Climate change and environmental issues have been increasingly in the forefront of the media and government agendas. However, despite much discussion and fanfare, little has been done in the way of serious commitment and clear course of actions since the adoption of the UN Framework Convention on Climate Change in 1992 to bring carbon emissions to sustainable levels. To tackle the immensity of the climate change challenge, a paradigm shift in understanding is necessary to balance the course of global human development with energy demand and consumption patterns. Accounting for over 40% of global energy demand and more than 30% of greenhouse gas emissions, the building sector offers the greatest mitigation potential for reducing carbon emissions in both the short and long term, with positive implications for a range of associated sectors and industries. Promoting behavioral change among end-users for reduced energy consumption as well as encouraging the building industry to embrace sustainable design, low-carbon construction practices and materials, and renewable technologies, is fundamental to mitigating the impact of the built environment on planetary biospheres and preserving quality of life for generations to come. This paper starts by drawing attention to the building sector and related EU policy, outlining the challenges and opportunities for reducing energy consumption and carbon emission levels. Such policy provides the essential framework to engage stakeholders and allow supporting factors to foster progress in the sector. The paper contends that information on climate change has not led to significant improvements in meeting global targets and that what is needed is behavioral change among individuals and society as a whole. On the basis of research project experiences and literature review, it puts forth and explores five key elements contributing to behavioral change for reduced energy consumption and lower carbon emissions in the building sector, focused on: information and education; financial incentives and energy services; modern technologies and sustainable design; social and community norms; and biophilia (contact with the natural environment). The paper suggests opportunities for further research and concludes with recommendations for policy-makers and related stakeholders.

Keywords: building sector; EU Buildings Directive; environmental consciousness; behavioral change; low-carbon lifestyle; biophilia

Introduction
Increasing societal awareness with the aim of fostering behavior and lifestyle changes towards a low-carbon future is among the paramount challenges to be addressed by developed societies in advancing the global climate change agenda. Reducing
consumption levels, eliminating fossil fuel dependency and possibly even “managing without (economic) growth” are the harsh realities the Western world must confront if we are to maintain a sustainable quality of life into the near future (Victor 2008). Government leadership and commitment to this task continues to fall short, as evidenced by the COP15 lack of consensus and the shortfall of countries meeting the European 20-20-20 targets. According to German Watch, so limited has been the positive change in relation to the problem that, since 2009, the Climate Change Performance Index (CCPI) has not identified any country for the first three rankings owing to the lack of reduction of per capita emissions to keep global temperatures increases to below 2°C.

Current global trends in population growth, increased urbanization and economic development are placing excessive demands on the planet’s natural resources and biospheric habitats. The impact of these trends is multi-faceted, affecting environmental, socio-economic and energy systems in ways that raise serious questions and ethical concerns about how much longer developed societies can continue on their business as usual course before reaching a point of diminishing returns on a global scale. Already, countries and societies have surpassed the planet’s ecological footprint by 30% in 2005, or the equivalent of 1.3 Earths, to accommodate worldwide consumption (Ewing et al. 2008).

According to the Stern Review 2006, the business as usual scenario forecasts direct and upstream (indirect) CO2 emissions from buildings to increase by 70% and 140% to 2030 and 2050, respectively (Figure 1). Upstream emissions in the form of electricity use in buildings are seen to grow most rapidly on account of new connections to the grid and increasing demand for household appliances and equipment.

**Opportunities in the building sector**

On a global scale, buildings are the greatest energy consumers, accounting for 40% of total energy use, with corresponding carbon emissions of more than 30%, exceeding those of the transport sector. The heating (and cooling) of homes and buildings is responsible for approximately 56% of the energy consumed, and as comfort levels rise, the demand for air-conditioning systems, white goods, technology equipment and even larger homes throughout the wider Europe increases. Rapid urbanization and population growth will only exacerbate the need for energy as the demand for housing and commercial space grows.

The building sector offers the greatest potential for mitigation of carbon emissions and rivals the transport sector threefold on a global scale (Figure 2). Exploiting the low-hanging fruits of building technologies and energy efficiency practices and accelerating their societal acceptance and market absorption is instrumental in shaping low-carbon environments and a more effective climate change agenda. Europe could benefit from an additional 11% reduction in energy consumption beyond its 20-20-20 targets by curtailing energy use in buildings by 30% (Lui et al. 2010).

The EU Energy Performance in Buildings Directive (EPBD) aims to exploit this potential and mainstream energetic retrofits and low-carbon construction within the building industry across Europe. Enhancing societal and market understanding of the benefits of energy savings and value of lower emissions is an essential component for stimulating behavioral change towards reducing energy consumption in the building sector.
As the guiding policy framework for European building stock, the Buildings Directive was met with initial disappointment and limited impact despite an implementation timeframe extending from 2002 to 2009. As of March 2009, only six Member States had fully complied, whereas three Member States were in court and 12 were under infringement procedures. The reasons vary, including a lack of expertise, legislative discrepancies on national and regional levels, weak political will and a lack of co-ordinated support on the part of stakeholders. Austria, for example, struggled to harmonize technical building standards on the national level and align energy targets to subsidy levels, whereas Italy’s weak national framework jeopardized credibility with the public and led to delayed implementation by many regions. Yet, despite the weak level of compliance, it was found necessary to strengthen the Directive to put in place effective control and enforcement mechanisms to ensure that adequate energy savings resulted from building system inspections and other requirements. Stakeholder groups and public consultations greeted the EPBD Recast with optimism and promoted the notion of advancing the role of buildings on the basis of a positive impact assessment of market conditions, energy and emission reduction potentials. Impact targets suggest that the following environmental and market gains can override the investment and administrative costs associated with the reinforced policy:

- 60–80 Mtoe/year energy savings by 2020, i.e. a reduction of 5–6% of the EU final energy consumption by 2020;
- 160–210 Mt/year CO₂ savings by 2020, i.e. 4–5% of total EU CO₂ emissions by 2020;
- 280,000–450,000 potential new jobs by 2020, mainly in the construction sector, energy certifiers and auditors, and inspectors of heating and air-conditioning systems.³

The Energy Performance Certificate, a key feature of the EPBD, will in time raise the level of importance of energy as a key market criteria for real estate transactions and place greater financial value on the sustainability and efficiency of buildings. Yet the biggest challenge for Europe is the existing and old building stock and accelerating the pace of energetic retrofits, currently very low at approximately 1% per year. This onerous undertaking warrants in part a paradigm shift in thinking towards a low-carbon society as well as a multi-faceted approach to supporting evolving legislation with financial incentives, strengthening of technical capacities and energy performance contracting, incorporation of sustainable design and renewable technologies and increased awareness and behavioral change among industry stakeholders and end-users.

Leadership within all sectors is essential to mobilize higher energy awareness among government, business and civil society and in turn put forth respective, yet mutually reinforcing, solutions, that contribute to a heightened sense of urgency and value of individual and collective action in light of the enormity of the climate change agenda and need for a sustainable world.

Beyond awareness-raising
Raising awareness of environmental issues has been tackled on a multitude of levels for years. Policy-makers, industry executives, building practitioners, school children
and the movie viewing general public have been exposed to some degree to the need
to constrain consumption and fossil fuel use to preserve the planet’s air and water
quality, natural resources supply and quality of life. Award-winning films like An
Inconvenient Truth and other releases such as the Age of Stupid and No Impact Man
convey environmental messages in different forms, targeting a mix of audiences, and
have presumably informed viewers, but their ability to evoke attitudinal and
behavioral change is unclear. International events such as Earth Day, UN Climate
Summit and the annual EU Sustainable Energy Week, among many others, are
representative of fora that engage stakeholders and society in information-sharing
and learning; yet their outreach is limited and despite their aim of galvanizing
environmental commitment, their impact in fostering sustained behavioral change is
questionable.

Encouraging action on the basis of information alone has proven ineffective and
not conducive to a sustained change in environmental behavior (Schultz et al. 2004).
Although learning theory calls for incentives to elicit the desired responses, the
climate change dilemma warrants behavior that goes beyond initial reward to rather
consistent and long-lived actions. Such behavior is considered in some circles to be
based on “social learning” and in cases premised on public participation that extends
beyond a collective activity (Bull et al. 2008). Sustained behavioral change is linked
to a heightened sense of environmental consciousness (or cognitive enhancement)
among individuals and societies that stimulates transformative action reinforced by
an enabling governance structure that values a sustainable environment and low-
carbon lifestyle. This aim demands an integrated policy and sectoral approach that
connects technical, socio-economic and environmental aspects to facilitate energy
savings, reduced consumption and natural resource protection. Within these three
pillars, numerous tools are available to reinforce awareness-raising efforts to foster
changes in understanding, attitudes and ultimately behavior. This paper argues that
the following elements are important building blocks for cultivating a state of being
that translates into positive behavioral change towards a more sustainable world
through reduced energy consumption in the building sector. These building blocks
advance the implementation of a legislation adopted on the premise that the sector is
instrumental in addressing the climate change agenda. Where no framework policy
exists, the impact of these factors is limited in scope and reach, yet nevertheless, they
offer valuable opportunities to penetrate forward-thinking markets and commu-
nities.

Building blocks of environmentally conscious behavior (for the building sector):

1. Information and education.
2. Financial incentives and energy services.
3. Modern technologies and sustainable design.
4. Social and community norms.
5. Biophilia – contact with the natural environment.

Awareness-raising: information and education

Information and research

Communicating climate change in a manner that encourages constructive action
remains a challenge. Its implications and its relation to energy and sustainable
development are often misunderstood on account of the issues being too abstract and complex, and the lack of qualified personnel to define issues in a comprehensible manner (Leal Filho 2000). Such perceptions reinforce the need to communicate climate change on a human scale, wherein messages target individuals’ day-to-day realities. Japanese research has indicated that the effectiveness of environmental information is also dependent on its content and the occupation and environmental consciousness of the individual targeted (Suzuki 2009). Important elements for catalyzing enhanced engagement include the need to reiterate individual responsibility, to enhance commitment and environmental awareness, and to encourage more “climate-friendly” behavior. Localization of issues and highlighting their interlinkages to the surrounding environment are needed to embrace a greater range of stakeholders. Similarly, informing and educating residents on solutions and practical measures to address significant local concerns provides the opportunity for individual motivation and action, and helps break the frustration associated with the complexity of climatic challenges (Leal Filho 2008).

Figure 1. Direct and upstream CO₂ emissions in 2003 and projected business as usual emissions for 2030 and 2050. Source: Stern (2006).

Australian research has shown that a person’s consciousness of the environment is also a function of self-consciousness, understanding of self, and the role played within society, with the level of education and gender also important contributing factors. Boys were seen to be more de-sensitized from nature, in part owing to greater exposure to video games and violence-related materials. Girls, on the other hand, despite ranking lower than boys in environmental knowledge, were more willing to join an environmental movement or take action, partly on account of association with traditional roles that connect them with the natural environment, such as preparation of meals, caring for siblings and tending to a garden (Hampel and Holdsworth 1996). Similarly, in an Icelandic study (Arnason 2004), females were more likely to have an ecocentric approach, valuing nature protection for the sake of the biosphere over human interests: 65.2\% compared with 53.7\% of males, at a level of significance of $p < 0.05$. These findings are supported in part by literature attributing socialization and an “ethic of care” as well as higher altruistic values (Detz et al. 2002) to women. Although men registered a higher understanding of environmental matters, women were more likely to be take action in support of the environment, including the purchase of organic products and identification with nature protection groups, suggesting a significant correlation between gender and environmentally responsible behavior (Arnason 2004). However, Momsen (2000) contends that, as gender roles change, particularly in the developing world, and economic development pressures on natural resources become more apparent and access to information and education becomes more available, environmental gender differences are narrowing to, in turn, suggest a political ecological approach as more indicative of behavioral roles.

However, information alone has been shown to have limited effect in provoking changes in behavior, despite gains in attitudinal views. While conventional marketing can help create public awareness, social marketing identifies and overcomes barriers to long-lasting behavioral change (McKenzie-Mohr and Smith 1999). Schultz (2010) demonstrates in Figure 3 the inverse correlation between outreach and impact, underscoring the importance of complementing information with reinforcing measures that enhance direct contact with the individual.

![Figure 3. Inverse correlation between outreach and impact (Schultz 2010).](image-url)
With governments encouraged to lead by example under the EPBD Recast, the Display Campaign (http://www.display-campaign.org) managed by Energie-Cités, is a cost-effective tool available for use by local authorities to inform tenants about energy consumption and efficiency measures within their public housing stock and facilities. Similarly, it offers opportunity for data collection for local energy planning and the prioritization of refurbishment actions for the building inventory. Yet, a key determining factor is clearly the willingness of public authorities to make use of the Display Campaign as a tool for communication and information-sharing on energy usage and application of efficiency measures to a broader public. Preliminary investigation has shown the Display Campaign to have produced limited results in energy performance among surveyed buildings (Bull et al. 2009). Further research is underway to more fully understand how to convert information into action for reducing energy consumption in public facilities. Collecting and displaying information on energy usage with thermal camera mapping systems in 270 municipal buildings (kindergarten, schools, health centers, administrative and social/cultural buildings) in the City of Helsinki has proven effective in saving energy. Other tools for the building sector are found in communication and information-sharing portals, such as the EU’s Build-Up site (http://www.buildup.eu), aimed at centralizing information and facilitating access of stakeholders to the latest policy, technical and energy related developments in the sector.

Other EU experiences demonstrate the value of information dissemination to a multi-faceted audience, including home-owners and renters, housing companies, environmental NGOs, financial institutions and building professionals. However, the impact of efforts such as media campaigns, one-stop-shops and advisory call centers, is uncertain and mixed at best, yet they offer the beginnings of what may produce behavioral change towards building retrofits and energy savings (IMPLEMENT Project 2009). The use of societal multipliers (i.e. persons who can serve as ambassadors and gatekeepers) to enhance outreach within community circles as well as to the general public can be effective information dissemination and awareness-raising, but the degree to which they can promote actual behavioral change remains unclear. Training programs that educate unemployed people to become general energy advisors and deliver basic information on energy saving measures have been effective at the neighborhood level and are easy to institute and fund. Similarly, training salespersons to become knowledgeable in selling low-energy and energy-efficient electrical equipment has been tested in Austria and highlights the potential value of marketing energy efficiency as a way forward. Events and exhibitions in the form of fairs, workshops or even theatrical skits are useful activities for conveying and disseminating information on energy saving practices on a short-term and wider public basis.

Awareness-raising campaigns are low-cost instruments to communicate positive yet simplified messages to target audiences, highlighting the benefits to end-users for greatest impact. Negative messaging tends to produce less constructive results, as does content emphasizing morality, social responsibility and Kyoto obligations. However, this point may be culturally sensitive with different reactions to normative messaging, depending on the country and system.

As important as informational content is, so are control and accountability. Technology in the form of smart metering is helping enhance the impact of information by allowing the individual to react according to personal desires and set parameters (e.g. temperature levels) according to lifestyle choices. Yet, additional
factors are necessary to incentivize end-users to make use of such information to modulate behaviors towards reduced energy consumption (Bartiaux 2009).

**Education**

It is essential to broaden the spectrum of understanding of climate change beyond that of the traditional physical sciences domain. A multi-disciplinary approach offers more opportunities to effectively inform about the socio-economic implications of depleted natural resources and unsustainable consumption practices.

Incorporating climate change issues into all dimensions of academia is a necessary step for cultivating an inherent sense of environmental consciousness among future generations, whereby responsible environmental behavior is the norm. Developing an understanding and appreciation for the natural environment at the primary education level has the potential to multiply its impact throughout an individual's professional and private life. Schools as centers of learning are ideal venues for disseminating information to pupils and the community at large. Examples of local initiatives such as Energy Action Days financed by municipalities, as the owners of schools buildings, have led to substantial energy savings in the cities of Heidelberg and Ludwigshafen in Germany. The coupling of education and installation of technology can be another effective approach to enhancing understanding and demonstrating immediate and tangible results. Such a coupling is reflected in Italy's "Sun in the Schools" Programme, an effort of the national environmental ministry, which subsidizes the purchase and installation of photovoltaic systems (PV) at primary and secondary schools as a means of energy conservation. The PV installation in turn serves as a valuable tool to reinforce the environmental education curriculum and demonstrates the application of modern technology in contributing to a sustainable and low-carbon environment. Such initiatives are valuable for cultivating heightened cognitive enhancement through the demonstration of clean energy generation and reflect the concept of "architecture as pedagogy", whereby people can learn from buildings and not solely in them (Orr 1997).

In Germany, more than 2000 schools have participated in efforts in which understanding of energy costs and CO2 emissions as well as water consumption and other environmental externalities is conveyed through employing a number of models that encourage energy conservation through bonus savings, budgeting, competitions and specific energy-related activities. The most successful model has been the 50/50% Project initiated by the city of Hamburg in 1994, where changes in behavioral practices led to significant energy and water savings on account of pupils, teachers and building managers alike, benefiting from the financial savings. Currently, approximately 443 Hamburg schools participate in this project, which has documented a savings of 132,000 tonnes of CO2 and a total financial savings of 38 million euros (32.5 million euros for energy and water and 5.3 million euros for solid waste) during the period 1994–2008. The impact of the project has been significant in its reaching beyond Hamburg and even Germany to serve as the model for Euronet 50/50 (http://www.euronet50-50.eu), a European Commission (IEE) funded initiative that aims to engage 50 educational facilities throughout the EU to save energy to help combat climate change.

The concept of informal learning is being investigated by the EU Project INSPIRE (Inspire school education by non-formal learning; http://www.inspire-project.eu). The project aims to provide ongoing resources for sustainable
development education through curriculum development on climate changes issues, renewable technologies and energy efficiency for teacher training institutes. Establishing synergies between informal learning sites, e.g. museums and community centers, and formal learning institutions (schools) would provide opportunities to maximize the potential of local, neighborhood facilities to advocate action for climate change problems. The efficient use of energy and renewable technologies forms the core of the teaching modules being developed for teaching facilities to enhance teacher capacities in the field of sustainable development and provide valuable didactic resources for increasing understanding among the general public for energy savings at home and within the built environment. Establishing a platform for lifelong learning using educators as information multipliers within community networks aims to cultivate a culture of environmental consciousness and action in future generations.

Financial incentives and energy services
An enabling environment marked by financial incentives and energy services is fundamental to a governance structure committed to a low-carbon building sector. In the case of the market pursuing energetic retrofits for its building stock, this argument becomes all the more vital (UK Green Building Council 2009). Direct and indirect incentives of both a public and private form are important complementary instruments to expedite implementation of policy measures as well as valuable generators of private investment for the green economy. Public subsidies in the form of grants and tax credits have been shown to increase public demand for and enhance market absorption of renewable technologies, efficiency measures, and green materials and services, but can vary significantly across countries owing to legislative norms and perceptions (ICCR 2009). The one-stop-shop, full-service approach, whereby information, technical expertise and financial opportunities are facilitated, is documented to be beneficial, yet only for specific target groups. Also, financial incentives are not sole determining factors for energetic retrofits, but function more as decision-making catalyzing agents for already environmentally motivated individuals rather than promoting new interest in others (Van As 2009).

Incentives and technical services are valuable instruments to accelerate the rate of energetic retrofits within the multi-family and commercial building stock. As a model, energy contracting offers a variety of arrangements and services that can bring economic benefit to owners of real estate properties, with public institutions leading the way. Energy contracting companies (ECOs) provide third-party services that can help overcome the landlord–tenant (split-incentives) dilemma thwarting the advancement of the industry towards higher energy performance and supporting low-carbon environments. Yet, at an initial stage, informed owners and investors need to demand qualified energy services in the market (Bleyl-Androschin et al. 2008). The formation of new partnerships with ECOs can provide the planning, technical expertise, up-front capital and maintenance services, necessary to enhance the energy performance of buildings (TSB – Technology Foundation Berlin 2010). The savings in the energy expenditures resulting from the services performed are used to pay for some or all of the transaction costs owed to the contracting firm. In this arrangement, energy performance contracting can be an important motivator to encourage investors and owners to undertake energetic retrofits despite a lack of in-house financial and technical resources. The challenge for ECOs is attaining a certain
economy of scale for their portfolios. Research indicates ESCO services to be economically feasible for larger buildings – greater than 13 units or approximately 1000 m² or above 100 kW therm projects (Bleyl-Androschin et al. 2008). Despite the inclusion of ECOs in the EU Energy Services Directive, the model suffers to date from limited applicability throughout Europe owing to a lack of standardization of prices and services and nonsupporting legislation in many countries.

Two EU-sponsored projects, BewareE and IMPLEMENT, contribute to the literature and knowledge base on promoting energy efficiency in buildings, and support the implementation of the Building Directive. The BewareE Project profiles energy services throughout Europe to assess their impact in promoting behavioral change towards energy conservation. Of 139 types of energy services identified, 36 were selected as best practices on the basis of various quantitative and qualitative factors that measured their potential to be instrumental in effecting change in human activity. Criteria included issues related to cost, target group acceptance, energy saving and innovation. The broader dissemination of energy services best practices was undertaken in Germany through a series of workshops for the development of implementation strategies and guidelines targeting housing companies and other stakeholder groups and outlining the value of different communication approaches. The project demonstrated a top-down approach, whereby services were developed with the provider and proved to be time- and cost-efficient and simple to incorporate and adapt as part of a process. On the other hand, a bottom-up approach that gave residents the opportunity to drive the design of services offered the benefit of greatest acceptability but with higher investment in time and resources, and an associated risk of lack of consensus or inability to objectively identify needs. In general, energy services and campaign models that offer the opportunity of face-to-face contact and personalized advice were seen as the most effective, supporting the research cited earlier (Schultz 2010) as to the greatest impact of communication methodologies.

Similar scientific research about changing behavior demonstrated direct feedback to end-users at the household level to be quite effective in inducing energy savings (Abrahamse et al. 2005). Related studies have documented energy savings of 4–12% in electricity consumption. Such feedback scenarios become even more effective when combined with the setting of individualized goals, resulting in savings of up to 22%. Coupling feedback and incentives schemes further increases the impact of energy-saving activities, although the sustainability of such actions upon cessation of financial benefits tends to be limited (Kortman 2008). Research into understanding how behavioral change can be internalized and sustained for the long term warrants greater attention.

An important behavioral consideration in raising the profile of energy savings and efficiency is to safeguard against the “rebound effect”, defined as reduced energy consumption in one respect being offset by increased consumption in the same or others. This human tendency is often attributed to misguided thinking that, because products and equipment are energy-efficient, greater use is legitimized. This increased consumption reduces the overall technical gains in energy efficiency, with an economy-wide rebound effect estimated at approximately 10%, and in the range of 30% for the household sector (Sorell 2007). Understanding the implications of rebound in the building sector is crucial both for the industry and policy-makers as the embodied energy (indirect rebound) of renewable technologies and building materials must be considered in life-cycle calculations to achieve a true low-carbon structure and environment.
The growing global trend of consumerism for household appliances and electronics driven by higher comfort levels in Europe and GDP growth in developing countries will serve to exacerbate the rebound effect and increase demand for energy consumption predominantly in the electricity sector (Figure 4).

Cultivating a sense of environmental consciousness to in turn promote behavioral change in a manner that reduces overall consumption patterns becomes even more crucial as technological advancements increase efficiencies and reduce energy expenditures in relative terms. Education and graduated energy tariffs are among the measures that may help stem the rebound effect in the short term and allow consumers to rethink household practices based on greater awareness and economic costs. However, in the long term a low-carbon environment may only be achievable through draconian measures, whereby economic growth in Western societies is held in check and individuals are forced to re-evaluate behavioral and lifestyle practices and priorities (Victor 2008).

**Modern technologies and sustainable design**

An integrated, holistic approach needs to define the construction and retrofit of buildings in the present day to ensure a low-carbon environment for the future. Sustainable design and modern methods and technologies are fundamental to reducing energy demand and lowering emissions in the building sector. Policy at the European and local levels is accelerating the application of low-carbon technologies in buildings and promises to expedite market absorption, lower emission levels and serve as an economic driver for more sustainable products and services. With low- and zero-carbon buildings as the goal advocated by the European Union in the Recast of the Buildings Directive, it is expected that the market for skilled labor and
renewable technologies will expand. Yet such developments are predicated on the experience or “learning curve” of the building industry leading it to embrace energy-efficient practices and utilize modern technologies as a matter of course. Mainstream acceptance by building professionals and practitioners will reduce material costs and help accelerate building retrofits through economies of scale (Jakob and Madlener 2004). This, in and of itself, remains a great obstacle, whereby, despite a good general awareness of green buildings, involvement is significantly lower owing to underestimation of the contribution of buildings to carbon emission levels (average estimate 19%, while in reality it is 40%) and an overestimation of the cost of efficiency measures (average estimate 17%, in reality 0–5%; World Business Council for Sustainable Development 2009).

Technologies

Accelerating the application of low-carbon practices and technologies in buildings will encourage greater market absorption, lower emission levels and serve as an economic driver for a more sustainable environment. A multitude of technologies are currently available to mitigate fossil fuel consumption in buildings and comprise of a mix of innovative methods and materials with traditional and vernacular practices.6 Utilizing basic technologies such as insulation, yet with a modern and sustainable approach, entailing greater thicknesses, alternative materials and broader applications, i.e. in ceilings and between floors, can be the most cost-effective of measures. Ensuring an airtight building envelope and eliminating thermal bridges can optimize building system efficiencies and reduce energy demand. Similarly, double- and triple-glazed window installations appropriate to the respective climatic zone can reduce energy consumption. Cost optimization in buildings can be achieved through the use of multi-disciplinary experts that employ building information management systems and prioritize the use of sustainable design and passive measures over renewable technologies (Architects Council of Europe 2009). Renewable technologies are playing an increasingly critical role in reducing traditional fossil fuel energy demand and abating emission levels and will do so long into the future. However, their initial capital investment and longer payback periods still thwart greater market commitment.

The application of new technologies and the curtailment of the use of energy are both in part a function of awareness-raising and convincing individuals that their

Figure 5. Improvements in effectiveness through monitoring. Source: TSB Berlin (2008).
actions make a difference in the broader sense. Although both strategies reduce energy consumption, the research of Stern and Gardner (1981) places greater emphasis on increasing energy efficiencies in appliances and building systems vs behavioral practices. Insulating a house is of higher value than turning off lights; however, it is the latter that has the greater propensity to be undertaken owing to its visible nature (Kempton et al. 1985). Promoting higher building efficiencies requires additional support measures, including financial incentives and education, to encourage decision-making and purchases of modern systems and equipment. Yet in terms of impact, increased energy efficiency must be seen in the broader context of human behavior and consumption trends to determine if the associated rebound effect lessens the positive impact and in the worst case “backfires” and offsets total energy savings (Sorell 2007).

Upgrading building systems for heating/cooling and hot water, utilizing an integrated renewable technology approach, can offer substantial benefits of up to 40% savings. Yet, achieving optimal efficiency levels requires skilled technicians and periodic maintenance for careful monitoring and calibration of systems to meet required comfort levels as well alignment to initial forecasts (see Figure 5). Improper end-user behavior can reduce the efficiency of modern building systems and offset potential energy savings, underscoring the importance of maximizing building performance through coordination of the needs and expectations of builder, user and technicians.

Building technology is inevitably starting to play a significant role in modulating the behavior of residents. Providing end-users with real-time information has demonstrated energy savings of up to 10% (BewareE 2009). New software and IT platforms enable home-owners to gage their energy use with the help of personalized dashboards to regulate their consumption levels. Increasingly, such tools are also providing individuals and utility companies with ways to compare consumption levels across an array of users offering new opportunities to stimulate behavioral change. Utility and power companies have an instrumental role to play in encouraging energy saving behavior through the EU Energy Services Directives having laid down the policy framework for constructive engagement. With most European households expected to be equipped with smart meters by 2020, providers are able to offer a range of energy awareness opportunities and services to their broad consumer base premised on demand-side management and real-time information. Keeping the technology simple and maximizing its visibility (i.e. meter in the kitchen) will increase the probability of fostering constructive energy-saving behavior among end-users (IMPLEMENT 2009).

Sustainable design
The built environment encapsulates the modern day individual for the majority of their living existence, while living and work premises dominate inhabitants’ time in developed societies. Given that humans have limited information-processing capacity and finite time and resources, they are constrained in the number of behavioral changes or new behaviors that are possible (Gardner and Stern 2002). In this respect, the design of the buildings (offices and homes) and urban spaces offers valuable avenues for influencing behavior through spatial layouts, physical formations, technical systems and accessibility to and contact with the natural environment, all of which can encourage energy savings that carry over into other elements of daily life. A number of
low-carbon design concepts are becoming popular, including passive house, zero-carbon and even positive-energy buildings, expanding opportunities for the sector to make a long-lasting positive impact on the climate change agenda. Sustainable design that incorporates a substantial element of green infrastructure and expands boundaries to green roofs and façades can provide benefits and the chance to heighten environmental consciousness and influence behavioral norms.

The end-user or household plays a pivotal role in the utilization of the building space, its systems and immediate surroundings; yet it is the planner, architect, designer and builder who are instrumental in organizing that space and can optimize its use. These stakeholders can mitigate energy losses and enhance performance through employing passive and active (technological) measures in the context of the local and natural environment, while foreseeing the potential short-sightedness and uninformed nature of the user, leading to their failure to act responsibly. The idiosyncratic and complex behavior of individuals should be anticipated and recognized in that the information deficit model is not always relevant given other factors that influence human actions (Janda 2009). This discourse has led some circles, including the World Business Council for Sustainable Development in its Energy Efficiency in Buildings Report 2009, to advocate a new profession, alluding to the development of the field of public health, that teaches people how to use buildings in an energy-efficient manner and functions as a “system integrator” and liaison between the end-user and the building industry to support energetic retrofits and low-carbon living environments.

Social and community norms
Climate change and the deterioration of planetary biospheric resources can be perceived as a tragedy of the commons. The capacity of community and social groups to organize and exert collective action for the benefit of the common pool resources suggests that behavior can be encouraged towards a low-carbon environment (Ostrom 1990). Along these lines, one approach being explored is based on human psychology and the fact that individuals as social beings react to social norms or peer pressure. Real-time information can be compared on a group, community or city level as part of a social-norm based campaign. The use of normative messaging through feedback on utility bills (happy and sad faces depending on consumption) has been shown to elicit a reduction in energy use of 2% over one year within a sample set of 35,000 households because of positive reinforcement as well as the relative grading to their peers in the community (Schultz et al. 2007). Application of such psychological techniques as normative messaging to climate change issues is gaining support in Australia and the United States, where the cliché “keeping up with Joneses” may eventually work in reverse and encourage greater energy savings. Whether this social normative approach is effective in all countries and cultures as well as its capability to produce longer-term and sustainable results are questions for further research.

Empowerment models in which building residents are trained to play a central role in communicating energy-saving measures to other tenants or contributing to a building’s advisory board were cost-effective and resulted in reduction of consumption levels of between 5 and 20%. Also, personalized feedback to households via energy performance assessments can be effective in reducing short to medium-term consumption levels, yet its long-term prospects are unclear, although hopeful if mandated by local policy.
Biophilia and the natural environment

The nexus between human beings and the natural environment has traditionally been a guiding element in the development of physical environments, yet has carelessly deteriorated in modern times as an initial consequence of industrialization and more recently the exponential growth of technology. In the quest for continuous economic growth and consumption, Western societies have lost their focus on the essential balance between the planet’s life-sustaining natural resources and lifestyle demands. Yet the human evolutionary and genetic relation to nature has determined the survival of mankind and defined its protective habitats for centuries. “Humans have spent 99 percent of the time on earth living in tremendously close contact with forests, grasslands, and other intact ecosystems”, writes Sullivan (2005), questioning whether a disconnection of this symbiotic link will negatively impact man’s future existence. The concept of biophilia contends that this genetic, inherent relationship is essential and contributes to a sense of environmental consciousness in humans; however, its potential to foster behavioral change towards a low-carbon environment is relatively untested. Nevertheless, numerous studies in biophilia document the positive effects that nature conveys on the human physical and mental states, and therefore it seems logical that increased exposure to the natural environment may incite commitment and pro-active behavior for its preservation. Greener environments are shown to encourage stronger socialization (Kuo et al. 1998), and thus indirectly may hold hope for galvanizing collective action for addressing the planet’s climatic commons dilemma.

The relationship between the built and natural environments has been explored in medical research, and attention has been drawn to the importance of elements such as access to nature, type and design of buildings, public spaces and urban form in modulating human behavior. Such studies have demonstrated that hospital patients with views of trees have shorter hospitalizations periods (7.96 vs. 8.70 days), reduced demand for pain medication and fewer negative medical entries from staff compared with patients having only views of physical structures with no natural qualities. Such results indicate that contact (even if only visual) with green space and natural elements (trees in this case) can promote a healthy and beneficial effect on the human condition and reinforce the value of greenery in the design of buildings and urban spaces (Frumkin 2003, Ulrich 1984).

The restorative benefits of nature were recognized early on by the landscape architect Frederick Law Olmstead, who stressed its particular importance for urban inhabitants. Research conducted by Kaplan (1995) further documented the positive value of nature in mental functions requiring directed attention as well as in the alleviation of stress. Similar studies have significantly demonstrated the value of nature in preventing aggression in public housing projects in the United States – documenting how even limited amounts of greenery in the nearby surroundings had a positive impact in reducing levels of violence (Kuo and Sullivan 2001).

The return of man to nature is the premise of the Japanese philosophy Half-farmer, Half-X, which espouses that contact to the land and natural environment (Half-farmer) provides the inspiration to discover one's natural calling (Half-X). Strength of spirit and mental clarity are attained through tangible contact with soil and natural elements as well as simply through caring for pot plants in urban settings. Commenc ing a dialogue or interaction with nature enhances the appreciation for it and allows one to discover one’s true sense of being (Shiomi 2008). As with biophilia, basic visual contact generates benefits for the individual, while Half-farmer, Half-X
proposes physical contact for even greater added value. In both cases, environmental consciousness is heightened and enhances the potential to mobilize behavioral change towards climate protection. Testing the application of this philosophy together with biophilia for promoting energy conservation in the built environment and cultivating low-carbon lifestyles in an urban setting is a subject for future research. Schultz et al. (2004) have raised similar questions emanating from their research ascertaining the positive correlation between connectedness (to nature) and environmental attitudes. In addition, nature’s capacity to enhance attention and information processes presents research opportunities for communicating climate issues in a manner that penetrates the human evolutionary state to influence behavior and lifestyle towards sustainable habitats and environmental (self)-protection.

Conclusion and recommendations
Buildings constitute an integral component of the physical landscape and an inherent part of daily life as commercial, residential and public spaces. Buildings, in and of themselves, are complex systems made up of numerous sub-systems with internal and external interactions relating to energy flows, technological applications, human behavior and the natural environment. In the broader sense, buildings are also multi-dimensional drivers of carbon emissions, green economic growth, renewable technologies, societal behavior and the urbanscape. The influence of buildings on society and their functions suggests the climate change agendas at the global and national levels would benefit significantly from elevating the role of the built environment in mitigation strategies and considering its contribution as an energy producer in forward-looking adaptation policies.

Changing the manner in which Western societies currently operate, use and design the built environment could profoundly mitigate climate change concerns and offer more promising opportunities for the developing world. Cultivating a culture that is environmentally conscious could foster the essential behavioral change for individuals and societies to embrace low-carbon lifestyles and create energy efficient environments. In doing so, significant gains in the reduction of energy consumption and carbon emissions could be achieved. The building sector offers the greatest potential for mitigation on a global scale, where change is a function of the following factors when overlaid in an enabling regulatory environment:

1. Information and education.
2. Financial incentives and energy services.
3. Modern technologies and sustainable design.
4. Social and community norms.
5. Biophilia – contact with the natural environment.

The challenge of climate change must be embraced by all, with government ideally suited to take the lead and spearhead legislation and adopt supportive measures to motivate households, industry and the private sector of the value of individual and collective action for the benefit of the local and global environment. Guiding legislation such as the EU Buildings Directive and EU Energy Services Directive provides a framework in which stakeholders can operate within their capacities, yet are obliged to participate. The lack of a regulatory environment thwarts meaningful advancement in the climate agenda in many countries and allows
societies with subsidized and cheap energy to opt out of sustainable change. The earlier energy sustainability is placed on the political agenda, the easier it will be for societies to comprehend the total cost of energy and adopt efficiency practices and technologies in support. Such was the case in Europe with the introduction of building energy efficiency codes in the 1970s as well as California in 1978. Such pioneering efforts led to the acceptance of broader and more prescriptive measures over time, underlining the importance of a regulatory basis by which a transformative process can commence and involve all stakeholders, particularly the construction industry in this case (Lui et al. 2010).

The Energy Performance in Buildings Directive (EPBD) aims to stimulate market demand for energy-efficient real estate, encouraging change among consumers and builders alike. The EU Energy Services Directive encourages energy suppliers to play a greater role in promoting energy efficiency in the building sector and offers tremendous opportunity for broad societal outreach. Mainstreaming the use of smart metering systems and energy consumption data (at the community and neighborhood level as comparative benchmarks) can heighten awareness across all users and foster eventual change. Recognizing such opportunities, France has more aggressively pursued implementation of the directive and requires energy providers to meet legislated efficiency targets or face penalties.

A carrot and stick approach can be an equitable means to accelerate energetic retrofits in the building sector and employ a variety of instruments such as a progressive (emissions) tax, energy inefficiency tax, performance targets and efficiency standards, and financial incentives. Collected tax revenues earmarked for energy-saving initiatives or replenishing subsidy schemes through transparent mechanisms offer important financial support to engage a greater segment of the population in energy-reduction activities. Bonus-sharing models for public institutions, similar to the Hamburg 50/50%, provide necessary incentives for institutions to embrace sustainability measures and encourage local participation and the opportunity for local authorities to lead by example. Linking business license renewal and energy savings allows government bodies to use financial incentive/disincentive schemes (based on measures with short pay-back periods) to increase engagement of the commercial building sector. For its part the private sector (or businesses using more than 50,000 kW h per year of fossil fuel, gas or equivalent consumption) should be obliged to develop environmental/energy plans aimed at energy reduction in operations and encourage energy efficiency practices among employees. Similarly, the provision of employer incentive plans that promote the link between energy reduction in the workplace and in the home offers wide application to communicate the value of energy savings and lifestyle change.

Clear and concise communication on the role the building sector and households can play to address energy demand and constructively contribute to the global climate change agenda warrants high priority. Such campaigns dedicated to the low hanging fruit of energy-saving measures offer the most cost-efficient and effective instruments for engagement. Government leadership for climate change can be demonstrated through informational campaigns ideally initiated and/or backed by the highest authority levels, employing a range of communication tools and media for broad outreach and societal penetration. Campaigns coupled with reinforcing mechanisms, e.g. advisory centers, hotlines and grant schemes that illustrate and support conservation measures able to be undertaken on a daily basis to reduce energy consumption, tend to have the greatest impact. Integral yet difficult
audiences, such as tenants, housing associations and commercial/private sector energy consumers, warrant special attention by all levels of governments to effectively address the landlord–tenant dilemma. Utilities and energy suppliers are well positioned to raise awareness within these markets and provide informative benchmarks to better assess social norms. Broad dissemination and integration of environmental education as part of national teaching curricula at the compulsory and higher education levels should become an important priority for policy-makers to cultivate a new generation of environmentally minded building professionals and practitioners. The application of sustainable design in planning and building practices bestows cost-effective and passive methodologies, whereby biophilic tendencies can be nurtured and a market cognizant of the value of energy efficient buildings and low-carbon living environments fostered.

Promoting a sustainable and low-carbon future will require not only the retrofitting of buildings in a sustainable manner, but also the retrofitting of cities to tackle overarching macro issues and current global trends of economic development, demographic growth and raising energy consumption. The transformation of cities into low-carbon environments will be dependent on reform within their respective systems and sub-systems to optimize the use and reuse of local and finite resources by means of technological advancements, behavioral and lifestyle changes and integrated policy frameworks. Cities with the capacity and resources to embed a large ICT infrastructure will be the smart cities of the future with “instrumented, interconnected and intelligent” systems. An integrated and multi-modal public transportation system, compact land-use planning and the sustainable use of energy and material flows, e.g. soils, water and waste, must define any low-carbon urban environment with the concept of a “city of short distances”, exemplifying the eco-city of the future. In either case, buildings will play an increasingly central role in the path towards a more sustainable use of energy and environmental resources.

Notes
1. In June 2009, the European “climate and energy package” became law and mandated targets of 20% reduction in carbon emissions, 20% increase in use of renewable technologies and 20% increase in energy efficiency; see www.ec.europa.eu/clima/policies/package [Accessed 17 April 2011].
5. BewareE (2006–2010) (www.izt.de/beware) was funded by the Executive Agency for Competitiveness and Innovation and coordinated by the Institute for Future Studies and Technology Assessment, while the IMPLEMENT Project was sponsored by Intelligent Energy Europe and coordinated by the Province Groningen of the Netherlands with Ecofys as a key partner.

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