Pathway to 2020 for Increased Stringency in New Building Energy Efficiency Standards: Benefit Cost Analysis: 2016 Update for Residential Buildings

transport | community | mining | industrial | food & beverage | carbon & energy

Prepared for:	**Department of Industry, Innovation and Science**
Client representative:	**Gordon McAllister**
Date:	**13 May 2016**
	Rev 00

Inspired thinking embracing
the challenges of a changing world.

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Prepared by: ……… ………… Date: 13th May 2016
Philip Harrington

Reviewed by: ………… . Date: 13th May 2016
Mark Johnston

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1. Summary of Analysis

Purpose

This purpose of this study is to update the findings of the building benefit cost analysis, for residential buildings only, undertaken in **pitt&sherry**'s report *Pathway to 2020 for Increased Stringency in New Building Energy Efficiency Standards: Benefit Cost Analysis* (2012)[1].

The original report was commissioned by the former Department of Climate Change and Energy Efficiency as a contribution to the National Building Energy Framework measure described in the former *National Strategy on Energy Efficienc*y. In December 2015 the COAG Energy Council agreed to the National Energy Productivity Plan which includes a measure to advance the building energy performance requirements in the National Construction Code. The Department of Industry, Innovation and Science commissioned this update on the benefit cost analysis contained in the 2012 report, for residential buildings, to help inform potential policy settings for future.

Approach

The methodology used in 2012 has been adopted, although different carbon price and learning rate scenarios have been modelled. In summary this updated benefit cost analysis uses:

- Residential building forms, building specifications and climate zones as per the 2012 Report;
- Contemporary energy price projections based on AEMO forecasts without a carbon price and with two different shadow carbon prices: i) based on the second ERF auction outcomes ($12.25 tonne) increasing at CPI (that is, constant in real terms) and ii) the medium scenario from the Climate Change Authority 2014 Targets and Progress Review[2];
- 3 learning rates: i) 0% (no learning), ii) 100% after 7 years (*i.e.* the incremental cost falls to zero after 7 years), and iii) 3% per annum for 10 years (that is, 70% of the incremental cost remains after 10 years).
- Incremental costs used in the 2012 study were reviewed with reference to the Rawlinsons Cost Guide and other relevant literature and were considered to remain broadly relevant to the current update.
- A 7% real discount rate.

The scope of energy consumption considered includes space heating and cooling, water heating and lighting equipment. Cooking and plug load are excluded as they fall outside the current scope of the building energy performance requirements.

The benefit cost analysis assumes that performance requirements are introduced in 2019-20 and apply to a cohort of buildings constructed between FY2020 – FY2024. This assumption is consistent with the 2012 study, noting that the window for an upgrade to the performance requirement from 2014-15, anticipated in the 2012 study, was missed. All buildings are assumed to have an economic life of 40 years and the benefit cost analysis is conducted over this period. Cost effective levels of energy savings are calculated on a breakeven basis (benefit-cost ratio or BCR of 1) and then BCRs of 1.2 and 1.5.

Key Findings

First, this updated analysis found that there are significant cost effective opportunities for energy savings in new residential buildings in 2020, relative to BCA2010, ranging from 8% to 49% across Australia, depending

[1] Available from http://www.industry.gov.au/Energy/Energy-information/Documents/pathwayto2020newbuildingenergyefficiencystandards.pdf

[2] The shadow price of carbon in this scenario begins at $5.49/t CO_2-e in 2015 and rises to $30.14 in 2020, $36.67 in 2025, $44.61 in 2030 and $56.45 by 2036.

on assumptions made about industry learning rates and possible future carbon prices (see Table 1). This equates to star ratings potentially up to 8 star for Class 1 dwellings and up to 9 star for Class 2 dwellings, depending on the state/territory.

Table 1 – Australian weighted average energy savings at BCR 1.0

	0% learning rate	3% pa learning rate	100% after 7 years
No carbon price	8%	13%	49%
Low carbon price	8%	14%	49%
Medium carbon price	10%	18%	49%

Second, the results are found to be relatively insensitive to assumptions about (shadow) carbon prices. This is because energy prices have already risen strongly compared with those assumed in the 2012 study, while the range of shadow carbon prices tested here is smaller than in 2012. We also note that these results assumes no contribution from photovoltaic systems, which in reality could add significantly to the level of cost effective savings available, however they have been defined out of scope for this study.

Third, however, the results are *highly* sensitive to assumptions about learning rates, or the rate at which incremental compliance costs fall over time (and, implicitly, to assumptions about the initial level of incremental costs). For example, the maximum result is based on an assumption that incremental costs fall to zero after 7 years. If instead it is assumed that incremental costs do not fall at all through time (zero learning rate), then the cost effective level of savings falls to between 8% and 10%, on average across Australia and all dwelling types, depending upon shadow carbon price assumptions.

We note that the cost effective level of energy savings declines when target BCRs greater than 1 are demanded. For many scenarios, higher levels of savings (in percentage terms relative to BCA2010) are indicated as cost effective for Class 2 buildings.

Limitations

There are several limitations associated with this update due to time, scope and resource constraints. We note that each of these limitations would tend to underestimate the likely extent of cost effective energy efficiency improvements reported here.

First, the direction in the 2012 report that house designs should not be changed has been carried through to this update. However, subsequent research by **pitt&sherry**[3], Sustainability House[4] and CSIRO[5] has demonstrated that minor design changes can lead to zero or negative incremental costs while at least an additional star of thermal performance is added.

Second, our professional opinion is that each of the learning assumptions used in this study is likely to be less than would be expected in reality, although we note there is a paucity of objective research in this

[3] pitt&sherry, *Increased Housing Energy Efficiency Standards in WA: Benefit Cost Analysis*, May 2012, available from https://www.commerce.wa.gov.au/sites/default/files/atoms/files/energyefficiencycostbenefit.pdf

[4] Sustainability House, *Identifying Cost Savings through Building Redesign for Achieving Residential Building Energy Efficiency Standards*, March 2012, available from http://www.industry.gov.au/Energy/Energy-information/Documents/identifyingcostsavingsbuildingredesignachievingenergyefficiencystandards.pdf

[5] Ambrose MD, James M, Law A, Osman P, White S (2013) *The Evaluation of the 5-Star Energy Efficiency Standard for Residential Buildings*. CSIRO, Australia.

area. To the extent that our opinion is correct, the extent of cost effective savings is being under-estimated here.

Third, changes in incremental costs since the original study, and also changes in the 'opportunity set' due to new/improved materials or technologies, have not been accounted for here. Finally, the option of including photovoltaic cells as part of the building fabric – which in the 2012 study enabled zero net energy to be cost effective in all states and territories by 2020 – was not requested for this update.

Overall, our key finding is that significant, evidence-based research, utilising sound methodologies, will be required prior to undertaking a definitive RIS or benefit cost analysis of cost effective energy performance requirements in Australia. A set of eight key research questions is identified in Section 4.3 below.

2. Results

The results are presented under the 3 carbon price scenarios. For each scenario, energy savings are then shown for the 3 different modelled learning rates at BCR 1.0, BCR 1.2 and BCR 1.5. Energy savings were calculated for each of the residential building types (as per the original study) in each state/territory. The weighted results shown below are based on the energy savings of each residential building type and their proportions of the total stock. The Australian weighted average is also shown.

To help with interpretation of the results below, the benefit cost analysis model that generates these results models each climate zone and building type independently, based on a unique set of savings opportunities for that climate zone and building type. This means that when small changes in scenarios are modelled – such as the difference between the 'no carbon price' and the 'low carbon price' scenarios – this change may be too small to make additional savings opportunities cost effective in one climate zone, but large enough to make them cost effective in another climate zone. This is why the results below show that additional savings become cost effective in some states, but not others, as policy scenarios change.

2.1 No carbon price

All end-uses excluding plug load and cooking

Tables 2-4 below show the results under the no carbon price scenario. The results illustrate that the extent of cost effective improvement in current (BCA2010) energy performance requirements for houses is highly sensitive to the learning rate assumption, and is also sensitive, to a lesser degree, to benefit-cost ratio targets.

Modest energy savings can be achieved in most jurisdictions with no learning rate and no carbon price, with an 8% reduction at 'break even', falling to 3% at a BCR of 1.5. When a learning rate of 3% p.a for 10 years (a 30% reduction in cost after 10 years) is applied, slightly higher savings are achieved for most jurisdictions. At 100% learning after 7 years there is a big jump in the level of energy savings, which range from 41% in NT to 56% in Victoria.

Table 2: Energy savings at BCR 1.0

Learning rate	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	WEIGHTED AVERAGE
0%	9%	3%	7%	11%	18%	14%	3%	7%	**8%**
3% p.a for 10 years	19%	4%	7%	11%	32%	17%	9%	11%	**13%**
100% after 7 years	44%	56%	49%	50%	47%	53%	41%	55%	**49%**

Table 3: Energy savings at BCR 1.2

Learning rate	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	WEIGHTED AVERAGE
0%	4%	3%	3%	7%	18%	12%	3%	4%	**5%**
3% p.a for 10 years	14%	3%	7%	11%	18%	14%	3%	7%	**10%**
100% after 7 years	35%	45%	39%	40%	37%	42%	32%	44%	**39%**

Table 4: Energy savings at BCR 1.5

Learning rate	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	WEIGHTED AVERAGE
0%	3%	2%	0%	1%	11%	11%	2%	1%	**3%**
3% p.a for 10 years	9%	3%	7%	11%	18%	14%	3%	7%	**8%**
100% after 7 years	22%	28%	25%	25%	23%	26%	20%	27%	**25%**

2.2 Low carbon price based on ERF auction price

Tables 5-7 below contain the results of the ‘’low carbon price’ scenario based on the ERF auction price. The assumed price of $12.25 per tonne of CO_2-e is based on the results of the second ERF auction[6] increasing at CPI, i.e. constant in real terms. We note that this level of carbon price is extremely low, resulting in only marginal increase in savings for selected climate zones.

All end-uses excluding plug load and cooking

Table 5: Energy savings at BCR 1.0

Learning rate	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	WEIGHTED AVERAGE
0%	9%	3%	7%	11%	18%	14%	3%	7%	**8%**
3% p.a for 10 years	19%	7%	7%	11%	32%	17%	10%	13%	**14%**
100% after 7 years	44%	56%	49%	50%	47%	53%	41%	55%	**49%**

[6] The average price of the third ERF auction, released on the 5th May 2016, was $10.23.

Table 6: Energy savings at BCR 1.2

Learning rate	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	WEIGHTED AVERAGE
0%	9%	3%	7%	7%	18%	12%	3%	4%	**8%**
3% p.a for 10 years	14%	3%	7%	11%	26%	14%	3%	7%	**11%**
100% after 7 years	35%	45%	39%	40%	37%	42%	32%	44%	**39%**

Table 7: Energy savings at BCR 1.5

Learning rate	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	WEIGHTED AVERAGE
0%	3%	2%	0%	1%	11%	11%	2%	1%	**3%**
3% p.a for 10 years	9%	3%	7%	11%	18%	14%	3%	7%	**8%**
100% after 7 years	22%	28%	24%	25%	23%	26%	20%	28%	**24%**

2.3 Medium carbon price based on Climate Change Authority Review

All end-uses

Tables 7-9 below show the 'all-end use excluding plug load and cooking' results under the medium carbon price scenario. With no learning rate there is overall a slight increase in the break-even savings at a medium carbon price, compared to the two lower energy price scenarios. With a 3% learning rate p.a., slightly higher energy savings can be achieved in most jurisdictions as compared with the no and low carbon price scenario. Significant savings, on average around 50% across all jurisdictions, can be achieved when the learning is 100% over 7 years.

All end-uses excluding plug-load and cooking

Table 8: Energy savings at BCR 1.0

Learning rate	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	WEIGHTED AVERAGE
0%	14%	3%	7%	11%	18%	14%	3%	7%	**10%**
3% p.a for 10 years	19%	14%	16%	11%	32%	17%	13%	17%	**18%**
100% after 7 years	44%	56%	49%	51%	47%	53%	41%	55%	**49%**

Table 9: Energy savings at BCR 1.2

Learning rate	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	WEIGHTED AVERAGE
0%	8%	3%	5%	6%	18%	13%	3%	4%	**7%**
3% p.a for 10 years	19%	7%	7%	11%	32%	15%	6%	7%	**14%**
100% after 7 years	35%	45%	39%	40%	37%	42%	32%	44%	**39%**

Table 10: Energy savings at BCR 1.5

Learning rate	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	WEIGHTED AVERAGE
0%	3%	3%	0%	1%	17%	11%	2%	1%	**4%**
3% p.a for 10 years	14%	3%	7%	11%	18%	14%	3%	7%	**10%**
100% after 7 years	22%	28%	24%	25%	23%	26%	20%	28%	**24%**

2.4 Thermal shell performance at BCR 1.0 (with no carbon price)

Table 11 below shows the star rating of dwellings at BCR 1.0 (with no carbon price). For the no learning rate/no carbon price scenario, with the exception of Class 2 dwellings in Tasmania and the ACT, moving beyond a 6 star thermal shell is not cost effective (remembering however, that 'no cost' design changes have not been modelled and that a zero learning rate is unlikely). On the other hand when the learning rate is 100% after 7 years, at least 8.5 star and 9.0 star thermal shells are cost effective for class 1 and 2 dwellings respectively in all jurisdictions. The sensitivity of this key result again highlights the importance of objectively establishing an appropriate learning rate for analytical purposes.

Table 11: Star rating at BCR 1.0

	NSW		VIC		QLD		SA		WA		TAS		NT		ACT	
Learning rate	Class 1	Class 2	Class 1	Class 2	Class 1	Class 2	Class 1	Class 2	Class 1	Class 2	Class 1	Class 2	Class 1	Class 2	Class 1	Class 2
0%	6.0	6.0	6.0	6.9	6.0	6.0	6.0	6.0	6.0	6.0	6.1	7.3	6.0	6.0	6.0	7.5
3% p.a for 10 years	6.0	6.0	6.01	7.1	6.0	6.0	6.0	6.0	6.0	6.0	6.2	7.9	6.1	6.2	6.0	8.0
100% after 7 years	8.7	9.0	8.5	9.0	8.8	9.0	8.8	8.9	8.95	9.0	8.4	9.0	8.1	8.65	8.5	9.0

3. Discussion of results

The different energy/carbon price scenarios have little effect on the results because the carbon prices modelled are very modest. The target benefit cost ratio has a predictable impact on the level of cost effective savings, with higher savings at BCR = 1 and progressively lower savings at BCR = 1.2 and 1.5. This occurs because savings that are cost effective from a societal perspective are not taken up when a BCR greater than 1 is specified.

However, by far the biggest influence on the varying level of energy savings is the learning rate. Under the no carbon price scenario, break-even energy savings range from between 3% (Vic and NT) and 18% (WA) where the learning rate is zero; increase slightly in some cases with a 3% p.a. learning rate, but then jump to between 41% (NT) and 56% (Vic) where the learning rate is 100% after 7 years. At the highest learning rate, 8.5 and 9.0 star thermal shells for class 1 and 2 dwellings respectively, are cost effective in all jurisdictions.

Other factors that influence the residential building results can be summarised as:

- the expected prices of electricity and gas in each climate zone over time, as these determine the economic value of the energy savings that are achieved;
- differences in climates, as the severity of winter and summer conditions influence the total energy demand for space conditioning purposes, and therefore the benefits of improving thermal shell performance;
- the cost of achieving given levels of improvements in the building shell (in turn reflecting differences in construction techniques and distribution of residential building types by state/territory);
- the cost of achieving energy efficiency improvements in the fixed appliances, such as hot water, lighting and pool pumps (which also vary by state/territory including differences in the starting point distribution of hot water appliance types in particular, e.g., solar, electric storage, gas storage, instantaneous gas, etc); and
- the 'starting point' energy efficiency (e.g., 6 star houses required in BCA2010).

4. Comparison with 2012 Results

4.1 2016 vs 2012 scenarios

The 2012 study called for an analysis of energy savings at 'break-even' benefit cost ratio (BCR = 1), although some scenarios also tested a BCR of 1.2. The 2012 study used two different discount rates and two different time periods, and for this section we report only those with a 7% real discount rate and 2020 results.

In terms of policy scenarios, the 2012 study specification required that scenarios reflected a mix of different carbon prices, differing learning rates and inclusion/exclusion of PV, rather than treating these as independent variables. We also undertook a sensitivity analysis in the 2012 report that allowed for improved thermal performance through no-cost design changes – a form of 'learning'.

Specifically, Scenario 1 in the 2012 study assumed no carbon prices and no learning and so is conceptually comparable to the similar scenario from this study. Scenario 2 in the 2012 study assumed 3% p.a. learning rate and a 'low' carbon price assumption. The carbon price assumptions for that study were based on the "Government policy" or "Base Case" (Scenario 2) and "High price" (Scenario 3) are based respectively on and scenarios in the Treasury's 2011 economic modelling of the *Clean Energy Future* legislative package. For Scenario 2, a carbon price of \$21/t CO_2-e was assumed to apply in 2013, rising to \$29.40 by 2020, \$39.40 by 2025, \$52.60 by 2030 and \$69.90 by 2035. We note that this carbon price assumption was higher than the 'medium' carbon price scenario in this report, let alone the 'low' scenario.

Scenario 3 in the 2012 study assumed a 5% p.a. learning rate over 10 years (that is, 50% of the incremental costs remain after 10 years) and a carbon price trajectory of $27.50 in 2013, $62/t in 2020, and $147.80 by 2035. While these carbon prices are significantly higher than any scenario in the current report, electricity prices have in fact already risen much more rapidly than was anticipated in the 2012 study. Overall, the price series in Scenario 3 is reasonably comparable with those in the 'medium' carbon price scenario in this report, as the lower carbon prices but higher electricity (and gas) prices tend to offset each other. This is illustrated below for Sydney, as an example, below.

Table 12: Comparison – Electricity Prices – Sydney ($/MWh)

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
2012 Study, Scenario 3:	252.1	254.2	260.5	268.0	271.1	277.5	280.6	282.8	283.8	287.0	283.8	289.1	294.4	300.7	305.0	313.4
2016 Study, 'medium scenario:	263.8	261.3	259.6	266.5	273.6	281.2	282.5	283.8	285.3	286.8	288.3	289.9	291.6	293.3	295.1	297.0

4.2 Comparison of Results

With no carbon price and no learning, the break-even (BCR = 1) 2016 results are only modestly higher than the 2012 ones: on average across Australia in this study, 8% energy savings would be cost effective in this scenario, cf 6% savings in 2012 for a similar scenario. The slightly higher figure now reflects higher energy prices in the meantime. Considering the thermal shell performance, 6 star remains the cost effective point for Class 1 buildings in this scenario, as it was in 2012, but Class 2 buildings in the cooler climates of Victoria, Tasmania and the ACT are cost effective at 7 star or more, even in this rather unrealistic scenario. This result is consistent with the 2012 Report which showed that there was much greater cost-effective potential to lift the efficiency standards for Class 2 buildings than Class 1 buildings.

In the 2012 study, the learning rate was not able to be varied independently of other variables, like carbon pricing, whereas in 2016 we have kept them separate. As a result we can see that even in the 'no carbon price' scenario, the cost effective level of energy performance is highly contingent on the learning rate assumption. A very modest learning rate of 3% per year – which we consider unrealistically low – already lifts the cost effective improvement from 8% to 13%, while an assumption of 100% learning over 7 years lifts the figure to 49%. The comparable figures from the 2012 study are 6% (no carbon/learning), 23% (Scenario 1) and Scenario 2 was not reported but would have been higher again. The greater spread in the 2012 results, as compared to 2016, reflects two factors: the faster rate of growth in energy/carbon prices assumed in 2012, and the fact that learning rates are also increasing in the latter scenarios.

In the 2016 study, the no carbon/no learning rates results are relatively insensitive to carbon price assumptions, only rising from 8% to 10% on average even in the 'medium' carbon price scenario. This is because the absolute level of assumed carbon pricing is much lower than in the 2012 study.

In terms of star ratings, a low 3% learning rate assumption makes little difference to the no-learning results above – that is, 6 star remains cost effective in most states for Class 1 dwellings – but with a more realistic learning rate assumption of 100% over 7 years, star ratings of at least 8 for Class 1 dwellings, and generally 9 for Class 2s, are cost effective.

The impact of targeting a higher benefit cost ratio, such as 1.2, on the cost-effective level of energy efficiency improvement is predictable and broadly consistent in the 2012 and 2016 studies. In 2012, for example, and in the 'base case' (no carbon, no learning) scenario, the weighted average results fell from 6% improvement at BCR = 1 to 5% at BCR = 1.2; while in Scenario 2 (medium carbon price and learning) the cost effective level fell from 23% to 20%. In 2016, and in the no carbon price/no learning scenario, the cost effective level falls from 8% at BCR = 1 to 5% at BCR = 1.2. With a 100% learning rate over 7 years, but still no carbon pricing, the corresponding change is from 49% at BCR = 1 to 39% at BCR = 1.2. We note that these values don't change as a function of the carbon pricing specified, reflecting the relatively low level of carbon pricing assumed but also a modelling assumption that these levels of energy saving are cost effective even without carbon pricing, and remain so with carbon pricing. This modelling could be refined in a longer study.

4.3 Research Questions

The comparison of the 2012 and 2016 study results reinforces the need to address some key research questions before conducting a definitive benefit cost analysis or regulation impact statement on future energy performance requirements.

First, amongst these is the choice of an appropriate learning rate, along with the underlying question of how best to establish the extent of expected incremental costs. Since the learning rate is clearly a significant variable, an evidence-based rather than assumption-based methodology is critical. Targeted research using one or more sound methodologies needs to be undertaken to establish a value or plausible range of values for modelling purposes. Industry stakeholders may be able to contribute to this research, but there is a clear risk of strategic bias that must be understood and designed into the research methodology. In particular we highlight that the assumption that house designs do not change in response to a regulatory stimulus is unrealistic and has the effect of eliminating low-, zero- or negative-cost responses from the modelled opportunity set. This has the effect of overstating costs and understating the value of energy savings benefits available.

Second, the choice of benefit cost ratio for regulation impact assessment purposes also requires a rigorous treatment. There is widely held belief that higher benefit cost ratios are 'better' than lower ones, and/or that a BCR > 1 should be used be used as a 'confidence margin', or to manage possible uncertainty in results. These beliefs are not supported by economic or public finance theory. Setting a policy target where the BCR > 1 by definition means that cost-effective savings opportunities are being foregone, creating an opportunity cost of foregone economic welfare and, this case, additional greenhouse gas emissions and associated damage costs. Where there is uncertainty in values, the first-best solution is to conduct evidence-based research to reduce that uncertainty. Second, for remaining and legitimate uncertainty, appropriate research techniques such as the use of probability-weighted or 'expected' values, and/or ranges of results, should be used rather than varying benefit cost ratios as a proxy.

Third, the significant difference in results for Class 1 and Class 2 dwellings suggests that future research should treat these separately and fully describe the reasons for the differences. Our suggestion is that the lower starting point for Class 2s in BCA2010 is the key explanation. Also as noted elsewhere, taking into account common area energy use for Class 2s is important and likely to increase the level of cost effective savings available.

Fourth, we note again that this quick update has not updated underlying cost assumptions, the energy savings opportunity set (including in particular the dramatic and continuing improvement in the cost effectiveness of photovoltaic systems), or the cost/savings opportunities in fixed appliances. As noted in the 2012 study, these factors will become more and more important to overall or whole-of-house performance requirements in the future, as the relative contribution of thermal shell energy savings diminishes rapidly with increasing star ratings in a non-linear fashion. This finding supports a greater emphasis on whole-of-building performance and not only star ratings.

Fifth, both the 2012 and 2016 studies have an implicit assumption that NCC energy performance requirements are in fact complied with. However, our 2014 *National Energy Efficient Buildings Project*

Phase 1 report raises material doubt about that. As recommended in that report, we note that significant quantitative research will be required to establish the extent and materiality of non-compliances with respect to their impact on the actual energy performance of the housing stock.

Sixth, while not highlighted in this study, a central assumption of a 7% real discount rate is increasingly out of line with financial opportunity costs in Australia, where real, risk-free interest rates are close to zero. While real interest rates are only one conceptual basis for discounting, the use of 7% real as a central value is increasingly likely to understate the actual economic benefits of higher energy efficiency. This is particularly so where high incremental compliance costs, low learning rates, and no or low shadow carbon prices, are assumed.

Seventh this study, as per the 2012 one, did not consider the value of avoided network expenditure (in 2012, this was to be addressed at a later RIS stage which never eventuated). Other research conducted by **pitt&sherry** has shown that the value of these avoided costs can be of a similar order of magnitude as the induced energy savings, and may therefore double the economic benefit for any given level of costs. We note that when this question is addressed, there will be a range of important research questions: the extent to which recent declines in both electrical demand and peak demand are expected to persist in the future; the impact of the recent deceleration of network expenditure following the past overshoot on opportunities to avoid future network expenditure (and how quickly this overshoot is absorbed by (peak) demand; the impact of PV in particular, but also storage and other decentralised energy solutions, on future network expenditure and opportunities to avoid that expenditure.

Eighth, this study and the 2012 study both make the simplifying assumption of a constant climate over the 40 year assumed life of the new buildings. However, with evidence of climate changes already in, the impact of potentially milder winters but more severe summers on thermal loadings on buildings will be important, including from the perspective of occupant health and wellbeing (avoiding heat stress). Failure to address this question would again tend to underestimate the economic benefits associated with higher (thermal) energy performance requirements for houses in Australia.

Contact:
Philip Harrington
Senior Principal – Carbon & Energy
pharrington@pittsh.com.au
(03) 6210 1489
0419 106 449

transport | community | mining | industrial | food & beverage | carbon & energy



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

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