Cost Effective Energy Savings in Australian Houses to 2020

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Abstract

This paper analyses the level of cost-effective energy savings that new residential buildings could achieve in Australia by 2015 and 2020, relative to buildings compliant with the energy standards in the 2010 Building Code of Australia (BCA2010). It draws on research undertaken by the authors for the Australian Government (Department of Climate Change & Energy Efficiency). Twelve different residential building forms/construction types were modelled in each capital city climate zone in Australia. Cost effectiveness in this study was defined as a social benefit cost ratio of at least unity at a 7% real discount rate.

The results show that on average, building shell thermal performance improvements and more efficient fixed appliances provide only modest cost effective energy savings by 2020, but there is significant variation in cost effective energy savings by climate zone. However, the results change dramatically when photovoltaics (PV) are included as part of the energy saving solution. Zero net energy for new residential buildings is shown to be cost effective by 2020 in all capital city climate zones, and even by 2015 in most climate zones.

It was found that the key factors influencing the results are (1) the expected prices of electricity and gas in each climate zone over time, as these determine the economic value of the energy savings; (2) the differences in climates, as the severity of winter/summer conditions influence the total energy demand for space-conditioning purposes, and therefore the benefits of improving thermal shell performance; (3) 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); (4) 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 due to differences in the starting point distribution of hot water appliance types in particular, e.g., solar, electric storage, gas storage, instantaneous gas, etc); (5) the 'starting point' energy efficiency (e.g., 6 star houses required in BCA2010); and (6) whether or not PV is allowed as part of the building solution.

Keywords: Residential buildings, cost effectiveness, energy savings

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1. Study Background

This paper reports the results of analysis of the cost effectiveness of possible future improvements in the energy performance requirements of the Building Code of Australia, compared to current residential energy requirements introduced in 2010 (BCA 2010). The study was commissioned by the Commonwealth Department of Climate Change Energy Efficiency as a contribution to the National Building Energy Standard-Setting, Assessment and Rating Framework measure described in the *National Strategy on Energy Efficiency* (NSEE), which was approved by the Council of Australian Governments (COAG) in July 2009 (COAG 2009). The COAG Framework aims *inter alia* to lay out a pathway for future stringency increases in the Building Code of Australia (BCA) to 2020, in order to increase certainty for stakeholders and to facilitate strategic planning and innovation by industry.

The study commenced in the first half of 2011, and initial assumptions on gas electricity prices were revised in late 2011. It should also be noted that assumptions on photovoltaic costs are in hindsight conservative, with costs having fallen more dramatically than assumed in the modelling.

2. Approach

The study comprised four key steps. First, twelve different and representative residential buildings were identified and their energy performance simulated at a range of performance levels in each capital city in Australia. The performance levels begin with BCA2010 as a Base Case (not including any jurisdictional variations), and then move through successively challenging energy performance levels: BCA2010 –40%, BCA2010 –70% and BCA2010 –100%, or zero net energy buildings.

Second, independent estimates of the costs of these buildings at each performance level were provided by quantity surveyors, Davis Langdon, and also by Dr Mark Snow, a leading expert on building-integrated photovoltaics (BiPV), specifically with respect to PV system costs. This enabled the *incremental* cost of achieving the higher energy performance levels to be calculated with some precision, using conventional costing approaches routinely employed for building commissions in Australia.

Third, benefit cost and break even analysis was carried out for each building type, climate zone, and performance level. For this analysis, the Base Case reflects the decisions announced in the Government's *Clean Energy Package* and underpinning Treasury modelling (2011), including a carbon price of $23/t in 2012 rising at 2.5% (in real terms) per year for two years and then assumed to increase 4% per year. (3) The Base Case also assumes a rate of industry learning (how rapidly the real incremental cost of complying with new performance requirements declines through time) of 30% over 10 years, and a real discount rate of 7%.

All buildings are assumed to have an economic life of 40 years and the benefit cost analysis is conducted over this period. It is important to note that the economic analysis in this report is based on energy required for space conditioning, hot water, lighting and swimming pool pumps – all of which are subject to regulation in BCA2010. Like conditioning energy, the energy requirements for hot water and pool pumps are climate sensitive.

3. Energy and Economic Modelling Details

3.1 Building Stock

There are significant differences between climate zones in terms of the distribution of construction types and, to a lesser extent, the prevalence of detached and semi-detached houses and flats. For example, medium-sized detached houses with brick veneer walls and concrete slab on ground (CSOG) represent over 50% of the current housing stock in the ACT and SA, but only 11% in NT and just 6% in WA. Cavity brick walls feature in over 70% of the housing stock in WA and 40% in NT (EES 2008). These differences affect both the potential for realising energy efficiency gains in the new housing stock and the costs of doing so in particular locations.

The varying composition of the housing stock is taken into account when weighting results in this Report. The results for each individual climate zone are the weighted averages of the results for that climate zone of the 12 building types modelled, with weightings for each climate zone based on ABS building stock surveys reflecting the prevalence of each building type in the state stock. Full details of the construction types are available in the full study report.[4]

3.2 Building Improvement Cost Estimates and Assumed Learning Rates

An independent quantity surveyor, Davis Langdon (an AECOM company), was retained to provide robust estimates of the costs associated with achieving the different energy performance levels for each building type for key building elements (Full details can be found in the full study report). Regional variations in the costs of plant and materials, as well as climate zone based variations in the building specifications, were taken into account.

This analysis generated, firstly, robust estimates of the total costs of each building type in each climate zone as specified to comply with the BCA2010 Base Case (noting that this version of the Code is not yet in force for all building types in all states/territories). Secondly, the analysis provided a commercially-relevant incremental cost to be established for improving each building type to the required 40%, 70% and 100% energy savings relative to BCA2010.

Learning rates were modelled by assuming reductions in the real costs of building materials used to reduce future energy costs for the Base Case (15% by 2015, 30% by 2020). The cost reduction is meant to encompass reduced labour costs resulting from learning, lower

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[4] http://www.climatechange.gov.au/publications/nbf/pathway2020-increased-stringency-in-building-standards.aspx

manufacturing costs from scale economies and market competition, and new technology developments that offer equivalent outcomes at lower costs.

3.3 Photovoltaic Cost Estimates

Dr Mark Snow, an Australian expert on applications of PV to buildings, provided PV system output (solar yield by location with standard orientation) and cost data. It was assumed that residential buildings would use standard PV modules rack mounted on the roof (rather than integrated as part of the roof or façade). Using current technology, the area required for 1kWpeak mono-crystalline module (m-Si) system with 15% efficiency is 7m². However, module efficiency is expected to improve in the future, thus reducing the area required for a 1kWp system over time. This approach simplified cost estimates, though at the time it was recognised that rapid market and technology improvements made cost forecasts rather difficult. The cost estimate was based on a turnkey approach per 1kWp, and did not include any government subsidy through the RET/SRES certificates.

Table 1: Cost of 1kWp PV system (standard PV modules) 2010-2020

	2010	2015	2020
Turnkey price (AU$/kWp)	AU$/kWp	AU$/kWp	AU$/kWp
Standard PV modules	$5,950	$4,400	$2,990

From the perspective of 2013 these are very conservative estimates, and single per kWp prices do not recognise scale economies from purchase of larger systems. In subsequent modelling, the discrete nature of PV is recognised by limiting PV additions to the nearest 0.1kWp required to deliver an appropriate reduction in utility energy. In subsequent economic modelling, it is assumed that PV systems are replaced after 20 years and inverters are replaced after 10 years. It is assumed that in all jurisdictions that net PV pricing is applied – that is, householders receive a price from utilities for each kWh generated by PV that equals the cost per kWh, without any feed-in tariff.

3.4 Energy Modelling and Climates

All energy modelling was undertaken with the AccuRate energy modelling software, which includes 69 separate climate zones across Australia, and a much finer delineation of energy performance requirements than the 8 climate zones relevant to deemed-to-satisfy (DTS) requirements in the BCA. Energy efficiency performance standards in BCA2010 are defined in terms of DTS construction requirements, or modelled energy performance that equates to AccuRate 6-Star performance, expressed as total conditioning energy in MJ/m^2 of conditioned space. In addition, BCA2010 contains requirements relating to hot water system efficiency, lighting requirements, and pool pump performance. Full details of the residential energy modelling can be found in the full study report.

The sensitivity of 6-Star energy performance to climate can be seen in Table 2. Note that the Sydney climate used is Richmond, which is relevant to residential land developments in

Western Sydney rather than to coastal areas of Sydney. The climates range from tropical (Darwin) through relatively mild climates to the heating dominated climates of Melbourne, Hobart, and Melbourne.

Table 2: Residential Space Conditioning Energy Requirements (MJ/m2.a) by AccuRate Star Band and Climate Zone

	5 star	6 star	7 star	8 star	9 star	10 star
Sydney (West)	112	87	66	44	23	7
Melbourne	165	125	91	58	27	1
Brisbane	55	43	34	25	17	10
Adelaide	125	96	70	46	22	3
Perth	89	70	52	34	17	4
Hobart	202	155	113	71	31	0
Darwin	413	349	285	222	140	119
Canberra	216	165	120	77	35	2

The 10-Star performance is virtually zero conditioning energy, except for removal of latent heat due to humid air. Prior to BCA2010, many jurisdictions had set energy performance standards at the 5-Star level. The step from 5- to 6-Star represented a typical energy performance improvement of 20-25%. The specific requirements of the study required modelling 40% and 70% reductions in energy consumption – significant steps to ~7.5- and 8.5-Stars, respectively.

3.5 Energy and Carbon Prices

Electricity prices were constructed as the sum of major cost components, comprising wholesale costs, network (transmission and distribution) cost, operating costs, and retail margin. Real network costs were assumed to increase by 1% per year to 2020, and remain constant thereafter. Retail operating costs, derived from the cost component data, are assumed to remain constant in real terms throughout the projection period. The wholesale cost component was calculated as the sum of two sub-components. The lesser sub-component is costs other than the direct cost of purchased electricity and the major sub-component is the average pool price of sent out cost of electricity generated. The approach used to construct projected natural gas prices was similar to that used for electricity. For this analysis, energy prices reflect the decisions announced in the Government's *Clean Energy Package* (2011) and underpinning Treasury modelling, including a carbon price of $23/t in 2012 rising at 2.5% (in real terms) per year for two years and then assumed to increase 4% per year.

It is important to note that both electricity and gas prices vary significantly by climate zone (see Table 3). Those climate zones with higher electricity or gas prices tend to show more cost effective savings. These two factors interact so that, for example, Darwin has a high use of electricity (natural gas is not reticulated in Darwin) but a relatively low electricity price.

These two effects tend to cancel each other out, leading to modest savings being reported for Darwin residential buildings.

Table 3: Gas and Electricity Retail Prices (real 2012 prices) - Residential Sector in 2020, by Climate Zone

	Sydney	Melbourne	Brisbane	Adelaide	Perth	Hobart	Darwin	Canberra
Gas ($/GJ)	21.1	17.6	31.4	19.2	28.4	26.1		23.2
Electricity ($/GJ)	60.6	62.3	66.7	78.2	70.7	65.4	54.9	46.9

3.6 Economic Modelling

The benefit cost analysis considers the value of (purchased) energy savings over an assumed 40 year building life arising from the higher energy performance requirements modelled, compared to the energy costs that would have been incurred had the same buildings been constructed to BCA2010. This means, for instance, that energy derived from a building's PV installation is represented as a reduced requirement for purchased electricity. Separate calculations are made for each scenario, building type, climate zone and performance level, for each of the 40 years of building use after construction in 2015 or 2020. The energy savings are measured in annual MJ/dwelling for residential buildings. Electricity and gas are treated separately, and use of minor fuels (e.g., wood, LPG) is also measured for residential buildings and is taken into account in the benefit cost analysis. All prices and costs are represented as *real* 2012 prices, so that the effect of inflation is excluded.

Finally, it should be recalled that the energy costs considered for these buildings exclude those costs associated with internal appliances and equipment ('plug load') that are not currently regulated by the BCA, including cooking energy. The exception to this rule is for the -100% or 'zero net energy' buildings, where the study required inclusion of the plug load and cooking energy. This has the effect of increasing the incremental costs of this solution, when compared to the other performance levels targeted, as the PV system has to be sized to also cover the plug load and cooking energy.

The value of future energy savings and incremental costs are discounted back to a present value. The primary rationale for discounting is the observation that people display 'time preference'; that is, a dollar today (of benefit or cost) tends to be valued more highly than a dollar in the future. This effect is reinforced by the 'opportunity cost of money', which in effect is defined by the real interest rate. That is, one can choose to spend a dollar today or next year, but the value of the dollar next year is increased by the real interest rate available. In effect, the real interest rate represents the amount that must be offered to induce someone to defer the value of present consumption. In this way, the real interest rate is taken as a working proxy for the time value of money.

The Office of Best Practice Regulation requires a 7% real interest rate to be used for present value calculations for regulatory analysis. Energy savings at break-even and at 40%, 70% and 100% have been calculated using a 7% discount rate. It may be noted that this is considerably higher than current real interest rates in Australia, and relatively high for long lived assets.

4. Modelling Results

The starting point stringency of the energy provisions in BCA2010 (6-Star) is a factor that could be expected to influence the overall level of future cost effective savings. The Regulatory Impact Statement (RIS) on the introduction of 6-star into the BCA indicated that it was marginally cost effective on an Australia average basis. This tends to limit the scope for further cost effective savings beyond that level - at least, in the absence of PV, as discussed below.

4.1 Impact of PV

Where PV is allowed as part of the building solution, it has a dramatic effect on the break-even level of energy savings reported, and results are presented below on a without/with PV basis. Where, for a given climate zone, PV becomes cost effective in its own right, then the break even energy savings for residential buildings in that climate zone becomes 100%. This is because any level of residual energy demand can be covered cost effectively by the PV system due to the scalability of PV systems to any size through the addition of extra modules and components, subject only to physical constraints such as suitable roof area and the capital cost. The results *without PV* are driven by the cost effectiveness of: a) improvements to the thermal shells, and; b) improvements to fixed appliances.

In this study, PV systems were treated as if they were another ‘fixed appliance’ which may be traded off against efficiency gains in the thermal shell and those fixed appliances already regulated by the BCA (hot water, lighting, pool pumps) in determining a least cost mix of measures that provide at least break-even benefits (BCR = 1.0). We therefore analysed the cost effectiveness of PV systems in each climate zone, taking into account the differences in electricity prices and PV yield by climate zone.

As previously discussed, the cost of PV is projected to fall dramatically into the future. The most significant price reduction is occurring for the cost of panels (and to a lesser extent for inverters). While these costs currently represent a large share (60+%, depending on total installed capacity) of the current total cost of the turnkey price of a solar energy installation, there is no certainty about future market prices of these components in Australia. The capital cost assumes a 20-year life for the PV panels and replacement of the inverter after 10 years, both of which are conservative.

Table 4 shows the resulting benefit cost ratios (BCRs) for residential PV systems. It can be seen that in 2020 PV is cost effective in all climates. All the economic modelling for residential buildings is based upon improvements being added to dwellings in order of declining BCRs until the break even or specified energy reduction is achieved. This means that building shell or other improvements are made up to the point when the BCR of PV is reached but no further. Moreover, when the BCR >1 for PV, any required level of energy reduction can be achieved cost effectively (i.e. above breakeven), although not necessarily at low absolute cost. Further, there may be a practical limit in terms of suitably oriented and unshaded roof area for real dwellings, which has not been explicitly taken into account in the modelling.

Table 4: BCRs for Residential PV by Climate Zone

	Sydney West	**Darwin**	**Brisbane**	**Adelaide**	**Hobart**	**Melbourne**	**Perth**	**Canberra**
2015	1.01	1.07	1.12	1.36	1.01	0.98	1.39	0.77
2020	1.41	1.47	1.57	1.89	1.41	1.37	1.96	1.09

4.2 Break Even Energy Savings

Table 5 shows the energy savings at break even for the Base Case compared to the same buildings constructed according to the energy performance requirements of BCA2010.

The energy savings from reductions in space conditioning and fixed appliance (hot water, lighting, pool) energy are expressed as reductions from BCA2010 performance. The building shell rating (in AccuRate stars) indicates that most energy savings relate to improved performance of fixed appliances and not improvements in the building shell. The 6-star building shell performance means that in mild climates (Brisbane, Perth, Sydney, Adelaide) the space conditioning energy requirement is small both in absolute terms and as a share of total energy consumption (excluding plug load and cooking which is not regulated under the BCA). As a result, there is relatively little space conditioning energy remaining to save in these climates and there are very few improvements that can be shown to be cost-effective for these climate zones. By contrast, in the locations with the highest space energy requirements (Canberra, Melbourne and Hobart) some improvements in the building shell performance are cost effective in this scenario.

Table 5: Break Even Energy Savings Relative to BCA2010, All Residential Buildings, Without PV, Base Case, 7% Real Discount Rate

	Space Conditioning and Fixed Appliance Savings		**2020 Break Even Thermal Shell Star Rating#**	**2020 Space Conditioning Energy**	**2020 Space Conditioning Energy at Break Even**
	2015	2020			
Sydney West (CZ6)	9%	14%	6.0	30%	4.7GJ
Darwin (CZ1)	3%	3%	6.0	69%	17.3GJ
Brisbane (CZ2)	7%	7%	6.0	20%	1.6GJ
Adelaide (CZ5)	11%	11%	6.0	45%	6.9GJ
Hobart (CZ7)	14%	17%	6.4	67%	18.3GJ

Melbourne (CZ6)	3%	7%	6.2	66%	21.8GJ
Perth (CZ5)	18%	32%	6.0	29%	2.8GJ
Canberra (CZ7)	4%	7%	6.2	70%	26.8GJ

Notes: # = composite star rating for Class 1 (detached) and Class 2 (flats) buildings. Space conditioning energy consumption is shown in Column 5 as a percentage of total energy consumption excluding plug load and cooking energy then, in Column 6, in absolute terms.

Additional sensitivity analysis around these 'without PV' results was undertaken to examine the impact of assuming a range of 'no cost' design changes to some of detached dwelling forms which resulted in building shell improvements in the range 0.2 – 0.9 stars (depending on climate). In such cases, the overall energy savings improved and the building shell rating at break-even also improved.

When PV is added into the mix, the results change dramatically. Zero net energy housing is shown to be cost effective by 2020 in all climate zones studied. The cost of PV panels has declined dramatically in recent years and is projected to decline further by 2020. This combined with rising electricity prices is making the electricity produced from PV installations increasingly cost effective. Indeed by 2015, except for Melbourne and Canberra, PV installations are cost-effective in their own right, and by 2020 this is true for all climate zones. This means that essentially <u>any</u> level of energy savings, relative to BCA2010, is also cost effective when PV is allowed in the building solution - constrained only by physical considerations such as the area of North-facing roof upon which to mount PV systems. As soon as this condition occurs in a climate zone, the break even or cost effective level of energy savings immediately rises to 100% (i.e., zero net energy).

Another way to interpret these results is to note that the various 'treatments' or upgrades that may be applied to a 6 star, BCA 2010 house have different costs and benefits. In our analysis, these treatments are selected in declining order of cost effectiveness (that is, the most cost effective are selected first). As soon as PV panels become the next most cost effective treatment, no further treatments (and hence no further costs) are required to reduce the house's energy consumption to zero. While PV is a cost effective solution, the break even with PV results required 1.5 – 7.4kW of PV, with net present costs from $5,000 to $30,000.

4.3 Benefit Cost Analysis at Targeted Performance Levels

Modelling was undertaken to determine the benefit cost ratios at reductions of 40% and 70% from the BCA 2010 level (covering the building shell, water heating, lighting and pool pumps). Additionally, at 100% reduction, a net zero energy solution was required in which all cooking and plug load energy was also offset by renewable energy. The results shown in Table 6 are the 'without PV' solutions. There are no cost effective solutions, with the best results occurring for the three cool climates. For both -70% and -100% energy reductions, the best results occur for Canberra at around 40% BCR.

The results shown in Table 7 below are the 'with PV' solutions. All climates except Canberra and Melbourne have cost effective solutions for each energy reduction target. As soon as other improvements with BCRs better than that of PV are exhausted, PV is then used to reach the required energy reduction at the BCR of the PV. If the BCR of PV exceeds break even, any level of energy reduction is possible at better than break even because of the scalability of PV systems. It should be noted, however, that the upfront cost of PV systems may be significant, even if they are cost effective: the current net present costs per kWp of PV installed are about $7,300, $4,900 and $3,600 (7% discount rate) in 2010, 2015, and 2020, respectively. It should also be noted that around 7m^2 of appropriately oriented and un-shaded roof is required per 1kWp.

Table 6: Benefit Cost Ratios without PV in Solution, at 40%, 70% and 100% Reduction from BCA2010 by Climate Zone, 7% Real Discount Rate

	-40%		-70%		100%	
Climate Zone	**2015**	**2020**	**2015**	**2020**	**2015**	**2020**
Sydney	0.17	0.21	0.13	0.17	0.13	0.17
Darwin	0.25	0.31	0.24	0.31	0.24	0.31
Brisbane	0.35	0.41	0.10	0.12	0.10	0.12
Adelaide	0.25	0.33	0.16	0.21	0.16	0.21
Hobart	0.47	0.60	0.27	0.35	0.27	0.35
Melbourne	0.37	0.47	0.20	0.26	0.20	0.26
Perth	0.20	0.26	0.19	0.25	0.19	0.25
Canberra	0.40	0.55	0.30	0.41	0.31	0.42

Table 7: Benefit Cost Ratios with PV in Solution, at 40%, 70% and 100% Reduction from BCA2010 by Climate Zone

	-40%		-70%		-100%	
Climate Zone	**2015**	**2020**	**2015**	**2020**	**2015**	**2020**
Sydney	1.03	1.43	1.02	1.43	1.01	1.42
Darwin	1.07	1.47	1.07	1.47	1.07	1.47
Brisbane	1.14	1.58	1.13	1.58	1.13	1.57
Adelaide	1.38	1.90	1.38	1.90	1.37	1.90
Hobart	1.10	1.53	1.05	1.47	1.03	1.44
Melbourne	0.98	1.38	0.98	1.37	0.98	1.37
Perth	1.43	1.99	1.41	1.98	1.40	1.97
Canberra	0.77	1.09	0.77	1.09	0.77	1.09

5. Sensitivity Analysis

A sensitivity analysis was undertaken using a higher carbon price and a higher rate of industry learning. Table 8 below shows that the cost effective level of energy savings, relative to BCA2010 and without PV, is significantly higher than in the Base Case, reaching 23% on a weighted average basis. The spread of results by climate zone continues to reflect differences in relative fuel prices, which are exacerbated by carbon pricing, increasing the relative attractiveness of electricity savings. Note that in Australian conditions, this result also leads to higher greenhouse gas emission savings than occur from savings of natural gas.

Table 8: Break Even Energy Savings Relative to BCA2010, All Residential Buildings, Higher learning rate and higher carbon price, Without PV

Scenario 2	**2015**	**2020**	**2015**	**2020**
	@ 5%	**@ 5%**	**@ 7%**	**@ 7%**
Sydney West (CZ6)	19%	26%	14%	19%
Darwin (CZ1)	5%	23%	3%	15%
Brisbane (CZ2)	7%	30%	7%	22%
Adelaide (CZ5)	11%	22%	11%	22%
Hobart (CZ7)	19%	30%	16%	25%
Melbourne (CZ6)	13%	33%	4%	25%
Perth (CZ5)	32%	32%	26%	32%
Canberra (CZ7)	13%	43%	7%	29%
Weighted Average:	**15%**	**30%**	**11%**	**23%**

6. Conclusion

The study demonstrates that there is limited scope to regulate further cost effective building shell improvements other than in the heating dominated cooler climates of southern Australia. Energy reductions of 1-Star (or ~30% below the BCA2010 6-Star level) would be cost effective. Such regulation would need to be applied by AccuRate Climate Zones rather than by the wider BCA climate zones or by jurisdiction with wide ranges of climates.

It is clear that improvement of the current building shell performance level cannot cost effectively compete against future improvements of fixed appliances covered within the BCA. More significantly, PV as a fixed appliance with its output valued at the householders electricity tariff (net metering), is a more cost effective approach than building shell improvement for most of Australia. This is demonstrated by the conservative cost approach used for PV in the study undertaken in 2011 – from the perspective of 2013 PV makes an even more significant contribution to cost effective reduction of energy consumption and greenhouse gas emissions.

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