# CONSUMPTION-BASED AND EMBODIED CARBON IN THE BUILT ENVIRONMENT: IMPLICATIONS FOR APEC'S LOW-CARBON MODEL TOWN PROJECT

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## ABSTRACT

In accordance with international protocols and directions, the APEC Energy Working Group has concentrated on constraining *operational* energy use and greenhouse gas (GHG) emissions in cities across the Asia Pacific, especially from the widespread consumption of fossil fuels. In addition to economy level policies and recognising the different characteristics within the region, APEC has sought to take action at the town/city level via the Low-Carbon Model Town (LCMT) project, including the development of self-assessment tools and indicator systems. However, the "low carbon" landscape is changing. There is increasing recognition of *embodied* carbon, accompanied by the emergence of methods for its measurement, while the C40 Cities Climate Leadership Group has recently highlighted the significance of *consumption-based* carbon. Similarly, the Greenhouse Gas Protocol for Cities (GPC) is likely to extend its ambit from Scope 1 GHG emissions, derived from energy use within a city boundaries, and Scope 2 emissions from grid-supplied electricity, heating and / or cooling, to Scope 3 emissions derived from materials and goods produced outside the boundaries of a city but associated with construction within that city. After describing these emerging approaches and the current landscape, the paper examines the significance and implications of these changes for APEC approaches, especially in relation to the LCMT project, its indicators and the varying characteristics of towns and cities within the Asia-Pacific region. Special attention is given to the built environment, which is known to be a major contributor to operational and embodied emissions. Consistent with the theme of the Asia-Pacific Energy Sustainable Development Forum covering "sustainable development of energy and the city," a case is put forward for the current APEC approach to be extended to encompass both embodied and consumption-based emissions.

## KEYWORDS

built environment, consumption-based emissions, embodied emissions, resource efficiency, circular economy

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## 1. INTRODUCTION

The rapid increase in energy consumption within the developing economies of the Asia Pacific region (APEC) has been a major concern, compounded by high rates of urbanisation and the use of fossil fuels. In response, the APEC Low-Carbon Model Town (LCMT) project aims to reduce energy and $CO_2$ emissions within the region, focussing on energy efficiency measures and renewable energy. It seeks to assist towns to systematically plan and realise LCT development, including town structure, buildings, transportation, energy, water and waste management systems, supported by policies, education and management. Local and central governments are provided with self-assessment tools and an indicator system for monitoring progress towards improvement (Tanaka and Irie 2017).

The APEC initiative has been within the context of international actions to reduce emissions and tackle climate change, which have focused almost exclusively on reducing direct and operational energy use and resultant emissions; direct emissions are those from sources within a city boundary. This emphasis is consistent with the Greenhouse Gas (GHG) Protocol for Cities (GPC), which concentrates on Scope 1 and 2 operational emissions generated within the boundaries of cities (WRI et al. 2015). Whilst aiming to give cities the tools they need to measure their emissions, provide an accounting and reporting standard, and a road map to reduce their carbon footprint, the GPC currently excludes indirect or Scope 3 emissions (including those "embodied" in construction materials) generated outside the boundary of a city. Direct, operational emissions have been recognised as "the low hanging fruit," being simpler to measure. Thus, most climate change mitigation strategies—as with APEC—continue to have a primary focus on reducing direct energy use, accompanied by the purchase of carbon offsets.

However, as Seto et al. (2014) pointed out, there is widespread recognition of the need to report beyond direct, territorial GHG emissions. The GPC, moreover, acknowledges that consumption-based accounting is an alternative, complementary approach that can provide a different insight into a city's GHG emissions profile (WRI et al. 2015, 33). This method captures direct and life cycle GHG emissions of goods and services (including embodied emissions), and allocates GHG emissions to final consumers of those goods and services, rather than the original producers (C40 Cities 2018). In this regard, the significance of more complex measurement and accounting of "consumption-based" and "embodied" emissions associated with resource use is becoming increasingly recognised (Wiedmann et al. 2015: Xing et al. 2019).

The built environment, encompassing not only buildings but also infrastructure for transport, energy, water and the other utilities, is one of the largest consumers of resources. It is responsible for 40 per cent of material consumption, 40 per cent of waste and over 33 per cent of GHG emissions (Ness and Xing 2017; Ness 2019). The World Green Building Council (WGBC 2019), however, now recognises that building and construction is responsible for a significant amount of embodied emissions.

Thus, the "low carbon" landscape is now changing. A recent report by the C40 Cities Climate Leadership Group (C40 Cities 2018) found that total consumption-based emissions of 79 cities were 60 per cent more than those emissions calculated using the GPC, of which construction, utilities and housing represent a substantial proportion. Embodied emissions and "capital carbon" have also received more attention; HM Treasury (2013) has long recognised capital carbon, while the UK Green Building Council (UKGBC 2019a) has pioneered the adoption of embodied emissions within its framework for net zero low carbon buildings. In addition, tools are beginning to emerge that enable the calculation of both operational and embodied emissions, such as the Precinct Carbon Assessment Tool (Xing et al. 2019) developed via the CRC for Low Carbon Living in Australia.

In light of the above developments, it is timely to review the APFED approach, with its focus on direct, operational emissions that are merely "the tip of the iceberg," as Waldron et al. (2013) have noted. This led to the formulation of the research question:

> *What are the implications of emerging international approaches, which recognise consumption-based and embodied carbon, for APEC and its LCMT project—especially in the pursuit of a low carbon built environment?*

Firstly, the paper reviews the literature concerning responses to climate change, highlighting increased recognition of consumption-based and embodied emissions (Section 2). The research methodology and focus is then explained in Section 3, followed by a description and analysis of the APEC approach to its LCMT project (Section 4). The implications of the findings for APEC are then discussed (Section 5), with examples of strategies for low carbon development being introduced in Section 6. Finally, some brief recommendations and conclusions are provided in Section 7.

## 2. LITERATURE REVIEW

As C40 Cities (2019a) has recently highlighted, "new ways of measuring the climate footprint of C40 cities show that urban consumption is a key driver of global GHG emissions." It was recognised that while cities have strong action plans to significantly cut emissions produced directly within their geographic boundaries (known as "territorial emissions"), "emissions due to what is consumed within C40 cities are rising and, if left unchecked, will nearly double by 2050.

The IPCC (2018) has pointed out that restricting global temperature increases to 1.5°C is still possible, but this would require "rapid and far-reaching transitions" in systems of consumption and production, accompanied by the protection and restoration of eco-systems. As Welch and Southerton (2019, 31) have argued, this will necessitate "radical shifts" in the societal organisation of consumption and production, with reduction in "demand-side emissions" being urgently required—especially by wealthy, high consuming nations.

As Stahel (2008, 508) has highlighted, "reducing resource consumption also reduced $CO_2$ emissions." According to a Club of Rome study by Wijkman and Skånberg (2015, 9):

> *The general level of resource use in society is seldom taken into account—in spite of the fact that the climate benefits from using products longer and from enhanced rates of recycling and reuse . . . As a consequence, climate change mitigation strategies need to become more holistic and consider resource efficiency as a key instrument.*

### *2.1 Consumption-based and embodied carbon*

While data is not provided at a city-level, and further analysis is needed for more accurate assessments, the C40 Cities (2018) examination of 79 of its cities revealed that consumption-based emissions represent *a 60 per cent increase* for the emissions estimated for the same cities using the GPC. Moreover, 85 per cent of emissions associated with goods and services consumed in the C40 group are imported from regions outside the cities.

Thus, consumption activities within a "consuming" city have a significant impact on the generation of GHG emissions beyond its boundaries, such as by a "producing" city. The consumption-based approach, therefore, accounts for Scope 3 emissions associated with materials and products imported for building and construction projects, in which embodied emissions play a major role.

To avoid climate breakdown, C40 Cities (2019a) emphasised that emissions from global urban consumption must be halved by 2030. For this to be achieved, "*emissions from consumption in high-income cities must decrease by two thirds within the next decade*," with much of this reduction to take place in Europe, North America and East Asia. C40 Cities (2019a, 13) further reported that, "*at the same time, rapidly developing economies need to adopt sustainable consumption patterns when growing*."

Turning to the built environment, the WGBC (2019) has acknowledged that building and construction is responsible for 39 per cent of global energy-related emissions; 28 per cent of these arise from the operational "in-use" phase, including heating, cooling and power, "while 11 per cent are attributed to embodied carbon emissions released during the construction process and material manufacturing." Consequently, the WGBC is developing a "call to action" report, focused upon embodied emissions, and the systemic changes needed to achieve a net zero carbon built environment by 2050 through its Advancing Net Zero Campaign. The report, due to be released during World Green Building Week in September 2019, will "help shape a net zero carbon future for the whole life cycle of buildings"; it will draw upon the use of life cycle analysis (LCA) in existing certification schemes.

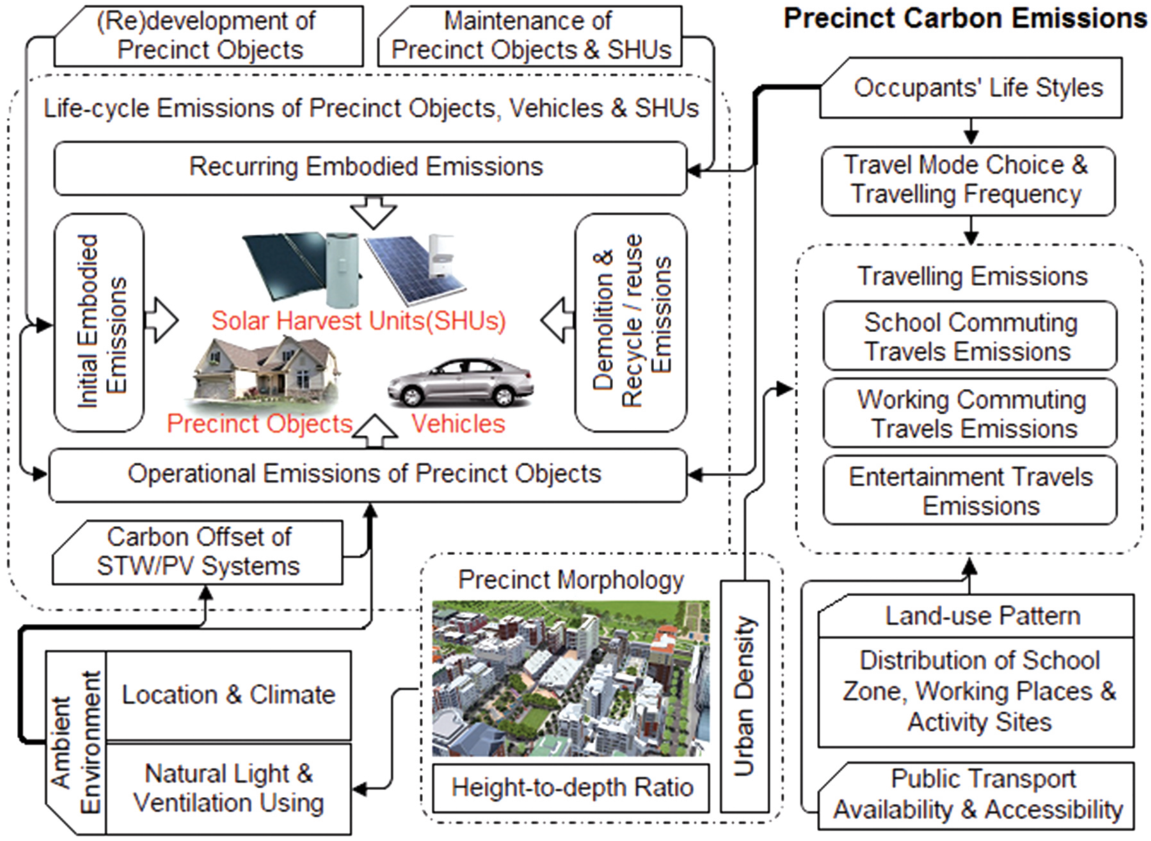
Meanwhile, the UK Green Building Council (UKGBC 2019a) has boldly taken the lead by releasing a "framework definition" towards net zero carbon buildings, which recognises that embodied emissions can account for up to half of the carbon impacts associated with a building over it lifecycle. To reduce impacts during the construction phase, it recommends that "a whole life carbon assessment should be undertaken and disclosed for all construction projects to drive carbon reductions." The UKGBC also proposed, as a longer-term task, that another assessment method for "net zero carbon-whole life" should be developed, encompassing both operational and embodied emissions.

## *2.2 Carbon assessment*

While there have been some practical and policy issues in the analysis of embodied carbon and its contribution to low carbon urban development, these barriers are now being overcome (Pears 1996; Waldron et al. 2013; Beattie et al. 2012). In this regard, Australia is at the forefront of embodied carbon research, especially for the urban built environment. For example, the Precinct Carbon Assessment (PCA) is a carbon modelling and analytics tool, developed as part of the Integrated Carbon Metrics project (ICM), to examine the whole life carbon of the urban built environment at a precinct scale. The scope and system boundary for assessment of consumption-based life cycle carbon is illustrated in Figure 1.

The carbon assessment takes into account morphological factors and occupants' behaviours, encompassing four aspects: embodied, operational and travelling carbon emissions, as well as carbon offsetting contributed by renewable energy harvesting. It enables highly aggregated as well as more detailed assessment of operational and embodied carbon of "precinct objects," including residential and commercial buildings and infrastructure, building appliances, transport vehicles and discrete energy generation. By modelling and examining the consumption

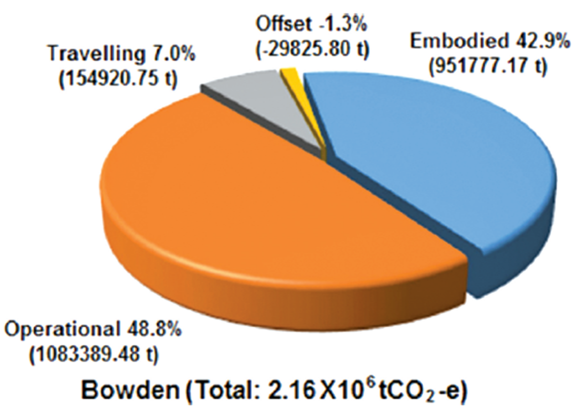
**FIGURE 1.** System boundary for carbon evaluation of urban precincts (Huang et al. 2017, 114).




related carbon across the whole precinct system, this can help map out full carbon profiles, to identify carbon "hot-spots" (Xing et al. 2019).

Figure 2 illustrates application of the PCA tool to the Bowden inner urban precinct in Adelaide, South Australia. Bowden comprises high-density apartments and townhouses, has efficient access to public transport, and is undergoing renewal for transit oriented development

**FIGURE 2.** Life cycle carbon profile of a precinct (Huang et al. 2017, 120).



(TOD). The results highlight the significance of embodied carbon, accounting for 42.9 per cent of the overall precinct carbon (Huang et al. 2017).

The multi-dimensional and multi-scale assessment capability of the PCA tool can provide planners, urban designers and policy makers with an understanding of where operational and embodied emissions reside, as well as the capability to assess different morphological scenarios and development pathways towards a target of a carbon-neutral precinct or town.

Having reviewed recent literature, research and practice that place more emphasis on consumption-based and embodied carbon, we now consider an appropriate research method by which the current APEC approach may be examined.

## 3. RESEARCH METHOD AND SCOPE

A qualitative research method is adopted, by which APEC's LCMT project and associated reports are examined, assessed and gaps identified, in the light of recent literature, the current state of knowledge, and alternative approaches being adopted by other organisations such as C40 Cities for Climate Leadership (C40 Cities 2018, 2019), the WGBC (2019) and the UK Green Building Council (UKGBC 2019a, b).

APEC's approach is examined under the theoretical lens of consumption-based and embodied carbon, especially related to buildings and infrastructure. This is responsible for over 11 per cent of emissions—the largest consumption category—of C40 cities (2019a, b).

It is important to have a clear understanding of these key terms:

"Consumption-based carbon" is that arising within the boundaries of a city or town, minus that associated with the production of buildings, goods and services exported to meet demand outside the city, plus that associated with those produced outside the city or town but imported for consumption by its occupants (C40 Cities, 2018). Assessment of consumption-based carbon may encompass life cycle operational carbon, embodied carbon, travel related carbon, and the use of carbon offsets. This reflects PAS 2070: 2013 (BSI 2013), which captures both direct GHG emissions—from sources within the city boundary—as well as indirect emissions from goods and services produced outside the boundary for consumption within the city. On the other hand, "Embodied carbon" is that released during the production of buildings and goods, including extraction, transport, processing, fabrication, refurbishment and demolition. The two terms are related, in that consumption-based carbon primarily encompasses embodied carbon under Scope 3 emissions of the GHG protocol (known as the GPC).

In addition, the paper prefers to use the word "carbon," which is the carbon dioxide equivalent of all GHG "emissions." The term "capital carbon," to describe emissions associated with the creation of an asset, is used in the infrastructure sector because it accords with the concept of capital cost (HM Treasury 2013). However, "embodied carbon," often used at a product level, is preferred in this paper as is used by C40 cities and green building councils (WGBC 2019; UKGBC 2019).

Rather than attempting to quantify consumption-based and embodied carbon for APEC cities and towns, which is seen as a further phase of research, the paper draws upon data from the literature and other research, including that by Xing et al. (2019) and Huang et al. (2017) related to low-carbon precincts.

According to the research method, the APFED approach is now examined and analysed using a consumption-based lens.

## 4. THE APEC APPROACH: DESCRIPTION AND ANALYSIS

### *4.1 The Low-Carbon Model Town Project and Indicator System*

The LCMT Project was launched in response to the declaration at the 9th APEC Energy Ministers Meeting (EMM9) held in Fukui, Japan, 19 June 2010. Ministers discussed cooperation on low-carbon pathways to energy security as well as growth strategies. Introducing low-carbon technologies in city planning, to boost energy efficiency and reduce use of fossil fuels, was vital to managing rapidly growing energy consumption in urban areas of the Asia-Pacific region (APEC 2018). Simply put, the main objective of the project was to reduce $CO_2$ emissions in the APEC region.

The APEC Low Carbon Town (LCT) means cities, towns and villages that seek to become low-carbon with a quantitative $CO_2$ emissions reduction target, a time frame for its achievement, and a concrete low-carbon development plan (APEC 2015). APEC has recognised, though, that most towns in developing economies of the region, grappling with challenges such as air and water pollution, waste management, and recycling, may at present lack such a development plan and quantitative targets. Establishing such targets, which are town specific rather than broad-based, "may not be an easy task" (APEC 2015, ix).

The Low-Carbon Model Town indicator system (LCT-I) was designed to be as simple and practical as possible, given that many developing economies in APEC lack sufficient data (APERC 2016). As Tanaka and Irie (2017) explained, low-carbon measures were originally designed from the energy perspective: two main categories were selected, measures directly related to energy usage (covering demand and supply), and those indirectly related (environment and resources, governance). Assessment targets comprised five major items (Tier 1), 14 mid-level items (Tier 2) and 36 lower-level items (Tier 3), as shown in Figure 3.

Within the framework, direct energy "demand"—which forms the focus of this paper—covers town structure, buildings and transportation. It is important to consider the Tier 2 and Tier 3 indicators for these topics, which form the basis of the scoring criteria:

1. Town Structure
   - 1.1 Adjacent Workplace and Residence: Achieve concentration of urban functions by locating workplaces and residences adjacent to each other.
   - 1.2 Land Use: Efficient land use and mixed use of the land concentrate the urban functions
   - 1.3 TOD: Transit Oriented Development promotes the shift to an urban structure that is not dependent on private cars.
2. Buildings
   - 2.1 Energy Saving Construction: Contribute to the creation of a low-carbon town by reducing the amount of energy consumed by a building.
   - 2.2 Green Construction: Expansion of buildings with high energy performance contributes to a low-carbon town.
3. Transportation
   - 3.1 Promotion of Public Transportation: Dependence on private cars can be decreased by promoting the use of public transportation, such as railways and buses, as well as introducing mass-transportation systems.
   - 3.2 Improvement in Traffic Flow: Improve traffic flow and traffic congestion by traffic management.

3.3 Introduction of Low-Carbon Vehicles: The dissemination of low-carbon vehicles contributes to the low-carbon town development.

3.4 Promotion of Efficient Use: Reduction of fuel consumption by promoting eco-driving contributes to the low-carbon town development.

Self-assessment of "achievement level" is conducted using a five or three point scale. Assessment results then appear as "overall rank," "radar chart" and "individual assessment," which identifies the achievement level and areas to be improved for the realisation of a low-carbon town. It should be noted that LMT-I system is not intended for comparing the performance of different towns.

The APEC system utilised existing assessment indicators under the Leadership in Energy and Environmental Design (LEED system developed by US Green Building Council, and the Comprehensive Assessment System for Built Environment Efficiency (CASBEE) developed by Japan. Such systems are heavily oriented towards energy saving and thermal performance measures, including insulation, equipment and use of "natural energy" or "passive design" features such as utilisation of daylight and natural ventilation. CACBEE-City, for example, focuses upon GHG emissions as an indicator of a low carbon and sustainable city. APEC has also been involved with the development of energy indicators for city services and quality of life within ISO 37120 (ISO. 2018) the standard for sustainable cities and communities.

As we have seen from the foregoing, such assessment systems have concentrated on direct, operational energy and carbon, although some are beginning to recognise the importance of consumption patterns and embodied carbon.

**FIGURE 3.** Assessment framework of the LCT-1 System (adapted from Tanaka and Irie 2017, and highlighting demand that is the focus of this paper).

| | Tier 1 | Tier 2 (No. of Tier 3 indicators) |
|---|---|---|
| Directly Related | Demand | 1. Town Structure (3)<br>2. Buildings (4)<br>3. Transportation (6) |
| | Supply | 4. Area Energy System (1)<br>5. Untapped Energy (1)<br>6. Renewable Energy (1)<br>7. Multi Energy System (1) |
| | Demand & Supply | 8. Energy Management System (3) |
| Indirectly Related | Environment & Resources | 9. Greenery (2)<br>10. Water Management (3)<br>11. Waste Management (2)<br>12. Pollution (3) |
| | Governance | 13. Policy Framework (4)<br>14. Education & Management (2) |

### *4.2 The Low-Carbon Model Town Project: Implementation*

APEC Energy Ministers encouraged the APEC Energy Working Group to implement the LCMT project to encourage development of the concept and to share best practices. Accordingly, via its Research Centre (APERC) and Sustainable Energy Centre (APSEC), the Working Group has been working with case study towns in a series of phases (Phase 1 to Phase 6), while conducting policy reviews.

The pursuit of Low Carbon Model towns has involved countries including China, Japan, Thailand, Vietnam, Indonesia, the Philippines and Peru. This has encompassed area planning, area energy management, environmental planning, renewable energy, eco-life styles and low carbon buildings, which were viewed in terms of photovoltaics, building energy management systems, green rooftops and the like. Again, the emphasis is on direct and operational energy and emissions (Scope 1 and 2. Consumption based and embodied carbon (Scope 3) is yet to be addressed.

The following discussion of case studies concentrates on the LCT indicators (Tiers 2 and 3) related to "town structure" and "buildings," where embodied energy and emissions may have a greater influence.

*Case 1. Mandaue City, Cebu Province, Philippines:* The feasibility study for Mandaue (APEC 2016b), an industrial city of over 331,000 people located in the midst of Metro Cebu`, provides a well-developed example of the APEC Phase 6 approach to developing a low-carbon town. Consistent with the overall planning process set out in the LCMT concept (APEC 2015, 24), this began with consideration to economy level plans of the central and local government, followed by a close examination of the selected town, grasping its particular characteristics, and understanding its current status and future changes in energy demand. Using local data for energy consumption, a baseline scenario with emission projections for "business-as-usual" was determined, followed by establishing a quantitative reduction target derived from the overall Philippines target and local conditions.

The use of the LCT indicators, for self-diagnosis at the beginning of the low-carbon town process, was effective in identifying priorities and targets for development projects. Using the scoring system, progress towards energy management of buildings and areas was rated highly, while transport demand and advanced energy supply systems received lower ratings. This led to flagship projects to transform the city's urban structure, including a "Green Loop" transport corridor and light rail airport connection.

Building related indicators of energy saving and green construction were heavily reliant upon the Green Building Ordinance of Mandaue City and the "Building for Ecologically Responsive Design Excellence (BERDE) Green Building Rating System. Similar to other rating systems such as CASBEE (Japan), LEED (US) and Green Star (Australia), this covers criteria such as land use and ecology, water, energy, indoor air quality, materials, emissions, waste and innovation. Low carbon building measures included energy efficient building envelope, roof greenery, natural and passive lighting and ventilation systems, energy efficient equipment (chillers, lighting) and on-site renewable energy.

From this brief study, it can be seen that little attention is currently given to embodied carbon, life cycle analysis and reducing the volume of resources consumed.

*Case 2. Yujiapu, Tianjin, PR China:* The Yujiapu Financial District, Tianjin, which was expected to set "a new standard for the sustainable development and construction of cities in Asia," was selected by APEC as a key case study (APEC 2011). Tianjin eco-city can be viewed in the context of policies for sustainable low carbon city development in China (World Bank 2012). Low-carbon indicators were established for local governments, covering smart urban form, energy efficient "green" buildings, low carbon transportation, waste management and other services. Consistent with the World Bank's agenda, the focus was upon carbon reductions from transportation, building energy efficiency, and waste. Similar to the Mandaue case above, Yujiapu exhibited a limited understanding of low carbon construction; this was viewed in terms of a 20 per cent reduction in energy consumption for the entire construction works, 80 per cent of components fabricated off-site in factories, a 50 per cent loss of materials for the works, and reduced transport energy consumption by sourcing materials close to the site. At least twelve buildings in Phase 1 of the CBD were intended to be "green buildings," again based largely on energy efficiencies. However, unfinished office and residential blocks, which stand eerily empty after the property bubble burst, represent a massive waste of resources, cost and carbon.

Fernández (2007, 99) highlighted the unprecedented volume of China's additions to its urban built environment, where "new urban zones of high density and material-intensive commercial and residential buildings has consumed enormous quantities of domestic and imported resources." He urged the formulation of strategies for a circular economy that include a more resource-efficient urban China (see Ness 2008). However, APEC's LMT project, with its focus on reducing direct Scope 1 and 2 emissions, appears unable to account for the considerable embodied emissions generated by highly consuming, burgeoning cities such as Tianjin.

### *4.3 The gaps*

It is evident that APSEC's approach to "low carbon" buildings and infrastructure has been dominated by energy efficiency considerations, as reflected by the LCT-I categories of "town structure," "buildings" and "transportation."

Whilst concentration of urban functions and efficient use of land is desirable in relation to town structures, this may promote high density, tall, highly resource consuming structures (as in the case of Tianjin), which are likely to increase consumption-based and embodied carbon. Furthermore, energy saving and green construction is heavily reliant upon green building assessment systems.

Although change is on the way, with embodied carbon being addressed by the WGBC (2019) and others, this is currently not incorporated within most rating systems. If embodied energy/carbon is to be taken into account, indicators and scoring systems will require further review; indicators for material resource consumption and associated embodied carbon will be required, in addition to the present indicators for solid waste management.

However, APEC (2015, 31) has acknowledged that:

> *". . . the amount of energy used to produce materials used for construction can be significant on a life-cycle basis. So use of materials with low embodied energy and carbon emissions, and efficient utilisation of materials, are issues of increasing importance."*

## 5. IMPLICATIONS FOR APEC AND ITS LCMT PROJECT

With regard to the C40 Cities Report (2018), it is important to note that 16 (20 per cent) of the 79 cities that were investigated, located in South and West Asia, Southeast Asia and Africa, have larger sector-based emissions that consumption emissions. Such cities, some of which fall within the purview of APEC, fall into the category of "producer" cities, compared with "consuming" cities such as those in Europe, North America, East Asia and Oceania. The C40 Cities (2018) recommended that cities within these regions, or others that have high operational and embodied emissions—such as some within China or Japan—should use consumption-based inventories alongside their sector-based inventories.

Any changes to green building and related assessment systems that recognise embodied emissions, therefore, will have most impact upon APEC fast growing and highly consuming cities. This may include Tianjin (China), Melbourne and Sydney (Australia), or cities within Japan, Korea, the US or Canada.

The high resource consumption within such cities is exemplified by commercial developments such as Barangaroo, Sydney (Figure 4). This was lauded by the Australian Green Building Council (AGBC) and touted as "one of the greenest urban regeneration projects of its kind anywhere in the world" (Jabour 2015), despite being criticised as "overdevelopment" and privatisation of public space. Although Barangaroo is featured as a "market leader" by the WGBC, it is revealed that this is because it "aims to be world's first high-density carbon neutral development *in operation*" (WGBC 2017, 33, italics added). Increasing recognition of consumption-based and embodied emissions, including Scope 3 emissions in commercial real estate, is likely to constrain such profligate, inequitable and extravagant urban growth in future (Ness 2019; UKGBC 2019a, b).

Self-assessments of cities and towns that take account of these factors, to give a more accurate picture of their low carbon characteristics, is a more complex exercise that necessitates the availability of more data—especially in relation to the more sophisticated PCA tool. As mentioned earlier, the availability of data, combined with the need for human capabilities and monetary resources, is likely to pose a challenge for many developing cities within the APEC region.

Embodied carbon associated with resource consumption will assume more importance in "consuming" cities, such as those in the developed world, rather than "producing" cities in the developing world. Arguably, in meeting international emissions reduction targets, Scope 3 emissions should be attributed to consuming rather than producing cities. Consistent with APEC roles of economic cooperation and sharing best practices, "consuming" cities could assist

**FIGURE 4.** How Barangaroo, Sydney, will look after completion (Courtesy Barangaroo Delivery Authority).

and mentor "producing" cities to grow in a more resource efficient way, to deliver more value and infrastructure with less consumption and less carbon. Furthermore, carbon trading could be utilised so that credits from projects in APEC cities within the developing world could offset emissions from "consuming" cities within the more developed world (Ness 2015), while a tax on carbon emissions consumption—directed at consuming cities—could act as a powerful price signal to redirect such economic actors towards a low carbon future.

In order to assess the implications of assessing both operational and embodied emissions, it is recommended that APEC consider undertaking a pilot study of a "consuming" city, preferably one that is already involved with the LCMT programme as well as being a member of the C40 Cities for Climate Change—in particular, a city that was one of the 79 cities assessed by the C40 Cities as part of their 2018 report. Yokohama, Japan, may be one such candidate. Alternatively, the City of Adelaide—a medium sized Australian city—could be considered, as it has ambitions to be among the world's first carbon neutral cities. Adelaide has already had some involvement with APSEC and APERC and, although not a member of C40 Cities, could no doubt access data. Adelaide is also much involved with Precinct Carbon Assessment, and a pilot study could utilise the aggregated rather than detailed data capabilities of the tool (Xing et al. 2019).

Such adaptation of the PCA tool to certain APEC cities could constitute a more sophisticated advance upon Phase 6 of the LMT-I system described earlier, and represent a further step in the evolution of the LCMT project (Pears 2016). This could involve collaboration with C40 Cities and other kindred organisations.

## 6. LOOKING FORWARD: STRATEGIES FOR CONSTRAINING CONSUMPTION IN LOW CARBON CITIES

As C40 cities (2019a, 13) has highlighted, emissions measured by what is consumed with cities are rising and, left unchecked, will increase by 87 per cent (nearly double) by 2050. Accordingly, *". . . emissions from consumption in high-income cities must decrease by two-thirds within the next decade. At the same time, rapidly developing economies need to adopt sustainable consumption patterns when growing."*

Accordingly, C40 Cities (2019a, b) sought to achieve a cut of 29 per cent in consumption-based emissions by 2050, whilst more ambitions targets could achieve a 44 per cent reduction. It identified strategies for "consumption intervention" for buildings and infrastructure that had the highest emissions reduction potential. These included reducing building demand and enhancing building utilisation, such as via sharing and refurbishment of facilities, in addition to material efficiency and switching, low carbon cement and reuse of building components. However, as explained by Ness (2019, 183), strategies to improve material efficiency are not enough; they may only lead to marginal improvements, with rebound effects: "most of all, the developed nations of the world need to "use less" and reduce material demand in constriction and other sectors."

Although recognised in the Paris Agreement (UN 2015), the need to reduce profligate consumption of resources has been largely overlooked (UN Environment and IEA 2017; Alfredsson et al. 2018). The importance of this challenge is reflected in writings on the circular economy and a resource efficient built environment (Stahel 2008; Ness and Xing 2017). It is further emphasised by the World Resources Forum, UN Environment (2018) and the UN Sustainable

Development Goals (SDGs), especially SDG 12: "to ensure sustainable consumption and production patterns."

The circular economy concept, based upon gaining more value from resources by extending their useful life, is seen as not only reducing resource use and waste but also GHG emissions, while creating more employment and competitiveness. It has been widely embraced within some jurisdictions, such as the European Commission and China (see Ness 2019). The study of urban metabolism, which maps stocks and flows of resources, is also becoming highly developed (Kennedy et al. 2011; Kennedy et al. 2007). However, as Bocken and Short (2016) pointed out, a circular economy may lead to greater resource consumption if the total volume of consumption is not mitigated. For the developed world, which includes some APEC countries, this also necessitates dramatically reducing service demands by embracing "sufficiency" principles, accompanied by a rebalancing between rich and poor worldwide via "shrink and share" strategies (Allwood 2014: Ness 2019; Alfredsson 2004).

As Allwood (2014) advocated, with the developed world uppermost in mind, demand for material production would be reduced if the overall demand for *services* were to itself reduce. In this regard, the extended urban metabolism model (Newman 1999) was ground-breaking by including various liveability measures at its core, including health, education, employment and housing *services*. This was later enlarged by Newton and Bai (2008) to support greater liveability, with less resource use, reduced waste and emissions, and improved environmental quality, via improved urban systems and processes. The UN (2011) developed a simplified representation of the model, via "eco-efficient and sustainable urban infrastructure." It was envisaged that various building and infrastructure systems, such as energy, water, waste, transport and facilities, could be planned in a holistic, integrated, symbiotic and resource efficient manner (UN 2011). This led to the conceptual model for a resource efficient built environment developed by Ness and Xing (2017), which sought to deliver (at its core) quality of life and services, economic return, local employment and carbon neutrality via collaboration involving actors, their resources and policy development.

Whether for buildings, precincts or infrastructure, strategic asset management principles should be followed, whereby assets are always seen as supporting community needs and *service* demands—not as an end in themselves (ISO 2014: Ness 2019). Consistent with this approach, the framework devised by the UK Green Building Council (UKGBC 2019a) recognises that the early inception and planning phases of a project represent most potential for reducing embodied carbon. For example, "build nothing" and "build less" options should be considered, challenging the root cause of the service demand and exploring alternative approaches to achieve the desired outcome.

The use of existing resources should be maximised to reduce the extent of new construction required, such as by sharing, adaptation or refurbishment of existing assets (Ness and Xing 2017). Such principles may be applied to both buildings and infrastructure. If new construction is required, it is important to recognise that "big" and "low carbon" do not usually sit well together. The greenest, most low-carbon building or infrastructure project is one that doesn't need to be built, such as via adaption of existing facilities, demand management, or delivering services via online means. The UKGBC (2019a) also advocates "build clever," such as by use of low carbon materials, or "build efficiently" via embracing new construction technologies, and designing for reuse, change of use and ease of adaptation of facilities over their lifecycle.

In the pursuit of genuine carbon neutrality, which acknowledges consumption-based and embodied carbon, cities, towns and precincts should find ways to meet their needs while constraining their consumption. This challenge will require changes in approaches to providing facilities and infrastructure to meet service demands.

## 7. CONCLUSIONS

This paper has examined the APEC LCMT project, using the theoretical lens of consumption-based and embodied carbon emissions, to determine the possible policy implications—especially for the built environment. It has shown that self-assessments covering only operational emissions are often misleading, especially in regard to "consuming" cities and towns, where consumption-based emissions can be considerably greater than what is usually assumed. The task of extending the current APEC system to include consumption-based and embodied emissions may be less demanding for cities that are more developed and enjoy greater access to data and capabilities to undertake holistic assessments. However, applying such more complex methods can be unsuitable for developing APEC economies, as many of their LCTs are still in the primary stage and lack the data necessary for a full evaluation. This points to the need for a staged "decarbonisation" approach, tailored to particular circumstances, for towns to transition progressively to being "low-carbon." This could begin with simpler scoring methods and progress to more sophisticated quantitative assessments, such as the PCA. In this regard, a pilot study has been suggested, as a further phase of the LCMT project, to examine the implications in more depth. Such a study, conducted under the auspices of APSEC and APERC, could draw upon the work of the C40 Cities Climate Leadership Group and recently developed methods for assessment of the whole-of-life carbon emissions.

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