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Green economy, urban technology and eco-city transitions

Peter W. Newton

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Three radical and interconnected transitions are central to sustainable urban development in the 21st century: transition to a green economy, to sustainable urban infrastructures and to eco-cities. They are framed against a formidable set of challenges to urban sustainability and resilience now confronting all societies as identified by Newton and Doherty (Chapter X, this volume). These include resource constraints, climate change, extreme events exhibiting shorter return periods, population growth, urbanization and built environment intensification, biosecurity, financial uncertainty, failing infrastructures, widening socio-demographic disparities and fragmenting social and human capital.

This chapter explores the essential features of each prospective transition, some of the critical cross-connections, the barriers to change as well as emerging pathways for transformation. A common feature for all transitions is the set of normative goals that they address, viz. using resources more efficiently and reducing non-renewable resource consumption, reducing emissions and utilizing wastes as resources, restoring environmental quality, enhancing human wellbeing, and developing human settlements that are liveable, productive, environmentally sustainable and socially inclusive.

Green economy transition

The green economy has been advanced as the sixth major wave of socio-technical innovation to emerge since the beginning of the industrial era. It has the capacity for major urban infrastructure transformation capable of providing the platform for an evolution of the eco-city (Hargroves and Smith 2005; Newton and Bai 2008; OECD 2012; UNEP 2011; UN DESA, UNEP and UNCTAD 2012; see Figure 1).

<INSERT FIGURE 1 NEAR HERE>

The driver of this green economy transition is the search for new products, manufacturing and urban processes and organizational behaviours capable of enabling *sustainable development* in the 21st century – development that is able to remain within the boundaries of the earth's ecosystem support systems (Intergovernmental Panel on Climate Change 2011; WWF 2010) and to provide the basis for international as well as intergenerational equity among an increasing global population. For example, we live in a world which is witnessing increasing concentrations of greenhouse gases in the earth's

atmosphere predicted to trigger climate change of a scale which could take centuries to reverse (Parry et al. 2007). How we generate and consume energy is central to this issue. We also live in a finite world where peak oil, water shortages, decline in agricultural land and loss of biodiversity are indications that our harvesting of the earth's natural resources is now occurring at a pace which is exceeding replacement rate (Rees 2006; WWF 2010). Our patterns of consumption of housing, travel, energy, water and manufactured products are central to this issue (Newton 2011). Population growth – forecast to reach 9 billion by 2050 – when coupled with per capita consumption defines the magnitude of the sustainability challenge. The task of winding back unsustainable levels of consumption is a challenge for the citizens of developed countries in North America, Western Europe and Australia-New Zealand that have ecological footprints three to four times the global average. Additionally, we live in a world of increasingly concentrated populations. With the world's 9 billion population forecast to be 75% urban by 2050, the sustainability challenge will focus more closely on the consumption emanating from cities – their built environments and their populations. In this regard, recent reports are not encouraging (Randers 2012; Newton 2011; EIONET 2009; OECD 2002), especially when coupled with forecasts that consumption pressures are expected to intensify significantly by 2030 (OECD 2008). A green economy is central to enabling sustainable development in the face of these unprecedented sets of environmental, population and urban challenges.

It is increasingly being argued (Milani 2000; Laszlo 2001; Brown 2001; Rischard 2002; Diamond 2005; Newton 2008; UNEP 2008; Newman et al. 2009) that what is required to deal with the mounting pile of global problems is a wholesale restructuring of global societies and economies no less significant than the earlier agricultural, industrial, service and information revolutions. Unlike these earlier transformations, however, there is an *urgency for transition* to a green economy – a window of a few decades according the UN DESA (2011): 'only three or four decades are left!'; a theme echoed by OECD (2008) and the UN Millennium Ecosystem Assessment (2005).

A green economy can be defined as one that works with the environment and not against it. It involves a transition from the current model of development that continues to give primacy to economic decisions and assumes that environmental problems and externalities can be solved or accommodated if the economy is sound. It is based on an integration of ecological thinking and innovation into all social and economic planning by government and industry from the beginning – not after the issues have been framed. It involves a recognition that the macro economy is part of a larger natural ecosystem and resource base which has capacity constraints that will be severely tested in the 21st century (Daly 1996; Krugman 2010). We are currently at some distance from embracing this paradigm, but some of its central principles are now being articulated.

<INSERT FIGURE 2 NEAR HERE>

A green economy is multi-faceted, and being in its infancy is yet to be explored in any depth and represented with clarity. A number of its key dimensions are outlined in Figure 2 as a precursor to such an examination. The principal societal *drivers* have already been flagged. As with prior socio-technical transitions, the green economy will be based on the maturation and diffusion of several *enabling technologies*. Phillimore (2001) and others view the green economy as revolving primarily around energy and the transition from fossil fuels to renewables. Figure 3 illustrates the magnitude of the challenge involved with an energy transition. It will rely heavily on the eco-efficiencies of technologies attempting to harness solar, wind, geothermal, bio-energy and hydrogen sources of power (some include nuclear and carbon capture and storage in this cluster, while others exclude them on the grounds of environmental risk).

<INSERT FIGURE 3 NEAR HERE>

These ‘core green’ low emission energy industries are beginning to emerge, but none represent an easy option. This is evident from a recent comparative assessment of low emission energy options undertaken from an Australian perspective (see Table 1).

<INSERT TABLE 1 NEAR HERE>

Each country and region will view this portfolio differently, given variations in climate, geography of natural endowments (related to hydro, geothermal, wind, solar, as well as fossil fuels), population and settlement configurations, the existing regime of energy industries and associated infrastructures, and government energy policies. For example, a comparison of Australian and Korean low carbon green growth strategies (ATSE and NAEK 2012) indicates that both countries are heavily dependent on fossil fuels and are planning to expand the contributions that renewable technologies can make to the energy mix in combination with the introduction of a cost to carbon emissions. Australia is a net energy exporter while Korea is almost entirely dependent on energy imports. Korea is focused on developing energy technologies for export whereas Australia appears to be focused on development of technologies to address local requirements (e.g. carbon capture and storage).

To stimulate a market for renewable energy in Australia, the federal government introduced in 2008 a target of 20% of the nation’s energy supply to be sourced from renewables by 2020, amounting to some 45,000 gigawatt hours (ABARE 2010). Targeted primarily at encouraging the development of large-scale solar thermal on-grid power stations, off-grid solar PV has been more agile in responding to incentives such as state government guaranteed feed-in tariffs for electricity sold by households to the grid. The growth in installed capacity has been rapid (Figure 4). The *geography* of take-up of solar

PV in Australia's cities is distinctive (Figure 5): there is a clear attraction with detached houses, suggesting that it will become one of a number of new technologies for 'greening the suburbs' (also, see Kellett 2011).

<INSERT FIGURES 4 AND 5 NEAR HERE>

However, in its broader conceptualization (again, see Figures 1 and 2), the green economy extends beyond 'core' industries associated with low and zero carbon energy generation. It can be seen to embrace innovations that enable achievement of green goals relevant to several other major sectors of the economy and the industries within those sectors (Elder 2009). Some examples are listed in Table 2.

<INSERT TABLE 2 NEAR HERE>

Urban technology innovation and urban infrastructure transition

Many of the products and services that will characterize a green economy will find their application in the built environment of cities, given their central role in the urbanization process. The most sustainable cities will be those capable of drawing from a pipeline of innovative technologies, products and processes that can be substituted as existing applications and vintages show signs of failure (Newton 2007). Three horizons of innovation have been identified for such a pipeline, with each making superior contributions to sustainable urban development (see Figure 6 and Table 3).

<INSERT FIGURE 6 AND TABLE 3 NEAR HERE>

Horizon 1 (H1) innovations are those where the technology is commercially available and has a demonstrated level of eco-efficiency (cost + environment) performance that is superior to products or processes currently in the marketplace and which should be more rapidly substituted. Examples would include energy rated housing, energy and water rated appliances, green building products and processes and smart greenfield development, among many others (Sustainable Insight 2010).

Horizon 2 (H2) innovations are those where there are examples in operation but not yet widespread, such as hybrid and electric cars (Paevere 2010), distributed energy (Jones 2008), hybrid buildings or precincts (Newton and Tucker 2010) and water sensitive urban design (Wong and Brown 2010). These better-performing innovations have a capacity to be applied more broadly, but may require further examination of how they would perform in different regions or markets before becoming more ubiquitous (like H1). Several renewable energy technologies are in this category (Graham et al. 2008; Melbourne Energy Institute 2010).

Horizon 3 (H3) innovations are those which reside, for the most part, in research laboratories as prototypes or visionary systems undertaking field trials and awaiting implementation, but whose sustainability impact can be truly transformational. Examples include:

- ▶ Integrated urban water systems (Diaper et al. 2008; Maheepala and Blackmore 2008) which enable the creation of a sustainable yield of water in urban regions subject to periods of drought and climate variability, by augmenting diverted water from environmental flows (i.e. dams) with treated greywater and stormwater (Blunt 2010). The challenge lies in accommodating decentralized integrated water systems with the long established centralized system networks, as well as addressing current barriers to implementation associated with public health regulations involving water recycling and reuse in domestic settings (Brown and Farrelly 2009; Syme and Nancarrow 2008). Desalination is an established H2 technology, but in a context where the high levels of embodied energy used in the treatment sea water to potable standards is supplied from renewable forms of energy – enabling a sustainable carbon neutral water supply – the resultant ‘integrated system’ would exemplify H3 innovation.
- ▶ Eco-industrial clusters can emerge around new industries and products which utilize multiple waste streams and energy streams synergistically, based on industrial ecology principles and advances in green chemistry (Graedel and Allenby 2009). Converting waste to resources and products and creating wealth from waste represents a major opportunity for shrinking the ecological footprint of cities and creating the basis for new green economy jobs, typically in the employment-poor outer urban regions of cities where eco-industry parks are likely to be established. Initial involvement of government as a catalyst for the ‘integrated’ activity is a common feature, given the added complexity of engagement among multiple firms (Batten et al. 2008), unlike the cradle-to-cradle product stewardship involved in closed loop manufacturing by an individual company (McDonough and Braungart 2002; Kaebernick et al. 2008).
- ▶ A solar-hydrogen/solar-electric economy is one capable of application to both stationary power generation (for buildings and industrial plant) and portable power (e.g. for transportation) and offers the prospect for a totally renewable source of energy which is free of CO₂ emissions (Dicks and Rand 2008; Lamb 2008). There are variants of the solar-hydrogen/solar-electric economy penetrating the marketplace seeking to gain a commercial foothold, and all represent technology platforms which are capable of winding back atmospheric concentrations of greenhouse gases – limiting harmful global warming and associated climate change. Variations exist in relation to eco-efficiency performances, as Table 1 has illustrated, and there is the added spatial planning challenge associated with developing an urban infrastructure capable of supporting a decarbonization of the housing and transport sectors (Newton et al. 2012b) – innovation which confronts the path dependencies built around each of the

still dominant 20th century infrastructure regimes. Integration of low emission distributed energy generation technologies with a national grid developed for a different (fossil fuel-based) energy generation landscape represents a major challenge at present (Newton and Mo 2006).

- ▶ High speed wireless networked digital communications and computing provides a platform for mobile personal connectivity and information processing and exchange – any time, anywhere. This communication infrastructure platform creates an increased menu of flexible location options for both business and workers in determining what activities are undertaken and where: within cities, nations and globally (Brotchie et al 1987; Friedman 2007; Newton 1995). The ability to electronically export or import jobs as well as telecommuting has the potential to significantly shape future urban labour markets and housing markets, and to reduce traffic congestion to a level that does not unduly inhibit the productivity benefits that accompany urban agglomeration. The centrifugal forces unleashed by this new platform interplay in a manner not yet well understood with the centripetal forces of agglomeration economies – centralization *with* decentralization (Newton 1995)
- ▶ High speed commuting via high speed rail converts large towns and provincial cities located up to 200 kilometres from major cities into the equivalent of middle ring suburbs in those cities, relieving pressure from increasingly unaffordable city housing markets as well as decentralizing jobs (Newton et al. 1997a). High speed rail, high speed telecommunications and intelligent arterial and freeway systems combine to provide the connectivity required for a 21st century mega-metropolitan region. High speed travel and communications are for the most part H1/H2 urban infrastructures – innovations that will continue to play out in our cities. However, as Table 3 suggests, H3 challenges will continue to focus on attempts to achieve more integrated transport and land use within cities than has been demonstrable over the last 60 years of urban development. The benefit of more sustainable urban development resulting from integrated land use-transport planning is evident in reductions in carbon footprints of at least 30% with more compact urban forms (Newton et al. 1997b, 2012b). Opportunities for reducing car dependence and promoting opportunities for e-mobility (environmentally friendly modes of travel such as walking, cycling and public transit) within urban communities then become more achievable.
- ▶ Buildings have become the focus for challenging targets relating to environmental performance – carbon neutral, zero carbon or zero energy (Newton and Tucker 2010), zero waste water (Foliente et al. 2008), designed for disassembly, reusability and recyclability (Crowther 2009), smart, healthy and productive indoor environments (Paevere 2009). There are many examples of recently constructed buildings that could be classed as meeting these H2 challenges. However, they are but a small percentage of all new buildings and are far removed from the environmental performance of the total existing stock. Radical and accelerated regeneration of housing and associated

infrastructure is required in the ageing brownfield and greyfield precincts of cities (Newton 2010; Newton et al. 2012b).

- Virtual building and construction: A convergence of advanced information technologies with knowledge from design science, building sciences, environmental science and engineering is creating a platform for the emergence of the digital city – another major technology contributor to the delivery of sustainable built environments. Building information models and city-information models provide the basis for real-time visualization and automated eco-efficiency performance assessments of virtual designs for buildings, city precincts and urban infrastructure systems, from concept stage to detailed design specification, through construction and into operation and management: providing an ability to evaluate performance *prior* to construction. The order of magnitude of savings in time, capital and lifecycle cost and environmental performance of buildings and urban infrastructures capable of being delivered via technological change is proving to be significant (Newton et al. 2009).

In each of the key urban infrastructure domains it is possible to envision a more sustainable future, based on innovative technology platforms that currently exist across the three horizons of urban technical innovation. Those familiar with attempting to implement technological change will be acutely aware that the forces opposing technological progress have tended to be stronger than those striving for change. Yet together, these innovations constitute the basis for the next major techno-social transition: to a green economy (Fulai 2009). It seems apparent that in each of these domains, institutional change will prove more challenging to achieve than technological change (Geels and Schot 2010; Newton 2012).

Transition to eco-city

Transition to eco-city is a 21st century challenge and, as represented in Figure 7, is speculative. It is a transition yet to be figured out.

<INSERT FIGURE 7 NEAR HERE>

The 20th century witnessed a transformation of cities in what are now classified as developed societies from an industrial phase of development centred on the (mass) manufacture of tradeable goods (and their archetypal production landscapes) to one based on services and consumption (and their equally familiar landscapes). It was also a century that saw many societies grasping the opportunities provided by the globalization of production to move out of poverty. Urbanization has been a feature of both these phases of industrial evolution.

Transition to eco-city involves a more complex and multi-faceted process, however, than the socio-technical transformation of specific urban infrastructures. The performance criteria established for eco-cities extend beyond environmental sustainability to include competitiveness and productivity, liveability and social inclusion. At yet finer granularity, an eco-city needs to reflect such features as walkability, optimal mix of land uses, small ecological footprint, healthy population and environment, strong local economy with national and global connectivity and so on (Figure 8). How a city is spatially configured to deliver such outcomes requires a search for new place-making models of urban planning. Green urbanism has been advanced as one such model (Calthorpe 2010; Lehmann 2010; Newton 2012), in that it engages with the three principal spatial arenas of cities – greenfields, brownfields and greyfields – each with their own particular geographies, challenges and opportunities.

<INSERT FIGURE 8 NEAR HERE>

The processes required for transition to eco-city require a step change in innovation. In listing key processes associated with sustainable urban development, examples are increasingly emerging of instances where a particular jurisdiction or organisation has advanced thinking and practice beyond that which could be classed as ‘business as usual’. In an increasingly networked world, the identification and ‘posting’ of such instances of innovation and their rapid communication via the internet as well as face-to-face contacts provides some basis for optimism that broad based sustainable urban development may become a reality in the 21st century. Key arenas for urban innovation include:

- ▶ **Principles** for sustainable urban development, e.g. *Melbourne Principles for Sustainable Cities* (UNEP 2002, <http://www.iclei.org/fileadmin/user_upload/documents/ANZ/WhatWeDo/TBL/Melbourne_Principles.pdf>);
- ▶ **Envisioning** what a particular city should become: a realistic image of a not too distant future, e.g. *Guide to Copenhagen 2025* (Sustainia 2012, <http://issuu.com/sustainia_me/docs/cph2025?mode=window&backgroundColor=%23222222>); narratives of a possible future capable of capturing the imagination and support of a metropolitan population;
- ▶ **Leadership** by individuals with a capacity to be change agents, e.g. as represented by the C40 Cities Leadership Group, <<http://live.c40cities.org/>>;
- ▶ **Urban policy** which conveys an aspirational public statement, usually by the government of the day, concerning long-term objectives for cities, e.g. COAG 2009, <http://www.coag.gov.au/coag_meeting_outcomes/2009-12-07/index.cfm#cap_city_strat>;

- ▶ **Urban governance** operates within a spectrum of political systems ranging from pluralist liberal democracies to one party states, and across different tiers ranging from national to local. Decision making arrangements will vary substantially, but ‘successful’ cities have been found to reflect a common set of themes: high and sustained level of public engagement, consistency of strategic direction, collaboration across different sectors of society, regional cooperation and a political will for cooperation (Kelly 2010, <http://grattan.edu.au/static/files/assets/69a79996/052_cities_who_decides.pdf>);
- ▶ **Strategic urban planning** which articulates the spatial form and functioning of a city considered capable of best delivering future competitiveness, liveability, sustainability and social inclusion, e.g. as represented in *Metro Vancouver Regional Growth Strategy*, <<http://www.metrovancouver.org/planning/development/strategy/Pages/designations.aspx>>;
- ▶ **21st century information platform and planning/design tools** enabling visualization and real time performance assessment during design, construction and management based on digital information platforms, e.g. Esri 2012, <<http://video.esri.com/series/66/2012-geodesign-summit>>;
- ▶ **Implementation processes** – where most urban planning comes unstuck (Mees 2011); a *traditional* planning process can be represented as: top-down (elites) → impose plan → community resistance (slow or no progress) versus alternative *new* process characterized as: multi-level (multi-actor) → engagement → consensus plan (implementable) (Roggema 2012);
- ▶ **Exemplars** are evidence-based best practice innovations capable of broad replication, e.g. Ecocities Emerging, <<http://www.ecocitybuilders.org/ecocity-newsletter/>>; Living Labs Global, <<http://www.livinglabs-global.com/>>; Pecan Street Inc., <<http://www.pecanstreet.org/>>; *replicable* exemplars are the holy grail;
- ▶ **Measurement and monitoring.** Peter Drucker is credited with the proposition that ‘what gets measured improves’. It is critical to assess how cities are performing against eco-city targets established in urban policies or strategic plans (Sustainable Seattle, <<http://www.sustainableseattle.org/programs/regional-indicators>>; State of Australian Cities 2011, <http://www.infrastructure.gov.au/infrastructure/mcu/soac_files/00_INFRA1267_MCU_SOAC_2011_FA1.pdf>.

Taken together, these provide a process for delivering the future eco-city.

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Table 1. Comparative assessment of low emission energy technologies in Australia, 2012

Energy domain	Scaleability	Current costs, trends	Extent of commercial deployment	Prospects for private sector involvement	Government barriers
Wind	Could supply ~ 20% Australia's electricity needs	Potential for rapid scale-up	Significant deployment underway	Significant, given effective subsidy via 20% renewable energy target	Grid infrastructure and system integration needs to be improved; some community resistance to wind farm noise
Solar PV	Could generate >30% with grid integration management and storage	Costs are fair and falling rapidly	Already widespread, but not yet at scale to impact grid	Growing strongly, but dependent on government subsidies	Large-scale deployment constrained by integration with electricity grid
Concentrating solar power	Resource sufficient to meet total national needs; thermal storage and gas cogeneration needed to overcome intermittency	Currently non-commercial; costs likely to decline with development and broader deployment	Some deployment overseas; currently higher cost c.f. wind, solar PV	Some activity in Australia; dependent on government subsidies	Grid infrastructure and system integration need to be improved for remote sites (cf. wind)
Geothermal	Abundant resource could underpin a major contribution	Reliability and costs highly uncertain; still at development stage	Minimal deployment in Australia; private companies involved in exploration	Investor confidence required for the more difficult hot rocks resource	More government involvement in resource mapping, grid development and clear regulatory framework

Carbon capture and storage (CCS)	Could contribute significantly and extend life of existing coal and gas plants	Projected costs competitive but not proven; early costs high due to development costs	Only deployed for gas production fields which are less complex than CCS for power generation	Absolute size of investment major barrier for early mover	As above
Nuclear	Could meet a large proportion of national electricity needs	New build costs uncertain as few new plants in last 25 years	Widespread deployment overseas in past, but little recently in high income countries and none in Australia	High costs; significant financial and regulatory risks	Challenge of winning public support as well as legal and regulatory frameworks
Bioenergy	Significant energy available, although unlikely to be more than 20% of energy demands given competing needs for food. Easy to control short-run output to meet peak daily demand, but some seasonal variation	Not competitive unless supply chain from production to transport improved, likely to take over 10 years. Local customization required, particularly for nature of demand for electricity and heat and feedstock. Commercial viability also may be enhanced through improvement to reduce minimum economic scale to <5MW plants	Employed at significant scale in a number of countries and the combustion technology well understood. Feedstocks with greatest potential in Australia only deployed in a handful of projects	Several private sector developers already involved in Australia. At current costs, some form of additional government support will be necessary for meaningful levels of project development	Grid infrastructure and system integration needs to be improved to cater for connection of large number of relatively small power stations in regional areas

Source: derived from Wood and Edis (2012)

Table 2. Greening the economy: key sectors and green goals

Industry sectors	Green goals associated with sector
Manufacturing	Cradle-to-cradle; closed loop production; industrial ecology
Energy utilities	Renewables; distributed (local) generation; green design
Water utilities	Integrated (stormwater, wastewater) systems; water sensitive urban design
Waste	Recycling, reuse; eco-industrial development
Construction	Smart, green building; virtual design and construction; life cycle analysis
Trade (retail/wholesale)	Zero waste (packaging, food etc.); carbon management
Transport	Hybrid, electric, hydrogen vehicles; land use integration
Finance and property	Green accounting; urban retrofitting; building accreditation
Services	Zero waste; reduced consumption, carbon management; e-services
Government	Green procurement; de-coupling policies; sectoral decarbonizing schemes; regulation

Table 3. Three horizons of urban innovation

Urban environmental domain	Level of innovation		
	Horizon 1	Horizon 2	Horizon 3
Energy	Energy efficiencies in housing and industry; dwelling energy rating; appliance rating	Distributed renewable and low emission energy generation systems; methane bridge (substitution of gas for coal)	Renewables-based solar-hydrogen or solar-electric economy
Water	Water-smart appliances; domestic rainwater tanks; desalination	Sewer mining; water sensitive urban design	Integrated urban water systems (recycled stormwater and wastewater)
Waste	Product stewardship; waste separation and recycling; domestic composting	Extensive cradle-to-cradle manufacturing based around single enterprises, e.g. motor vehicles, computers, building products	Eco-industrial clusters based on utilization of multiple waste streams
Transport and communications	Road pricing; high speed rail; telepresence via broadband internet communications	Hybrid and electric vehicles; telecommuting, teleshopping, telebanking etc.	Integrated transport and land use; intelligent transport systems; e-mobility
Buildings	Checkbox system for green building design; tall buildings	Real-time lifecycle sustainability performance assessment during design; building information models; hybrid buildings	Ultra-smart buildings and linked infrastructures; green building materials with embedded intelligence

Source: Newton (2012)

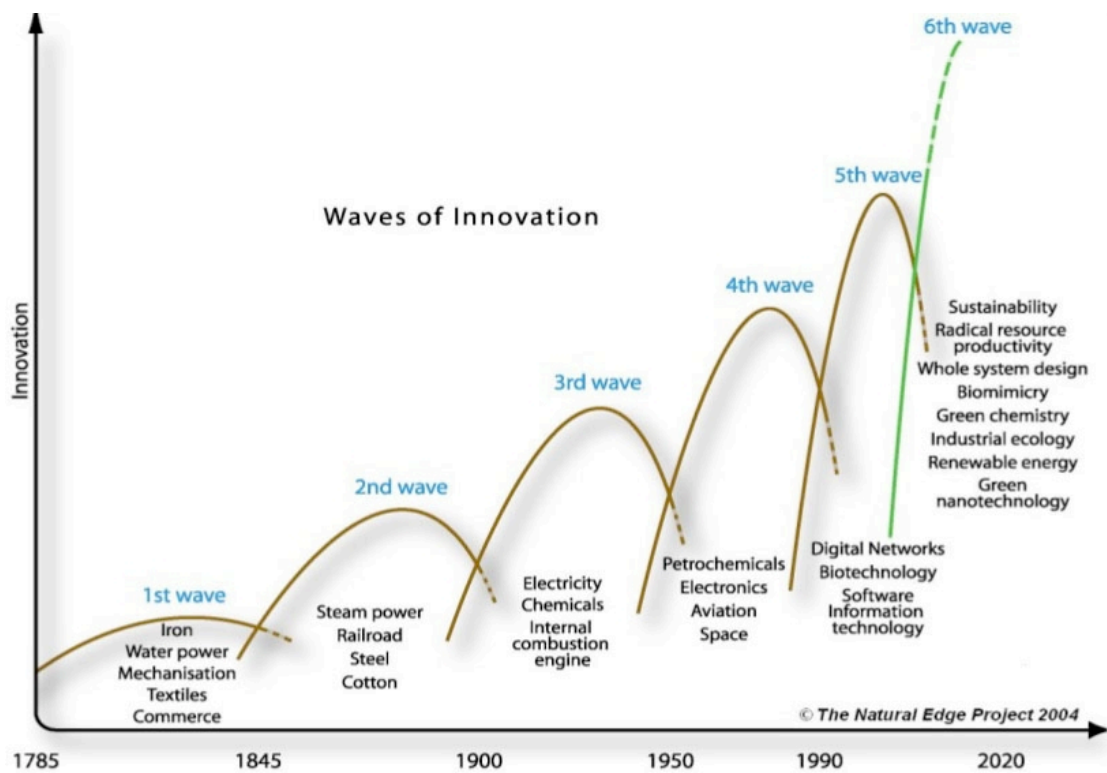


Figure 1. Major societal scale techno-economic transitions

Source: Hargroves and Smith (2005)

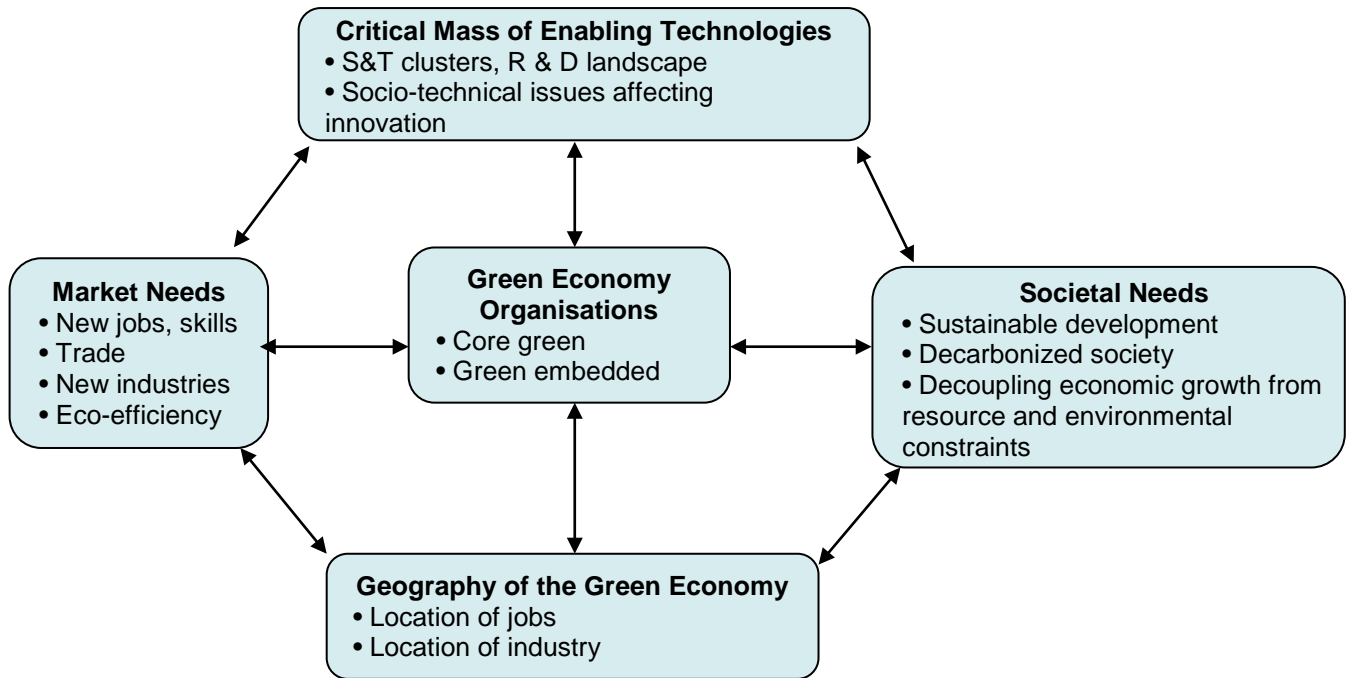


Figure 2. Conceptual framework for exploring green economy arena

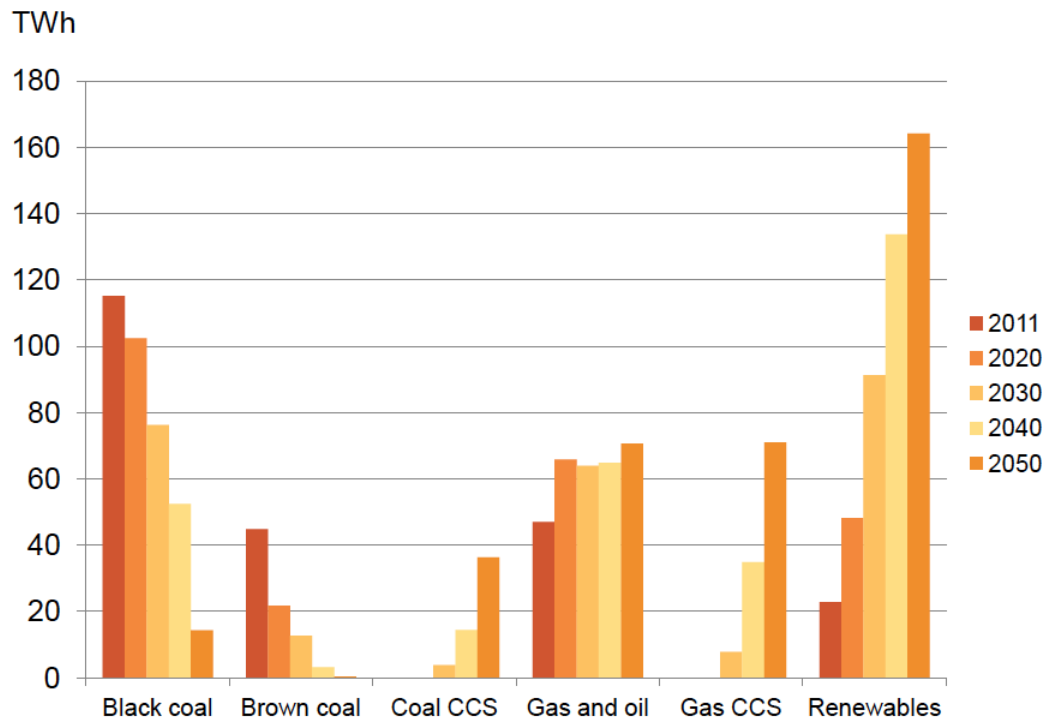


Figure 3. Projected sources of Australian electricity generation under average of 450 ppm and 550 ppm scenarios

Source: Australian Treasury(2011) *Strong Growth, Low Pollution: Modelling a Carbon Price*, Commonwealth of Australia, Canberra

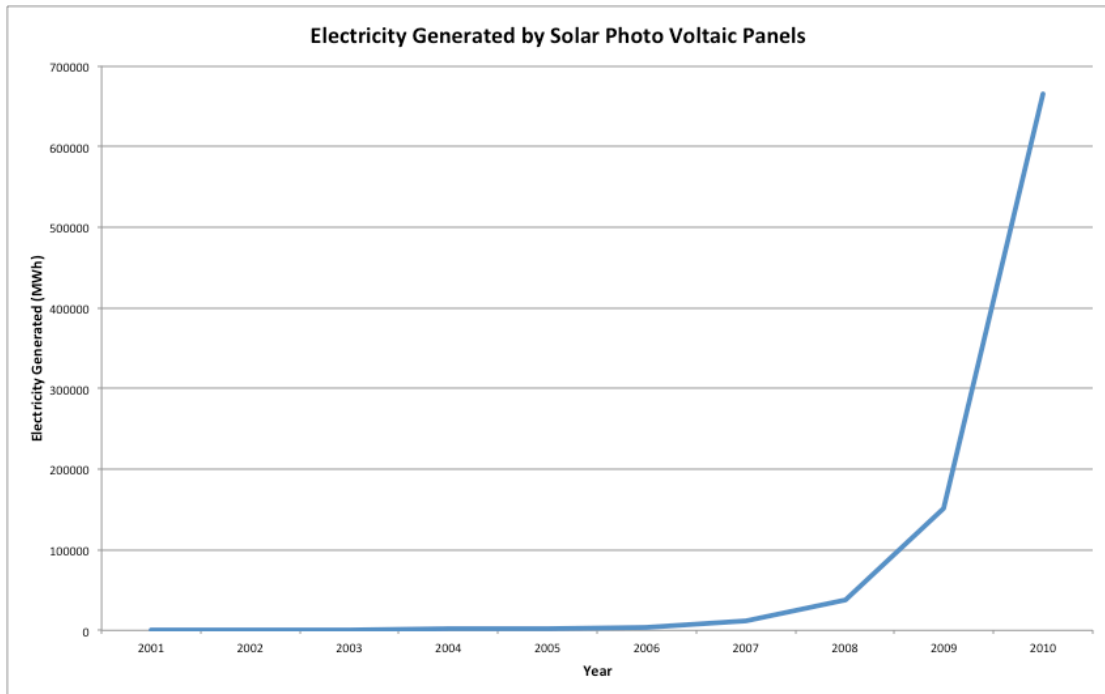


Figure 4. Growth of solar photovoltaic electricity generation in Australia

Source: calculated from data provided by Office of the Renewable Energy Regulator, Canberra.

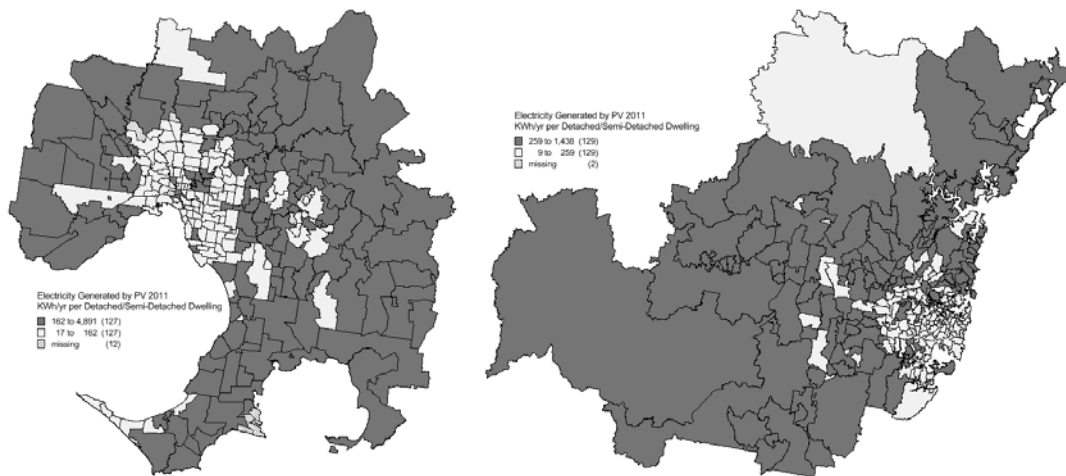


Figure 5. Installed solar PV capacity in Melbourne and Sydney by postcode (to December 2011)

Source: data provided by Clean Energy Australia

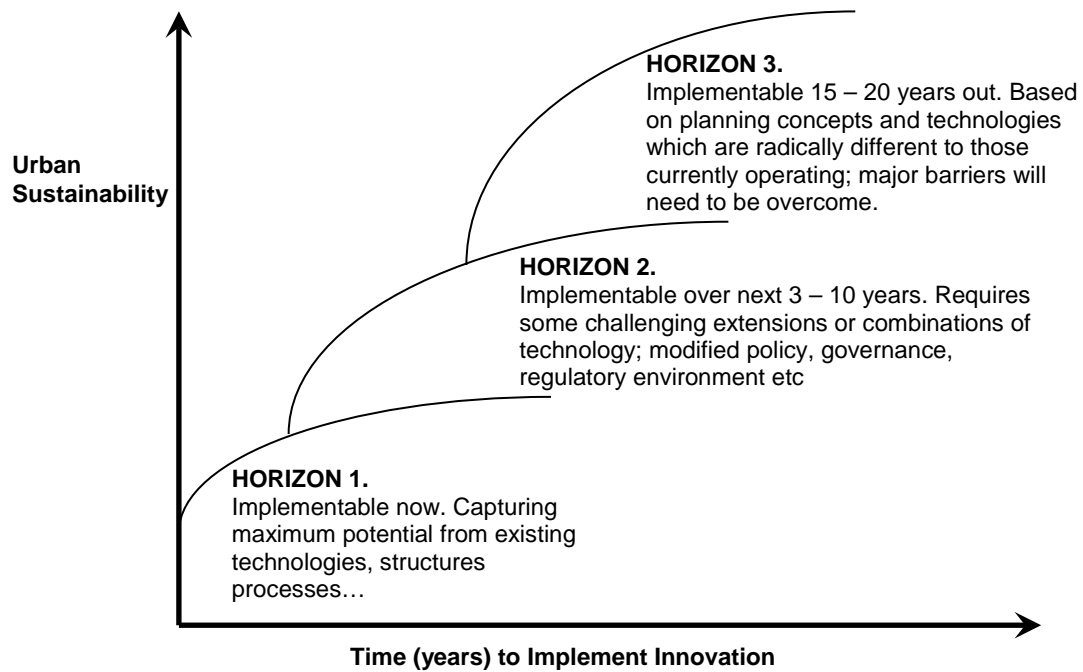


Figure 6. The three horizons of urban technology innovation

Source: Newton (2007)

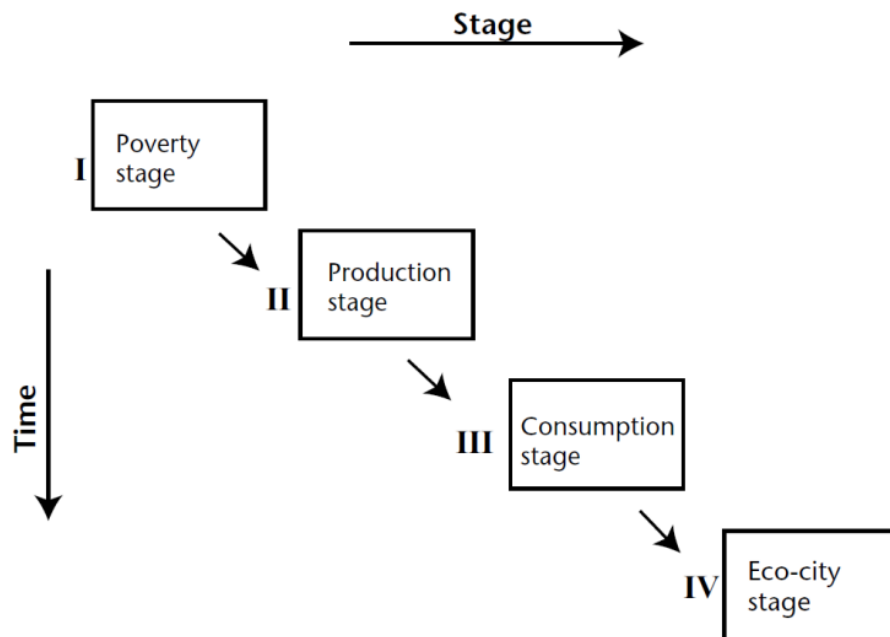


Figure 7. Stages of urban environmental evolution

Source: Bai and Imura (2000) in Newton and Bai (2008)

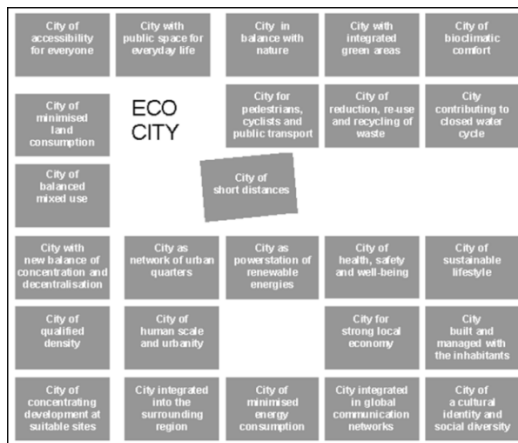


Figure 8. Principal features of an eco-city

Source: *Ecocity Builders*, July 2012,

<<http://archive.constantcontact.com/fs072/1100594362471/archive/1110372977492.html>>