ATTACHMENT B

TECHNICAL APPENDIX: ENERGY EFFICIENCY MASTER PLAN FOUNDATION REPORT

ATTACHMENT B

Energy Efficiency Master Plan – Foundation Report

transport | community | industrial & mining | carbon & energy

pitt&sherry

Prepared for:	**City of Sydney**
Date:	**2 February 2015** **Rev 01**

In association with:

EXERGY

sustainable*thinking*®

Table of Contents

List of figures

List of table

Appendix A References

Addenda No.1 City of Sydney Energy Efficiency Master Plan Foundation Report

Prepared by: ………………………………………………………. Date: 2 February 2015
Phil Harrington

Reviewed by: ………………………………………………………. Date: 2 February 2015
Phil McLeod

Authorised by: ………………………………………………………. Date: 2 February 2015
Phil Harrington

Revision History					
Rev No.	**Description**	**Prepared by**	**Reviewed by**	**Authorised by**	**Date**
00	Energy Efficiency Master Plan – Foundation Report	P. Harrington	P. McLeod	P. Harrington	27/03/2014

Glossary

ABCB	Australian Building Codes Board
Anthropogenic Climate Change	Human-induced climate changes caused primarily by combustion of fossil fuels, but also land clearing and other activities.
BCA	Building Code of Australia (also known as the National Construction Code or NCC)
Benefit cost ratio	The present value of benefits (associated with a measure or scenario) divided by the present value of costs
Business-as-usual	A projection of energy consumption or greenhouse gas emissions based on the assumption that all existing policy measures remain in place, at their current stringency, and that no new measures are introduced
CO_2-e	Carbon dioxide equivalent
Discount rate	The (interest) rate at which future benefits or costs are discounted to the present value
Economic potential	The potential for energy savings that are cost effective (social benefit cost ratio >1)
EEO	The Energy Efficiency Opportunities Program
Energy efficiency	Energy efficiency is defined as the amount of *useful work* or *output* that results from using energy. Energy efficiency is higher when more useful work or output is achieved with the same amount of energy use, or when less energy is used to achieve the same amount of useful work or output as before
Energy intensity	Energy intensity is the inverse of energy efficiency: it is defined as the energy consumption per unit of output or area. For buildings, this is generally expressed in units of megajoules of energy per square metre of floor space per annum ($MJ/m^2.a$)
Frozen efficiency	A counter-factual projection of energy consumption or greenhouse gas emissions based on the assumption that energy intensity remains constant over time
GFA	Gross floor area
Incremental benefit	The *additional* benefit (energy savings) associated with a higher energy efficiency investment, relative to an industry standard (or minimally code compliant) investment
Incremental cost	The *additional* cost associated with a higher energy efficiency investment, relative to an industry standard (or minimally code compliant) investment
MJ	Megajoule – a unit of energy consumption equal to 10^6 Joule or 0.278kWh of electricity
MEPS	Minimum energy performance standards (and/or labelling)
MUDS	Multi Unit Dwellings

Mt CO_2-e	Million tonnes carbon dioxide equivalent
Net present value (NPV)	The present value (in today's dollars) of a stream of revenue (benefits or costs) over time, discounted (at 7% real discount rate in this report) to account for 'time preference' or the 'time value of money'
Policy potential	The potential for energy savings expected to be realised by a defined set of policies
Section J	A section of the Building Code of Australia that specifies energy performance requirements
Stringency	Refers to the degree of change enforced by a policy measure – normally a regulatory measure: a measure with high stringency would impose significant energy savings, while measures with low stringency requires fewer energy savings
SQM	Square metres
Technical potential	The potential for energy savings regardless of cost
TJ	Terajoule – a unit of energy consumption equal to 10^{12} Joule or 278,000 kWh of electricity

Assumptions and Data Sources

BASIX	The NSW Basix scheme is assumed to over-ride BCA energy performance requirements for residential buildings in NSW. Assumptions about the energy savings attributable to BASIX are drawn from NSW Planning publications and Energy Australia (2010) - see References. Generally we assume full compliance with existing BASIX targets (differentiated by dwelling type), although compliance is phased in over the early years. No new BASIX targets are assumed in the business-as-usual scenario.
Building Code of Australia (BCA) – Section J	The energy savings effect of the BCA (Section J) is modelled separately for BCA (2006) and BCA (2010), drawing on the relevant RIS's (see References). There is uncertainty about the extent to which Section J (commercial buildings) applies to major refurbishments (see also Major Refurbishment Rate), and it is often argued that there is under-compliance with Section J requirements. While the extent of any under-compliance is not known, an under-compliance effect has been modelled – based on an assumption that one third of the area refurbished annually is upgraded to current Code standards. No new Section J requirements are assumed in the business-as-usual scenario. For residential buildings, we assume some under-compliance with BASIX in past years (based on Energy Australia evidence for Class 1 only), but then assume actual compliance matches that claimed/published by NSW Planning (for want of better data).
Building Floor Area Growth	Most building types experience a net annual increase in GFA of 0.8%. However, in the residential sector the assumed growth rates are 0% per year for detached dwellings, 0.3% per year for semi-detached dwellings, and 2.1% per year for multi-unit dwellings. These values are consistent with other planning outlooks and Master Plans by the City of Sydney. Data source: CCAP.
Commercial Building Disclosure (CBD)	CBD is modelled based on data from the CBD program, together with assumptions from the relevant RIS (see References). Note that at the time of analysis, only 12 months of actual data was available for this program. Given the high penetration rate expected for CBD (in offices > 2000 sqm), we assume declining savings through time due to the saturation effect of the same space being rated many times. Savings are reported jointly with NABERS due to interactions between the two measures.
Data Centres	Data centres are not separately resolved in the model. Larger data centres are likely to be high voltage connections, and Ausgrid does not publish energy consumption at high voltage connections. The energy consumption of smaller data centres (low voltage connection points), and also of other ITC equipment in buildings, is captured in the model and distributed by building type and end-use (eg, 'equipment').

Demolition Rate	1% per year for all building types, and that demolished buildings are replaced the following year. This value represents a 'rule of thumb' assumption in absence of specific information.
Embodied Emissions	This study examines emissions associated with the use of electricity and natural gas in the *operation* of buildings; it does not examine emissions embodied in materials used buildings or in the construction process, nor emissions associated with the use of minor fuels such as LPG.
End use shares	End use shares for gas and electricity are generally sourced from COAG (2012), and estimated for those building classes not covered by that source. For example, car-parks are not resolved in COAG (2012) and are assumed to be 100% electrical. End-use shares are assumed to remain constant over the projection period (to 2030).
Energy consumption data	Historical energy consumption data (2006 – 2012) is sourced from Jemena (gas) and Ausgrid (electricity), directly and via CCAP. Note that gas consumption data is not differentiated by customer type, while electricity data is split into residential (general and hot water) and commercial (greater and smaller than 160 MWh/y). Consumption at high voltage electricity connections is not reported for confidentiality reasons.
Energy intensity of buildings	See Table 11 for details. Data sources for 2006 energy intensity include CCAP (residential only), COAG (2012) and BZE (2013). The path of energy intensity by building type post-2006 reflects the effect of energy efficiency measures at the level of individual building types.
Floor Area	Floor area data by building type is detailed in Section 4.2. Total floor area in 2006 (base year) was 33.9 million sqm, and it is projected to grow to nearly 43.8 million sqm by 2030 (a 29% increase). The data source is the City of Sydney's Floorspace and Employment Census 2006. See Section 4.2 for details.
Fuel Coverage	Consumption of electricity and natural gas only is modelled; minor fuels (LPG, fire wood) are not considered.
Fuel Mix	Fuel mix assumptions by building type are drawn from COAG (2012), modified where necessary to balance with actual historical data regarding electricity and gas consumption in the LGA. Fuel mix trends through time reflect the differing impact of electricity and gas savings measures.
Greenhouse Intensity Factors	The greenhouse gas intensity of electricity supply to the Sydney LGA is assumed to fall gradually by around 12% over the period to 2030, reaching 258 t CO2-e/TJ[1]. Natural gas is assumed to have a constant emissions intensity of 65.4 t CO2-e/TJ. Both gas and electricity emissions intensity are measured using the full fuel cycle, in order to reflect emissions associated with transmission and distribution in addition to production/generation.

---

[1] The Trigeneration Master Plan assumes higher values, notably for the period 2020 – 2030.

Green Star	Energy savings attributable to Green Star are modelled based on data sourced from the Green Buildings Council of Australia. As this data is reported only by State (and not LGA), assumptions were sourced from the City of Sydney regarding the uptake of Green Star in the LGA. Due to interactions between the measures, energy savings from Green Star, NABERS, CBD and related City of Sydney programs (Better Buildings Partnership, City Switch) are reported jointly. As with other policy measures, no change to current stringency levels is assumed in the business-as-usual scenario.
Incremental Savings	The energy and emissions savings over time of those measures that were already in place in the base year for this study of 2006 are estimated as *incremental* savings over those that were being achieved in 2006, as their savings in 2006 are by definition already captured in the measured energy consumption in 2006. This is important to avoid double-counting savings.
Major Refurbishment Rate	We assume a rate of major refurbishment, sufficient to trigger the application of Section J of the current version of the Building Code of Australia (or BASIX for residential buildings) to all major energy using systems, of 1% per year for all building types. This assumption is based, in turn, on an industry 'rule of thumb' of around a 3% refurbishment rate on average across the building stock. We assume that only one-third of these refurbishments trigger Section J.
Minimum Energy Performance Standards (MEPS) and Labelling	MEPS and labelling are modelled based on Wilkenfeld (2009), separately for commercial/industrial and residential equipment/appliances. Note that an update of this reference may be published in the near future. Changes to the program since 2009 are not reflected in our estimates, making them somewhat conservative. We have applied projected savings in percentage terms to our own energy consumption baseline, which is notably lower than in the above reference. Post 2020 (the reference analysis ceases at 2020) we have assumed increasing savings but at a diminishing rate, due to saturation effects (when a MEPS-compliant product is replaced, at end of life, with another MEPS-compliance product, no additional savings arise. Note that this reflects an assumption of no new MEPS or changes in stringency of existing MEPS under the business-as-usual scenario.
NABERS	Energy savings attributable to NABERS are based on reporting from the NSW Office of Environment and Heritage, including an average reported savings rate of 9% for buildings rated more than once. Assumed future uptake rates vary by building class, but are capped at 90% for offices. As with other measures, we assume no change to current NABERS settings in the business-as-usual scenario (eg, no new building classes covered). Savings are reported jointly with Green Star and CBD due to interactions between these measures.
NSW Energy Savings Scheme (ESS) and Action Plan	ESS is modelled based on recent analysis released by NSW OEH (see References). The savings estimates commence in 2011, and this underestimates past savings from ESS and its predecessors. Additional data may be able to be sourced from OEH with respect to the latter. Consistent with the 'business as usual' scenario

	conventions, we do not include any energy savings that may be associated with future actions noted in the recently-released NSW Energy Efficiency Action Plan.
Other Master Plans	No account is taken of the expected outcomes of the City of Sydney’s Trigeneration or Renewable Energy Master Plans, in order to avoid double counting the benefits of these Plans.
Policy Environment	All major policy measures now in force remain in force to 2030 at their current levels of stringency, except where an end-date is already planned or announced (as in the case of carbon pricing); and no new policy measures are introduced (except as modelled for this project).

Executive Summary

Objectives and Background

This Foundation Report aims to provide a sound and detailed evidence base upon which the City of Sydney can craft an ambitious but achievable *Energy Efficiency Master Plan*. In particular, the focus of this Report is to quantify the potential for energy savings, and associated reductions in greenhouse gas emissions, that could be realised in buildings in the City of Sydney local government area, over the period to 2030, under a range of different scenarios.

The driver behind this project is the City's objective of achieving a 70% reduction in greenhouse gas emissions by 2030 over a 2006 base. This objective was adopted in the context of the *Sustainable Sydney 2030* community strategic plan.

Acknowledgements

This Report has been prepared with the benefit of extensive reviews at preliminary findings and Draft Report stages by City of Sydney staff, an external reference group, the *Better Buildings Partnership* and international reviewers. While the analysis remains that of **pitt&sherry**, we warmly appreciate the extensive input and feedback from stakeholders.

Disclaimer

We present a number of energy efficiency scenarios in this Report, and it is important to stress that there are uncertainties associated with each. The results reported should be interpreted as indicating the *likely scale* of cost-effective energy and emissions savings opportunities. They should not be interpreted as forecasts. Actual energy and emissions outcomes will be affected by factors such as the national, state and local policy environment; energy prices; resource costs; the greenhouse intensity of electricity supply; overall investment activity levels and the impacts of the whole suite of Master Plans (particularly those on Renewables and Trigeneration, in addition to Energy Efficiency).

Second, it should not be assumed that the average savings or costs indicated for a given building class could be achieved in *all* buildings in that class – for some buildings, the potential will be less than indicated and/or the cost of achieving energy savings higher, while for other buildings, the potential will be greater and/or more cost-effective than the average values we report.

Key Findings

Baseline Projections of Energy Consumption

Figure 1 below shows, firstly, a hypothetical energy consumption trend that would occur if energy efficiency were frozen at 2006 levels until 2030 (known as a 'frozen efficiency' scenario). As the City of Sydney expects total floor area in the local government area to rise by some 29% over this period, then total energy consumption would be expected to rise by close to this amount (actually a little less than this - around 26% - due to expected changes in the mix of buildings over this time).

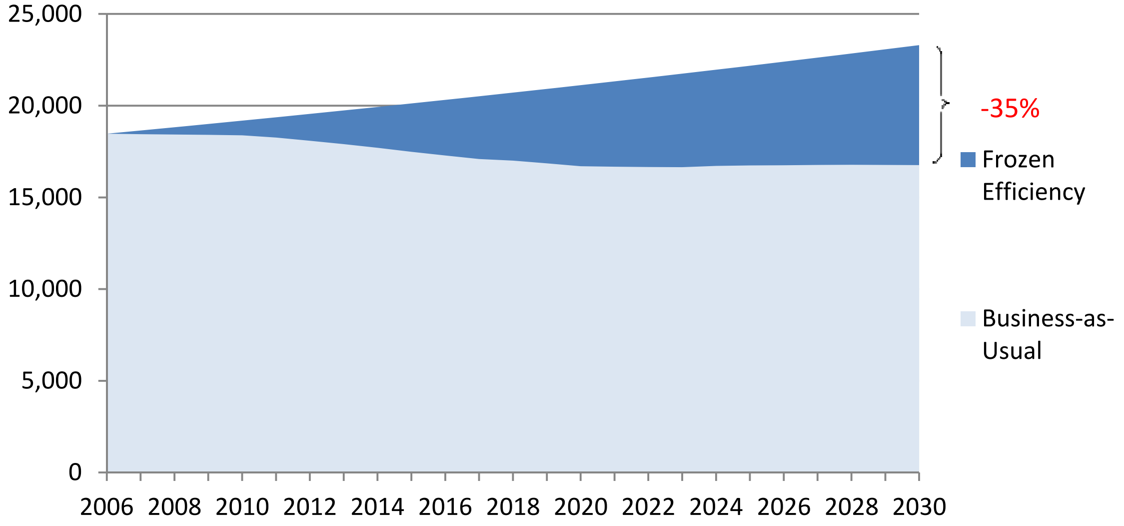


Figure 1: Building-Related Energy Consumption, City of Sydney, Frozen Efficiency vs Business as Usual (TJ)

However, Figure 1 also shows the energy savings that are expected under a 'business-as-usual' (BAU) scenario.[2] These savings are expected to arise due to existing policy measures, as detailed in Figure 2 below.

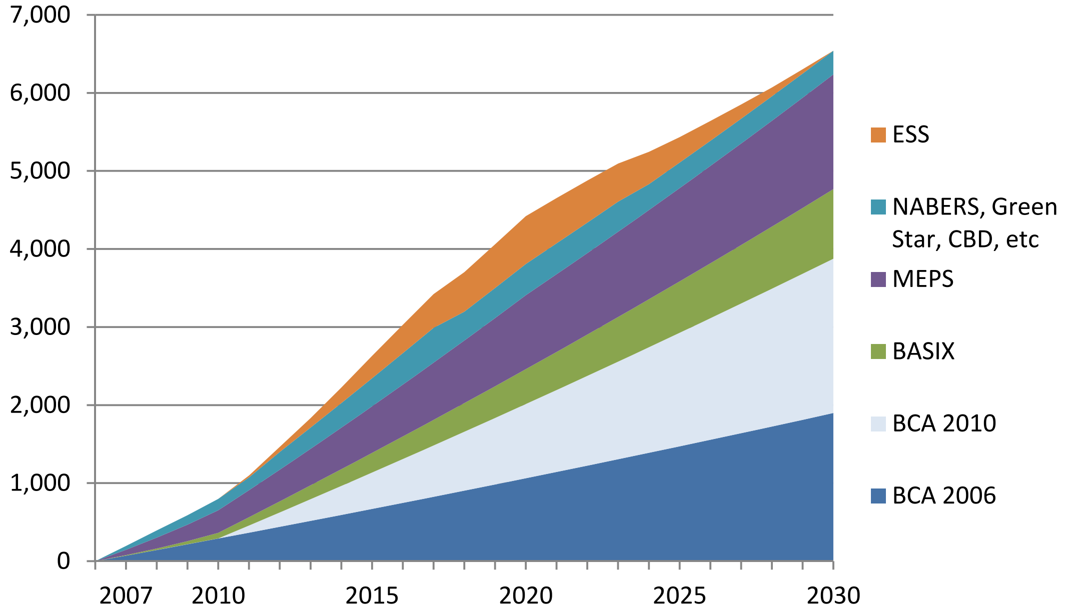


Figure 2: Energy Savings from Major Policy Measures, Business As Usual relative to Frozen Efficiency, City of Sydney (TJ)

---

[2] The 'frozen efficiency' scenario assumes that energy efficiency remains at 2006 levels until 2030 (no improvement), while the 'business as usual' scenario assumes that existing policy measures (except the carbon price) remain in place (and without change) until 2030.

As may be noted, the Building Code of Australia energy performance requirements (and BASIX for residential buildings), together with minimum energy performance standards (MEPS) and labelling for energy-using equipment and appliances, account for the majority of the expected energy savings. NABERS, Green Star, Commercial Building Disclosure and the NSW Energy Saver Scheme[3] also make significant contributions. Total savings from all measures are modelled at a substantial 6,500 TJ, compared with frozen efficiency. This amounts to a saving of some 35% relative to frozen efficiency (as shown on Figure 1).

When compared with actual energy consumption in 2006 (of around 18,500 TJ), then total energy consumption in the LGA is projected to fall by around 9% (26% increase – 35% decrease = 9% net decrease) to some 16,800 TJ by 2030. The savings from the existing energy efficiency measures are expected to more than offset the energy consumption growth pressure from additional floor area within the city.

This 'BAU' projection - of falling demand for energy, even without further policy measures - represents a significant departure from baseline assumptions that may have been made in the past. Until around 2008, rising annual energy (particularly electricity) consumption has been the norm in Australia. However a combination of modest economic growth (recent and projected), energy efficiency measures, and behavioural responses to higher energy prices, have led to a structural reduction in the demand for energy in buildings. It is likely that saturation of key energy end-uses (such as space conditioning) is also contributing to this effect. Generally we expect these effects to persist through to 2030, although there are risks which are discussed further below.

Energy Savings Beyond Business-as-Usual

We examine the potential for energy (and greenhouse emissions) savings beyond business as usual under three broad scenarios:

- Technical opportunities (those available regardless of cost);
- Economic opportunities (those that are cost effective); and
- Policy opportunities (those that are expected to be achieved by defined policy measures).

In order to estimate total energy and greenhouse savings potentials, we also model two different rates of take-up of the economic and policy opportunities. We describe rather than model the technical opportunities, as these opportunities may not be cost effective and may also be subject to technical risk, at least until new technologies and designs are proven.

Noting the qualification above, it is nevertheless clear that the *technical* potential for energy savings in buildings is very high. Leading edge technologies and solutions can deliver energy savings of 90% or more are available in some applications (like lighting or ventilation in areas that are currently over-serviced (eg, where natural lighting or ventilation is available). For the core energy using systems in buildings – space conditioning, ventilation, lighting, appliances and equipment, and domestic hot water – savings potentials are highly context dependent but can reach 80% when compared to default solutions.[4] These values are more likely to be achieved in new buildings, but potentially also with retrofits.

---

[3] Note that at the time this measure was modelled, it was scheduled to end in 2020, hence the declining savings after this date shown in Figure 2.

[4] USEPA (2010)

However, not all of the technical opportunities will be cost effective to implement now, and their degree of cost effectiveness in future may depend on a host of factors such as economies of scale in their production, reductions in their cost and (often) improvements in their reliability or performance, as well as energy prices locally. Buildings are complex systems and their energy performance context-dependent. The technical potential for energy savings depends on the building's design, the way in which components and design features are integrated into the whole building, and the way in which the building is used by its occupants. New technologies may well bring even higher savings potentials as we move towards 2030, but it is also possible that whole new classes of energy-using technologies may also arise that are not currently anticipated.

We find that the *economic* potential for cost-effective energy savings is also high. This scenario has been modelled using real-world data from investments already undertaken, including in buildings in Sydney, and therefore we consider this scenario to be fully achievable. Energy savings of 26% overall (around 21% for residential buildings and 27% for commercial) are cost effective, relative to 2006 consumption levels, with full take-up of the cost-effective opportunities by 2030 (see Figure 3 below).

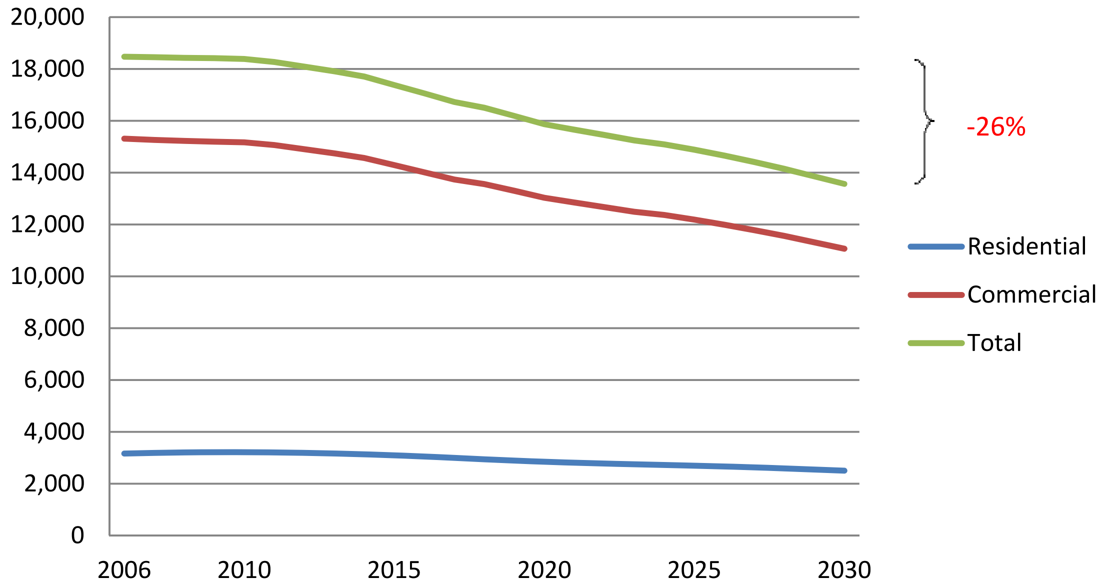


Figure 3: Energy Consumption with Rapid Uptake of Economic Potential, City of Sydney (TJ)

We stress that this is a conservative estimate of economic potential, due to the fact that we have based it on proven and existing opportunities. This is evidenced by the attractive economics associated with this scenario (see *Economic Performance of Savings Measures* below).

The third scenario – the (new) policy potential – is modelled to deliver somewhat greater energy savings than the economic potential scenario, with savings of around 29% overall (45% for residential, 26% commercial). However, this result assumes that *all* the new policy measures described are taken up. In reality, some are likely to be treated as alternatives (such as voluntary and mandatory disclosure of energy performance). Also, some measures (like higher energy performance requirements in the Building Code of Australia) may be beyond the direct scope of the City of Sydney to determine[5].
These energy savings scenarios are summarised in Figure 4 below.

---

[5] Although we note that some Councils in Australia are setting above-Code-minimum energy performance requirements for buildings through their planning schemes.

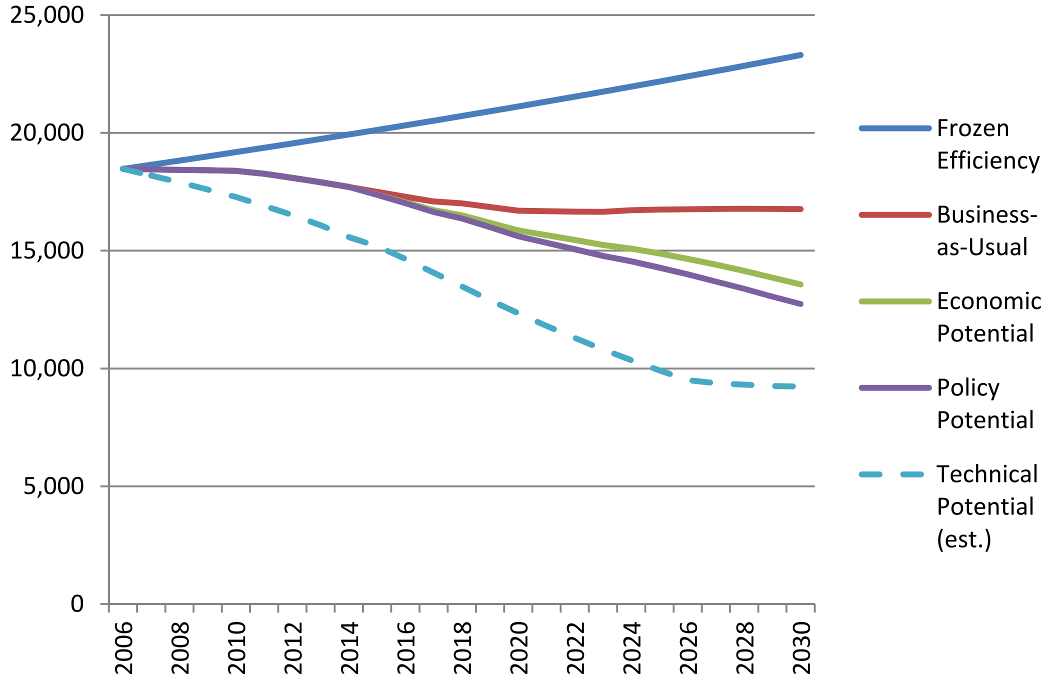


Figure 4: Building-Related Energy Consumption by Scenario, City of Sydney, 2006 – 2030 (TJ)

Table 1: Building Related Annual Energy Consumption by Scenario

Scenario	2006 (TJ)	2030 (TJ)	% change, 2006 - 2030
Frozen efficiency	18,473	23,305	+26%
Business as usual	18,473	16,765	-9%
Economic potential	18,473	13,652	-26%
Policy potential	18,473	13,136	-29%
Technical potential (est.)	18,473	9,236	-50%

Greenhouse Gas Emissions

The pattern of greenhouse gas emissions associated with the above energy scenarios is affected by two key factors. First, the greenhouse intensity of electricity consumption (greenhouse emissions per unit of electricity consumption) is expected to decline over time. This has been occurring, and is expected to continue to occur (by around 12% over the period to 2030), due to changing fuel mix used for electricity generation in NSW. In particular, coal use has been falling, while the use of gas and renewable energy sources has been rising. While the reasons for these changes are complex, we expect they will continue into the future, at least to some degree. This reflects the impacts of the ageing profile of coal plants, the national Renewable Energy Target[6], climate change policies (noting that the policy mix may change through time), and fuel price movements (rising gas prices and the abolition of carbon pricing will create greater 'headroom' for coal in future, but at the same time, renewable energy sources are generally moving to the lowest levelised cost of all the generation technologies)[7].

The second factor that affects the expected trends in greenhouse gas emissions in the City of Sydney area is a changing fuel mix. Generally our modelling shows greater savings in electricity use than in gas use. This effect tends to accelerate the greenhouse gas reductions associated with energy efficiency gains, as the greenhouse gas intensity of electricity consumption is over four times higher than that of gas.
As a result of these two factors, the growth in greenhouse gas emissions is less than the growth in energy consumption, even in a frozen efficiency scenario (11% growth in emissions vs 26% growth in energy). Similarly, the BAU and other scenarios show larger emissions savings in percentage terms than do the energy savings. See Figure 5 below. This is important for the City of Sydney, as its policy target is expressed in greenhouse rather than energy metrics.

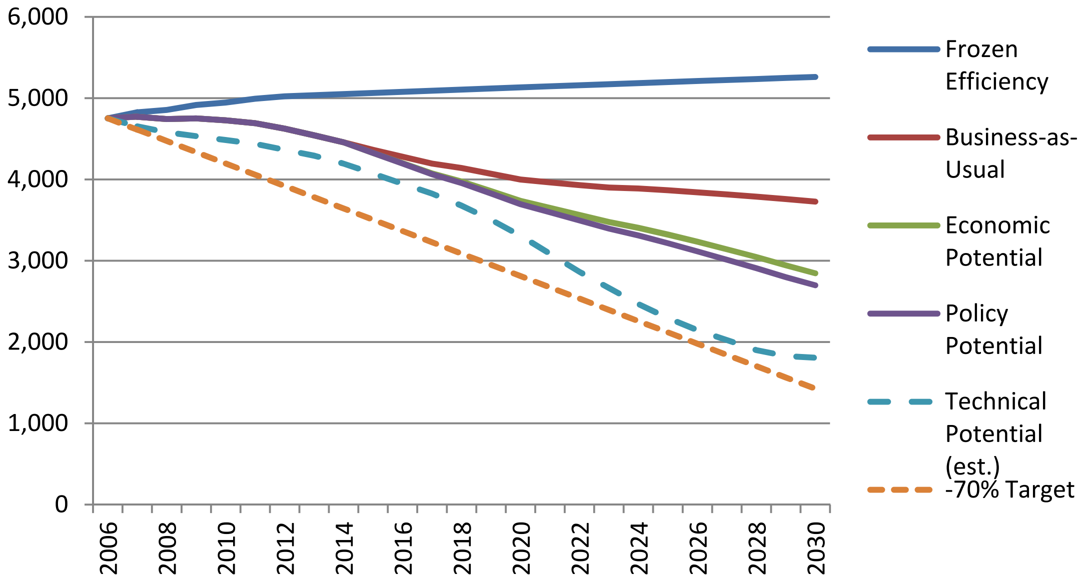


Figure 5: Building-Related Greenhouse Gas Emissions by Scenario: City of Sydney: 2006 – 2030 (kt CO_2-e)

---

[6] While this is currently under review, it is unlikely to be removed.

[7] See for example the Australian Energy Technology Assessment published by the Bureau of Resource and Energy Economics: http://www.bree.gov.au/publications/australian-energy-technology-assessments

Table 2: Building Related Annual Greenhouse Gas Emissions by Scenario

Scenario	2006 ($ktCO_2$-e)	2030 ($ktCO_2$-e)	% change, 2006 - 2030
Frozen efficiency	4,751	5,260	+11%
Business as usual	4,751	3,728	-22%
Economic potential	4,751	2,845	-40%
Policy potential	4,751	2,778	-42%
Technical potential (est.)	4,751	1,805	-62%
-70% Target	4,751	1,425	-70%

In summary, we project that full uptake of the economic potential for energy savings described in this report by 2030 would enable a 40% reduction in building-related greenhouse gas emissions to be realised. This would represent a fall of 1.9 Mt CO_2-e over the 2006 – 2030 period.

Economic Performance of Savings Measures

There a number of ways of analysing the economic performance of energy savings measures. Table 3 provides the highest-level analysis. For each sector and scenario modelled, it shows the net present value (NPV)[8] of energy savings over the 2015 – 2030 period (column 3), associated costs[9] (column 4), electricity infrastructure savings (column 6) and the NPV of the net financial savings (column 8, which is equal to columns 3 + 6 – 4). Column 5 shows the benefit cost ratios[10] considering energy savings and costs only (column 3 divided by column 4), while column 7 show the benefit cost ratios taking into account energy and infrastructure savings and costs (column 3 + column 6, divided by column 4). Infrastructure cost savings are discussed further below.

Table 3: Summary of the Economic Performance of Measures by Scenario and Sector

Scenarios (Rapid Uptake)	Sector	NPV of energy savings @ 7% ($m, 2014 real)	NPV of costs @ 7% ($m, 2014 real)	Benefit Cost Ratio (energy savings only)	NPV of infrastructure cost savings @ 7% ($m, 2014 real)	Benefit Cost Ratio (energy + infrastructure savings)	NPV of net financial savings @ 7% real
Economic Potential	Residential	$163.7	$77.1	2.1	$36.6	2.6	$123.2
	Commercial	$710.8	$514.0	1.4	$186.5	1.7	$383.2
	Total	**$874.5**	**$591.1**	**1.5**	**$223.1**	**1.9**	**$506.4**
Policy Potential	Residential	$389.2	$224.0	1.7	$90.1	2.1	$255.4
	Commercial	$230.1	$184.3	1.2	$154.9	2.1	$200.6
	Total	**$619.3**	**$408.3**	**1.5**	**$245.0**	**2.1**	**$456.0**

---

[8] Meaning the value in today's dollars of the stream of values - costs or benefits - over the period 2015 – 2050, discounted at 7% each year to allow for 'time preference' or the 'time value of money'.

[9] For the economic potential, these are investment costs only; for the policy potential, the values include investment costs, compliance costs and costs to government.

[10] The present value of benefits divided by the present value of costs.

We find that there is the potential to realise net financial savings of between $456 million and $506 million, in present value terms over the 2015 to 2030 period, if the policy potentials or economic potentials (respectively) described in this report are able to be realised. These financial benefits could be realised at the same time as achieving up to 1.9 Mt CO_2-e in greenhouse gas emission savings, as noted above. While this would clearly be an attractive outcome, there are risks and challenges associated with realising it (see *Risks and Opportunities* below).

Payback Period

A key reason why these two scenarios generate positive economic outcomes is that they are calling up investments that are fundamentally sound – that is, for the most part, they pay back in a short timeframe. Tables ES4 and ES5 below show that payback times for the groups of measures analysed in the economic potential is scenario are generally quite short, with the notable exception of lift upgrades (which are normally timed due to safety and design life considerations rather than energy efficiency – for this reason, we exclude lift upgrades from our opportunity set). Where the simple payback period is considerably shorter than the economic life of the investment, then these may be considered as cost-effective investments.

Table 4: Residential Buildings: Investment Parameters: Economic Potential Scenario

Measures	Unit capital cost ($2014real/m^2)	Unit electricity savings (kWh/m^2.a)	Unit gas savings (MJ/m^2.a)	Simple payback (years)	Economic life of investment (years)
New Builds - Detached	$ 2.79	3.0	5.3	3.0	10
New Builds - Semi-detached	$ 2.79	3.9	6.9	2.3	10
New Builds - Low-mid-rise MUDS	$ 9.78	11.6	20.5	3.0	10
New Buildings - High-rise MUDs	$ 14.9	14.8	26.2	3.5	10
Pool/pump upgrades	$ 0.28	1.1	3.3	0.8	10
Fans/VSDs	$ 0.63	1.9	0.0	1.3	10
HVAC Upgrades	$ 0.40	1.0	1.0	1.4	15
Lighting Upgrades	$ 0.50	2.3	0.0	0.9	7
Timers and Sensors	$ 0.69	0.9	0.0	2.9	8
Voltage Reduction	$ 2.68	2.9	0.0	3.7	10
Hot Water System Upgrades	$ 0.27	0.2	1.8	3.9	15
Building Management Systems	$ 2.35	1.9	0.0	4.7	10
Energy Savings from Water Savings Measures	$ 1.33	5.8	15.8	2.8	8

**For new builds, the investment life refers to fixed appliances only.*

Table 5: Commercial Buildings: Investment Parameters: Economic Potential Scenario

Measure	Unit capital cost ($2014real/m^2)	Unit electricity savings (kWh/m^2.a)	Unit gas savings (MJ/m^2.a)	Simple payback (years)	Economic life of investment (years)
New Builds	$111.33	87.0	74.0	7.0	10
Lighting upgrades	$3.83	4.8	0.0	3.5	7
HVAC upgrades	$23.60	15.3	8.9	6.5	15
Lift upgrades	$144.27	6.1	0.0	102.7	25
Appliance/DHW upgrades	$0.75	1.6	0.6	2.0	7

Abatement Cost Curves

Another way of assessing the financial performance of measures aimed at greenhouse emission reduction is to calculate their average cost of abatement.[11] As with all 'average' measures, it is important to note that not all investments will perform at the averages measured here – some will cost more and some will cost less. In Chapter 6 we present abatement cost curves for each building type and scenario, an example of which is shown below as Figure 6. The key information presented includes the marginal cost of abatement of the measures shown (on the vertical axis) and the cumulative abatement over the 2015 - 2030 period (on the horizontal axis). Note that a negative cost of abatement equates to a benefit cost ratio greater than 1, while a positive cost of abatement equates to a benefit cost ratio less than 1.

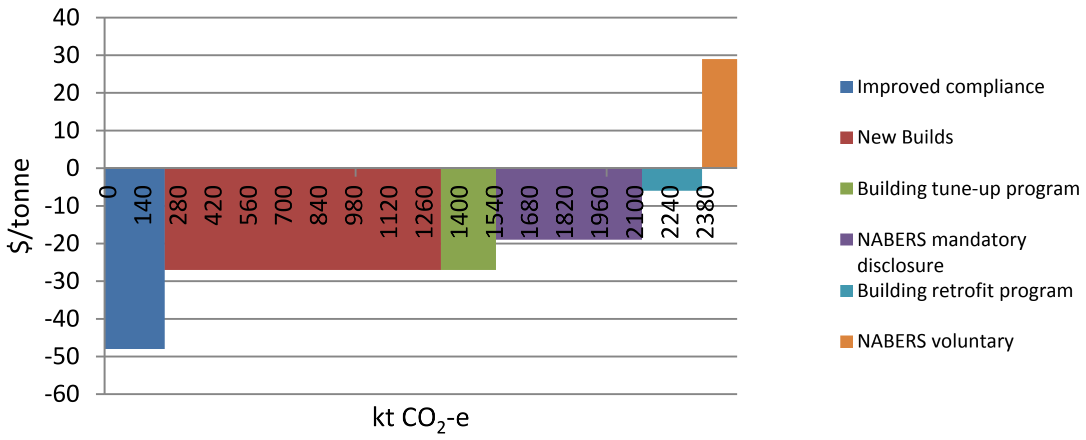


Figure 6: Abatement Cost Curve – Residential Buildings, Policy Potential, Medium Uptake

---

[11] Average cost of abatement is calculated as the present value of the net financial cost (energy savings only) associated with a given measure or scenario, divided by cumulative greenhouse gas emissions savings over the 2015 – 2030 period associated with that measure or scenario. It is expressed in $/t CO$_2$-e. A positive value indicates a net financial cost per tonne abated, while a negative value indicates a net financial saving per tonne abated.

Avoided Electricity Infrastructure Costs

Another form of potential economic benefit associated with electricity savings in particular is the reduced demand for electricity infrastructure[12]. The costs of investing in and maintaining this infrastructure represent the single largest share of a typical customer's electricity bills. However, estimating the potential for lowering infrastructure costs associated with reduced electricity demand is difficult, particularly in the current circumstances where, as noted, energy demand and peak demand are both falling. Whilesoever these circumstances continue, the need for new investment in electricity infrastructure (as compared to maintenance of existing infrastructure) is likely to be limited, for example to local demand growth 'hot-spots'. As a result, the opportunity to avoid infrastructure costs through energy efficiency measures will also fall.

We therefore take a conservative approach to estimating this opportunity, as described in Section 6.5. On this basis, we estimate that the need for some 211 MW of network capacity could be avoided in 2030 under the economic potential, rapid take-up scenario (see Table 6). In that year, electricity infrastructure costs would be some $67 million dollars lower than if the energy savings had not been realised. However, as the energy savings (and consequent infrastructure savings) would build up through time, a better indicator is to note that the present value of the cost savings over the 2015 – 2030 period, discounted at a 7% real discount rate, would amount to some $232 million. Note that other scenarios are shown in Table 3 above.

Table 6: Potential for Electrical Capacity Savings: Economic Potential, Rapid Uptake Scenario

Sector	Electrical network capacity savings in 2030 (MW)	Value of electrical network capacity savings in 2030 ($m, 2014 real)	PV of capacity savings, 2015 - 2030, @ 7% real discount rate ($m, 2014 real)
Residential	33	$10.2	$36.6
Commercial	178	$55.3	$186.5
Total	211	$65.4	$223.1

Risks and Opportunities

The energy and emissions savings potentials that we identify in this report are not guaranteed. Some of the potential may be contingent on factors beyond the control – but perhaps not beyond the *influence* – of the City of Sydney. Key risks include changes in the national and state-level policy environment – although such changes could also present new opportunities. Crafting a practical and effective *Energy Efficiency Master Plan* will help businesses and households to realise this potential.

On the risk side, this study highlights that measures such as the Building Code of Australia and minimum energy performance standards are projected to make a substantial dent in the growth in demand for energy. If these measures are removed or weakened, then the progress that is currently being made in reducing consumption growth could be reversed. Also, noting that the national Renewable Energy Target is currently under review – and also that gas prices are set to substantially rise in future, while the removal of carbon pricing will tend to favour coal – then the expected reduction in the greenhouse intensity of electricity supply could also be at risk. If the rate of reduction slows or even reverses, this would increase the amount of energy savings that the City of Sydney would need to leverage in order to achieve progress towards its -70% emissions target.

---

[12] In principle, the same effect occurs for gas networks as well, but the nature of joint costs in gas networks is such that only large changes in demand are likely to have significant infrastructure costs or savings.

Another risk, discussed in Section 5.3, is that a combination of anthropogenic climate change and the urban heat island effect could lift the demand for energy for cooling purposes. Quantifying such effects, however, is challenging, not least because additional cooling demand in summer may be offset by lower heating demand in winter, and also because local weather effects (such as sea breezes) can affect outcomes and are hard to correlate with these longer term climate changes. However, noting that a net warming of up to 3.7 degrees has been forecast in the Sydney area by 2050[13], this may merit a dedicated study.

On the opportunity side, the NSW Energy Efficiency Action Plan could result in strengthened targets under BASIX, or the Energy Savings Scheme, or both, and this would bring direct benefits in the form of energy and emissions savings within the City of Sydney. The Federal Emissions Reduction Fund (ERF) may create funding opportunities, although at the time of writing there is insufficient detail in the public domain to be certain about this. One potential opportunity under this scheme could be for the City of Sydney to act as an 'aggregator' of energy savings in the local government area, thereby potentially accessing funding from the ERF to assist with the necessary investments.

Conclusions

This study set out to determine the scale of cost effective energy and greenhouse gas emissions savings opportunities in the City of Sydney' built environment. We find that, compared to a 2006 baseline, energy savings of around 29% – depending upon the scenario – and greenhouse gas savings of 40% or more, are expected to be cost effective over the period to 2030.

Realising these energy and emissions savings would generate large economic benefits for Sydney's residents and businesses. Energy cost savings of up to $220 million per year could be realised by 2030, while another $70 million or more per year could be saved in avoided electricity infrastructure costs. In present value terms, the scenarios could deliver between $456 million - $506 million in net financial benefits. The value of financial benefits is expected to be around double that of financial costs, resulting in *negative* costs of abatement (that is, net financial savings, on average, for every unit of greenhouse gas abatement achieved).

Overall we conclude that proceeding to develop and implement a well-crafted *Energy Efficiency Master Plan* – in close consultation with relevant stakeholders – has the potential to deliver very significant environmental and economic benefits for Sydney.

---

[13] Argueso et al (2013)

1. Introduction and Context

1.1 Introduction

In 2008 the City of Sydney adopted a Community Strategic Plan entitled *Sustainable Sydney 2030*[14]. It is a plan for the sustainable development of the City to 2030 and beyond. Through a process of community consultation, the City adopted a vision of Sydney in 2030 as a city that is green, global and connected. The 'green' elements include:

- Sydney will be internationally recognised as an environmental leader, with outstanding environmental performance and new 'green' industries driving economic growth.
- The City will reduce its greenhouse gas emissions, with a network of green infrastructure to reduce energy, water and waste demands, led by major renewal sites.
- The City will help contain the Sydney Region's urban footprint by planning for new housing opportunities integrated with vital transport, facilities, infrastructure and open space.
- The City will protect native flora, fauna and ecologies.

Strategies for achieving this vision are embodied in a rolling 4 year Delivery Program, annual Operational Plans and a 10-year Resourcing Strategy. The City set 10 over-arching targets for 2030 including, as Target #1, reducing greenhouse gas emissions across the entire local government area (LGA) by 70% by 2030 compared to 2006 levels.

To deliver on this target, a Green Infrastructure Plan – focusing on maximising the capacity for local energy and water use and efficiency – is being developed. The Green Infrastructure Plan will comprise Master Plans for:

- Decentralised Energy - Trigeneration
- Decentralised Energy - Renewable Energy
- Advanced Waste Collection and Treatment
- Decentralised Water; and
- Energy Efficiency.

There are many synergies that reinforce the benefits of acting in all of these areas. Reducing water consumption means using less energy for water distribution. Reducing energy consumption makes it easier and cheaper to meet renewable and decentralised energy targets. Generating decentralised energy from trigeneration or renewables also improves energy efficiency, by reducing transmission and distribution losses in electricity networks.

The City recognises that there are limits to what it can achieve alone, and it is seeking partnerships for change with community, business and government. At the same time, it is leading by example. The City has already reduced greenhouse gas emissions in its own buildings by 18% via building energy efficiency retrofits, and the savings are expected to climb to around 42% thanks to a major energy and water efficiency retrofit contract it has let, to further improve its own buildings. The City is also replacing all City-owned street lighting with energy efficient LEDs, which will reduce emissions in its street lighting by over 50%.[15]

---

[14] Updated in 2011.

[15] Refer to http://www.cityofsydney.nsw.gov.au/vision/sustainability

The Energy Efficiency Master Plan is intended to engage all of the owners and users of Sydney's built environment, to showcase leading examples in Sydney providing recognition of good performance, to motivate and assist them to achieve similar results.

1.2 Background

The City of Sydney commissioned **pitt&sherry** in June 2013 to prepare a Foundation Report that would provide a sound evidence-base upon which to build its Energy Efficiency Master Plan. The process of creating the Foundation Report involves:

1. Projecting the expected energy use, greenhouse gas emissions and peak demand of the different building classes and sectors in the LGA to 2030 under 'business as usual' conditions, taking into account factors like the growth and turnover of the spaces, functional changes, new technologies and existing policy measures;
2. Identifying possible new measures, including by examining best practices from around Australia and the world, but also drawing on the experience of our research partner, Exergy Australia Pty Ltd, with their deep insight into the actual performance, and potential for improvement, of Sydney's building fleet;
3. Consulting with key stakeholders to capture their insights into the current issues and optimal solutions, and to identify preferred energy efficiency initiatives or measures;
4. Feeding the stakeholder insights and research findings into our baseline projections model, to generate definitive projections for achievable targets, and calculating the associated benefits and costs;
5. Finalising and presenting this Draft Report;
6. A Final Report will then be produced, taking into account stakeholder feedback on this Draft.

2. Towards an Energy Efficiency Master Plan for Sydney

2.1 Why Energy Efficiency?

Some 80% of the greenhouse gas emissions in the Sydney LGA are attributable to electricity and gas consumption in buildings. With most of the electricity consumed in Sydney being generated from coal, the greenhouse intensity of this energy use is high by world standards. Climate change is a global challenge that demands urgent action by every community around the world. Sydney's Green Infrastructure Plan rises to this challenge and provides a powerful framework for action[16].

Further, energy prices have been rising very rapidly in recent years – particularly for electricity, and more recently for gas (Figure 7 and Figure 8). Higher energy prices mean that the financial value of the energy savings resulting from improved energy efficiency is also higher, and so it is cost effective for households and businesses to save more energy.

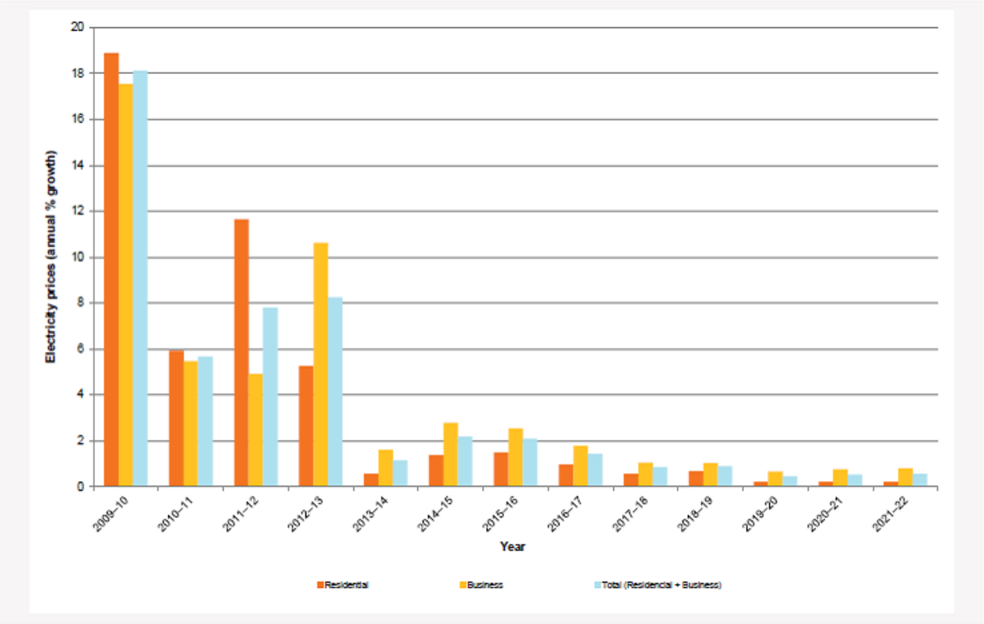


Figure 7: Electricity Price History and Projections, 2010 – 2022, NSW (including ACT)

AEMO, 2012, Economic Outlook Information Paper

Electricity price rises have also been given considerable media attention – unsurprisingly, given the rapid rate of change since 2008. This attention, and the resulting heightened awareness of price changes, has probably also driven behavioural responses on the part of energy users, probably leading to more energy conservation as well as additional investment in energy efficiency.

---

[16] *Ibid.*

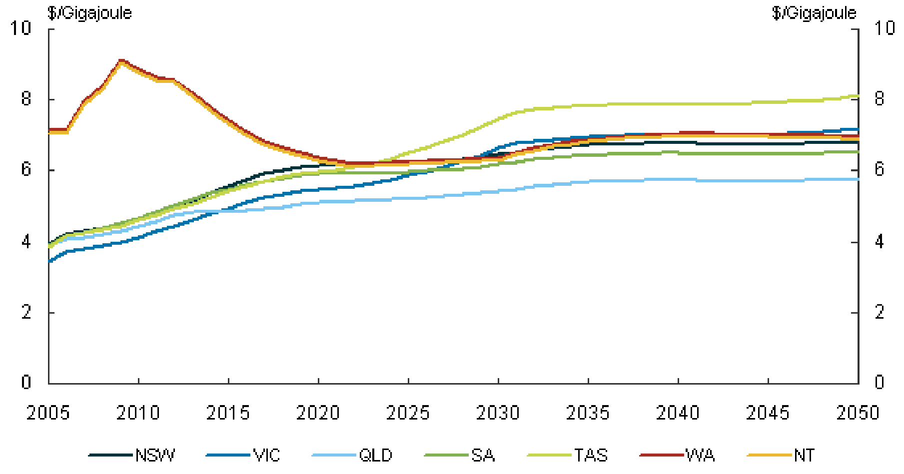


Figure 8: Australian (Wholesale) Gas Prices 2005 - 2050

Source: Treasury, Annex B, Climate Change Mitigation Policy Modelling Assumptions, http://archive.treasury.gov.au/lowpollutionfuture/report/html/09_AnnexB.asp

Box: What is Energy Efficiency?

Energy efficiency is defined as the amount of *useful work* or *output* that results from using energy. Energy efficiency is higher when more useful work or output is achieved with the same amount of energy use, or when less energy is used to achieve the same amount of useful work or output as before.

From the perspective of physics, the First Law of Thermodynamics states that energy can neither be created nor destroyed, but only transformed from one form into another. When coal is burned to produce electricity, for example, between 30% and 40% of the energy stored in the coal is converted into electrical energy. The rest is transformed into low grade heat and other energy forms that are difficult or expensive to recover. This energy is, practically speaking, ‘lost’ as it is not available to do useful work.

A more energy efficient power station (e.g. a combined cycle gas turbine) recovers some of the waste heat from the initial conversion process (the gas turbine) and uses a secondary process (a steam turbine) to capture this waste heat and create more electricity. Overall, more of the energy contained in the fuel is captured and available to do ‘useful work’, and therefore we describe this process as more energy efficient than the coal-fired example.

Many factors affect the efficiency of energy use. Better design of energy-using technologies and systems can reduce losses and increase useful outputs. However, behaviours are at least as important as technologies. If the world’s most technically efficient lighting system is left on when no-one is in a building, then it is still wasting energy, as it is performing no useful work.

Importantly, much of the financial cost and environment damage associated with use of fossil fuel based energy can be avoided through cost-effective strategies that lift energy efficiency. Other strategies can further reduce these costs (such as fuel switching and renewable energy)[17]. It is important to improve energy efficiency as much as possible in the first instance, in order to minimise the demand for energy services (like heating and cooling) as far as possible. This then reduces the capacity of renewable energy and other supply side technologies (like co- or trigeneration) required to meet emission targets.

Improving energy efficiency reduces energy cost and greenhouse gas emissions at the same time, with the energy cost savings generally paying for themselves over a short period of time, making the associated greenhouse gas emission savings effectively free of charge. Since there are often other benefits from improving energy efficiency as well – like improved comfort levels in houses and buildings – energy efficiency is a clear winner as an abatement strategy.

As an example of energy efficiency's cost effectiveness, a report on the national minimum energy performance standards and labelling program showed that the average cost of abatement under this program is *negative* $56/tonne[18]. That is, there is a net financial saving of $56 for every tonne of greenhouse gas emissions avoided through this efficiency regulation. That can be compared to the current carbon price of around $24/tonne – making the energy efficiency savings fully $80/tonne cheaper than the carbon price.

The Paris-based International Energy Agency (IEA) recently noted that energy efficiency is expected to deliver almost 50% of global greenhouse gas abatement by 2020 – and that 60% of that abatement is expected to be delivered in the buildings sector[19]. Another IEA study noted that, despite improved energy efficiency policies in some countries, "...a significant share of the potential to improve energy efficiency – four fifths of the potential in the buildings sector and more than half in industry – still remains untapped"[20].

These international findings gel with our own research in Australia. Our detailed examination of the scope for cost-effective energy efficiency improvements in (new) Australian buildings[21] found that houses that use no net energy will be cost-effective in most States (including NSW) by 2015 or even earlier, helped along by dramatically lower prices for photovoltaic panels. New commercial buildings could use between 58% - 68% less energy, on average, than current Code-compliant designs by 2020, although there is much greater variability depending upon the building type and location. Some commercial building types, like supermarkets, could also be built cost effectively to use zero net energy by 2020.

2.2 Market Barriers and Market Failures

Since the case for improving energy efficiency is so strong, it is often asked 'Why do we need to do anything – won't it just happen anyway?' While some energy efficiency improvement will occur without policy intervention – for example, due to the extraordinary rate of electricity prices rises in Australia in recent years – such price rises also impose very large economic and social costs on the community.

---

[17] Note that emissions savings associated with renewable energy and trigeneration/cogeneration are covered by separate Master Plans and therefore fall outside the scope of this Report.
[18] Wilkenfeld (2009).
[19] IEA (2012a), p. 10.
[20] IEA (2012b), p. 2.
[21] pitt&sherry (2012).

Pricing carbon emissions – in one form or another – is appropriate, as anthropogenic climate change has been described as "...the greatest market failure the world has seen...[since] those who damage others by emitting greenhouse gases generally do not pay for the costs they impose".[22] At the same time, relying on price rises *alone* to achieve important public policy outcomes, such as controlling greenhouse gas emissions, would be regressive and unnecessarily expensive.

As noted above, energy efficiency policies are most often cheaper than carbon pricing, and they are also more targeted, minimising 'collateral damage'. Therefore they should be retained and optimised regardless of whether carbon is priced or not. However, where carbon is priced[23], cost-effective energy efficiency measures can not only save costs for energy users, but also reduce the cost of carbon in the economy, by reducing the demand for emissions permits.

Some market trends – like a shift towards more efficient lighting and space conditioning technologies, for example – tend to improve energy efficiency. However, particularly in the absence of effective policies, market trends may equally deliver outcomes that worsen energy efficiency as well as those that improve it. Examples of the former include the trend towards larger (detached) houses in Australia and increased use of new electronic appliances, including portable devices and their recharging equipment. Also, some of the 'market based' improvements in the efficiency of imported appliances and equipment in fact reflect the benefits of energy efficiency regulations in the countries that manufacture the equipment, such as Japan, Korea, the United States and Europe.

Despite the cost effectiveness of many energy efficiency strategies, there are a large number of factors that impede the improvement of energy efficiency in Australia. Generally these are referred to as 'market barriers', although some of them relate to factors like our overall levels of wealth and our attitudes and behaviours in energy consumption – these may reflect inherent preferences rather than barriers related to markets.

Nevertheless, there are numerous market barriers including split incentives (see below) throughout the whole building supply chain, from building designers, construction companies, equipment and system suppliers and installers, owners, tenants or owner-occupiers, building managers, maintenance and cleaning contractors, real estate agents and many others. The term 'split incentive' refers to the fact that while the ultimate occupier of a building will generally bear the financial consequences of hundreds of decisions that affect the building's energy efficiency, they may have limited or no role in those key decisions. They may lack the knowledge to participate in such decision-making, or even an awareness of why it would be important to do so. If they are a tenant, the key decisions may have been made long ago.

Once a tenant (or owner occupier) is installed in a building, they may often lack targeted information, for example with respect to the commissioning and energy efficient operation of building management systems and controls. This can lead to buildings using much more energy than necessary to maintain comfortable operating conditions. There may also be a real or perceived lack of trusted service-providers to implement efficiency projects.

---

[22] Stern, N. (2006).

[23] For example, under a floating carbon price regime or emissions trading scheme.

For others, access to suitable financing for investment can be a key barrier. Certain building title structures – like strata titles – may be particularly susceptible to this due to complex decision-making processes and dispersed ownership structures. For others again, including some house owners, the *perceived* value of energy savings may be too small – even if cost-effective – to capture. For many businesses operating in Sydney, energy only represents a fairly small percentage of total business costs or household budget, so saving energy may struggle for management time and focus, even if it is cost effective. Alternative greenhouse reduction strategies – like investing in PV or solar hot water – may be preferred. House owners are also more likely to invest in energy efficiency at certain times, such as when a house/apartment is being extended or refurbished, or when it is being made ready for sale or lease. Being aware of and tapping into these opportunities is an important way of maximising efficiency outcomes.

Simply waiting for the market (in its current configuration) to deliver may mean that cost-effective efficiency improvements are delayed, making it more difficult to meet the City of Sydney's, and national, greenhouse gas emission abatement targets. Delaying the achievement of emissions targets also locks energy users into higher than needed energy bills. As noted in IEA (2012a), "...all countries will need to take supporting action to overcome the barriers to effective implementation [of efficiency measures]". [24]

In short, there is a clear role for governments – specifically including local governments – to help overcome these barriers and to allow the capture of more of the benefit that energy efficiency improvement offers. Therefore, an important focus for the design of possible additional efficiency measures that could be championed by the City of Sydney will be to identify which market barriers those measures address and how they will overcome the barrier. These issues are taken into account in the modelling of economic potential in Chapter 6.

---

[24] IEA (2012a), p. 10.

3. Energy Efficiency in Action Today

3.1 Existing Drivers of Energy Efficiency in Sydney's Buildings

This section provides information on some of the policy and market drivers already supporting energy efficiency in Sydney and beyond.

There are numerous national, state, and City of Sydney policies and programs targeting energy efficiency. Generally these policies fall within, or across, three main types.

1. Regulatory policies set standards related to energy performance. The National Construction Code and NSW's BASIX are examples.
2. Market based policies are a second type. Subsidies (in the form of grants for example), adjustment of tax rates, and cap and trade schemes are all examples of tools that are used to increase incentives to improve energy efficiency. The national carbon price scheme is an example. Large emitters have a direct incentive to improve energy efficiency to reduce emissions – and the size of their liability.
3. A third policy type is voluntary and information based programs. The CitySwitch program is an example. Incentives are provided to organisations to voluntarily commit to energy efficiency improvement, and information that helps the achievement of commitments is supplied to participants.

All the above policies interact with other drivers including energy prices and commercial factors such as portfolio value and marketability. Some of the important policies and drivers are described below.

3.2 City of Sydney – Building Energy Efficiency Measures

3.2.1 Sydney Development Control Plan – December 2012

A cornerstone policy is Sydney's planning arrangements. A Development Control Plan (DCP) supplements the Sydney Local Environmental Plan (LEP) 2012 by providing more detailed guidance on development.

The Council assesses Development Applications (DA) with regard to the DCP, LEP and other matters listed in Section 79C of the Environmental Planning & Assessment Act 1979.

There are six aims of the DCP, including 'achieve the objectives of the City's Sustainable Sydney 2030 Strategy'. The DCP sets out provisions for energy efficiency in non residential developments under Clause 3.6.1. [25] These are that:

(1) Development is to be designed and constructed to reduce the need for active heating and cooling by incorporating passive design measures including design, location and thermal properties of glazing, natural ventilation, appropriate use of thermal mass and external shading, including vegetation.

(2) Lighting for streets, parks and any other public domain spaces provided as part of a development should be energy efficient lighting such as LED lighting.

(3) In multi-tenant or strata-subdivided developments, electricity sub-metering is to be provided for lighting, air-conditioning and power within each tenancy or strata unit. Locations are to be identified on the development plans.

(4) Electricity sub-metering is to be provided for significant end uses that will consume more than 10,000 kWh/a.

---

[25] City of Sydney (2012).

(5) *Car parking areas are to be designed and constructed so that electric vehicle charging points can be installed at a later time.*

(6) *Where appropriate and possible, the development of the public domain should include electric vehicle charging points or the capacity for electric vehicle charging points to be installed at a later time.*

3.2.2 Energy Efficiency and Sustainability Programs

In addition the city runs, or participates in, a significant range of programs that enhance the sustainability of the built environment. They are summarised in Table 7 (business programs) and Table 8 (residential programs) below. Note that these measures may relate to specific building types – see Table 9 in Chapter 4 for a description of the building types resolved in this study.

Table 7: Sustainability Programs in the City of Sydney - Business

Sector	Program Name	Start	End	Comment
Business **22,000 businesses** **80% SMEs**	Smart Green Business	Sep-09	Jun-12	A Waste, Water & Energy program with Sydney Water. 100 SMEs. Energy audits via NSW Government programs. 4588t CO_2e savings to date
	CitySwitch Green Office - National	Jul-08	Jun-15	An office tenant program. Advice, resources and recognition for participant commitment to achieve high NABERS ratings. 416 tenancy participants nationally
	City Switch Green Office - Sydney	Jul-08	Jun-15	Part of the national program. 101 tenancy participants. 881,317 office floor space
	Better Buildings Partnership	Mar-11	Jun-16	A partnership of the CoS and leading commercial building owners to support the implementation of the city's green infrastructure plan
	Environmental Upgrade Finance Service	Dec-11	Ongoing	Part of the NSW Government's Environmental Upgrade Agreements. The finance provider supplies funding to the building owner with repayments via Council charges on the land. The tenant can also share the cost of the upgrade. 1 EUA for the redevelopment of the formers brewery site at Broadway. 7,600 tonnes annual CO_2e reductions.

Source: ***pitt&sherry***

Table 8: Sustainability Programs in the City of Sydney - Residential

Residential **Pop. of 188,000 (rising)** **73% live in apartments (rising)** **50% rent** **high transience** **10% social housing**	Smart Green Apartments	May-11	Jun-13	30 apartment building participants. Energy assessments provided to building owners. Low Carbon Australia are assisting the program develop new financial products and services.
	Green Villages	Oct-10	Jun-14	Encourages the development of sustainability programs and activities in local communities
	Green Living Centre	Sep-09	Sep-14	An information and education hub in Newtown - growing a culture of environmental sustainability within the urban community

Source: ***pitt&sherry***

3.3 NSW Government Building Energy Efficiency Measures

3.3.1 BASIX

The Building Sustainability Index (BASIX) part of NSW's planning system. It drives energy and water efficiency in all residential dwelling types. BASIX is implemented under the Environmental Planning and Assessment Act. It applies to buildings containing one or more dwellings (not hotels/motels).

When lodging plans to council for the construction of new buildings or for alterations with an estimated construction cost of over $50,000 a BASIX assessment must be completed. The plans are measured against BASIX targets of up to 40% reduction in energy use / greenhouse gas emissions and potable water use against the NSW average benchmark. The NSW energy benchmark is 3292kg of CO2e per person. [26] In the City of Sydney LGA, BASIX targets range from 40% below this benchmark for detached and semi-detached houses, to 35% for low-rise units (2 – 3 storeys), 30% for mid-rise units (4 – 5 storeys) and 20% for high-rise units (6 storeys or more), reflecting an expectation of higher compliance costs for the latter types. The BASIX State Environmental Planning Policy also mandates that a DCP cannot include provisions which require a development to exceed its minimum standards.

Note that in our modelling of all policy measures, we take into account information regarding the actual performance of measures, as distinct from their intended performance, wherever such information is available.

3.3.2 NSW Energy Savings Scheme

The NSW Energy Savings Scheme was established in July 2009. Specific energy savings measures are able be generate certified savings, which may then be purchased b by electricity retailers (and other liable parties) to acquit energy savings targets. Targeted savings began at 0.4% of total electricity consumption, rising to 4% by 2014. The scope of the scheme includes residential and commercial/SME sectors electricity use only.

As noted below, the Scheme is currently under review in the context of the 2013 Energy Efficiency Action Plan, with a view to enhancing the scheme's scope and effectiveness.

3.3.3 NSW Energy Efficiency Action Plan

In August 2013 the NSW Government released the NSW Energy Efficiency Action Plan to help drive energy efficiency across the state and help achieve an energy savings target of 16,000 GWh by 2020 and support 220,000 low income households reduce energy use by 20% by 2014. Of particular relevance to the City of Sydney is the intention to deliver retrofit programs with a target of 50% of commercial floor space achieving a 4 star NABERS energy and water rating by 2020. Under the Plan the existing **Energy Savings Scheme** will be strengthened. A voluntary energy rating system for residential buildings at the point of sale or lease will also be investigated. [27] Consistent with the 'business as usual' convention – under which policy changes that are announced, rather than actually implemented, are excluded – these changes have not been modelled.

---

[26] NSW Government Planning and Infrastructure – BASIX Website, https://www.basix.nsw.gov.au/basixcms/

[27] See http://www.environment.nsw.gov.au/resources/climatechange/130588eneffap.pdf

3.4 National Building Energy Efficiency Measures

3.4.1 Section J of the National Construction Code

The National Construction Code (until recently known as the Building Code of Australia or BCA) started to introduce energy efficiency measures in 2003. In 2006 all building classes were covered and the stringency of requirements was increased in 2010. The objective of the energy efficiency requirements (detailed in Section J of the Code) is to reduce greenhouse gas emissions. [28]

Section J sets out whole of building energy performance levels and 'Deemed-to-Satisfy' provisions for elements of buildings that impact energy consumption such as building fabric, sealing, air-conditioning and ventilation systems, lighting, etc. The precise application of the code varies slightly from state to state. In NSW it is mainly applied to new buildings and significant renovations in the non-residential classes of buildings where BASIX does not apply.

It should be noted that energy savings associated with the BCA are estimated rather than measured. To this point, no studies have been published that demonstrate the *actual* energy savings achieved by Section J. There are many critiques of the BCA including:

- Suggestions that compliance with Section J requirements is low and not effectively enforced;
- Difficulties in interpreting specific Code requirements (eg, when it applies to refurbished buildings);
- Limited coverage of existing buildings (except where major refurbishments occur to energy using systems);
- A lack of performance requirements in key areas including air tightness and heat recovery;
- Performance requirements are 'as designed' rather than 'as built' making them hard to verify;
- Shortcomings with regulatory impact assessments; and
- Lower than optimal energy performance requirements, particularly for non-residential buildings.

We note that **pitt&sherry** and Swinburne University of Technology are currently undertaking a *National Energy Efficient Buildings Project* – project-managed by the South Australian Department of Manufacturing, Innovation, Trade, Resources & Energy (DMITRE), on behalf of all states and territories and the Australian Government – which is examining the causes of and possible remedies for non-compliance (of all building classes) with the energy performance requirements in the National Construction Code. Notwithstanding, it is clear that the BCA is generating large and cost effective energy savings, as demonstrated in Chapter 5. However these savings could be better documented, and any shortcomings addressed, in order to build community and industry support for the continuation and indeed expansion of this key policy tool.

3.4.2 Commercial Building Disclosure

Since July 2010 the Australian Government program has targeted improved energy efficiency of Australia's large office buildings. It mandates that credible and useful energy efficiency information is available to purchasers and lessees of large commercial office space. When commercial office space of over 2000m is up for sale or lease, a Building Energy Efficiency Certificate (BEEC) must be obtained and disclosed. BEECs are valid for one year and include a NABERS energy star rating, an assessment of tenancy lighting, and energy efficiency guidance.

---

[28] ABCB (2010), p. 423.

The mandatory nature of the scheme, and the credibility of NABERS, has driven improved awareness of energy efficiency in the commercial property market and provided a clear incentive for property owners to attract tenants by offering relatively energy efficient office space. [29] The scheme may be extended to other building types over time.

3.4.3 NABERS

The National Australian Built Environment Rating System – NABERS is an environmental performance rating system. It is voluntary and allows existing buildings of several types to be assigned a star rating on the basis of actual operations and their annual energy use. Buildings currently covered by NABERS include offices, hotels, shopping centres, data centres and houses. The NSW Government Office of Environment and Heritage (OEH) are the administrators of NABERS.

OEH supports NABERS through the publication of information on energy management and other relevant topics. Building owners, operators and tenants can use this information to implement energy efficiency opportunities that lift NABERS scores. Just one example of the useful information provided is the Energy Management Guide for Tenants. [30]

NABERS ratings are easily understood and credible and provide the basis for several other programs, such as Commercial Building Disclosure, Green Leases, and the energy element of Green Star.

3.4.4 The National Green Lease Policy

Green leases set standards for both tenants and landlords. The Commonwealth policy requires a minimum 4.5 NABERS rating for both government tenancies and buildings over 2000m^2. The policy is designed to allow application of green lease policies by state governments. Actions under the NSW Government's Sustainability Policy include the use of Green Lease schedules in new or negotiated leases where practical. [31]

3.4.5 Green Star

The Green Building Council Australia administers the voluntary Green Star multi-faceted rating system that evaluates the environmental impact of the design, construction and operation of buildings and building related communities.

There are a number of rating tools developed for particular building types – such as office buildings, industrial buildings, shopping centres (base buildings) and multi-unit residential buildings.

The rating tools cover 9 performance categories. The energy category rewards energy efficiency, and this assessment is based on the NABERS tool described above.[32]

Note that in this study we group together the energy and emissions savings attributable to NABERS, Green Star, CBD and also City of Sydney programs such as City Switch and the Better Buildings Partnership. We adopt this approach because there are strong linkages between these measures and, therefore, significant risks of double-counting savings. Also, attributing the energy savings accurately to each of these initiatives is complex and not the central focus of this study.

---

[29] Australian Government, Commercial Building Disclosure Website, http://cbd.gov.au/

[30] OEH (2012).

[31] NSW Government Office of Environment and Heritage Website - http://www.environment.nsw.gov.au/government/neutral.htm

[32] http://www.gbca.org.au/green-star/what-is-green-star/green-star-rating-tool-categories/2141.htm

3.4.6 Minimum Energy Performance Standards (MEPS) and Labelling

Australian and state governments in Australia require that several classes of products meet Minimum Energy Performance Standards. Products that don't meet the minimum standard cannot be sold in Australia – this lifts the overall energy efficiency of the product class above the 'business as usual' average. MEPS and labelling also encourage investment in energy efficiency innovation by helping to ensure that such investments are not undermined by competition from low-efficiency alternatives that reduce overall consumer welfare (as their additional running costs generally far outweigh any initial savings on the equipment purchase price).

By targeting products that use energy, MEPS improves the energy efficiency of building systems – such as lighting and HVAC systems, and the energy efficiency of the activities that take place in buildings – such as use of electronic equipment like televisions and computers. Indeed, it is worth recalling that buildings themselves do not use energy – it is the equipment and appliances within buildings that use energy. For this reason, and as is demonstrated in Chapter 5, MEPS and labelling make an important and cost effective contribution to the overall energy and emissions savings potential in buildings.

The Energy Rating website lists product classes that are subject to MEPS. Those product classes and links to the further information are listed below.[33]

- Refrigerators and Freezers;
- Mains Pressure Electric Storage Water Heaters;
- Small mains pressure electric storage water heaters (<80L) and low pressure and heat exchanger types Three Phase Electric Motors (0.73kW to <185kW);
- Single Phase Air Conditioners;
- Three Phase Air Conditioners up to 65kW cooling capacity
- Ballasts for Linear Fluorescent Lamps Note that in addition to MEPS, ballasts also have to be marked with an energy efficiency index (EEI);
- Linear Fluorescent Lamps from 550mm to 1500mm inclusive with a nominal lamp power >16W Distribution Transformers 11kV and 22kV with a rating from 10kA to 2.5MVA;
- Commercial Refrigeration (self contained and remote systems);
- Incandescent Lamps;
- Compact Fluorescent Lamps;
- External Power Supplies;
- Set Top Boxes;
- Televisions;
- Commercial Building Chillers;
- Close Control Air Conditioners;
- Transformers and Electronic Step-down Converters for ELV Lamps.

These products and appliances cover a large share of residential electricity use, but smaller shares of residential gas use and commercial/industrial electricity use, while commercial/industrial gas use is currently not impacted by these measures.

---

[33] http://www.energyrating.gov.au/programs/e3-program/meps/about/

3.4.7 Energy Efficiency Opportunities – EEO

This Australian Government program requires businesses that use large amounts of energy to undertake detailed energy assessments that identify and evaluate opportunities to improve energy efficiency. The businesses must report on these opportunities and whether they will be implemented. The energy use of EEO participating businesses in the services sector typically occurs in buildings. These businesses adopted 4.4PJ energy savings in 2010-11. [34] This quantity of energy is roughly equivalent to the annual use of 90,000 households. [35] Given reporting limitations, we have not separately estimated the contribution of EEO to energy savings in the City of Sydney LGA. While there may be some, such savings may also be counted by NABERS, Green Star and other measures.

3.4.8 EEX – the Energy Efficiency Exchange website

eex.gov.au is a web-based information hub administered by the Commonwealth Department of Resources, Energy and Tourism on behalf of Australian, state and territory governments. It offers a wide range of material on energy efficiency, chiefly targeting medium and high energy using businesses. The site has a section for the 'Commercial and Services' sector which contains, or has links to, quality information on opportunities relating to building energy efficiency. [36]

As with other information-based initiatives, we do not attempt to ascribe specific energy savings to this measure. This is because information-based initiatives, if successful, tend to enhance the uptake of other measures, and the savings are counted under those measures. It is possible, in principle, to estimate savings attributable to information-based measures, but this requires access to very specific information, generally via surveys of those who are the intended users of the information.

3.4.9 YourBuilding.org

The Your Building Website is run by the Property Council of Australia. The website is a portal to a large amount of information, in a variety of formats and styles, on improving the environmental impact of existing and new buildings. There are case studies, tools, advice, articles with a target audience that includes building investors, designers & constructors, managers and occupants. [37]

3.4.10 Carbon Pricing Scheme/Direct Action Scheme

The Australian Government introduced a price on greenhouse gas emissions on 1 July 2012. Australia's largest emitters are required to pay a price, which commenced at $23, on each tonne of CO_2e emitted.

While this scheme remains in force in FY2014, the current Australian Government has signalled an intention to remove this scheme, with potential effect from FY2015, and replace it with a 'direct action' scheme. The government has released a green paper on the direct action scheme. For modelling purposes, we assume no carbon price through the projection period, but do model the past/current price effect. We do not attempt to model any greenhouse savings that may be attributable to the direct action scheme, due to a lack of detail available at this point in time about the likely effects of this scheme.

---

[34] RET (2011).

[35] Department of Resources, Energy and Tourism, EEO Factsheet, see http://www.ret.gov.au/energy/documents/energyefficiencyopps/Info%20sheet%201_web20060725155118.pdf

[36] http://eex.gov.au/industry-sectors/other-sectors/commercial-and-services/

[37] YourBuilding website - http://www.yourbuilding.org/

The vast bulk of emissions directly priced by the carbon pricing scheme occur outside Sydney – through activities like electricity generation, energy intensive manufacturing, and oil and gas processing. The chief impact of carbon pricing on the City of Sydney has been a modest effect on electricity prices, estimated at some 8%.[38] Figure 9 below shows the contribution of carbon pricing, and other factors, to residential electricity prices in 2012-13.

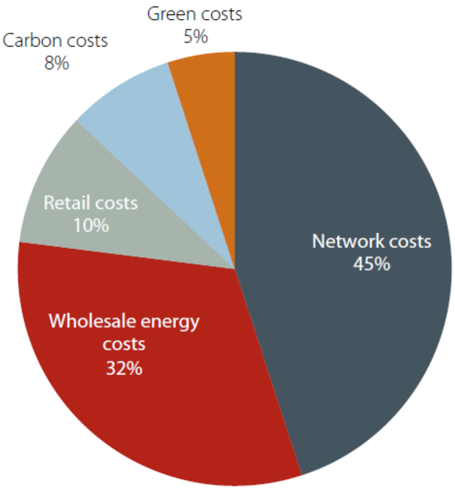


Figure 9: Composition of residential electricity costs 2012/13

Source: Figure 17, BREE, Energy in Australia May 2013

3.4.11 Smart Blocks

The Smart Blocks program is a web-based information initiative that targets improved energy efficiency in the common areas of apartment buildings (base buildings). Two main types of information are provided. The first is information on opportunities for building owners to lift energy efficiency. Opportunities for projects are divided into the energy-use groups of lighting, water systems, pools and amenities, heating and cooling, and ventilation.

Secondly, advice on the process of moving from idea to action is provided. This includes advice on gaining strategy approval for a project, funding a project and dealing with contractors.[39]

3.5 Examples of Excellent Practice - Australian and Global

There are many energy efficiency policies and programs which are achieving impressive results in cities around the world. These illustrate some of the possibilities for building on the existing initiatives in the City of Sydney. Some of these examples are outlined below.

3.5.1 Sydney's 1st Environmental Upgrade Agreement

The Central Park development of the old brewery site at Broadway is the subject of an Environmental Upgrade Agreement (EUA) involving the City of Sydney, developers Frasers Property and Sekisui House and financiers ANZ, Eureka Funds Management and the Clean Energy Finance Corporation.

---

[38] BREE (2013), Figure 17.
[39] Smart Blocks website http://smartblocks.com.au/

The EUA funding of some $26.5 million will be used to install a 2 megawatt trigeneration system which will provide heating, hot-water and cooling. The cost of the trigen unit will be repaid by a charge on the land, called the Environmental Upgrade Charge that is levied and collected by the City of Sydney on behalf of the financiers.

The development is aiming for a minimum of 5 stars under Green Star. The trigeneration system is one of the energy efficient aspects of this 5.8 hectare site that will be developed from 2013 to 2018. Eventually Central Park will include over 2000 apartments, student housing, 50,000m^2 of commercial office space, 20,000m^2 retail space and a public park[40].

3.5.2 Sydney – Smart Green Apartments

The goal of City of Sydney's Smart Green Apartments program is to improve the resource efficiency of the city's huge population of apartments.

The program is learning by doing, with the executive committees, building managers and strata managers of thirty buildings working with the City.

The comprehensive energy audits carried out on each building (subsidised by the NSW Office of Environment and Heritage's Energy Saver program) give the program its integrity. Every building is different. An energy audit provided by experts is the key to identifying the most energy and cost effective opportunities for efficiency improvement in individual buildings.

The energy savings of up to 30%, identified across a range of energy using activities such as lighting, swimming pools and ventilation, are a great example of the savings that can be unlocked via an energy audit.

The City is sharing program data and lessons to support the efforts of other apartment buildings to boost efficiency[41].

3.5.3 Energise Barnet - locally leveraging a national scheme

Barnet is a Borough of London in the UK. A community company Energy Barnet has been set up to work in partnership with the Barnet Council, the National Health Service and local groups to deliver energy efficiency measures, water efficiency, and renewables projects. The company hopes to drive energy efficiency in 40,000 homes and buildings and create 300 new 'green jobs' on the way to reducing CO_2e emissions by 35%.[42]

The project builds on the UK Government's **Green Deal**, which allows private companies to offer energy efficiency improvements without imposing up-front costs on the building owner. Measures that have been evaluated as cost effective are paid back via a separate charge on electricity bills. The 'green deal' stays with the property, removing the risk to the property owner that they might sell before the value of energy savings has exceeded the investment. An owner deciding to sell after 3 years for instance will not be disadvantaged as the repayments will be the same or smaller than the value of annual energy savings.[43]

---

[40] See http://www.sydneymedia.com.au/media-releases/innovative-green-finance-to-power-broadway-site/ and http://www.centralparksydney.com/assets/Uploads/EUA-Case-Study-Central-Park-ProjectMarch2013.pdf

[41] Smart Green Apartments fact sheet http://www.cityofsydney.nsw.gov.au/__data/assets/pdf_file/0003/146829/6388_FA3_LR_Smart-Green-Apartments-Pilot-Study-handout_covers.pdf

[42] DECC (2012).

[43] See https://www.gov.uk/green-deal-energy-saving-measures

3.5.4 City of Houston – Building Retrofit Program

The City of Houston, Texas is a partner of the C40 network and a member of the Clinton Climate Initiative's (CCI) Energy Efficiency Building Retrofit Program. Houston adopted CCI support and advice in retrofitting the entire City owned building stock through energy performance contracting with a target of exceeding an average 25% energy savings. 2 ESCOs were awarded contracts for a total of 271 buildings with a combined area of 11 million square feet (just over 1 million square meters). Houston financed the project through the issue of a tax-exempt short-term loan. It intends to re-finance the loan with a general obligation bond. A long term view was taken with a blended payback cut-off of 20 years. [44]

3.5.5 New York – high standards for the energy efficiency of existing buildings

New York City's progress towards greenhouse reduction targets are strongly aided by *The Greener, Greater Buildings Plan*. The plan consists of 4 laws with supplementary measures that target the city's largest buildings. Those buildings make up half the city's building area and 45% of carbon emissions. The basic requirements are:

- All renovations impacting energy systems must meet the standards of the New York State Energy Code;
- Annual benchmarking of energy and water use must be submitted for public disclosure;
- Every ten years an audit and tuning or retro commissioning energy using equipment must occur;
- Lighting upgrades to meet the energy code in non-residential spaces and the installation of electrical meters or sub meters for large tenant spaces.

The regulatory requirements are backed by programs that help provide the information and skilled workforce necessary to deliver improved energy efficiency. An energy efficiency financing mechanism that helps with funding for energy upgrades. **[45]**

3.5.6 Case Study – Seattle. Utilising national building energy rating schemes to drive energy efficiency

Seattle has made good use of LEED building ratings (Leadership in Energy and Environmental Design) in improving the energy and environmental performance of the city. All new City buildings over 5000 square feet (465 square meters) are required to meet LEED standards. Private commercial building projects that meet *LEED Gold*, and residential developments meeting *Built Green* 4 Star are given priority permitting and may be eligible for financial, height and density bonuses**[46]**.

---

[44] City of Houston Building Retrofit Case Study. Available at the C40cities website http://www.c40cities.org/c40cities/houston/city_case_studies/city-of-houston-building-retrofit-case-study

[45] The Greener, Greater Buildings Plan Case Study. Available at the C40cities website http://www.c40cities.org/c40cities/new-york/city_case_studies/the-greener-greater-buildings-plan

[46] Seattle sets the Standards for Green Buildings Case Study. Available at the C40cities website http://www.c40cities.org/c40cities/seattle/city_case_studies/seattle-sets-the-standards-for-green-buildings

3.5.7 Leadership in Energy and Environmental Design (LEED)

LEED is a US building rating system, roughly analogous to the Green Star system used in Australia. It was launched by the US Green Building Council in 2000 and provides benchmarks for design, construction and operation of sustainable buildings. These ratings allow the verification of 'green buildings'. Such buildings can earn LEED certification (certified, silver, gold, platinum) by meeting prerequisites and benchmarks in 5 areas: sustainable site development; water savings; energy efficiency; materials selection and indoor environmental quality; innovation and process.[47]

3.5.8 London – ambitious targets backed by regulation

The London Plan July 2011 is the latest edition of the plan first published in 2004 and updated in 2008. It sets out a framework for the development of London that considers economic, environmental, transport and social issues.

The plan includes policies to deliver a carbon dioxide emissions reduction target of 60% below 1990 levels by 2025. Additional supporting policies are in The Mayor's Climate Change Mitigation and Energy Strategy.

Improved energy efficiency is a clear policy goal under the plan.

- Development proposals are required to address the following hierarchy of energy principals:
  - Be lean: use less energy
  - Be clean: supply energy efficiently
  - Be green: use renewable energy
- Major developments are required to better Target Emission Rates set out in national building regulations. From 2016 buildings are required to be Zero carbon (this does not include emissions from energy use not covered in regulations – from electrical equipment and appliances)
- Major development proposals are required to include a detailed energy assessment demonstrating how targets (e.g. zero carbon) will be met. Assessments need to cover estimated energy demand and emissions and specify details of how the development uses energy efficient design and equipment. [48]

3.5.9 Building Labelling – Europe

The European **Energy Performance of Buildings (EPB)** Directive has, amongst other things and since 2006 (2009 at the latest), required the labelling of energy performance of buildings, including affixing a plaque showing the building's energy efficiency in the building's foyer, using the A – G rating scale also used for appliances in Europe. Since 2010, the Directive has also required the mandatory disclosure of energy performance information upon advertising a building for sale or lease, similar to Australia's CBD scheme. The scheme applies to all new and existing buildings including apartments.

In 2013, a major study was published demonstrating that each one-letter improvement in a building's rating is associated with higher prices (for buildings sold) or rents (for those leased) by up to 11%.

---

[47] US Green Building Council - LEED website http://www.usgbc.org/leed

[48] Greater London Authority, *The London Plan 2011, Chapter 5: London's response to Climate Change*. Accessed at: http://www.london.gov.uk/sites/default/files/LP2011%20Chapter%205.pdf

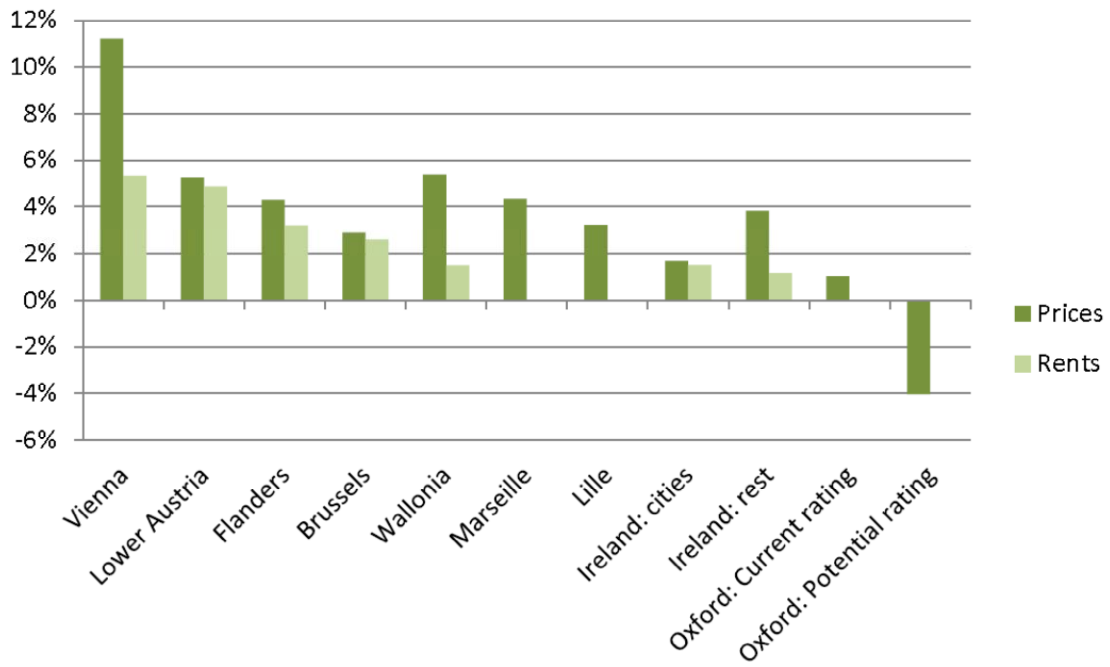


Figure 10: Changes in Sale and Rental Values associated with 1-letter Improvement in Building Certification, Selected EU Cities

Source: EC (DG Energy) 2013, p. 15.

3.5.10 Zero Energy Homes in Norway

The town of Arendal, a town of 40,000 people in Norway[49], is the location of a residential development targeting 'zero energy'.

This development exceeds the minimum requirements of the European **Energy Performance of Buildings Directive** (discussed above), by requiring that by 2020 all new buildings will be 'nearly zero energy'. [50]

A Zero energy building is one that, over the course of the year, will have a net zero use of energy that is purchased, or delivered. In other words energy will be produced on-site, and any delivered fuel or electricity brought in via the grid will be more than offset through onsite production.

The Arendal project of a 40 dwelling development will demonstrate the feasibility of achieving net zero energy over the course of a year.[51]

The development combines passive house methods (using orientation, design and construction quality to maximise energy efficiency) and a smart energy production system to show that new buildings can already achieve zero net greenhouse emissions.

---

[49] http://www.visitnorway.com/en/Where-to-go/South/The-Arendal-Region/Key-facts/

[50] European Commission, 'Energy Efficiency: Buildings' Webpage http://ec.europa.eu/energy/efficiency/buildings/buildings_en.htm

[51] Papers presented at the conference Passivhusnorden 2012 Thyholt Marit, Dokka Tor Helge, Rasmussen Roald 'The Skarpnes residential development – a zero energy pilot project'. Accessed via http://www.tapironline.no/fil/vis/960

4. Analytical Framework

This Chapter provides a technical description of the analytical framework used to estimate energy use and greenhouse gas emissions in Sydney's buildings under a range of scenarios. It describes key assumptions and data sources relied upon, and notes any related uncertainties. Finally, it presents the 'baseline' projections of energy use and greenhouse gas emissions to 2030 under a 'business as usual' scenario; that is, assuming existing efficiency measures and trends continue, but no new measures.

4.1 Overview

In order to create transparent and evidence-based estimates of the potential for energy and greenhouse gas emissions savings in the City of Sydney building stock, **pitt&sherry** created a model known as **BEEMS** (Building Energy Efficiency Model for Sydney). Figure 11 below provides a schematic overview of the model.

The model comprises a number of modules, vis:

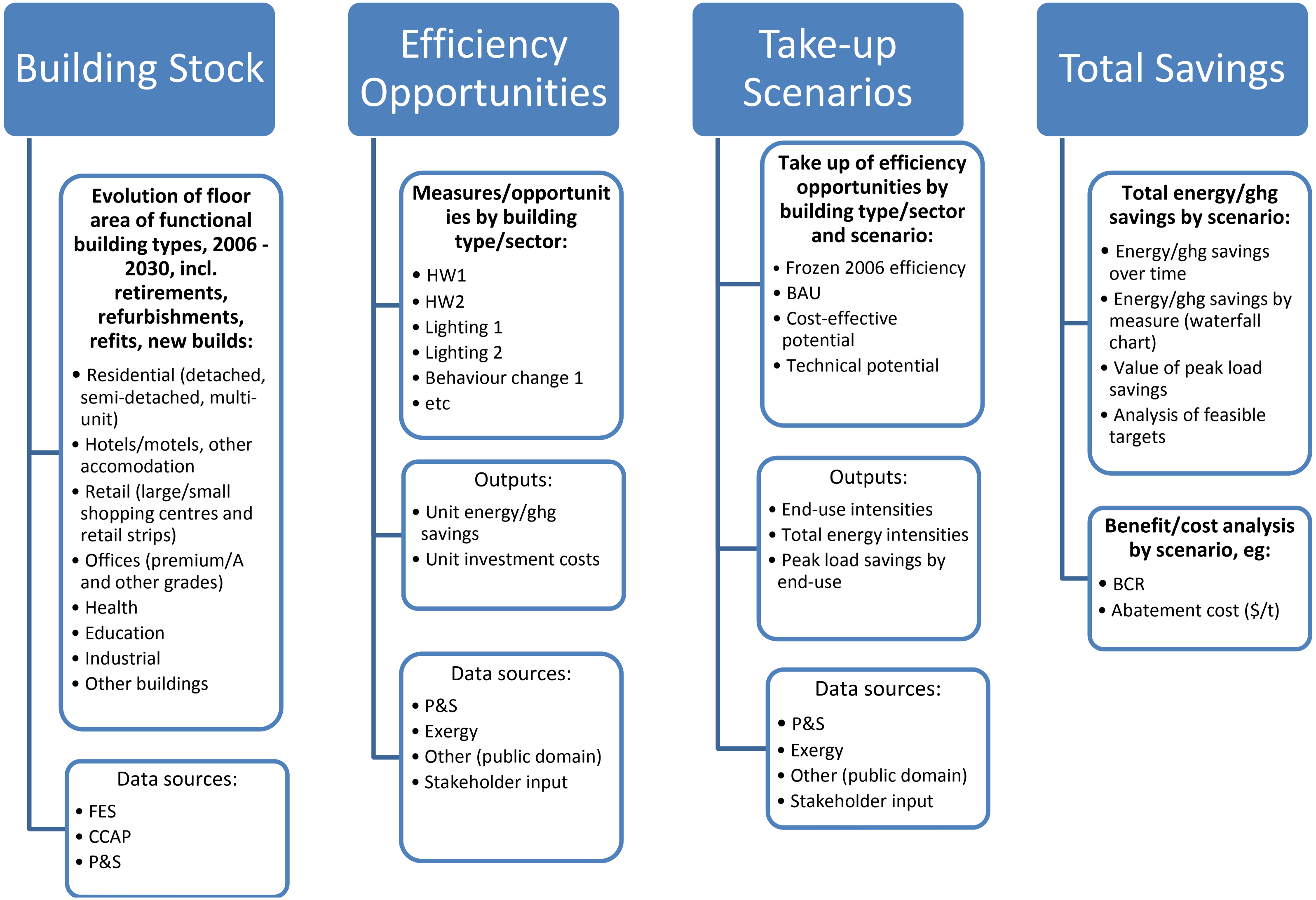
- **A stock model**: this describes the expected change in the area of different building types, from 2006 to 2030, including estimates of stock turnover (additions, retirements and major refurbishments);
- **Energy/emissions models for each building type**: these describe the energy consumption of each major building type, broken down by fuel, by building sub-type where appropriate, by end-use, and by base building/tenancy where appropriate. These modules then calculate energy savings as a function of three scenarios relative to a 'frozen efficiency' baseline (see Section 4.3.1 below for details), greenhouse gas CO_2 equivalent savings, and peak load savings;
- **A savings opportunities module**: this module houses the data on additional technical and policy opportunities, which is then drawn on for different building types and savings scenarios.

The following sections provide further detail on each module type.

4.2 The Stock Model

Fundamental to the amount of energy use and greenhouse gas emissions associated with Sydney's buildings is the question – how many buildings will there be in Sydney over time? We need to project:

- What is the expected total floor area of each building type and sub-type in each year (to 2030)?
- What is the composition of this floor area including new build, replacements of demolished buildings and major refurbishments?
- As a function of the above, what portion of the floor area in each time period is expected to comply with different versions of the energy performance requirements of the National Construction Code?



Building Stock

Evolution of floor area of functional building types, 2006 - 2030, incl. retirements, refurbishments, refits, new builds:

- Residential (detached, semi-detached, multi-unit)
- Hotels/motels, other accomodation
- Retail (large/small shopping centres and retail strips)
- Offices (premium/A and other grades)
- Health
- Education
- Industrial
- Other buildings

Data sources:

- FES
- CCAP
- P&S

Efficiency Opportunities

Measures/opportunities by building type/sector:

- HW1
- HW2
- Lighting 1
- Lighting 2
- Behaviour change 1
- etc

Outputs:

- Unit energy/ghg savings
- Unit investment costs

Data sources:

- P&S
- Exergy
- Other (public domain)
- Stakeholder input

Take-up Scenarios

Take up of efficiency opportunities by building type/sector and scenario:

- Frozen 2006 efficiency
- BAU
- Cost-effective potential
- Technical potential

Outputs:

- End-use intensities
- Total energy intensities
- Peak load savings by end-use

Data sources:

- P&S
- Exergy
- Other (public domain)
- Stakeholder input

Total Savings

Total energy/ghg savings by scenario:

- Energy/ghg savings over time
- Energy/ghg savings by measure (waterfall chart)
- Value of peak load savings
- Analysis of feasible targets

Benefit/cost analysis by scenario, eg:

- BCR
- Abatement cost ($/t)

Figure 11: Building Energy Efficiency Model for Sydney (BEEMS) - Model Structure

ATTACHMENT B

For some building types we may need also to estimate other parameters as the project proceeds, such as the rate of new tenant fit-outs for retail and office buildings, as these can represent important investment opportunities affecting the energy efficiency of tenanted areas.

For the total floor area estimates, particularly in the base year for this study of 2006, we were fortunate to be given access to extremely detailed data from the City of Sydney's *Floor Space and Employment* Census (known as FES). This world-class research is undertaken by the City of Sydney every five years to coincide with the Australian Bureau of Statistics national Census of Population and Housing. The FES is based on an exhaustive census of essentially the entire LGA, including site visits, and it maps a host of parameters including floor area allocated to a comprehensive set of functional descriptors, including 'major use', 'space use' (at a more detailed level), ANZSIC code, etc. Since the 2006, the data has been captured spatially, enabling three-dimensional visualisations of the functional typology of Sydney's buildings, including by floor, above and below ground (see Figure 12 below).

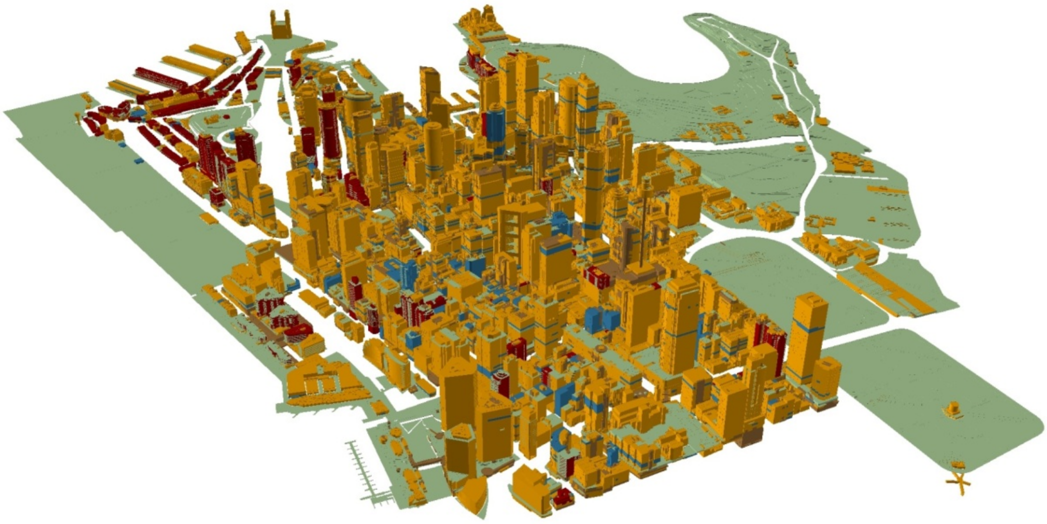


Figure 12: 3-D Spatial Resolution of Sydney CBD

Source: City of Sydney, Floor Space and Employment Census

4.2.1 Functional Classification of Floor Space

The FES provided an extremely robust basis for determining two key parameters in the stock model: first, the total floor area in the entire LGA (in the base year); and second, the distribution of floor area by major building type/sub-type. The typology adopted is based on the Australian Bureau of Statistics' *Functional Classification of Buildings* (Cat. No. 1268.0.55.001). However, we have added further sub-types where:

- There are significant areas of that sub-type in Sydney (eg, car parks), or
- Where the sub-types differ significantly in energy intensity (eg, cold storage vs. warehouses), or both.

Additional sub-types could be resolved within the model over time where there is a policy need and suitable data available.

Each functional type with BEEMS is able to be broadly associated with the other key building classification typology in Australia, which is the one used in the National Construction Code, as shown in Table 9 below. However, readers should exercise caution, as the conceptual basis and coverage of the BCA classifications is unique to the Code and applies to areas within buildings, and not simply to whole buildings. Thus a single building may comprise more than one BCA building class.

Table 9: Building Classifications - BEEMS, ABS and BCA

BEEMS Type/Sub-Type	ABS Classification	BCA Classification
Offices	231 Offices	Class 5
• Premium/A Grade		
• Other Grades		
Accommodation		
• Hotels/Motels	462 Hotels, Motels, etc	Class 3, Class 1b
• Other Accommodation	46 Short Term Accommodation, excl. 462	Class 3, Class 1b
Health	44 Health Facilities	Class 9a
Education	411 Education Buildings	Class 8, Class 9b
Other Commercial		
• Storage		
– Warehouses	321 Warehouses	Class 7b
– Cold storage	331 Cold store	Class 7b
• Car parks	223 Commercial Car parks	Class 7a
– Enclosed		
– Open		
• Pubs, clubs, etc	211 Retail; 451 Entertainment and Recreation	Class 6
• Residual (balancing item)		
Residential		
• Detached	11 Separate houses	Class 1a i)
• Semi-detached	12 Semi-detached	Class 1a ii)
• Multi Unit Dwellings **(1 – 2 storeys, 3 storeys, 4 or more storeys)**	13 Flats, units, apartments	Class 2
Retail		
• Major Shopping Centres	211 Retail and wholesale trade buildings	Class 6
• Smaller Shopping Centres		
• Retail strips		
Industrial	3 Industrial, excl. 321 (warehouses)	Class 8

Source: ***pitt&sherry***

While the ABS classification structure classifies whole buildings based on their 'primary function' (so, a building is categorised as an 'office' if it is 'primarily' used for office activities), in BEEMS we have been able to allocate essentially every square metre of building floor area by its functional type. Thus, the area of 'offices' in the BEEMS stock model is not the number or area of buildings for which the primary function is 'office activities' (the ABS definition), but rather it describes the total floor area of space actually used for office functions, regardless of what kind of building this floor area is situated in. While the latter is more accurate, in terms of allocating space to functions, it does mean that some care needs to be used in using the stock model to represent whole buildings. For example, BEEM/FES indicates that 31% of the total floor area in the LGA in 2006 was used for office functions (see Figure 13 below). However, this does not mean that 31% of the buildings are office buildings, using the ABS definition. Differences can arise due to the prevalence of 'mixed use' buildings which may contain differing areas of office, retail, accommodation, etc, functions within the one building.

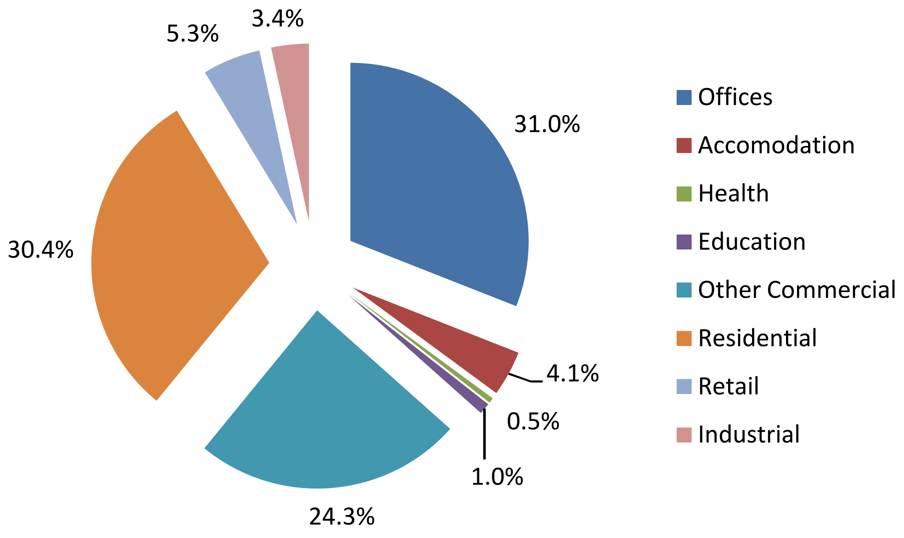


Figure 13: Distribution of Floor Area by Function, City of Sydney, 2006

Source: BEEMS, based on COS Floor Space and Employment Census 2006

4.2.2 Evolution of the Building Stock to 2030

The BEEMS stock model shows growth in the net floor area for the different building types, annually from FY2006 (2005-06) to FY2030 (2029-30). The values can be thought of as the total floor area of that type standing at the end of the period, after demolitions, replacements and net growth have been accounted for. The growth rates for individual building (functional) types are taken from the City of Sydney's CCAP database[52], in order to ensure consistency between this and other Master Plans and planning documents. Most types show a net growth of a little less than 1% per year, but some types (such as detached dwellings) show no net growth at all. We note that, while not modelled, it is likely that some building types – such as detached residential and industrial buildings, for example – may in fact show negative growth in floor area over time, due to competition from higher-value building types.

---

[52] http://www.kinesis.org/tools

4.2.3 Demolitions and Major Refurbishments

There is no ready data source that provides good statistical information on the area of buildings demolished or subjected to 'major refurbishment' annually including, with some exceptions, for the City of Sydney.[53] Both values are very important, however, as the replacements for demolished buildings, and those deemed to undergo 'major refurbishment' (generally, refurbishment of 25% of the area or value of the building) may have to comply with the current version of the BCA, including Section J energy efficiency requirements. As a result, the net area of buildings required to comply with the Code grows at a faster rate than the net growth in the stock. This is good news for energy efficiency, as it means that the energy performance requirements in the BCA are taken up more rapidly as the rate of demolition/replacement and refurbishment increases. However, it also means that the modelled energy savings in BEEMS are sensitive to these parameters. In the absence of better information, we have applied a 'rule of thumb' that there is a 1% per annum demolition rate (with demolished area assumed to be replaced in the next year), and also 1% major refurbishment rate. Note that a figure of 3% per year is more commonly used for major refurbishments, but we assume that only a third of these will be so extensive as to replace most or all of the energy-using plant, thereby triggering Section J for all those systems.

Figure 14 below shows the expected evolution of the building stock – or more strictly, the floor area by space type – over the period 2006 to 2030. By 2030, the total floor area is projected to increase by some 29%, or just under 10 million sqm. This projection 'looks through' the ups and downs of the business cycle, which will see the total floor area grow in a less constant manner than suggested below. However, this average growth rate in floor area is consistent with the City of Sydney's overall expectations, as reflected in the other Master Plans. For clarity, a data table is also provided at Table 10.

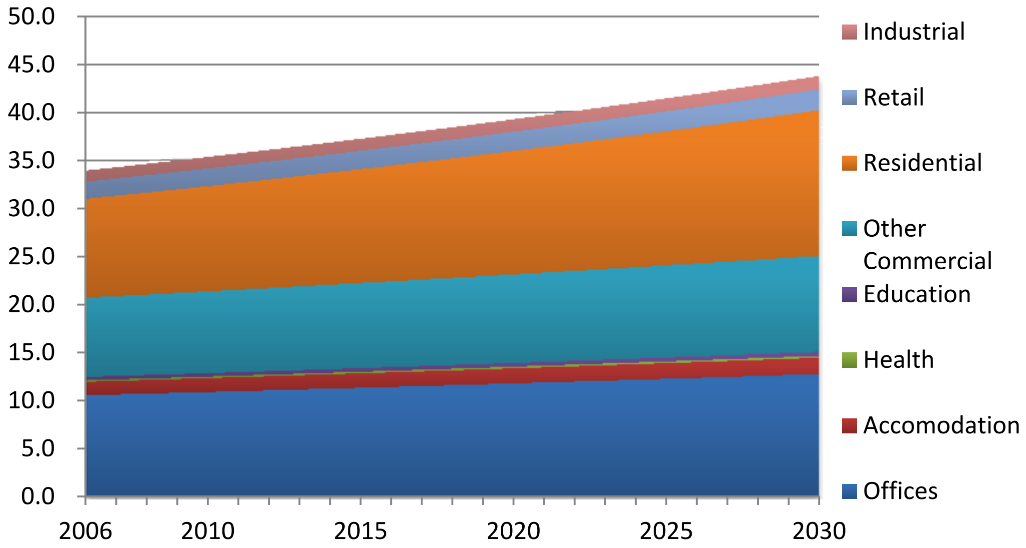


Figure 14: Total Floor Area by Space Type, City of Sydney, 2006 – 2030, million sqm GFA

Source: ***pitt&sherry**, from COS Floor Space & Employment Census*

---

[53] The City of Sydney is currently examining DA records to determine whether statistically valid data can be extracted for this study.

Table 10: Summary of Floor Area by Building Type, Selected Years (million sqm)

	2006	2010	2015	2020	2025	2030
Offices	10.5	10.8	11.3	11.7	12.2	12.7
Accommodation	1.4	1.4	1.5	1.6	1.6	1.7
Health	0.2	0.2	0.2	0.2	0.2	0.2
Education	0.3	0.4	0.4	0.4	0.4	0.4
Other Commercial	8.3	8.5	8.9	9.2	9.6	10.0
Residential	10.3	11.0	11.9	12.9	14.0	15.2
Retail	1.8	1.8	1.9	2.0	2.1	2.2
Industrial	1.2	1.2	1.2	1.3	1.3	1.4
Totals	33.9	35.3	37.2	39.3	41.4	43.8

*Source: **pitt&sherry**, from COS Floor Space & Employment Census*

4.3 Energy and Emissions Models

The model for each building type has the same overall structure, albeit with variations depending upon the number of sub-types resolved or other factors.

4.3.1 Frozen Efficiency Scenario

The models begin by creating a ‘frozen’ or ‘static’ efficiency projection of energy use to 2030, assuming that energy efficiency remains frozen at 2006 levels. The purpose of this projection is two-fold. First, it facilitates a reconciliation of the modelled energy consumption in the base year, 2006, with actual energy consumption as evidenced by data sourced ultimately from the energy suppliers, Ausgrid (electricity) and Jemena (gas)[54]. Second, it provides a reference scenario from which the other, more realistic scenarios are constructed, as described below. In this scenario, the change in energy use is simply driven by the change in area of each building type, while fuel mix is also assumed to remain static.

It’s important to note that this projection is not intended to describe reality: rather, it provides a starting point that enables the quantitative contribution of existing savings measures to the actual path of energy consumption to be identified. It also provides an indication of the ‘savings at risk’ if any of the existing policy measures were to be weakened or removed altogether.

The logical structure of this projection is as follows:

- A value is referenced for total energy intensity (for each building type/sub-type) in 2006;
- For offices and retail buildings, total energy intensity is also broken down by base building and tenant energy consumption;
- Total energy intensity is then divided into total electricity intensity and total gas intensity (note that minor fuels, such as LPG, are ignored) using values specific to each building type/sub-type;
- The fuel intensities are further sub-divided by end-uses (eg, lighting, heating and cooling, ventilation, etc), again using values specific to each type/sub-type;

---

[54] Access to this data was provided through the City of Sydney’s CCAP database.

- End-use intensities are multiplied by the relevant floor areas for each time period (from the stock model) to calculate total energy consumption by fuel and end use for each year;
- Sub-totals for electricity and gas consumption by building type/sub-type are then summed into total energy consumption for each time period by building type/sub-type, along with 'grand totals' for each type.

4.3.2 Business-as-Usual Scenario

A business as usual (BAU) scenario provides a second, critical reference projection. It provides an analysis of what future energy consumption (and greenhouse gas emissions) should be expected to 2030, on the assumption that all key existing policy measures remain in place, and at their current level of 'stringency', and that no new policy measures are introduced. This scenario provides the relevant baseline against which to test the potential additional savings that could be attributed to possible new efficiency measures. Note that, given the importance of the carbon pricing mechanism to energy efficiency savings, and the fact that it is scheduled to be removed in 2014, we have undertaken all modelling on the assumption that there is no carbon price. If a carbon price were retained, then higher energy savings would be cost effective than reported here.

The BAU scenario begins with the frozen efficiency scenario above, but then models energy savings resulting from the more quantitatively significant energy efficiency policies and measures that apply to each building type/sub-type.

The measures that have been modelled in this study include:

- National Construction Code (Section J) energy performance requirements for Class 2 – 9 buildings, including separate treatment of the two key steps for commercial buildings, BCA2006 and BCA2010;
- BASIX for residential buildings;
- The National Australian Built Environment Rating System (NABERS);
- Commercial Building Disclosure (CBD);
- Minimum Energy Performance Standards (MEPS) and Labelling;
- Green Star.

We note that other efficiency policies, programs and measures exist that may impact upon the energy use of buildings in Sydney. For time economy, we have drawn a line at these major measures, but note that other measures could in principle be modelled.

Deducting the savings attributable to these measures from the frozen efficiency scenario results in a 'BAU projection'. The resulting projection of energy consumption should reasonably closely match actual historical energy consumption (2006 – 2012, for example). The match will not be exact, as the model does not simulate:

- Weather variations from year to year, which have an important influence on building energy consumption;
- Occupant responses to higher energy prices (including through carbon pricing) – often referred to as 'price elasticity effects'.

Both of these effects are discussed in Section 5.4 below.

4.3.3 Technical Potential Scenario

The technical potential scenario is based on the potential for technological and design changes to realise energy efficiency gains, regardless of cost. As buildings are complex systems – where the energy consumption of individual energy-using technologies generally depends upon building design, system design, control strategies, occupancy, climate and many other factors – it is not possible to be definitive about the scope for technical efficiency potential in the abstract. Particular building designs and solutions -incorporating state of the art technologies, systems or designs - could be simulated, but this is outside the scope of the current study. Therefore we document examples of the scope for energy savings associated with whole buildings and key building systems. These should be interpreted as indicative only.

4.3.4 Economic Potential Scenario

The economic potential for savings is modelled on the basis of known, cost-effective energy efficiency investments. The underlying data is drawn essentially from energy audit and actual investment business cases, drawn from Exergy Australia's internal databases and also from the Smart Green Apartment audit set. Further details are provided in Chapter 6.

4.3.5 Policy Potential Scenario

The policy potential scenario is drawn by modelling the expected energy savings (and associated costs) that would arise from a particular set of policy measures or programs. The choice of measures has been made in consultation with the City of Sydney, but it is important to note that it would be possible to model additional measures, or the same measures but with different parameters or assumptions, and this would result in different policy potentials being expressed. There is no definitive potential to be discovered, but rather a set of choices to be made about the feasibility of and appetite for particular policy measures. Again, see Chapter 6 for further details.

4.4 Model Validation

Since the data on floor area in the City of Sydney is so well documented, model validation has focused on energy consumption. As a result of past research, including the preparation of Trigeneration and Renewable Energy Master Plans, the City of Sydney has previously compiled electricity and gas consumption data for the LGA from Ausgrid and Jemena. This data is broken down for residential and non-residential customers only, although for electricity, there are separate observations for residential hot water tariffs and for non-residential tariffs greater and smaller than 160 GWh per year. This data is currently available to end FY2012.

It should be noted that the Ausgrid data excludes electricity consumed at high voltage sites, which in the City of Sydney would include railways, water and sewage pumping stations, data centres and similar sites. The energy consumption at these sites is thought to add around another 10% to reported electricity consumption in the LGA, but this cannot be confirmed by Ausgrid as consumption at high voltage sites is considered confidential. While this is a substantial amount of energy, it is not strictly related to building floor area but rather is proportional to the nature of the processes undertaken at these sites. Also, the energy consumption may service areas well outside the LGA's boundaries. For these reasons, we exclude this energy use from our model, and also assign the related floor area to a 'residual' building class for which we model no energy consumption. This ensures that the estimated energy intensity of other building classes is not affected by the exclusion of these high voltage energy users.

The primary reconciliation point for the BEEMS model is the 2006 base year, although it is also possible to utilise later historical data for energy consumption to validate model outputs. We note, however, that differences between assumed and actual growth rates in the floor area of the city between 2006 and 2012, as well as other influences on energy consumption not modelled, may lead to gaps between modelled and actual consumption.

In practice, BEEMS replicates 100% of actual electricity and gas consumption in the base year of 2006 for residential and non-residential customers[55]. We have also balanced the model with actual reported greenhouse gas emissions in 2006, as provided to us by the City of Sydney.

---

[55] Ausgrid has informed the authors that its Community Energy Report for the City of Sydney allocates 'common area' (or base building) electricity consumption associated with larger Class 2 buildings to 'commercial', rather than 'residential', as customers are classified by annual consumption size, rather than strictly whether the consumption is commercial or residential in nature. Our model has been adjusted to compensate for this fact, and therefore shows slightly higher residential and slightly lower commercial electricity consumption than reported by Ausgrid.

5. Baseline Projections

This Section presents the quantitative results, for energy consumption by fuel and building type, and for greenhouse gas emissions, under two of the four scenarios discussed above: the frozen efficiency scenario and the business-as-usual scenario. The first of these is presented in a summary fashion for, as noted above, it serves only to provide a 'counter-factual' scenario of what *would* have happened to energy consumption and emissions to 2030 in the absence of any energy efficiency policy measures or improvement.

5.1 Frozen Efficiency Scenario

5.1.1 Energy Consumption

Figure 15 below shows that, without any efficiency improvement over 2006 levels, energy consumption in buildings in the City of Sydney local government area would be expected to increase by some 4,500 TJ, or almost 25%, by 2030.

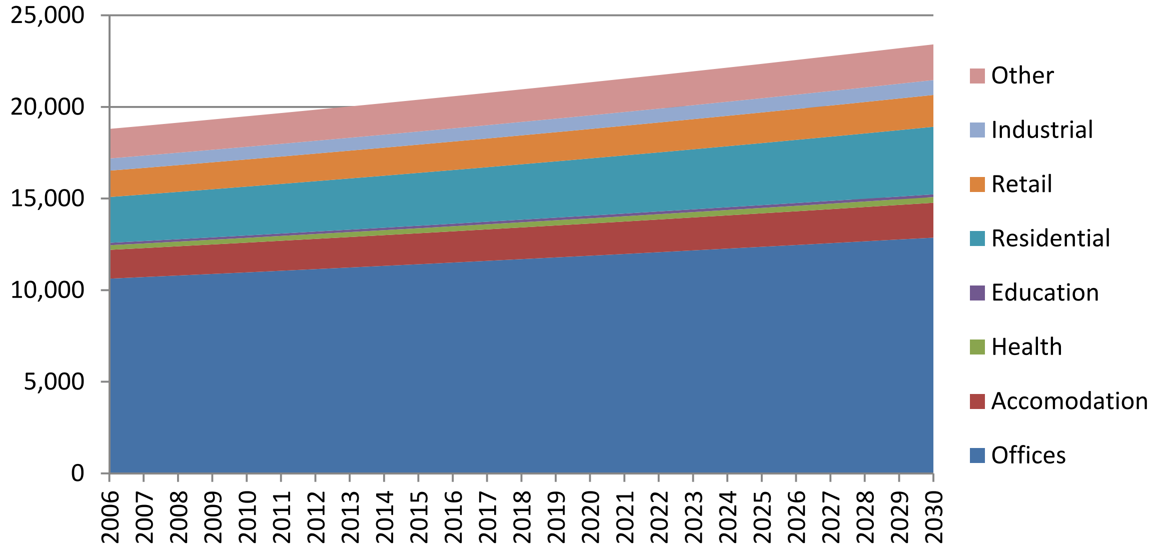


Figure 15: Total Energy Consumption – Frozen Efficiency, TJ

Source: ***pitt&sherry***

The growth in energy consumption, in this 'counter-factual' scenario, would be driven exclusively by the increase in the floor area of different space types, weighted by their average energy intensity in 2006[56]. As noted in Figure 13 above, the overall space use in the LGA is dominated by offices and residential buildings. However, offices are generally much more energy-intensive than dwellings, and so they dominate total energy use, accounting for nearly half (47%) of total energy use in 2030 in this scenario.

---

[56] Energy intensity is the inverse of energy efficiency: it is defined as the energy consumption per unit of output or area. For buildings, this is generally expressed in units of megajoules of energy per square metre of floor space per annum (MJ/m^2.a).

5.1.2 Fuel Use and Greenhouse Gas Emissions

As is shown in Figure 16 below, the trend for greenhouse emissions under the frozen efficiency scenario is notably different to that for energy consumption. Total emissions growth over the period is a little less than 10%, as compared to nearly 25% for energy consumption. There are two key reasons why this difference arises.

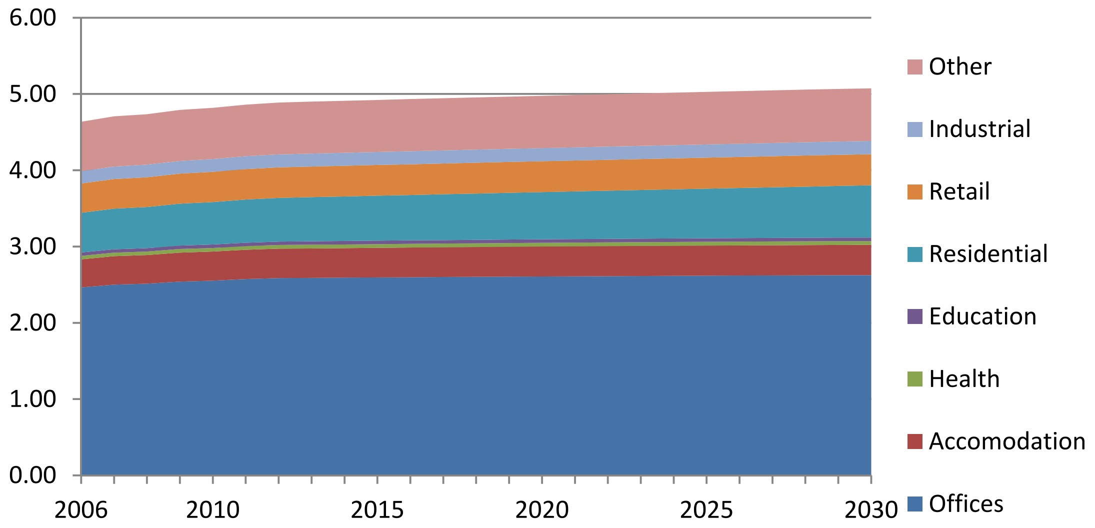


Figure 16: Total Building Related Greenhouse Gas Emissions (Full Fuel Cycle) – Frozen Efficiency, MtCO$_2$-e

Source: ***pitt&sherry***

First, energy consumption in the buildings of Sydney is dominated by electricity, at over 83.5% of total energy use in 2006, while gas' share is just 16.5%. This is important because in NSW, electricity is nearly *five times* more greenhouse gas intensive than natural gas, per megajoule (MJ) of energy consumed. As a result, consumption of electricity in the City of Sydney area is far and away the primary key driver of greenhouse gas emissions. Note that, for the same reason, electricity savings dominate the greenhouse emission savings discussed later in this Chapter.

Second, while the greenhouse gas intensity of natural gas (delivered by pipeline) is expected to remain fairly steady over time[57], the greenhouse intensity of electricity supply is expected to fall significantly. The reasons behind this are manifold, but include the progressive retirement of older and less efficient coal fired electricity generation plant, and its replacement with renewable energy sources, more efficient gas fired sources or potentially much more efficient and modern coal fired power stations (although this is less likely). While this trend towards lower greenhouse gas intensity is being pushed along at present by the carbon pricing scheme, it would be expected to occur in any case. This is because the national Renewable Energy Target scheme, investment in rooftop PV by households and businesses, and investment in cogeneration and trigeneration, would all tend to push down the greenhouse gas intensity of electricity supply to the City of Sydney, even in the absence of a carbon price. However, the greenhouse intensity of electricity supply would be expected to fall further and faster in the presence of a (significant) carbon price.

---

[57] Noting that possible changes from fossil fuel to renewable gases, envisaged in other Master Plans, are not considered here, to avoid double counting.

In this study, we assume that the greenhouse intensity of electricity supply in NSW will fall modestly over time by some 12%, from around 294 t CO2-e/TJ (on full fuel cycle basis[58]) in 2006 to some 258 t CO2-e/TJ by 2030. This fall in greenhouse intensity of electricity supply tends to offset the increase in electricity consumption, resulting in a significant reduction in the rate of growth of greenhouse gas emissions over the period to 2030, even without improvement in energy efficiency. The modest growth of greenhouse gas emissions in this scenario helps to explain why the expected improvements in energy efficiency in the City of Sydney – expected because they are resulting from policy drivers and market trends already in place that help to drive quite significant reductions in greenhouse gas emissions in the business as usual scenario, as discussed below.

5.2 Business-As-Usual Scenario

A business-as-usual or BAU scenario is defined as a world in which current policy and market trends continue, but no new policies or unanticipated (i.e., currently unknown) technologies are assumed to be present. While at one level this is unrealistic, as technologies and policies do change, we do not have any knowledge today about the nature of these changes. Making projections based on unknown future changes is risky at best and potentially misleading. The purpose of making business as usual projections is not to predict the future, but rather to understand what kind of future our current policies, technologies and market trends are taking us to. Then, if there are aspects of this future that we would wish to change, we know that we need to consciously change one or more of the factors driving those future outcomes.

As the BAU scenario is a more realistic scenario than frozen efficiency, the preliminary findings of our analysis are presented in more detail noting, for example, differing results for differing building/space types. Further, since the key difference between the frozen efficiency and BAU scenarios is the energy savings attributable to existing energy efficiency policy measures and market factors, the estimated quantitative impact of these measures is also described. However, we begin with an overview of the key results.

5.2.1 Overview

Energy Consumption

Figure 17 below shows that in the BAU scenario, total energy consumption in buildings in the City of Sydney area is projected to fall modestly over the period to 2030, despite the expected 29% increase in floor area over this period. In total, energy consumption is projected to fall by just over 9% by 2030, compared to the 2006 value. Relative to the frozen efficiency scenario (which showed growing energy consumption), the BAU scenario shows a 35% saving in energy consumption. That is, without the existing policy measures that are in place, energy consumption in 2030 would have been 35% higher than it is expected to be under a business-as-usual scenario.

---

[58] In this study, as with other Master Plan documents, we apply full fuel cycle emission factors in order to take account of emissions associated with the transmission and distribution of fuels to Sydney.

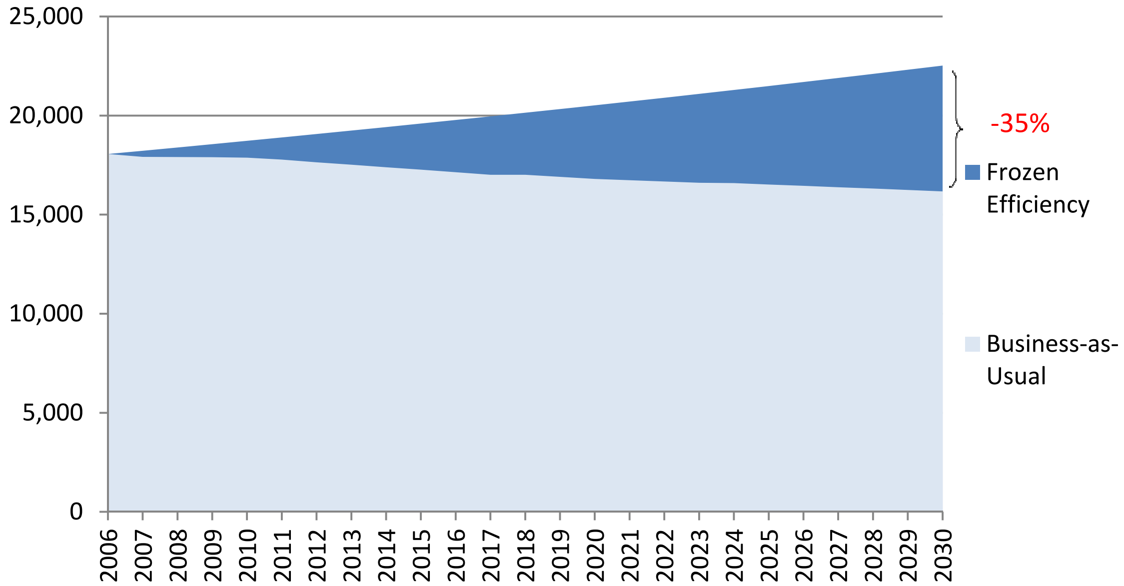


Figure 17: Total Energy Consumption, Business-as-Usual vs. Frozen Efficiency Scenarios, TJ

Source: ***pitt&sherry***

5.2.2 Contribution of Policy Measures to Energy Savings

The key mechanism driving energy savings in the BAU scenario is that existing energy efficiency policies are steadily improving the energy efficiency of the building and appliance/equipment stock as it is replaced or refurbished through time. The key policy measures that are contributing to this outcome include:

- The National Construction Code (BCA) energy efficiency provisions;
- BASIX;
- Minimum Energy Performance Standards (MEPS) and labelling of equipment and appliances
- NABERS;
- Commercial Building Disclosure (CBD); and
- Green Star.

As discussed further below, the energy savings associated with NABERS, CBD and Green Star, and also the CitySwitch and Better Buildings Partnerships programs delivered by the City of Sydney, are modelled jointly due to significant inter-dependencies between these initiatives.

With respect to appliances and equipment, the savings estimates take into account known trends, for example, increasing penetration rates and installed capacity of air conditioners in houses, at least to the extent to which these trends have been quantitatively analysed (see “MEPS and Labelling” below for further details).

The contribution of each of the key policy measures to total energy savings in the BAU scenario is shown in Figure 18 below. The savings attributable to each measure is shown as a ‘wedge’ of savings, relative to frozen efficiency. The BAU energy consumption follows the bottom line (BCA2010), which takes all the wedges into account. Note that in this figure, the savings attributable to BCA2010 are almost obscured by the CBD saving line, and y-axis is not set to zero, to accentuate the differing contributions of measures.

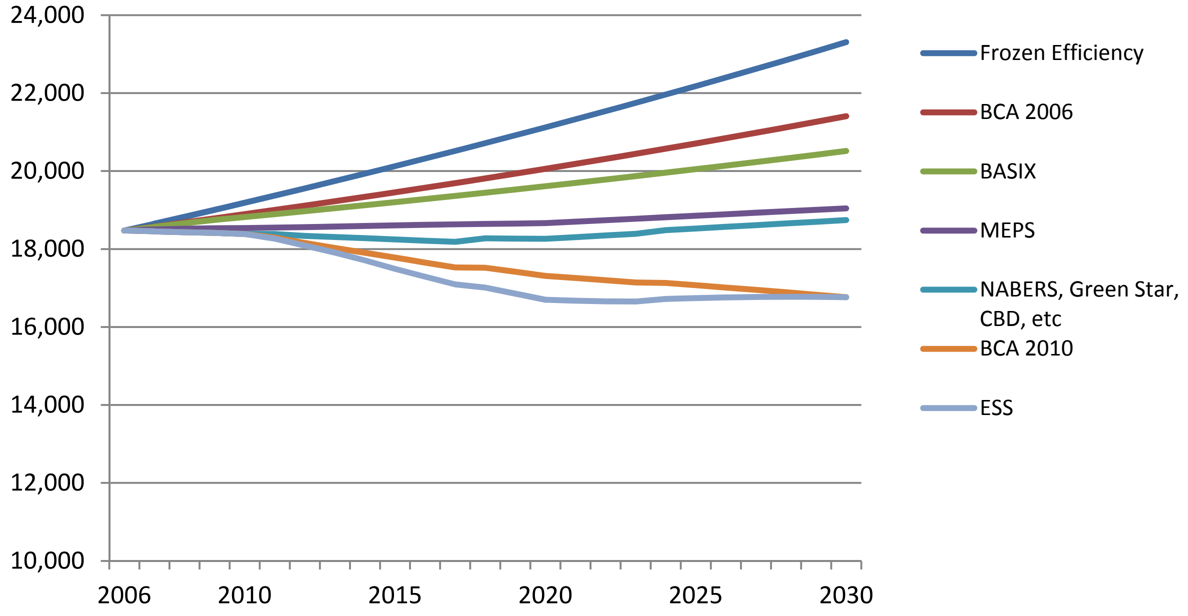


Figure 18: Contribution of Major Policy Measures to Energy Savings, Business-as-Usual Scenario relative to Frozen Efficiency, TJ

Source: ***pitt&sherry***

The relative contributions of measures to total savings in each year are highlighted in Figure 19 below. Note that the data underpinning Figures 5.4 and 5.5 is identical – only the presentation format has changed. Here the dominance of savings from BCA2006 in particular is clear, while BCA2010 savings grow quickly from 2011 onwards. MEPS and BASIX contribute significant and growing savings through time, while the group of NABERS, Green Star, etc, also contributes important energy savings. These are expected to diminish in relative terms through time, primarily as the gap between current stringency settings and the ‘business as usual’ efficiency of new buildings closes.

As an overall caution, it should noted that modelling multiple policy measures that operate on the same energy end-uses is complex, as measures can interact in positive or negative ways. While we have taken care to avoid double-counting of savings, as noted with reference to particular measures below, it is beyond the scope of this study to undertake a definitive analysis of all possible policy interactions. Also, we are reliant on published estimates of the savings attributable to specific measures, and not all of these have been verified by retrospective and independent analyses. Finally, other measures and trends may also be affecting energy consumption in a BAU scenario, but these have not been modelled.

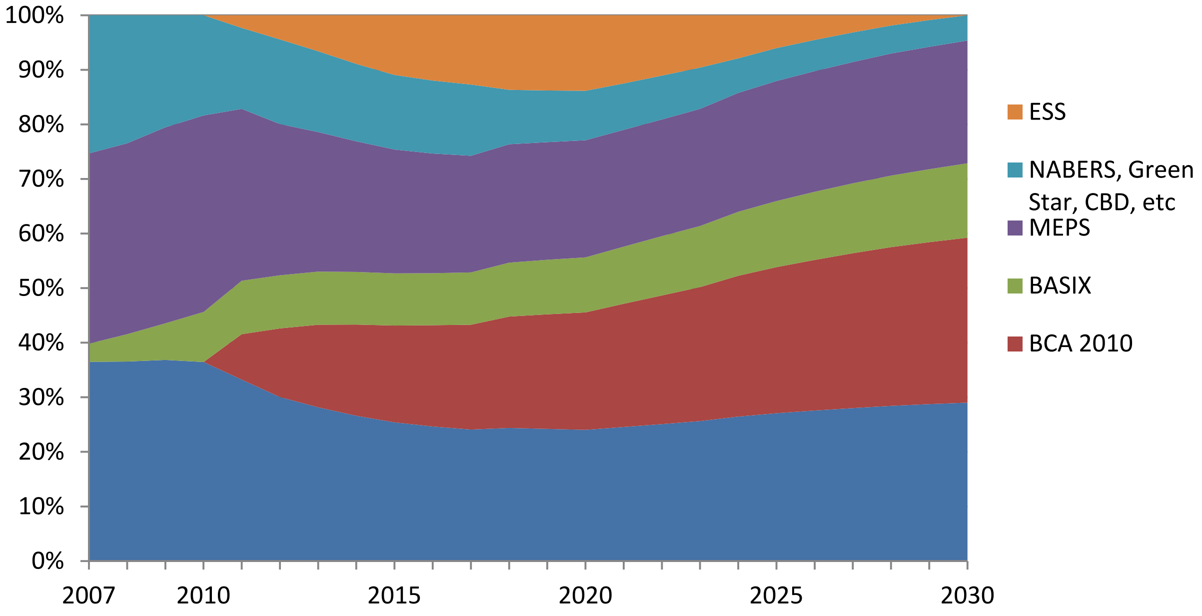


Figure 19: Contribution of Major Policy Measures to Energy Savings, Business-as-Usual Scenario, 2007 – 2030, % Shares

*Source: **pitt&sherry***

Building Code of Australia 2006

The significant share of total energy savings contributed by BCA2006 occurs for at least three reasons. First, the measure has been in place from 2006 (first savings in 2007) and is assumed to remain in place until 2030. Indeed, by 2030, the rate of 'turnover' of some classes of buildings is such the most of buildings of that class that are standing in 2030 are expected to have been built or upgraded to the energy performance requirements of BCA2006 (if not to a higher standard). Second, the measure applies to virtually every building class considered in this study, with the exceptions being BASIX (which effectively takes the place of the BCA energy performance requirements for residential buildings in NSW) and cool stores, where we assume no significant impact from BCA provisions. Third, since BCA2006 included the first set of energy performance requirements for commercial buildings in Australia, it contributed significant energy efficiency improvements *relative to* the performance of the unregulated stock before that date. This is so even though the 'stringency' of the Code provisions embodied in BCA2006 was modest[59].

A note of caution here, however, is that the standard of Regulatory Impact Statements (RIS) has generally speaking improved through time, and some analysts believe the savings (particularly gas savings) attributable to BCA2006 were overestimated in the RIS. Second, we are not aware of any retrospective analysis to determine what the realised savings from BCA2006 actually were, as distinct from what they were expected to be. Again, many analysts believe that the level of compliance with Section J provisions, and hence the level of energy savings that result from them, is lower than the 'official' estimates in the relevant RIS', as they are based on an assumption of full compliance. Also, it should be noted that not all building types covered in this study were modelled in the relevant RIS', and therefore some assumptions have had to be made about the expected impact of those provisions on certain building types.

---

[59] The Regulatory Impact Statement for BCA2006 notes that the benefit cost ratio for the measure was a generous 4.9:1, meaning that a significant number of energy savings opportunities – that could have been realised cost-effectively – were in fact 'left on the table'.

BCA2010

Turning to the 2010 version of Section J provisions (referred to as BCA2010), the 'stringency' of these provisions is higher than BCA2006, as evidenced by generally higher energy savings (measured in $MJ/m^2.a$) and a lower benefit cost ratio, estimated at around 2:1.[60] Therefore the energy savings ramp up quickly, as new buildings (including replacements of those demolished) and buildings subject to major refurbishment, are required to comply with these provisions. There is some uncertainty within the buildings community itself about what exactly constitutes 'major refurbishment' sufficient to trigger the application of the current version of the BCA, and also about which elements or sub-systems of a building have to comply, depending upon the nature of the refurbishment undertaken. For the purposes of this study, we assume that 1% of each building class is refurbished annually to the extent that the full Section J savings measures apply. Similarly, we assume 1% of the stock is demolished and replaced annually. Note that we show the *incremental* savings attributable to BCA2010, over and above those attributable to BCA2006, to avoid double counting the two measures.

BASIX

For the business-as-usual scenario, we model existing BASIX targets. We note that these targets are currently under review in the context of the NSW Energy Efficiency Action Plan. The 'new building' measures modelled in Chapter 6 may be interpreted as higher performance requirements in the National Construction Code and/or as higher BASIX targets (for residential buildings) in NSW.

Estimates of energy savings attributable to BASIX are derived mainly from the numerous reports published by NSW Planning (please refer to Appendix A, References). We also note that a single report, Energy Australia (2010), examines the actual measured performance of BASIX houses (detached dwellings only) over the period 2007 – 2009. This shows that *actual* energy savings for these dwellings averaged around 16%, rather than the 40% targeted. The key reasons were the increased average size of dwellings, compared the benchmark year of 2004, and also an increasing density and use of appliances, including air conditioners, IT equipment and the like. These factors may be argued to be independent of BASIX, however they do affect the actual energy savings realised.

For this reason our analysis assumes that the savings rate achieved by BASIX detached dwellings tracks the Energy Australia results over the 2007 – 2009 period, but progressively moves up to the targeted savings rate (40% - or higher where there is over-compliance 'as designed') over the subsequent 4 – 5 years. The justification for this is that it appears that, for the time being at least, the previously relentless growth in the average size of new detached dwellings, and also growth in residential energy consumption, in Australia has slowed and indeed reversed in recent years. There is considerable doubt about the extent to which these recent trends will continue, particularly if economic growth rebounds and/or key policies are removed or amended.

Note that our analysis applies a more modest 'discount factor' to the improvement in energy efficiency of semi-detached and multi-unit dwellings (MUDS) under BASIX, as there is evidence that the average size of these dwellings has, in fact, fallen slightly since 2006, and this would tend to offset the trend towards higher energy consumption associated with appliance and equipment use. We note that there is no similar retrospective study for these dwellings types as the Energy Australia study for detached dwellings, nor has this study been repeated in more recent years. Also, as noted earlier, the targets for multi-unit dwellings are lower than those for detached and semi-detached dwellings, and lower for the high-rise and compared to low-rise units. Since the dwelling stock in Sydney is weighted heavily towards multi-unit dwellings, these lower BASIX targets translate into lower energy savings over the period to 2030 than is expected for some other building types. For the multi unit dwellings, the average savings expected from BASIX, weighted by the different areas of low-, medium- and high-rise MUDS, is just under 30%.

---

[60] CIE, 2009.

NABERS

This measure has been modelled in line with our own previous studies, drawing on estimates of performance improvements published by the NSW Office of Environment and Heritage which manages the program. While these estimates have not been independently verified, they appear plausible. Buildings rated more than once are reported as achieving around 9% energy savings on average. The estimates, however, are not fully differentiated by building type and time period.

The future take-up rate of NABERS (separate to Commercial Building Disclosure, as discussed below) is not a known value and has had to be estimated, particularly for building types where the take-up is currently modest (eg, hotels and shopping centres). Here we assume a steady growth in take-up in the City of Sydney market, reaching close to 30% of the floor area of those building types by 2030. For the offices market, we assume that the take-up rate of NABERS continues to climb steadily to reach 90% of the total stock by around 2020.

A further challenge in estimating energy savings attributable to NABERS is to avoid double counting those savings that are also claimed by CBD and by Green Star (discussed further below). This is because Green Star utilises NABERS for its energy ratings (meaning that there is no additionality[61] between the two, while CBD essentially requires mandatory, rather than voluntary, disclosure of efficiency in its niche (office spaces over 2,000 sqm). As noted earlier, we therefore report NABERS, Green Star and CBD savings jointly. A dedicated study would be required to tease apart interactions between these measures (and the NSW Energy Savings Scheme) in a more forensic manner.

Commercial Building Disclosure (CBD)

This measure has also been modelled in line with a previous, detailed study we undertook for the then Federal Department of Climate Change and Energy Efficiency.[62] The CBD program also publishes excellent data on the take-up and savings attributable to this measure. However, the program has only been in place since late 2011 and, at the time of writing, there is only data available on the first 12 months' experience with the measure. During this period, the take-up of the measure has been faster than anticipated, due mainly to the practice of many larger building owners of rating all covered properties annually, which is not strictly required under the program. As a result, energy savings attributable to the measure are also assumed to be somewhat higher than anticipated in the relevant RIS. As with NABERS and Green Star, we assume a declining savings rate for CBD over the longer term due to saturation effects and no change in current policy settings (eg, no expansion to new building types).

Green Star

Energy savings attributable to Green Star are also estimated from official estimates available from the Green Building Council. These estimates are reasonably detailed, but not fully broken down by state and time period. Estimates for the take-up of Green Star for NSW, and then the City of Sydney, were made, with a higher share of the total in early years and plateauing at an average of 20 buildings per year thereafter in the LGA. The share of the 20 buildings by type and also their average floor area is assumed to match the national averages reported. As with NABERS and CBD, we assume initial energy savings rates as reported, but a diminishing rate of growth in energy savings through time, as the 'reference' energy efficiency of new buildings will be improving each year. Consistent with the BAU scenario, we do not assume any tightening of the energy performance requirements under Green Star in future which, if they did occur, would tend to offset this diminishing returns effect.

---

[61] 'Additionality' refers to the extent to which energy (or emissions) savings attributed to one measure are additional to those that might be also claimed by other measures. It is important to take this issue into account to avoid double-counting energy savings.

[62] Published as NSEE (2013).

MEPS and Labelling

The MEPS and labelling program is a long-standing and highly successful regulatory program that requires, depending upon the product, increasing energy efficiency and/or efficiency labelling, as a form of 'mandatory disclosure'. Energy savings associated with the program have been estimated in the past in GWA (2009), and these estimates are employed in this study.[63] Savings are estimated in groups of residential and non-residential appliances/equipment, and separately for gas and electricity. For certain building types (like cool stores), chiller MEPS are applied separately to estimate energy savings. Since savings estimates are only available to 2020, we extended these to 2030 assuming a 25% saturation effect, due to appliances and equipment already sold to MEPS standards being replaced, at the end of its economic life, with equipment at the same efficiency level, leading to no *additional* savings. As with other measures, we assume no expansion of the program or increase in the stringency of individual measures over the period to 2030 in the business-as-usual scenario.

5.2.3 Energy Intensity

The energy savings from the above policy measures leads to a steady reduction in the average energy intensity of all building types over the period to 2030. However, the rate of change varies by building type depending upon the number and stringency of energy efficiency measures that affect them, the rate of stock turnover or take-up of measures.

Figure 20 below shows the stock-average energy intensities for each building type modelled in the business-as-usual scenario in 2006, 2012 and 2030. It should be noted that this Figure does not indicate the expected energy intensity of new builds in 2030; rather, it shows the *average* energy intensity of all buildings standing in that year. Different and more elaborate modelling techniques would be required to account for the incremental intensity of new builds in each year. For greater clarity, the values of Figure 20 are replicated in Table 11 below.

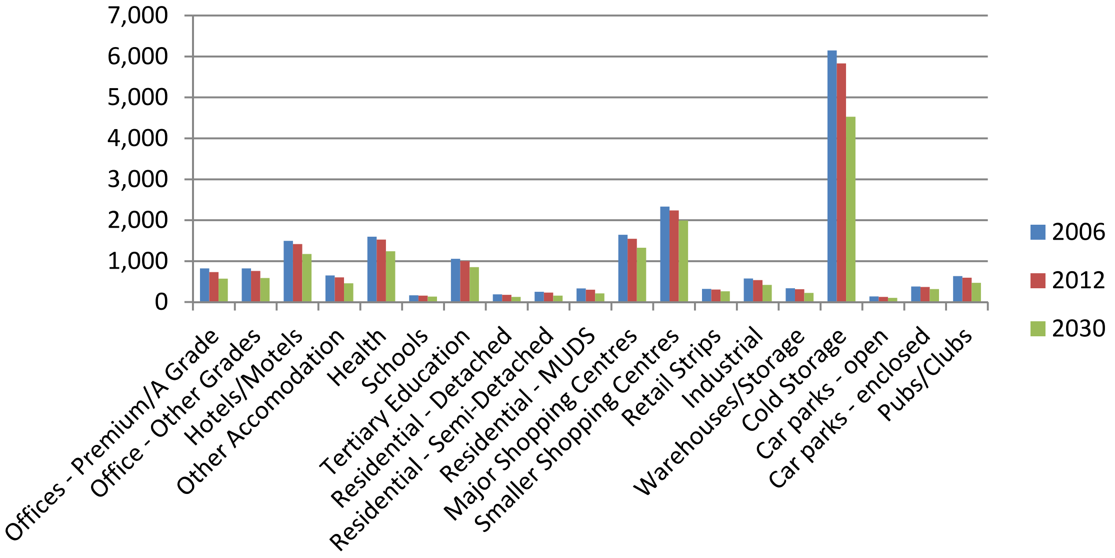


Figure 20: Stock Average Energy Intensities by Building Type, City of Sydney, Business-as-Usual Scenario, Selected Years, MJ/m2.a

Source: ***pitt&sherry***

---

[63] We understand that new estimates have been prepared in 2013 but these are not yet published.

Table 11: Stock Average Energy Intensities by Building Type, City of Sydney, Business-as-Usual Scenario, Selected Years, MJ/m2.a

	2006	2012	2030
Offices - Premium/A Grade	825	734	573
Office - Other Grades	825	760	588
Hotels/Motels	1,496	1,417	1,177
Other Accomodation	650	606	458
Health	1,597	1,528	1,241
Schools	167	158	135
Tertiary Education	1,059	1,002	856
Residential - Detached	190	176	125
Residential - Semi-Detached	253	232	160
Residential - MUDS	332	303	214
Major Shopping Centres	1,645	1,548	1,328
Smaller Shopping Centres	2,334	2,241	1,993
Retail Strips	322	307	262
Industrial	576	538	419
Warehouses/Storage	337	316	223
Cold Storage	6,147	5,831	4,526
Car parks - open	137	128	102
Car parks - enclosed	382	368	317
Pubs/Clubs	637	597	470

Source: ***pitt&sherry***

5.2.4 Greenhouse Gas Emissions Savings

Overview

With the energy savings of the above measures taken into account, as well as the declining greenhouse gas intensity of electricity supply discussed in Chapter 4, greenhouse gas emissions associated with building energy use in the City of Sydney LGA are expected to fall by some 21.5% by 2030 as compared with 2006 (see Figure 21). This represents of fall of just over 1 Mt CO_2-e, from 4.75 Mt CO_2-e to just over 3.7 Mt CO_2-e, despite a growth floor area of 29% over the same period.

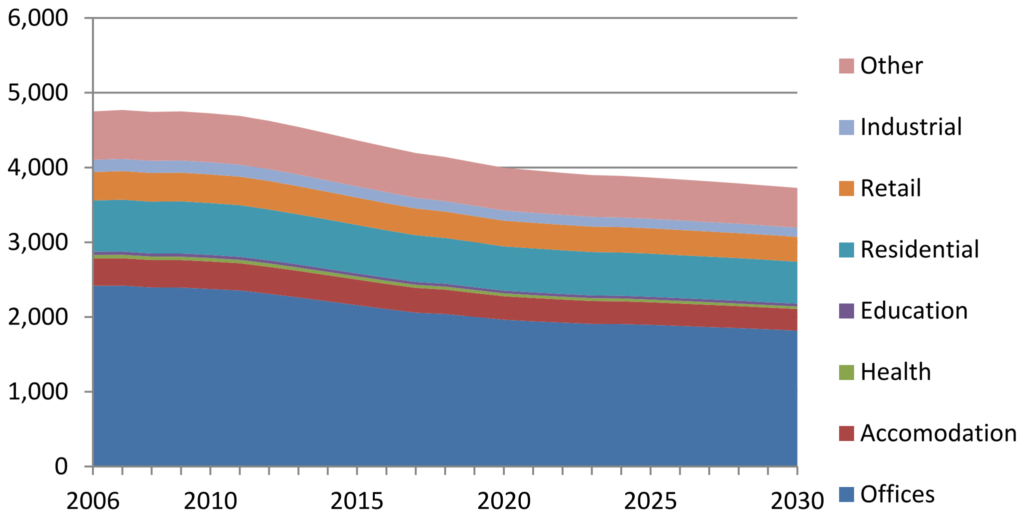


Figure 21: Total Building-Related Greenhouse Gas Emissions, Business-as-Usual Scenario, 2006 – 2030, kt CO_2-e

Source: ***pitt&sherry***

Emissions and Savings by Building Type

Figure 21 above also reveals that emissions are dominated throughout the period by offices. This reflects their 31% share of the floor area (Figure 13), their relatively high energy intensity (Table 11), and also their high electricity share in total energy use (estimated at 89% on average). By contrast, while residential buildings have a similar floor area to offices (Figure 13), their energy intensity is considerably lower (Table 11) and they also have a lower electricity share (around 62% for the dominant multi-unit type). Therefore their share of total emissions is much lower than that of offices.

A notable result is the high share of 'other commercial' buildings in total emissions. These buildings have a significant floor area of over 24% of the LGA total (Figure 13) and include a mixed bag of energy intensities (Table 11). While cool stores are extremely energy intensive, for example, at some 5,800 MJ/m^2.a in 2012, there were only some 36,000 sqm GFA of cool stores in the LGA in that year and therefore their share of total emissions is modest. By contrast, enclosed car parks were estimated to occupy some 3.2 million sqm GFA in 2012. While their energy intensity is estimated to be much lower than coolstores, at around 369 MJ/m^2.a, this energy is 100% electricity and, when multiplied by the significant floor area, adds up to a significant emissions profile for this building type.

Figure 22 below shows the contributions that individual building/space types make to the 23% average reduction in greenhouse gas emissions by 2030 in the business-as-usual scenario. Generally the buildings that have higher than average energy intensities, on an area-weighted basis, show greater savings, and those with lower intensity tend to show lower proportionate savings. Sectors such as retail include some building/space types with very high energy intensity (Table 11), however, overall the floor area is weighted towards 'retail strips' with lower energy intensity. However, other factors that affect the relative contributions of different building types are the number (and stringency) of efficiency measures that apply to each type and also their fuel mix (as noted, electricity savings lead to larger emissions savings than do gas savings).

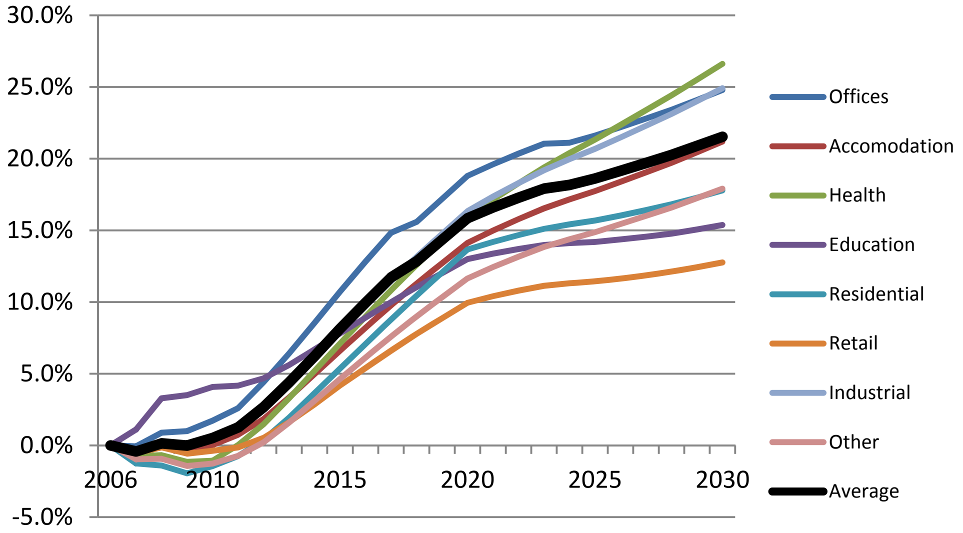


Figure 22: Greenhouse Gas Emissions Savings by Building Type, 2006 – 2030, BAU, %

Source: ***pitt&sherry***

Contribution of Efficiency Measures to Greenhouse Emission Savings

Figure 23 below shows the contributions that the various policy measures, modelled as part of the business as usual scenario, make to overall greenhouse gas emissions savings. This is shown as a 'wedges' diagram, in order to visualise how each measure helps to bend down the expected trajectory of emissions, from around 10% growth in the frozen efficiency scenario, to the 23% fall projected in the business-as-usual scenario, relative to the 2006 emissions level (recalling that this is equivalent to nearly 18% when measured as a share of the LGA's *total* emissions, including waste and transport).

Figure 24 shows the relative contributions of measures in each time period more starkly, with the overall pattern reflecting that for energy savings (see Figure 19 - subtle differences are attributable to the differential impacts of measures in saving electricity vs. gas, with the former leading to higher emissions savings per unit energy savings).

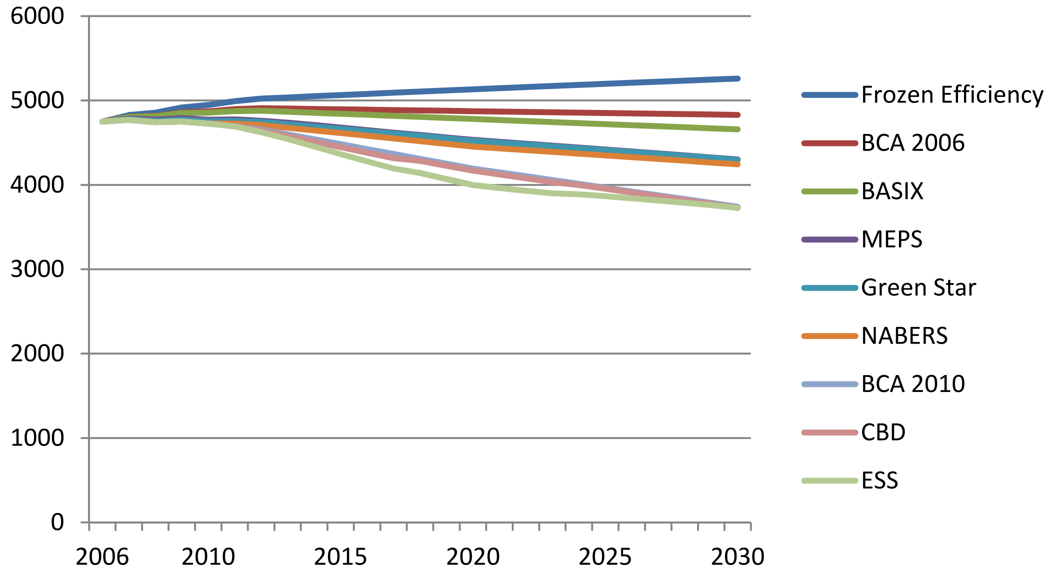


Figure 23: Contribution of Policy Measures to Greenhouse Gas Savings, 2007 – 2030, Business-as-Usual Scenario relative to Frozen Efficiency, Mt CO_2-e

Source: ***pitt&sherry***

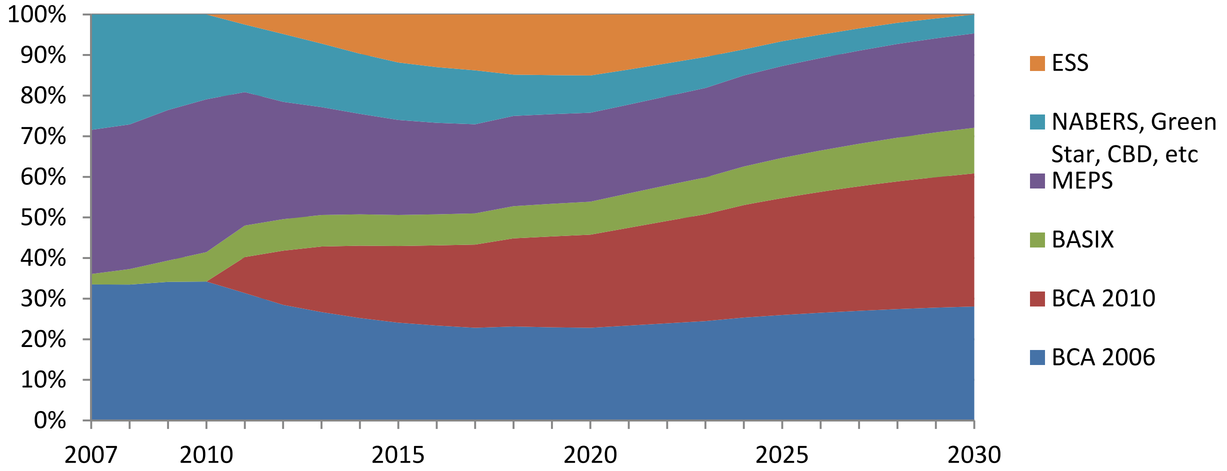


Figure 24: Contribution of Policy Measures to Greenhouse Gas Savings, Business-as-Usual relative to Frozen Efficiency, 2007 – 2030, %

Source: ***pitt&sherry***

5.3 Key Trends and Uncertainties

This Section discusses some of the factors that could lead to the future path of energy use and greenhouse gas emissions in the Sydney LGA varying from the one described thus far. These factors include behavioural, economic or structural effects that may influence energy demand, and climate related-effects. As noted, variations in existing energy efficiency policies could also impact on these trends, and while a quantitative assessment of any such variations is beyond the scope of this research, possible new policy and program options are discussed in Chapter 6.

5.3.1 Demand Trends and Price Effects - Residential

An analysis was undertaken of seven years of annual residential electricity consumption data in the City of Sydney LGA, provided by Ausgrid. The starting point was to compare measured actual annual electricity consumption per residential customer with the estimates of BAU consumption per customer resulting from detailed bottom-up modelling of the various regulatory energy efficiency measures which affect residential electricity consumption in Sydney.

Ideally, the first step should have been to adjust the actual consumption data for year on year changes in the relative severity of successive summers and winters in Sydney (measured in terms of cooling and heating degree days respectively). Unfortunately, making this correction requires monthly, not just annual, consumption data, and this was not available. Our judgment, however, is that making such an adjustment would have a relatively small effect on the overall outcome of the analysis. However, see further analysis of this effect in Section 5.3.3 below.

The bottom-up modelling of BAU residential electricity consumption earlier in this Section includes a significant element of building central services consumption in high rise apartment buildings. This consumption, which is typically large per building, is the responsibility of the property manager. Property managers are typically businesses, often large businesses, specialising this work. For this reason, and also because of the size of the total consumption, Ausgrid classifies this consumption is commercial, rather than residential (as do relevant statistical agencies). In the initial year of the modelling, this consumption accounted for 25.5% of total residential electricity consumption. A factor of 0.745 was therefore applied to the BAU modelling figures to obtain estimates of annual residential electricity consumption net of apartment building central services consumption. This is probably a conservative assumption, in that high rise apartments are a growing share of total dwellings in the City of Sydney.

The adjusted BAU modelled residential electricity consumption was then compared with the actual consumption, with the results shown in Table 12 below. It can be seen that the modelled estimates track very closely with the actual consumption figures until the last two years, when the actual are much lower than the modelled numbers.

The final step in the modelling was to apply a price response to the gap between the actual consumption and the BAU modelled consumption results which emerged over the last two years. Price data used were the successive values of the electricity component of the Sydney CPI, divided by the All Groups CPI for the same period, to give an estimate of the real price in each year. Values for the March quarter in each year were used; these are likely to give a good representation of electricity prices for the whole year, since in NSW most price elements are increased annually, on 1 July.

The year on year changes in real prices were applied to the BAU model estimate of consumption in each year, to generate a modelled estimate of consumption in the following year. A number of different combinations of price elasticity value and response lag were applied to find which combination gave a result which most closely reproduced the actual consumption values. Two sets of results are shown in the Table. The first set, applying no response lag, gives the closest replication of the observed consumption with a price elasticity value of 0.35. The second set applies a response lag of three years and a price elasticity value of 0.30. This gives a close result because the large fall below BAU in 2012-13 is influenced by the first large price increase (19% real), which occurred in 2009-10.

Table 12: Annual per customer residential electricity consumption under various modelling approaches (MWh/customer)

Year ending June	2007	2008	2009	2010	2011	2012	2013
Actual	4.88	4.76	4.70	4.55	4.50	4.27	4.08
BAU model	4.88	4.80	4.67	4.57	4.50	4.42	4.31
BAU model plus price response, elasticity -0.35, no lag	4.88	4.72	4.57	4.27	4.40	4.23	4.07
BAU model plus price response, elasticity -0.30, 4 year lag	4.87	4.71	4.61	4.53	4.44	4.34	4.07

Source: ***pitt&sherry****, from Ausgrid data*

5.3.2 Demand Trends – Commercial

An analysis was also undertaken of seven years of annual commercial and industrial (i.e. non-residential) electricity consumption data in the City of Sydney LGA, provided by Ausgrid. These actual data were compared with the estimates of BAU consumption resulting from detailed bottom-up modelling of the various regulatory energy efficiency measures which affect non-residential electricity consumption in Sydney.

The modelled data includes consumption for all categories of electricity consumers except residential. To this was added the estimate of the share of modelled residential consumption attributable to building central services in multi-story apartment blocks. This consumption is the responsibility of the property manager. Property managers are typically businesses, often large businesses, specialising this work, so this consumption is, appropriately, classified by Ausgrid as commercial rather than residential. The estimated quantity of this consumption was subtracted from the modelled estimate of BAU residential consumption, and for this analysis it has been added to the modelled estimate of commercial consumption, so as to enable comparisons with actual consumption to be made on a consistent basis.

Ausgrid classifies its non-residential customers into two groups: small sites, defined as those using less than 160 MWh/year (equivalent to an average of about 440 kWh per day), and medium/large sites, defined as those using more than 160 MWh per year. Customers consuming energy at high voltage connections are excluded from the data for confidentiality reasons. The data, shown in Table 13, suggest that this classification was introduced in the 2007-08 year, so that the data for the two groups in earlier years cannot be used for the purpose of constructing a consistent time series for the two groups. It can, however, be used for the total of all commercial and industrial consumption.

Table 13: Non Residential Electricity Consumption Trends – Sydney LGA

Year ending June		2007	2008	2009	2010	2011	2012	2013
Consumption (GWh)	Small	1,481.5	925.0	850.3	808.0	788.8	769.1	754.5
	Medium/large	2,283.4	2,879.3	2,857.3	2,852.2	2,809.7	2,719.6	2,635.0
Customer numbers	Small	28,772	28,036	28,729	28,774	29,321	29,936	NA
	Medium/large	1,066	3,040	3,271	3,368	3,392	3,336	NA
Consumption per customer (MWh)	Small[64]		33.0	29.6	28.1	26.9	25.7	
	Medium/large		947.1	873.5	846.9	828.3	815.2	
Decrease from 2008	Small			-10%	-15%	-18%	-22%	
	Medium/large			-8%	-11%	-13%	-14%	

Source: ***pitt&sherry****, from Ausgrid data*

The comparison for modelled BAU results is shown in Table 14 below. The bottom-up modelling uses seven separate categories of electricity customers, as follows: Offices, Accommodation, Health, Education, Retail, Industrial, Other. The customer-specific consumption data which would be required to map these categories onto the two consumption size classes used by Ausgrid are not available. Therefore, comparisons between modelled and actual consumption can only be done on the basis of non-residential consumers as a whole. The results of the comparison are shown in Table 2. It can be seen that, as with residential customers, consumption per customer in the first few years covered by the analysis fell at about the same rate, or slightly slower than actual consumption. More recently, however, actual consumption has clearly fallen faster than modelled consumption. To confirm this trend it would be valuable to examine customer numbers for 2012-13 when they become available.

Table 14: Non Residential Electricity Consumption – Sydney LGA – Modelled (BAU) vs Actual

Year ending June		2007	2008	2009	2010	2011	2012	2013
Consumption (GWh)	Actual	3,765	3,804	3,708	3,660	3,599	3,489	3,390
	Modelled	3,753	3,739	3,730	3,722	3,692	3,647	3,603
Consumption per customer (MWh)	Actual	126.2	122.4	115.9	113.9	110.0	104.9	
	Modelled	125.8	120.3	116.6	115.8	112.9	109.6	
Decrease from 2007	Actual		-3%	-8%	-10%	-13%	-17%	
	Modelled		-4%	-7%	-8%	-10%	-13%	

Source: ***pitt&sherry****, Ausgrid*

---

[64] Note that there was a change in the definitions of "Small" and "Medium/large" between 2007 and 2008 – for this reason, it would be misleading to calculate consumption per customer for 2007.

5.3.3 Temperature and Climate Impacts on Energy Demand

There are at least three kinds of climate variability or change that are impacting, and will impact in future, on energy consumption in Sydney's building stock. These are:

- Year-on-year weather variations, such as cooler than average summers or milder than average winters;
- The 'urban heat island' effect; and
- Anthropogenic climate change.

Temperature Effects

Normal variations in the climate impact significantly on energy consumption in buildings, primarily by changing the demand for space heating and cooling, which typically represents around 50% of a building's annual energy consumption (depending upon the design and function of the building). In this study, the effect of historical variations in summer and winter conditions has been examined by calculating total consumption of electricity in the four highest consumption summer months, which are consistently December to March, and the four highest consumption winter months, which are, also consistently, May to August. This requires access to monthly consumption data, for which Australian Energy Market Operator (AEMO) data has been used. These data are only available at the state region level, i.e. the whole of NSW, including the ACT. The analysis starts from summer 2004-05, at which time total annual demand was still growing at much the same rate as it had been for some years previously.

Estimates of total demand for winter 2012 and 2013 and summer 2011-12 and 2012-13 have been adjusted upward by our estimate of the monthly electricity consumption at the Kurri Kurri aluminium smelter, prior to its closure, which we estimate to be approximately 3.0 TWh per annum for two potlines. The first potline closed in January 2012 and the second in September 2012.

Overall, milder weather in 2011-12 may have contributed to the fall in electricity consumption in that year, but are less likely to have caused the further and only slightly smaller fall in 2012-13 (see Table 15).

Table 15: Recent Seasonal Trends - NSW

Season	Severity
Winter 2011 (half in 2011-12)	Average
Summer 2011-12	Mild, i.e. below long term average temperatures
Winter 2012 (half in 2011-12 and half in 2012-13)	Average
Summer 2012-13	Severe, i.e. above long term average temperatures
Winter 2013 (half in 2012-13)	Mild, i.e. above long term average temperatures

*Source: **pitt&sherry** from Bureau of Meteorology data*

Seasonal electricity consumption is shown in the graphs in terms of both total energy consumption (adjusted for Kurri Kurri) and energy per residential customer in the year, taken from ESAA statistics. Residential customers account for about 30% of total annual consumption and nearly 90% of customers.

The severity, or otherwise, of the season was defined by the total number of cooling degree days, for summer, and heating degree days, for winter, over the same four month periods. Cooling degree days are referenced to 23 deg. C and heating degree days to 18 deg. C. The reference meteorological station used was Richmond, in outer north west Sydney.

The results suggest that, for NSW as a whole, while seasonal demand is affected by seasonal severity, changes in severity for year to year have not caused the decrease in demand since 2009. Specifically, summer 2012-13 was almost identical with summer 2010-11, but seasonal electricity demand was 5% lower and 6% lower in terms of demand per residential customer. Similarly, heating degree days gradually increased over the three winters of 2010, 2011 and 2012, while seasonal energy consumption, both in total and per residential customer, gradually decreased.

It would be desirable to confirm this analysis for Sydney by undertaking a similar analysis for the Ausgrid supply are or, better still, the City of Sydney area only, if the relevant monthly energy demand were available. Observatory Hill would be an appropriate meteorological station for such an analysis.

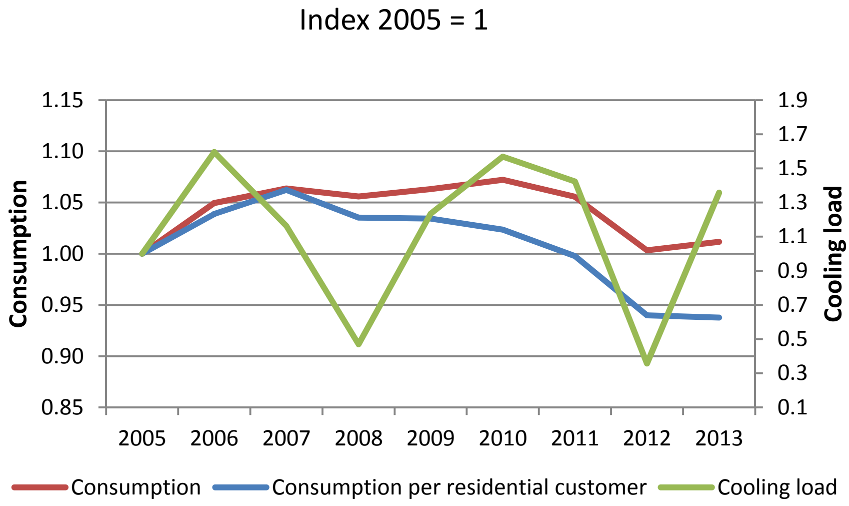


Figure 25: NSW Summer Electricity Consumption Trends: 2005 - 2013

*Source: **pitt&sherry**, from AEMO data*

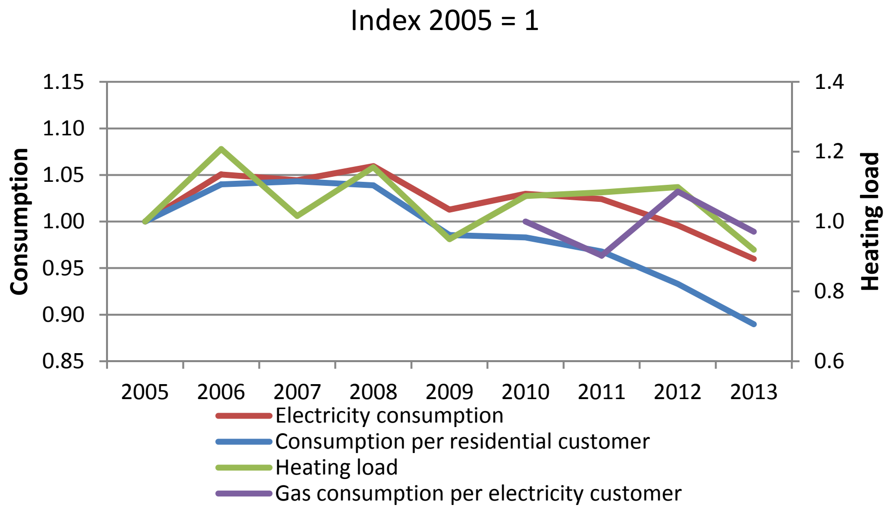


Figure 26: NSW Winter Electricity Consumption Trends: 2005 - 2013

*Source: **pitt&sherry**, from AEMO data*

The Urban Heat Island Effect

A second kind of climate change relevant to the City of Sydney is known as the 'urban heat island' effect. This effect documents the tendency for cities to be warmer than their surrounding areas, due to:

- Heat build-up in the thermal mass of cities (eg, buildings, pavements, roads) – particularly when the albedo of the surfaces is low (dark), for example due to bitumen roads and pavements, and when green space and trees are limited;
- Reduction of wind flow (and hence natural cooling) due to the physical obstruction created by the urban form;
- Heat rejection from ventilation air outlets and heat exchangers.

The heat island effect can add significantly to thermal loads on buildings in summer, significantly increasing the demand for energy for cooling purposes. At the same time, the same effect tends to reduce demand for space heating in winter, although not to the same degree as the increase in cooling load. This is due to lower solar gain in winter and the fact that the space conditioning demand of most commercial buildings in particular is dominated by cooling, rather than heating, loads. This in turn reflects the need for such commercial buildings to reject surplus heat from large glazed surfaces and from the density of equipment (and even people) within the buildings. The City of Sydney is currently collecting data to determine the extent to which shade trees and changed pavement colours affect urban ambient temperatures. It should be noted that the impact of the urban heat island effect on energy consumption in 2006 will be present in the actual energy consumption data for that year, however its contribution to the total is unclear.

Anthropogenic Climate Change

Finally, a third form of climate variability is anthropogenic climate change, which is caused primarily by the combustion of fossil fuels but also by land-clearing and the reduction of natural carbon sinks. The global climate change negotiations under the United Nations Framework Convention on Climate Change reflect an ambition to limit concentrations of greenhouse gases in the atmosphere to 450 ppm (parts per million) by 2050. If this is able to be achieved, it is believed that there will be a 50% chance of limiting the rise of global average temperatures to 2^{o} Celsius. Current concentrations of greenhouse gases in the atmosphere are around 400 ppm – a level believed not to have been reached in at least the last million years. Since there is uncertainty about whether the global community will be able to limit greenhouse gas emissions sufficiently to achieve this goal, and also uncertainty about the extent of climate change that would actually accompany such an emissions trajectory, an increasing number of climate scientists are calling for more urgent and rapid reductions in emissions, in order to limit the risks of much greater global warming with its attendant risks for human populations and the natural environment.

Research conducted by the Centre of Excellence for Climate System Science has estimated that the combined temperature increase in Sydney, due to both the urban heat island effect and anthropogenic climate change, could reach 3.7 degrees by 2050.[65]

5.3.4 Building Compliance Issues

As discussed in Section 4.2.3, there is uncertainty both about the rate of demolition and major refurbishment of buildings in Sydney, as this data is not readily available from the City's data systems, and also about the extent to which refurbished buildings are being upgraded to meet at least current minimum requirements in the National Construction Code. We note that this issue is not restricted to Sydney, and indeed **pitt&sherry** (in conjunction with Swinburne University) is undertaking a National Energy Efficient Buildings Project to identify solutions for this and related Code non-compliances across Australia.

However in Sydney, our modelling indicates that this issue has the potential to have a surprisingly large impact on future energy consumption and, hence, greenhouse gas emissions. This is firstly because there is a great deal of refurbishment activity that occurs each year, ranging from fit-out to complete renewal of building plant, equipment and interiors, and also facade renewals. At least 50% of building work each year is of this type rather than the construction of new buildings. As a natural investment point in a building's life cycle, refurbishment and fit-out represent opportunities to upgrade the energy performance of building systems and even whole buildings. If this opportunity is not captured – for example, because compliance with BCA requirements might not be effectively enforced – then the 'opportunity cost' of lost energy savings will accumulate through time. Possible policy/program solutions are modelled in Chapter 6.

---

[65] Argueso et al (2013).

6. Additional Energy Efficiency Opportunities

The analysis in the previous sections represents the starting point for identifying the new and additional scope to identify and capture energy efficiency opportunities in the City of Sydney LGA. This Chapter examines these additional opportunities in detail.

Note that the savings referred to in this Chapter are savings additional to those already described under the 'business as usual' scenario in the previous Chapter. Where specifically noted, we also compared savings against the 2006 baseline, as this is the target metric for the City of Sydney. All new measures and potential are estimated over the period 2015 – 2030, noting that FY 2015 (ending 30 June 2015) may be the first year in which any new initiatives, resulting from the *Energy Efficiency Master Plan*, take effect.

We have divided this analysis into two broad categories: residential and non-residential/commercial building types. We stress that each building type and market is unique, and the opportunities we identify in each should be considered as average or typical values – they will not be available in all cases. Also, many buildings have been and are being upgraded under the influence of initiatives such as NABERS, Green Star, Smart Green Apartments and Environmental Upgrade Agreements, to name just some of the current initiatives, and these buildings may not require further upgrading in the near future. In this study, an estimate is made of the 'base case' uptake of all measures studied, to ensure that the residual energy efficiency potential across the LGA is not over-estimated.

A second split in the analysis, for each building type, is between the *economic* potential for additional savings (those that are cost effective) and the *policy* potential for additional savings (those attributable to specific policy measures). Finally we illustrate present 'medium' and 'rapid' uptake scenarios, where 'medium' is defined as reaching 50% of the estimated full potential by 2030, and 'rapid' is defined as reaching 100% of the estimated potential by 2030.

In the analyses of economic potential, we do not attempt to describe any particular policy or program mechanisms that might be able to capture some or all of this potential. This is left to the analyses of policy potential. Here we take into account the market and information barriers that often impede a rate of energy efficiency improvement that can, based on technical potential only, appear cost effective. But as noted in Section 2.2, in fact such barriers are common. The assessments of policy potential in this Chapter are based on assumed policy or program models, and they take into account both market barriers and estimates of the costs of designing and administering policies and programs, in addition to the starting-point uptake of efficiency measures.

Finally, at the end of the chapter there is an additional analysis of the opportunity to reduce peak energy demands via energy efficiency improvements. Peak load reductions may or may not represent energy efficiency improvements, and conversely, there are other ways to address peak loads, including by adding distributed generation from renewable or fossil fuel sources. However, peak load reductions can arise from energy efficiency improvements, representing a significant 'spillover' economic benefit that should be taken into account when assessing the overall case for energy efficiency improvements.

6.1 Technical Potential

The potential for buildings to reduce energy consumption by maximising efficiency is very high. Studies in the United States have estimated that commercial building energy use could be reduced by 80% through efficiency measures alone.[66]

A residential 'Ultra-Low-Energy-Building' can require up to 90% less energy compared to a conventional new residential building. The magnitude of savings depends on climate zones, varying between 60% and 90%. Savings can be very large in cold climate zones for instance, as a 'normal' building in such zones consumes large amounts of energy for heating. In milder, temperate climates, the underlying need for heating and cooling is lower presenting the opportunity for very low energy use.[67]

Cutting edge upgrades to existing buildings can also yield impressive savings. The Lawrence Berkeley Laboratory recently conducted a 'deep retrofit' study on a small number of Californian homes. One home reduced energy use to 75% less than the average.[68]

These high levels of energy savings depend on the entire building system being fine tuned for energy efficiency. Each energy end use system (heating/cooling, lighting, etc) must be highly efficient. These end use systems should sit within a smart building envelope that minimises the work required of the energy using equipment.

The broad potential for energy savings by major end use is explored below and the section concludes with a brief discussion of the design principles that allow for very low energy use.

6.1.1 Cutting edge space conditioning

There are numerous methods and technologies that can dramatically reduce the energy consumed to provide heating and cooling. They include:

- *Separate ventilation, heating and cooling*. In Australia HVAC systems commonly combine into a single system that functions of heating, cooling, ventilation, humidity control. The use of highly efficient equipment, combined with automatic sensors can produce very useful efficiency gains. However these combined systems have large ducts and must move heat and cool over long distances, which must result in energy waste. It is also difficult for such integrated systems to finely manage the various loads that differ in the various building zones (size and people). This leads to under performance in the actual conditioning task.

  A cutting edge method of minimising energy waste is to separate the HVAC functions. For instance a dedicated outdoor air system can provide ventilation. This allows air to be moved only when ventilation is needed, not when heating or cooling is needed. Energy is saved and superior air quality is also delivered. Heating and cooling should be also separately provided to discrete zones. The provision of 'zone systems' allows the energy optimum to be achieved. Load can be precisely sized and ducts are short so resulting equipment efficiency can be maximised, while thermal losses and pressure drops are minimised. Reductions of well over 40% are feasible.[69]

- *Low temperature hydronic systems.* Hydronic delivery of heat and cool using systems that run at a low temperature difference (27 degrees for heating and 19 degrees for cooling) are a recognised solution for very low energy buildings. The most efficient hydronic systems capture low temperature waste heat and incorporate active solar heating and evaporative cooling.

---

[66] USEPA (2010).
[67] Schuwer et al (2012).
[68] LBNL (2013).
[69] Building Science Corporation (2009, 2014); IEA (2013).

- *Solar Thermal Air Conditioning.* These systems use solar energy to drive a cooling or refrigeration process rather than electricity. While the use of such technology is slight in Australia, the potential energy savings across an HVAC system are very large – in the order of 75%.[70]

6.1.2 Cutting edge lighting

Highly efficient lighting options are now available, and LED lighting continues to improve, seemingly month to month. At present halogen lamps produce in the region of 20 lumens per watt. CFLs are around 3 times as efficient at about 60 lumens per watt. The best linear fluorescents can better 100 lumens per watt, while High Intensity Discharge Lamps are near 120 lumens per watt. White LED lamps are improving at a very rapid rate and are expected to exceed 150 lumens per watt in the short to medium term.[71]

The integration of highly efficient light producing technologies, a sophisticated lighting control system (that ensures light is provided only when needed) and a design that capture available daylight can reduce lighting energy use by more than 80%.[72]

6.1.3 Cutting edge hot water

Maximising the energy efficiency of hot water production in buildings revolves around two principles. The first is the selection of efficient equipment. The second is to design the system to minimise energy waste.

Large, centralised systems require the transfer of water over long distances – resulting in thermal (energy) losses. Additionally it is difficult to ensure that such large systems are always optimised to meet rises and falls in demand – again resulting in energy waste.

Small systems, that are positioned and optimised to meet 'at point' hot water needs, minimise energy waste. Sensors that monitor for water leaks can also prevent energy (and water) waste. Water efficient appliances and fittings ensure that energy is not wasted on the heating of surplus water. Heat pump or solar technologies can be used (or combined) to ensure needs are met efficiently. Efficiency can be maximised through the use of heat recovery technologies (making use of warm, waste heat from other building systems.

Consumption of electricity or gas for hot water can be reduced by around 80%.[73]

6.1.4 Cutting edge design

Cutting edge design for energy efficiency minimises the energy use of the entire building system.

Designs that capture and control natural light, natural heat/cool and natural ventilation can greatly reduce the need for the building system to consume electricity or gas in the supply of light, space conditioning and other 'services'. Best practice design involves highly thermally efficient building envelopes (through insulation, sealing and glazing design and technology selection) that integrate the energy using systems to meet service needs for minimal energy consumption.

The energy savings opportunities of advanced envelope design in large commercial buildings are impressive - the need for additional heating and cooling can be reduced by up to 60%.[74]

---

[70] Kohlenbach and Dennis (2010).
[71] IEA (2014).
[72] OEH (2012b) and http://eex.gov.au/technologies/lighting/
[73] OEH (2014)
[74] IEA (2013).

Design can also greatly reduce the energy consumption of residential buildings. European studies have found that 'passive house' designs (for both individual and small to medium multi-unit dwellings in Germany) can lower primary energy use to 28% of that consumed in an existing dwelling.[75] The Californian house upgrade mentioned in the introduction of this section was done to 'passive house' standards.

6.1.5 Conclusion

Overall, we conclude that the technical potential to reduce energy consumption in buildings – using energy efficiency strategies alone, and without consideration of cost-effectiveness – is at least 80%. However, how much of this potential is practically realisable for any given building (new or retrofit) will depend on a wide range of factors: the owner/designer's intent, location, tolerance for capital investment, access to innovative and expert service providers, etc. It is important that 'cutting edge' buildings and technologies continue to be developed and trialled, even if not fully cost-effective in the short term. This kind of applied research, development and demonstration is vital to prove up new techniques, designs and technologies; to drive down costs; to increase scale efficiencies; and to upskill the whole building supply chain in their use.

6.2 Benefit Cost Analysis and Abatement Cost Curve Methodologies

The economic and policy potentials for energy savings are modelled, rather than researched, and therefore we introduce these scenarios with an overview of the methodology we have used to assess the potentials and also of key assumptions made.

6.2.1 Benefit Cost Analysis

Benefit cost analysis is undertaken on each of the economic and policy opportunities studied, in order to estimate for each measure:

- The quantity of energy savings by fuel (TJ);
- The quantity of greenhouse gas savings (t CO_2-e);
- The value of energy savings ($'000 2013 real); and
- Incremental costs ($'000 2014 real/ t CO_2-e).

Features of the cost benefit analysis methodology includes an assumption that the new measures are applied between 2015 and 2030, and that savings accrue until the end of the economic life of the investments made (see Table 18) or 2050, whichever is earlier. Where the end of the economic life occurs before 2030, we model reinvestment of the required capital.

Generally we assume a 1% 'learning rate' on the value of incremental costs per year. Learning can occur as a result of new technologies, economies of scale (leading to cost reductions) and increased skill/know-how on the part of building professionals. However, where certain aspects are labour-intensive (such as the conduct of audits) we assume no cost reduction through time, but rather constant cost in real terms.

A real discount rate of 7% is applied to bring future costs and benefits back to a present value. All prices are in 2014 real (inflation adjusted) dollars.

---

[75] Joosten, S (2006).

We assume no carbon prices from FY 2015 onwards, given the current Australian Government's announced intentions to remove the carbon pricing mechanism. We note that while a carbon tax would further enhance the business case for energy efficiency improvements, this case is already very strong. Our assessment is that non-price barriers – including a lack of targeted information and trusted service providers, and specific market failures such as the tenant/landlord split incentive – are the key barriers to these savings being taken up.

Electricity Prices

Electricity prices have been modelled in detail through to 2020 by **pitt&sherry**'s Dr Hugh Saddler, using a bottom-up methodology that separately models wholesale costs, carbon costs (where relevant), transmission costs, distribution costs, retail costs and margins, feed-in tariffs, large and small renewable energy scheme costs and also costs associated with the NSW Energy Savings Scheme. Key data sources include IPART's Review of Regulated Retail Prices for Electricity (IPART, June 2013), Frontier Economics (2013) and AEMC (2013).

A volume weighted average NSW pool price for 2012-13 was used as the starting point for the wholesale component ($56.05/MWh), while the starting point for the residential retail tariff in 2013-14 is Energy Australia's plan tariff second tranche price (above 11 kWh/day), ex GST, of 27.2 c/kWh. Average prices to commercial customers are no longer transparent but are generally lower than for residential customers. We assume an average price of 22.2 c/kWh in 2013-14. A 50/50 weighted average of the two price series is constructed for multi-unit dwellings, on the advice of Ausgrid, noting that base buildings at larger MUD sites generally attract a commercial tariff, whilst the units themselves attract the residential prices. After 2020, we simply assume an average 0.5% real price increase each year to 2050.

The resulting price projections are illustrated in Figure 27 below. The traces are quite flat overall, at least until 2030 – a stark difference to the actual trend of recent years. This reflects factors such as the removal of the carbon price, very modest AEMO demand projections to 2020, declining SRES costs to 2017 and falling LRET costs from 2026. Faster electricity price growth than assumed would improve the benefit cost analysis for electricity-savings measures, other things being equal.

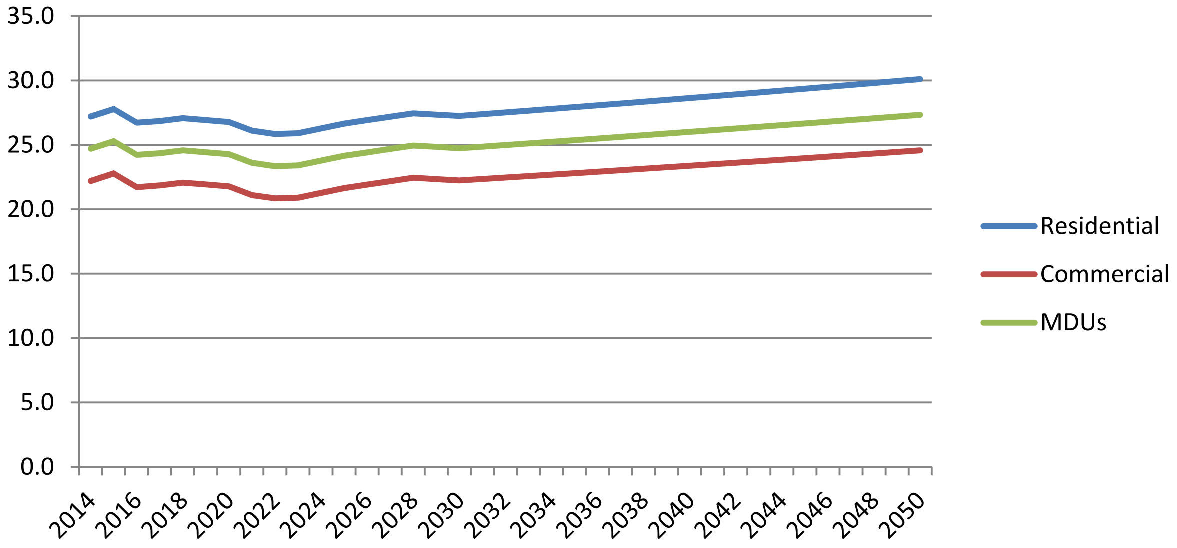


Figure 27: Retail Electricity Price Projections: 2014 - 2050 (c/kWh)

Source: ***pitt&sherry***

Gas Prices

Gas prices have also been projected by Dr Hugh Saddler on a bottom-up basis. Key data inputs for this analysis include IPART's Review of Regulated Retail Prices and Charges for Gas 1/7/2013 – 30/6/2016 (IPART 2013b) and AER (2010). Wholesale prices in 2012-13 start at $7.66/GJ excluding carbon costs. While wholesale gas prices are expected to rise in the short term, this effect is offset by an assuming phasing out of the carbon price. After 2017, wholesale prices are assumed to rise by $0.30/GJ per year in real terms.

Network costs average around $9/GJ, while we assume a retail margin of 7%. For the residential sector, the 'baseline' retail price observation, of $19.20/GJ in 2013-14, is based on AGL's second tranche residential tariff. We assume business tariffs are, on average around 16% lower (so starting at around $16/GJ retail). Again we construct an MUD average tariff, weighted at 27% commercial (common areas) and 73% residential (dwellings), based on consumption patterns revealed in the Smart Green Apartment audit set.

The price projection is illustrated in Figure 28 below. The initial fall reflects carbon price assumptions, as noted, but also an expected drop in the network cost component and the flow-on effect of these assumptions for the retail cost component. Were gas prices to rise more quickly than assumed, this would favour lower abatement costs and improved benefit cost ratios for gas savings measures, other things being equal.

Further assumptions specific to individual building classes are noted in the relevant sections (6.3 and 6.4) below.

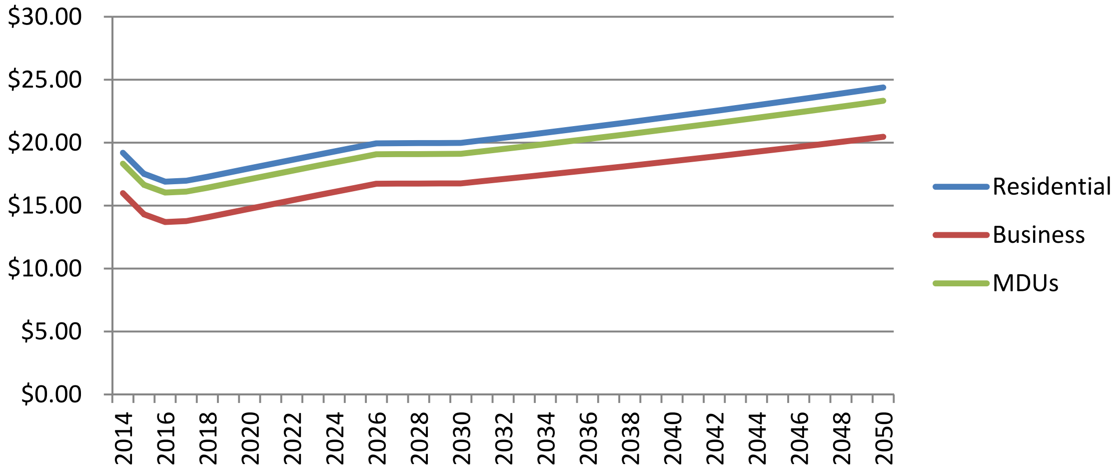


Figure 28: Retail Gas Price Projections: 2014 – 2050 ($/GJ)

Source: ***pitt&sherry***

6.2.2 Abatement Cost Curves

Greenhouse gas abatement cost curves are useful devices, in that they compress a large amount of information into simple, intuitive charts. Each bar represents a unique measure or opportunity. Because of this, the abatement effect of measures can be added together (within a single cost curve) to reveal the total abatement potential, given the scenario being presented (medium uptake, rapid, etc).

The height of each bar indicates the average abatement cost, over the period 2015 – 2030, measured in $ (2014 real)/tonne CO_2-e. If the bar is below the x-axis, this indicates that the measure has a negative abatement cost. This means that there are net financial savings to be realized at the same time as emissions are reduced. Strictly, the abatement cost is the present value of net annual costs in each year over this period, discounted at a 7% real discount rate, divided by the cumulative greenhouse gas abatement over the same period. Note also that abatement costs are *incremental costs*, or just the additional amount required to pay for the more energy efficient technology or design in question. The analysis remains balanced, because the benefits described (energy savings) are also measured as incremental benefits, i.e., only those attributable to the more energy efficient design or technology.

These values are calculated using the benefit cost analysis model, as described above. A negative abatement cost indicates that the present value of the savings exceeds the present value of the costs over the time period in question, while a positive abatement cost indicates the reverse. An abatement cost of 0$/t would indicate a measure with a benefit cost ratio of 1.

The final dimension of these charts is the width of each bar. This indicates the number of tonnes of carbon dioxide equivalent (CO_2-e) that are estimated to be associated with the measure, at the abatement cost shown. Both the height and width of each bar is affected by assumptions made about the nature of the measure undertaken, energy prices, carbon prices, take-up rates and many other factors. They should therefore be regarded as indicative only. Further assumptions specific to individual building classes are noted below.

6.3 Residential Buildings – Economic and Policy Savings Potentials

This section of the Report is enhanced by two additional analyses, commissioned by the City of Sydney, providing deeper insights into a) opportunities for higher BASIX targets for multi-unit dwellings and b) retrofit energy (and water) efficiency opportunities for these same buildings. While separate Reports have been prepared for these tasks, the findings are also summarised here.

6.3.1 Detached Dwellings

Detached dwellings represented just over 3% of all residential building space in the LGA in 2006, and this value appears to have fallen marginally in recent years (2011 FES vs 2006) possibly to accommodate the growth of multi-unit dwellings, discussed further below. Their share of energy consumption is lower than their floor area share, as their average energy intensity in 2015 is estimated at some 164 MJ/m2.a, lower than semi-detached or multi dwelling units.

We have therefore conducted a limited analysis of this building type, divided into an examination of the efficiency potentials in new dwelling and retrofits. For new builds, there is conflicting evidence about the potential for efficiency improvement in the Sydney climate zone. **pitt&sherry** (2012) was commissioned by the Federal Government to examine this and related questions and concluded that few improvements to the thermal shell would be cost effective in the base case, with no carbon price, no industry learning and based on a conventional quantity surveying approach to cost estimation. A further limitation on this study is that it includes no examination of peak load savings. With medium range carbon price, and allowing for industry learning (which reduces the cost of compliance with higher efficiency standards), savings close to 20% would be cost-effective (across all residential forms except multi-dwelling unit base buildings) by 2020.

However a second reference, Sustainability House (2012), was tasked to examine the scope for no or low-cost efficiency improvements in residential buildings, and finds that up to 1 NatHERS star improvement can often be achieved, at essentially no cost, through simple design changes such as:

- Optimising orientation;
- Mirror-imaging floor plans to ensure living areas face North;
- Optimising window placement;
- Optimising window/wall area;
- Internal zoning;
- Improved management of thermal mass.

In some cases, these changes may actually reduce construction cost, including where windows or unnecessarily complex wall forms are rationalised[76]. The opportunity for such changes are potentially limited by a number of factors, primarily being the design preferences of building occupants, but also solar access considerations, the location of desired and undesired views, and the slope and orientation of building blocks. We model the effect of this below. The very low abatement cost (notionally around *minus* $130/t – see Table 16 and Figure 29) reflects the virtually no-cost improvements modelled. Since there are few such dwellings of this type being constructed in the projection period, the opportunity for greenhouse gas savings is very low, even in the rapid uptake scenario.

Table 16: Data Table: Detached Dwellings: Rapid Uptake: 2015 – 2030

Opportunity	Abatement Cost ($/t)	Cumulative Abatement (t CO2-e)
New Builds	-$129	1,126
Retrofit Program	$13	16,043
Reduction of 2006 residential emissions by 2030:	0.3%	

*Source: **pitt&sherry** (note tonnes abated are cumulative over 2015 – 2030, while the 0.3% reduction in 2030 refers to annual emissions in that year relative to 2006 residential emissions)*

---

[76] We understand that a forthcoming CSIRO Report, for example, will find empirical evidence that 5 star houses can often cost significantly less to construct than 4 star or less houses.

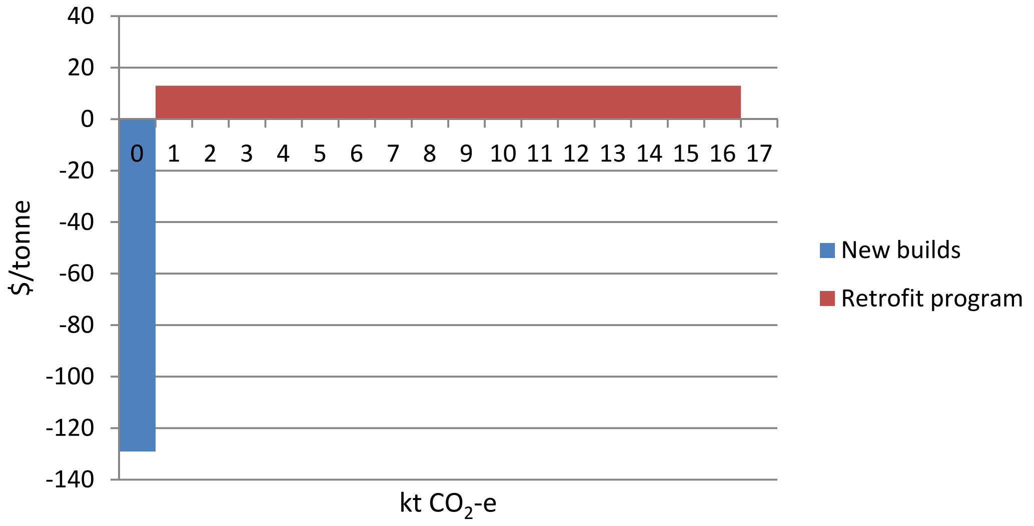


Figure 29: Abatement Cost Curve: Detached Dwellings: Economic Potential: Rapid Take-up

Source: ***pitt&sherry***

Figure 29 also shows the results for a retrofit program for existing detached dwellings. The program is modelled on upgrades to the fixed appliances only, such as hot water, lighting and space conditioning, noting the limited potential for thermal shell upgrades, at least in the base case noted above. This analysis shows that there is significantly greater potential for saving emissions via such a retrofit program than via new builds, primarily due to the greater stock of existing detached dwellings. The upgrades, on average, have a modest but positive cost of abatement, at around $13/t CO2-e. Together, the new builds and retrofits make a very modest contribution to the LGA's overall targets, in a medium uptake scenario, reducing emissions by some 0.1% beyond BAU relative to the 2006 residential baseline (all residential buildings).

In the rapid uptake scenario, where 100% of new builds (by 2030) achieve 1 extra NatHERS star (or equivalent in BASIX), and retrofits are applied to 75% of the detached stock (assuming that some buildings are not available or suitable for upgrades), the abatement cost curve has the same form and values for $/t CO$_2$-e, but more than twice the amount of abatement, at some 17,100 t CO$_2$-e over the period to 2030, representing around a 0.3% reduction from the residential 2006 baseline.

Overall, we find that there is modest potential for achieving additional greenhouse gas savings in detached residential dwellings, primarily due to their small (and declining) share of the building stock. Nevertheless, there is potential for very cost effective savings setting higher efficiency standards (such as BASIX targets) for these dwellings.

6.3.2 Semi-Detached Dwellings

The abatement modelling for semi-detached dwellings, such as terrace houses, shows a very similar pattern to the detached dwellings. Semi-detached dwellings represent a much larger share of the residential stock, however, at some 26.7% in 2006. Unlike for detached dwellings, the City of Sydney assumes modest net growth in the stock of these dwellings over the period to 2030, at 0.3% per year, and we model some demolition/ rebuild activity (which triggers current BASIX requirements), at 1% per year, and the same rate for major refurbishments.

With similar assumptions regarding the potential for upgrades both to new and the existing semi-detached housing stock, the abatement cost curve for this building type (see Figure 30) has a similar form to that for the detached dwelling, although the total abatement potential (width of the curve) is much greater, as also shown in Table 17. The total abatement for this opportunity set is estimated at some 66,000 t CO_2-e cumulatively over the 2015 - 2030 period with a medium uptake, or 154,000 t CO_2-e with rapid uptake. In 2030 due to these measures (with rapid take-up), emissions in the residential would fall by some 2.5% relative to the 2006 residential baseline.

Table 17: Data Table: Semi-Detached Dwellings: Rapid Uptake: 2015 – 2030

Opportunity	Abatement Cost ($/t)	Cumulative Abatement (t CO2-e)
New Builds	-$147	15,106
Retrofit Program	$13	139,034
Reduction of 2006 residential emissions by 2030:	2.5%	

*Source: **pitt&sherry** (note tonnes abated are cumulative over 2015 – 2030, while the 0.1% reduction in 2030 refers to annual emissions in that year relative to 2006 residential emissions)*

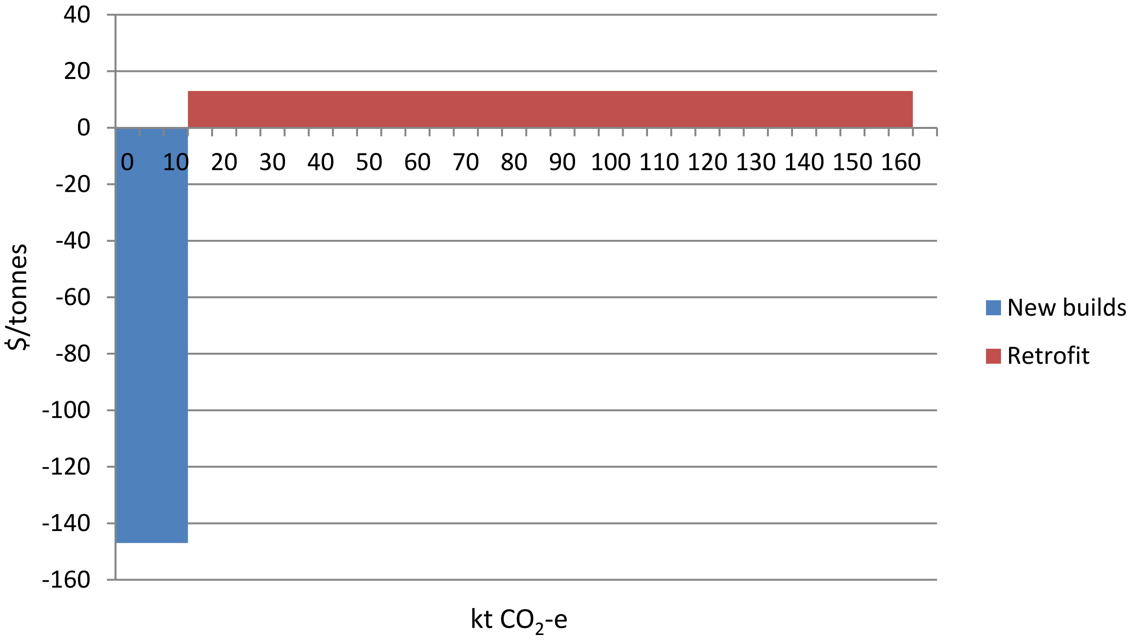


Figure 30: Abatement Cost Curve: Semi-Detached Dwellings: Economic Potential: Rapid Take-up

*Source: **pitt&sherry***

Overall we conclude that there is significant potential for reducing greenhouse gas emissions, beyond their business as usual path, in semi-detached dwellings. Higher standards for new semi-detached dwellings are more cost effective, but retrofit options offer greater abatement potential at modest net cost of abatement, on average. Further analysis would be required to isolate the most cost effective retrofit options for this building class.

6.3.3 Multi-Unit Dwellings

By far the dominant form of residential building in the Sydney LGA is the multi-unit dwelling, or MUD. These represented just over 70% of the residential stock in 2006 (some 7.4 million sqm) and are estimated (by the City) to grow in total floor area by some 2.1% per year to 2030.

MUDs are categorised in different ways by the Australian Bureau of Statistics and under the NSW BASIX program. In this study we have adopted the ABS approach, under which low rise MUDs have 1 – 2 storeys, medium rise have 3 storeys and high rise have 4 storeys or more. Based on ABS (2011), the respective shares of these three MUD types are estimated (in 2006) at 6%, 14% and 80% respectively. For practical purposes and data limitations (discussed below), we group the low and mid rise MUDs together, so they represent MUDs with 1 – 3 storeys and a 20% share of all MUD floor space in 2006.

We examined a total of ten technical options for MUDs. These were analysed based on data from a rich set of detailed audits prepared under the Smart Green Apartments program (see Section 3.2). The results of these 30 audits, with reports of up to 200pp in length and which covered both energy efficiency and water efficiency measures, were synthesised and analysed in depth to derive primary analyses of key values used in our model, including electricity and fuel intensities, floor area, savings opportunities (by type), savings potentials (MJ/m2.a) and incremental cost ($/t).

New builds: Our analysis of the potential for energy efficiency improvement in new MUDs is based on a separate analysis that **pitt&sherry** was requested to undertake, that looks at the scope for cost-effective increases to BASIX targets for MUDs in the Sydney LGA. This analysis was undertaken using the BASIX calculator tool and other sources (notably **pitt&sherry** 2012), and with the assistance of the NSW Dept of Planning which administers BASIX (although no presumption should be made that the Department has endorsed our findings). We note that the BASIX tool does not award incremental percentage points for thermal shell upgrades, but only a pass/fail mark. Therefore we were not able to model shell upgrades using this tool. However **pitt&sherry** (2012) has found in other studies that there is very limited scope for cost effective thermal shell upgrades in Class 2 buildings in Sydney in any case.[77] This study examined opportunities such as higher performance glazing but not shading structures or solar films. We note that appropriate shading can (and should) be integrated into new building design at marginal cost; however, retrofitting shading devices to an existing building may or may not be cost-effective depending on many factors specific to the individual building and site. As a result, the modelled savings for new Class 2 buildings relate to appliances and equipment, as below.

In this analysis, we do not include lift upgrades – as discussed further in Section 6.3 below, we find that these are not cost effective on energy/greenhouse grounds alone...although some minor upgrades will be, such as replacing lights and reducing standby power consumption. Also we exclude PV from this analysis, even though it is eligible within the BASIX calculator, as it falls outside the scope of this Foundation Report and to avoid double counting with the City's Renewable Energy Master Plan.

Pools/pool pumps: Energy savings can be made through adjusting the set temperature of the pool and also by installing pool covers, and the use of more efficient pool pumps e.g. ones with variable speed drives, can also lead to significant energy savings.

Fan/VSD controls (including VSD fan controls): Considerable energy savings can be made through the optimisation of air handler controls. One suitable method is to reset air handler pressures based between commissioned minimum and maximum pressures, which provides considerable fan energy savings. Many buildings contain variable speed drives, but with poor, or no configuration. Variable speed drives on pumps and fans can achieve considerable energy savings through reconfiguration.

---

[77] pitt&sherry (2012), p. 50.

HVAC maintenance/upgrades: Lack of HVAC maintenance in existing buildings can result in excessive energy consumption. For example poor seating of a heating hot water valve can cause a flow of hot water through the heating coil even when this is not called by the Building Maintenance System. The unit itself compensates by supplying increased cooling, resulting in the same temperature air leaving the unit.

Lighting Upgrades: There is the potential for considerable energy savings in residential buildings through lighting upgrades, such as changing fluorescents to LEDs, and halogens to LEDs.

Timers and sensors (excl BMS): Perhaps the simplest saving that can be made is by turning off a service when it is not needed. Time of use control modifications include reduced run hours for central plant, and switch-off achieved by using triggered sensors such as occupancy sensors.

Upgrades to domestic hot water systems: Substantial energy savings can be made through the replacement of hot water systems with either gas or electric heat pump systems, or solar gas or electric boosted systems. Note that the inclusion of solar hot water may lead to a small overlap between this Foundation Report and the Renewable Energy Master plan, which also examines the scope for solar hot water.

Voltage Reduction: It is feasible in some circumstances to reduce voltage to fluorescent lighting systems without affecting lighting quality, notably where relatively high voltages (can exceed 250V) are being supplied. Step down transformers or more sophisticated voltage monitoring and control systems may be used, with energy savings reported at up to 8%.

BMS: A Building Management System (BMS) provides great opportunities for improvements in energy efficiency by allowing energy use to be controlled and optimised. It also allows for early identification of equipment failure and unusual patterns of energy usage, such as equipment being left on.

Water savings measures: Because hot water systems are a significant user of energy in residential buildings, reducing hot water consumption, for example through the use of low flow showerheads, can reduce total energy consumption considerably and for very little cost.

The key drivers of the benefit cost analysis for these technical measures were derived, as noted, from the original Smart Green Apartments audit data. The underlying data points – in this case, shown as incremental costs and payback periods in years – are indicated in Figure 31 below. This shows all measures, regardless of type. It may be noted that the vast majority of measures cost less than $2/sqm to implement and have a simple payback period of less than 5 years. This is one of the underlying drivers of the generally very attractive (negative) abatement costs shown in this Report (the second is the strong growth in real electricity prices in recent years, which increases the economic value of energy savings).

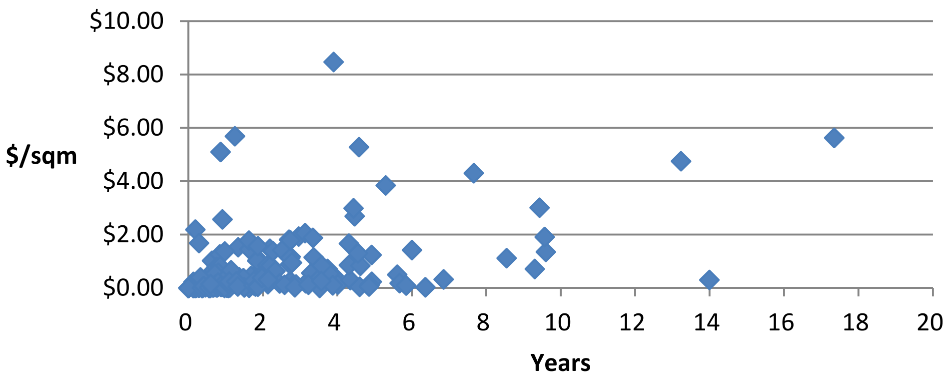


Figure 31: MUD Retrofit Options: Incremental Costs vs Payback Periods

Source: ***pitt&sherry***

The next step was to allocate these individual measures into 'buckets', or groups of like projects. These buckets are shown, with their average paybacks, in Figure 32 below.

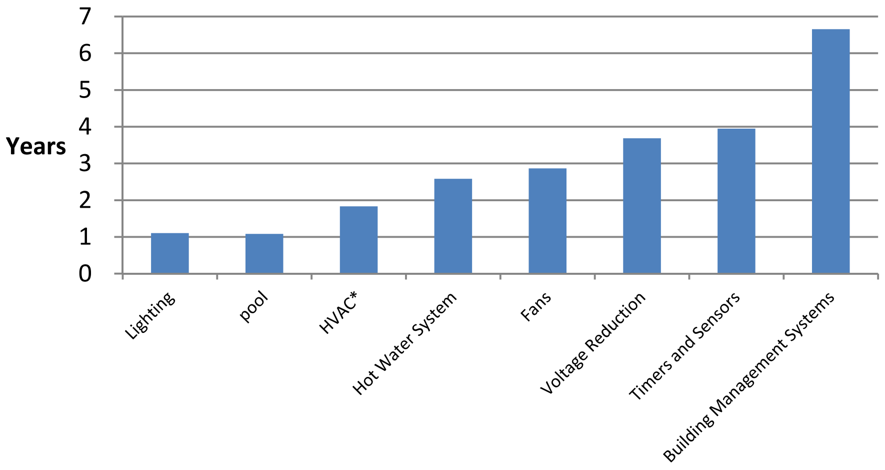


Figure 32: MUD Retrofit Measures, 'Bucket' Average Simple Paybacks (Years)

Source: ***pitt&sherry***

Low-Mid Rise – Economic Potential

The analysis above was then applied, as appropriate, to the low-mid rise MUDs model, using the modelling parameters and assumptions shown in Table 18 below, for both the medium and rapid uptake scenarios. The starting point and maximum take-up of technical measures requires the exercise of some judgement, as hard data is lacking in this area. It may be noted that, for the low-mid rise MUDs, for example, there are low maximum take-ups specified for swimming pool, HVAC and Building Management System upgrades, as these systems are less common in low-rise residential buildings. The 10 year life for new builds refers to the equipment, rather than the shell of the building.

Table 18: Low-Mid Rise MUDs: Technical Opportunities and Assumptions

	Life of investment (years)	Electricity savings rate (MJ/m2.a)	Gas savings rate (MJ/m2.a)	Maximum take-up of measure (share of eligible stock)	2014 Take-up rate	Additional take-up annually (medium take-up rate)	Additional take-up annually (rapid take-up rate)
New builds	10	36.5	18	100%	0%	3.15%	6.50%
Pool/pump upgrades	10	4	3.3	5%	2%	0.10%	0.20%
Fans/VSDs	10	6.80	0	100%	50%	1.60%	3.20%
HVAC upgrades	15	3.7	1	10%	5%	0.15%	0.30%
Lighting upgrades	7	8.1	0	100%	50%	1.60%	3.20%
Timers and sensors	8	3.3	0	100%	30%	2.20%	4.50%
Voltage reduction	10	10.3	0	20%	10%	0.31%	0.70%
Hot Water system upgrades	15	0.5	1.8	100%	30%	2.20%	4.50%
Building Management systems	10	7	0	20%	5%	0.63%	1%
Energy Savings from Water savings measures	8	21	15.8	80%	60%	0.63%	1.30%

Source: ***pitt&sherry***

The benefit cost analysis model takes these values and the underlying assumptions detailed earlier (such as energy prices), and produces the following greenhouse gas abatement curve for low-mid MUDs, under a rapid take-up scenario (Figure 33 and Table 19 below).

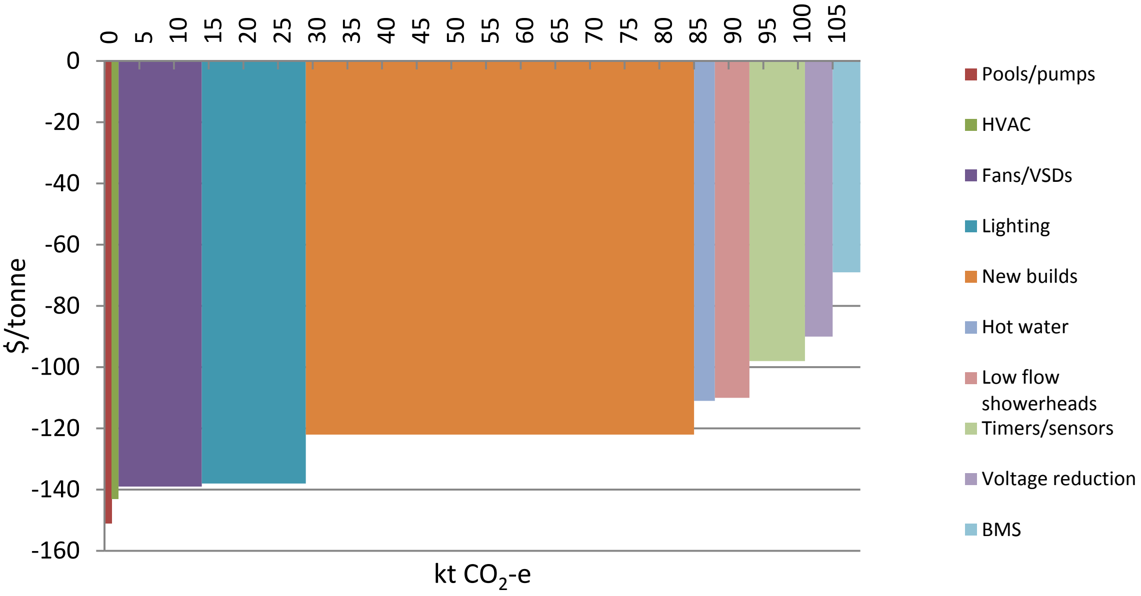


Figure 33: Abatement Cost Curve: Low-Mid Rise Units: Economic Potential - Medium Take-up: 2015-2030

Source: ***pitt&sherry***

Table 19: Data Table: Low-Mid Rise MUDs: Abatement Costs: Economic Potential: Rapid Take-up: 2015 - 2030

Opportunity	Abatement Cost ($/t)	Cumulative Abatement (t CO2-e)
Pools/pumps	-$151	533
HVAC	-$143	708
Fans/VSDs	-$139	12,305
Lighting	-$138	14,561
New builds	-$122	55,566
Hot water	-$111	2,454
Low flow showerheads	-$110	4,820
Timers/sensors	-$98	8,417
Voltage reduction	-$90	3,753
BMS	-$69	3,912
Reduction of 2006 residential emissions (efficiency measures only):	2.1%	

Source: ***pitt&sherry***

These measures, while all highly cost effective, only save 1% of 2006 residential greenhouse gas emissions with medium uptake, although 2.1% with rapid uptake. These modest results are due to the smaller number of low-mid rise MUDs (around 14% of the total residential floor area in 2006), and the lower level of take-up modelled in this scenario. The negative abatement cost values – like benefit cost ratios significantly greater than 1 – may be read as indicating that there is a cost effective economic opportunity to increase greenhouse gas savings, beyond the level noted in the curve and data table, while still saving energy costs.

In summary, there is attractive economic potential to achieve greenhouse gas savings, beyond those already expected to be captured under 'business as usual', in low-mid rise MUDs.

Low-Mid Rise – Policy Potential

To take account of market barriers to the take-up of technical measures, a second analysis was run, for low-mid rise MUDs, based on a potential set of policy/program initiatives that could, in principle, be undertaken. Other measures could also be envisaged, and we caution that we have not undertaken the detailed level of analysis that would be necessary to develop fully specified and risk-managed energy efficiency initiatives. Nevertheless we believe the assumptions applied are plausible and provide a first-order indication of the relative attractiveness of the different options modelled.

The measures modelled include:

- Higher BASIX targets (noting that this is modelled as identical to the technical potential for new builds, as above);
- Development of a voluntary ratings tool for MUDs, such as NABERS;
- Mandatory disclosure of efficiency ratings upon sale or lease;
- A building 'tune-up' program;
- A retrofit program; and
- Improved compliance with existing minimum energy efficiency requirements.

Higher BASIX Targets

Thanks to a separate commission from the City of Sydney, **pitt&sherry** was able to undertake research into the potential for higher BASIX targets for residential buildings in the City of Sydney area. The primary focus of this research was multi-unit dwellings, as these dominate the residential stock and energy use/greenhouse gas emissions.

With input from the NSW Office of Environment & Heritage, the BASIX calculator tool, together with an extensive energy audit set derived from the Smart Green Apartments program, was used to simulate the potential for higher but still cost-effective targets. We excluded PV systems from consideration in this context, even though they are cost-effective, as they have the potential – in some circumstances - to generate 100% of the annual energy needs of residential buildings. Also the primary focus of this study is energy efficiency measures: other technologies are included for comparison purposes only.

The BASIX targets modelled were 55% for high rise and also mid rise apartment buildings, and 58% for low rise apartment buildings. The abatement cost curves below (eg, Figures 6.8 and 6.9) show that higher BASIX targets for new buildings are far and away the largest opportunities, and that for all building types studied. This is consistent with the opportunity to achieve larger performance improvements more cost effectively at the design stage for new buildings, than is available through retrofitting existing buildings. These curves suggest a strong *prima facie* case for lifting these targets.

For detached and semi-detached dwellings, which make up around 26% of the residential dwelling stock, we note that there are conflicting views in the literature regarding the cost-effective potential for achieving improved energy efficiency. Our own past research suggested modest potential[78] (**pitt&sherry** 2012), but this study used a conventional, quantity surveying approach to cost estimation, and also we were not allowed to alter housing designs to take account of low/no-cost redesign opportunities. When these are taken into account, for example in Sustainability House (2012)[79], it has been shown that up to 1 additional star can be achieved for essentially no cost, taking advantage of small changes to factors such as:

- Window size and positioning;
- Orientation;
- Internal zoning;
- Shading;

---

[78] pitt&sherry, *Pathway to 2020 for Increased Stringency in New Building Energy Efficiency Standards: Benefit Cost Analysis*, January 2012. Report for the Department of Climate Change & Energy Efficiency.

[79] Sustainability House, *Identifying Cost Savings through Building Redesign for Achieving Residential Building Energy Efficiency Standards: Part Two.* Report for Department of Climate Change & Energy Efficiency.

- Minor wall changes.

This study adopts the latter approach. Note that it would therefore not be valid to extend this abatement cost observation for savings greater than 1 star (NatHERS). Further information on these issues may be found in **pitt&sherry** (2012).

NABERS for Apartment Buildings

The next measure considered was the development of a NABERS (or equivalent) rating tool for apartment buildings. A key assumption here is that the uptake of the tool would be entirely voluntary. As a result, and noting significant market barriers in particular with strata-title buildings, we assume only modest take-up rates of between 5% - 10% of the eligible stock.

Energy savings induced by this measure – for those buildings that take it up - are assumed to match the reported performance of other NABERS rated buildings of some 9% energy savings on average. The costs of achieving these savings are based on the average of the Smart Green Apartments data set, as it is unclear which technical measures would be deployed in response to this policy measure. We model an average rating cost at $3,000 for low-mid rise buildings and $5,000 for high rise buildings. We assume that the NABERS tool would cost $250,000 to develop and 2 FTEs ($200,000) per year to administer. However, as this tool would be available for use nationally, and not just in the City of Sydney, we factored down the costs attributable to this program in Sydney by 90%.

These assumptions show that a voluntary NABERS tool for apartment buildings would have a small net abatement cost for low-medium rise buildings (less than the current cost of carbon), but a negative cost for high-rise apartment buildings. This reflects the greater number of the latter building type (spreading fixed costs over a larger base) but also their greater energy intensity and energy savings potential.

Mandatory Disclosure for Apartment Buildings

This measure is conceptually similar to the previous, but instead of relying on voluntary take-up, it assumes that disclosure of building (eg, NABERS) ratings are required upon sale or lease of apartment buildings and apartments within them. Given that most apartment buildings would have apartments available for lease at most times, this would effectively amount to ‘continuous’ disclosure, at least for many buildings. We therefore assume that the take-up of this measure rises to 100% of the potential market, over a 10 year period, and remains at that level thereafter. This increases the total costs of this measure, compared to voluntary implementation, but also dramatically increases the savings.

Due to the high take-up rate, we apply a ‘saturation effect’ that assumes diminishing savings, per unit uptake, through time. This reflects the fact that low-cost efficiency opportunities are likely to be implemented first, with progressively higher costs and smaller opportunities through time. Note that due to the mandatory nature of this measure, we model a single take-up rate through time.

Building Tune-Up Program

Building tune-up programs are widely used in the United States and Europe due to their cost-effectiveness. Details of the programs vary from place to place, but generally they commence with an initial walk-through audit by an accredited service provider (to determine whether the building is suitable and eligible for the program), followed by a thorough, Level 3 audit to identify and establish the business case for efficiency measures. The nature of the efficiency measures targeted fall short of major plant upgrades and replacement, which are more expensive, but instead focus on tuning building management systems, lighting controls, fans, etc. Lower cost investments - eg, in sensors and controls, or additional switching - may be in-scope. The building owner then commits to a specific investment program, with the service provider's costs, audit costs, and sometimes even a percentage of the capital investment cost, subsidised by the program.

Note that in the US, where these schemes are common, levies are collected from electricity users to fund such schemes, which are collectively known as 'demand side management' programs. These programs in turn fall within a framework known as 'least system cost', as they can save energy at a lower cost than it can be generated, thus reducing the total cost of meeting energy service needs. In addition, the environmental footprint of this approach is much lower than the alternative of investing in additional generation, transmission and distribution infrastructure.

To model such an initiative for Sydney we assumed a $5,000 total audit cost and applied the measure to high rise buildings only, given that many low-mid rise Class 2 buildings may not have centralised HVAC systems. Note that the *social* cost of abatement for this measure is not changed by any decision to subsidise part or all of the audit or other costs – this merely redistributes the cost from one party to another. However, such decisions may also impact on building owners' willingness to engage with this measure and therefore on take-up rates. This would be a matter for the City of Sydney to consider on affordability and cost-effectiveness grounds.

The investment costs and benefits associated with the tune-up activities are taken from our analysis of the Smart Green Apartment audit set. Administration costs assume one FTE ($100,000) per year plus $100,000 for promotion in the first year and $50,000 per year thereafter (to 2030). Two take-up rates are modelled, medium and rapid, with medium assumed to reach 35% of the eligible stock by 2030, while rapid is assumed to reach the full potential (75%) by the same date. Note that we only apply this measure to high rise buildings (existing pre-2015 stock) only, as low-medium rise may not have centralised building services, while new buildings are assumed to benefit less from tuning (however, see Section 3.1.6 below).

Building Retrofit Program

A retrofit program differs from a tune-up program primarily in scale – it seeks to encourage building owners to undertake larger and more expensive building energy performance improvements, which also bring larger financial and environmental benefits. The challenge with such programs is how to leverage or induce take-up. As with previous cost curves demonstrate, retrofit activity is highly cost effective. In economic theory, therefore, nothing needs to be done to ensure a high level of uptake – after all, people can make money by doing so.

Reality begs to differ. As with the previous measure, we leave open the question as to whether initial audit/assessment costs are subsidised in any manner, as this does not affect the social cost of abatement. We leave take-up rates as for the tune-up program, with a maximum take-up of 75% of the eligible stock (all heights, but only the pre-2015 stock). We assume average audit costs of $5,000 for low-medium rise buildings and $10,000 for high-rise buildings. The higher assumed average audit cost for this program, relative to the building tune-up program, reflects the greater scope of the audits in this program and also the need to establish a business case for larger capital investments. Investment costs, and resulting energy savings, are again taken from our analysis of the Smart Green Apartments audit set.

It may be noted that the social cost of abatement falls somewhat, for all building heights, with faster uptake. This is because the underlying investments are inherently cost effective, while the fixed costs of program delivery (the same as for the tune-up program) are spread over a larger activity base.

Improved Compliance with Energy Performance Requirements on Retrofit

The final measure considered would be a program to try to lift the energy performance standards of retrofitted buildings, for example to at least the current Building Code of Australia/BASIX requirements. In effect, we model this as a 'tune-up' program for the whole building stock, triggered when the building (or part building) undergoes a major refurbishment. As a compliance driven measure, we assume that there is no additional audit cost incurred. The onus would be on the building owner to demonstrate, to the satisfaction of the City, that all applicable energy efficiency standards have been complied with. This initiative is modelled to generate similar results, in terms of abatement, as a tune-up program, but the cost-effectiveness is greater (social cost of abatement lower) due to the absence of audit costs. We assume an ongoing administration cost of 1 FTE, and $100,000 for promotion of the initiative in year 1 only, for all building heights.

The results of our analysis of these initiatives are presented below in Figure 34, and supported by Table 20.

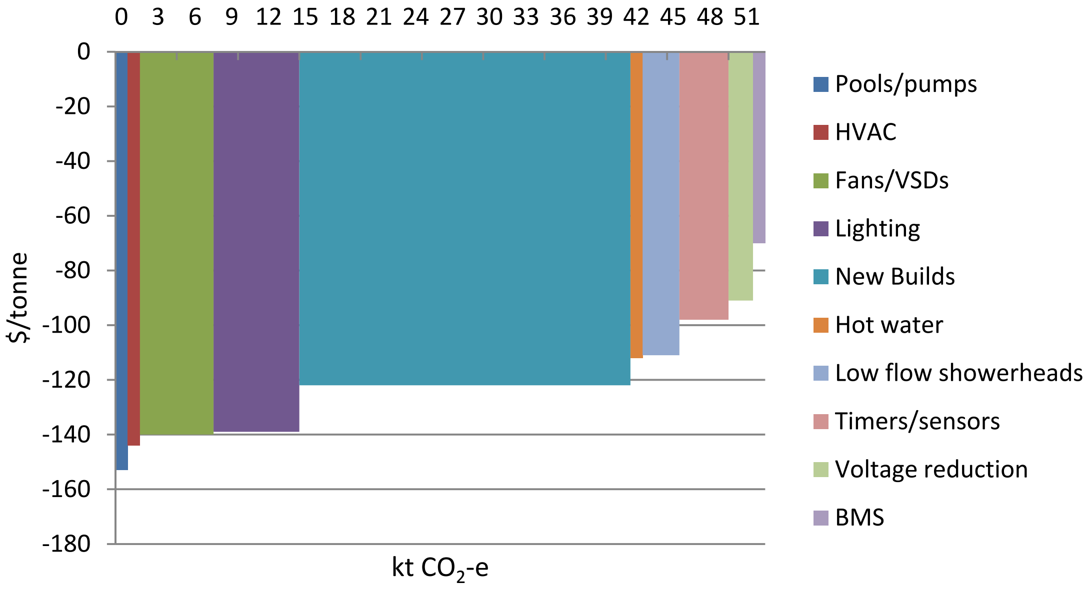


Figure 34: Abatement Cost Curve: Low-Mid Rise Units: Economic Potential – Medium Take-up: 2015-2030

Source: ***pitt&sherry***

Table 20: Data Table: Low-Mid Rise Multi-Unit Dwellings: Policy Potential – Medium Take-up: 2015 - 2030

Opportunity	Abatement Cost ($/t)	Cumulative Abatement (t CO2-e)
Higher BASIX targets	-$122	26,951
Retrofit program	-$91	50,797
Improved compliance with BCA on retrofit	-$89	18,297
NABERS mandatory disclosure	$0	121,284
NABERS (voluntary)	$18	3,235
Reduction of 2006 residential emissions, beyond BAU, by 2030:	4.1%	

Source: ***pitt&sherry***

From this analysis, it is apparent that higher BASIX targets for low-mid rise MUDs, a retrofit program and improving compliance with existing mandatory minimum efficiency requirements would all be highly cost effective, even after allowing for the administrative costs associated with these measures. However, there are much larger gains to be made – in terms of reducing greenhouse gas emissions – by implementing a mandatory disclosure scheme. While these savings are not as cost effective as the other set, they remain cost effective and, together, they could contribute a 4.1% reduction in 2006 residential emissions, even in this medium take-up scenario[80].

In a rapid uptake scenario, the costs of abatement are similar. They may differ in small degrees, for example because the fixed costs of establishing and administering these schemes may be spread over a wider abatement base with more rapid uptake. On the other hand, more administrative effort, regulation or promotion may be required to achieve more rapid uptake. Nevertheless, the greenhouse gas saving rise significantly, and remain cost effective overall. Figure 35 below depicts this rapid uptake scenario, again for low-mid rise and high-rise MUDs. The data table (Table 21) draws attention to the fact that savings equal to some 6.3% of baseline residential emissions in 2006 could be saved with this measure set.

It can be seen that, in both the medium and rapid uptake scenarios, voluntary ratings for MUDs, such as NABERS, are shown to be both less effective and less cost effective than mandatory disclosure. This occurs even though we assume that the savings achieved in each building assessed, and the cost of achieving those savings, is identical for the two schemes. The substantial difference arises because market barriers in low-mid rise MUDs are strong - due to a high degree of strata title ownership structures and associated difficulties in undertaking collective investments – and these are likely to lead to very low take-up on a purely voluntary basis. If mandated however – as is already the case for office buildings and tenancies of 2,000 sqm or greater – then it would be expected that close to 100% of these properties would need to be rated regularly...possibly annually, subject to scheme design. Even allowing for a saturation of the energy savings effect over time, as described above, this mandatory measure effectively overcomes the market barriers and leads to both substantially higher and more cost effective emissions savings. They are more cost-effective for the reason noted earlier – fixed costs associated with running this program would be spread across a greater abatement base, leading to lower costs per unit of abatement achieved.

---

[80] As noted, we model only one rate of take-up for mandatory disclosure.

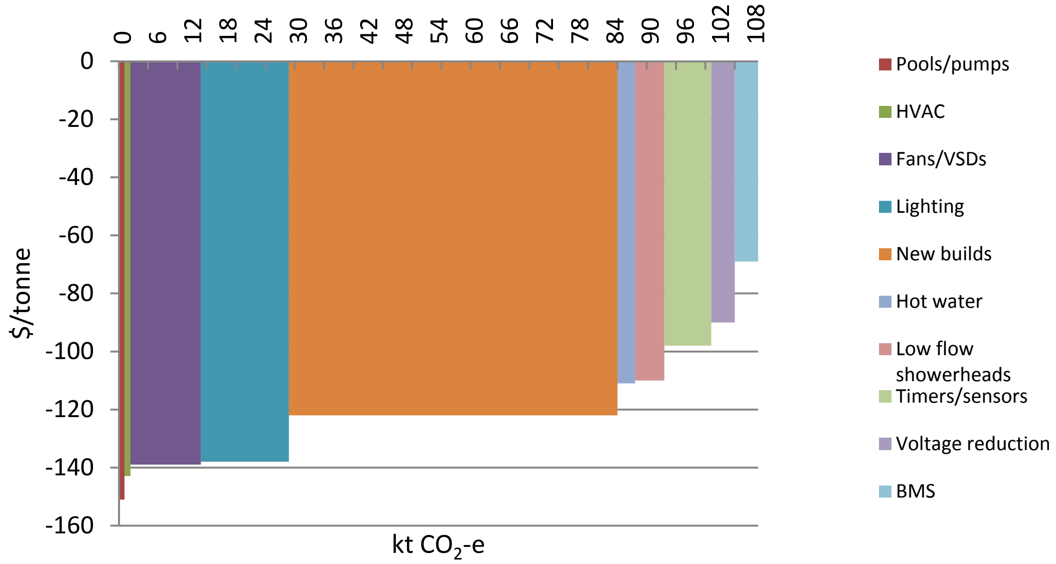


Figure 35: Abatement Cost Curve: Low-Mid Rise Units: Economic Potential – Rapid Take-up: 2015-2030

Source: ***pitt&sherry***

Table 21: Data Table: Low-Mid Rise Multi-unit dwellings: Economic Potential – Rapid Uptake: 2015 - 2030

Opportunity	Abatement Cost ($/t)	Cumulative Abatement (t CO2-e)
Higher BASIX targets	-$122	55,566
Retrofit program	-$107	120,049
Improved compliance with BCA on retrofit	-$104	43,240
NABERS mandatory disclosure	$0	121,284
NABERS (voluntary)	$11	7,234
Reduction of 2006 residential emissions, beyond BAU, by 2030:	6.3%	

Source: ***pitt&sherry***

Overall, we conclude there are significant, cost-effective greenhouse savings to be won in the low-mid rise MUD segment. The measures outlined range from highly to marginally cost-effective, with perhaps only the voluntary ratings approach, such as NABERS, being of limited value.

High Rise Multi-Unit Dwellings – Economic Potential

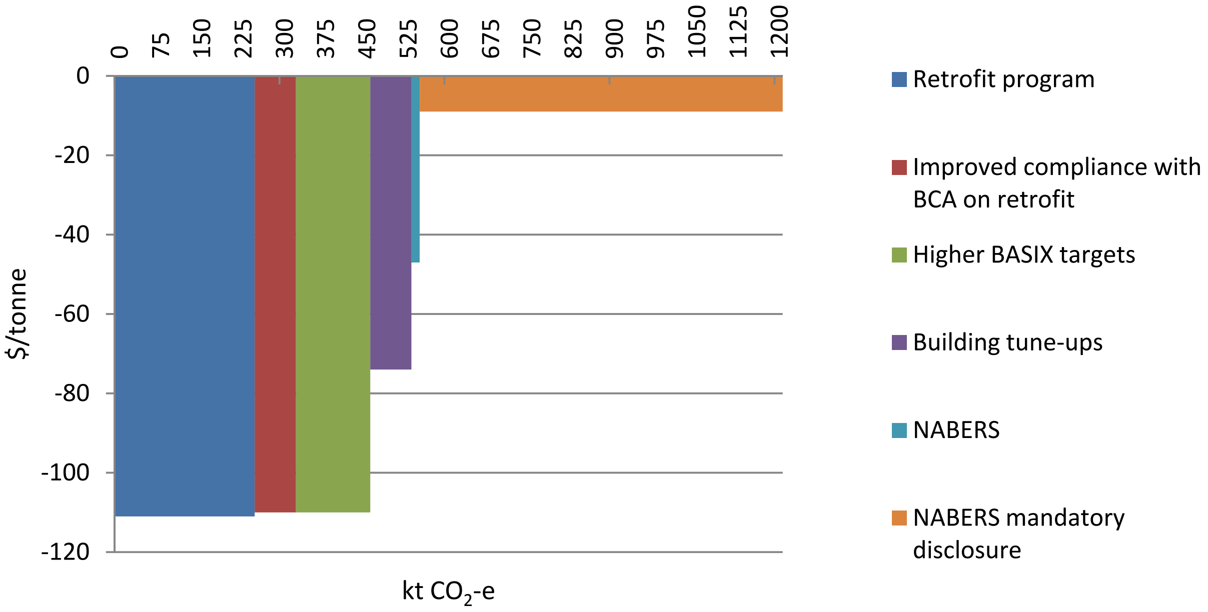
For high rise MUDs, the technical opportunity set is substantially similar, and the methodology employed the same, as above. Therefore we describe the results of our analysis in a more summary fashion. It should be noted, however, that the floor area of high rise MUDs is significantly greater than low-mid rise, at some 56% of the residential total in 2006, and this floor area is growing more rapidly. Second, high rise MUDs are, on average, more energy intensive than lower rise buildings. This may be attributed to the higher level of centralised energy services often found in such buildings, which may include centralised air conditioning, lifts, underground car-parks, swimming pools and spas, and perhaps other facilities such as laundries and cafes. We find that on average, high rise MUDs are consuming around 38% more energy per square metre than low-mid rise, and of course the high rise buildings are typically much larger. These factors combine to mean that larger opportunities for cost-effective energy savings and greenhouse gas emission abatement may be found in this segment.

Some differences within the technical opportunity set for high rise MUDs, as compared to low-mid rise, can be noted in Table 22 below. For example we assume – informed by the Smart Green Apartments data set – that up to 90% of high rise dwellings will have centralised HVAC systems, while up to 50% of them may have a swimming pool. Therefore we assume greater opportunity for efficiency gains in these areas than in the smaller MUDs. We also take into account the expected impacts of initiatives such as the NSW Energy Savings Scheme, in assuming that the 'starting point' take-up of certain technical opportunities – like low-flow shower heads, lighting upgrades and high-efficiency fans with variable speed drives – is already reasonably high.

Table 22: High Rise MUDs: Technical Opportunities and Assumptions

	Life of investment (years)	Electricity savings rate (MJ/m2.a)	Gas savings rate (MJ/m2.a)	Maximum take-up of measure (share of eligible stock)	2014 Take-up rate	Additional take-up annually (medium take-up rate)	Additional take-up annually (rapid take-up rate)
New builds	10 (equipment only)	36.5	18	100%	0%	3.15%	6.50%
Pool/pump upgrades	10	4	3.3	50%	5%	1.00%	3.00%
Fans/VSDs	10	6.80	0	100%	50%	1.60%	3.20%
HVAC upgrades	15	3.7	1	90%	10%	2.50%	5%
Lighting upgrades	7	8.1	0	100%	50%	1.60%	3.20%
Timers and sensors	8	3.3	0	100%	30%	2.20%	4.40%
Voltage reduction	10	10.3	0	20%	10%	0.31%	1.30%
Hot Water system upgrades	15	0.5	1.8	100%	30%	2.20%	4.40%
Building Management systems	10	7	0	90%	10%	2.50%	5.00%
Energy Savings from Water savings measures	8	21	15.8	80%	60%	0.65%	1.90%

Source: ***pitt&sherry***



Source: ***pitt&sherry***

Figure 36: Abatement Cost Curve: High- Rise Units: Economic Potential – Medium Take-up: 2015-2030

Figure 36 above shows the costs of abatement, for high rise MUDs, for the policy/program measures modelled, with a medium rate of take-up. Figure 37 below shows the similar curve for the rapid take-up scenario.

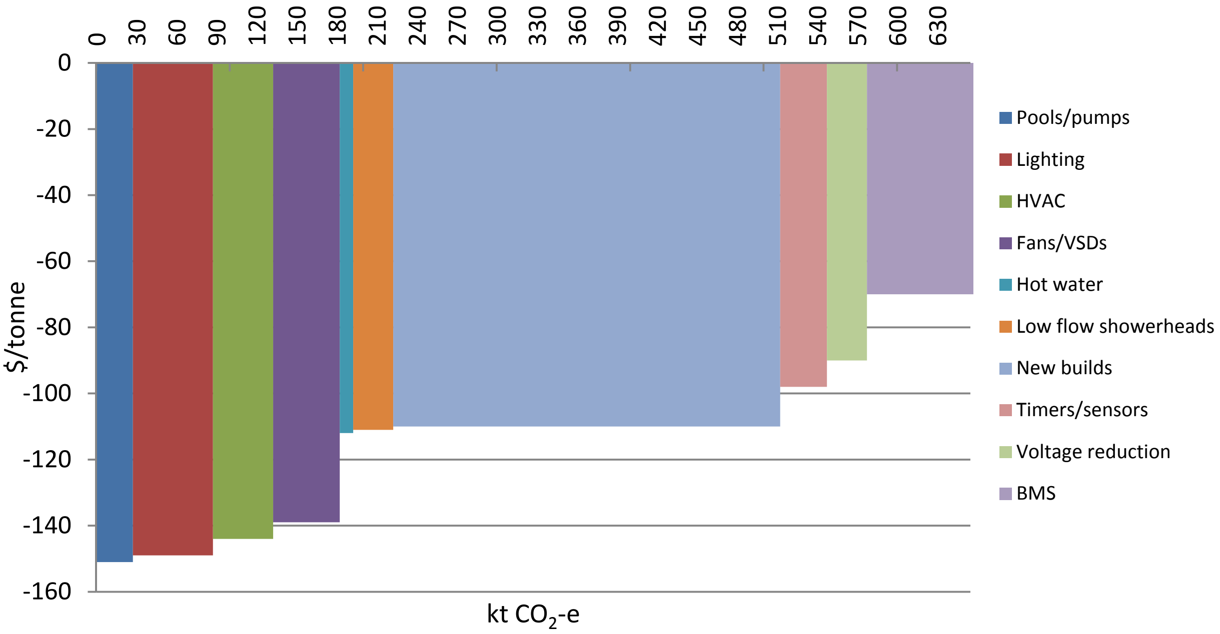


Figure 37: Abatement Cost Curve: High- Rise Units: Economic Potential – Rapid Take-up: 2015-2030

Table 23: Data Table: High Rise Multi-Unit Dwellings: Economic Potential: 2015 - 2030

Opportunity	Abatement Cost ($/t)	Cumulative Abatement (t CO2-e)	Opportunity	Abatement Cost ($/t)	Cumulative Abatement (t CO2-e)
Medium Uptake			Rapid Uptake		
Pools/pumps	-$153	13,392	Pools/pumps	-$151	31,982
HVAC	-$144	22,166	Lighting	-$149	58,243
Fans/VSDs	-$140	24,654	HVAC	-$144	44,332
Lighting	-$139	29,175	Fans/VSDs	-$139	49,219
Hot water	-$112	4,811	Hot water	-$112	9,617
Low flow showerheads	-$111	9,671	Low flow showerheads	-$111	28,239
New builds	-$110	137,433	New builds	-$110	283,356
Timers/sensors	-$98	16,495	Timers/ sensors	-$98	32,975
Voltage reduction	-$91	7,413	Voltage reduction	-$90	30,027
BMS	-$70	39,307	BMS	-$70	78,614
Reduction of 2006 residential emissions (efficiency measures only):	5.8%		Reduction of 2006 residential emissions (efficiency measures only):	12.2%	

Source: ***pitt&sherry***

High Rise Multi-Unit Dwellings – Policy Potential

For high rise MUDs, we add into the set of measures analysed for low-mid rise a building tune-up program, as described above. Other measures are substantially similar, although we assume higher NABERS ratings costs for the taller buildings (at $5,000 each, on average, as compared to $3,000) and similarly higher audit costs for the tune-up and retrofit programs (also $5,000 each, on average). As discussed earlier, we take no position on whether these costs could be subsided to the building owner, as such decisions do not impact on the net social benefits of the initiatives but rather redistribute the costs between parties.

Figures 6.12 and 6.13 below show the abatement cost curves for high rise MUDs, with medium and high take-up rates respectively, of the policy potential. The corresponding data table is shown as Table 24 below.

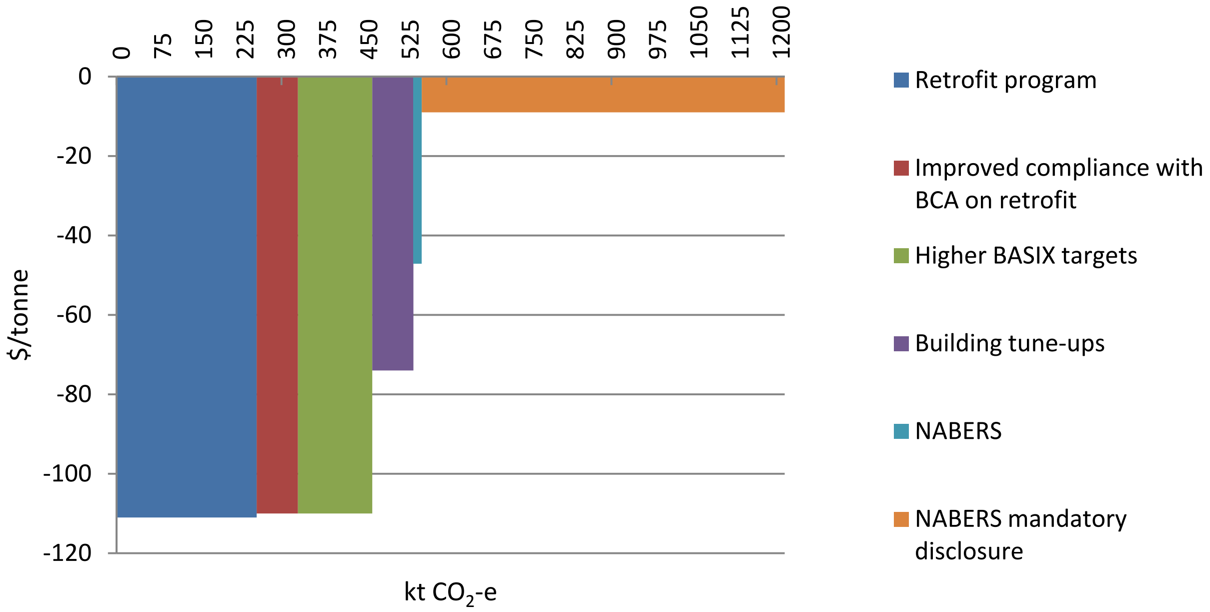


Figure 38: Abatement Cost Curve: High Rise MUDS: Policy Potential: Medium Uptake: 2015 – 2030

Source: ***pitt&sherry***

It can be seen that the overall greenhouse gas savings for both are significant, with a medium rate of take-up reducing 2006 emissions from this building class by some 22.5%, while a rapid rate of take-up would reduce 2006 emissions by nearly 35%. As with low-mid rise MUDs, mandatory disclosure is doing the heavy lifting, in terms of abatement, and the uptake of this measure is identical in both scenarios. Therefore the rapid take-up rate does not double emissions savings, as with earlier scenarios.

Overall, there is *very* significant economic potential to reduce emissions in high rise MUDs cost effectively in the Sydney LGA. All of the measures described are cost effective, with a negative cost of abatement. This indicates that there are net financial benefits to be realised while reducing emissions.

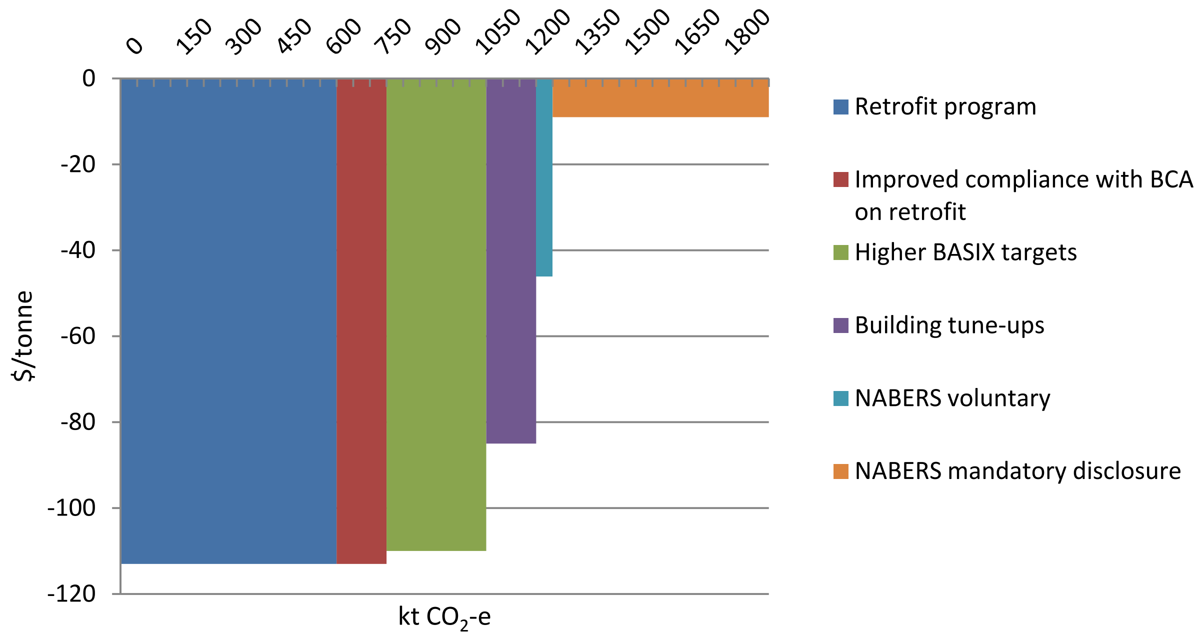


Figure 39: Abatement Cost Curve: High Rise MUDS: Policy Potential: Rapid Uptake: 2015 – 2030

Source: ***pitt&sherry***

Table 24: Data Table: High Rise Multi Dwelling Units: Economic Potential: 2015 - 2030

Opportunity	Abatement Cost ($/t)	Cumulative Abatement (t CO2-e)	Opportunity	Abatement Cost ($/t)	Cumulative Abatement (t CO2-e)
Medium Take-up			Rapid Take-up		
Retrofit program	-$111	245,736	Retrofit program	-$113	580,746
Improved compliance with BCA on retrofit	-$110	73,186	Improved compliance with BCA on retrofit	-$113	172,958
Higher BASIX targets	-$110	137,433	Higher BASIX targets	-$110	283,356
Building tune-ups	-$74	73,186	Building tune-ups	-$85	172,958
NABERS	-$47	18,194	NABERS (voluntary)	-$46	40,247
NABERS mandatory disclosure	-$9	673,039	NABERS mandatory disclosure	-$9	673,039
Reduction of 2006 residential emissions, beyond BAU, by 2030:	22.5%		Reduction of 2006 residential emissions, beyond BAU, by 2030:	34.6%	

Source: ***pitt&sherry***

6.3.4 Summary – Residential Buildings

Economic Potential

Overall, there are very significant cost-effective opportunities to enhance the energy efficiency of new and existing residential buildings in the City of Sydney. Taking advantage of the *economic* potential could realise annual energy savings in 2030 – beyond those expected in the business as usual scenario –of between 235 TJ and 478 TJ in the local government area, depending upon whether a medium or more rapid rate of take-up is secured (see Tables 6.11 and 6.12 below).

By far the largest economic opportunity for energy savings arises from more efficient new buildings (from 2015 onwards). However there are also significant potentials associated with building management system upgrades, lighting upgrades and others. All of the measures noted are highly cost effective, as indicated by the negative abatement costs and also short payback periods (see Table 27). This indicates that these measures represent a conservative estimate of the technical potential for cost-effective energy savings: greater savings could in principle be achieved without driving the cost of abatement above a relevant benchmark, such as the current price of carbon ($24.50/t).

Table 25: Residential Buildings (All Sub-Types): Technical Potential (Beyond BAU): Medium Uptake

Measure	Annual energy savings in 2030 (TJ)	Value of annual energy savings in 2030 ($'000, $2014 real)	Annual electricity savings in 2030 (GWh)	Annual gas savings in 2030 (TJ)	Cumulative GHG emissions savings to 2030 (t C0$_{2-e}$)	Average abatement cost ($/t CO2-e)	Annual electrical capacity savings in 2030 (MW)	Annual value of electrical capacity savings ($M) in 2030 ($2014 real)
New Builds	147.9	$7,773.0	27.5	48.8	172,256	-$114	7.9	$2.4
Pool/pump upgrades	8.2	$379.8	1.3	3.7	13,660	-$153	0.4	$0.1
Fans/VSDs	12.1	$832.1	3.4	0.0	30,818	-$140	1.0	$0.3
HVAC Upgrades	10.6	$614.2	2.3	2.2	22,498	-$144	0.7	$0.2
Lighting Upgrades	14.3	$984.6	4.0	0.0	36,468	-$139	1.1	$0.4
Timers and Sensors	8.1	$556.7	2.3	0.0	20,619	-$98	0.6	$0.2
Voltage Reduction	0.7	$248.6	0.2	0.0	9,209	-$91	0.3	$0.1
Hot Water System Upgrades	5.8	$175.6	0.4	4.4	6,013	-$112	0.1	$0.0
Building Management Systems	15.7	$1,079.3	4.4	0.0	39,975	-$70	1.2	$0.4
Energy Savings from Water Savings Measures	11.9	$352.5	0.7	9.4	12,014	-$111	0.2	$0.1
Totals (weighted average for abatement cost)	235.2	$12,996.5	46.3	68.5	363,531	-$115	13.5	$4.2

Source: ***pitt&sherry***

In fuel terms, these technical potentials comprise between 46 and 98 GWh of electricity (medium vs rapid uptake) and between 69 TJ and 165 TJ of natural gas in 2030. Together the fuel savings would be valued at $13 million (medium uptake) and $27 million (rapid take-up) in 2030, measured in today's dollars.

In greenhouse terms, the technical potential translates into cumulative emissions reductions of between 363 kt CO2-e (medium take-up) and 770 kt CO2-e (rapid take-up) over the period to 2030, noting that these savings areadditional to those projected in the ‘business as usual’ scenario in Chapter 5.

Finally, these energy savings would reduce the need for growth in electrical system capacity (generation, transmission and distribution). By 2030, we estimate the avoided capacity requirements at between 14 MW (medium) and 28 MW (rapid), valued at between $4.2 million and $8.7 million in that year. These infrastructure cost savings represent a social benefit from the energy efficiency measures, in addition to the private benefit of energy cost savings. The reduced demand for infrastructure investment, thanks to these efficiency gains, would translate - other things being equal - into lower energy prices for consumers. These values were revised downwards significantly, when compared with our original analysis, following consultation with Ausgrid and taking into account the weak outlook for electricity demand.

Table 26: Residential Buildings: Economic Potential (Beyond BAU): Rapid Uptake

Measure	Annual energy savings in 2030 (TJ)	Value of energy savings in 2030 ($'000, $2014 real)	Electricity savings in 2030 (GWh)	Gas savings in 2030 (TJ)	Cumulative GHG emissions savings to 2030 (t C0$_{2-e}$)	Average abatement cost ($/t CO2-e)	Electrical capacity savings in 2030 (MW)	Value of electrical capacity savings ($M) in 2030 ($2014 real)
New Builds	303.6	$15,959.6	56.5	100.2	355,153	-$113	16.1	$5.0
Pool/pump upgrades	20.5	$865.0	2.9	10.2	32,515	-$151	0.8	$0.3
Fans/VSDs	23.8	$1,634.3	6.6	0.0	61,523	-$139	1.9	$0.6
HVAC Upgrades	21.1	$1,229.2	4.6	4.5	45,040	-$144	1.3	$0.4
Lighting Upgrades	28.1	$1,933.9	7.8	0.0	72,804	-$147	2.2	$0.7
Timers and Sensors	16.1	$1,109.7	4.5	0.0	41,392	-$98	1.3	$0.4
Voltage Reduction	12.9	$887.8	3.6	0.0	33,780	-$90	1.0	$0.3
Hot Water System Upgrades	11.5	$350.1	0.7	8.8	12,071	-$112	0.2	$0.1
Building Management Systems	32.4	$2,223.6	9.0	0.0	82,526	-$70	2.6	$0.8
Energy Savings from Water Savings Measures	7.8	$958.7	1.9	0.9	33,059	-$111	0.5	$0.2
Totals (weighted average for abatement cost)	477.8	$27,152.0	98.1	124.6	769,864	-$115	28.0	$8.7

Source: ***pitt&sherry***

Considering the energy efficiency potentials as investment opportunities, Table 27 below sets out the key parameters for each of the technical measures studied: incremental capital costs, unit electricity and gas savings, simple payback in years, and the average economic life of the investments. In the case of new builds, the energy efficiency opportunities modelled relate to the fixed appliances rather than the thermal shell of the building, hence the ‘economic life’ referred to in these cases is that of the appliances and not the building as a whole. Note that these values will change through time as a result of market-driven changes in the costs of different technologies and the energy performance of these technologies, while the simple payback time will respond to the price of energy (shorter when energy prices rise, longer when energy prices fall).

Table 27: Residential Technical Measures – Investment Parameters

Measures	Unit capital cost ($2014real/m^2)	Unit electricity savings (kWh/m^2.a)	Unit gas savings (MJ/m^2.a)	Simple payback (years)	Economic life of investment (years)
New Builds - Detached	$2.79	3.0	5.3	3.0	10
New Builds - Semi-detached	$2.79	3.9	6.9	2.3	10
New Builds - Low-mid-rise MUDS	$9.78	11.6	20.5	3.0	10
New Buildings - High-rise MUDs	$14.9	14.8	26.2	3.5	10
Pool/pump upgrades	$0.28	1.1	3.3	0.8	10
Fans/VSDs	$0.63	1.9	0.0	1.3	10
HVAC Upgrades	$0.40	1.0	1.0	1.4	15
Lighting Upgrades	$0.50	2.3	0.0	0.9	7
Timers and Sensors	$0.69	0.9	0.0	2.9	8
Voltage Reduction	$2.68	2.9	0.0	3.7	10
Hot Water System Upgrades	$0.27	0.2	1.8	3.9	15
Building Management Systems	$2.35	1.9	0.0	4.7	10
Energy Savings from Water Savings Measures	$1.33	5.8	15.8	2.8	8

**For new builds, the investment life refers to fixed appliances only.*

Source: ***pitt&sherry***

Policy Potential

Turning to the *policy* potential for residential energy efficiency gains, we found the unusual result that there *appears* to be slightly greater policy potential than economic potential. By comparing Tables 6.14 (below) and 6.11, for example, we can see that – assuming medium take-up in both cases, the policy potential for energy savings in 2030 is shown to be some 1,118 TJ as compared to just 235 TJ as economic potential.

There are three primary explanations for this result. First, as may be noted from Table 28 and also Table 29, the majority of the energy savings in the policy potential scenarios are being generated by a single measure, mandatory disclosure. The mandatory nature of this measure, combined with the underlying rate of turnover (vacancies as well as new builds) in the building stock, leads to a very rapid application of both costs and energy savings. By 2030, these have amounted to very large values. Second, we noted above that our estimates of economic potential are conservative, and could indeed be 'pushed' to higher values, albeit at the expense of falling cost-effectiveness (for example, as more difficult or smaller retrofit opportunities are called upon). The conservative nature of the scenario is underscored by the weighted average cost of abatement being *minus* \$115/t CO_2-e. Third, it should be noted that NABERS is not likely to be rolled out on both a voluntary and a mandatory basis, therefore the savings from these two measures strictly should not be added together. As noted in Chapter 4, the policy potentials scenarios are best interpreted as menus of options, rather than bounded total potentials.

Table 28: Residential Buildings: Policy Potential (Beyond BAU): Medium Uptake

Measure	Annual energy savings in 2030 (TJ)	Value of energy savings in 2030 ($'000, $2014 real)	Electricity savings in 2030 (GWh)	Gas savings in 2030 (TJ)	Cumulative GHG emissions savings to 2030 (t $C0_{2-e}$)	Average abatement cost ($/t CO2-e)	Electrical capacity savings in 2030 (MW)	Value of electrical capacity savings ($M) in 2030 ($2014 real)
New Builds	147.9	$7,773	27.5	48.8	172,256	-$114	7.9	$2.4
NABERS	12.7	$665	2.4	4.2	21,429	-$38	0.7	$0.2
NABERS Mandatory Disclosure	496.0	$25,966	92.3	163.7	794,323	-$8	26.4	$8.2
Building Tune-up program	38.5	$2,014	7.2	12.7	73,186	-$77	2.0	$0.6
Retrofit Program	125.6	$8,042	31.6	11.8	241,108	-$132	9.0	$2.8
Improved compliance with EE standards	48.1	$2,518	9.0	15.9	91,483	-$106	2.6	$0.8
Totals (weighted average for abatement cost)	868.7	$46,977	169.9	257.1	1,393,785	-$53	48.5	$15.0

Source: ***pitt&sherry***

Table 29: Residential Buildings: Economic Potential (Beyond BAU): Rapid Uptake

Measure	Annual energy savings in 2030 (TJ)	Value of energy savings in 2030 ($'000, $2014 real)	Electricity savings in 2030 (GWh)	Gas savings in 2030 (TJ)	Cumulative GHG emissions savings to 2030 (t $C0_{2-e}$)	Average abatement cost ($/t CO2-e)	Electrical capacity savings in 2030 (MW)	Value of electrical capacity savings ($M) in 2030 ($2014 real)
New Builds	303.6	$15,960	56.5	100.2	355,153	-$113	16.1	$5.0
NABERS	25.4	$1,328	4.7	8.4	40,258	-$44	1.3	$0.4
NABERS Mandatory Disclosure	496.0	$46,744	92.3	163.7	794,323	-$8	26.4	$8.2
Building Tune-up program	89.2	$4,669	16.6	29.4	172,958	-$85	4.7	$1.5
Retrofit Program	291.0	$18,641	73.2	27.4	700,795	-$112	20.9	$6.5
Improved compliance with EE standards	111.5	$5,836	20.7	36.8	21,675	-$112	5.9	$1.8
Totals (weighted average for abatement cost)	1,316.7	$93,176	264.1	365.9	2,085,162.9	-$69	75.4	$23.4

Source: ***pitt&sherry***

All the policy measures modelled are cost effective, albeit less so (on average) than the investment measures analysed in the economic potential scenario. This is due to the fact that we take into account the administrative costs associated with these policy measures, in addition to market barriers to their take-up. Also we model saturation effects with mandatory disclosure, as its high rate of uptake would be expected to lead to diminishing returns over time.

As with the technical potential, realisation of these economic potentials could yield very large and cost effective energy and greenhouse gas emissions savings. With medium take-up of these measures, annual energy cost savings of between $47 million a $93 million could be realised by by 2030, with the further benefit of avoided electricity infrastructure costs of between $15 million and $23 million in that year. As with the previous scenarios, these infrastructure savings have been conservatively estimated on the advice of Ausgrid.

We stress that this study presents potentials, while the actual savings will be a function of the nature of the initiatives adopted under the City of Sydney's Energy Efficiency Master Plan, in addition to the underlying market drivers (energy prices, technology prices, etc).

6.4 Commercial Buildings – Economic and Policy Savings Potentials

6.4.1 Introduction

This section of the Report provides similar analysis to the above but for the non-residential buildings (referred to in this report as 'commercial buildings' for short). While a very similar approach has been taken to these buildings as for the residential buildings, we note several changes.

First, we have relied on very detailed audit and retrofit data supplied by our project partner, Exergy Australia Pty Ltd, to represent the savings opportunities in these building segments. This data is of very high quality, reflecting as it does the commercial experience of Exergy in assessing and implementing tune-up, retrofit, retro-commissioning and other opportunities in Sydney and elsewhere. Data was provided separately for office, hotel, retail buildings and retail tenancies. Having examined the data, we have grouped values (costs and energy savings) of similar technical measures together.

In addition, Exergy has undertaken a detailed analysis of lift upgrade opportunities (Exergy 2011) for the Australian Government, and we reviewed this report and data for this project. However, we note that lift upgrades are far from cost-effective on energy efficiency grounds alone.

The starting-point energy intensities for the commercial building types (in FY2014) have been taken from the 'business as usual scenario' in the previous chapter (see Table 11). As with residential buildings, we then apply two analyses – technical and economic potential – at each of two up-take rates – medium and rapid. We note that more detailed results exist within the model for each individual building type. However, as there are 15 non-residential building types resolved in the model, it is not practical to show separate results for each one.

We note that the same benefit cost analysis and greenhouse gas abatement curve methodologies are used for commercial buildings and for residential, as described in Section 6.1. Commercial fuel price projections are also set out in that Section. Further and more detailed assumptions relating to individual building types or scenarios are set out in the sections below.

6.4.2 Commercial Buildings – Economic Potential

In the economic potential scenario, we examine five 'buckets' of opportunities:

1. The potential for more energy efficient new buildings (beyond the current BCA requirements);
2. Lighting upgrades for the balance of the stock (that is, everything except the new builds);
3. HVAC upgrades;
4. Lift upgrades;
5. Appliances/domestic hot water (DHW) upgrades.

These are described as 'buckets' since, as with the residential technical efficiency opportunities, they represent the average values (incremental costs and fuel savings) from a much larger set of individual upgrades to actual buildings, taken from Exergy's data files. It should be noted that some lighting upgrades, for example, will cost less and save more than the average values used, but also that some will cost more and save less. They should not be read as predicting what could be achieved in any particular building, but rather as an indicative, average result with that savings class (eg, lighting upgrades). Further detail on each technical measure is set out below.

New Builds

The potential for energy efficiency improvements, beyond the current requirements of the National Construction Code, was the subject of **pitt&sherry** (2012a). This comprehensive, 18-month study for the Australian Government modelled, inter alia, four different commercial building forms (a 3-storey office-style building, a 10-storey office-style building, a 10-storey hospital building and a low retail building representing supermarket), at four energy performance levels (minimal compliance with Code, Code – 40% (40% less energy consumption), Code -70% and Code -100%, or zero net energy), in every capital city climate zone, with and without solar PV, and at three different policy scenarios (combinations of carbon prices and learning rates). Incremental costs were independently modelled by quantity surveyors, Davis Langdon. Limitations of the study include:

- Non-inclusion of peak energy savings (inclusion would increase the % savings found to be cost effective);
- Not all building forms or climate zones were studied;
- Some buildings modelled use trigeneration (which falls outside the scope of this study) to reach higher performance levels. However, this only occurs at energy performance levels that are higher than the 'break even' or cost-effective thresholds (often at the -70% performance level or, in some buildings like the smaller office not at all). Therefore we can be confident that the break-even values (costs and energy savings) used in this study are not affected by trigeneration;
- Results were produced for 2015 and 2020, and not 2030.

The study is also 2 years old. That said, we are not aware of any more recent work for commercial buildings in Australia and the results remain valid.

For this report, we have taken average 'break even' savings values, expressed as percentage reductions from BCA 2010 (the current energy performance requirements in the BCA), from the nearest relevant building form in **pitt&sherry** (2012a), Sydney climate zone, with no PV, and applied these to the 15 commercial building types studied here. We have chosen the most conservative scenario, which assumes no carbon prices but also no industry learning. Higher savings percentages would apply if carbon pricing or learning were assumed. Also, we have assumed no *additional* savings over the 2020 – 2030 period, but rather than the same savings rate is achieved as was found to be cost-effective for 2020. These settings are conservative, and therefore the estimates provided for new building technical potentials should be regarded as a lower bound. As can be seen in Table 30, we have assumed that the energy savings apply equally to electricity and gas, although this may not be the case in reality.

Table 30: Key Assumptions – New Commercial Buildings – Technical Potential

2015/2030 Reference Intensities:	2015 Total Energy Intensity (MJ/m2.a)	2015 Electricity Intensity (MJ/m2.a)	New Build % Improvement	2030 Average Electricity Intensity	2015 Gas Intensity (MJ/m2.a)	New Build % Improvement	2030 Average Gas Intensity	Incremental Cost ($m2)
Offices	688	639	43%	365	48	43%	27	$112.00
Hotels	1359	871	43%	497	488	43%	278	$112.00
Other Accommodation	574	354	40%	212	219	40%	132	$153.00
Hospitals	1465	684	40%	410	782	40%	469	$146.00
Schools	152	128	25%	96	24	25%	18	$70.00
Tertiary	963	785	40%	471	178	40%	107	$112.00
Major shopping centres	1488	1245	40%	747	243	40%	146	$112.00

2015/2030 Reference Intensities:	2015 Total Energy Intensity (MJ/m2.a)	2015 Electricity Intensity (MJ/m2.a)	New Build % Improvement	2030 Average Electricity Intensity	2015 Gas Intensity (MJ/m2.a)	New Build % Improvement	2030 Average Gas Intensity	Incremental Cost ($m2)
Smaller shopping centres	2165	1823	40%	1094	342	40%	205	$112.00
Retail strips	295	248	25%	186	47	25%	35	$112.00
Industrial	510	390	40%	234	120	40%	72	$112.00
Warehouses/ Storage	296	233	40%	140	63	40%	38	$112.00
Cold storage	5600	5600	25%	4200	0	25%	0	$112.00
Car parks - naturally ventilated	122	122	25%	91	0	25%	0	$70.00
Car parks - enclosed	353	353	50%	176	0	50%	0	$70.00
Pubs & clubs	568	358	40%	215	210	40%	126	$153.00

Source: ***pitt&sherry***

Note that no building forms were studied in **pitt&sherry** (2012a) that would adequately describe car parks, schools or cool stores. Therefore we have applied our own professional judgement to estimate savings potentials for these building types. Of these, only car parks represent a major building type in Sydney, and the energy consumption of these buildings is limited to one or two end-uses – primarily lighting and ventilation – and therefore we have estimated potentials from these end-uses only.

Lighting Upgrades

There are many different lighting upgrades options that could be applied to Sydney's building stock. These include, for base buildings, luminaire replacements and upgrades (the light fitting), and upgraded hardware (lamps) and controls (sensors, switching). For tenancies (retail and office), similar measures are examined but also an 'other' category which essential includes delamping and voltage control.

Figure 40, for example, shows the spread of actual results for office base building luminaire replacements/upgrades. Note that the y-axis shows electricity savings in kWh/sqm, while the x-axis shows incremental costs (that is, just the additional cost beyond the industry-standard solutions). These counter-factual cases – the standard against which incremental costs are measured – will inevitably vary from building to building and audit to audit. For this reason we use average values, as represented by the linear regression shown. It can also be seen that most luminaire upgrades fall within a $2/sqm incremental cost boundary. The one or two outlier results shown represent opportunities that are not cost-effective.

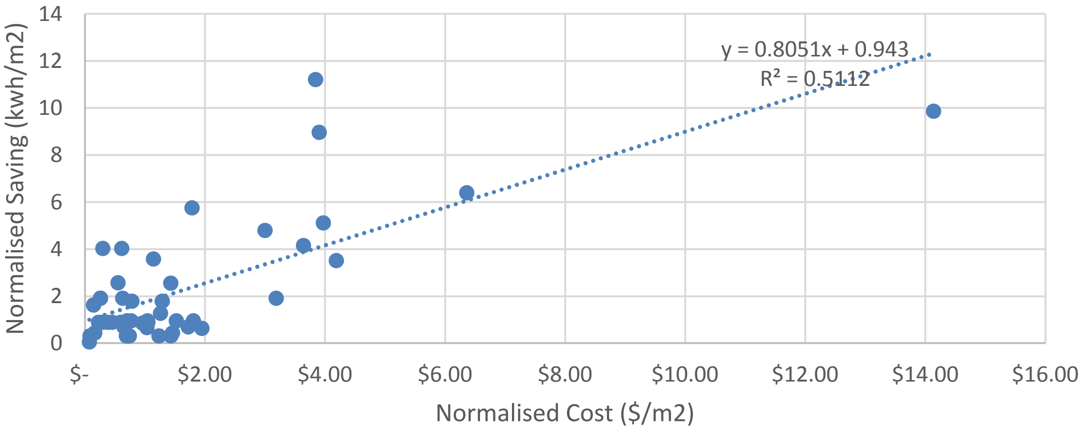


Figure 40: Office Base Buildings: Luminaire Replacements/Upgrades: Cost Curve

Source: Exergy Australia Pty Ltd

Tenancy lighting cost curves, and indeed those for hotels and retail, were observed to have a similar form to those for base office buildings, and therefore in our model we use a single average value. This reflects the fact that artificial lighting systems are reasonably generic and, within functional limitations, the economics of retrofit are more determined by the starting point technology being replaced than the nature of the building in which the system is housed. This is not to overlook the need for functionally-appropriate lighting design, but simply to note that our savings estimates are averages that can readily be transferred across building types, but they should not be applied to represent unique or specialised lighting applications.

HVAC Upgrades

HVAC upgrades also cover a wide range of individual treatments including:

- Replacing plant (e.g., chillers, cooling towers, chilled water and heating hot water)
- Improving and tuning controls systems (e.g., economy cycles, fan controls, changing running hours, installing building management systems, and many others), and
- Retro-commissioning (air flow rebalancing, repairing leaking ducts and valves, improving exhaust fans, and recommissioning whole HVAC systems).

Incremental cost curves are shown for HVAC plant upgrades/replacement (for office base buildings (Figure 41) and also for controls upgrades and tuning (Figure 42). It may be seen that these options are again characterised by a weighting towards relatively low cost, high-impact measures, with a few outlier results. By contrast, HVAC retro-commissioning costs and energy savings are more variable.

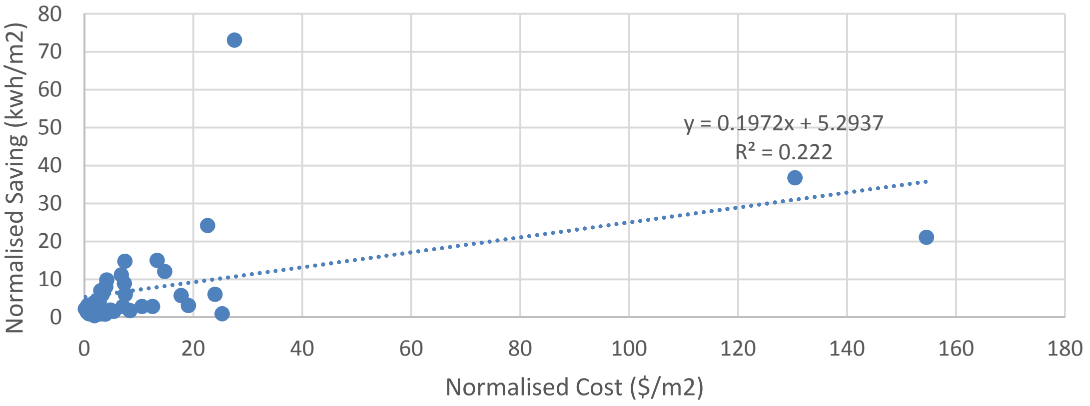


Figure 41: Office Base Buildings: HVAC Plan Upgrades/Replacement: Cost Curve

Source: Exergy Australia Pty Ltd

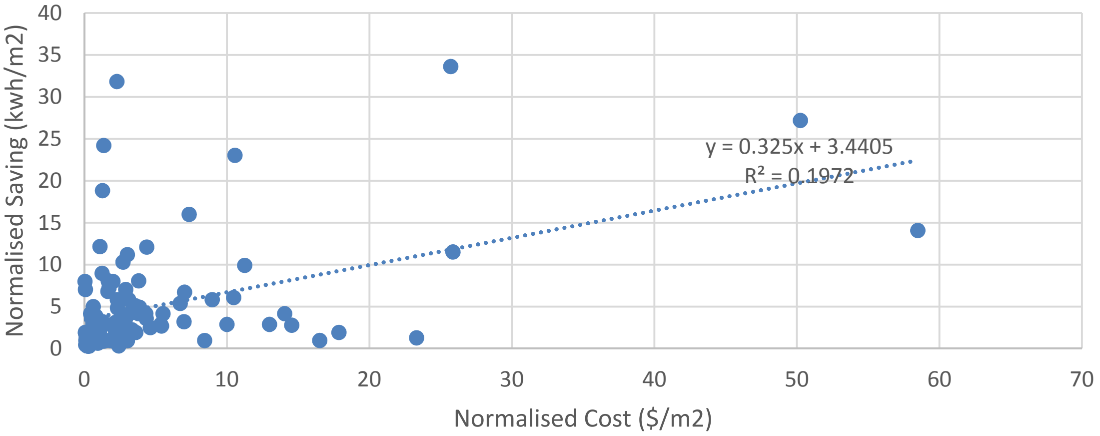


Figure 42: Office Base Buildings: HVAC Controls Upgrade/Tuning: Cost Curve

Source: Exergy Australia Pty Ltd

In our analysis we have compiled average values for energy savings and utilised the regression analysis to associate incremental costs with these average savings values. We found limited variation from one building type to another (the set included offices, hotels, hospitals and retail shopping centres) in terms of the relationship between energy savings and incremental costs. For more detailed studies of these building types, it would be possible to refine estimates for each one. We exclude schools, warehouses and car parks from our estimates on the grounds that few will feature centralised building services.

Lift Upgrades

Lift upgrades were analysed using data from Exergy (2011). Apart from smaller measures, such as improving lift lighting and standby power consumption, it appears that more substantial lift upgrades are quite expensive (estimated at up to $500,000 per car) and, even though they offer significant energy savings, the costs do not justify the investment of energy efficiency grounds alone. Of course, most lift upgrades occur for safety reasons, or at the end of the long economic lives of lift equipment, and it is likely that uptake of efficiency options will continue to be limited by the overall pace of lift refurbishment. Nevertheless, we have included lift upgrades in the options set for purposes of comparison.

Appliance and Domestic Hot Water Upgrades

This data set primarily features hot water upgrades for base buildings – including switching to heat pumps, high-efficiency gas, and reducing losses through insulation and flow reduction. For tenancies, options are dominated by upgrades to computers, screens, and standby power management.

Economic Potential – Medium Take-up

Applying the above analysis to our benefit cost model, we need to make assumptions about the rate at which new measures are taken up in the building stock. For the more energy efficient new buildings, the stock model described earlier enables us to model the area of each commercial building type that is constructed annually, be that to meet demand for growth in total floor area, or replacement of demolished older stock or major refurbishments of the existing stock sufficient to trigger Section J of the National Construction Code. We assume only one third of the refurbished stock is upgraded to Section J requirements, given uncertainties about this value discussed in Section 4.2.3. In the medium take-up scenario, we assume that 50% of the new build stock is built to the higher standard over the period to 2030.

Similarly for the retrofit technical options, we assume that only 50% of technical potential is reached in the medium take-up scenario. Note that this does not mean that 50% of the existing stock is retrofitted – the maximum take-up is modelled to take into account characteristics of the stock, and 100% take-up may never be possible for some options. For example, the measure 'HVAC upgrades' can only ever apply to buildings that have centralised HVAC systems. Some classes, such as schools, warehouses and car parks, are assumed to not have such systems. For other classes, such as hotels and other accommodation, many - often the smaller ones - will feature split system air-conditioners by room rather than centralised HVAC systems. It is also necessary to take into account the extent to which certain upgrades (like high efficiency appliances and hot water systems, for example) may already have been taken up by the market – as this reduces the residual opportunity.

Another factor that affects the benefit cost analysis is the expected economic life of the upgrades. This is because we model full replacement of capital at end of economic life, as noted in Section 6.1.1. Note that for new builds, building shells may have an economic life of 40 years or more but we model the life of upgraded equipment, such as HVAC, lighting and other building services. This may penalise the new builds somewhat, as less than 100% of the incremental cost of the higher performance buildings (as assessed by Davis Langdon in **pitt&sherry** (2012a) will be attributable to building services.

For clarity, the assumptions we make with respect to FY2014 uptake (recalling that the new measures are assumed to commence from FY2015), maximum uptake by scenario and economic life, are set out in Table 31.

Table 31: Commercial Buildings: Technical Potential: Uptake Assumptions

Measure	Life of Measure (Years)	2014 Uptake (%)	Maximum Uptake by 2030 (Medium Scenario)	Maximum Uptake by 2030 (Rapid Scenario)
New builds	10 (equip. nly)	0%	50%	100%
Lighting upgrades	7	20%	50%	100%
HVAC upgrades	15	20%	45% (excl. classes noted)	90% (excl. classes noted)
Lift upgrades	25	10%	15%	30%
Appliance/DHW upgrades	7	30%	50%	100%

Source: ***pitt&sherry***

Applying these assumptions, the measures achieve almost 2.6 Mt CO_2-e of abatement in *cumulative* terms over the 2015 – 2030 period, with a medium rake of uptake. Perhaps a better indicator, however, is that emissions in 2030 would be some 345 kt CO_2-e lower, a reduction of 8.5% of the 2006 non-residential emission baseline. It can be seen from Figure 43, however, that lift upgrades have a positive abatement cost of some $900 per tonne CO_2-e avoided, and therefore would not form part of a least-cost abatement set. The lift upgrades would have contributed less than 7 kt CO_2-e to abatement in 2030, but we exclude these savings.

Table 32: Data Table: Commercial Buildings: Technical Measures: Medium Take-up: 2015 - 2030

Opportunity	$/t	Cumulative Abatement (t CO2-e)	2030 Abatement (t CO2-e)
Appliance/DHW upgrades	-$66	85,060	9,244
Lighting upgrades	-$45	380,438	41,326
HVAC upgrades	-$38	940,764	102,255
New Builds	-$27	1,112,163	185,744
Lift upgrades	$902	65,823	7,150
Reduction of 2006 non-residential emissions, beyond BAU, by 2030 (without lift upgrades):	8.5%		338,568

Source: ***pitt&sherry***

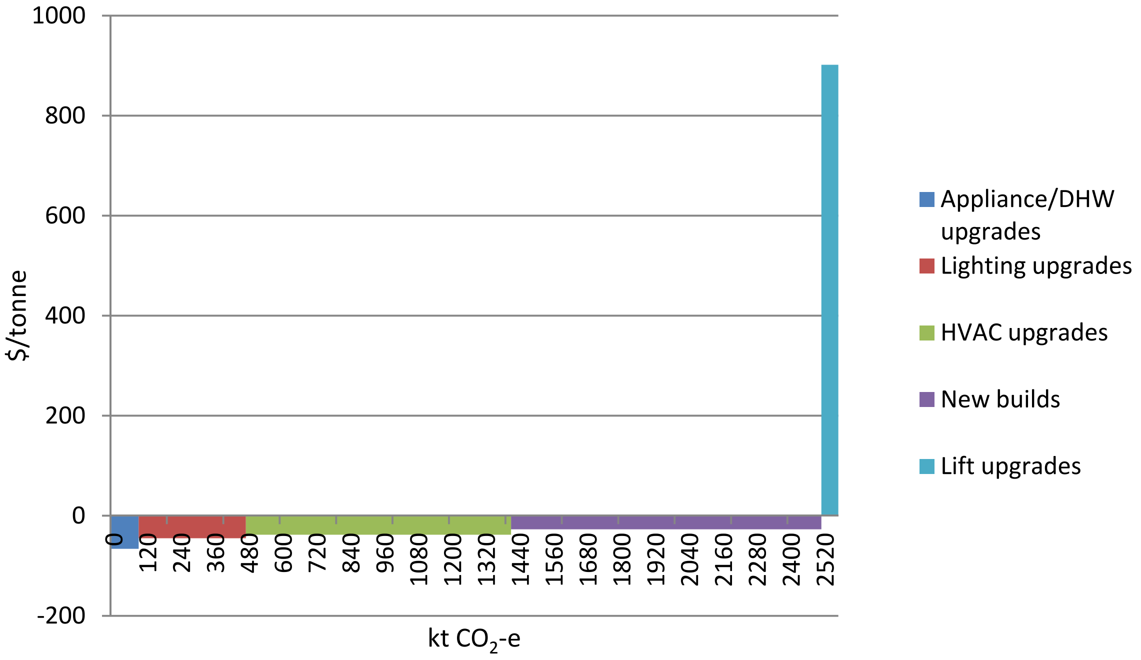


Figure 43: Greenhouse Gas Abatement Cost Curve: Commercial Buildings: Economic Potential: Medium Take-up: 2015 - 2030

Source: ***pitt&sherry***

This data indicates that there is very significant and cost effective abatement potential in HVAC upgrades in particular. This in turn reflects the fact that HVAC often accounts for around half of total energy consumption in commercial buildings, and also the large potential for higher efficiency components, better controls and integration, and better management via building management systems. Higher efficiency new builds are also an important abatement opportunity – more cost-effective than the retrofit options (due to the ability to access low cost design improvements and to upgrade equipment/systems at marginal cost during new-build design/construction, avoided mobilisation costs for service providers, etc), but not as large in total due to the slow accumulation of savings at the rate of new build (only a small percentage of the total stock each year).

Economic Potential – Rapid Take-up

The rapid take-up values are set out in Table 33 below. Applying these values we find that the abatement costs remain virtually the same but the tonnes saved, beyond business as usual, more than double, reaching just over 726 kt CO_2-e by 2030, equal to 17.9% of the 2006 non-residential emissions baseline (see Figure 44 and Table 36).

Table 33: Data Table: Commercial Buildings: Technical Measures: Rapid Take-up: 2015 – 2030

Opportunity	$/t	Cumulative Abatement (t CO2-e)	2030 Abatement (t CO2-e)
Appliance/DHW upgrades	-$66	305,517	32,579
Lighting upgrades	-$45	1,001,152	108,752
HVAC upgrades	-$37	1,880,650	203,632
New Builds	-$27	2,293,198	381,540
Lift upgrades	$860	329,952	34,912
Reduction of 2006 non-residential emissions, beyond BAU, by 2030 (excl. lift upgrades):	17.9%		726,503

Source: ***pitt&sherry***

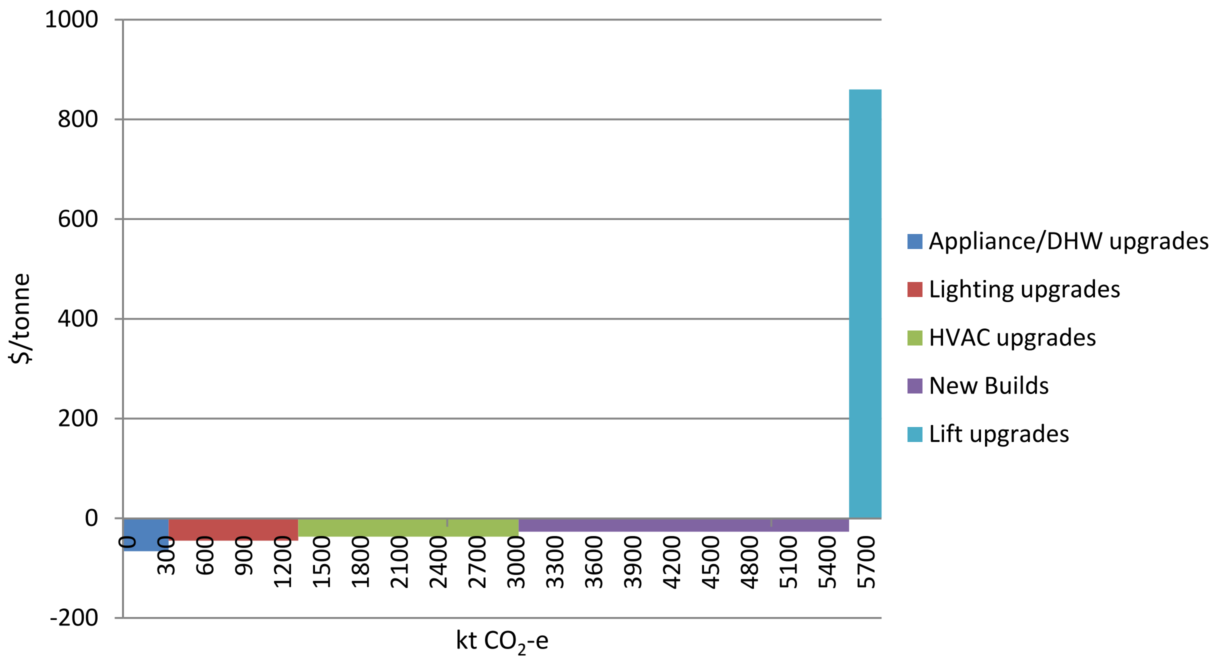


Figure 44: Greenhouse Gas Abatement Cost Curve: Commercial Buildings: Economic Potential: Rapid Take-Up: 2015 - 2030

Source: ***pitt&sherry***

6.4.3 Commercial Buildings – Policy Potential

This analysis models the expected impact of a range of defined policy/program measures. As such, it aims to provide a realistic indication of the energy and emissions savings that could be achieved with potentially feasible measures. Some measures may be mutually-exclusive, or at least interact negatively with each other (such as mandatory and voluntary ratings), and we have not taken this effect into account when summing up totals for the economic potential scenarios.

Two take-up scenarios are again provided – with the exception of the mandatory disclosure measure (which we include in both scenarios with the same take-up) – medium, meaning 50% of the assessed potential is taken up by 2030, and rapid, meaning 100% of the assessed potential is taken-up by 2030.

Higher Energy Performance Requirements for New Builds

This measure could be given effect via the National Construction Code or, potentially, a revised BASIX tool, with the agreement of other parties. We note that some local governments are also introducing 'environmentally efficient design' (or 'ecologically sustainable design') policies into their planning schemes, which have the effect of imposing (or seeking) higher than mandatory minimum energy performance requirements.[81] This measure is described in 6.3.2 – New Builds. Care should therefore be taken not to double count the savings. It is included in this set as it forms part of the economic potential for savings and is a readily-definable measure.

---

[81] See, for example, Cities of Melbourne, Yarra, Port Phillip, Banyule, Stonnington, Whitehorse and Moreland in Victoria.

Voluntary Ratings, e.g., NABERS

This measure assumes that a suitable ratings tool, such as NABERS or equivalent, is developed (for all classes of buildings) and marketed to building owners and developers as an opportunity to differentiate their products and attract market premiums. Offices, hotels and shopping centres are excluded from the analysis, as they are already covered by NABERS tools. For modelling purposes we assume an average ratings cost of $3,000 per building, and an average building size rated of 10,000 sqm. The energy savings achieved per building are modelled on the 9% savings claimed by the Office of Environment & Heritage under the existing NABERS program for buildings rated more than once. The incremental investment costs are calculated as an average from the Exergy audit set, applying all measures (except lift upgrades), as it is not clear in advance which technical measures will be rolled out as part of a NABERS-induced upgrade. We calculate this cost at just over $21/sqm.

We assume program development costs of $300,000 (in the first year), and four FTEs for administration (through to 2030). However, these costs would support a national, or at least NSW-wide, tool. Therefore it would be inappropriate to hold even the majority of these costs against benefits derived in the City of Sydney area alone. We therefore factor these costs down by 90%; that is, 10% of these costs are attributed to the City of Sydney.

In terms of uptake of this measure, we note that there would be significant barriers. Not all building sectors included in our analysis are highly commercial (eg, schools, hospitals) and may respond poorly to a voluntary program. This is because ratings tools, when used voluntarily, seek to induce competition between building owners, and competitive upgrading of energy performance. In the absence of such competition, take-up could be expected to be lower. We assume that, on average across the buildings studied – and excluding offices – only 20% take-up is achieved by 2030.

Mandatory Disclosure

Mandatory disclosure of the energy performance of commercial office spaces greater than 2000 sqm has been in place since 2011 under the Commercial Building Disclosure (CBD) scheme. This measure initially assumed that a similar requirement is placed on all other building types. However, feedback from the *Better Buildings Partnership* suggested this may not be realistic, as the many of the building types are institutional in nature (schools, hospitals, tertiary education) and/or not (or rarely) tenanted (carparks, warehouses). Therefore for this Final Report we have scaled back this measure to only cover retail buildings (in addition to offices and Class 2 residential buildings as discussed in the previous section).

Technical and cost parameters for this measure are the same as for voluntary NABERS; the key difference is the uptake. With mandatory application, we assume that take-up reaches 100% by 2030. In practice, the rate of uptake would depend on the rules and incentives created by the enabling legislation. In the case of CBD, and on current take-up, it is expected to achieve 100% coverage of its target segment within 5 years or less (**pitt&sherry** 2013).

Building Tune-up Program

This measure is described in detail in Section 6.2.3 above, for high-rise residential buildings. The same program design is assumed here, including the need for an audit, which we assume will cost $5,000 on average. We note that a more limited audit is assumed for tune-ups than for retrofits due to the lesser scope of the tune-up program and no- or small-capital nature of the investments targeted in the tune-up program. While most of the investments are likely to focus on the base building, in some cases tenanted areas could be including within the scope of a tune-up, with the tenant’s agreement.

The energy savings are modelled as the average values from the sub-set of Exergy's audit and investment measures database that are likely to be included within a tune-up program. That is, we exclude asset replacements and instead select measures such as HVAC control upgrades and tuning, HVAC retro-commissioning, lighting control upgrades, other lighting measures like delamping – with values taken from all building types included in the Exergy data set. Incremental investment costs are derived in the same manner. We also assume $100,000 in program development costs in FY2015 and 2 FTEs for administration of the program through to 2030. The uptake of the program would be voluntary. Whether or not any costs associated with the program would be subsidised to the building owner is not defined, as it does not affect the benefit cost analysis.

Building Retrofit Program

This measure is also similar to the one described under this heading for residential buildings. It assumes an average audit cost (in order to identify the business case for specific retrofits) of $10,000. Note that no 'learning', or reduction in unit cost through time, is assumed for either retrofits or tune-ups, given the higher labour cost share involved. Energy savings and incremental costs are also compiled as the averages of all the retrofit options, for all building classes, from Exergy's database.

Improved Building Compliance

The final measure modelled is a program to enhance compliance with existing minimum mandatory standards in the National Construction Code, both in the case of new builds but, perhaps more importantly, also in the case of major refurbishments. As discussed earlier, there is doubt about the extent to which existing requirements are being met – not just in Sydney, but generally around Australia. Yet the cumulative effect, in terms of missed savings opportunities, of such under-compliance could be very large.

For modelling purposes, we assume that the energy savings available through such a measure would be similar to those associated with a building tune-up, as poor commissioning is understood to be one of the most common sources of under-performing commercial buildings. However, we remove the audit cost, and assume that instead improved compliance processes are utilised to ensure the savings are achieved. For this reason, it may be noted below that this measure shows a slightly lower cost of abatement than the tune-up program.

Table 34 below shows the key values, in terms of take-up and economic life, for this set of measures, for both the medium and rapid take-up scenarios.

Table 34: Commercial Buildings: Economic Potential: Uptake Assumptions

Measure	Economic Life of Investments (Years)	2014 Take-up (%)	Maximum Take-up (Medium Scenario)	Maximum Take-up (Rapid Scenario)
New builds	10 (equip only)	0%	50%	100%
NABERS Voluntary	10	0%	10%	20%
Mandatory Disclosure	10	0%	100%	100%
Tune-up Program	7	5%	35%	75%
Retrofit Program	7	25%	40%	75%
Improved compliance	7	25%	35%	75%

*Source: **pitt&sherry***

Policy Potential – Medium Take-up

With the measures noted, and assuming a medium rate of take-up over the period to 2030, we estimate that emissions savings in 2030 would be some 540 kt CO_2-e. This is equal to a saving of 13.3% of the non-residential 2006 emissions baseline (see Figure 45 and Table 35 below). It is clear that higher efficiency standards for new builds would yield the greatest greenhouse savings dividend, followed by mandatory disclosure measure. All measures are cost-effective, with the exception of voluntary NABERS. This result occurs as the low take-up rate leads to modest emissions and energy savings, while same fixed costs as for mandatory disclosure still must be paid with this measure.

Table 35: Data Table: Commercial Buildings: Policy Potential: Medium Uptake: 2015 – 2030

Opportunity	$/t	Cumulative Abatement (t CO2-e)	2030 Abatement (t CO2-e)
Improved Compliance	-$48	227,295	24,706
New Builds	-$27	1,112,163	381,540
Building Tune-up Program	-$27	227,295	24,706
NABERS Mandatory Disclosure	-$19	567,331	66,433
Building Retrofit Program	-$6	231,739	25,202
NABERS Voluntary	$29	153,799	18,139
Reduction of 2006 non-residential emissions, beyond BAU, by 2030:	13.3%		540,725

Source: ***pitt&sherry***

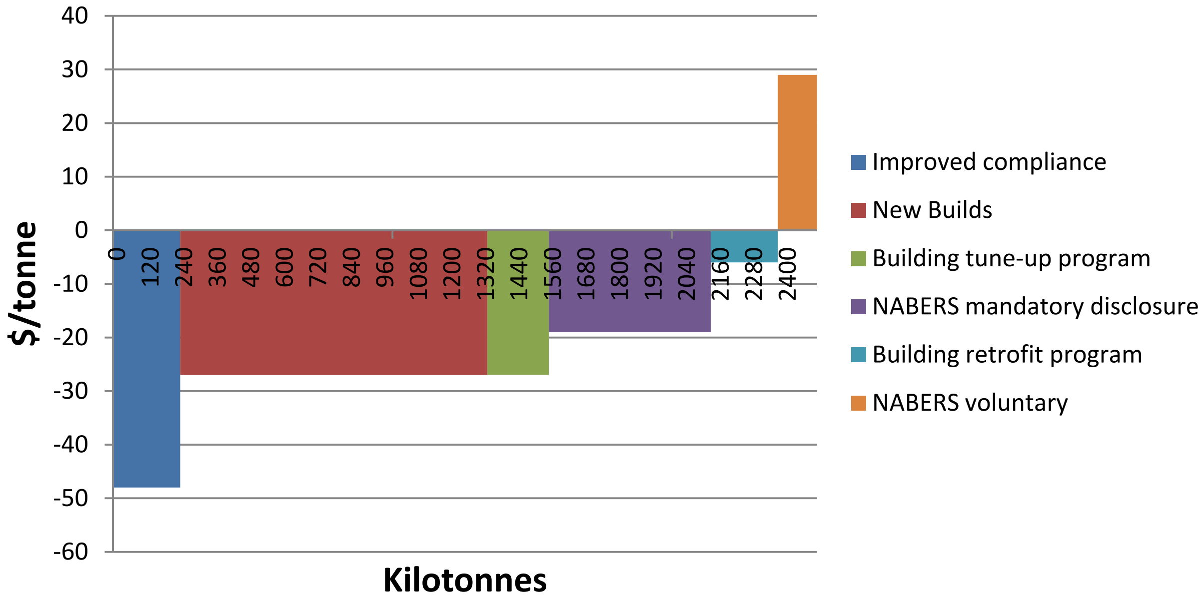


Figure 45: Greenhouse Gas Abatement Cost Curve: Commercial Buildings: Policy Potential: Medium Take-Up: 2015 - 2030

Source: ***pitt&sherry***

Policy Potential – Rapid Take-up

With rapid take-up of these measures (as set out in Table 33), greater energy and greenhouse gas emission savings are realised. Savings reach 280 kt CO_2-e per year by 2030, equivalent to a 7.1% reduction in 2006 non-residential emissions (see Figure 46 and Table 36). Note that savings do not double in this scenario, vis-a-vis the medium take-up scenario, as the mandatory disclosure measure achieves the same savings in both scenarios.

Table 36: Data Table: Commercial Buildings: Policy Potential: Rapid Uptake: 2015 – 2030

Opportunity	$/t	Cumulative Abatement (t CO2-e)	2030 Abatement (t CO2-e)
Improved Compliance	-$53	382,076	40,873
Building Tune-up Program	-$34	537,102	57,285
New Builds	-$27	2,293,198	381,540
NABERS Mandatory Disclosure	-$19	567,331	66,433
Building Retrofit Program	-$15	798,686	84,596
NABERS Voluntary	$49	321,009	36,561
Reduction of 2006 non-residential emissions, beyond BAU, by 2030:	16.4%		667,288

*Source: **pitt&sherry***

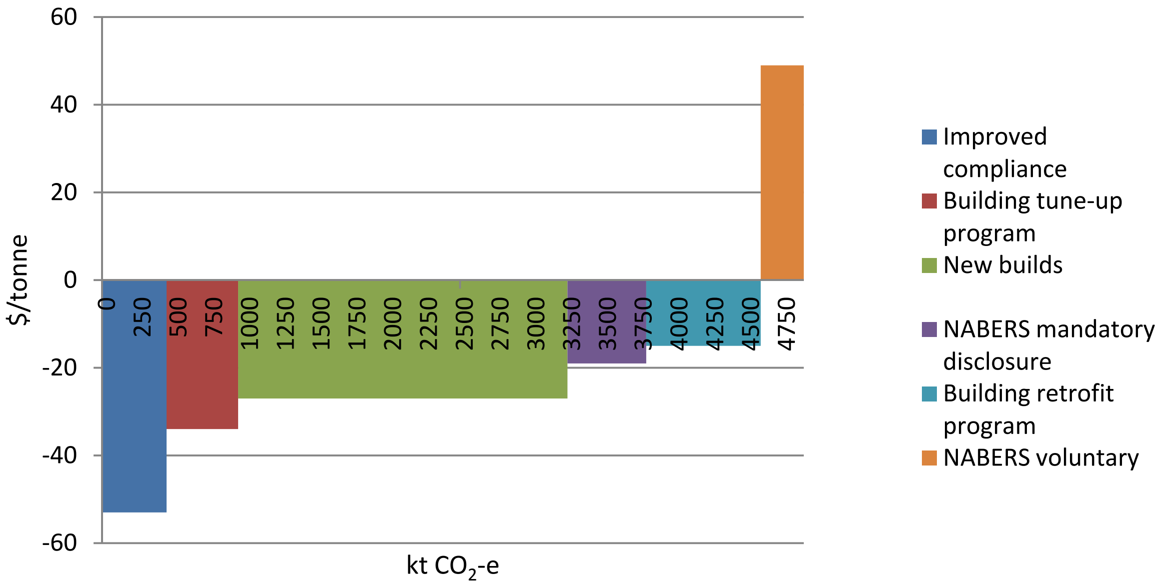


Figure 46: Greenhouse Gas Abatement Cost Curve: Commercial Buildings: Policy Potential: Rapid Take-Up: 2015 - 2030

*Source: **pitt&sherry***

6.4.4 Commercial Buildings – Summary

Economic Potential

The economic potential energy savings in commercial buildings in the City of Sydney is large – indeed larger than in the residential sector – and most measures studied are highly cost-effective. Only the lift upgrade measure is not cost effective in energy savings terms alone. As noted in Tables 6.23 and 6.24, total energy savings could range between 885 and 2,590 TJ, depending upon whether a medium or rapid rate of up-take of the measures is achieved. As with the residential sector, lifting efficiency standards for new builds proves to be the most effective measure, and is also the most cost effective of the technical measures.

Table 37: Summary: Commercial Buildings: Economic Potential: Medium Uptake

Measure	Energy savings in 2030 (TJ)	Value of energy savings in 2030 $'000 ($2014 real)	Total electricity savings in 2030 (GWh)	Gas savings in 2030 (TJ)	GHG emissions savings t C02-e (2030)	Average abatement cost ($/t CO2-e)	Electrical capacity savings in 2030 (MW)	Value of electrical capacity savings in 2030 ($2014 real)
New Builds	770.9	$43,024	185.8	102.1	185,744	-$27	53.1	$16.4
Lighting upgrades	99.6	$6,151	27.7	0.0	41,326	-$45	7.9	$2.4
HVAC upgrades	15.6	$17,345	3.7	2.2	102,255	-$38	21.3	$6.6
Lift upgrades	18.1	$1,116	5.0	0.0	7,150	$902	1.4	$0.4
Appliance/DHW upgrades	3.4	$1,380	0.3	2.3	9,244	-$66	1.7	$0.5
Totals (average for abatement cost, excl. lifts)	889.5	$67,890	217.5	106.6	338,568	-$33	84.0	$26.0

Source: ***pitt&sherry***

Realising these economic potentials would generate annual energy savings (beyond business as usual) valued at between $68 million (medium uptake) and $144 million (rapid uptake) in 2030, also avoiding the need for investment in between 84 MW (medium) and 178 MW (rapid), valued at an additional $26 million (medium) or $55 million (rapid) per year. These energy savings would also amount to a cumulative reduction in greenhouse gas emissions over the period to 2030 of between 339 kt CO_2-e and 727 kt CO_2-e. Details of the unit costs, energy savings by fuel, payback and average economic life of the technical measures studied are noted in Table 39. These values represent averages across the different commercial building classes and will vary from building type to building type.

Table 38: Summary: Commercial Buildings: Economic Potential: Rapid Uptake

Measure	Energy savings in 2030 (TJ)	Value of energy savings in 2030 $'000 ($2014 real)	Electricity savings in 2030 (GWh)	Gas savings in 2030 (TJ)	GHG emissions savings C02-e (2030)	Average abatement cost ($/t CO2-e)	Electrical capacity savings in 2030 (MW)	Value of electrical capacity savings in 2030 ($2014 real)
New Builds	1,583.2	$88,361	381.5	209.7	381,540	-$27	109.0	$33.8
Lighting upgrades	262.0	$16,187	72.8	0.0	108,752	-$45	20.8	$6.4
HVAC upgrades	622.2	$34,532	148.7	86.8	203,632	-$37	42.5	$13.2
Lift upgrades	84.0	$5,187	23.3	0.0	34,912	$860	6.7	$2.1
Appliance/DHW upgrades	84.5	$4,859	21.2	8.0	32,579	-$66	6.1	$1.9
Totals (average for abatement cost, excl. lifts)	2,551.9	$143,938	624.3	304.5	726,503	-$35	178.3	$55.3

Source: ***pitt&sherry***

Table 39: Summary: Commercial Buildings: Technical Potential: Investment Parameters

Measure	Unit capital cost (\$2014real/m^2)	Unit electricity savings (MJ/m^2.a)	Unit gas savings (MJ/m^2.a)	Simple payback (years)	Economic life of investment (years)
New Builds (average)	$111.33	312.4	74.0	7.3	10
Lighting upgrades	$3.83	17.3	0.0	3.5	7
HVAC upgrades	$23.60	55.2	8.9	6.5	15
Lift upgrades	$144.27	22.0	0.0	102.7	25
Appliance/DHW upgrades	$0.75	5.7	0.6	2.0	7

Source: ***pitt&sherry***

Policy Potential

The policy potential for energy savings in the commercial building sector has been modelled on the potential savings attributable to a range of specific policy measures or programs. Note that we include higher efficiency new buildings in both economic and policy scenarios.

Overall we find that the policy potential for energy savings from commercial buildings in the City of Sydney area in 2030 ranges between 1,480 and 2,750 TJ (see Tables 6.26 and 6.27), noting that NABERS (or a similar ratings tool) is unlikely to apply under both voluntary and mandatory regimes at the same time. These savings would be valued at between \$46 million and \$64 million in 2030, generating between 32,000 and 53,400 t CO_2-e in annual greenhouse gas emission reductions. All bar the voluntary application of NABERS are shown to be cost effective, with an average cost of abatement, across all measures, of minus \$17/tonne CO_2-e. Recall that each of these savings values is additional to those achieved under the business-as-usual scenario.

Avoided infrastructure costs associated with these measures are not as significant as for the residential sector, due to the less ‘peaky’ nature of commercial building energy demand. Nevertheless, the measures could reduce electrical system capacity requirements in 230 by between 106 MW and 182 MW, valued at between $33 million and $57 million in that year.

Table 40: Summary: Commercial Buildings: Policy Potential: Medium Uptake

Measure	Annual Energy savings in 2030 (TJ)	Value of annual energy savings in 2030 $'000 ($2014 real)	Annual Electricity savings in 2030 (GWh)	Annual Gas savings in 2030 (TJ)	Cumulative GHG emissions savings C02-e (2015-2030)	Average abatement cost ($/t CO2-e)	Annual electrical capacity savings in 2030 (MW)	Value of annual electrical capacity savings in 2030 ($2014 real)
New Builds	771	$43,024	186	102	185,744	-$27	53.1	$16.4
NABERS voluntary	38	$2,068	9	7	18,139	$29	2.5	$0.8
NABERS mandatory disclosure	139	$7,565	32	22	66,433	-$19	9.2	$2.9
Building tune-up	3	$3,696	1	0	24,706	-$27	4.5	$1.4
Building Retrofit program	57	$3,786	16	1	25,202	-$6	4.5	$1.4
Improved compliance program	12	$3,696	1	9	24,706	-$48	4.5	$1.4
Totals (average for abatement cost, excl. lifts)	1,021	63,836.1	244	142	344,929	-$23	78.4	$24.3

Source: ***pitt&sherry***

Table 41: Summary: Commercial Buildings: Policy Potential: Rapid Uptake

Measure	Annual Energy savings in 2030 (TJ)	Value of annual energy savings in 2030 $'000 ($2014 real)	Annual Electricity savings in 2030 (GWh)	Annual Gas savings in 2030 (TJ)	Cumulative GHG emissions savings C02-e (2015-2030)	Average abatement cost ($/t CO2-e)	Annual electrical capacity savings in 2030 (MW)	Value of annual electrical capacity savings in 2030 ($2014 real)
New Builds	1,583	$88,361	382	210	381,540	-$27	109.0	$33.8
NABERS voluntary	77	$4,159	18	14	36,561	$49	5.0	$1.6
NABERS mandatory disclosure	139	$7,565	32	22	66,433	-$19	9.2	$2.9
Building tune-up	154	$8,560	37	22	57,285	-$34	10.5	$3.3
Building Retrofit program	248	$12,688	53	58	84,596	-$15	15.0	$4.7
Improved compliance program	110	$6,109	26	16	40,873	-$53	7.5	$2.3
Totals (average for abatement cost, excl. lifts)	2,312	$127,442	547	341	667,288	-$17	156.3	$48.5

Source: ***pitt&sherry***

6.5 Peak Demand Infrastructure Cost Savings

With lower demand for energy, consequent upon the energy efficiency measures modelled in this study, investment in electricity network and generation infrastructure could be deferred or avoided. This amounts to an additional economic benefit attributable to the efficiency measures. Note that a similar effect occurs for gas savings, but the potential for avoiding gas network costs through efficiency measures would only occur in specific circumstances, such as when the gas network was close to fully utilised. We have therefore not modelled such an effect.

The methodology we describe and employ below is ultimately based on quantitative research linking different types of avoided demand to amounts of avoided electricity infrastructure capacity investment. It should be noted that the underlying relationships can vary through time. In particular, Section 5.3 describes how patterns of energy and peak demand are changing in ways never before experienced in Australia's history. Electricity demand has been falling for many years now - despite continued growth in GDP, population and other key variables - and peak electricity demand appears to be falling as well, albeit by a smaller amount than energy demand. This – combined with the very large investment in electricity capacity that has occurred in NSW, along with other Australian states, in recent years means that requirements for additional capacity may be modest over the medium term. Therefore over this same period, the scope for avoiding infrastructure costs may be more limited than recent analysis would suggest. Following consultations, including with Ausgrid, we have adopted more conservative values for residential peak savings in particular, as detailed below.

We stress that the linkage between energy demand and peak load is complex and difficult to forecast. It cannot simply be assumed that avoided demand always leads to the same quantum of reduction in required system capacity – this is also affected by the load shape in different regions, the nature of generation technologies supplying those regions, reserve and other security requirements, load shedding capabilities and other factors. Therefore the estimates below should be treated as indicative only.

Modelling the connection between energy efficiency and the economic benefits of peak load reduction involves two steps: firstly, to link energy efficiency improvements to reductions in consumer demand; and secondly, to link reductions in consumer demand to reduced network costs. Recent studies in Australia (UTS 2010) and (EES 2011) have addressed these issues to develop estimates of the economic benefits of peak load reduction as a consequence of energy efficiency. Both studies drew on the concept of the Conservation Load Factor (CLF) (Koomey 1990) which is a method of estimating the likely energy savings in peak load due to the application of an energy saving measure.

The CLF concept was developed in order to provide a simple basis for estimating the peak load savings and consequential financial benefit from a reduction in peak load.

The CLF is defined as the average annual load savings divided by the peak load savings, where both are based on measured data or the output of an hourly simulation model.

$$CLF = [\text{Annual Energy Savings (kWh)}/8760]/\text{Peak Load Savings (kW)}$$

The concept is analogous to a demand side capacity factor, or a measure of the peakiness of end use. For end-uses like refrigeration, with a relatively flat based load throughout the year, values of 0.7 are typical. For end-uses such as residential air conditioning, with a relatively peaky performance throughout the year, the CLF value is much lower, typically between 0.01 and 0.1. High air conditioning demand is weather related, so that air conditioning use is peak coincident with large peak demand relative to total annual energy used. In this study, we initially applied a CLF of 0.05 for residential savings, and 0.4 for commercial savings. However, noting that the residential building stock is weighted towards class 2 buildings, and taking into account the perspectives of Augrid – which include a view that the class 2 buildings may be mostly air conditioned and operating more like a commercial building – we revised the residential CLF value to 0.4. A value of $0.31 million/MW.a is assumed for value of electricity infrastructure savings, following UTS (2010). Table 42 summarises the results.

Despite the more conservative assumptions, the avoided infrastructure costs amount to valuable additional savings from a societal perspective – noting the earlier discussion on uncertainty. Larger infrastructure savings occur with the rapid uptake scenarios, and notably larger infrastructure savings for residential energy efficiency improvements, as compared to commercial, due to the 'peakier' nature of residential demand.

Table 42: Electricity Infrastructure Savings from Avoided Peak Load

Scenario	2030 Capacity Savings (MW)	Value of Infrastructure Savings in 2030 ($m)	Present Value of Infrastructure Savings @ 7% real discount rate ($m)
Residential – Economic Potential – Medium Take-up	13.5	$4.2	$17.0
Residential – Economic Potential – Rapid Uptake	28.0	$8.7	$36.6
Residential – Policy Potential – Medium Take-up	48.5	$15.0	$56.3
Residential – Policy Potential – Rapid Take-up	75.4	$23.4	$90.1
Commercial – Economic Potential – Medium Take-up	84.0	$26.0	$86.5
Commercial – Economic Potential – Rapid Take-up	178.3	$56.3	$186.5
Commercial – Policy Potential – Medium Take-up	78.4	$24.3	$77.1
Commercial – Policy Potential – Rapid Take-up	156.3	$48.5	$154.9

Source: ***pitt&sherry***

Reduced expenditure on electricity infrastructure will, other things being equal, lead to reduced electricity prices to households and businesses. As a result, economic welfare and competitiveness are boosted. Despite this, individual companies (such as electricity networks) may be worse off, but this depends in part upon the nature of their business model and the regulatory regime that applies to them. Given the importance of reducing energy demand and greenhouse gas emissions, regulatory systems will need to evolve to enable network service providers to maintain their socially valuable infrastructure services, without there being an explicit or implicit assumption of continual energy demand growth.

7. Summary of Key Findings

This Report finds that:

Issue	Key Findings
Building stock	• The City of Sydney assumes that total floor area in the LGA will increase by some 29%, or just under 10 million sqm, between 2006 and 2030. • Key assumptions include more rapid growth in multi-unit dwellings (2.3% per year) than for other buildings, which average 0.8% year growth in total floor area.
Frozen efficiency	• If there were no improvements in energy efficiency over the 2006 to 2030 period, energy consumption in buildings in the City of Sydney local government area would be expected to increase by some 26% or 4.8 PJ. • Building-related greenhouse gas emissions, however, would be expected to grow more slowly, by just under 11% or 0.5 Mt CO_2-e, due to expected declines in the greenhouse gas intensity of electricity supply.
Business-as-usual	• In a business-as-usual scenario, where current policy measures and trends continue[82] but no new measures are introduced, energy consumption would be expected to fall by nearly over 9%, or nearly 1.7 PJ, over the 2006 to 2030 period – electricity consumption would fall by some 11.8%, while gas consumption would be expected to rise by 4.3%, reflecting greater efficiency gains in electrical end uses and some fuel switching towards gas, for example in water heating • This perhaps surprising result reflects a history of continuously falling demand from around 2008 (or 2009, depending on the sector), and falling per-customer demand since at least 2007. • This trends appears to be driven by a combination of factors including: – the energy-saving effects of the wide range of current and past energy efficiency measures at national, state and City of Sydney levels – the likely saturation of some energy service demands in buildings, such as residential cooling and hot water consumption – ongoing improvements in the efficiency of appliances and building services – the large rises in electricity prices, in particular, over the past five years, which: ▪ Justify, on economic grounds, higher investment in energy savings (and also renewable energy generation, such as solar PV systems)

---

[82] Note that we assume no carbon price in this study.

Issue	Key Findings
	▪ Appear to have induced greater awareness of energy costs and may have contributed to both energy efficiency investments and energy conservation behaviours – a growing awareness of the need to reduce greenhouse gas emissions. • Due to the expected fall in the greenhouse intensity of electricity supply, this reduction in energy consumption translates into larger reductions in building related greenhouse gas emissions: these could reach just over 1 Mt CO_2-e by 2030, representing a 21.5% reduction in 2006 building related emissions. • While numerous energy efficiency policy measures contribute to the energy savings, it appears that the largest savings are attributable to mandatory efficiency measures including the National Construction Code's energy performance requirements, minimum energy performance standards and labelling, and BASIX (for residential buildings).
Risks and trends	• The business-as-usual trends above are not guaranteed. • Key risks include: – weakening of policy settings, which could include a failure to lift regulatory settings in line with cost-effective opportunities to do so; – rising average temperatures due to anthropogenic climate change and the urban heat island effect, leading to additional cooling energy demand (noting that further research would be required to quantify the effect of these trends on energy consumption and greenhouse emissions); – compliance with mandatory building energy efficiency standards being less than assumed; – income growth and unanticipated new sources of energy demand.
Additional savings opportunities – residential sector	• There are significant cost effective energy and emissions savings opportunities, beyond business-as-usual, in the residential sector. • The quantity of energy and emissions savings depends upon the extent to which identified economic and policy opportunities are taken up, which in turn will be influenced by policy/program design choices in the *Energy Efficiency Master Plan*, as well as similar choices made by the NSW and Australian Governments, along with market trends. • The economic potential from more efficient new residential buildings, together with efficiency retrofits of existing buildings, could *total* 362 TJ and 179 kt CO_2-e by 2030 relative to 2006 with medium take-up (50% of the opportunity by 2030), or 658 TJ and 243 kt CO_2-e with rapid take-up (100% of the economic potential by 2030). These values include the BAU savings and the additional savings from realising the economic potential. • All the measures studied for the economic potential scenario are

Issue	Key Findings
	cost effective. - The policy potentials - savings available from defined policy measures - are even larger, at some 966 TJ and 305 kt CO_2-e by 2030 with medium take-up, relative to 2006; or 1,414 TJ and 404 kt CO_2-e by 2030 with rapid take-up. Again, these values include BAU savings as well as the policy potential. - The largest policy savings are attributable to mandatory disclosure and a building retrofit program, followed by higher efficiency standards for new builds (eg, via higher BASIX targets). However, retrofits and new builds are the most cost-effective options, while mandatory disclosure is marginally cost effective. - Voluntary ratings, for example under NABERS, appear to be the least cost effective option studied, primarily due to an expectation of a low take-up rate due to market barriers in this sector. - With rapid uptake of the policy potential, energy savings by 2030, relative to 2006, could reach nearly 45% in the residential sector, while residential greenhouse emissions would fall by some 59%.
Additional savings opportunities – commercial sector	- There are also significant savings opportunities in the commercial (non-residential) sector. - These are larger in absolute terms than those available in the residential sector, although smaller in proportionate terms, as commercial sector emissions are larger overall than residential. - With a medium take-up rate of the economic potential, energy savings of over 2,800 TJ, or over 18%, by 2030 relative to 2006. With a rapid uptake, energy savings could reach 4,100 TJ, or over 27% by 2030 relative to 2006. - Realising the policy potential in the commercial sector – modelled as a defined set of policy/program measures – could deliver some 2,700 TJ in energy savings by 2030, compared to 2006, with a medium rate of uptake. At a rapid rate of uptake, savings could reach 3,900 TJ, or close to 26%, relative to 2006. - In greenhouse terms, medium uptake of the policy potential would deliver some 1.2 Mt CO_2-e in emissions savings by 2030 relative to 2006. With rapid uptake, those savings could exceed 1.9 Mt CO_2-e.
Electricity Infrastructure savings	- The energy efficiency improvements modelled in this Report have the secondary benefit of reducing the need for electricity infrastructure investment. - The extent to which this occurs will vary depending on the nature of the efficiency investments made, and also reflect assumptions that may vary through time. Generally, energy savings in the residential sector have a greater impact, in reducing the need for supply infrastructure, than equivalent savings in the commercial sector due to the greater ‘peakiness’ of residential demand. - Depending upon the savings scenario, and taking a conservative approach in the light of the restrained outlook for electricity demand growth, realisation of the energy savings potential

Issue	Key Findings
	modelled in this Report would avoid the need for up to 211 MW of network capacity, with a present value (at 7% real discount rate) of avoided costs of up to $232 million.

Appendix A

References

ABCB (2006)	Australian Building Codes Board, *Regulation Impact Statement (RIS 2006-02), Proposal to Amend the Building Code of Australia to include Energy Efficiency Requirements for Class 5 to 9 Buildings*, Commonwealth of Australia, 2006.
ABCB (2010)	Australian Building Codes Board, *BCA 2010: Building Code of Australia: Class 2 to Class 9 Buildings: Volume 1*, Commonwealth of Australia, 2010.
AEMO (2012)	Australian Energy Markets Operator, *Economic Outlook Information Paper*, 2012.
API (2011)	Australian Planning Institute, *Building Better Returns: a study of the financial performance of green office buildings in Australia*, September 2011.
Argueso et al (2013)	Argueso et al. *Temperature response to future urbanisation and climate change*, Climate Dynamics, May 2013 (DOI 10.1007/s00382-013-1789-6)
BBP (2012)	Better Buildings Partnership, *Better Buildings Partnership: Interim Progress Report*, December 2012.
Building Science Corporation (2009)	Building Science Corporation, *Building Science Insights: The Perfect HVAC,* 2009.
Building Science Corporation (2012)	Building Science Corporation, *Building Science Digest 200: Low-Energy Commercial and Institutional Buildings*, 2014.
BREE (2013)	Bureau of Resource and Energy Economics, *Energy in Australia*, May 2013.
BZE (2013)	Beyond Zero Emissions, *Zero Carbon Australia: Buildings Plan*, 2013.
CIE (2009)	Centre for International Economics, *Proposal to revise energy efficiency requirements of the Building Code of Australia for commercial buildings (RIS 2009-04)*, December 2009.
City of Sydney (2007)	City of Sydney, *Baseline Indicators Working Paper: Sustainable Sydney 2030*, June 2007.
City of Sydney (2011)	Sustainable Sydney 2030, http://www.sydney2030.com.au/
City of Sydney (2012)	City of Sydney, *DCP 2012 – December 2012*, Section 3 General Provisions, available from http://www.cityofsydney.nsw.gov.au/__data/assets/pdf_file/0020/128018/4_WEB_Section3_DCP2012_130213.pdf
ClimateWorks (2010)	ClimateWorks Australia, *Australian Carbon Trust Report: Commercial buildings emissions reduction opportunities*, December 2010.
ClimateWorks (2011)	ClimateWorks Australia, *Low Carbon Growth Plan for Australia: retail sector summary report*, June 2011.
Clubs NSW (date?)	Clubs NSW, *10 Ways to Green Your Club*, date unclear, available from http://www.environment.nsw.gov.au/resources/sustainbus/2006_10ways.pdf
COAG (2012)	Council of Australian Governments, Baseline Energy Consumption and Greenhouse Gas Emissions in Commercial Buildings in Australia, Part 1 – Report, November 2012, prepared by **pitt&sherry**, available from http://ee.ret.gov.au/energy-efficiency/non-residential-buildings/commercial-buildings-baseline-study
Colliers (2013)	Colliers International, Research and Forecast Report: Sydney CBD Office: Second Half 2012), available from http://www.colliers.com.au/~/media/Files/Corporate/Research/Office/Sydney%20CBD%20Office%20RFR%20-%20Second%20Half%202012b.ashx
Deloitte (2012)	Deloitte/Energy Supply Association of Australia, *Analysis of initiatives to lower peak demand: Final Report*, April 2012.
DECC (2012)	UK Department of Energy and Climate Change, *Community Energy: Call for Evidence*, Case Study 20, June 2012.

DCCEE (2013)	Department of Climate Change and Energy Efficiency, *CBD First Year of Mandatory Disclosure – Statistical Overview*, 2013.
EC (DG Energy) 2013	European Commission (DG Energy). Energy performance certificates in buildings and their impact on transaction prices and rents in selected EU countries: final report. April 2013. Available at: http://ec.europa.eu/energy/efficiency/buildings/doc/20130619-energy_performance_certificates_in_buildings.pdf
EEX (2014)	eex.gov.au (a joint Australian, state and territory government website), Lighting page, accessed at http://eex.gov.au/technologies/lighting/ on 26/3/2014.
Energy Australia (2010)	Energy Australia, *BASIX Monitoring Report: electricity consumption for 2007-98 and 2008-09*, June 2010, available at www.basix.nsw.gov.au
IEA (2012a)	International Energy Agency, Redrawing the Energy-Climate Map, June 2012.
IEA (2012b)	International Energy Agency, *World Energy Outlook*, 2012.
IEA (2013)	International Energy Agency, *Technology Roadmap – Energy efficient building envelopes,* 2013
IEA (2014)	International Energy Agency, Transitions to Sustainable Buildings (presentation at http://www.iea.org/etp/buildings/), accessed 26/3/2014.
Joosten, S. et al (2006)	Joosten, Strom, Boonstra, 2006, *Energy Saving Potential*, European Commission – Intelligent Energy Europe Program.
Kohlenbach and Dennis (2010)	Kohlenbach and Dennis, Solar Cooling in Australia: The Future of Air Conditioning?. See: http://www.airah.org.au/imis15_prod/Content_Files/EcoLibrium/2010/December/2010_12_01.pdf
LBNL (2013)	Lawrence Berkeley National Laboratory, 2013, 'Saving 70 Percent of More of Energy Use in Your Home', accessed at http://eetd.lbl.gov/news/article/48634/saving-70-percent-or-more-of-energy-use-in-your-home-berkeley-lab-scientists-stud
NABERS (2010)	*NABERS energy for office Benchmarking Factors*, 21 October 2010, available from http://www.nabers.gov.au/public/WebPages/ContentStandard.aspx?module=21&template=3&include=Energy.htm
NERA (2010)	NERA Economic Consulting, *BASIX Post-Implementation Cost Benefit Analysis*, August 2010.
NSW Govt Planning (2011a)	NSW Department of Planning, *2006-09 Multi-Dwelling Outcomes, BASIX Ongoing Monitoring Program*, January 2011, available at www.basix.nsw.gov.au
NSW Govt Planning (2011b)	NSW Department of Planning, *BASIX Five Year Outcomes Summary*, February 2011, available at www.basix.nsw.gov.au
NSW Govt Planning (2009?)	NSW Department of Planning, *Single Dwelling Outcome 05 – 08 BASIX Ongoing Monitoring Program,* 2009(?), available at www.basix.nsw.gov.au
OEH (2012a)	Office of Environment and Heritage 2012, *Energy Management Guide for Tenants. Accessed at http://www.nabers.gov.au/public/WebPages/DocumentHandler.ashx?docType=3&id=66&attId=0*
OEH (2012b)	NSW Office of Environment & Heritage, *Energy Saver: Energy efficient lighting: Technology report*, 2012.
OEH (2013)	NSW Office of Environment and Heritage, NSW Energy Efficiency Action Plan, August 2013, available from www.environment.nsw.gov.au

OEH (2014)	NSW Office of Environment and Heritage, 'Choosing a hot water system' webpage, accessed at http://www.environment.nsw.gov.au/energy/hwschoose.htm
pitt&sherry (2012a)	**pitt&sherry**, The Pathway to 2020 for Low-Energy, Low-Carbon Buildings in Australia: cost benefit analysis, available from http://ee.ret.gov.au/energy-efficiency/strategies-and-initiatives/national-construction-code/pathway-2020-increased-stringency-new-building-energy-efficiency-standards-benefit-cost-analysis
pitt&sherry (2013)	**pitt&sherry**, *Quantitative Assessment of Energy Savings from Building Energy Efficiency Measures*, prepared for the Department of Climate Change & Energy Efficiency, April 2013.
RET (2011)	Commonwealth Department of Resources, Energy & Tourism, *Energy Efficiency Opportunities Program: continuing opportunities*, Commonwealth of Australia, 2011.
Schuwer et al (2012)	Schuwer et al, 2012, *The Strategic Approach to improving energy efficiency in buildings: New Residential buildings – Ultra Low Energy Buildings*, Wuppertal Institute for Climate, Environment and Energy.
Stern, N. (2006)	Stern, N. Stern Review on the Economics of Climate Change, HM Treasury, London, 2006.
US EPA (2008)	United States Environmental Protection Agency, Sector Collaborative on Energy Efficiency Accomplishments and Next Steps, 2008, available at www.epa.gov/eeactionplan
USEPA (2010)	United States Environmental Protection Agency, *Untapped potential of Commercial Buildings: Energy Use and Emissions,* accessed via the U.S Energy Star website. See http://www.energystar.gov/buildings/tools-and-resources/untapped-potential-commercial-buildings-energy-use-and-emissions
Wilkenfeld (2009)	Wilkenfeld, G & Associates, *Prevention is cheaper than cure – avoiding carbon emissions through energy efficiency*, January 2009.

Addenda No. 1

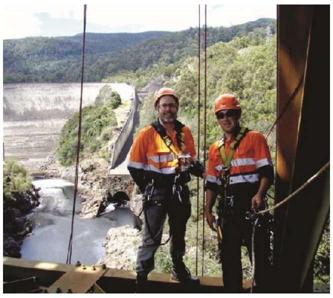
City of Sydney Energy Efficiency Master Plan Foundation Report

ATTACHMENT B

City of Sydney Energy Efficiency Master Plan Foundation Report – Addendum

transport | community | industrial & mining | carbon & energy

pitt&sherry



Prepared for:	City of Sydney
Client representative:	Nik Midlam, Manager Carbon Strategy
Date:	23 January 2015 Rev02 – Final Report

sustainable*thinking*®

Prepared by: ……… ……………. Date: 23 January 2015
P. Harrington

Reviewed by: …… ………… Date: 23 January 2015
P. McLeod

Authorised by: ……………… …… Date: 23 January 2015
P. Harrington

Revision History					
Rev No.	Description	Prepared by	Reviewed by	Authorised by	Date
01	Draft	PH	PMcL	PH	13/1/15
02	Final	PH	PMcL	PH	23/1/15

Table of Contents

1. Background

The City of Sydney commissioned pitt&sherry in 2013-14 to produce an *Energy Efficiency Master Plan Foundation Report*, to underpin the City's development of an *Energy Efficiency Master Plan*. Both documents are expected to be published in February or March 2015.

In November 2014 the City requested a review of its draft Master Plan and its amendments to the BEEMS model (Building Energy Efficiency Model for Sydney) that we created for the *Foundation Report*. This new project included reviewing financial assumptions and results with the City's Commercial Manager Green Infrastructure and reviewing figures and charts derived from BEEMS. In addition, the City requested additional analyses as follows:

- Extract (or create) the data required to separate 'new buildings' from 'existing buildings and refurbishments' for the 2030 energy and emissions scenarios;
- Quantify (or qualify) the role of behaviour change in the policy scenario (given that the savings are greater than the cost effective technology scenario);
- Develop 'best practice' intensity targets for each sector (based on at least achieving the overall policy target) for 2015 and 2030;
- Estimate additional energy and greenhouse gas savings that would arise in 2030 if new buildings were constructed to best practice standards;
- Remodel the NSW Energy Savings Scheme based on the Energy Efficiency Action Plan;
- Model a new NABERS measure that could apply to new builds of offices, hotels and shopping centre developments, and remove the existing 'NABERS voluntary' from the savings estimates for both residential and commercial buildings;
- Ensure that the overall model is rebalanced and internally consistent; and
- Comment on the concepts of 'cost effectiveness' and also on interim targets, including in the light of outcomes achieved by the Better Buildings Partnership.

The review aspects of this project were completed in December 2014. This Addendum addresses the additional analyses noted above. It is accompanied by an updated version 1.5 of BEEMS, which includes the quantitative analysis and derivation of tables and figures presented in this Addendum.

2. New/Existing Buildings Split

2.1 Approach

The City was interested to understand the respective contributions towards its overall greenhouse gas abatement target – of 70% reduction in greenhouse gas emissions relative to a 2006 baseline – of those buildings completed prior to FY2015 (that is, prior to 1 July 2014) and those completed subsequently. This will help inform the balance of policy measures addressing new buildings as compared to those seeking to influence the operation, maintenance and refurbishment of existing buildings.

BEEMS was constructed with a 2006 baseline, in order to align with the City's targets. As a brief recap, BEEMS models the expected evolution of the building stock in Sydney to 2030, based on the City's own expectations of growth in floor area by building type, and drawing extensively on the City's *Floorspace and Employment Survey* (FES) and related 3D model of building space. It then models the expected evolution of energy use, related greenhouse gas emissions and peak demand to 2030, by fuel and end use, for each of twenty building types/sub-types and for multiple scenarios, including frozen efficiency, business as usual (continuation of existing policies – with each explicitly modelled), a range of technical efficiency upgrades for new and existing buildings, and a wide range of new possible policy measures (again, each separately modelled for each building sub-type). The model is calibrated against actual energy consumption data from Ausgrid and Jemena, and it accurately tracks the (unprecedented) decline in energy demand and related emissions that we have witnessed over the period since 2006, which has occurred notwithstanding continued growth in economic activity and floor area in the City.

Given the 2006 baseline for BEEMS, retrofitting an analysis of savings attributable to pre-2015 and post 2014 stock required significant new modelling. The key steps in our methodology are described here. First, the building stock model for each building subtype was modified to include annual and cumulative floor area of 'new builds' from FY2015 onwards, with a residual being the 'pre-2015' floor area. The new build floor area each year is modelled as the net increase in floor area (for each building type), plus an allowance for demolition/rebuild (assumed to average 1% of the stock annually). Major refurbishments of the pre-2015 stock (and related energy savings) are attributed to the pre-2015 stock, regardless of the year in which they occur. Buildings built post-2014 are not likely to undergo major refurbishments ahead of 2030.

A second step was to allocate the relevant policy-induced energy savings, from FY2015 onwards, to the two building cohorts. This was done firstly for the 'business as usual' or 'existing policy measures' scenario, and then a second time for the 'policy measures – rapid uptake' or 'new policy measures' scenario. The allocation methodology varied according to the measure and building type, but two approaches dominate. For measures such as new building codes, these are assumed to apply proportionately to both cohorts (as major refurbishments of the existing stock are required to meet current Code standards – even if, as noted in the primary Report, there is doubt about the extent to which this occurs in reality). Therefore the unit savings were simply applied to each cohort. Other measures, such as minimum energy performance standards (MEPS) apply equally to existing and new buildings (as they primarily apply to energy using equipment), therefore the modelled energy savings were simply apportioned according to the shares of the two cohorts in each year. In each case, the annual electricity and gas consumption of each cohort is then calculated, summed for total energy, and then expressed as greenhouse gas emissions. Finally, the total energy use is divided into the relevant floor area of each cohort to reveal the implied average energy intensity of each cohort in each year, from 2015 to 2030. The results of this analysis, including summary tables, are carried into a new tab in BEEMS marked 'pre and post 2015'.

2.2 Results

Table 2.1 below summarises the results in the BAU or existing policies scenario. This indicates that by 2030, the pre-2015 cohort would be expected to account for 74% of total (building related) energy and 75% of emissions; while the post-2014 cohort would account for 26% of energy and 25% of greenhouse gas emissions, in this scenario. Note that shares vary by individual building class. The slight differences in energy and greenhouse emission shares for the two cohorts reflects minor differences in the incidence of energy savings measures, which in turn affect the fuel mix and hence emissions intensity.

The above figures can be compared with the shares of the 2030 total floor area that each cohort accounts for. The post-2014 cohort reaches between 16% of the 2030 total for detached dwellings (where no net growth in floor area is assumed, and therefore the new builds are only assumed to be those replacing demolitions) and as high as 42% for multi-unit dwellings and offices (where the floor area is assumed to grow more rapidly). The new buildings account for a lower share of total energy use than their share of the floor area, as their energy intensity is lower – thanks to the National Construction Code and other measures that impact on new buildings.

Table 2.1: Pre-2015/Post-2014 Building Energy Use and Greenhouse Emissions: Business as Usual Scenario

BAU Scenario	2006		Existing (pre 2015) Buildings in 2030			New (post 2014) Buildings in 2030			Total energy in 2030 (TJ)	Total GHG Emissions in 2030 (t CO2-e)
	Total energy use (TJ)	Average energy intensity (MJ/m2.a)	Total energy use (TJ)	Average energy intensity in 2030 (MJ/m2.a)	GHG Emissions (t CO2-e)	Total energy use (TJ)	Average energy intensity in 2030 (MJ/m2.a)	GHG Emissions (t CO2-e)		
A Grade Offices	2,462	825	1,380	658	338,266	613	403	149,517	1,993	487,783
Other Offices	6,197	825	4,120	620	1,009,712	1,030	420	249,896	5,150	1,259,607
Warehouses	448	337	318	270	68,640	81	186	16,677	399	85,317
Cold storage	212	6,147	138	4,526	35,582	51	4,526	13,115	189	48,697
Above ground carparks	169	137	117	107	30,077	30	75	7,858	147	37,935
Below ground carparks	1,152	382	755	283	194,899	247	251	63,691	1,002	258,590
Pubs & clubs	411	637	277	485	52,917	81	383	14,749	358	67,666
Hotels/motels	1,404	1,496	1,015	1,222	186,978	289	945	49,080	1,304	236,057
Other accommodation	298	650	202	497	35,978	47	313	7,114	249	43,092
Major shopping centres	441	1,645	324	1,363	72,682	95	1,082	20,823	418	93,505
Smaller shopping centres	626	2,334	475	2,001	107,318	151	1,724	33,612	626	140,930
Retail strips	403	322	297	268	67,010	87	214	19,268	385	86,278
Industrial	667	576	457	446	95,426	113	299	22,000	569	117,425
Healthcare	256	1,597	188	1,322	27,453	50	948	5,378	237	32,831
Schools	38	167	28	138	6,349	8	111	1,849	36	8,198
Tertiary	125	1,059	91	873	20,741	27	701	6,053	118	26,795
Detached dwellings	62	190	37	136	6,727	7	136	1,281	44	8,009
Semi-detached dwellings	697	253	425	180	74,411	108	180	18,928	533	93,339
Low-mid rise MUDs	760	262	493	177	90,648	353	177	64,996	846	155,644
High rise MUDS	1,643	379	1,155	278	213,193	828	278	152,862	1,983	366,055
Totals	18,473		12,291		2,735,006	4,296		918,748	16,587	3,653,754

Source: pitt&sherry

Turning to the ‘Existing and New Policy Measures’ scenario – which adds the modelled impact of the range of modelled new measures to the above savings – the results are set out in Table 2.2 below. In this scenario, total energy use and greenhouse gas emissions are around 24% lower in 2030 than for the BAU scenario, due to the additional savings measures (noting that total energy use in 2030 is some 32% lower than it was in 2006 in this scenario).

Energy use and greenhouse gas emissions in 2030 are lower for both cohorts of buildings when compared with the BAU scenario. However, the *share* of energy use in 2030 of the post-2014 cohort is slightly higher in this scenario than it was in the BAU scenario. Table 2.2 shows that the post-2014 cohort is expected to use around 29% of total energy in 2030 in this scenario, while the pre-2015 cohort is expected to account for around 71%. Shares again vary by building class, depending upon the relative balance of policy measures affecting new and existing buildings in each class.

The higher *share* of total energy use that is attributable to the post-2014 cohort in this scenario, when compared with BAU – stressing again that total energy use is lower in both cohorts in this scenario than in BAU – occurs because we are modelling a faster *rate of improvement* in energy efficiency in the pre-2015 cohort than in the post-2014 cohort. There are two reasons for this. First, there are simply more energy savings measures impacting on the pre-2015 cohort, and in total, they deliver more energy savings. Second, there are more savings to be made, and more cost effectively, in the existing building stock than in the new building stock, because the older buildings are using more energy (in total and per square metre).

Table 2.2: Pre-2015/Post-2014 Building Energy Use and Greenhouse Emissions: New and Existing Measures Scenario

Existing and New Policies	2006		Existing (pre 2015) Buildings in 2030			New (post 2014) Buildings in 2030			Total energy in 2030 (TJ)	Total GHG Emissions in 2030 (t CO2-e)
	Total energy use (TJ)	Average energy intensity (MJ/m2.a)	Total energy use (TJ)	Average energy intensity in 2030 (MJ/m2.a)	GHG Emissions (t CO2-e)	Total energy use (TJ)	Average energy intensity in 2030 (MJ/m2.a)	GHG Emissions (t CO2-e)		
A Grade Offices	2,462	825	988	471	244,114	586	386	143,020	1,574	387,135
Other Offices	6,197	825	3,132	471	772,736	963	393	233,545	4,095	1,006,281
Warehouses	448	337	245	208	52,544	77	178	15,898	322	68,442
Cold storage	212	6,147	125	4,087	32,130	50	4,433	12,846	174	44,976
Above ground carparks	169	137	83	76	21,445	30	73	7,624	113	29,069
Below ground carparks	1,152	382	565	212	145,813	236	240	60,825	801	206,639
Pubs & clubs	411	637	224	391	42,432	77	368	14,152	301	56,584
Hotels/motels	1,404	1,496	804	968	147,347	274	895	46,228	1,078	193,575
Other accommodation	298	650	163	403	28,548	44	297	6,692	208	35,239
Major shopping centres	441	1,645	221	932	49,687	89	1,017	19,555	310	69,242
Smaller shopping centres	626	2,334	329	1,385	74,217	143	1,630	31,754	471	105,970
Retail strips	403	322	207	187	46,761	84	207	18,586	292	65,347
Industrial	667	576	368	360	76,377	108	285	20,909	476	97,286
Healthcare	256	1,597	159	1,123	22,822	48	909	5,064	207	27,886
Schools	38	167	20	100	4,626	8	108	1,802	29	6,427
Tertiary	125	1,059	76	733	17,513	26	676	5,837	102	23,350
Detached dwellings	62	190	30	111	5,024	7	127	1,193	37	6,217
Semi-detached dwellings	697	253	366	155	59,396	101	169	17,572	467	76,967
Low-mid rise MUDs	760	262	236	85	35,664	216	108	38,319	452	73,983
High rise MUDS	1,643	379	591	142	95,671	546	183	97,974	1,137	193,645
Totals	18,473		8,933		1,974,865	3,712		799,393	12,645.5	2,774,258

Source: pitt&sherry

3. The Role of Behaviour Change in Policy vs Technical Scenarios

It is noted in the main Foundation Report that the energy and greenhouse gas savings modelled for the 'policy potential' scenario (referred to as 'existing and new policies' in the EEMP) are slightly greater than for the ‘economic potential’ scenario (referred to as ‘technical measures’ in the EEMP). This difference is partly random in nature – a function of the number of technical vs policy measures that are assumed to apply in the two scenarios. However there are also behavioural factors that contribute to diverging results between technical and policy scenarios, as set out below.

The technical measures in BEEMS (such as lighting upgrades or improved HVAC controls) are modelled on the basis of incremental costs and energy savings observed in the real world. Generally this data is sourced from Exergy Australia Pty Ltd (now Energy Action), who partnered with pitt&sherry in the Foundation Report. It is based on actual investments that were managed by Exergy and its clients, or else very detailed audits. As a result, the vast majority of measures (and all measures assumed to be implemented) are known to be cost effective – noting that some measures, such as lift upgrades, were discarded due to poor economics. Also we note that even within a given class of technical measures, say lighting upgrades, the cost effectiveness varies from building to building due to site-specific factors.

Nevertheless, the total potential for *take-up* or implementation of the modelled technical measures is therefore not limited by financial considerations (poor investment performance), but rather by practical or behavioural considerations. The practical considerations include the extent to which the building stock has already been retrofitted with these measures, and also whether the measure is relevant for each building type. For example, HVAC upgrades cannot be applied to all buildings, as some have no centralised HVAC systems to upgrade, while others may be been upgraded recently. Such take up assumptions are explicitly documented and modelled in BEEMS for every building sub-type and every policy measure.

However, behavioural considerations also affect the rate of take-up. Simply because a technical energy efficiency measure is cost effective (and practical) does *not* mean it will be implemented in any given time period, or indeed at all. If it did, there would be no need for energy efficiency policies! The behavioural factors that impact on the rate of take up include at least the following:

- Awareness – does the building owner/manager know about this savings opportunity?
- Relevant information – even if they are aware of the opportunity in general terms, do they have the information that *they* consider relevant and necessary to making an investment decision? The nature of this information will vary from person to person.
- Access to capital – cost effective investments are still investments – they require capital to be invested upfront in order to realise a stream of savings over time. Strata-titled buildings, for example, typically have greater difficulty raising investment capital (and making investment decisions) than owner-occupied or corporately-owned buildings.
- Time preference – individuals vary in what is known as their ‘time preference’, or the willingness to wait. If you have a preference (or need) to utilise available capital for another purpose today, then you may be willing to forego the future benefit associated with energy savings. By contrast, ‘patient investors’ may be willing to forego consumption now, preferring to invest capital and to reap greater benefits down the track.
- Culture and values – different people and organisations have different cultures and values that can affect their willingness to invest in energy efficiency measures. Those with strong ‘extrinsic’ or money-based values may well invest (subject to the points above about access to capital and time preference) primarily because it is cost-effective to do so, or – strictly – more cost-effective than other investment opportunities open to them at the time. Those with strong ‘intrinsic’ values – for example, those aware of and concerned about the damage caused by greenhouse gas emissions associated with energy use – might invest in energy efficiency even it is *not* cost effective – again, subject to the other factors above. In-between these two extremes, personal and organisational cultures vary widely. Many will simply not have a focus on making such investments, regardless of their economic or environmental credentials: they may be more

focused on alternative uses of their time and money which *they* value more highly than energy efficiency.

A final point to appreciate in this context is that policy measures create specific (and differing) incentives that affect take-up and investment behaviours. Policy measures may change the financial equation (eg, via a subsidy) or raise awareness or provide specific information (via information based measures). Depending upon culture and values, as noted above, even voluntary measures that simply draw attention to the financial and/or intrinsic benefits of energy efficiency can affect their rate of take-up.

A further class of policy measures is those that are applied mandatorily – like building codes, MEPS and mandatory disclosure of building energy efficiency (noting that the latter schemes only mandate the disclosure, not any particular *response* to the disclosure). These measures can be thought of as having greater 'stringency', or as exercising greater 'leverage' over decisions, than voluntary measures. In effect, they involve an element of compulsion justified on public policy grounds (such as reducing greenhouse gas emissions for example). Whatever the reason, the effect of this greater stringency or leverage is to generate a faster rate of uptake of technical opportunities than would occur in the absence of the policy measure or measures. In the Foundation Report, we do model some mandatory measures in the 'policy potential' or 'new and existing measures' scenario, and the additional stringency or leverage of these measures leads to greater energy savings being modelled than for the technical measures without such leverage.

As a possible qualifier on the above, we note that mandatory measures (such as building codes) will only achieve the high rate of take-up of actual energy efficiency savings that they are assumed to do if the measures are being effectively implemented and policed, with a high rate of compliance. Since the Foundation Report was completed, pitt&sherry has completed a project known as the National Energy Efficient Buildings Project (NEEBP)[1] which documents a widespread view around the building industry, regulators and planning authorities that compliance with the energy performance requirements in the National Construction Code may be quite poor. In such a case, the actual leverage of such measures may be over-estimated. However, we have not yet been able to quantify the extent of any such under-compliance.

4. Best Practice Energy Intensity Targets

4.1 Definition of Terms

'Best practice'

A current best practice 'benchmark' can be defined with reference to an actual building (in Australia) with lowest known energy intensity, when measured in an objective manner, using metrics such as energy consumption per square metre of building floor area. However, determining this value in practice is challenging, partly because the best practice benchmark is continually being reset as new projects and technologies roll out around Australia and/or the world. Also, actual energy performance results for some buildings may not be made public, as some companies consider such information to be commercially sensitive. Therefore it is difficult to be certain what the current best practice benchmark actually is at any given point in time.

Projecting best practice benchmarks into the future is even more fraught, as many factors (here and overseas) will affect the rate at which performance benchmarks improve, such as energy prices, product

---

[1] Available from https://www.sa.gov.au/topics/water-energy-and-environment/energy/government-energy-efficiency-initiatives/national-energy-efficient-building-project

and factor prices, investment rates in R&D, resulting technological break-throughs, international trade in products and/or designs, and government policies that affect each of these.

'Energy intensity' or 'greenhouse intensity' as a target metric/benchmark?

Many high performance buildings do not separately identify their energy *consumption* intensity from their generation of renewable energy on-site. Rather they may simply report a net or *purchased* energy intensity value, or a greenhouse intensity value. The underlying energy consumption intensity of the building value may not be available or even known by the building owners/managers.

Both NABERS and Green Star use greenhouse gas intensity metrics, rather than energy intensity, and indeed the relevant objective of the National Construction Code is 'to reduce greenhouse gas emissions', not to reduce energy consumption. While it is possible to 'back calculate' energy intensity from NABERS or Green Star sources, such calculations are increasingly being complicated by a) embedded PV or wind (which, being on the customer's side of the meter, simply shows up as a reduction in demand for purchased energy, indistinguishable from energy efficiency); and b) co- and tri-generation, which bring their own complications. In particular, in high performance buildings that target low carbon intensity (eg, 6 stars under Green Star) by using co- or tri-generation systems, the *energy* intensity of such buildings may be *higher* than similar 4 or 5 star buildings (that do not use co- or tri-generation). However, the *greenhouse* intensity of the 6 star building will be lower than for the 4 or 5 star building. This perverse effect (from an energy intensity perspective) largely occurs because the conversion losses associated with converting gas to electricity via a co- or trigeneration unit onsite are counted as part of the energy intensity equation for such a building, while a building that instead imports purchased electricity from the grid is not required to count the losses of the primary fuel used to generate that electricity, simply because they occur off-site. We documented this effect in *Pathway to 2020*, cited above, and it is also clearly evident in data from the Green Building Council of Australia[2].

In short, it is becoming increasingly artificial to draw a sharp line between energy efficiency and renewable energy technologies in the buildings space. Solar hot water systems can be regarded as both as an energy efficiency and a renewable energy technology, for example. Building owners, managers and users are likely to care little about the distinction – they are more likely to focus on the outcome delivered and its cost-effectiveness. Our focus in this project is restricted to energy *consumption* efficiency, and therefore we effectively screen out renewable energy technologies, at least to the extent that it is possible to recognise their presence in the benchmark data.

'Zero net energy/carbon'

Specifically in the case of building energy performance, and as detailed in pitt&sherry (2012) inter alia[3], very large energy savings relative to current minimum Code requirements are already in evidence today – including all the way down to or beyond 'zero net energy' or 'zero net carbon' – let alone achieving these levels in 2030. While we do not rely on such terms in this Addendum or the Foundation Report, 'zero energy' or 'net zero energy' buildings are generally defined as buildings that generate at least as much energy on site as they consume over a typical year. 'Zero carbon' or 'net zero carbon' may simply mean the same thing, but with energy units converted to greenhouse units, but more often also estimate the carbon emissions embodied in the building's construction materials and construction process, amortised

---

[2] Green Building Council of Australia, The Value of Green Star – a Decade of Environmental Benefits, May 2013, available from http://www.gbca.org.au/uploads/194/34754/The_Value_of_Green_Star_A_Decade_of_Environmental_Benefits.pdf

[3] pitt&sherry, The Pathway to 2020 for Increased Stringency in New Building Energy Efficiency Standards: Benefit Cost Analysis, January 2012, published by the Department of Industry and available from http://www.industry.gov.au/Energy/Energy-information/Documents/pathwayto2020newbuildingenergyefficiencystandards.pdf

over the life of the building, with the requirement at least as much zero carbon energy is produced onsite to offset both the energy consumption (in a typical year) plus the amortised carbon emissions embodied in the building. ‘Carbon positive’ or ‘beyond zero emissions’ buildings are those that, in an average year, generate a *surplus* of carbon free energy relative to both their own energy consumption and their amortised embodied emissions.

Grocon’s *Pixel* provides a celebrated example of a ‘carbon positive’ office building in Australia[4]. Of course, such buildings rely on distributed renewable energy generation systems, in addition to energy efficient designs and technologies. While such renewable energy technologies fall outside the scope of the City of Sydney’s *Energy Efficiency Master Plan*, in practice such technologies are more and more available to building designers, are increasingly cost effective, and are increasingly being selected where very low (purchased) energy intensity or carbon intensity outcomes are targeted.

‘Target’ vs ‘Benchmark’

The discussion above relates to ‘benchmarks’, which can be considered as examples of actual buildings that are exemplary performers when measured in an objective manner, using metrics such as energy consumption or greenhouse gas emissions per square metre of building floor area. We noted earlier that a current best practice benchmark might be considered to be the building in Australia with lowest measured energy intensity, for example. However, such an exemplary building from a technical point of view (as in the case of Pixel, referred to above) may not be cost effective (see below for a definition of this term) at the time it is built. Grocon have reported (personal communication) that they estimate that Pixel cost around 13% more per square metre than current Code requirements – although they expected that value to fall very rapidly. In this sense, the performance benchmark of Pixel could only be considered to be a reasonable “target” if a) cost effectiveness was not considered important for setting targets, or b) it was firmly expected that such a benchmark would be able to be achieved cost effectively in the near future.

By contrast with ‘benchmarks’, ‘targets’ are generally set with some eye to the practicality of their achievement, both in technical and economic terms. Put another way, a target that is not cost effective is only likely to be met if some coercion is used, such as mandatory (and effective) policy measures, or else by chance (for example if technology costs fall unexpectedly).

‘Cost effective’

In the Foundation Report and in this Addendum, the term ‘cost effective’ is used on a regular basis. We note that there is more than one definition of this term. However, we use this term in a precise manner. A cost effective investment or policy is one where the present value of the stream of future benefits from that investment or policy, discounted at the rate of 7% real per annum, exceeds the present value of the stream of costs associated with the same investment or policy over time, discounted at the same real discount rate.

In principle, and in what is known as *social* benefit cost analysis, all classes of benefits and costs should be taken into account to the extent feasible, and we attempt to account for at least major classes. However, in this project, we place no financial value on avoided greenhouse gas emissions or other pollutants, for example. In this sense, the net societal worth of the investments or policy measures may be under-estimated.

Mathematically, ‘cost effective’ thus defined is equivalent to a benefit cost ratio (BCR) of at least 1. When expressed as an abatement cost (as is done in the Foundation Report), ‘cost effective’ as thus

---

[4] See http://www.studio505.com.au/work/project/pixel/8 for example.

defined is mathematically equivalent to ‘no more than $0/tonne CO_2-e’. Investments or policies are that are ‘not cost effective’ will have a present value of costs that exceed the present value of benefits; a benefit cost ratio less than 1; and a positive abatement cost greater than $0/tonne CO_2-e. We note that when Australia had a carbon pricing regime, an abatement cost lower than the then current carbon price would also be considered to be cost effective, even if greater than zero, as the ‘next best alternative’ may have been to pay the carbon price. Arguably the same calculation should apply today – using a ‘shadow’ carbon pricing benchmark to ensure that investment decisions are optimal. However, in this Addendum and in the Foundation Report, no carbon price or shadow price is assumed.

4.2 Approach

Noting the above, our approach to this task has been as follows.

For the 2015 best practice benchmark, we have applied the reported improvements in Green Star buildings relative to the average stock (in this case, interpreted as the average energy intensity of Sydney’s buildings in 2006. We note that these benchmarks are expressed as percentage reductions in greenhouse, and not energy, intensity. These values will only diverge over longer periods of time, assuming that the greenhouse intensity of electricity is falling (as has been the case in Australia until around July 2014). We note that Green Star percentage improvements are also cited on the basis of ‘relative to current minimum Code compliance’. These could be used for benchmark-setting purposes. However, noting that there is currently some doubt as to the extent to which energy performance requirements under the National Construction Code are actually being met, we have chosen to not rely on these estimates. That said, in some cases that we tested, the results of the two approaches were virtually identical.

Further, in some cases, NABERS 6 star benchmarks are available and could be considered as relevant ‘2015 best practice’ benchmarks. Energy intensity values of offices, hotels, shopping centres can in principle be established using ‘reverse energy calculators’ for these building types, available on the NABERS website. However, the hotels reverse energy calculator is not currently working, and the shopping centre calculator is for base buildings only. In practice, we have relied in this Addendum on the NABERS 6 star performance benchmark (for a typical building in Sydney) for ‘other grade’ offices only. All other 2015 benchmarks are derived from Green Star, as further described below. In passing we note that the NABERS 6 star calculated energy intensity value (336 MJ/m_2.a) is higher than the equivalent benchmark from Green Star (297 MJ/m_2.a), but broadly comparable. The latter value is not specific to any particular climate zone, while the NABERS value relates specifically to Sydney, and this could account for the difference.

In particular, where the Green Building Council of Australia report building-type-specific results from Green Star (as built), we have used these results for those building classes, as described above. We note that the reported values are *averages* of the Green Star stock, relative to the rest of the building stock, and not ‘best in class’ intensity values. In this sense, the 2015 best practice benchmark values below are conservative – higher savings in % terms, or lower energy intensity values, will be achieved by exemplary buildings.

However, in the cases of hotels/motels, other accommodation, health buildings, schools, cool-stores and warehouses/storage buildings, there are no building-specific results published by the Green Building Council of Australia at this time. Therefore we have applied the ‘all tools average’ savings to these building types. The percentage reductions, relative to the existing building stock, vary between 56% and 76%. However, we have arbitrarily down-graded cool stores to 20% based on a) the energy intensity of these buildings and b) their relatively simple energy using design and correspondingly *relatively* limited energy efficiency opportunities.

For the 2030 best practice benchmarks, and recalling the previous discussion regarding the uncertainties associated with such estimates, we have generally applied a further 25% reduction in energy intensity to the 2015 best practice benchmark. This approach yields percentage improvements by 2030 relative to the existing (2006) building stock of generally between 67% and 82%. As noted, since zero net energy (or 100% energy savings) is already available today – albeit with the aid of renewable energy technologies – and that 2030 is still 15 years away, then such values may also be considered conservative. They are comparable with values cited in the Foundation Report from a range of sources, such as the International Energy Agency but also our previously cited *Pathway to 2020* report.

We diverge from this general approach in two specific cases: cool stores (where as noted we assume a less stringent 2015 benchmark than for other buildings, but then apply a 25% reduction to that value to generate the 2030 benchmark) and schools (where we apply a lower, 10%, reduction to the 2015 best practice benchmark in 2030, on largely the opposite grounds from that of cool-stores; that is, that their energy intensity is already, on average, very low – in part due to the absence of centralised HVAC systems as a rule in Sydney – and therefore the benchmark approaches zero when large percentage reductions are applied to an already low value.

4.3 Results

The results of this analysis have been added to the bottom of the Summary tab in BEEMS, and are captured in Table 4.1 below. Stepping through the results by column:

- The first column of results simply recalls the 2006 average energy intensity values by building type/sub-type, as reported in the Foundation Report. Note that they represent the average energy intensities of *all* buildings of that type standing in 2006, whereas the later columns refer to the average energy efficiency of, or benchmark value for, *new* buildings. Therefore the two are not strictly comparable in this sense. However, this data is presented for reference, as 2006 is the baseline year for City of Sydney's overall greenhouse emissions target.
- The second column (2015 new build average energy intensity) shows that average new building energy intensity in 2015, deriving from the analysis presented in Section 2.2 above. These values result from the application of existing policy measures (and new ones from 2015 through to 2030) to the frozen efficiency values, as described in detail in the Foundation Report. As noted above, these values rely in particular on estimated energy savings attributable to different iterations of the energy performance requirements in the National Construction Code. As also noted, there is increasing concern whether these modelled savings are in fact being achieved. To the extent that they are not, then these 2015 values may be too low. Unfortunately there is a paucity of audit based actual energy consumption data for most (new) building types with which to assess this thesis, and a full investigation of this issue falls well outside the scope of the current project.
- Column 3 expresses the previous column values (average new build energy intensity in 2015) over column 1 (2006 reference energy intensity) as a percentage reduction. The values are generally large, in part because column 1 values are the stock averages, whereas column 2 values are new builds.
- Column 4 (2015 new building best practice benchmarks) is calculated as noted above using Green Star and NABERS reference values.
- Column 5 expresses column 4 (the 2015 best practice benchmark) as a percentage of the 2006 reference energy intensities (column 1).

ATTACHMENT B

Table 4.1: New Building Energy Intensity Benchmarks, 2015 and 2030 relative to 2006 Actual, MJ/m$_2$.a and % points

	2006 Stock Average (MJ/m2.a)	2015 New Build Average (MJ/m2.a)	2015 New Build Average % Reduction cf 2006	2015 New Build Best Practice Benchmark (MJ/m2.a)	2015 New Build Best Practice Benchmark (% reduction from 2006)	2015 New Build, Additional savings, best practice versus 2015 average (% points)	2030 New Build Average (MJ/m2.a)	2030 New Build Average (% reduction cf 2006)	2030 New Build Best Practice (MJ/m2.a)	2030 New Build Best Practice (% reduction cf 2006)	2030 New Build, additional savings, best practice versus 2030 average (% points)
Offices - Premium/A Grade	825	380	54%	297	64%	10%	386	53%	223	73%	20%
Office - Other Grades	825	388	53%	336	59%	6%	393	52%	252	69%	17%
Hotels/Motels	1,496	919	39%	568	62%	23%	895	40%	426	72%	31%
Other Accommodation	650	288	56%	247	62%	6%	297	54%	185	72%	17%
Health	1,597	902	43%	607	62%	19%	909	43%	455	72%	28%
Schools	167	97	42%	63	62%	20%	108	35%	57	66%	31%
Tertiary Education	1,059	675	36%	434	59%	23%	676	36%	326	69%	33%
Residential - Detached	190	164	14%	83	56%	42%	127	33%	63	67%	34%
Residential - Semi-Detached	253	218	14%	111	56%	42%	169	33%	84	67%	34%
Residential - MUDS (low-mid rise)	262	216	17%	115	56%	39%	107	59%	86	67%	8%
Residential - MUDS (high rise)	379	323	15%	167	56%	41%	181	52%	125	67%	15%
Major Shopping Centres	1,645	1,027	38%	395	76%	38%	1,017	38%	296	82%	44%
Smaller Shopping Centres	2,334	1,668	29%	560	76%	47%	1,630	30%	420	82%	52%
Retail Strips	322	197	39%	77	76%	37%	207	36%	58	82%	46%
Industrial	576	276	52%	190	67%	15%	285	51%	143	75%	25%
Warehouses/Storage	337	101	70%	128	62%	-8%	117	65%	96	72%	6%
Cold Storage	6,147	5,600	9%	4918	20%	11%	4,433	28%	3,688	40%	12%
Car parks - open	137	73	46%	52	62%	16%	73	46%	39	72%	25%
Car parks - enclosed	382	227	41%	145	62%	21%	240	37%	109	72%	34%
Pubs/Clubs	637	345	46%	242	62%	16%	368	42%	181	72%	29%

Source: pitt&sherry

- Column 6 shows the *additional* percentage point savings in moving from average 2015 energy intensities (column 3) to best practice 2015 energy intensities (column 5). We note a negative gap is shown for warehouses/storage buildings. This is most likely due to the energy savings attributed to the National Construction Code for this building class being too high. There is uncertainty about the appropriate value, as neither benefit cost analysis underpinning the 2006 or the 2010 commercial building code changes covered this building class at all.
- Column 7 (2030 new build average energy intensity) derives from the analysis in Section 2.2 above. As noted earlier, these values are generally marginally higher than those in column 2 (2015 new build average energy intensity), as we have more energy savings measures focusing on existing when compared with new builds.
- Column 8 expresses column 7 (2030 new build average energy intensity) as a percentage reduction relative to the 2006 baseline (column 1).
- Column 9 estimates 2030 best practice energy intensity, as described in the paragraphs above.
- Column 10 expresses column 9 (2030 best practice energy intensity) as a percentage reduction relative to the 2006 reference (column 1).
- Finally, column 11 shows the gap, in percentage points, between 2030 best practice (column 10) and 2030 average energy intensity (column 8).

4.4 2030 Energy Use and Greenhouse Emissions Best Practice

We conducted a quick estimation of the additional savings that would be realised in 2030 if new buildings were built to the identified best practice target, rather than the ‘new and existing policies and measures’ projection (that is, the savings shown in column 10 rather than in column 8 in Table 4.1).

To estimate these additional savings, we factored down the projected energy consumption and greenhouse gas emissions in 2030 under the ‘existing and new policies’ scenario, by an amount equivalent to the gap between the projected average energy intensity of new builds in that year, on the one hand, and the energy intensity that would have at the estimated ‘best practice’ level. This additional energy saving was applied to the new buildings only, which by 2030 is projected to reach between just 20% in some cases (eg, detached dwellings) or over 40% in other cases (eg, A grade offices) of the total stock standing in 2030. This, together with the modest gap (for most building classes) between the projected average energy intensity in 2030 and our conservative estimate of best practice, means that the additional savings are relatively modest. As set out in Table 4.2 below, the move to best practice is estimated to save an additional 963 TJ of energy 2030 or just over 200 kt CO_2-e. In total, it would shift a 2030 target from around a 32% reduction over 2006 levels to just under 37%, or from around 42% in greenhouse terms to just under 46%.

However, we stress that this is based on a conservative estimation of best practice energy intensity in 2030, and ignoring the (likely) prospect that building integration solar technologies could see the net purchased annual energy demand of new buildings in 2030 being zero or even negative. Also this scenario does not consider the additional savings that would be likely to arise in the existing (pre-2015) building stock if it were also refurbished to best practice standards.

Table 4.2: Additional Energy/GHG Emissions Savings in 2030 at Best Practice Energy Intensity Levels for New Buildings

	2030 energy use if BP applied to new builds (TJ):	2030 ghg emissions if BP applied to new builds (t CO2-e):
A Grade Offices	1,443	354,938
Other Offices	3,906	959,928
Warehouses	295	62,671
Cold storage	166	42,887
Above ground carparks	104	26,842
Below ground carparks	735	189,664
Pubs & clubs	274	51,544
Hotels/motels	979	175,837
Other accommodation	189	32,051
Major shopping centres	303	67,679
Smaller shopping centres	452	101,607
Retail strips	257	57,634
Industrial	409	83,707
Healthcare	181	24,417
Schools	27	5,999
Tertiary	96	21,820
Detached dwellings	36	6,096
Semi-detached dwellings	443	73,047
Low-mid rise MUDs	388	63,402
High rise MUDS	998	169,974
Totals (BP scenario):	11,682	2,571,745
Change over 2006 (BP scenario):	-36.8%	-45.9%
Change over 2006 (new + existing scenario):	-31.5%	-41.6%

5. New and Revised Policy Measures

5.1 NSW Energy Savings Scheme (ESS)

This measure had already been modelled in the Foundation Report, but based on expectations held prior to the announcement of the NSW Energy Efficiency Action Plan in August 2014. The Action Plan announces changes to the ESS including higher targets. While these announced changes have not yet been implemented, it appears likely they will be, and therefore we now take them into account in the current version of BEEMS. The additional savings are scheduled to occur over the 2015 – 2020 period only. The revised measure is modelled to contribute around 570 TJ of energy savings (in the Sydney LGA) at its peak, falling back after 2020 on the assumption that the measure is not extended beyond that date. Further details of our modelling of ESS are contained in the Foundation Report.

5.2 NABERS Minimum Requirements for New Builds

A possible new measure was modelled under which, from FY2017, the City of Sydney is assumed to require mandatory minimum NABERS ratings for those building types covered by NABERS ratings tools (office, hotels (base building) and shopping centres (base building)). The delayed start-up of FY2017 is assumed both for consultation with stakeholders and noting that the development pipeline is long for major buildings and so the energy savings would not be realised immediately.

With such as measure, the size of energy savings is a function of two key variables: first, the target NABERS value set by the City of Sydney as a mandatory requirement (assumed to be given effect via a NABERS Commitment Agreement); and second, the value that would otherwise have applied to new buildings in the absence of this measure.

On the first front, we assume for modelling purposes that the target is set at 5 star, but this value may be varied up or down in BEEMS (in half star increments). On the second front, we estimate that 4.0 stars best equates to minimal compliance with National Construction Code energy performance requirements, although there is uncertainty about this value. The value of 4 stars is used by the GBCA in the above-cited report as a benchmark for minimal NCC compliance. The results shown below include office base buildings and tenancies, as there are NABERS tools for both, but could in practice apply to one or other of these (and this option can be selected in BEEMS).

Despite its limited coverage of building types and ‘soft start’, this measure is modelled to generate significant energy savings by 2030, and also to be very cost effective. It is expected to generate energy savings of 447 TJ in 2030, which is more than double the next most effective measure. These energy savings would be worth nearly $25 million of avoided energy costs in 2030. The measure would also deliver around 109 kt CO_2-e of greenhouse gas savings in 2030, with an abatement cost of *minus* $54/t CO_2-e. Finally the measure would reduce peak demand in Sydney by some 31 MW in 2030, which would generate an additional financial saving of nearly $10 million in that year (in avoided electricity infrastructure costs).

Following discussion with the City of Sydney, this measure has now been included in the savings totals, while the ‘voluntary NABERS’ measure – discussed in the Foundation Report and found to be much less effective and cost effective – has been removed from the totals.

5.3 Impact on Energy Savings by 2030

The net impact of the changes noted in this Addendum to overall cost-effective energy savings in 2030, in the ‘new and existing policy measures’ scenario, is to lift them from around a 29% reduction over 2006 levels (as reported in the Foundation Report) to almost 32%. In greenhouse terms, this equates to around a 42% reduction in 2006 building related greenhouse gas emissions by 2030, on the assumptions set out in the Foundation Report – which include an expectation of continuing declines in the greenhouse intensity of grid-supplied electricity over the period to 2030, and also a continuation of major existing policy measures. As noted in the Foundation Report, and even more so today, some of these assumptions may appear questionable in the light of very recent policy and political developments nationally. However, over the longer term to 2030, we are confident that these trends remain sound assumptions.

6. Interim Targets

On the basis that the 'new and existing measures' scenario in the EEMP is the one preferred as the basis of target setting, then this implies an energy savings target (from building energy efficiency measures) of around 31% in 2030, as noted above. The same scenario can be traced annually, as shown in Figure 6.1 below, and this provides a sound basis for setting interim (pre-2030) targets, should the City of Sydney wish to do so. As a general rule, interim targets are a sound idea, as they provide early feedback of any underachievement against those targets, and allow time for learning and reshaping strategies in response to actual experience and contingency. This is to be much preferred to a distant target, where any under-achievement may not be known until it is too late to correct.

As shown in Figure 6.1, this scenario generates interim energy savings targets of 14% by 2020 (relative to 2006) and nearly 22% by 2025 (relative to 2006), en route to some 32% by 2030. These values could be adopted as interim targets on this basis. Alternatively, the same calculation could be made in greenhouse, rather than energy, metrics. As shown in Figure 6.2, this scenario generates interim targets of just over 20% emissions reductions by 2020 (relative to 2006), and just over 30% by 2025 (relative to 2006), on the way to 42% reductions by 2030.

Figure 6.1: Energy savings relative to 2006: new and existing measures scenario: 2006 – 2030 (possible basis for interim targets)

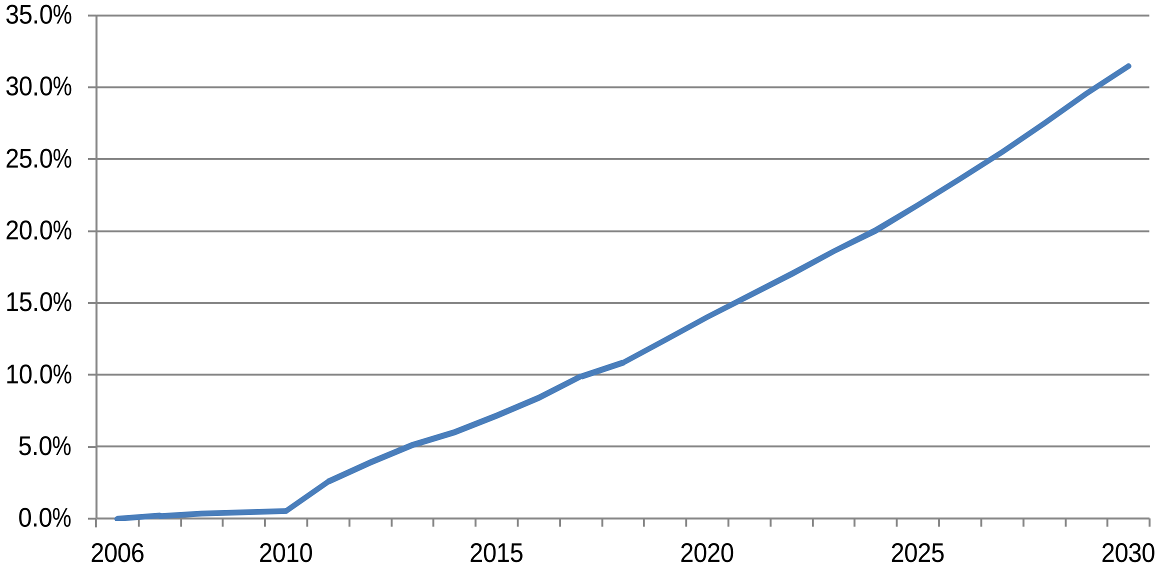
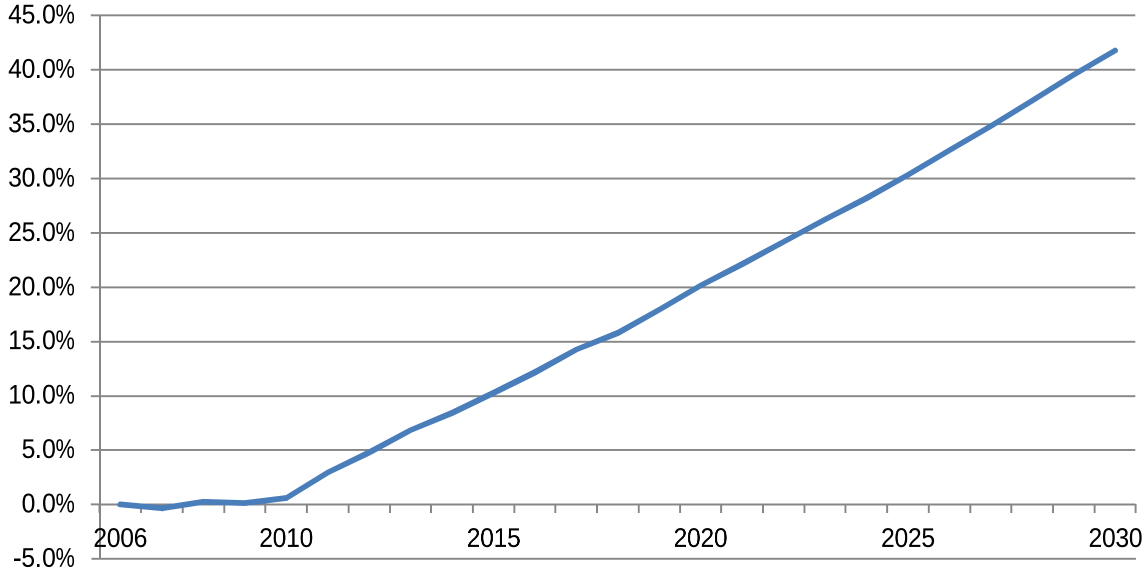


Figure 6.2: Greenhouse gas emissions savings relative to 2006: new and existing measures scenario: 2006 – 2030 (possible basis for interim targets)



ATTACHMENT B

Contact
Phil Harrington
03 6210 1489
pharrington@pittsh.com.au

transport | community | industrial & mining | carbon & energy

pitt&sherry

Brisbane
Level 2
276 Edward Street
Brisbane QLD 4000
T: (07) 3221 0080
F: (07) 3221 0083

Canberra
LGF, Ethos House
28-36 Ainslie Place
Canberra City ACT 2601
PO Box 122
Civic Square ACT 2608
T: (02) 6274 0100

Devonport
Level 1
35 Oldaker Street
PO Box 836
Devonport TAS 7310
T: (03) 6424 1641
F: (03) 6424 9215

Hobart
199 Macquarie Street
GPO Box 94
Hobart TAS 7001
T: (03) 6210 1400
F: (03) 6223 1299

Launceston
Level 4
113 Cimitiere Street
PO Box 1409
Launceston TAS 7250
T: (03) 6323 1900
F: (03) 6334 4651

Melbourne
Level 1, HWT Tower
40 City Road
Southbank VIC 3006
PO Box 259
South Melbourne VIC 3205
T: (03) 9682 5290
F: (03) 9682 5292

E: info@pittsh.com.au
W: www.pittsh.com.au

incorporated as
Pitt & Sherry (Operations) Pty Ltd
ABN 67 140 184 309

CONSULT AUSTRALIA
Member Firm

sustainable*thinking*®