Chapter 3
Energy-Based Transitions

Abstract The focus of this chapter is on reducing energy consumption in cities, including through decarbonisation efforts and transitions as well as improved energy efficiency. Continued investments in the production of renewable energy sources and the transmission (or distribution) of green energy are needed in order to sustain a low carbon supply as for instance in district heating and cooling (DHC) and as combined heat and power (CHP) or cogeneration. In addition to investing in such technologies, it is also pertinent to reduce energy consumption and promote energy conservation. City challenges regarding emissions are addressed. It helps to have building standards in place and building code guiding sustainable homes as well as effective planning to direct development, even amid rapid development. Spatial planning has potential when deployed alongside building control. Decisions regarding density building, suburbs, and transport are vital to examine in the context of the New Urban Design as well as sustainable development.

Keywords District heating and cooling (DHC) · Combined heat and power (CHP) · Building code · Spatial planning · New urban design · New technologies · Sustainable development

Climate mitigation efforts have focused on the energy sector and transport sectors, built environment and densification, and urban greenery. This reflects the efforts in relation to both the supply and demand side of power. Specific attempts have been made in the energy sector, on the supply side, to improve energy generation efficiency, shifting to less carbon-intensive fuels, keeping electricity affordable, as well as developing public and public partnerships. Hydroelectricity, wind, solar photovoltaic, solar thermal, geothermal, tide, and wave are all renewable types of energy that do not involve direct greenhouse gas (GHG) emissions (albeit there are indirect emissions from building power installations). Biomass (wood, biofuels, waste) can also be a carbon neutral source of energy if the burned biomass is renewed in a sustainable way.

Many countries have made decarbonisation efforts, by increasingly using a greater share of fuels with a reduced carbon content and technologies with fewer emissions and generating a larger proportion of electricity and heat from non-fossil fuels. According to IEA (2018) data, in Iceland for example, 83% of total primary energy

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supply (TPES) is derived from hydropower and geothermal power. Combined, these two types of power provide for all of the country's electricity needs (respectively, 75 and 25% of electricity generation). Geothermal power was found, in addition, to be responsible for 94% of the country's heat production. Under previous administrations, the USA formulated an extensive plan of decarbonisation that was based on proven technology and distribution systems (e.g. Shinnar & Citro 2006). The plan envisaged that in the next few decades, the USA would be switching to non-fossil energy sources, including concentrated solar thermal (CST), nuclear, geothermal and hydroelectric, wind, solar cells, and biomass energy. The plan did not include a major programme of carbon sequestration because it was considered to be more costly than CST and nuclear. Perhaps electricity is a suitable approach for infrastructure in a world currently in transition because it does not rely on the type of energy source, whether it is renewable or not, and is already broadly in use. This is advocated by Zerocarbonbritain2030 (ZCB2030) that proposes a future scenario, where '[t]he roads and rails will buzz with the sound of power lines, batteries and fuel cells' (Kemp & Wexler 2010, p. 105).

3.1 Urban Energy Infrastructure

Globally, there is not only an increased interest in renewable energy sources, but also in decentralised energy generation and distribution (Goodier & Rydin 2010). The call for low carbon energy offers opportunities to shift from 'large' vertically integrated energy industries to decentralised neighbourhood-scale generation, which can be sufficient to cover all local needs. Increasing use of decentralised energy is also a way to reduce energy transmission losses, since energy systems can be more efficient when power lines to consumers are as direct as possible and the number of transformation steps minimised. It is of course the city and regional levels that can play a key role in decentralised energy. Even when the city government does not own and operate power-generating facilities (although the opposite is often true), it can use a number of levers to promote local green energy infrastructure. For example, the city can purchase renewable energy for city operations; identify strategic sites where renewable and low carbon energy sources could be located; provide planning incentives and development land; permit the construction of only efficient and clean power installations; and require new developments to connect to district heating systems. In short, the following options are implemented at the city level for city-scale decentralised renewable and low carbon power supply (Golubchikov 2011):

(a) Switching to lower-carbon technologies and promoting district heating and cooling systems with cogeneration and tri-generation;
(b) Installing renewable power installations, e.g. wind turbines, solar farms, energy from biomass and waste plants;
(c) Promoting onsite microgeneration of heat and electricity in the buildings sector;
(d) Developing a smart grid and efficient municipal energy services.

The fuel mix used in power generation also matters. Increasing the share of gas in energy supply has been promoted in many cities; indeed, natural gas contains 40–50% less carbon than coal and 25–30% less carbon content than oil, only marginal quantities of sulphur, and is more energy-rich and efficient. Power stations with modern gas turbines can achieve 60–65% of conversion efficiency, but the most modern city-based gas-fired combined heat and power (CHP) plant can reach efficiencies of more than 90% at the point of end-use (due to lower losses from transmission, fewer condensation losses in boilers, and the close proximity to the consumers). It is evident that a considerable amount of primary energy and carbon emissions can be saved by the large-scale deployment of modern CHP plants. The CHP technology, which is also known as cogeneration, can be used for both industrial and non-industrial purposes and also at the micro (household) scale, but it is most advantageous if connected to district heating (also known as community heating) and deployed at a city- or neighbourhood-scale. In addition to satisfying local needs in heat, hot water, and power, CHP plants can provide cooling, by chilled water (this is known as tri-generation or as combined cooling, heat, and power).

Although district heating and CHP can function independently of each other, district heating and cooling (DHC) with CHP is today one of the most proven, efficient, and cheapest available technologies to reduce emissions and save energy at the city level. District heating, in particular, is considered for deployment in areas of high population densities with continuous demand. However, there are examples of countries where even low-density areas are supplied by district heating. Countries with significant shares of low-density, single-family houses connected to district heating in 2003 were Iceland (85%), Denmark (48%), Finland (13%), and Sweden (10%) (Nilsson et al. 2008). Remarkably, however, there is a strong opposition at the community level against district heating in countries such as the UK, which lack an appropriate tradition.

District heating and cooling can be designed as a flexible system, so that apart from CHP, DHC networks can be supplied from a variety of other sources, including geothermal and solar heating stations; fuel cells; biomass; surplus heat from industries; and energy from waste facilities. The ability to integrate diverse energy sources may provide for a flexible platform to reduce dependency on a single source of supply and to introduce competition into the supply chain. Similarly, CHP plants themselves can work on different fuel mixes. A challenge for climate neutral policies is to drive the whole energy infrastructure of district heating and CHP towards renewable supply; the anticipation of such a move should be integrated into the planning for new installations. For example, such 'future-proofing' has been a priority for London authorities planning for easy replacement or refuelling of new-build gas-powered CHP with renewable fuel or hydrogen in the future (Jones 2009).

Apart from cogeneration, cities promote other forms of renewable energy supply, such as city-scale or neighbourhood-scale power installations and even smaller (building-scale) microgeneration. Again, different sources of renewable energy are used—geothermal; wind; solar; ocean; biomass; landfill gas; and waste-to-energy. The small power generators can be linked to the common electricity grid and district heating or, alternatively, supply electricity and heat directly to the consumer (such as stand-alone renewable power operating at distribution voltage level). The introduction of electricity buy-back may promote renewable technologies in China, for instance, under a distributed energy system employing CHP, biomass energy, and photovoltaic technology (Ren et al. 2010). The city of Guelph (Ontario, Canada) has included wind energy in its community energy plans to produce energy within its municipal city boundaries. This scheme could generate between 8 and 29% of its total electricity demand from a baseline in 2005 (McIntyre et al. 2011, p. 1445). These trends will certainly affect the way cities are designed and planned. Microgeneration or onsite renewable energy generation in the buildings sector—both by commercial buildings and dwellings—is also increasingly promoted. Networked microgeneration might even be sufficient to cover all local electricity and heat demand, given that the final energy consumption is reduced through improving end-use efficiency. Microgeneration can include different types of heat pumps; small CHP plants; solar PV and thermal collectors; wood pellet stoves; small wind turbines; and other renewable technologies. For example, as part of the Hamburg Climate Action Policy for 2007–2012, Hamburg is carrying out a number of measures for the deployment of solar roofs. To this end, about 150,000 roofs in Hamburg were examined to determine their potential for generating energy, including by using a laser scanner flight programme, which measures both the direct and diffuse solar radiation potential of roofs in the city (City of Hamburg 2011).

In short, energy policy could provide a means by which to target energy consumption and the reduction of greenhouse gases or GHGs, as exemplified by Barcelona and London that are in carbon lock-in and using urban planning policies towards low carbon and renewable energy technologies in retrofitted and new buildings (Maassen 2010). One example is London's use of onsite decentralised energy generation in new developments. The project 'Challenging lock-in through urban energy systems (Clues)', for instance, raised important questions relating to urban areas in the UK and barriers to their energy systems, system decentralisation, aggregate decarbonisation targets, and sustainability (Rydin et al. 2010).

3.2 The Built Environment

Since cities are typically seen to be the largest source of carbon emissions (Hunt et al. 2007), they need to be redesigned to reduce their emissions. This can be achieved through strong legislation, especially building regulations, waste and water management as well as city planning, planned infrastructure changes, using the latest building technology and alternative (renewable) energy, such as solar and wind integrated into building design and retrofitted, local (in-city) power generation to reduce loss of energy via transportation, city-specific plans particularly for developing countries, and possibly the eventual abandonment of unsustainable (or highly vulnerable) cities.

There is no doubt that the built environment in particular poses a major challenge, especially since it is responsible for emitting over a third of the world's emissions and consumes about 40% of energy for residential and commercial buildings in Western societies alone (James 2009, p. 52), releasing much carbon dioxide or CO_2 into the atmosphere. Ürge-Vorsatz et al. (2007) postulate that it is possible to reduce these emissions by 30% (for a selection of best practices), having examined 60 policy evaluation reports, representing at least 30 different countries across four different continents. They discovered the most effective policy instruments in this sector to be appliance standards, building codes, tax exemptions, and voluntary labelling, which are found to be even more effective than Kyoto Protocol flexible mechanisms and carbon taxation. In their overall assessment, the most cost-effective instruments (of energy savings achieved with negative costs for society) are appliance standards, demand-side management programmes, and mandatory labelling.

A report by PRP Architects et al. (2008) examines six exemplary places with large-scale development situated from the city centre to suburbia. Namely Adamstown (near Dublin, Ireland), Amersfoort (the Netherlands), Freiburg (Germany), HafenCity (Hamburg, Germany), Kronsberg (Hanover, Germany), and Hammarby Sjöstad (Stockholm, Sweden) were subject. In Freiburg, people are using their cars less and either taking public transports or cycling. In terms of climate-proofing, there was a 60% reduction in CO_2 emissions in Kronsberg (p 18).

It is particularly beneficial for China's rapid urban development that considerable carbon emissions reduction can be gained from an approach that combines building design and construction along with urban planning and building material industries (Li et al. 2009). Even though China has adopted a low carbon economy (Jing et al. 2010), which is targeted to deploy clean energy, including renewable energy mainly derived from small and large hydro power plants (Zhang et al. 2010), it experiences barriers to carbon reduction, as in larger commercial buildings situated in Beijing and Shanghai that cannot employ energy managers of a sufficient calibre (Jiang & Tovey 2010). A study conveys that even though there was progress in carbon reduction in Chinese cities in the 1990s, this progress has slowed down or even reversed in recent years (Dhakal 2009). Urban management in China is restricted by departmentalisation as well as poor information sharing and coordination, creating an information isolation island problem (Wang & Cao 2010). Instead of investing in low carbon technologies, such as deriving renewable energy from wind or carbon sequestration, it was found that a better mitigation tool in terms of cost-effectiveness for China could be the improvements in building energy efficiency, like in cities located in northern China, such as Tianjin, which implemented building energy efficiency policies in its residential sector in the 1980s (Li et al. 2009). It has been postulated that new urban construction in China should move towards low carbon eco-city status (Li et al. 2010).

Other measures are suggested for existing buildings, for example Kelly (2009) advocates that: building fabric could be reengineered; appliance efficiency could be improved; electricity to homes could be decarbonised either through the grid or the use of renewable sources of energy; and changes in personal behaviour could provide solutions. Even historic buildings can be retrofitted, as with the case of The Hague's technological configuration (Peltier 2009), which did not require any major changes to its façade. Some European museums have adopted energy conservation techniques in their buildings in order to reduce energy consumption, including considerations of indoor temperature (heating and cooling) as well as lighting and other electrical devices (Zannis et al. 2006). It is possible to retrofit these non-domestic buildings, as also shown for Bristol, UK in attempts to reduce the (financial) risks associated with unsustainable buildings (Femenías & Fudge 2010). One of the most cost-effective solutions is insulation retrofitting, particularly with the use of nano insulation materials (Jelle et al. 2010).

A report by the Environmental Change Institute (Boardman et al. 2005), namely 40% House, was challenged by Power (2010), who opposes its proposal to achieve reductions in CO_2 emissions in building through the demolition of leaky homes. She advocates that the proposal is based on unsupported assumptions, including that new homes will have a better energy performance, and ignores both embodied energy and waste generated in the new building as well as the energy costs of infrastructure. An approach that is more conserving and recycles materials is likely to be more sustainable. For example, she suggests that ‘higher refurbishment standards for existing homes using known methods (including under-floor and solid wall insulation) offer better value and potentially greater gains more quickly and cheaply than demolition and replacement buildings’ (p 214). Research by Thornbush and Viles (2007) supports that old building stone, for example, is more stable and affected less (in terms of material loss) than newly exposed surfaces. This could indicate that there is some advantage to salvaging stone used in older constructions. Moreover, it is possible to improve existing building envelopes through measures taken to doors and entrances, draught-proof, window films and glazing, natural ventilation, solar shading, solar reflective surfaces, insulation, and green roofs (Rawlings 2010) as well as green walls. Using an optimum insulation thickness, for example, was found to reduce CO_2 emissions by 27% in Erzurum, one of Turkey’s coldest cities (Çomakli & Yüksel 2004, p. 939).

Leaky homes can be improved with increased insulation, as also offered by vegetation. Green roofs integrate the positive effects of vegetation cover directly into the buildings’ design. They reduce the over-heating of buildings in summer and provide a better thermal insulation in winter, thus, improving the building’s own energy performance in addition to the positive effects for the neighbourhood as a whole. For example, traditional rooftops in North America and Central Europe can reach temperatures as high as 90°C during the summer, but green roof temperatures stay below 50°C. This demonstrates that the difference in surface temperature between a green roof and an unplanted roof can reach 40°C and more (Gartland 2008). A cooling roof is also beneficial for solar panels, as they currently work best at temperatures up to 25°C and have a reduced productivity at higher temperatures. Furthermore, green roofs intercept stormwater runoff and reduce the load on the building’s drainage system, thereby extending its maintenance cycle. There are interesting examples of compulsory green roofs as posited by a recent by-law that requires the construction of green roofs on public and private buildings in the City of Toronto (Ontario, Canada). In Chicago (USA), government buildings require green roofs and cities in Austria, Switzerland, and Germany, following the original experiences of Basel and Linz, have introduced either compulsory requirements for greening all flat roofs on new buildings or additional subsidies for such measures for existing roofs (Golubchikov 2011).

This approach has the added benefit of urban greening, which will help to absorb atmospheric CO_2 through carbon capture by green façades and roofs in addition to other green spaces. Forests, for example, have been promoted as carbon sinks for low carbon cities (Jiang et al. 2010). They are believed to be an important strategy in global warming mitigation, moving towards the reduction in emissions associated with deforestation and degradation and the improvement of forest management and afforestation. This approach of urban greening has been recently extended to include urban agriculture (e.g., Thornbush 2015), such as food projects (Hopkins 2010). Living walls adopted in office buildings could also improve the quality of indoor circulated air and, hence, human health. Besides capturing CO_2 gas, plants are also capable of trapping particulate matter, which could reduce the incidence of human cancer in cities due to the inhalation of black carbon particulate.

3.3 Spatial Planning, Urban Density, and Mobility

Today, spatial planning in its various manifestations—regional and urban planning, land use zoning—finds itself right at the heart of adaptation and mitigation measures. Indeed, urban layout, public transit provision, and integrated district heat-electricity systems are some of the planning considerations that have long been acknowledged among the principal instruments to reduce urban energy intensity (e.g. Owens 1986). Planning is also instrumental in identifying risk-prone zones and providing spatial strategies to safeguard urban infrastructure. What is no less important is that planning decisions on land use and urban layout have impacts lasting for decades and even centuries. Particular land use and infrastructural patterns create the circles of ‘path dependence’, when future investments are predetermined by existing infrastructure, in this case, which may lock economies into particular lifestyles and patterns. Spatial planning is important to prevent being locked into high-carbon or hazard-prone conditions that would be expensive or impossible to alter later (World Bank 2008).

Spatial planning is relevant to all sectors of the urban economy and is principal for the integration of different sectors and urban systems into a consolidated spatial strategy (Rydin 2010). It is often the case, however, that links between territorial plans and climate policies are weak. This is because climate policies are often focused on particular economic sectors and may disregard spatial relations between and within urban sectors as well as the importance of how urban space is organised (OECD 2010). A purposeful integration of planning with policies for climate-smart growth is currently promoted in the context of climate change strategies.

Building control is a powerful tool to complement planning. Contrary to spatial planning itself, which may be opposed by some political ideologies as ‘excessive’ public interference (and, therefore, being limited in certain regions), building control is more easily accepted as a regulatory regime (this has been the case for the USA and some post-socialist countries; see Golubchikov 2004; Stanilov 2007).

Building control may also ensure the presence of planning targets in actual construction practice, including in the private sector. Legal provisions can be established such as those, for example, which require that building permits are only issued for projects that are optimised spatially to reduce energy demand, including density and transport considerations; taking advantage of natural heating, cooling, lighting, and shading potentials; and that incorporate building materials and other means for reducing urban heat island effects (e.g. cool walls, roofs and paving, increasing green areas). Moreover, urban development projects should be subject to a holistic assessment with regard to their environmental standards, which means that the full lifecycles of buildings (all stages from the manufacturing of construction materials to demolition and recycling of materials) are optimised in order to reduce the overall carbon Footprint.

Studies have found that multi-model land use and transportation design in planning for building improvements can reduce emissions; higher-density building is also important; energy efficiency can be achieved across a variety of building types; and affordable housing near work should reduce commuting costs (Condon et al. 2009). Research performed in the City of Toronto (Ontario, Canada) has broadly shown that urban form and density are important considerations (Norman et al. 2006). Policies that reduce operational energy and high-density development nearer to places of employment as well as increase the use of public transport and reduce private vehicle use in the suburbs should be given priority. Alternative fuels and renewable energy should be adopted in order to reduce transportation and operational energy use and GHG emissions from residential development. A study for the Chicago (USA) metropolitan area (Lindsey et al. 2011) has found that vehicle miles of travel, energy consumption, and CO_2 emissions from privately-owned vehicles are augmented with distance from the central business district, but reduced with residential density. This research suggests that high-efficiency vehicles may help to reduce emissions in cases of urban sprawl.

A modern approach to urban planning is the so-called New Urbanist design, which provides an alternative to conventional low-density development (Stevens et al. 2010). Steemers (2003), for instance, sees the benefits of a compact design for cities and towns with integrated public transport. Increased density is a part of this approach, which could use green standards at a lower cost (HTA et al. 2007). Some urban systems depend on achieving a critical density based on the mass of dwellings, such as the effective deployment of combined cooling heating power (CCHP) systems. Moreover, a sufficient volume of development would allow energy companies to support low carbon energy technologies that employ renewable sources of energy (wind, solar, woodchip, etc.). This combined with an integrated energy strategy, which includes a green transport plan, would go a long way to promote a low carbon lifestyle. For example, Power (2010, p. 206) specifies a home density of at least 50 homes per hectare, comprising some 110 people, over the current planning standard of 30 homes per hectare in order to maintain public transport (a regular bus service) as well as shops and schools in towns.

Many authors have also advocated such an approach towards sustainable development, where urban growth that is balanced, compact, and coordinated is geared towards achieving economic, social, and environmental benefits (Nadin 2006); as well as being aligned with the planning and decision-making process involving sociocultural, juridical, aesthetical, and ethical aspects (Vandevyvere & Stremke 2012). This can be attained through a more polycentric pattern in cities and towns and the prevention of urban sprawl. Urban planning needs to consider the size of the city and any associated characteristics of its residents. At a certain level of density, the negative environmental, energy, climate, and sociophysiological impacts start outweighing the gains. Super density also amplifies the negative effects of climate on cities—especially in areas with a high concentration of tall buildings (Roaf et al. 2009). Larger cities normally have larger surrounding areas and involve more long-distance travel, so that people's travel performance is connected to a country's spatial-economic organisation (Perrels 2008). For example, in Finland, medium-sized cities (of around 100,000 inhabitants) have the strongest mitigating effect on transport performance.

There is no consensus on what the optimal level of urban density actually is, nor on whether higher densities should always be encouraged. Moreover, key problems for intensified densities and the 'compact city' are that many cities already differ from an 'optimal' density and that the habits and aspirations of a considerable portion of the population are based on low-density models. There is, however, a broader consensus about the harmful effect of sprawl and the benefits of mixed-use development. The latter generally includes integrating housing, work, facilities, and entertainment in close proximity so that both trip distances and car dependence are reduced. Mixed-use development may also be accomplished in lower-density townscapes, so that existing low-density areas can be transformed towards mixed-use development, based on a strategy of stimulating urban polycentricity.

One case-in-point is the suburb. It is argued that measures associated with a compact city design have not been explicitly geared towards suburban areas, which have their own unique challenges in this transformation towards low or zero-carbon cities, including a slow pace of change (Williams et al. 2010). The built environment in the suburbs is also challenged by other problems revolving around the retrofitting of existing houses and fragmented property ownership and management. This was addressed by Rice (2010), who examines retrofitting existing suburbs towards sustainable urbanism using a compact city strategy that is promoted by the government of the UK. His analysis reveals that it is both feasible to retrofit the suburbs and that this endeavour is locally viable. It can even, in some cases, encourage more sustainable lifestyles, amongst them improved accessibility as well as social inclusion and even physical and mental health benefits.

There is also a broad consensus in the literature that public transport is a crucial consideration to curb emissions from travel. Developing countries, including China and India, are investing in public transport, such as city bus fleets that use alternative fuel in China (Ou et al. 2010). Indian cities such as Mumbai, with a higher share of public bus transport and suburban rail, has experienced a 60% reduction in energy and emissions compared to other cities like Delhi (Das & Parikh 2004), where future emissions (by 2020) are expected to be controlled by the adoption of efficient vehicles and fuels. The use of public transport (mass transit systems), rather than private passenger vehicles, can lead to energy savings in the transport sector for Bangkok due to less of an energy demand as well as reduced local air pollution, including carbon emissions (Phdungsilp 2010).

In addition to developing public transport and non-motorised transport infrastructure, transportation demand management includes optimising traffic flows. Improving the state of the road infrastructure and providing intelligent transportation system (i.e. using various forms of information and communication technologies for real-time information exchange between vehicles and road infrastructure) can reduce traffic bottlenecks and divert traffic from inner city areas. In this way, it helps to alleviate congestion and attendant air pollution, additional GHG emissions, and time losses. Speed limits can also be used, as high speeds lead to higher fuel combustion and, hence, amplified CO_2 emissions. Important options, which encourage modal shifts and rationalise transport flows, also include road pricing and car parking policies; congestion pricing tolls; park-and-ride facilities; ridesharing and car clubs; and travel planning. The promotion of remote forms of doing business and acquiring services (such as IT-based) in order to alleviate dependencies on traffic loads is also an important strategy.

Transport needs to undergo considerable change to accommodate the increasing number of city-dwellers and reduce reliance on private vehicles. There is an interesting trend, for example, of adopting aerial ropeways for urban transport. Many cities have such urban endeavours underway, including metro cables in Medellin and Caracas, Algeria's aerial ropeway serving the cities of Skikda and Tlecern, which is linked to their transit systems, and the new gondola system in Koblenz (UN-Habitat 2010). These aerial ropeways use less material and energy and are non-polluting. They have a small Ecological Footprint and are among the world's safest and most sustainable modes of transport. A relatively recent initiative by Google is to develop technology for self-driving vehicles (automated cars) that rely on video cameras, radar sensors, and lasers along with roadmaps to navigate through traffic. This could stimulate improved navigation, such as the shortest possible route taken in a single road trip as well as reduce road accidents.

Hydrogen is suggested as a sustainable transport fuel. For instance, Hart (2003) discusses a shift from transport energy derived from the burning of fossil fuels to hydrogen that is produced from renewable resources. According to him, this would reduce GHG emissions to zero and improve air quality, and even diminish noise pollution associated with the internal combustion engine. However, hydrogen energy infrastructure—the hydrogen road—implemented in Norway between Oslo and Stavanger, was affected by problems stemming from user technology, whereby sociotechnical networks failed usually due to technological immaturity (Kårstein 2010).

A need for a sociotechnical understanding of domestic consumption behaviour (particularly of the systems, standards, and norms that shape consumption) has been reinforced by others like Moloney et al. (2010), who analysed local carbon neutral community programmes in Australia. There is a business model for increasing the presence of electric vehicles (EVs) in private transport through an Electric Recharge Grid Operator that comes in advance of EVs in an intelligent rechargeable network that is based on renewable energy (Andersen et al. 2009). Some countries have already introduced this model, including Israel, Denmark, Australia, and the USA; it is in-line with a long-term goal for the automotive industry of zero emissions and a nil reliance on hydrocarbons for fuel (Sveum et al. 2007).

New technologies, however, are not a panacea. Satterthwaite (2011) argues that high standards of living can be achieved in cities with low GHG emissions through reduced resource use and waste, including lower material standards for the wealthy. In other words, adopting new (more energy-efficient) technologies is a consumerist approach to the problem, which could also be remedied by an alternative approach of reduced consumption. This would call for behavioural change, which could be reached at a lower cost. Such a non-consumerist approach could be useful, particularly for developing nations that cannot afford new technology and infrastructure. From the viewpoint of transport, changing people's travel habits from being convenience-oriented to low carbon-oriented could improve energy conservation based on behavioural change (Zhao & Chu 2009). Behavioural change can be established through policy, as through the provision of sustainable transport in order to reduce dependence on petroleum (Chapman 2007).

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