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Energy Strategies, the Urban Dimension, and Spatial Planning

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Abstract: The UN Paris Agreement of November 2016 recognises the need for a 'cleaner and more efficient energy system' as a core policy goal to address climate change. The spatial and urban form of cities is a key factor in achieving more efficient energy production and consumption and becomes more important with rapid urbanisation across much of the world. City urban form and planning are therefore potentially powerful levers for the energy transition. This paper examines the extent to which city 'energy strategies' address the critical spatial and urban form characteristics of cities as a means to achieve a more efficient energy system. We construct an assessment framework of key aspects of the spatial and urban development of cities related to transport and accessibility and urban form. The framework is used to assess the degree to which energy strategies take into consideration aspects of urban development in four cities that are taking significant action on the energy policy: Hong Kong Oakland, Oslo, and Vancouver. We conclude that in these cities there is only fragmentary consideration of the potential of shaping spatial and urban form in the interests of energy efficiency.

Keywords: energy transition; spatial planning; urban form; energy strategy; city governance

1. Introduction

The effect of increased greenhouse gas emissions and particularly CO_2 on global warming and climate change is well understood [1]. The 2016 the Paris Agreement, building on the 1994 UN Framework Convention on Climate Change, committed signatories to keep global temperature rise below 2 degrees Celsius above pre-industrial levels by making nationally determined contributions to reduce emissions, and to adopt adaptation policies that respond to the risks associated with climate change. Despite progress, especially on the production of energy through renewable sources, the concentration of greenhouse gases in the atmosphere continues to grow [2].

Globally, energy use is the most important contributor to greenhouse gas (GHG) emissions. Around two-thirds of GHG emissions arise from energy production and consumption which makes it a central issue in climate change mitigation [3]. The world demand for energy will increase by an estimated 1.3% each year to 2040, whilst energy efficiency declines and emissions increase [4]. In Africa, a huge growth in demand for energy is anticipated up to 2040, outstripping the growth in demand in China from 2000. Among the drivers for increasing demand for energy, the role of urbanisation, and especially the growth of large cities, stand out.

The objective of this exploratory paper is to make an initial assessment of the contribution of city energy strategies to climate action, especially in the way they deal with the pattern and process of urbanisation. City level energy strategies are becoming more common in the late 2010s. We select four cities in developed countries for examination, all of which have made good progress on developing policy for climate action through an 'energy strategy': Hong Kong, Oakland, Oslo, and Vancouver.

Cities play a dominant role in energy consumption. In 2014 the Intergovernmental Panel on Climate Change estimated that although cities only house about half the world's population, they 'account for between 71% and 76% of CO_2 emissions from global final energy use and between 67–76% of global energy use', and that 'the growth of transport infrastructure and ensuing urban forms will play important roles in affecting long-run emissions trajectories' [5]. It also pointed to opportunities for GHG emission reduction in rapidly urbanising areas because new, less energy-intensive urban forms could be adopted, but also noted the challenge of doing this where there is weak governance and limited capacity.

Figures for energy consumption in urban areas are inevitably broad estimates only. What counts as urban or a city is debatable. For the purpose of this study we consider the city as the administrative tier of the local government with the principal competence for policy related to the energy transition. City governments are key actors in relation to climate change and GHG emissions through their policy making. The administrative area of such governments varies from the functional city region depending on the country's government structure. We accept that aspects of energy consumption in the jurisdiction are affected by factors outside it, including suburban development and infrastructure and service provision in neighbouring jurisdictions, but this study can only address the policy making of the main city government.

City governments are working cooperatively in global networks such as the Global Covenant of Mayors for Climate and Energy, ICLEI – Local Governments for Sustainability, and the C40 Cities network, to develop strategies and policies on mitigation and adaptation in response to climate change. The United Nations Environment Programme's (UNEP) Climate Neutral Network of Cities has charged all cities to produce climate action plans by the end of 2020 to help deliver the objectives of the Paris Agreement. Many cities have or are preparing such strategies that include a 'city energy strategy' (although it is not always given this name). Even at this early stage in formulating city-scale energy strategies, reflection on the degree to which the four cities here have considered urban development in their thinking and practice on energy, will provide direction for future research and a spur to action in other cities.

2. Energy, Urbanisation, and Spatial Planning

2.1. Urbanisation's Impact on Energy Demand

This section explores the relationship between urbanisation and energy use, introduces the idea of the 'urban dimension', and argues that this should be given more attention in climate action strategies and energy policy. The effects of the form and transformation of urban development on energy use are varied and complex [6]. However, urbanisation, and especially the growth of megacities, is generally associated with increased energy consumption. Growing personal prosperity and expenditure, industrial production and travel, and the building and maintenance of urban infrastructure inevitably lead to sharp increases in energy demand. Partly because of the rapid speed of urbanisation, much of the demand generated by the growth of cities has had to be met by increased use of fossil fuels, with consequences for emissions and climate change [7]. With 66% of the global population predicted to be living in urban areas by 2050 [8] and energy related emissions set to increase by almost a quarter by 2040 [9], the importance of future energy use in urban areas cannot be emphasized enough.

Whilst the aggregate demand for energy from cities is set to grow further, the amount and characteristics of that demand vary from place to place, and are strongly influenced by the physical nature of the city and wider urban and regional development. Numerous studies have shown that many facets of cities and urbanisation have a significant impact on energy use [10–12] and need to be accounted for while devising strategies and policies to improve energy efficiency [13]. Furthermore, there can be a strong relation between the character of energy systems and the physical shape of urban areas. Indeed, it is 'energy' and related technologies that have largely determined the spatial form of cities in much of the world where urban development has evolved around automobile dependency and the consumption of oil [14,15]. Many urban planning strategies have taken the link between sustainability and the spatial configuration, density, mobility, and accessibility of the city as a central theme, notably through proposals for transit-oriented development [16].

Urbanisation proceeds in many different ways in terms of the characteristics of physical urban form or morphology, the design of buildings and infrastructure, and the mix and location of economic and social activities. 'Urban form' means the city's physical and spatial characteristics. These include the layout of streets and blocks, the design of buildings and neighbourhoods, the spatial structure of urban areas, and the wider patterns of regional settlements [17]. Variation in these aspects of urban form has a direct relation with the energy sector. For example, increases in the contribution of renewables in the energy mix results in changing demands in terms of the amount and location of space. The infrastructure for solar and wind energy generation generally takes up more space than fossil fuel energy generation [11]. Additionally, it is not always feasible or desirable to generate power at a centralised point, in which case decentralised distribution of generation is preferred, with consequences for the way that neighbourhoods are planned and organized. The physical form of cities may facilitate or hinder the changes needed for the energy transition, which in some places will have to be redesigned to accommodate the transition. That redesign will involve many stakeholders and inevitable competition or even conflict over the form it takes. It is the planning and urban design institutions of cities and regions that seek to resolve the competing demands for space.

The relationship between urban form and energy use is clear, but the precise connections are uncertain and depend on local conditions. For example, rising population density in a 'compact city' form with a high provision of public transport may result in less per capita energy use compared to dispersed urban development that relies more on personal transport [18]. At the same time, the incorporation of formerly rural and dispersed communities in more dense urban systems may see not only a rise in total energy demand, but also the demand per unit of economic production may increase. That is, the efficiency of urban areas in energy consumption cannot be taken for granted. Despite the strong interconnections, much of the policy debate on energy and climate change overlooks their critical relationship with the built environment. Thus, Rutherford and Coutard [7] (p. 1357) argue that:

> *' . . . while cities are sites of tremendous levels of energy consumption, and therefore (would appear to) have a direct influence on the nature and form of energy systems as a whole, the actors responsible for these systems tend to neglect the urban dimension, seeing cities strictly as the end points of a supply chain to which one merely has to deliver the flows.'*

2.2. The Role of Spatial Planning and Energy Strategies

The 'urban dimension'—the characteristics of spatial layout, urban form, and distribution of functions—is primarily the province of local government and planning authorities. Spatial or urban planning is the main tool that governments use to influence urban form and spatial development. In many countries spatial plans are taking up the energy question, setting the policy tone and challenging current norms in urban development that do not facilitate more energy efficiency. They propose alternative ways of shaping cities and processes that facilitate and require investors, developers, urban designers, and architects to produce innovative energy efficient urban development.

Aside from the urban development and planning sector, city policy makers pursue their commitment to decrease GHG emissions through the formulation of corporate 'city energy strategies' that set out policies for the production, distribution and consumption of energy. These arise in the context of commitments made by international city networks, and are the principal policy statements on how the city will make progress towards an energy transition [19]. City energy strategies tend to address GHG emissions as a core objective, recognizing that two-thirds of GHG emissions arise from energy production [3].

The 'energy policy domain' therefore, tends to be well connected to some economic and policy sectors such as energy production and renewables, transport, and waste. It is much less well integrated with other policy domains that may have a critical impact on energy efficiency such as the spatial layout of urban areas and urban form. Similarly, other policy domains such as economic development and information and communications technology are not always well integrated with the energy domain.

This weakens the city's response to climate change, because sectoral policy integration is needed to ensure that initiatives in each sector of activity are coordinated with others and, in particular, because it is spatial planning that has a leading role in integrating sectoral policy impacts on particular places and ensuring more sustainable development of the territory [20–23].

A comparative study of spatial planning systems in 32 European countries [24] found a mixed picture of interaction between energy policy and spatial planning policy. Only about a quarter of the countries were found to have integration between the two fields at the local government level, meaning that their policies were targeted at the same goals with joint decisions and actions. About a third were found to have cooperation between energy and spatial planning policy, meaning that there might be some adjustment of policy in each field, but they remained distinctive and separate. The other countries have little connection between the two fields, even though governance capacity is relatively strong. The weak connection between energy policy and urban form and development in many countries is concerning, especially because the policy goals for energy efficiency, environmental sustainability and climate change rely critically on combined and integrated actions [25]. The energy sector and the urban and regional planning sector are interdependent, but in many places, they are not working in concert, reducing the efficiency and effectiveness of interventions.

2.3. The Potential of the Urban Dimension for the Energy Transition

If and when city energy strategies address spatial planning and urban form, they must be well informed about the appropriate measures to take. How does the organisation of space and urban form in cities contribute to the efficiency of energy systems and how can it assist with the energy transition? There is a good deal of agreement on the key measures as we explain below, but there is still some uncertainty, not least because very different social, economic, and cultural conditions (the dominant social model) give rise to different urban forms and traditions of planning and managing the built environment [26]. Furthermore, the effects of planning and design of the built environment will generally be felt in the medium to long-term. Significant building and infrastructure projects will typically take between four to ten years from inception to completion, but the overall impact on the wider city and region will be measured in decades.

The body of research work on the impacts of measures in the urban dimension is large, but most individual studies deal with a particular contribution. For example, De Pascali and Bagaini [27] explain specific legal provisions connecting urban spatial planning and energy policy through, notably, the urban energy plan in Italy; Banister and Hickmn [28] consider the impact of transport on other sectors; contributions to Cullingworth [29] deal with a number of rather particular aspects of the urban environment. This reflects the nature of the literature where most studies are concerned with the performance of a single aspect of the urban dimension in relation to energy, for example, evaluating the performance of 'greening' buildings, or the effect of street design on energy use. Some studies are more encompassing, assembling and reviewing evidence from other sources available at the time [30]. The small number of studies that have taken a wider perspective of energy and the development and planning of cities reflects the sectoral nature of both government policy and academic enquiry. Despite this catalogue of work, significant uncertainties remain, which leads Cheshire to conclude that 'urban sustainability policies are being implemented on the basis of an insufficiently robust research base about energy use and planning' [31] (p. 1237).

The uncertainty gives rise to two questions. First, what are the measures in the planning and design of the urban dimension that are critical in the energy transition? Second, to what extent do corporate city energy strategies address the spatial and urban dimension, and specifically, the measures that will influence energy efficiency in the longer term? We are interested in individual approaches but also in identifying any common themes and significant variations in practice.

The next section of the paper explains how we created a novel and systematic framework of measures of the urban dimension for energy efficiency, and how we used that to assess practice in four cities.

3. Method

This is an exploratory paper. The logic of the research design is to first identify the main categorisation of potential measures in the planning, design, and construction of cities (the urban dimension) that are critical for the energy transition. The measures are the policies and actions that can be taken in spatial planning and urban design that impact on energy production and consumption and will thus affect GHG emissions and climate change. This categorisation is used to assess practice in the making of energy strategies in four cities, that is, the extent to which they address aspects of the spectrum of measures.

To build the assessment framework, we used an integrative literature review to refine and organise understanding and build a taxonomy of the 'urban dimension' to the energy transition (Synder 2019). The approach to the literature review was critical, broadly aiming to identify where there was agreement in the literature about the elements of urban structure and development that offer potential for the energy transition; aspects of the relationship between cities and energy use that are contested or controversial; and areas where there is uncertainty. In the event our review showed considerable agreement among authors although with varying emphases as explained in the following text. The review was not exhaustive. We concentrated on key texts which took a broad view of the impact of the design, planning, and the construction of cities on the use of energy and therefore GHG emissions. The selected texts provide reviews of wider literature and more specific studies, and the value of adding extra sources quickly diminished as there was considerable agreement amongst the selected texts. This approach to the design of a framework by literature review is an accepted method [32]. The reasons for the choice and organisation of categories is explained. The application and interpretation of the findings was logical and documented. It employed a simple and clear framework in a small number of cases which limited interpretation by the researchers. As only four city strategies were selected for assessment there was no benefit in applying a formal content analysis method or computer aided textual analysis.

The literature review resulted in three main categories of measure as discussed below. The emphasis was to identify universal principles using generic terminology rather than place-specific initiatives. These components can be considered as the agreed upon and common norms that underpin in different combinations, the urban dimension of energy strategies in cities. They are general, but the 'specific' policies and interventions will depend very much on local conditions.

The second part of the research was to apply the framework to a small number of city energy strategies to assess whether they are indeed addressing the full range of measures that could help to deliver the energy transition. The city strategies were selected from the C40 network of world cities. The C40 network was created to enable city administrations to collaborate and exchange experience in action on climate change. There are 96 affiliated cities (June 2020) that are claimed to have ambitious objectives for climate action planning. The network has a Climate Action Resource Centre that provides guidance on formulating plans that help to deliver the Paris Agreement specifically through 'climate action plans', a key component of which is 'a pathway to an emissions neutral city [. . .] [and] net zero emissions from fuel use in buildings transport and industry' [33]. Only a proportion of the cities in the network have made substantial progress on their climate action planning. A first review of the cities produced a list of 10 potential cities and regions for further study which had adopted and energy strategy, sometimes as part of a wider climate strategy. (The list of cities is Bergen, Boras, Brisbane, Bristol, Christchurch Costa Rica, Hong Kong, Oakland, Oslo and Vancouver.) Cities in the Global South had been discounted because of the special circumstances that apply in developing regions. Practical considerations of time and resources limited the study to four cases, and we selected cases that offered the potential for learning because the 'energy strategy' was complete, and to reflect different geographies of the Global North. The selected cases are Hong Kong, Oakland, Oslo, and Vancouver. These are all cities that have taken considerable steps towards addressing environmental sustainability, energy efficiency, and a contribution to GHG emission reduction. Other cities with a similar reputation that were considered may be taken forward in a subsequent study.

Each city energy strategy was tested against the assessment framework in terms of the inclusion or absence of measures. The assessment framework of components was used as a guide in reading the documents, no formal content analysis was needed for this small sample. There was little difficulty in identifying the various measures in the city strategies although each city used its own terminology. It should be noted that the analysis for the four cases is based on the available published material on the energy strategies. We are assessing the formal policy statements of the city governments and recognise that there may be other activities underway that are not recorded or revealed by the formal statements.

We noted the particular aspects of the measure which were identified as significant for each strategy. We refined the review by identifying the overlapping common themes and junctures among the studies particularly to judge where there was agreement among the cities. The findings corroborated and helped to refine the categorisation of spatial planning measures. There is an element of comparison in the research in that there may be lessons for others in terms of benchmarking. However, this is not a full comparative study which would require more attention to understanding the local conditions which underlie alternative policy choices. We recognise that in many ways these cities are not 'comparable'.

Overall, this exploratory qualitative study seeks to encourage and provide a first step towards further research on the urban dimension and energy transition. It is also intended, like other qualitative research on public policy, to spur action in policy making communities so as to investigate and understand the potential to address the urban dimension in those places [34]. The findings from this study are not generalizable, but they are transferable to other settings where energy policies are being written, now and in the future, and can inform decisions taken there.

This is a simple method, but the overall study makes a timely contribution to knowledge about policies on climate action in cities. First, there have been many contributions that might constitute an inventory of potential measures on climate action, both theoretical and practical, but no widely accepted comprehensive and organized assessment framework that concentrates on the 'urban dimension'. Indeed, this is an overlooked aspect to energy policy planning for cities. Second, the formulation and adoption of city energy strategies or climate action strategies is only emerging in the 2010s. Few cities have experience of this kind of work previously and it is important that we gauge the policies and actions of cities at an early stage with a view to much more of this policy making in the future. The paper also provides encouragement for deeper research into the urban dimension of city energy strategies.

4. Review of Literature on Urban Dimension Measures for the Energy Transition

4.1. Studies on the Urban Dimension of the Energy Transition

Though a large body of literature addressing the general contribution of the 'urban dimension' related energy policy does not exist, specific aspects of energy efficiency and urban development are addressed in many studies that investigate the sustainable development of cities. From the literature, seven studies stand out as providing a broader overview of the components of spatial and urban development that are important for the energy transition and climate change. Only a brief review of each can be given here.

The seminal work by Owens [30,35] provides a starting point, as it has for many subsequent studies exploring the link between energy, urban form, and city planning. Recognising the link between energy systems and city and regional patterns over many years, Owens calls for more attention to urban form and planning policies in fostering an energy transition. Owens emphasises that there can be no one 'good urban form' for energy efficiency because of the importance of local conditions and because there may be more than one good solution, especially since the precise effect of certain built environment interventions and policies on energy is difficult to measure. Owens makes a theoretical distinction between two types of intervention in the built environment for the energy transition. First, there are measures that reduce intrinsic energy needs and demand. In urban design this means for example, the design of buildings in ways that use less energy, the orientation of building so that they benefit from solar gain, and at the city-region scale, measures that reduce the need to travel. Second, there are measures which enable the provision of energy more efficiently from the point of view of GHG emissions, such as incorporating district heating in urban design, or requirements for renewable resources such as solar to be used or retrofitted into urban development. We come back to this distinction later as it anticipates alternative general directions for city energy strategies in the 2020s.

There are five other key studies that we have used to identify categories of measures that are summarised in Figure 1. Barton [35] illustrates the broad influence of spatial planning on energy use and resulting carbon emissions. He puts forward three policy areas to address energy use: transport policy, policies for urban form and location, and development layout and design.

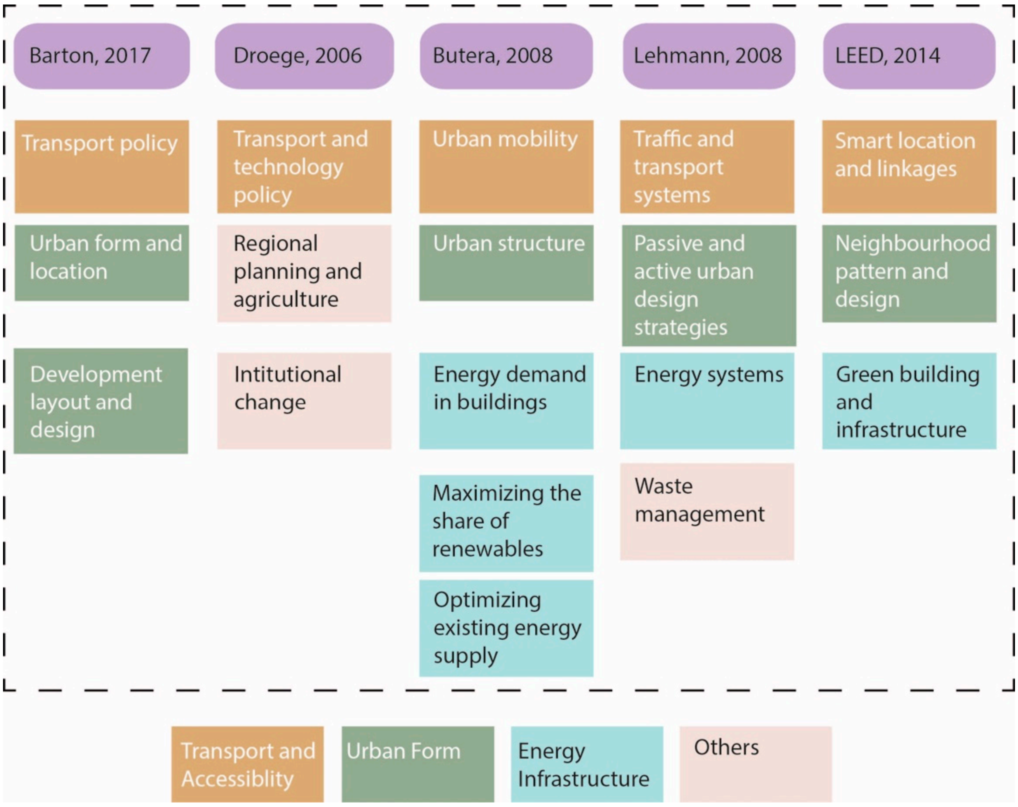

Figure 1. Urban components of the energy transition.

Droege's [36] work highlights the relationship between energy use and the urban structure of cities. He argues that energy use has resulted in the urban structure in cities today and introduces the idea of 'The Renewable City' as a solution to address climate change and peak oil. He suggests spatial planning measures to promote the energy transition in three categories: transport policy and technology, regional planning and agriculture, and institutional change.

Butera (2008) argues that the design of a 'low energy city' needs to be aimed at increasing energy efficiency of the urban structure, minimizing energy demand in buildings, maximizing the share of renewables, optimizing existing energy supply and rethinking urban mobility. The study makes the interconnectivity between these measures evident and discusses them in relation to each other. For example, urban layout, meaning the shape, orientation, and distances between buildings, will have an impact on the heat island effect. Both of these are considered essential while optimizing the energy efficiency of the urban structure. Similarly, the author argues for mixed-use development to bring places of living, work, and leisure closer to each other to reduce the need for travel.

Lehmann [37] argues that most of the discussion today about energy efficiency is driven by the use of sophisticated technology rather than addressing cross-cutting issues in architecture and urban design. He advocates 'green-urbanism' which states that energy efficiency in cities can and should be addressed in the early conceptual stages of planning when local climatic conditions are considered before technological solutions for energy efficiency, and when the potential for on-site renewable energy production can be assessed. Although he argues for a cohesive integration of climate responsive urban planning and design, he suggests that measures for a cohesive integration of climate responsive design or 'green-urbanism' should consider passive and active urban design strategies, energy systems, waste management, and traffic and transport systems.

The Leadership in Energy Efficiency Design (LEED) Reference Guide [10] for neighbourhood development addresses sustainable development, and consequently efficient energy use, in three main categories: smart location and linkages, neighbourhood pattern and design, and green building and infrastructure.

Of this long list of measures, there are three that are widely shared in the six studies: transport and accessibility, urban form and design, and energy infrastructure. We can conclude that these types of measure in spatial planning and design of the urban dimension are particularly significant for achieving the energy transition and we consider them in more detail below.

4.2. Transport and Accessibility

Transport contributes about 24% of global CO_2 emissions [10] and emissions are expected to double by 2050 [38], although there are efforts to substantially increase 'low emission mobility, for example, in the EU [39]. Whilst energy consumption in the transport sector continues to rise, the potential role of spatial planning in contributing to reducing transport energy consumption is largely underplayed [40]. Most studies agree that improved infrastructure and public transport options, fuel efficient transport solutions and behavioural change towards active travel, and are needed to decrease energy use from transport and mitigate its associated emissions [28].

The notion that integrating land use and transport planning as a forerunner to achieving a more efficient urban form is gaining widespread acceptance [40]. The relationship between land use and transport with respect to the energy transition includes the beneficial effects of more compact and dense urban form on transport demand, the 'walkability of the urban environment', and 'efficient' land use patterns involving a mix of accessible services and functions. These factors provide the conditions for reducing energy demand, although other factors are also important, not least changes in human behaviour [41,42]. For example, if communities are organized in a more compact manner, walkability increases as distances between facilities may be made shorter and it is easier to get around. Residents in 'walkable' neighbourhoods can drive up to almost 40% fewer kilometres than their counterparts in less walkable neighbourhoods. A study in Graz found that if a third of trips were made by bicycles instead of cars there would be a 25% less consumption in petroleum use for cars, a 37% reduction in hydrocarbon air pollutants and 30% reduction in traffic congestion [43]. There is considerable attention in the literature on energy in cities to 'active travel'. We understand active travel here as primarily walking and cycling which reduces the use of cars for relatively short journeys. For active travel, the interrelation of urban form, transport and accessibility is very strong. Considerable variation in the extent of active travel in societies is shaped by culture and norms, but there is no doubt that spatial planning makes a significant contribution. In the UK, for example, despite policy and rhetoric to the contrary, planning decisions have tended to undermine active travel [44].

4.3. Urban Form

Urban form refers to the organization of buildings and areas in a city and encompasses multiple scales and their interaction over time. The design and layout of a city has a critical impact on energy efficiency. For example, a compact arrangement of buildings can reduce the amount of heating and cooling needed by a neighbourhood and the individual buildings [45], and district energy centres can help increase the efficiency of cooling or heating within urban areas [46]. Neighbourhood design strategies combined with infrastructural upgrades can reduce energy and heating demands.

This is a very broad field of policy and action. Three studies help to define the most significant components of urban form for energy. Barton [17] puts forward five: greenspace, movement, jobs and services, housing, and density. Jabareen [47] identified seven areas related to sustainable urban form which are compactness, sustainable transport, density, mixed land use, diversity, passive solar design, and greening. Dempsey et al. [41] categorize the five interrelated elements of urban form as density, transport infrastructure, housing and building typology, layout, and land use. There is general agreement that among many factors in the design and construction of the urban environment, five have the greatest impact: the density of land and property use, the mix of function, the relationship between urban form and transport infrastructure, the availability of green space, and passive energy-efficient design.

4.4. Energy Infrastructure

Despite what was said above about the close interrelation of transport and accessibility, urban form and energy infrastructure, they are often treated as separate layers of energy policy. This is particularly so for energy related infrastructure which was seen in this way in almost all studies, though some do explicitly recognise the interrelationships [41]. This separation impacts the way energy related infrastructure is viewed and consequently dealt with while improving energy efficiency. Some examples of improvements in energy related infrastructure (referred to as energy infrastructure here onward) are upgrading heating and cooling systems or lighting systems in buildings; upgrading distribution networks with smart grids or neighbourhood energy centres; managing waste infrastructure to include reuse or recycling; promoting electrification or hydrogen as an alternative fuel for mobility; and integrating renewable energy production with rooftop solar panels or concentrated solar power (CSP) plants.

While these measures offer considerable reductions in energy consumption and facilitate switching to more sustainable fuel sources, they do not promote a transformation of the urban environment towards a long-term energy transition. These solutions do not challenge current norms that promote energy inefficient development patterns. For example, switching to electric cars does not change the need to own a car and use it for a daily commute. Energy infrastructure is an integral part of how transport, land use and buildings are organised.

To be able to address this disconnection, it is important to understand how it is brought on. The goals and actions in energy policies are often informed by engineered solutions dependent on the results from energy modelling tools that define targets and provide technology-based solutions to achieve them. For example, reducing GHG emissions, reducing energy demand, or increasing renewable energy production by a certain percentage can be achieved by installing n% more solar panels on rooftops, improving insulation on certain walls in buildings or connecting 'n' more buildings to the district energy network. However, modelling tools often lack precision because of data availability or assumptions in the modelling tool. Moreover, they are not capable of integrating multiple factors such as urban micro-climate, density, or mobility.

Keirstead et al. [48] conducted a review of 219 papers related to urban energy modelling in six categories—technology design, building design, urban climate, system design, policy assessment, and transport. A common challenge faced by all is the availability and relevance of data. Among the 219 studies, 68% found it difficult to acquire data. Other difficulties were encountered, the models need further development to more accurately represent the relations between transport, land use and energy use, and the models are able to deal with buildings but not the spaces between them, which makes up much of the city.

While urban energy studies recognize the importance of space in influencing the supply and use of energy, they emphasise changing energy infrastructure rather than examining urban development patterns that can support the shift to fewer carbon-based fuels. Infrastructure upgrades and improvements should complement the changes to urban development patterns rather than being treated as a stand-alone solution to address energy infrastructure. The interrelations of transport, accessibility, urban form, and energy infrastructure is generally a weakness in planning for the energy transition.

4.5. Other Measures

There are five other sets of measures that figure in one or more of the studies, but which are not considered in detail here. Regional planning considers a wider scale which can be especially important in relation to settlement patterns and reducing the need to travel. Landscape (including urban landscape) is raised because it considers spaces between and around buildings which can impact internal and external thermal comfort. It is also important in relation to the siting of energy and waste infrastructure. Institutional change refers to the governance of urban development, including laws and policies, the government bodies that are responsible for them, but also the informal rules and norms that govern people's behaviour and which can be especially important in the consumption of energy. The institutional dimension is particularly important where countries or regions have weak governance or are undergoing rapid change. Development layout is a sub-set of urban form and relates the extensive discussion in planning and urban design about alternative neighbourhood layouts and how they influence personal behaviour—they may, for example, encourage or inhibit use of motor cars for local journeys [49]. Finally, agriculture is a significant consumer of energy and is becoming more important in production through biofuels. Traditionally, this has not been within the competence of spatial or urban planning, but it has been drawn in because of the consequences of increasing biofuel production which offers opportunities for more circular local energy and waste systems, but also potential costs, for example, in relation to traffic movements and impacts on protected landscapes which require more integrated planning [50].

4.6. Limitations of the Study

The measures presented in Figure 1 and Table 1 should not be seen as a simple checklist. Rather, they are a starting point for assessment of the scope and thoroughness of strategies. As mentioned above, how they are interpreted will depend on other factors. Take first, for example, climate as one aspect of 'local conditions'. Being mindful of local climate while designing urban form is critical for the local microclimate and the avoidance of heat gain/loss within the building and its immediate surroundings. It may seem obvious, but for a city like Dubai, with a hot and arid climate, energy use is almost double during the summer months compared to the rest of the year. In practice it seems it is not obvious, because technology has allowed planners and designers to ignore this factor, and energy use is extremely and unnecessarily high. Lessons that are well known need to be relearned. For example, Shishegar [51] found that street orientation influences air movement within urban areas thereby impacting thermal gain/loss. A study on the data in sustainable urban planning projects by Lehmann [37] shows that savings in energy cost of 20–50% are possible through integrated planning that carefully considers site orientation and passive design strategies. This saving can be further increased with on-site renewable energy production. Kleerekoper et al., 2012, found that the use of vegetation and water in the spaces between buildings can help to mitigate heat in urban areas by about 1 to 4.7 °C and 1 to 3 °C, respectively. For a city like Dubai, prioritising local climatic conditions in urban and building design would result in more compact neighbourhoods with narrower streets and buildings with courtyards and less glass on their outer facades. This is seen in the historic areas of the city that reflect local climate and culture. This is just one example of how local conditions will determine the relevance of particular measures and how they are implemented within particular cities [52]. Energy strategies should assist professionals to give more priority to energy efficient ways of dealing with local conditions through planning and design interventions that are defined locally.

Second, the categories and measures are not mutually exclusive. They interact and overlap. Thus, this is not an ideal categorisation, but the reality of urban development is that transport and accessibility, urban form and energy infrastructure are interconnected and mutually dependent. For an initiative to make a difference in one field requires it to be complemented by changes in another. Transit oriented development (TOD) is a case in point. It is dealing with transport and accessibility improvements. It is unlikely to be successful without accompanying urban form interventions, not least in the density of associated development. It also has potential in relation to energy infrastructure, and connections to other measures. Newman [53] supports the idea that TOD development should be 'pedestrian oriented development' and 'green oriented development'; it should be designed to encourage pedestrian activity and promote energy efficiency as well as transit movements. The interdependence of measures is true for them all—and that is the nature of a 'strategy', as it connects and coordinates otherwise separate streams of sectoral policy [54].

Finally, the interconnectedness and interaction of these measures with each other as well as with other disciplines needs to be balanced. The impact of policies that promote renewable energy related technology such as installing solar panels or wind turbines at the neighbourhood or district level have come to light in the past few years. For example, in The Netherlands the promotion of on-site renewable energy production is beginning to impact energy grid providers as the capacity of the grid has been pushed to the limit since there are multiple production points that are difficult to regulate. This poses a new problem for policymakers, urban planners, and engineers.

Table 1. Measures in the urban dimension for the energy transition.

	Spatial planning measure	Impact on energy use	Recommendation for energy strategy/urban development plan
	Transport and Accessibility:		
1	Promote active travel: reducing the number of trips made by mechanical means of transport by encouraging residents to change their travel choices.	Increasing walkability at the neighbourhood scale can result in savings in energy use and its related greenhouse gas emissions.	Invest in infrastructure to support active travel with pedestrianisation, pavements and biking paths.
		[55,56]	
2	Encourage infill development: giving priority to the development of vacant sites within existing urban areas before urbanising open land.	Promoting infill development will result in the need for fewer resources to provide infrastructure such as transport or utilities.	Identify underused sites and give priority to development that increases the efficiency of land use consumption.
		[10,57]	
3	Promote transit-oriented development (TOD): integration of land use and transport planning to concentrate development around transit stops. A TOD area is a mixed-use community that is within walking distance of a transit stop and commercial activities.	More efficient use of land and potentially reduced car-based travel as job opportunities and homes are put in proximity.	Plan future developments within proximity to existing transit stops and increase mixed-use functions around public transit nodes.
		[58]	
4	Transport demand management: a policy tool used to manage an existing transport system to reduce traffic congestion, pollution and energy use.	Increases the use of public transit, reduces the number of trips made by cars, encourages the use of fuel-efficient vehicles and increases fuel efficiency.	Transport demand strategies are a policy tool that should be supported with incentives that are reviewed periodically.
		[59]	
	Urban Form:		
5	Promote compact development: seeking a denser urban form, reducing fragmentation of the urban fabric through intensification.	Reduces the need to travel and associated energy use and emissions, and increases land use efficiency in urban areas.	Promote policies that intensify land use and measures to improve public transport accessibility.
		[57]	
6	Designing with the urban microclimate: design principles that respond to the urban microclimate are necessary to avoid heat gain/loss within the building, its immediate surroundings, and the city as a whole.	Adjustments to built form, street canyon, building design, materials, traffic and vegetation and water, can ultimately decide the amount of energy needed to maintain a comfortable indoor environment.	Mandate considerations for urban and building design codes through regulations.
		[37,51]	

Table 1. *Cont.*

		Energy Infrastructure:	
7	Increase renewable energy supply: require developments to include renewable sources of energy.	Diversifies fuel sources and moves away from carbon-based fuels which have a high GHG emission rate.	Audit sites that have a potential to support renewable energy production, and subject to other constraints, designate in plans.
8	Implement district energy system: involving multi-building heating and cooling, usually by circulating hot water or low-pressure steam through underground piping from one or more central sources to industrial, commercial, or residential uses.	Reduces GHG emissions in two ways; (1) facilitating the use of non-carbon forms for heating and cooling, and (2) replacing less efficient equipment in individual buildings with a more efficient systems.	New neighbourhoods should be planned to incorporate district energy systems.
		[46]	
9	Implement a smart grid system: facilitate a two-way communication between the utility company and the consumer.	Improves network efficiency by balancing demand and supply, reduces energy consumption by increasing awareness amongst consumers, and can integrate different energy sources within the same network.	Promote policies to install smart grids.
		[60]	
10	Retrofit existing building stock: to improve insulation and heating and/or cooling systems to reduce energy loss and increase efficiency.	Retrofitting will modernise the built environment produced when energy efficiency and sustainability was not a priority, with potentially huge savings in demand	Evaluate buildings that can benefit from retrofits to improve energy efficiency and reduce energy loss and provide incentives to install the retrofits.
11	Use rating system or benchmarks to improve energy performance in buildings.	Encourages energy efficiency in new or existing buildings.	Employ ratings in planning permit procedures, and ensure design principles and technological standards are adopted.
		Other measures	
12	Conserve indoor and outdoor water use: reduce consumption and avoid waste through e.g., grey water systems.	Savings in all places but especially where water is scarce and is desalinated in an energy intensive process.	Retrofitting of buildings with upgraded systems, such as adoption of grey water systems, and outdoor landscape use for water treatment.
		[10]	
13	Reduce and recycle waste: to decrease waste's contribution to GHG emissions, through e.g., more circular self-sufficient cities and neighbourhoods.	Waste is the third largest contributor to GHG emissions in cities after transport and buildings, thus can have significant impact on reducing emissions, and the costs of infrastructure needed to support waste such as landfills, CCS or waste-to-energy plants.	Waste-to-energy plants to reduce landfill, supporting policies to encourage waste reduction and transition to circular economy, informing plans and designs for urban development.
		[10]	

5. Assessing Energy Strategies in Four Cities: Hong Kong, Oakland, Oslo, and Vancouver

5.1. The Assessment of the Energy Strategies

The main objective of this paper is to assess how the energy strategies of the four selected cities address the components of the urban dimension and spatial planning for the energy transition. The four cities, Hong Kong, Oakland, Oslo, and Vancouver were selected because of the progress they have made with an explicit energy strategy document. The assessment gives particular attention to policy and action for transport and accessibility, urban form, and energy infrastructure. The assessment identifies the strengths and weaknesses, and to some extent the gaps in each strategy that the cities could address going forward. It also allows for a limited form of comparative analysis in terms of benchmarking of each city against the others. As noted above any comparison should bear in mind the very different conditions that apply in each case.

The documents reviewed for the assessment are:

Vancouver: The Renewable City Strategy 2015-2050 [61]
Oslo: The Climate and Energy Strategy for Oslo [62]
Hong Kong: Hong Kong's Climate Action Plan 2030+ [63]
Oakland: Oakland's Energy and Climate Action Plan [64].

Tables 2 and 3 highlights the findings of the comparative analysis of the four cities. Table 2 summarises the main aims of each strategy to orientate the reader before engaging with the content according to the framework which is summarized in Table 3.

Table 2. Overall aims and approaches of the four strategies.

Vancouver	Hong Kong	Oslo	Oakland
Aim of the strategy			
80% reduction in GHG emissions 2050 (2007 as a base)	20% reduction in GHG emissions by 2020 and 36% by 2030	50% reduction in GHG emissions by 2020 and 95% reduction in GHG emissions by 2030	36% reduction in emissions by 2020
100% transition to renewable sources of energy	50–60% reduction in carbon intensity and 65–70% by 2030		
Approach of the energy strategy—increasing renewable energy supply or reducing energy demand			
Emphasis on increasing renewable energy supply.	Emphasis on reducing energy demand. All new developments are required to produce 1% of total power from renewable sources.	Strong emphasis to shift to an energy system powered entirely by renewables.	Strong emphasis on reducing energy demand through user behaviour. Target to supply 33% of total electricity from renewable energy sources.

Table 3. Comparative analysis of coverage of components of spatial planning.

Transport and Accessibility				
Spatial Planning Measure	*Vancouver*	*Hong Kong*	*Oslo*	*Oakland*
Promoting active travel	Focus on the 'complete streets' program which is an urban design focused initiative to deliver safe streets.	Already has a huge proportion of active travel and there is a focus on maintaining it.	Gives priority to the completion of pedestrian infrastructure.	Gives priority to the completion of pedestrian infrastructure.
Improving/extending public transit system	Specific targets and locations to improve public transit.	Specific targets and locations to improve public transit.	Improving and extension of public transit aligns with TOD planning.	Specific targets and locations to improve public transit.
Encourage infill development	Not explicitly considered.	Not explicitly considered.	Not explicitly considered.	Infill development is encouraged to reduce demand for transport. Sites are given a 'development priority' status by the transport commission.
Promote TOD	Not explicitly considered.	Not explicitly considered.	TOD is recognised and encouraged as a long-term development goal to make residents less dependent on privately owned vehicles.	Long term development strategy for the development of housing, infrastructure and services along existing transit hubs or planned corridors.
Transport form and demand management	Aim: Make the switch to electric cars.	Aim: Improve fuel efficiency.	Aim: Environmentally differentiated tolls and separate lane for efficient vehicles.	Aim: Encourage residents to use more public transport.
Urban form				
Spatial Planning Measure	*Vancouver*	*Hong Kong*	*Oslo*	*Oakland*
Promote compact development	Zoning policies to develop compact communities to encourage active travel.	Not explicitly considered (already a very compact urban system).	Not explicitly considered.	Not explicitly considered.
Designing with the urban microclimate	'Passive House' program which is an urban design initiative to deliver high performing energy efficient buildings.	Passive solar design strategies are a part of BEAM building guidelines which are encouraged.	Not explicitly considered.	Not explicitly considered.

Table 3. *Cont.*

Energy Infrastructure				
Increasing renewable energy supply	Target to produce 100% electricity demand with renewable energy.	Target to produce 3–4% electricity demand with renewable energy. All new developments need to produce 1% of total energy on-site using renewables.	Pilot projects are used to demonstrate the feasibility of technological solutions, such as micro-energy system in neighbourhoods.	Launch of community programmes to increase awareness and interest.
Implement district energy system	Implementation of neighbourhood energy systems is encouraged through a separate set of guidelines.	District cooling is considered for implementation.	District heating and cooling is a feature of the micro energy pilot project.	Not explicitly considered.
Implement a smart grid system	Smart grids are encouraged.	Not explicitly considered.	Smarts grids are a part of the micro energy system pilot project.	Not explicitly considered.
Upgrading existing building stock	Emphasis on retrofitting old building stock.	Emphasis on retrofitting old building stock.	Emphasis on retrofitting old building stock.	Emphasis on retrofitting old building stock.
Building rating systems	Benchmarking and labelling requirements for all new buildings.	BEAM (green building rating system) is widely used in addition to BEEO and B(EE)R, which are developed by Hong Kong.	Not explicitly considered.	All new buildings need to be 10% more efficient than the State's (California's) requirement of building energy performance.
Other measures				
Spatial Planning measure	*Vancouver*	*Hong Kong*	*Oslo*	*Oakland*
Conserve indoor and outdoor water use	Not explicitly considered.	Education efforts for water conservation include: a voluntary water efficiency labelling scheme, installing water-efficiency devices and flow controllers, & an education centre.	Not explicitly considered.	Education programmes on water efficient practices in outdoor landscaping, including the use of drought resistant plants, rainwater harvesting, efficient irrigation practices, etc.
Reduce and recycle waste	Waste to energy plants are considered as a short term/transition action.	Not explicitly considered.	Not explicitly considered.	Encourage waste reduction and reuse, expand recycling and composting by providing comprehensive incentives, encourage construction debris recycling, sustainable consumption patterns, and local food production.

5.2. Overall Aims of the Strategies

Not surprisingly, all four strategies are aligned to the global agreement of reducing GHG emissions. However, there is great variation in the way that they do this. Hong Kong at one extreme takes the line of managing demand through increasing efficiency of use per unit of economic output. Oslo at the other extreme is concerned mostly with creating a more efficient energy supply.

The Hong Kong Climate Action Pan 2030+ refers back to participation in the Paris Agreement, a running theme throughout the strategy. Apart from reducing GHG emissions, the plan sets targets to reduce energy intensity which is defined as the amount of energy it takes produce a dollar's worth of economic activity, and is calculated by dividing energy demand by the GDP. This is a part of its heavy emphasis on reducing energy demand. Most of the electricity supply is currently met by coal powered plants and from the strategy it is evident that this is not likely to change soon as no steps to phase out coal are being taken. Increasing efficiency through alternative sources at the city level is not on the agenda. Instead, all new developments are required to generate 1% of their total energy needs from renewable power. This is an extremely conservative target when compared to steps being taken in other cities. The potential for generating power from alternative sources such as solar, wind, and hydro are being studied but there is no significant action to deploy these technologies in comparison to the measures being taken to manage energy demand.

The theme of the Oslo strategy takes the alternative general approach concentrating on the supply of energy from more sustainable sources. It proposes to work in a multidisciplinary way to implement a 'green shift', which is promising from the point of view of integration of the energy and urban policy. Of the four cities, Oslo's Climate and Energy Strategy has the strongest emphasis on providing energy more efficiently by shifting to an energy system powered entirely by renewables. For example, policy bans fossil-based building heating from 2020; over a longer period, petrol stations are to be replaced with 'clean energy stations' powered by renewables; public transport is intended to be entirely powered by renewables; and all the buildings owned by the city have already made the shift to renewable-based power generation. Oslo's strategy places a heavy focus on transport and accessibility, urban form, and energy infrastructure, so as to get a better balance of demand and supply. It is also very inclusive with more than forty organizations from the City of Oslo, business community and state-owned enterprises participating in developing the strategy.

Oakland's Energy and Climate Action Plan emphasises the risks associated with climate change, organising its response around climate mitigation and adaptation. Local and community action alongside regional and federal collaboration is heavily emphasised as crucial to achieving the goals. This is one aspect of its strong commitment to engagement of communities and on bridging the gap between local and regional actions. Community centred design and action are employed under almost every action, relying on user behaviour to push for long term change. Since most measures aim to reduce energy demand, it appears that there is less attention on increasing renewable energy production. However, Oakland does set a target to supply 33% of total electricity from renewable energy sources which is also propagated through community-based action.

Vancouver's Renewable Energy Strategy 2015–2050 is a continuation of the previous environmental strategy. It seeks to be 'comprehensive' in addressing the three pillars of sustainability—environment, economic, and social, and it makes a strong statement linking sustainable development to energy use. The main goal is phasing out fossil fuels completely and it consequently concentrates mostly on the more efficient production of energy by increasing renewable energy supply, with less attention to reducing energy demand. Vancouver pursues policies to increase renewable energy supply at the building and neighbourhood scale through pushing for neighbourhood scale renewable energy centres, encouraging smart grids, and providing strict building regulations to install solar panels and the efficient use of infrastructure.

5.3. Transport and Accessibility

In relation to more specific categories of measure in the assessment framework, starting with transport and accessibility, all the energy strategies address the promotion of active travel (walking and cycling), improving and extending public transit, and using transport demand management to balance demands in the current transport system. Some of the plans discuss to a limited degree the impact of building more compact urban form to help reduce the demand for transportation.

On proposals for active travel, Vancouver gives most consideration to the urban dimension. It puts forward building and urban design measures in the 'complete streets program' which is an urban design approach to promote safer streets in residential neighbourhoods. It also emphasises community involvement and is strongly linked to the city's urban development plans. Hong Kong is known for its extensive and robust public transport system and already has a high proportion of active travel, mostly walking, which is encouraged by the density of urban development and traffic congestion. The city strategy emphasises the need to maintain and increase this rate largely through improving the quality of urban design and maintenance of the public realm. The feasibility of infrastructure for cyclists is tested in one of the neighbourhood plans.

The two other strategies are much less concerned with the relationship of their proposals on urban development and its planning and design—in the formal documentation. Oslo has a target to increase the total number of trips made by cyclists to 25% by 2025. It plans to achieve this by giving priority to the construction of supporting infrastructure, but the strategy gives no indication of where in the city that might be or how it should be planned and designed. Similarly, Oakland prioritises the completion of infrastructure to support active travel through planning and regulatory actions but says little about who is responsible for drawing up the detailed plan. There is generally little consideration of what these proposals mean for urban form of the city.

Improving and extending the public transit system is an ongoing task in almost every city worldwide, and our case cities are no exception. Vancouver, Oakland, and Hong Kong identify specific targets and locations where they want to extend public transit infrastructure. Hong Kong has an impressive level of ridership on public transit with about 90% of daily commuting using the metro system. The strategy proposes to extend the network by about 25%. In contrast, Vancouver has a public transit ridership of only about 17% which makes a strong point about understanding local conditions and taking care with comparing cities. In this case, there are signs of growth and the strategy aims to improve the frequency, reliability, and capacity across the network. Oakland, which has a similar low use of public transport, has adopted an aggressive policy to ensure that residents are aware and make use of a new metro infrastructure line. It will run a new bus rapid transit line for free for a certain amount of time. Oslo stands out in that it links public transit extension strongly with proposals for urban development. Transit oriented development (TOD) is set as a long-term goal and is used to determine the geographic location and combination of transport lines, stops and the buildings around them.

Transport demand management is used in the strategies of the four cities but in different ways. The dominant policy objective is a switch to electric vehicles by investing in infrastructure to support accessibility to charging. The switching to electric or hybrid cars and public transport powered by cleaner fuels including renewables-sourced electricity, are widely recognized as quick and direct ways to reduce greenhouse gas emissions. In Vancouver, electrification is extended to existing car sharing schemes which are encouraged to take up the new technology. Oslo and Hong Kong go further by supporting this switch through concrete regulatory and fiscal measures. Hong Kong, with its annual rate of growth rate of car traffic of 3%, provides tax reductions on the registration of new cars that are electric and have zero emissions, so as to incentivize drivers to buy cars that are more fuel efficient and cleaner.

Recognising the potential of electric vehicles is to be welcomed, but across all four strategies the link to the urban dimension is missing, indeed the impact of switching to electric vehicles for the built environment is not discussed. This is a worrying omission. In the urban development and planning sector the advent of electric vehicles (and subsequently) automated vehicles are very important topics. The relationship with the built environment is considerable. Neither are likely to produce a decline in the use of personal transport, but possibly the opposite. Electric vehicles will make demands for dedicated charging facilities and the impact of automated vehicles could be huge. Looking at this another way, planning authorities who are seeking an improvement to the 'liveability' of their cities will want to use the promotion of electric and automated vehicles as a positive tool to refit the urban environment. The energy and urban development sectors do need to collaborate on this.

There are numerous other initiatives designed to manage demand. Oslo introduces low/zero-emissions zones, environmentally differentiated tolls and traffic lanes reserved for 'environmentally friendly transport'. Oakland adopts complementary measures to encourage and enable telecommuting, flexible work schedules, car sharing programmes and better bicycle access. Hong Kong also encourages car owners and bus drivers to adopt 'eco-driving' skills which improve fuel efficiency, such as driving at constant speeds, and ensuring proper maintenance of the vehicle.

A very prominent area for consideration in the spatial and urban planning literature is the overall organisation of the urban fabric to use land more efficiently. Surprisingly, this is not a topic for the energy strategies that only partially pay attention to the advantages of building more compactly. Where they do address this measure, it is generally indirectly. In Oslo we have seen that TOD is used as a guideline for developing new public transit infrastructure—and compact development around transit stops is part of this approach. In Oakland, infill development is encouraged by building in 'development priority' areas to reduce the demand on transport. Vancouver promotes zoning policies to develop compact communities that encourage active travel.

5.4. Urban Form

In relation to urban form, none of the strategies discuss the potential of designing a compact urban form with principles that respond to the local microclimate, although it is sometimes discussed indirectly. Thus, designing with the local microclimate is not emphasized in any of the energy strategies but is sometimes a part of other tools advocated. For example, passive solar design is emphasised in the 'passive house' certification programme in Vancouver. Solar design strategies are a part of BEAM, which is the green building rating system widely used in Hong Kong. Vancouver encourages creating more compact communities through their zoning policies to encourage for pedestrians and cyclists to reduce transport-based energy.

5.5. Energy Infrastructure

In relation to energy infrastructure, all the energy strategies promote to some extent increased renewable energy supply (though see the discussion about the overall approach above) and retrofitting existing building stock. Some of them employ building rating systems as a tool to improve the environmental performance of building, and they mention the potential of installing district energy systems in neighbourhoods.

Increasing renewable electricity supply is addressed in different ways. Vancouver has set a target to supply 100% renewable sourced electricity by 2050 in a government-led action in collaboration with power generation companies. This involves a 'passive house' certification that incorporates several climate sensitive design principles, in the interests of confirming that a building is designed to achieve high energy performance. In Oslo, a 'lighthouse' or pilot project was launched to power one neighbourhood entirely by renewable sources of energy. This is meant to demonstrate the viability of using renewable power for electricity generation and to influence other urban developments to adopt the same principle. A ban on fossil fuel-based energy will be effective from 2020. In Oakland, a community solar programme has been launched with the aim to achieve a minimum of 33% renewable energy within the electricity grid.

Hong Kong is trying to move away from generating electricity by coal and moving towards natural gas. It has only low ambitions—of generating 3–4% of its total electricity through renewable power. This is a very different objective to other cities and reflects perhaps the city's commitment and stake in the current energy supply technology. Certainly, the target is not progressive and pays little attention to the potential in the urban dimension for energy production.

Many buildings in cities were built at a time when energy efficiency or sustainability was not a priority. Therefore, upgrading existing building stock with more efficient heating and/or cooling systems is necessary to reduce high consumption. In Vancouver, existing buildings are to be retrofitted to perform at the same level as new construction which are proposed to have zero-emissions, though little detail is provided on how this might be achieved. In Oakland, 30% of existing buildings are to be upgraded to consume less energy although there is no set target on the amount of energy to be consumed in comparison to the current situation. In Hong Kong, the benchmarking of buildings and requirements for retrofitting are stringently applied and revised every three years. Sophisticated meters are used to monitor energy consumption and the mechanical cooling and lighting systems will be retrofitted as per the standards set in the building code. For example, in a scheme launched in 2000 almost all buildings were retrofitted with a freshwater cooling tower (FWCT) to improve the efficiency of air conditioners by 20%. Since air conditioning contributes about 30% of the total electricity consumption in the city, this was a significant intervention.

Apart from Oslo, building rating systems to improve energy and environmental performance are a preferred regulatory approach to monitor and ensure energy efficient building design. Vancouver mandates energy benchmarking and labelling requirements. Oakland enforces stricter building energy codes that require all new building stock to be 10% more efficient than those of the California State requirement of building energy performance. BEAM is the green building rating system that is widely used in Hong Kong. In addition, the city has developed two regulatory tools, the B(EE)R or Building Energy Efficiency Regulations, and the BEEO or Building Energy Efficiency Ordinance, which are upgraded every three years to ensure energy use is monitored and improved.

6. Discussion and Conclusions

The paper has argued that it is critical that city energy plans address the urban dimension and spatial planning in their proposals. The urban dimension—that is the pattern of spatial development and urban form and the planning that shapes it—is inseparable from the energy system. Cities and energy systems have evolved on mutually dependent paths. Thus, the form of urban development will strongly influence the medium and long-term future of the energy transition and visa-versa. Spatial planning policies that seek to shape spatial development and urban form therefore, have much potential to assist in reducing energy demands and increasing efficiency.

There is some uncertainty about the precise impact of the urban dimension and spatial planning on energy consumption and production, and much depends on the local context. Sophisticated models of the relationship between aspects of the built environment and energy offer only limited assistance because they make extensive assumptions about user behaviour and citizen choices. Policies and interventions need also to consider what is acceptable and needed in the local cultural context. Nevertheless, interventions in the urban dimension do offer considerable leverage on the energy transition, alongside questions about new supply technologies or demand management, where they are informed by local knowledge.

If energy strategies are to address the urban dimension, guidance is needed on those aspects of spatial development and urban form that play a critical role in the energy transition. We have undertaken a review of literature on the relations between the energy system, the urban dimension and spatial planning, in order to create a synthesis of the key measures for the urban dimension that could be addressed to promote energy transitions and the environmental benefits they will bring. The review used six comprehensive studies to identify the critical measures, noting where there was agreement or not. There is a consensus among the studies that three interrelated categories of measure have the most potential: transport and accessibility; urban form and energy infrastructure.

The study examines four city energy strategies in Vancouver, Oslo, Hong Kong, and Oakland. These are cities that have adopted ambitious and innovative practices towards sustainable development and climate change including energy strategies (sometimes as part of a climate action plan). The objective is to assess the degree to which the strategies consider and take forward the main components of the urban dimension that offer potential for the energy transition.

We have four main conclusions about the urban dimension measures addressed in the energy strategies. In summary, the corporate energy strategies are broad with ambitious goals but with a relatively short-term and selective outlook. They are strongly related to the local conditions and the relatively short-term possibilities for improvement which means they tend to overlook measures that may yield benefits in the longer-term. The attention given to the urban dimension in city energy strategies is patchy with significant gaps, and are stronger on the transport initiatives than on urban form measures. The strategies make numerous proposals that have an impact on the urban dimension, but the linkage is seldom explicitly considered. There is little attention to innovation in the planning and design of the built environment that could assist in meeting energy strategy goals.

1. The four energy strategies investigated here reflect strongly the commitments made in international agreements, and have a clear goal to reduce GHG emissions, with concrete targets to reduce energy use and thus, GHG emissions. They are much less clear about outcomes. Objectives are not quantified, and they give no certain projections on the achievement of targets. This is understandable given the limitations of modelling tools and data availability. However, they are also selective in the scope of the measures proposed overall. Each strategy proposes a set of measures which are strongly related to local conditions, including climate, governance instruments, culture, and the existing profile of the energy system. Cities are concentrating strategies on those aspects of the energy system where they anticipate progress in the relatively short-term (measured in years). Interventions in the built environment may be potentially significant but they generally have a medium to long-term impact (measured in decades) because most of it already exists. New development or redevelopment makes only a relatively small proportionate impact and it takes time for the incremental changes to add up, for example, in shifting the location of homes, jobs and facilities. We recommend that the city mayors taking responsibility for climate action and energy transition strategies should engage with their urban and spatial planning departments and related stakeholders to ensure that the urban dimension is considered in future plans to address longer term impacts now, and that the corporate energy strategies are properly addressed in urban development plans.

2. In relation to the assessment framework of key measures in the urban dimension, all of the city energy strategies had significant gaps. Transport and accessibility are better covered, but largely through the provision of infrastructure. The potential of urban planning measures to improve access to services so that they are available locally, or to influence commuting patterns or shape demand for public transit are not addressed. The exception is in TOD where the close relation between transport investment and urban development is considered. Urban form is seldom addressed directly, despite the obvious connection where energy markets, through the development of the motor car, have driven the urban form of cities for so long. The opportunities to reverse this so that initiatives in urban form can stimulate changes in travel and transport are largely ignored. So too are innovations in building and neighbourhood design, which architects and planners are taking forward vigorously.

We recommend that city governments pay attention to the full scope of measures relating to the urban dimension, and to matters that may be more difficult to implement. It may be that action on the more difficult measures needs to start now, even if it will be decades before they can be realised.

3. Energy system measures proposed in each city have indirect impacts on the urban dimension, which are not considered systematically. Changes will be needed in the built environment to facilitate many energy efficiency measures. For example, promoting active travel can reduce the number of trips made by cars. In many cities a radical infrastructural and cultural change is needed to assist with this shift. The strategies do not address the necessary adjustments in urban form in any systematic way. There are examples of policies in energy strategies that would support neighbourhood scale urban

design solutions, through for example facilitating walking or a less energy intensive arrangement of buildings, as in Vancouver and Oslo. However, more is needed if the perception of space and its organization in urban areas is to be shifted to achieve an energy efficient built environment. Energy strategies need to have a stronger link with urban development plans to be able to effectively change the 'decision rules' that can lead to an improved energy performance.

We recommend that energy strategies consider how their proposals interconnect with the urban dimension and what changes are needed in spatial development and urban form to assist in implementation of energy policies, perhaps through an urban energy audit.

4. The strategies rarely consider innovation in the spatial planning and urban design of the built environment that would help to achieve their goals. Let us take the example of passive solar design. None of the energy strategies mention adopting passive solar design as a mandatory action to reduce energy consumption in buildings although many studies [65] have shown that passive solar design strategies have the potential to reduce energy demand in buildings and improve energy efficiency in cities. These and other planning and design initiatives, such as retrofitting neighbourhoods and housing estates to become more carbon neutral, are being tested in many places. City building regulations address solar energy as an inevitable consequence of advancement in building design, but it is not explicitly considered as a component in the energy strategies which tend to propose blanket and blunt policies to move to carbon neutral buildings. It appears that more cooperation is required between parts of government, other agencies, and civil society to ensure that the full range of experimentation and possible solutions are reflected in the energy strategies. In the C40 cities it is the mayors and their corporate offices that are taking the lead on climate action and emissions reduction. They should also take the lead here, but it is the planning departments that also need to contribute in their role of integrating policy sectors and cross-boundary collaboration, and by engaging citizens in policy making. Guidance and templates on climate action planning from international organisations such as C40 cities also should ensure they address the components of the urban dimension explained above.

These conclusions and tentative recommendations are made bearing in mind that the corporate city energy strategy is a relative new instrument in city governance. Cities have been quick to establish these policy statements and deserve recognition for the commitment and significant achievements so far. The strategies are mostly in their first iteration and will no doubt be reviewed and extended. We have endeavoured to provide a systematic framework of measures against which strategy making can take into consideration the urban dimension. We have provided a constructive review of four city energy strategies and given examples which may assist in the review process and spur a closer investigation of these relationships in other places. We argue that with this in mind, the strong trajectory of strategy, plan, and implementation to ensure that energy use becomes more environmentally responsible has even more chance of success.

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