuildings.
8. http://www.itu.int/en/ITU-T/jca/ictcc/Documents/docs-2013/Francesco Asdrubali_JCA_Feb 2013.pdf
9. IEC 61850, http://en.wikipedia.org/wiki/IEC 61850, 2012.
10. Irwin D, Wu A, Barker S, Mishra A, Shenoy P and Albrecht J (2011), "Exploiting Home Automation Protocols for Load Monitoring in Smart Buildings", *In BuildSys*.
11. Mishra A, Irwin D, Shenoy P, Kurose J and Zhu T (2012), "Smart Charge: Cutting the Electricity Bill in Smart Homes with Energy Storage", *In eEnergy*.
12. "SMART 2020: Enabling the Low Carbon Economy in the Information Age", United States Report Addendum, GeSI, 2008.
13. "US Department of Energy", *Building Energy Data Book*, http://buildingsdatabook.eren.doe.gov