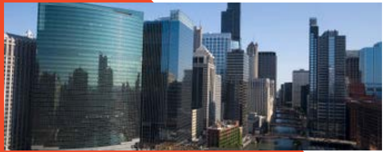
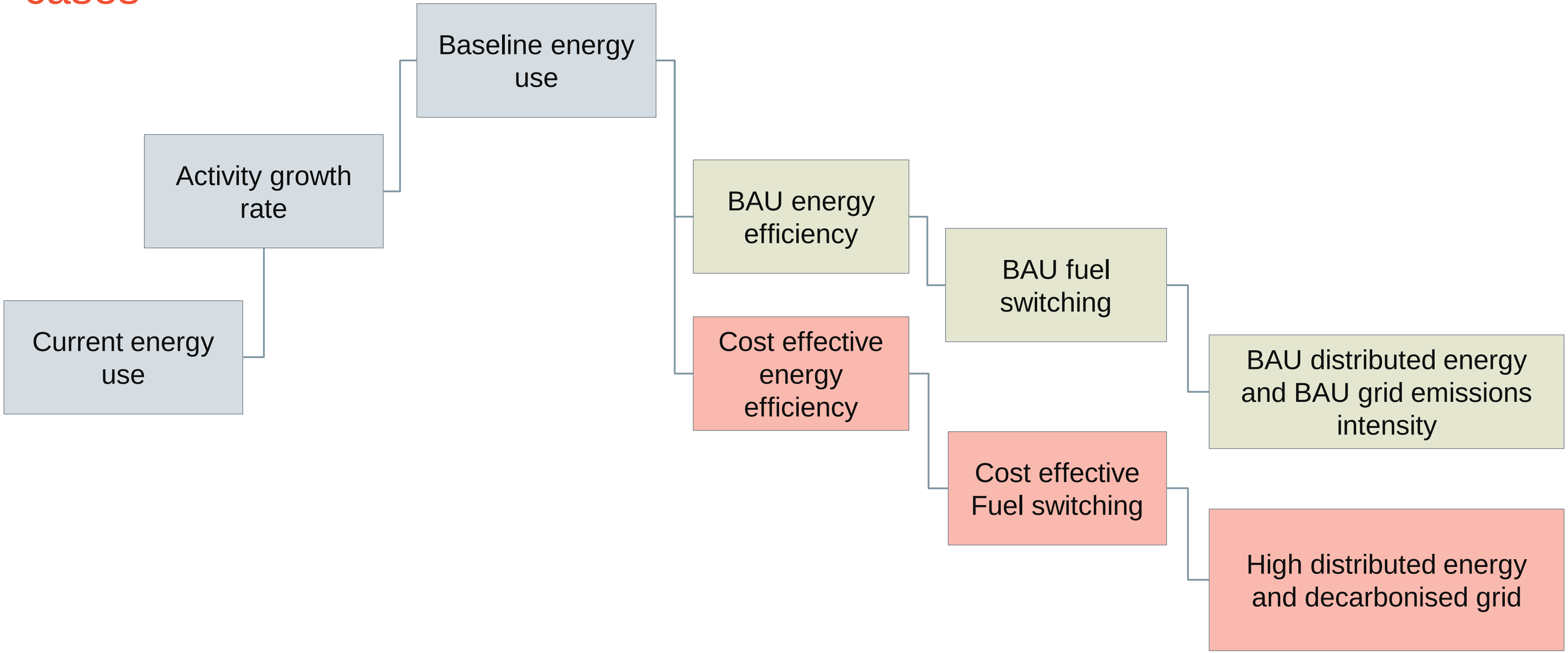
LOW CARBON. HIGH PERFORMANCE

MODELLING ASSUMPTIONS

Contents

Energy use is modelled by applying energy efficiency, fuel switching and distributed energy assumptions for business as usual and advanced abatement cases



Other modelling assumptions

Rebound effect of energy efficiency assumed to be 20% of energy savings based on mid range of reviewed literature *(for example SKM MMA, 2013).*

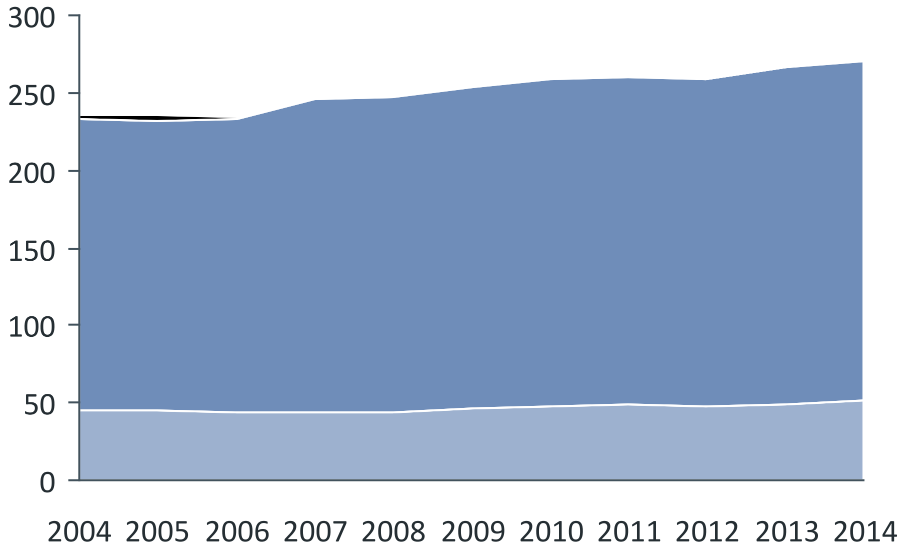
Wood and biomass used in residential buildings assumed to phase out by around 2030 and replaced with electricity and gas this builds on trends identified from EnergyConsult (2015).

Where energy efficiency improvements involve the replacement of equipment, this is assumed to occur at the end of the equipment life. This assumes that there is no opportunity costs associated with replaced equipment and that upfront costs of energy efficiency are equal to the marginal costs of equipment, installation and operation above a business as usual replacement.

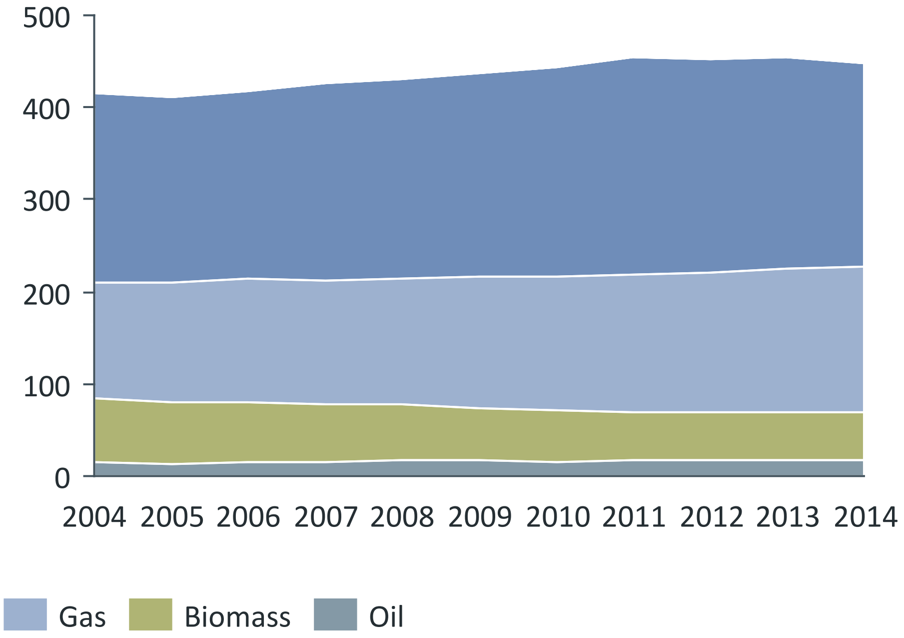
Contents

Historical energy use 2004 to 2014

Historical energy use in commercial buildings^ 2004 to 2014 (PJ) (OCE 2015)



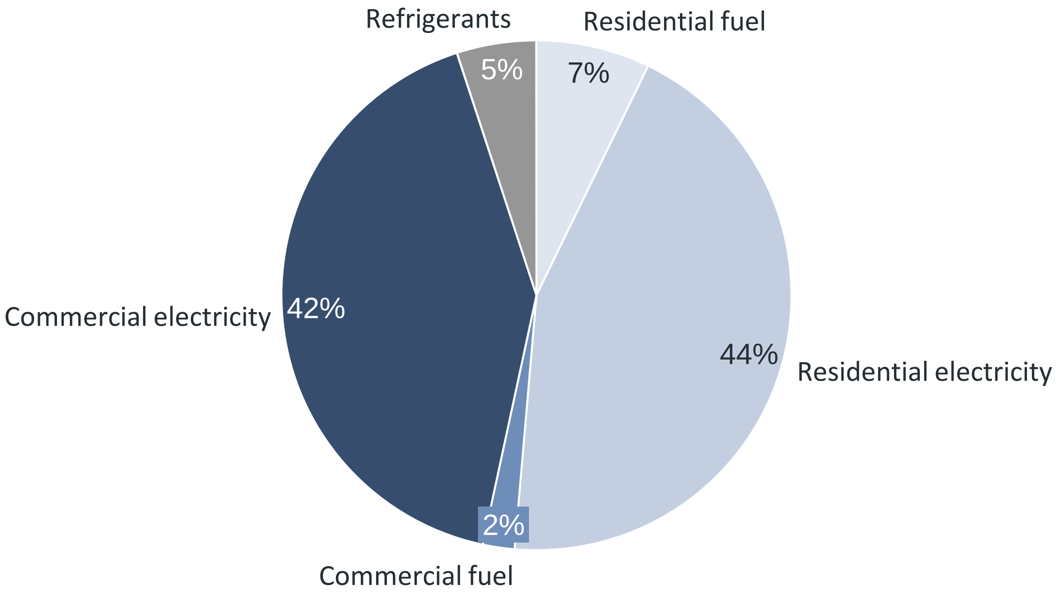
Historical energy use in residential buildings 2004 to 2014 (PJ) (OCE 2015)



^ Includes all commercial buildings in ANZSIC divisions F, G, H, J, K, L, M, N, O, P, Q, R, S. Excludes transport fuels

Assumptions on emissions from buildings

Breakdown of building emissions by building type 2013 (% of total emissions $MtCO_2e$)



Emissions from fuel use is based on the energy use by fuel type from Office of Chief Economist table F (2015) and the emissions intensity of each fuel type from Department of Environment National Greenhouse Account Factors (2014).

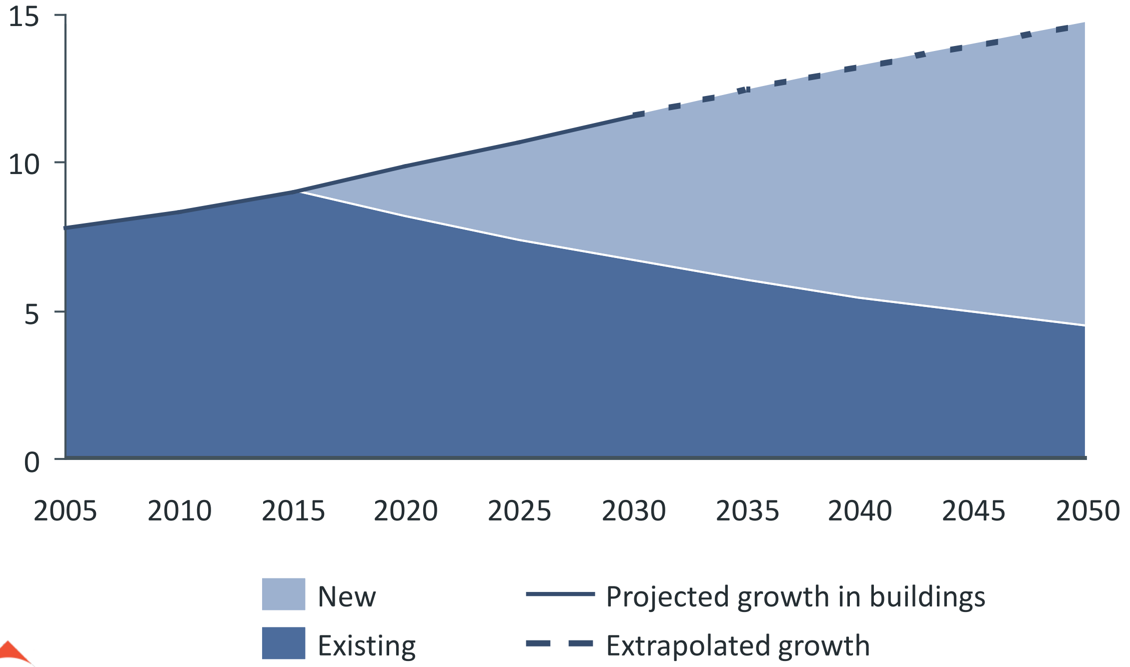
Emissions from Electricity based on electricity use from Office of Chief Economist table F (2015) with emissions intensity of electricity estimated based emissions in the National Greenhouse Gas Inventory (DoE 2015) and electricity production from ESAA (2015).

Fugitive emissions from refrigerant gasses is estimated based on National Greenhouse Gas Inventory (DoE, 2015b).

Future emissions intensity for fuels is assumed to remain constant and emissions intensity from electricity is adapted from ACIL Allen modelling as detailed on slide 40.

Baseline change in the stock of residential buildings

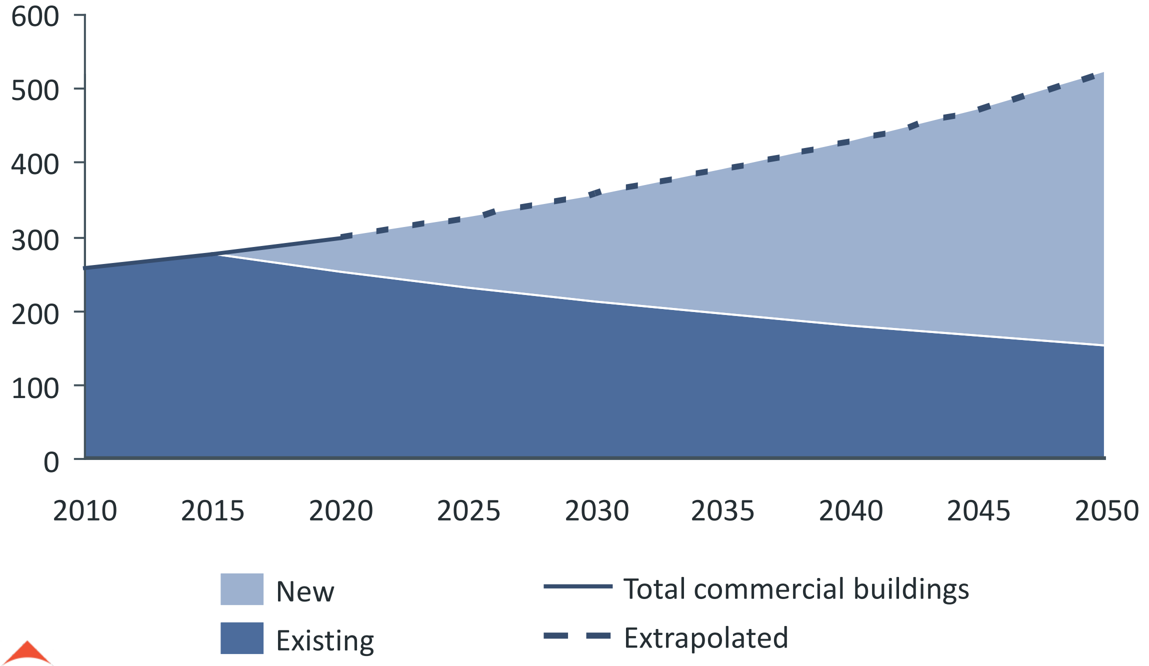
Number of new and existing residential buildings assumed in the modelling (millions of dwellings)



- Total number of households to 2031 based on ABS 2010 series 2
- Number of households to 2050 based on the assumed relationship between number of households and population and extrapolated based on population forecasts in ABS 2013
- “Existing” building stock reduces consistent with a 50 year asset life assumed to come from demolition and substantial retrofit

Baseline change in the stock of commercial buildings

Assumed floor-space of new and existing commercial buildings (million m^2)

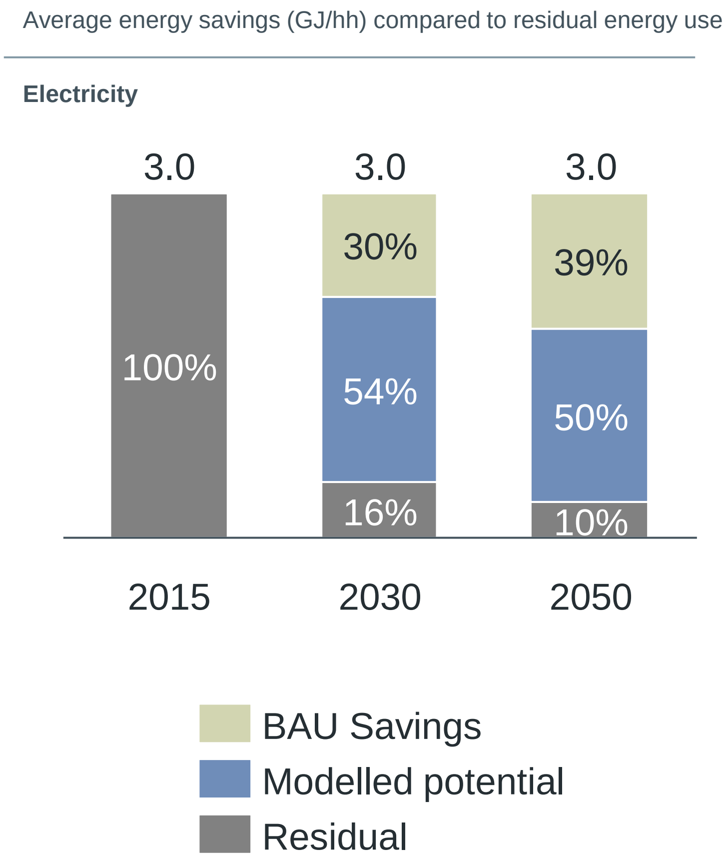


- Buildings from 2010 to 2020 is based on estimates from Pitt & Sherry (2012), extrapolated based on coverage of study relative to total sector energy use.
- Energy use based on floor area by building type and relative energy intensity of fuel use per unit of floor space for offices, retail, education, health accommodation, industrial and other buildings.
- Total buildings from 2020 to 2050 based on continuation of forecast trends from Pitt & Sherry (2012)
- "Existing" building stock reduces consistent with a 60 year asset life assumed to come from demolition and substantial retrofit

Contents

Energy Efficiency Potential
Lighting

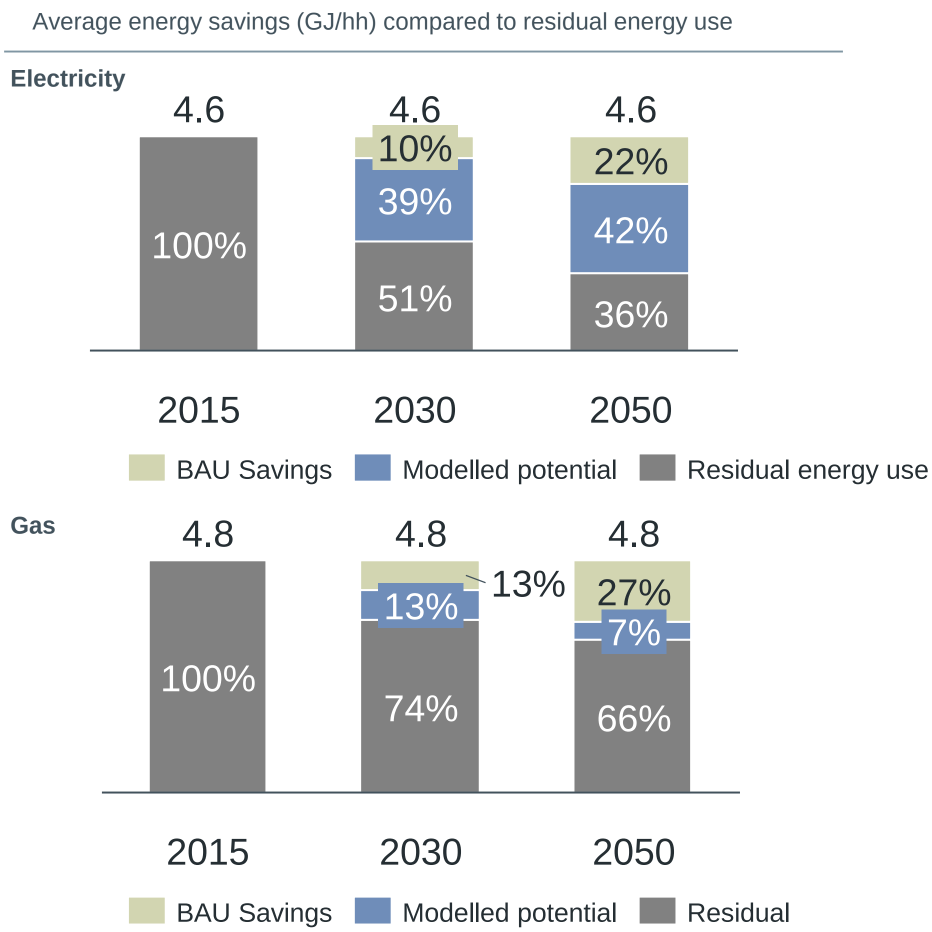
- **Description:** Assumes all lighting switched to LED or efficient fluorescent by 2030.
- **Total Potential Saving:** 84% of electricity by 2030 with continuous improvement delivering 90% savings by 2050 (BZE, 2013). Uptake of LED in business as usual yields a 39% savings.
- **Average Payback period:** 1.6 years



(BZE 2013)

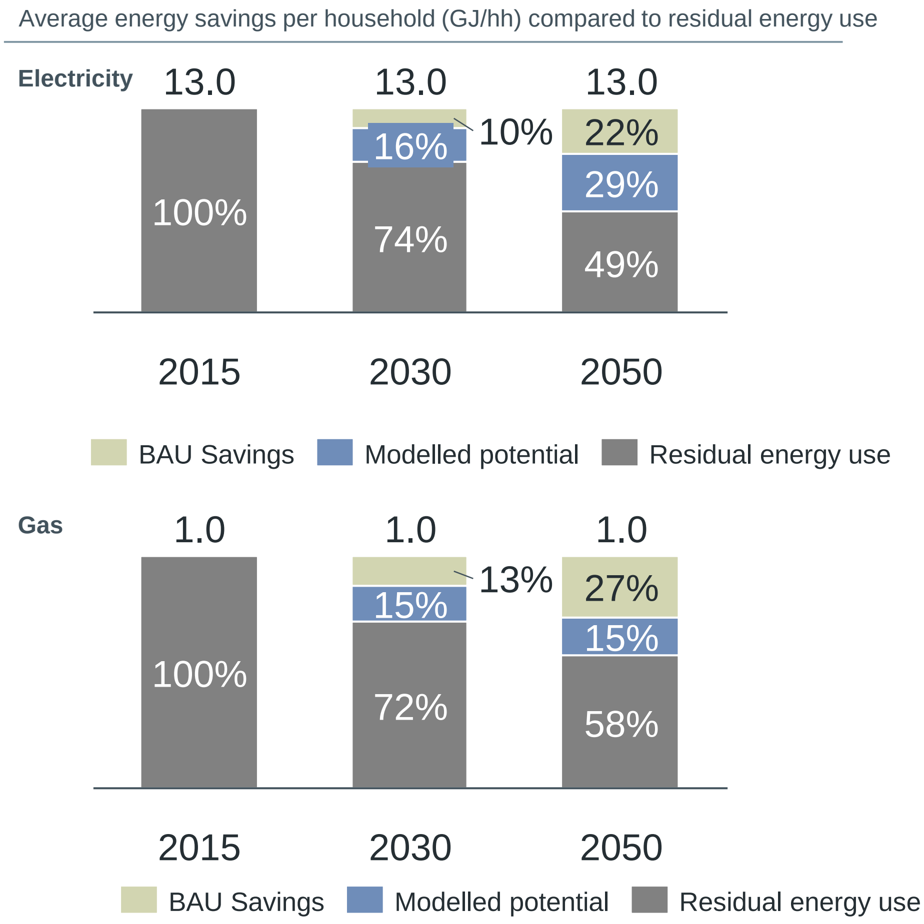
Energy Efficiency Potential
Hot water

- **Description:** Replacement of electric resistance hot water with heat pump. Replacement of gas hot water with efficient instantaneous (fuel switch from gas to electric modelled separately). Installation of water savings showerhead
- **Total Potential Savings:** 64% of electricity and 34% of gas by 2050 (IEA, 2011), (ClimateWorks Australia, 2012)
- **Average payback period:** 6.2 years



Energy Efficiency Potential Appliances

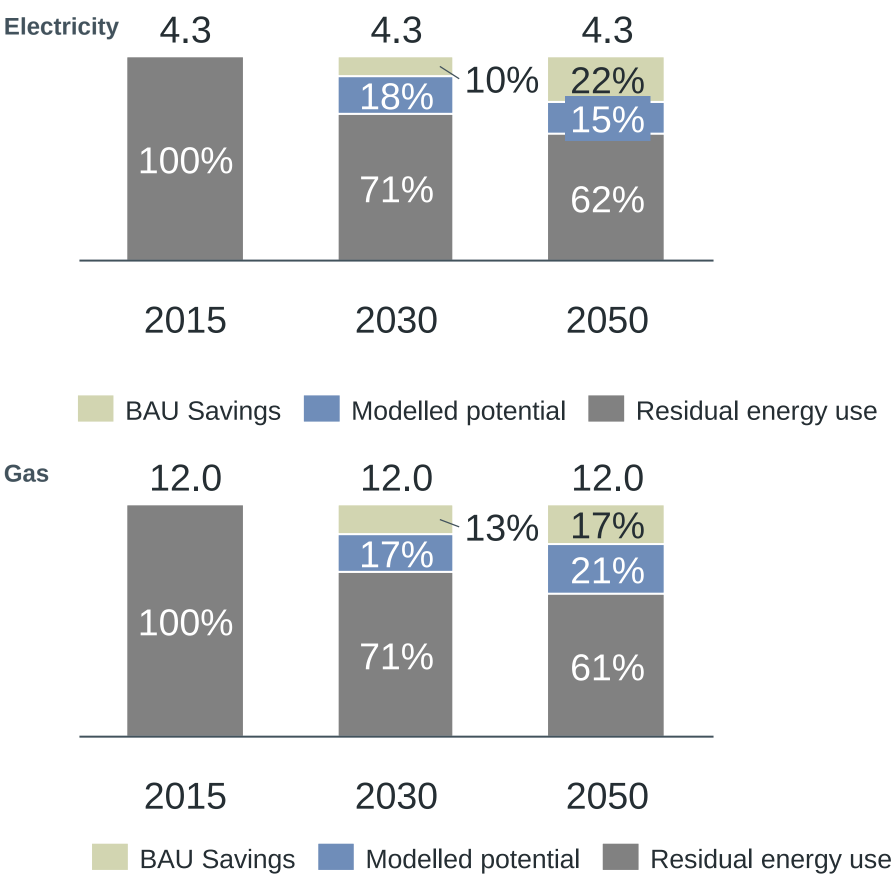
- **Description:** Upgrade to high efficiency appliances, assumed best on market technology today is standard in 2030 and best available technology is standard to 2050
- **Potential Savings:** 51% of electricity and 42% of gas by 2050 (E3 Equipment Energy Efficiency, 2016)
- **Average Payback Period:** 5.9 years



Energy Efficiency Potential
HVAC

- **Description:** Basic retrofit including sealing areas of air leakage, weather stripping doors and windows, insulating attic and wall cavities. Replacement of air conditioners/space heaters and improved maintenance (improved duct insulation, correct level of refrigerant and new air filters)
- **Total Potential Savings:** 38% of electricity and 39% of gas by 2050 (ClimateWorks Australia, 2010)
- **Average Payback Period:** 3 years

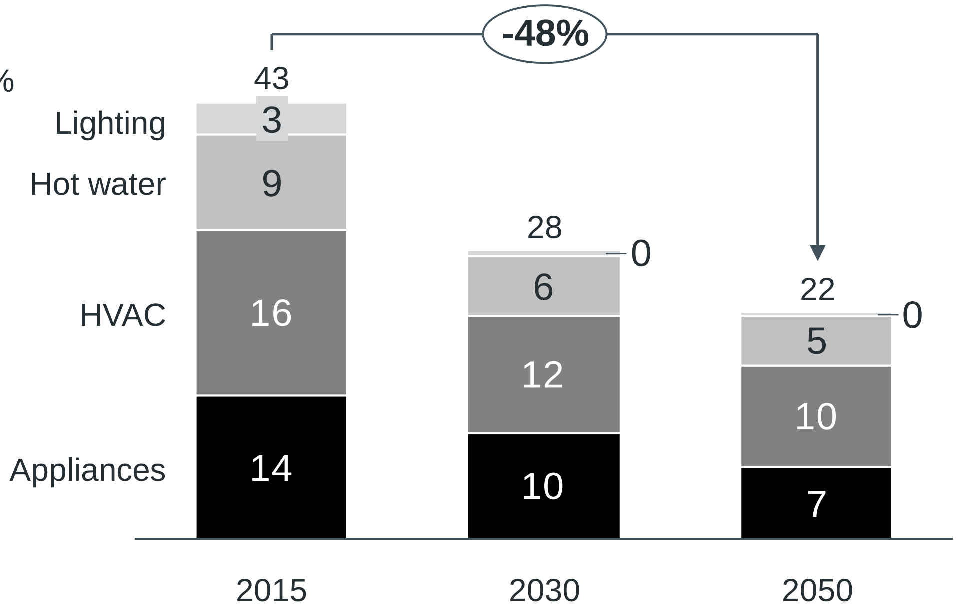
Average energy savings per household (GJ/hh) compared to residual energy use



Energy Efficiency Potential Outcome – Existing buildings

- Overall, base data suggests electricity and gas use in existing buildings could decrease by 48% between today and 2050

Residual energy use per household after energy efficiency (GJ/hh)

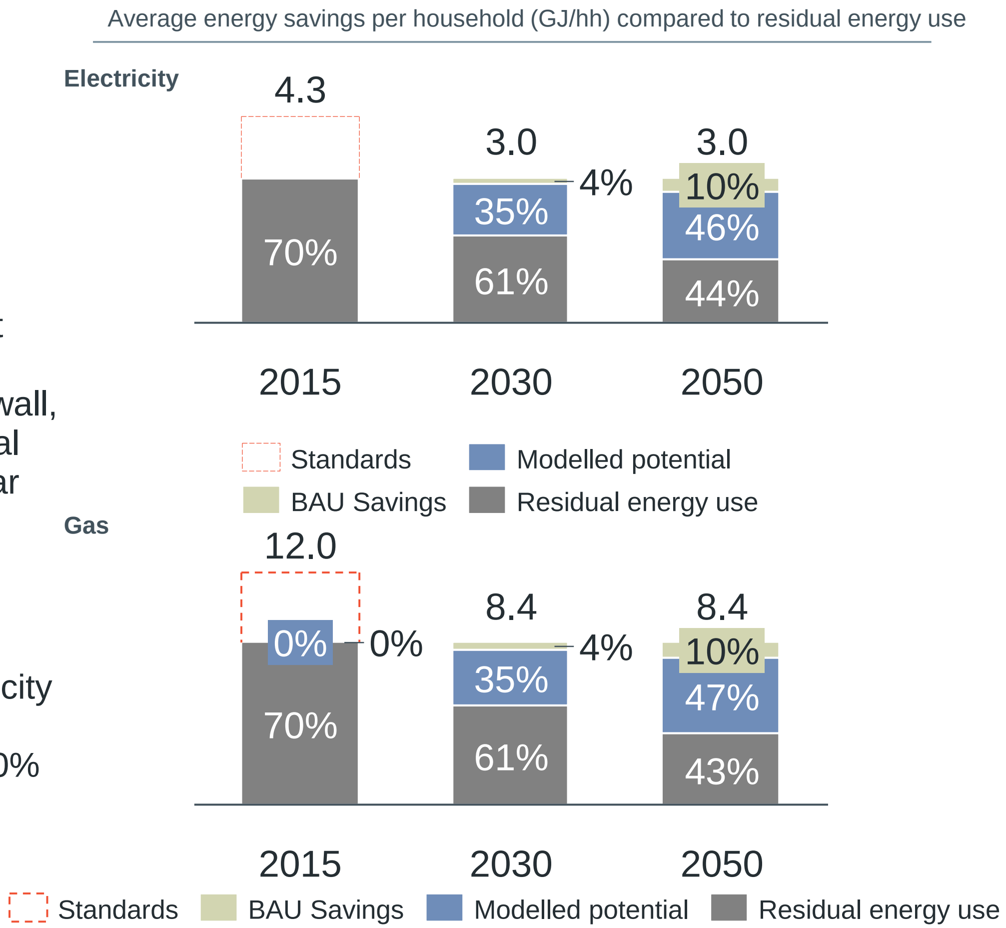


This graph does not include other fuels such as coal, oil and biomass as these are modelled to switch to gas and electricity by 2030

Contents

Energy Efficiency Potential
HVAC

- **Description:** Standards lead to 30% efficiency below existing buildings (assuming some non-compliance)
- All new buildings are built to a 7.2 star standard from 2019 to 2030 based on assessment of cost effective mitigation. Includes installing high efficiency windows and doors; increasing outer wall, roof, and basement ceiling insulation; mechanical ventilation with heat recovery, basic passive solar principles.
- Assumes that energy efficiency improves with trends to 2050.
- **Total Potential Savings:** 56% savings of electricity by 2050 and 57% savings of gas by 2050 (ClimateWorks Australia, 2010). This includes 10% autonomous improvement in BAU
- **Average Payback Period:** 6 years

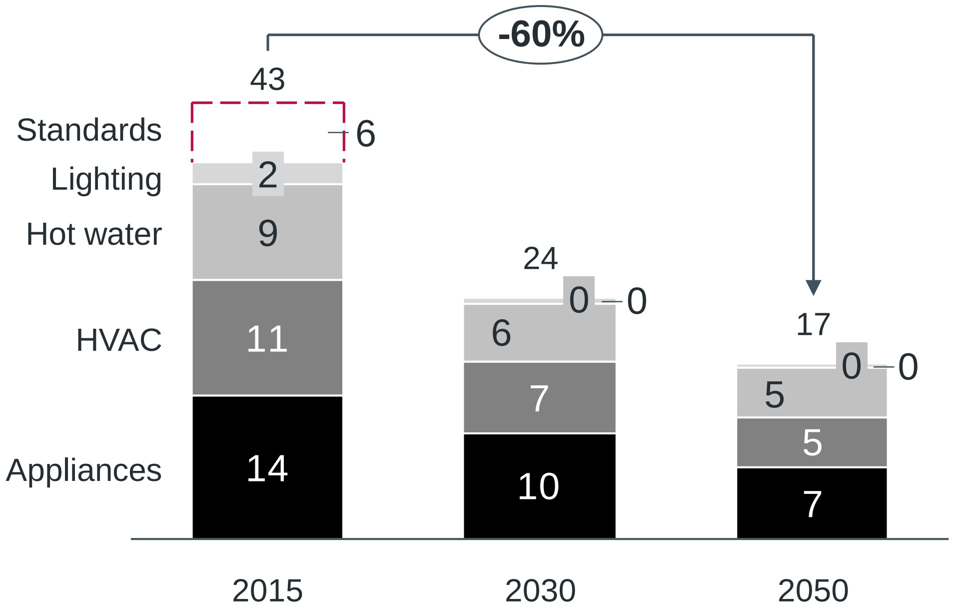


Energy Efficiency Potential Outcome – New buildings

- Overall, base data suggests electricity and gas use in new buildings could decrease by 60% between today and 2050

Note: savings available in appliances and hot water are assumed to be the same as for existing buildings

Residual energy use per household after energy efficiency (GJ/hh)



This graph does not include other fuels such as coal, oil and biomass as these are modelled to switch to gas and electricity by 2030

Contents

Switching gas use to electricity can reduce emissions from buildings, with a switch to decarbonised distributed or centralised electricity reducing emissions to near zero

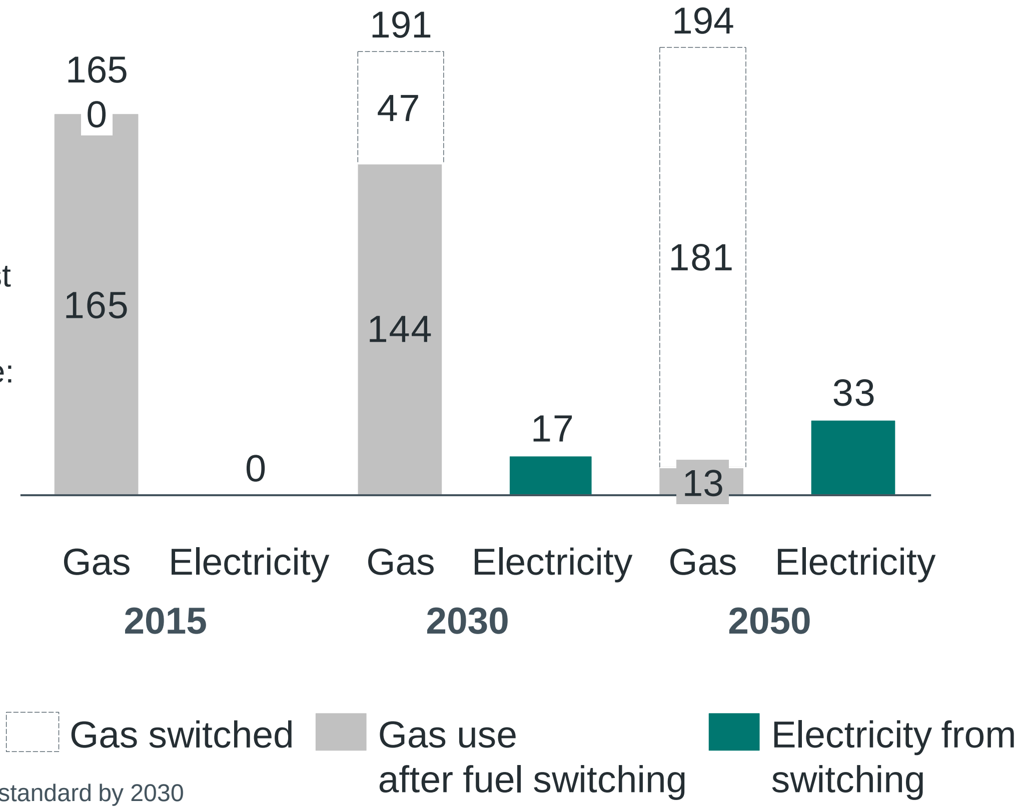
Key assumptions

Over 92% of direct fuels assumed to be able to switch to electricity by 2050 cost effectively, with HVAC and hot water being most attractive.

Uptake before 2030 assumed to occur in new buildings to abate costs of gas connection using best in market technology.

After 2030, 1 unit of electricity is assumed to replace:

- 7 unit of direct fuel in space heating* post 2030, 3 units pre 2030
- 5 unit of direct fuel in water heating* post 2030, 2.5 units pre 2030
- 2 unit of direct fuel in other applications (e.g. cooking, not generally considered profitable to switch)

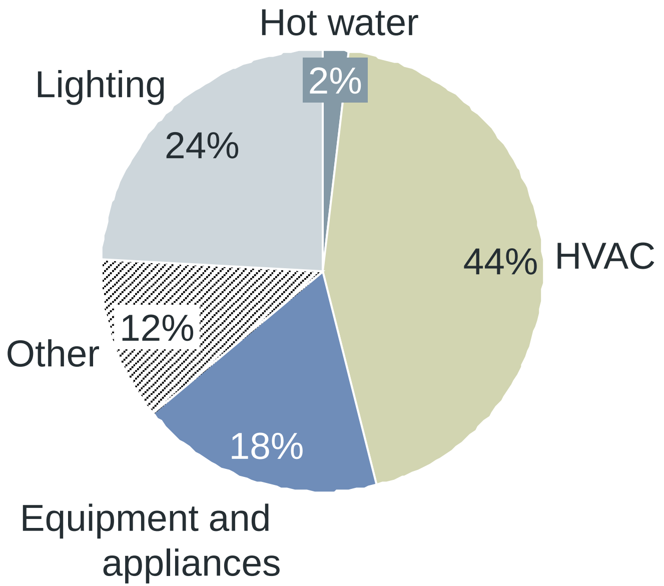


*Assumes best in class technology from IEA 2011 becomes standard by 2030

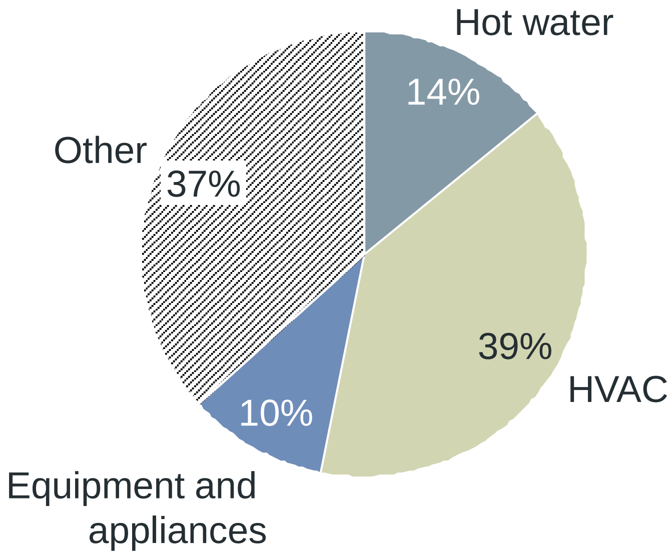
Contents

A high proportion of the sector's energy use is from HVAC although there are significant gaps in the data on energy end use

Proportion of electricity use in commercial buildings (pitt&sherry, 2012)



Proportion of gas use in commercial buildings (pitt&sherry, 2012)

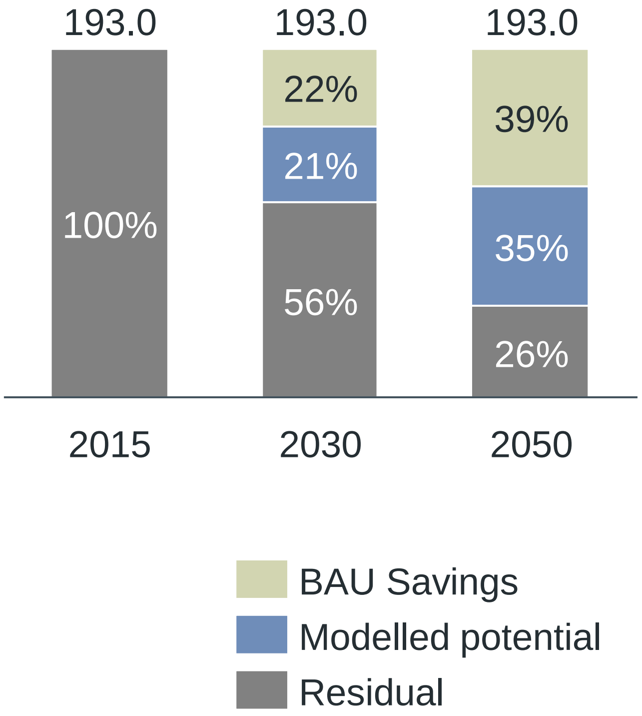


Other energy use is modelled as "equipment and appliances" for the purposes of this report.

Energy Efficiency Potential
Lighting

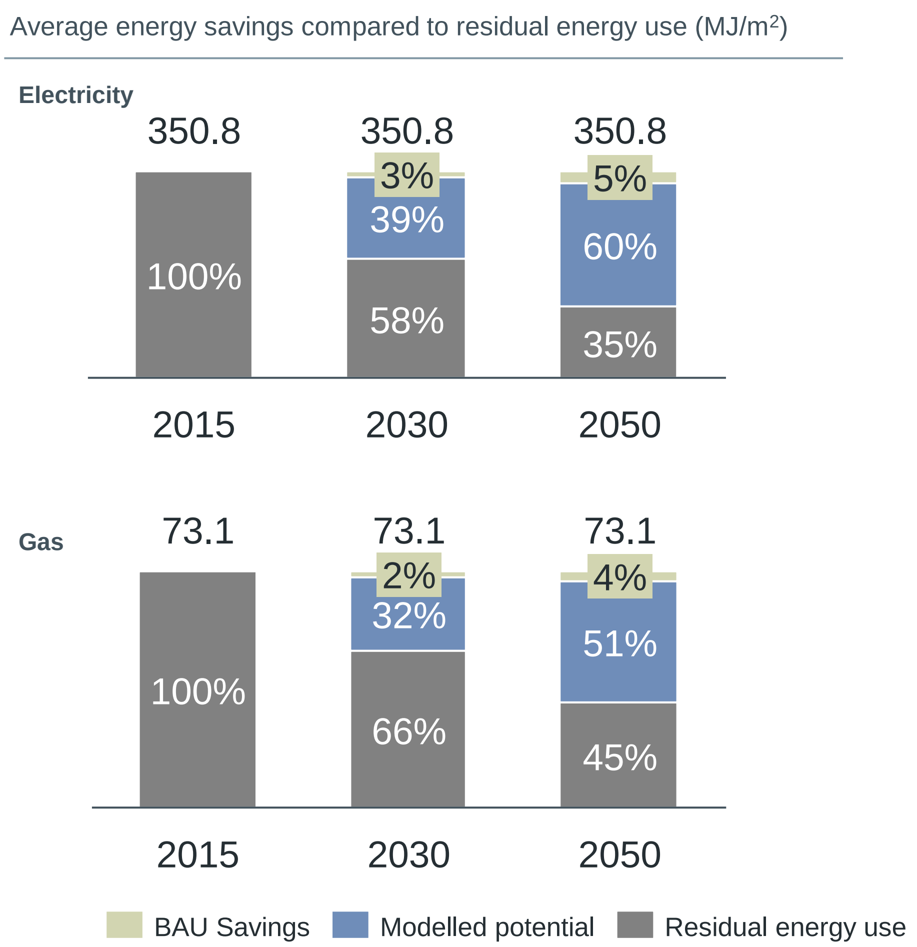
- **Description:** Lighting upgrades to most efficient LED and fluorescent technology equivalent to $5W/m^2$ to 2030. Assumes a linear rate of improvement in performance of LED from 2030.
- **Potential savings:** 74% on average in 2050
- **Average payback:** 2 years

Average energy consumption and savings (MJ per m^2) compared to residual energy use



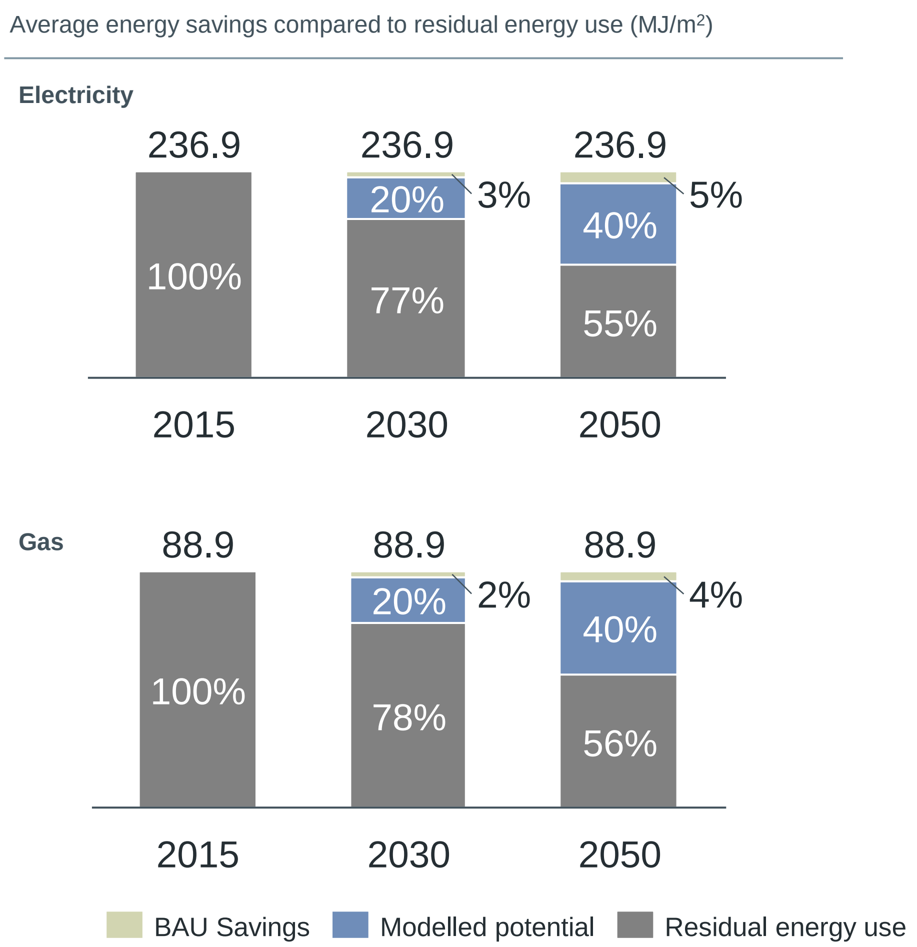
Energy Efficiency Potential
Commercial Retrofit HVAC

- **Description:**
  - Replace HVAC with highest efficiency system, improve building insulation, Improve HVAC control systems.
  - Improved operation of HVAC through building management systems
- **Potential savings:** 65% savings of electricity and 55% of gas on average by 2050 (ClimateWorks Australia, 2010).
- **Average payback period:** 2.7 years



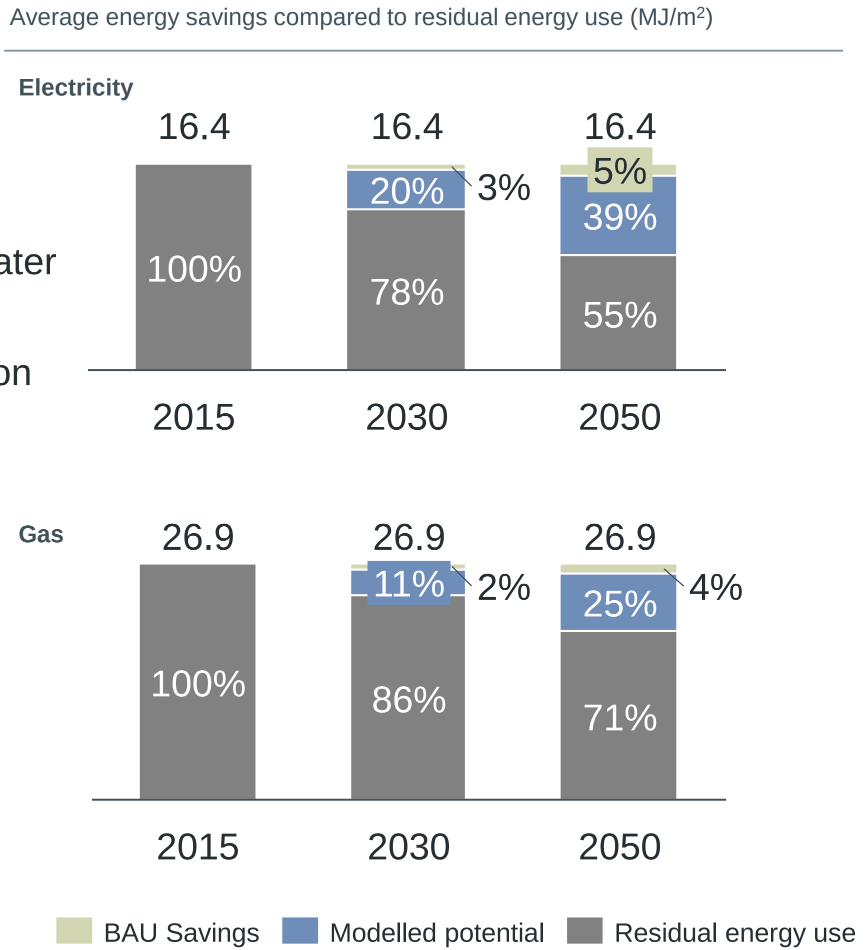
Energy Efficiency Potential
Electronics, Appliances & Elevators

- **Description:**
  - Replacement by high-efficiency (best identified technology (Identified through E3 Equipment Energy Efficiency, 2016)
- **Potential Savings:** 45% savings of electricity and 44% savings of gas on average by 2050 (ClimateWorks Australia, 2010)
- **Average Payback:** 1.5 years



Energy Efficiency Potential Water Heating

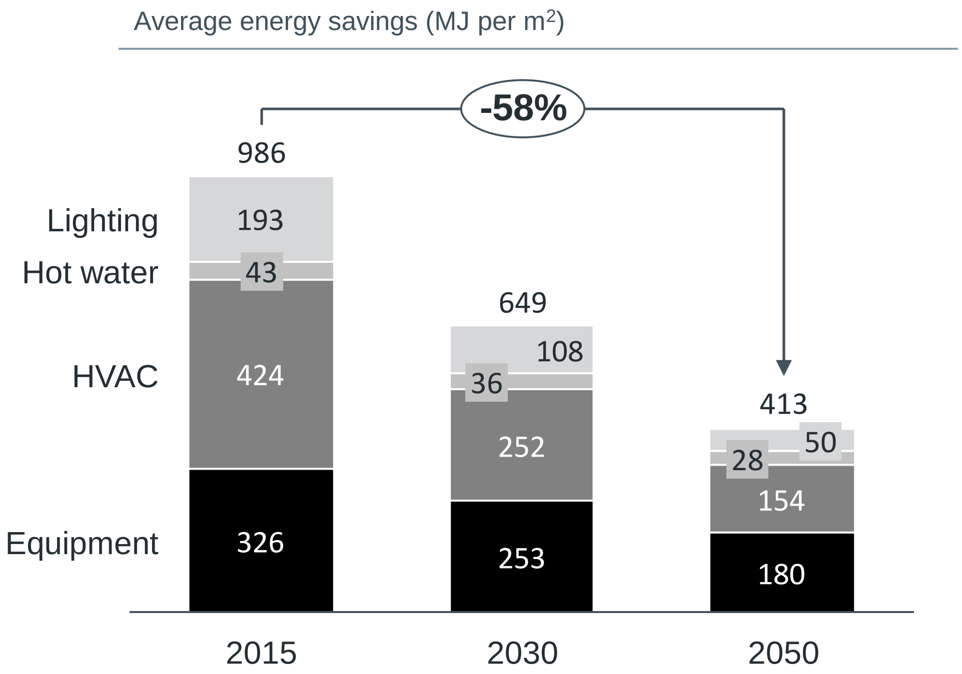
- **Description:** replace standard gas water heaters with tankless gas, condensing gas, or solar water heater; replace electric water heater with heat pump or solar water heater
- **Potential savings:** 45% savings of electricity and gas on average by 2050 (ClimateWorks Australia, 2010)
- **Average Payback:** 4.6 years



Energy Efficiency Potential
Existing commercial buildings

- Overall, base data suggests electricity and gas use in existing buildings could decrease by **58%** between today and 2050

This graph does not include other fuels such as coal, oil and biomass

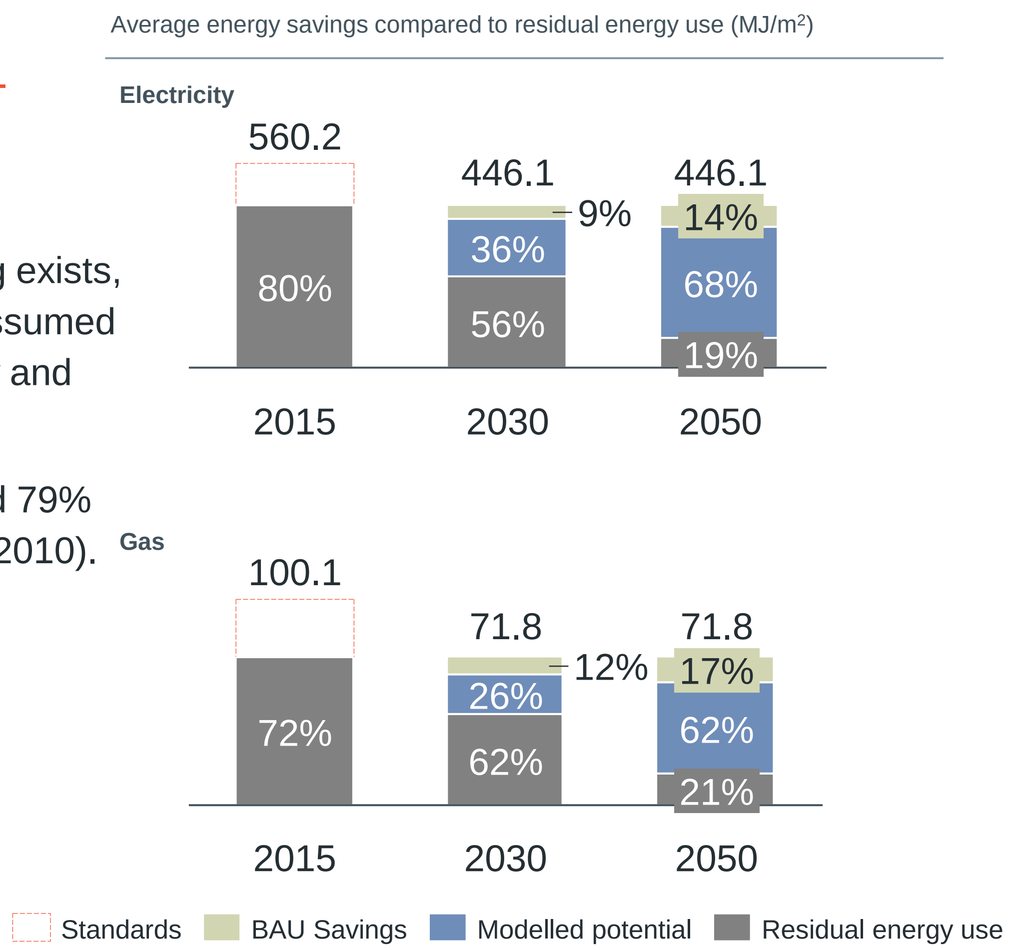


This graph does not include other fuels such as coal, oil and biomass as these are modelled to switch to gas and electricity by 2030

Contents

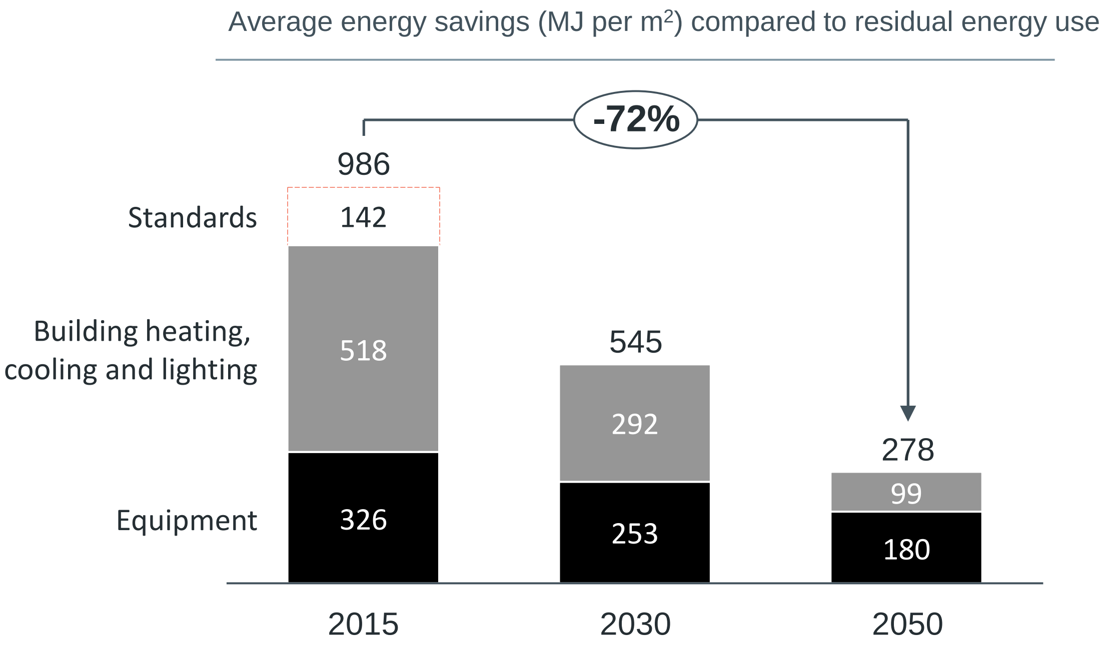
Energy Efficiency Potential
Building heating, cooling and lighting – New build

- **Description:** All new builds to a NABERS 6 star equivalent on average from 2019 (where no rating exists, equivalent savings above BAU). New buildings assumed to be 20% more efficient on average for electricity and 28% more efficient
- **Potential Savings:** 81% savings of electricity and 79% savings of gas by 2050 (ClimateWorks Australia, 2010).
- **Average payback:** 5.2 years



Energy Efficiency Potential
New commercial buildings

- Overall, base data suggests energy use in existing buildings could decrease by **72%** between today and 2050



This graph does not include other fuels such as coal, oil and biomass as these are modelled to switch to gas and electricity by 2030

Contents

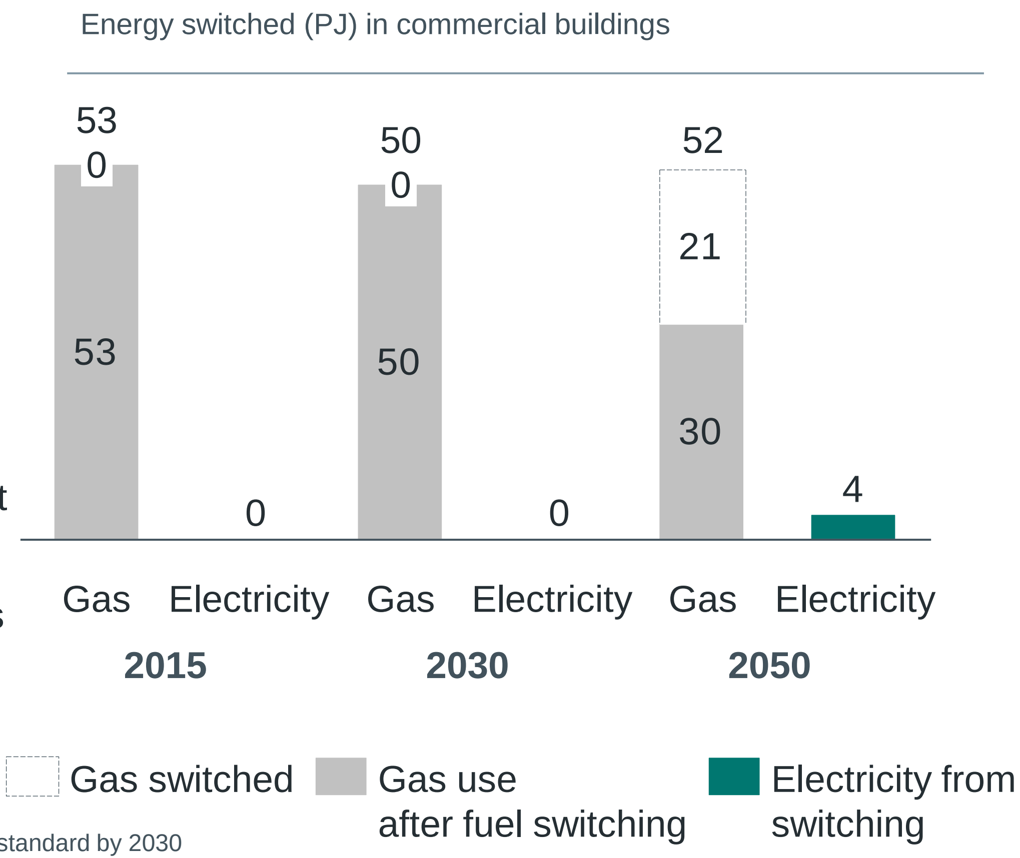
Switching gas to a decarbonised electricity supply can reduce emissions from buildings to near zero

Key assumptions

40% of direct fuels assumed to be able to switch to electricity by 2050, starting in 2030, primarily for heating and hot water.

1 unit of electricity is assumed to replace:

- 7 units of direct fuel in space heating and 5 units of direct fuel in water heating assuming use of highly efficient heat pumps*
- 1 unit of direct fuel in other applications (poorly defined use of gas in many commercial buildings Pitt & Sherry 2009)

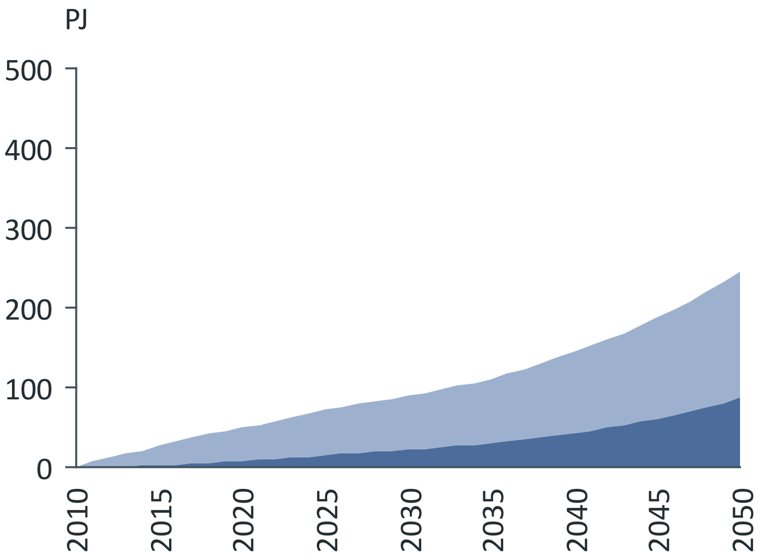


*Assumes best in class technology from IEA 2011 becomes standard by 2030

Contents

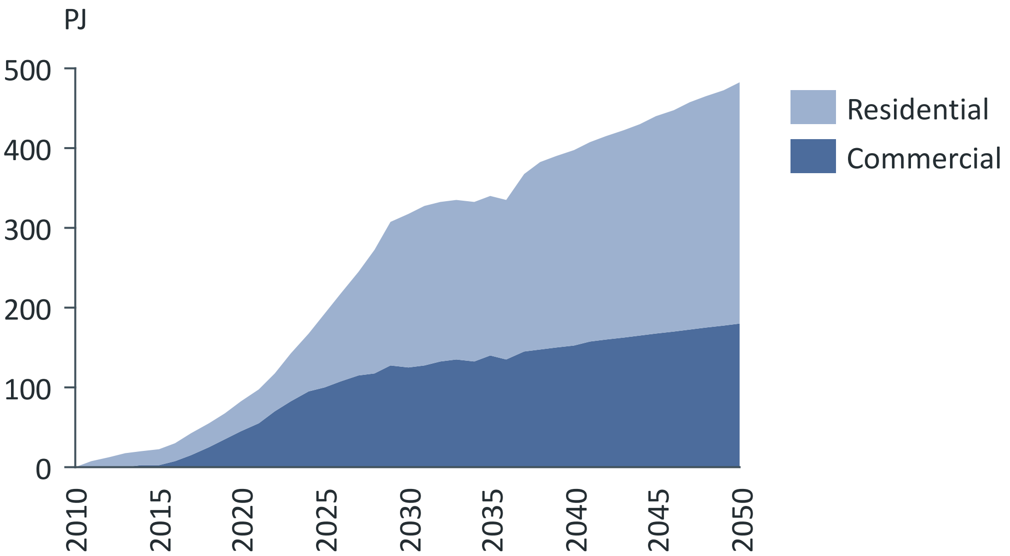
A range of previous modelling exercises show the potential uptake of distributed solar in residential and commercial sectors.

This report does not model the potential uptake of distributed generation or integrated solar and storage systems. A range of previous modelling such as Graham et al., (2015) show the potential for solar uptake in residential and commercial buildings. The AEMO scenario has been used as a proxy for Business as Usual scenario. The rise of prosumer shows a potential maximum potential under very advantageous conditions for the uptake for PV, this scenario is used to present an illustrative high end of potential uptake across the sector.



Scenario 1 (BAU) – AEMO

Source: AEMO (2015), Emerging Technologies Information Paper



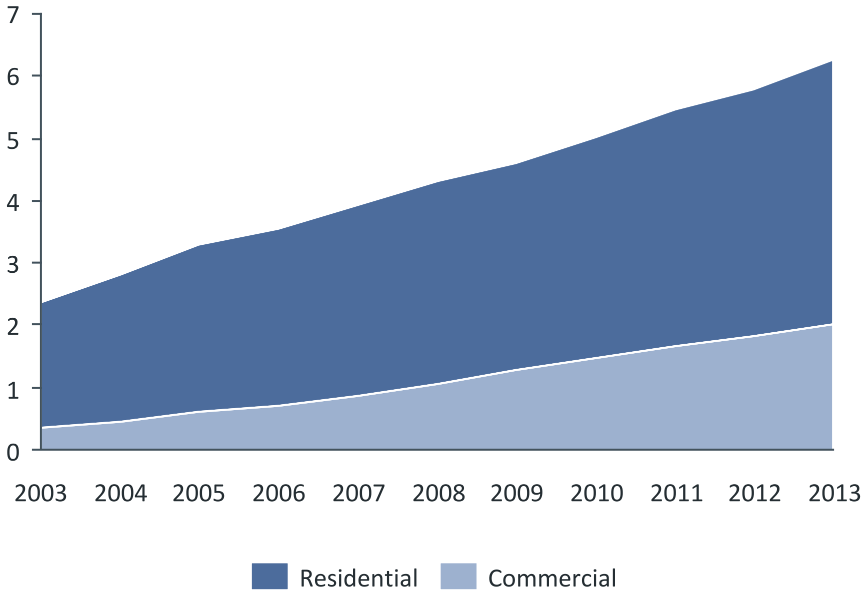
Scenario 2 (High) –Graham et al., Rise of the prosumer

Source: Graham el al. (2015), Electricity Network Transformation Roadmap, Future Grid Forum – 2015 Refresh

Contents

Emissions from refrigerant gasses in the national inventory have increased rapidly as refrigerant gasses measured in the Kyoto protocol replace ozone depleting gases

Emissions from refrigerant gasses in residential and commercial buildings ($MtCO_2e$) *(Department of Environment 2015)*



Emissions from refrigerants in the national inventory have increased from just over 2 $MtCO_2e$ to over 6 $MtCO_2e$ from 2003 to 2013.

Much of this rise has come as chlorofluorocarbon (CFCs) and hydrochlorofluorocarbons (HCFCs) – gases which are not accounted for in Kyoto reporting - have been phased out and replaced with hydrofluorocarbons (HFCs) that are accounted for in Kyoto reporting.

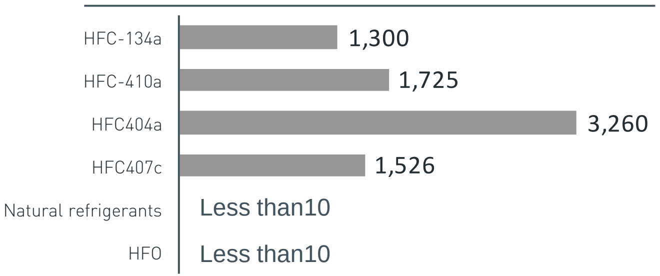
Despite an increase in reported emissions it is likely that actual emissions have decreased, as CFCs have higher global warming potential than HFCs despite not being counted in Kyoto reports.

The emissions from refrigerant gases are difficult to measure given the very high number of potential points of emissions and unknown rates of leakage, replacement etc.

Estimates of emissions vary between sources, national inventory emissions are presented here and used for the modelling of this report, although these emissions are higher than Expert Group (2015), who estimate emissions using a very detailed stock model.

The emissions intensity of refrigerant gases varies significantly from over 3,000 times more powerful than carbon dioxide to effectively zero

100 years Global Warming Potential (GWP)* of major refrigerant gases, (McCann 2012, IPCC 2007)



* Presents IPCC 2nd Assessment Report GWP factors for all non-CFC gasses, this is the factor currently used in government inventories. Factors for CFCs are from IPCC's more recent 4th Assessment Report, as these gases are not included in government inventories

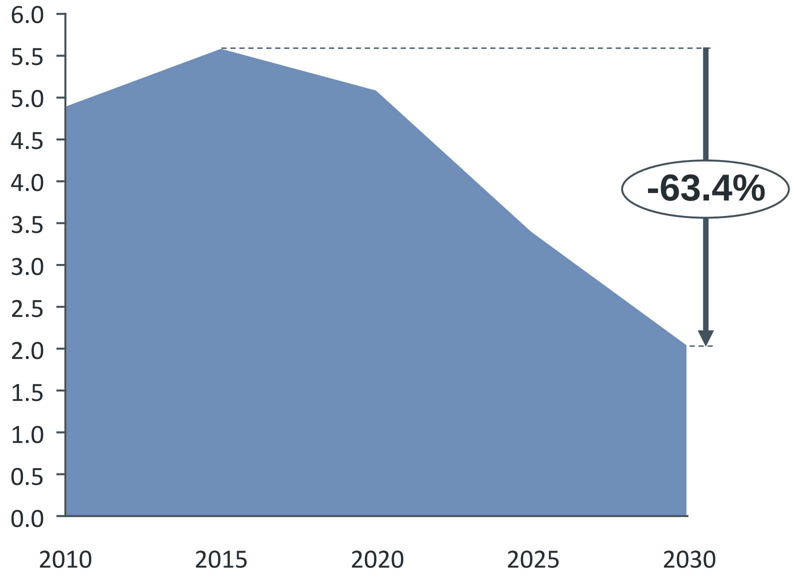
Natural refrigerants and low GWP synthetic refrigerant gasses such as HFO can substitute for high global warming potential gases in most applications.

In many cases these gases offer greater performance of refrigeration per unit of energy.

The technology is available for implementation of low greenhouse potential refrigeration in most application in the built environment, particularly in domestic refrigeration, domestic air conditioning and large commercial air conditioning. Further commercial development is required for full implantation of low greenhouse refrigerants in applications such as Centrifugal Chillers. Medium Air conditioning and some remote applications (Expert Group, 2015).

Reduced leakage and the planned phase out of many high global warming potential refrigerants is expected to reduce emissions significantly in the coming decades

Projected change in emissions from refrigerant gasses in business as usual ($MtCO_2e$) *(Expert Group, 2015)*

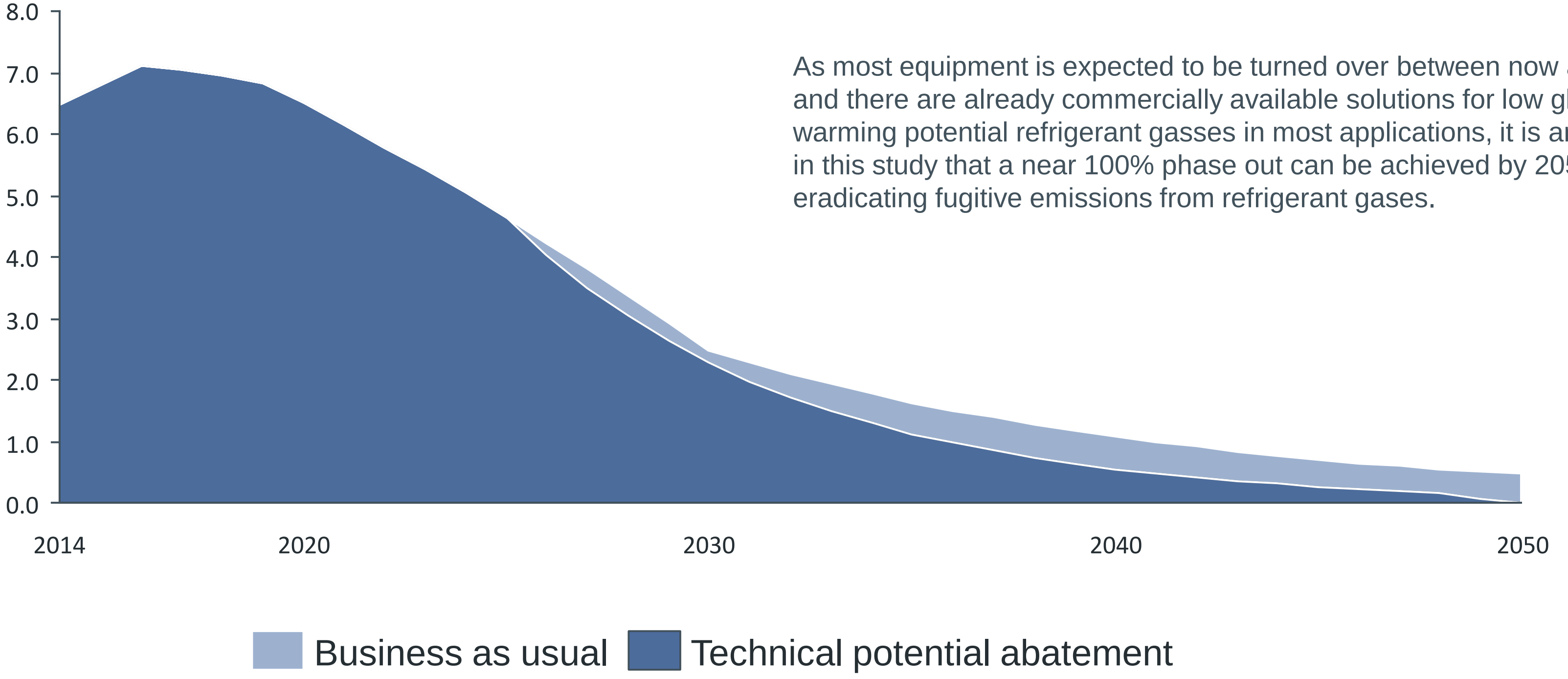


Policies are in place to reduce emissions by 85% by 2035, with Expert Group projecting a reduction in emissions of more than 60% by 2030.

Estimates of emissions from the Expert Group are lower than the national inventory figures which used in the modelling of this report.

A near eradication of fugitive refrigerant emissions is deemed feasible in a decarbonised scenario

Modelling assumptions for business as usual and abatement scenarios ($MtCO_2e$) *(ClimateWorks analysis)*

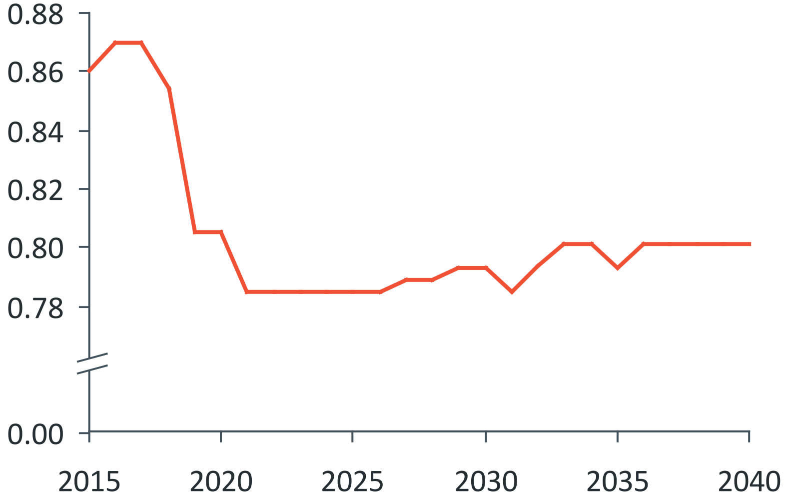


As most equipment is expected to be turned over between now and 2050 and there are already commercially available solutions for low global warming potential refrigerant gasses in most applications, it is anticipated in this study that a near 100% phase out can be achieved by 2050, nearly eradicating fugitive emissions from refrigerant gases.

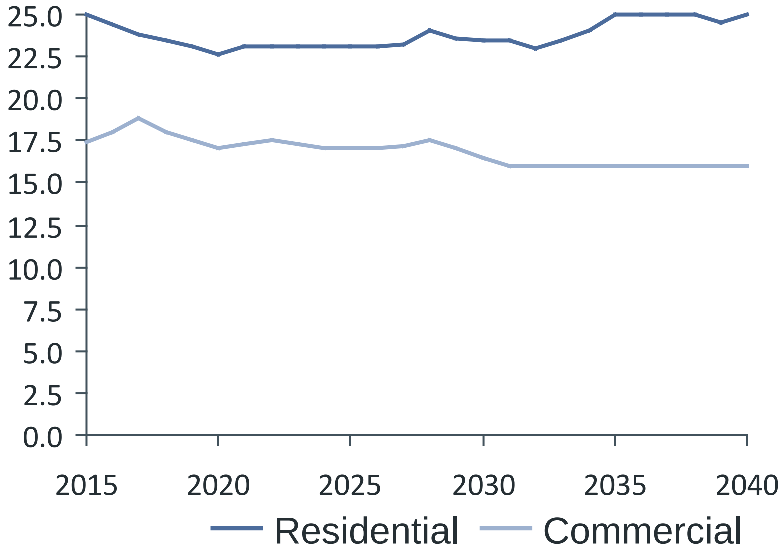
Contents

Electricity costs and modelling in the base case of the modelling comes from ACIL Allen (2014) modelling for the RET review Expert Panel.

Emissions intensity of electricity (tCO2e per MWh Sent out) Proportional point between Reference and Real 20% scenarios to reflect change in RET



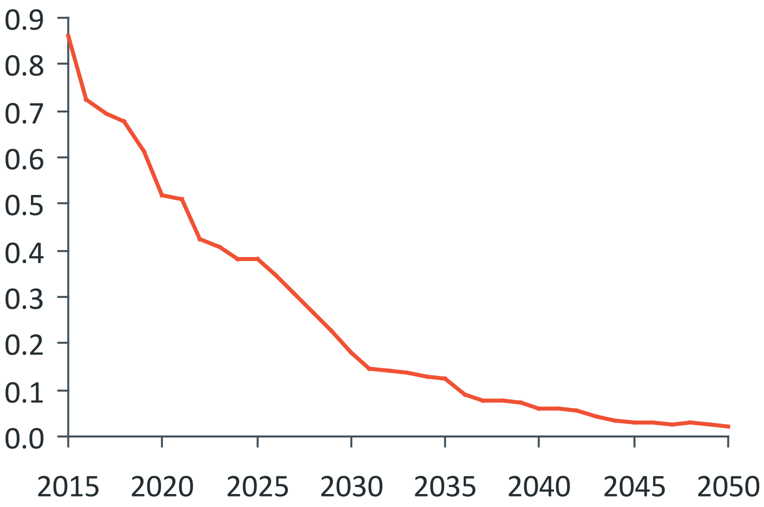
Residential and commercial energy costs (c/kWh) Proportional point between Reference and Real 20% scenarios to reflect change in RET



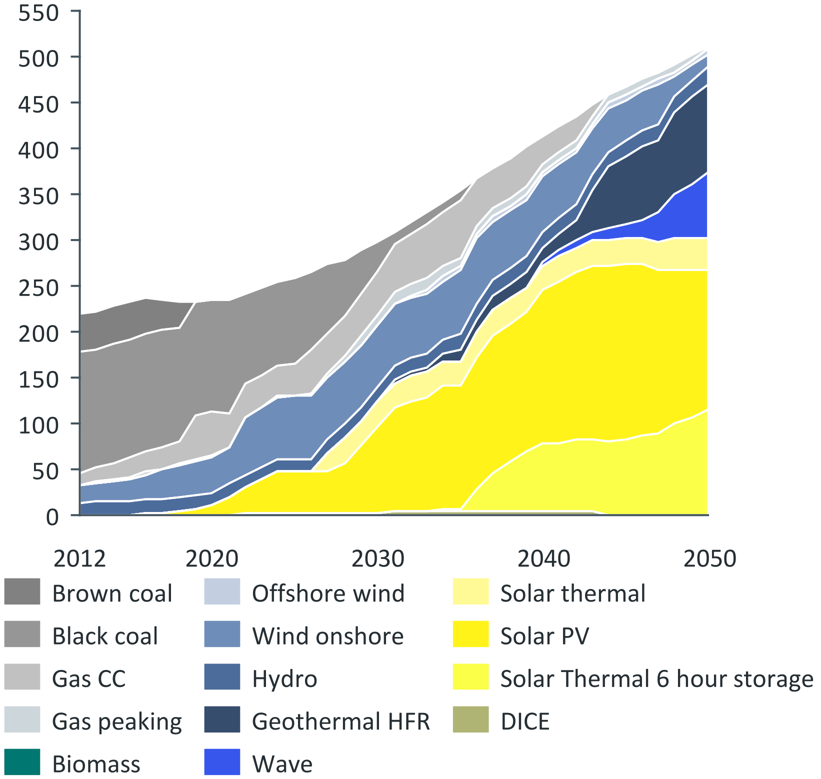
Energy costs and emissions intensities extrapolated to 2050 based on average of 2035 to 2040)

The emissions intensity from ClimateWorks and ANU's Deep Decarbonisation Pathways project was used to illustrate outcomes under a decarbonised grid scenario

Emissions intensity of grid electricity, based on CSIRO modelling for ClimateWorks and ANU (2014)



Electricity generation profile 100% renewable energy grid, based on CSIRO modelling for ClimateWorks and ANU (2014)



Contents

Loss of energy efficiency potential from delay

- Scenario developed where no action above the business as usual occurs to 2020. This inaction reduces energy efficiency improvement above BAU to zero in years 2016 to 2020.

- During the delay period, energy efficiency is “locked-out” as new equipment is installed that is less efficient than the potential in the “High scenario”

- Energy efficiency in the delay scenario converges with energy efficiency in the high scenario within one equipment lifecycle of the delay

Equipment	Assumed average life
Commercial - Existing buildings - Appliances	10
Commercial - Existing buildings - Hot water	15
Commercial - Existing buildings - HVAC - central	15
Commercial - Existing buildings - Lighting	10
Commercial - New buildings - Building heating, cooling and lighting, incl. building envelope	28
Commercial - New buildings - Equipment	10
Residential - Existing buildings - Appliances	10
Residential - Existing buildings - Hot water	15
Residential - Existing buildings - HVAC - central	15
Residential - Existing buildings - Lighting	10
Residential - New buildings - Appliances	10
Residential - New buildings - Hot water	15
Residential - New buildings - HVAC - central incl. building envelope	47
Residential - New buildings - Lighting	10

Contents

Segmentation of commercial buildings opportunity

- The segmentation was established based on estimated 2020 emissions by subsector
- The data used to build these estimates was sourced from Pitt & Sherry (2012) and ClimateWorks Australia (2010):
  - We used estimated floorspace by subsector from Pitt & Sherry (2012) for all subsectors covered in their analysis, and completed with estimated floorspace for the industrial sector from ClimateWorks Australia (2010)
  - We used estimated energy intensity (GJ/m2) by subsector from Pitt & Sherry (2012) where provided. We extrapolated energy intensity values for other subsectors based on Pitt & Sherry (2012) and ClimateWorks Australia (2010), calibrated with total energy use in the sector (OCE, 2015)
  - We used a similar approach to determine an average emissions intensity of energy by subsector (based on the fuel mix provided and BAU fuel emissions intensities)

Segmentation of commercial buildings opportunity

Segment Name	Segment Scope	Source of data
Retail	Shopping Centres, Supermarkets, Retail Strip (Outside shopping areas)	Pitt & Sherry, 2012
Offices	Stand alone and non-stand alone offices	Pitt & Sherry, 2012
Education	Universities, TAFEs/VET, Schools	Pitt & Sherry, 2012
Health	Hospitals	Pitt & Sherry, 2012
Accommodation	Hotels	Pitt & Sherry, 2012
Industrial	Wholesale facilities	ClimateWorks Australia, 2010
Other	Food service (Restaurants, cafes, pubs, bars, clubs), Public Buildings, Law Courts, Correctional Centres	Pitt & Sherry, 2012

*Embedded assumptions for wholesale facilities are drawn from *Unlocking Energy Efficiency in the U.S. Economy* by McKinsey & Company (2009). Estimates for floor space and energy consumption are scaled to derive Australian estimates - further detail on the scope of McKinsey's estimates, and building types included in their classification, is not available

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Financial analysis of the value of energy savings

The net present value (NPV) of energy savings is the primary metric used to present the financial benefits of energy savings projects in this report. NPV presents the difference between the present value of cash inflows and the present value of cash outflows. The formula for calculating NPV is:

$$NPV = \sum_{t=1}^{T} \frac{C_t}{(1+r)^t} - C_0$$

Where:
Ct = net cash inflow during the period
Co= initial investment
r = discount rate, and
t = number of time periods

The initial investment is calculated as the incremental upfront costs above a business as usual investment. This assumes that all equipment upgrades are taken up at the end of equipment life and does not consider early retirement of equipment.

The discount rate applied to all investments is 7 per cent, this is consistent with the Commonwealth Government's Office of Best Practice Regulation.

Where projects do not amortise their full capital costs within the modelled a given timeframe (e.g. 2030), only the annual component of the investment up to this date is considered.

This analysis presents the savings available from energy savings measures, after taking into account capital costs. In reality, some of this value will be incurred as transactions costs which include search, identification and brokerage as well as opportunity costs above the assumed discount rate.

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