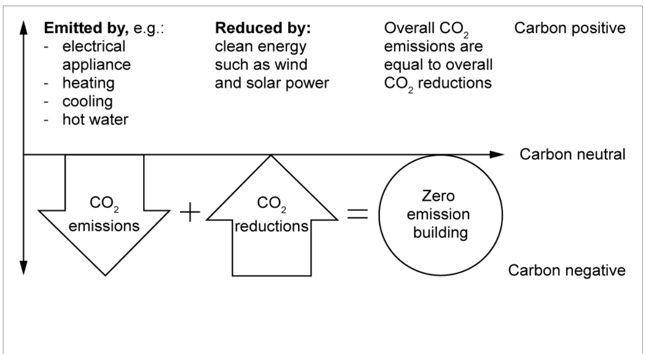
Carbon zero, carbon positive

A long-term sustainable solution to global warming and climate change requires that we eliminate or substantially reduce the amount of carbon being emitted into the atmosphere from human (anthropogenic) activities. It can be achieved by creating carbon zero or carbon positive homes.

Creating carbon zero and carbon positive homes cost effectively takes carefully planned application of the advice in several *Your Home* articles including *Affordability*, *Passive solar heating*, *Passive cooling*, and articles in the *Energy* section: *Hot water service*, *Heating and cooling*, *Renewable energy* and *Smart meters, in-home displays and smart appliances*.

The terms 'carbon zero', 'carbon neutral', 'zero energy' or 'zero emission' apply to buildings that use renewable energy sources on site to generate energy for their operation, so that over a year the net amount of energy generated on site equals the net amount of energy required by the building.



The overall approach to carbon neutrality.

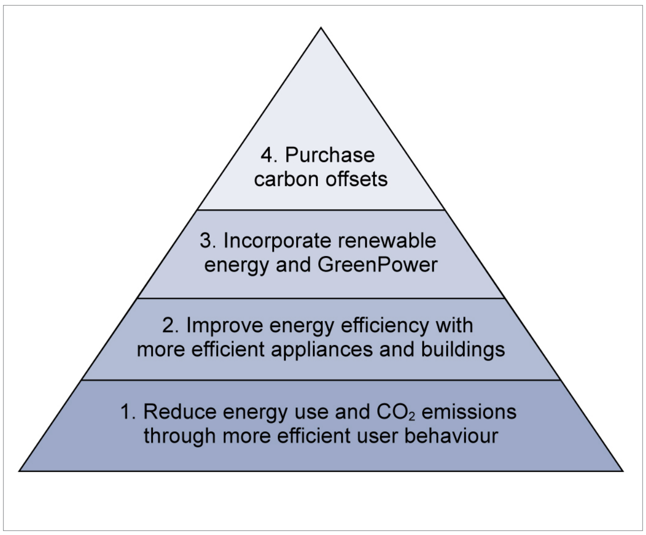
Carbon zero buildings are defined by the Australian Sustainable Built Environment Council (ASBEC) (Riedy et al. 2011) as having no net annual emissions from direct fuel combustion (e.g. burning natural gas) and electricity use from operation of building incorporated services.

- Building incorporated services include all energy demands or sources that are part of the building fabric at the time of delivery, such as the thermal envelope (and associated heating and cooling demand), water heater, built-in cooking appliances, fixed lighting, shared infrastructure and renewable energy generation.
- Zero carbon buildings must meet specified standards for energy efficiency and on-site generation.
- Compliance is based on modelling or monitoring of greenhouse gas emissions in $kgCO_2e/m^2/yr$.

Carbon positive moves beyond carbon zero by making additional 'positive' or 'net export' contributions by producing more energy on site than the building requires and feeding it back to the grid. Carbon positive projects can make significant contributions by helping to address the carbon intensity and damaging impacts of past building practices and lifestyles, and by offsetting situations where carbon zero homes are not possible.

While carbon zero is considered to be today's benchmark of best practice, carbon positive buildings will play an increasingly important role in the future to limit global warming.

When 'carbon positive development' becomes the norm, it will be standard for all housing to offset the carbon emitted to make the house and produce the food, goods and services consumed in it, during its operational lifespan.



Behaviour levels for a carbon zero, carbon positive lifestyle.

Creating a carbon zero home

The ASBEC definition of carbon zero buildings requires that all carbon emissions be offset by on-site renewable energy generation. It can be achieved relatively simply by installing an appropriately sized rooftop solar array or photovoltaic (PV) system (i.e. one that meets all current household needs) but that's often unaffordable.

Achieving carbon zero status cost effectively requires careful design and planning because, while the cost of PV installations has decreased markedly in recent years, this is still a relatively expensive way to offset carbon emissions compared to reducing your energy consumption.

Reducing the amount of energy you use and then increasing the efficiency of your home is the most cost effective place to start. If rooftop solar is not affordable at this time, you can still become carbon zero by subscribing to GreenPower or carbon offsets (*see 'Carbon offsetting' below*).

Design considerations

Designing a carbon zero home requires that each design solution be tailored to the specific location to maximise site advantages like solar or cool breeze access and diurnal temperature variations, or to identify alternative solutions when these are not available.

Designers should have an understanding of how to incorporate renewable energy sources on site and consider actual energy use — which is affected by both building features and occupant behaviour.

Basic principles for designing carbon zero homes used throughout *Your Home* include:

- incorporating energy efficiency strategies with renewable energy options from the outset of the project (see *Energy use*)
- choosing a site that allows for renewable energy generation, passive solar heating and cooling, and food production, and reduces transport (see *Choosing a site*; *Passive solar heating*; *Passive cooling*; *Transport*)
- maximising passive design strategies in the design of the home to reduce energy demand (see *Passive design*; *Passive cooling*)
- reducing water use — particularly hot water (see the section *Water*)
- choosing appropriate materials that enhance the passive design strategy and have a low embodied energy (see the section *Materials*; *Embodied energy*).

Locking in efficiencies

Maximising energy efficiency significantly reduces the amount of renewable energy required to meet your needs without carbon emissions. This improves viability at three levels:

- physical — reduces roof surface area requirements for PV
- economic — needs a smaller capacity system
- environmental — uses fewer resources to manufacture system components.

For example, a typical Sydney home uses around 5,000kWh of electricity per year. By applying the simple efficiency measures in the table on the next page, this can be reduced to 3,000kWh — and your PV system could cost 40% less. Energy savings of up to 80% are possible with carefully designed new homes and lifestyle modifications. System size varies depending on solar incidence in your region and array orientation and tilt angle. (see *Photovoltaic systems*)

Reducing carbon emissions depends on several factors listed in typical order of cost effectiveness when included in new housing and major additions:

- lifestyle emission reductions
- reduced house size (see *The design process*)
- appliance efficiency using solar hot water with efficient gas or heat-pump backup (see *Hot water service*)
- thermal efficiency (NatHERS rating) (see *Passive solar heating*; *Passive cooling*)
- heating/cooling and other appliance efficiency (MEPS star rating) (see *Heating and cooling*; *Appliances*)
- on-site (or community level) renewable energy generation (see *Renewable energy*)
- smart grid interactive demand management and on-site storage systems, appliances and plug-in hybrid electric vehicles (see *Home automation*; *Smart meters, in-home displays and smart appliances*).

Apart from the first two factors, cost effectiveness varies according to house type and climate. For example, existing householders with limited or expensive thermal upgrade options may find upgrading of major appliances (heating, cooling and hot water service), followed by installation of PV to make up any shortfall, to be the most cost effective option for eliminating energy bills — particularly in more benign climates.

In more extreme climates, higher NatHERS ratings usually deliver the most cost effective outcomes. RMIT found that in Melbourne across a 50 year time-horizon, Reducing energy demand in your home

Activity	Energy use	Initial load (kWh)	Energy efficiency measure	energy saving	New load (kWh)	Approx. annual savings assuming $0.2855kWh	Approx. annual savings assuming $0.5710/kWh
Heating and cooling	40%	1900	Improve house energy rating by at least 2 stars	35%	1235	$189.85	$379.71
Water heating	21%	1250	Change to solar HWS	50%	625	$178.43	$356.87
Other electrical appliances	19%	800	Improve efficiency and reduce use	10%	720	$22.84	$45.68
Lighting	6%	350	Change to efficient lighting (e.g. LED)	75%	88	$74.80	$149.60
Cooking	5%	200	Improve efficiency by using induction or microwave	30%	140	$17.13	$34.26
Refrigeration	6%	350	Improve efficiency by 2 stars	30%	245	$29.97	$59.95
Stand-by	3%	150	Turn off at plug	90%	15	$38.54	$77.08
Total	**100%**	**5000**			**3068**	**$551.56**	**$1,103.15**

Source: DEWHA. 2008; AGO 2007. Approximate annual savings figures updated January 2016.

an 8 star thermal performance with 3kW PV array and a solar hot water system provided cost optimal outcomes for achieving a carbon zero home (Moore et al. 2010).

In existing homes, improve energy efficiency by adding insulation, shading and draught proofing, and zoning areas to be heated and cooled.

Lifestyle emission reductions

- Actively operate your home to improve thermal comfort and reduce energy use:
  - night purge by opening windows in summer
  - open stairwell or clerestory (high) windows in summer for stack ventilation and close and insulate them in winter
  - operate or erect shading in summer, retract or remove it in winter
  - draw drapes at night
  - limit ventilation and air movement in winter
  - close doors to create a heating zone in winter and don't heat unused rooms.
- Turn your thermostat up a few degrees in summer and down a few in winter to reduce your heating and cooling costs by around 20%.
- Buy efficient appliances when replacing them and reduce electrical appliance use, turn off lights, and switch off appliances and equipment at the plug when not in use — especially a second refrigerator. (see *Appliances*)
- Switch to low greenhouse impact transport options like walking, cycling or public transport.
- If a car is essential, use a hybrid electric or fuel-efficient one. (see *Transport*)
- Reduce the time and cost of travel from your home to work, school, shops or leisure activities. Consider working from home via telephone, email and internet. (see *Transport; Choosing a site*)
- Divert food and garden wastes from landfill to composting — when food and garden wastes break down without fresh air they create a mixture of gases including the very damaging greenhouse gas, methane.
- Grow some of your own food.
- Purchase food, products and other services that have not been transported long distances, kept in storage and over-packaged.
- Minimise waste from packaging and materials — 'refuse, reduce, reuse, recycle'.
- Save water and the energy to heat it by taking shorter showers, washing clothes in cold water and leaving mixer taps in cold position to avoid unintended hot water draw with short uses.
- Reduce the purchase of non-essential products — ask 'do I really need it?' — and buy only durable, quality goods you really need from certified sustainable (e.g. Good Environmental Choice Australia) and socially preferred (e.g. Fairtrade) sources.
- Find more information at www.livinggreener.gov.au

Reduced house size

- Minimise the 'conditioned' floor area of your new home through smart design and/or zoning of areas that require heating and cooling.
  - This is the most cost effective step in achieving carbon zero status. (see *The design process*; *Renovations and additions*; *Buying a home off the plan*; *Buying and renovating an apartment*)
  - Approximately 40% of average Australian household emissions are from heating and cooling (varies with climate) and this is proportional to floor area. Your total household energy consumption decreases by up to 3% for every 10% decrease in conditioned floor area. (see *Energy*; *Heating and cooling*; *Passive solar heating*; *Passive cooling*).

Appliance efficiency

- Install a solar hot water service with an efficient heat pump or gas backup (note, gas still emits greenhouse gases). (see *Heating and cooling*; *Hot water service*)
- Install the most efficient heating and cooling system available. Heat pump or split system air conditioners are now among the most efficient. A minimum coefficient of performance of at least 4 is preferred. (A coefficient of 4 means that, for every 1kW of electricity used, 4kW of heating or cooling are extracted from external air, water or earth. The higher the number, the more efficient the appliance.) Unlike gas systems that emit greenhouse gases regardless of their efficiency, electricity systems can be offset by on-site renewable generation.
- Select smaller energy efficient appliances with low stand-by power use and avoid unnecessary purchases. (see *Appliances*; *Home automation*)
- Reduce water use (it takes energy to treat and pump water to a home) and reduce hot water demand by installing water efficient showerheads, taking shorter showers and using cold water for washing clothes. (see *Reducing water demand*)

Thermal efficiency

Improve the energy efficiency of the home when building, renovating, renting or buying by:

- ensuring effective orientation and layout to maximise solar-passive strategies (see *Design for climate*; *Passive solar heating*; *Passive cooling*)
- adding or increasing insulation levels and using well-designed, climate-appropriate, insulation solutions e.g. a combination of bulk and reflective foil (see *Insulation*)
- sizing and orientating windows to minimise summer heat gains and maximise winter solar gains (see *Glazing*)
- using appropriate glazing and window styles for climate (e.g. low U-value; high solar heat gain coefficient in cold climates and low in warmer climates) (see *Glazing*)
- using materials in ways that enhance passive solar heating and cooling (see *Thermal mass*)
- reducing unnecessary heat loss and heat gain with draught-seals and weather-strips on doors and windows, and setting thermostats appropriately (see *Sealing your home*)
- installing curtains and pelmets, external blinds and shading to reduce the need for additional heating and cooling (see *Shading*).

Renewable energy generation

Install on-site (or community level) renewable energy generation such as:

- grid connected roof top (or frame mounted) PV for individual households
- larger PV arrays and wind turbines on viable sites for community level installations.

Use grid electricity from accredited GreenPower providers, which encourages construction of cost effective, large scale renewable energy generation such as wind, solar thermal and biomass.

- GreenPower can be a simple, cost effective way for householders (particularly tenants) to reduce or eliminate their carbon footprint.
- GreenPower is less permanent than on-site generation because it can be discontinued at any time and does not give localised control and accountability for carbon emissions, which can deliver additional efficiencies.

Anecdotal evidence indicates that occupants of homes with on-site renewable energy generation are more likely to use energy more efficiently due to increased awareness and monitoring of consumption.

Smart-grid interactive demand management

Where available, install:

- smart-grid technologies
- energy management systems and smart appliances.

Store energy generated on site during off-peak periods for use or export during peak periods in hybrid electric vehicles or next generation batteries as they become more viable.

Setting targets to become carbon zero

As a first step, estimate your likely household energy requirements to help size and cost your renewable energy system.

1. Calculate current household energy consumption based on 12 months' worth of energy bills or use a carbon calculator to establish a target to eliminate or offset.
2. Adjust the figures to reflect likely efficiencies in your new home or after renovations using the figures in the table above:
   - minimise heating and cooling requirements by achieving the highest level of thermal performance possible — a NatHERS rating of your new home simulates typical heating and cooling needs for your climate in megajoules per square metre per year ($MJ/m^2/yr$)
   - minimise appliance energy use by installing the most efficient appliances and lighting during construction or at replacement.
3. Estimate your total energy needs and CO_2 emissions and decide how you will offset them.

To be carbon zero, total carbon emissions from energy used to operate your home is your minimum offset target. Don't be discouraged if carbon zero is currently unaffordable. Roof top generation capacity may be able to be added in the future and a range of other more affordable offset options such as accredited GreenPower and carbon offset programs are available in the interim.

Aim for a net annual surplus where possible to achieve carbon positive status to repay energy and carbon embodied in the materials used to build and maintain the home during its life. Additional net export surplus can be used to offset carbon emissions from transport and food through adequate net export of renewable energy or accredited carbon offset programs.

As the capacity of on-site generation increases, peak output on sunny days will exceed grid demand in many areas — the grid will be unable to use all the electricity being exported from on-site generation. On-site storage can be used to divert or delay electricity production to match demand.

System design

Final design and sizing of renewable energy generation systems is best left to accredited professional system suppliers. Get several quotes from referred installers and get them to check your demand calculations.

Your choice of inverter (see *Batteries and inverters*) is critical if you plan to expand your system at a future date. Oversized inverters can reduce efficiency but future replacement can be expensive. Recent developments in inverter technology offer more flexible solutions so check with suppliers and choose an inverter that best suits both current and future needs.

The design of a suitable roof area with uninterrupted solar access is essential. See *Renewable energy* design guidelines for orientation, tilt or elevation and the roof area required for your system. Where uninterrupted solar access is not available on the rooftop, freestanding frames in a sunny yard or on a carport roof may be a viable alternative.

Orientation of PV arrays to the west reduces output by 10–15% but can often more than offset any loss of net export return by better matching peak demand without the need for on-site storage systems. Tracking systems can increase output by as much as 15% but are expensive, subject to wind damage and require maintenance.

Monitoring

Monitor your consumption through energy bills and smart metering to identify any areas where further efficiencies can be gained. In particular, monitor changes in energy consumption after replacement of major appliances with more efficient ones.

When all cost effective efficiencies have been locked in, monitoring will determine whether you have achieved carbon zero or positive status based on actual rather than predicted demand. This will inform your decisions about whether to expand your existing system and by how much.

Future expansion

The addition or expansion of renewable energy generation systems, such as solar PV, can be a relatively simple but expensive process. It is therefore usually the last step in achieving carbon zero or positive status because thermal performance and appliance efficiency deliver more cost effective carbon reductions and are more expensive to add after construction or renovation.

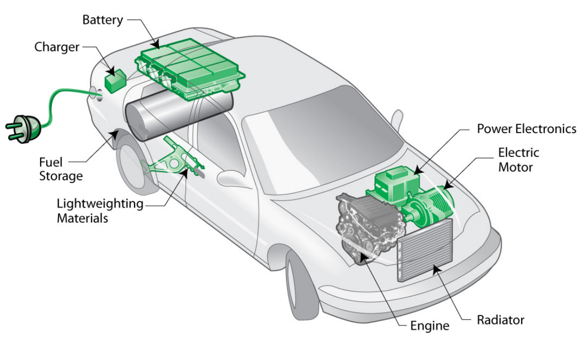
Renewable energy generation is usually the last step in achieving carbon zero or positive status, because thermal performance and appliance efficiency can deliver more cost effective carbon reductions and are more expensive to add after construction or renovation.

Unregulated growth in rooftop generation capacity is proving increasingly problematic for supply authorities.

Rooftop PV generation is overloading the grid on sunny days in some areas — a problem likely to increase as the number and size of rooftop systems increases. These systems can also cause grid fluctuations as clouds pass over areas with high concentrations of rooftop PV.

Automated activation of appliances and on-site or community level electricity storage systems are needed to overcome this problem. These systems include:

- stand-alone battery systems or plug-in hybrid electric vehicle (PHEV) charging
- automated switching on of heating and cooling systems that can store warmth or 'coolth' in thermal mass to limit or eliminate peak demand. (see *Batteries and inverters*; *Thermal mass*; *Heating and cooling*; *Home automation*; *Smart meters, in-home displays and smart appliances*)



Source: Chris Dunstan (ISF)

Plug-in hybrid electric vehicle.

When combined with energy management systems (EMS), on-site storage can maximise returns by allowing consumers to choose when they use their electricity or export it to the grid at peak prices.

Rapid development in smart grids, smart appliances, interactive home EMS and battery technology means systems suitable for both residential and commercial application are already commercially available, although most are still undergoing development (www.smartgridsmartcity.com.au).

Next generation PHEVs with increased battery capacity can be plugged directly into a standard 15amp power outlet in the garage for two-way energy management. (Household power outlets are generally 10amp; specify 15amp at design or have it retrofitted by a licensed electrician.) Battery charging via EMS facilitates storage of excess electricity generated on site to augment household supply during early evening peak demand or low on-site generation periods. PHEV batteries can be recharged with off-peak power during the night or in parking stations during peak daytime solar PV output.

PHEVS and stand alone battery systems also have potential to store off-peak grid electricity and return it to the grid during peak demand via grid interactive EMS and time-of-use metering. This helps to offset variable output from renewable sources like wind and solar and increases returns on investment by householders.

Beyond the carbon zero home

The ASBEC carbon zero definition requires that all efficiencies and renewable energy generation be achieved on site because off-site schemes can be unsubscribed or discontinued. However, when striving for affordable carbon zero living in a home that is unable to be altered (e.g. a rental or heritage listed property) or for beyond carbon zero status, off-site schemes are highly effective and often more efficient than on-site schemes.

Carbon offsetting

Carbon offsetting removes or averts greenhouse gas emissions that have been or would be emitted into the atmosphere and destroys, stores or 'sequesters' them for periods of varying duration depending on the sequestration method. Many carbon offset schemes are available in the market that can offset the emissions from our homes and lifestyles. Choose a scheme that guarantees permanent or long-term sequestration and creates local social and economic benefits.

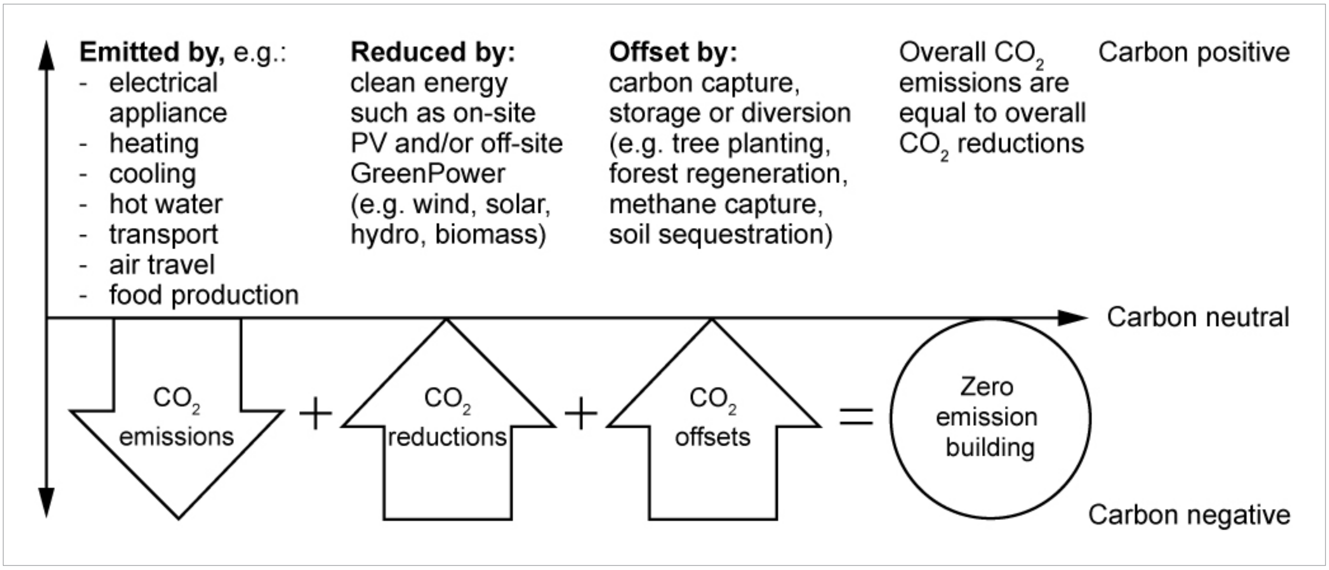
Calculation to offset emissions

CO_2 emissions are calculated for an activity		**Offset credits are purchased through an accredited scheme**		**Overall CO_2 in the system is neutral**
If 1 tonne of CO_2 is emitted each year, e.g. through transportation or burning of fossil fuels for electricity generation	+	1 tonne of CO_2 is absorbed by planting trees or other sequestration measures	=	the net result of CO_2 being emitted by the activity is deemed to be carbon neutral

Carbon offsetting through sequestration or diversion is a viable, low cost way to reduce atmospheric carbon emissions in the short to medium term. Because achieving carbon zero status is a voluntary act of best practice, it is desirable to achieve it by viable and affordable means, such as using renewable energy or recovering and offsetting through accredited schemes.

Housing

Carbon zero, carbon positive



Carbon neutral offset.

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