EC1322/2

ANZHERS – Space Heating Rating Tool

Author: Lynda Amitrano
(Manager Built Environment)
Nikki Buckett
(Building Technologist)

Reviewer: Roman Jaques
(Environmental Scientist)

Contact: BRANZ Limited
Moonshine Road
Judgeford
Private Bag 50908
Porirua City
New Zealand
Tel: +64 4 237 1170
Fax: +64 4 237 1171
www.branz.co.nz

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CLIENT

Department of the Environment, Water, Heritage and the Arts
John Gorton Building
King Edward Terrace
Parkes ACT 2600
GPO Box 787
Canberra ACT 2601
AUSTRALIA

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1. SCOPE

Using space heating appliance and equipment information from the BRANZ HEEP Study, the Australian MEPS programme, and other published and reliable unpublished sources:

a) **Determine the most appropriate metric for ranking buildings according to the environmental impact of the provision of space heating systems;**

b) **Determine the major factors that will impact the environmental performance of space heating systems;**

c) **Determine the minimum set of data to be collect to perform the assessment;**

d) **Develop a database of appliances and equipment products and their performance characteristics commonly found in residential buildings in Australia and New Zealand.**

e) **Chart the distribution of system performances commonly found in residential buildings in Australia and New Zealand using the metric from part (a) for the purpose of determining the ranking of systems between zero stars (poor performance) and 10 stars (excellent performance).**

2. AIM

The Space Heating Tool will be designed to fairly assess all space heating units independent of other government policy and MEPS. This means that each heater will potentially be rated according to differences in heater fuel, efficiency, and usage. The tool will produce an overall rating for the space heating derived from a carbon dioxide (CO_2) emissions per square metre (m^2) of floor area.

3. CHOOSING AN APPROPRIATE METRIC

Energy use is arguably the most significant environmental impact of buildings, according to the well respected *Environmental Building News* (1993). Space heating contributes to a considerable portion of this in Australia and New Zealand. Determining which space heating fuels are least damaging is a complex issue. There are several reasons for this:

– there isn't a standardised method of comparing the environmental impact of one fuel type to another
– each fuel type has different environmental impacts
– the environmental impact of some fuel types (such as electricity) is dynamic – changing from day to day and year to year.
– with some fuels, the primary impact is during combustion – which is relatively easy to measure – while other fuels have a greater impact during the mining of raw materials or disposal of waste products (see Table 1).

Table 1 provides a qualitative overview of different heating fuels and their impact on the environment. While the matrix offers some basis for comparison, it is only *within* a category, rather than *between* categories. As an example, in comparing electricity generated by PV and coal, we see that for most categories examined, the environmental impact of PV is less than coal – however, we don't know whether *overall*, generating electricity from coal is the most detrimental.

Environmental Impact: Minor ○ Moderate ◐ Severe ●

	Raw Materials/ Processing							Energy Use																Disposal		
	Mining	Drilling	Tanker Spills	Pipeline Leaks	Refinery Wastes	Flooding	Air Pollution	Fish/Aquatics Impact	CO_2	NO_x	SO_x	Particulates	CO	Methane/VOCs	Radiation	Siting	Noise	Visual Impact	Groundwater Impact	Surface Water Impact	EMF	Indoor Air Pollution	CFCs	Landfills/Ash Disposal	Radioactive Waste	Toxic Waste
Direct Combustion																										
Natural Gas/LPG	○	●	○	●	●	○	●	○	◐	◐	◐	◐	◐	◐	○	○	○	○	○	○	○	◐	○	○	○	○
Heating Oil	○	●	●	●	●	○	●	○	●	◐	◐	●	◐	◐	○	○	○	○	●	○	○	◐	○	○	○	○
Coal	●	○	○	○	○	○	◐	○	●	◐	●	●	●	●	○	○	○	○	○	○	○	●	●	●	○	○
Wood	○	○	○	○	○	○	◐	○	○	◐	◐	●	●	●	○	○	○	○	○	○	○	●	○	○	○	○
Electricity Generation																										
Coal	●	○	○	○	○	○	◐	●	●	●	●	●	◐	◐	○	●	○	●	○	●	○	○	○	●	○	●
Oil	○	●	●	●	●	○	●	◐	●	●	●	●	◐	◐	○	●	○	●	○	●	○	○	○	○	○	●
Natural Gas	○	●	○	●	●	○	●	◐	◐	◐	◐	○	◐	◐	○	◐	○	●	○	○	○	○	○	○	○	●
Nuclear	●	○	○	○	○	○	◐	●	○	○	○	○	○	○	●	●	○	●	○	○	○	○	○	○	●	●
Hydropower	○	○	○	○	○	●	○	●	◐	○	○	○	○	○	○	●	○	●	○	●	○	○	○	○	○	○
Geothermal	○	○	○	○	○	○	○	◐	○	○	○	○	○	○	○	●	○	●	●	○	○	○	○	○	○	○
Wind	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	●	●	●	○	○	○	○	○	○	○	○
PV/Solar Thermal	○	○	○	○	○	○	◐	○	○	○	○	○	○	○	○	●	○	●	○	○	○	○	○	○	○	○
Biofuels/Waste-to-Energy	○	○	○	◐	◐	○	◐	○	○	◐	◐	●	○	○	○	●	○	●	○	○	○	○	○	●	○	●
Electricity Transmission & Use	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	◐	○	◐	○	○	●	○	◐	○	○	○
Other																										
Efficiency	○	○	○	○	○	○	◐	○	○	○	○	○	○	○	○	○	○	○	○	○	○	●	◐	○	○	○
Passive Solar/Daylighting	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○

Adapted from the UNCED/Energy Issues paper: "Summary of Total Energy Cycle Analysis and Relationship to UNCED Issues"

Table 1: Space Heating Fuel Types and their Environmental Impacts. Source: Environmental Building News, 1 November 1993.

In a tool such as this, the best environmental metric to use is one which:

- is seen to be significant, both nationally and internationally
- preferably has an established and recognised metric already
- has robust (i.e. AccuRate and recent) data, which is in the public domain
- meets government objectives.

Since the primary environmental focus of space heating is energy use, it makes sense that an energy-related metric is used for the space heating rating tool. In terms of energy-related metrics that fulfil the above bullet-pointed requirements, none fulfil the role better than CO_2. Carbon dioxide emissions are inexorably tied into the critical issues that face the globe today, such as climate change, depletion of non-renewable resources, peak oil and global stability. Globally, CO_2 is the most significant greenhouse gas, and in Australia and New Zealand the second most important. All the major green building rating tools operating today (both nationally and internationally) now have extended their accounting of environmental metrics to include the (predicted or actual) carbon cost of the choices made at the design stage. In addition, there is accurate data on CO_2 emissions of the various fuel types which is easily assessable. Thus, $CO_2$is the environmental metric used in the space heating star rating tool.

It has been suggested that the metric of Equivalent CO_2 (CO_2e) could be used instead of CO_2, within the space eating tool. CO_2e is the concentration of CO_2 that would cause the same level of radiative forcing (i.e. global warming) as a given type and concentration of greenhouse gas. Examples of such greenhouse gases are methane, perfluorocarbons and nitrous oxide. For most fuel types, it is recognised that CO_2 is by far the largest greenhouse gas, and the non-CO_2 greenhouse gases are so insignificant that they can be discounted completely. For the purposes of this report, the two metrics – CO_2 and CO_2e can be used interchangeably.

4. INFLUENCES ON CO_2 EMISSIONS

This section looks at the major factors affecting the environmental (energy/CO_2) performance of space heaters in Australia and New Zealand and what key factors are required for the development of a rating tool.

4.1 Climate

Virtually all of New Zealand and most of Australia's homes require space heating at some point during the year. The cooler the climate, the more heating is required to achieve comfortable temperatures and the longer the heating season is likely to be. In some parts of Australia, such as Western Australia and the Northern Territories, little heating is required.

While this assumption may not reflect real practices of heating throughout the climate zones, this tool seeks to provide consistency and standardised heating patterns regardless of where the house is located.

4.2 Fuel Type and Fuel Region

Fuel type is an important component when considering the CO_2 emissions of space heating. Emissions can vary widely from state to state, region to region due to a variety of factors including generation, distribution, and fuel quality.

Electricity is generated through differing means throughout Australia, with Melbourne relying on brown coal, while Tasmania relies more on hydroelectricity. In New Zealand hydroelectricity dominates, with geothermal, thermal and wind electricity supplementing supply.

Emissions from woodburners are also highly variable depending upon the type of wood used, the average age of woodburners, and the moisture content of the wood (Environment Australia, 2002).

The impacts of fuel types used will be discussed later in this report.

4.3 Heated Space

The amount of heating required is highly dependent upon the volume the heater is required to heat. The larger the space, the more heat is required to maintain comfortable temperatures.

4.4 Heating Environment and House Factors

The amount of energy consumed for space heating depends on the thermal resistance of the thermal envelope of the space. A house without insulation in the walls or ceiling would require more heating energy than if it were insulated.

4.5 Efficiency of Heater

Efficiency will play a major role in determining the environmental performance and GHG emissions of certain types of heaters. The more efficient the heater, the less energy is required to produce a certain amount of heat.

4.6 Size of Heater

The sizing of the heater to maintain comfortable temperatures will vary, with uninsulated homes requiring more heat output than insulated homes. Poor sizing of heaters can have detrimental effects on the effectiveness of heaters.

Undersized heating may lead to some or all of the following:

- Compromised efficiency of the heater.
- Inability to maintain healthy temperatures – underheating.
- Required use of additional, possibly less efficient heaters.

Oversized heating may lead to some or all of the following:

- Inability to maintain healthy temperatures – overheating.
- Need for passive or potentially active cooling – especially in homes with solid fuel burners and heat pumps working in combination.
- Compromised efficiency of the heater.

4.7 Number of Heaters

Several heaters may be used in one space at one time, with differing efficiencies and fuel types. Or, one heater may heat several zones. This may cause substantial variation in the space heating rating index of the house depending on which heating types are used. These options have been addressed to allow the sharing of heaters across zones and prioritising heaters within a zone.

4.8 Preferred Heating Options

Because of the highly varied climates throughout Australia and New Zealand, the heating preferences will vary. In warmer areas residents are likely to perceive temperatures to be cold while people in cooler climates might view them as comfortable. This was evident in the HEEP study (Isaacs et al, 2005). where Aucklanders tended to switch on their heaters at temperatures higher than Invercargill's average summer temperature. Ideally, to take this into account, heating setpoints could vary according to location.

5. RATING TOOL CONSIDERATIONS

The following outlines issues that have been considered in the heating environmental rating tool.

5.1 Fuel Type

New Zealand has a national electricity network, whereas Australia has state-level and regional electricity networks. This means that while proportions of fuels used and therefore the rating index of electricity generation in New Zealand can be used on a nationwide basis (excluding Stewart Island and the Chatham Islands), zones should be used in Australia. This is important because Tasmania, for example, has a high proportion of hydroelectricity generation, while Victoria's electricity is predominantly generated through brown-coal-fired thermal electricity generators. These zones could be tied in with climate zones, but due to differences in fuel zones, this tool lists the fuel zoning separate from climate.

5.2 Heated Spaces

All conditioned (i.e. heated) zones in the assessed house must be taken account of, to provide a fair rating.

5.3 Heating System Parameters

For **new homes**, the information required to accurately determine a space heater's representative CO_2 emissions will be reasonably easy to find. This information can be divided into that which is necessary to perform an assessment of the star rating of home space heaters, and that which will be useful to have. The "useful to have" data, could be used for:

1. expansion of the scheme in the near future, to account for more factors, such as particulate emissions
2. benchmarking purposes, as the heating technology evolves
3. checks for the default values listed.

ESSENTIAL DATA

A. Heater type, from the following selection:

Electric	Solid Fuel	Liquid and Gas Fuel
Convective (e.g. column, fan)	Wood/Chipburner	Flued (natural gas or LPG)
Radiative (e.g. halogen)	Pellet burner	Unflued (natural gas or LPG)
Heat pump	Open fire	Open flued (natural gas or LPG)
Nightstore	Potbelly	LPG cabinet
Electric pad underfloor	Multi-fuel burner	Diesel fire
Hot water underfloor	Solid fuel range	Gas bayonet
	Coal burner	

B. Peak Rated Output (kW – capacity)

C. Heating efficiency – COP (% – overall or space for solid fuel)

D. Zones attached to heater (i.e. areas that it heats)

USEFUL TO HAVE DATA

A. Brand and Model

B. Age (year of installation)

C. Power usage (W-liquid/gas/solid fuels) or Input (kW – electric)

D. Presence of thermostat (Y/N)

E. Presence of timer (Y/N)

F. Inverter (if electric – Y/N)

G. Minimum operating temperature (for heat pumps only – °C)

H. Particulate emissions (g/kg or mg/MJ output)

I. Clean Heat Project registration or approval status – for information on wood burners installed in Christchurch as part of the Environment Canterbury Clean Heat programme

J. Ministry for the Environment/Nelson/Otago Council approval - for information on wood burners installed in Nelson or Otago as part of the Ministry for the Environment Canterbury Clean Air initiatives

K. Meets National Environmental Standards for under 2 hectares land area

L. Solid fuel appliance certification status and expiry by Australian Home Heating Association

M. Date heater information sourced

Both the ‘essential’ and ‘useful to have data’ may be available from either the house plans or form the house/homeowner. However, for **existing homes**, even the essential data may be hard to determine. In New Zealand, assessors could use HEEP data as a default and Lloyd Harrington is likely to be able to provide similar for Australia. There is the potential to set up training guides showing example pictures with heater sizes, for assessors to use as a reference. These options need further discussion between the parties involved.

5.4 Heat Pump Issues

Heat pump systems need special consideration. BRANZ has tried to create a robust de-rating algorithm to account for the widening performance differences between the newer and older units. At this stage, there is insufficient information to create an algorithm to account for this. There is no standardised performance curve to reflect all models of heat pumps. The example used in the 2004 MEPS report (see page 8) is now 5 years old and displays the performance of three individual models under the H2 testing regime. The best approach to address this issue needs to be discussed further with EECA.

In addition to this technical performance issue is that of climate performance, where the efficiency of heat pump units generally reduces rapidly below 7°C. Newer heat pumps are less affected by harsh climates. Ideally, a rating tool should account for this. Currently, there is no means of addressing this issue in a rigorous manner.

5.5 Efficiency of Heating Systems

A database of commonly found domestic heating appliances from both Australia and New Zealand is included as information to develop a specific heating database. Technical specifications and information for appliances were sourced from local and national government databases, the Australian Home Heating Association, appliance manufacturers and retailers.

In New Zealand, due to a lack of information on older and superseded wood burner models sold before National Environmental Standards (NES), which came in on 1 September 2005, information was collected on as many current popular models sold by chain outlets and larger manufacturers as was available. For older heaters and heaters without known technical specifications, default values were formulated based on efficiencies used in HEEP (Isaacs et al, 2006) and by the Ministry for the Environment (MFE, 2005).

Below are two tables of generic information on space heating efficiency ranges and averages, that will be applied to the prototype space heating rating tool. As part of the tool development there should be a mechanism to allow the list to be extended for future upgrades.

Space Heating Appliance	Max Space heating Output (kW)	ACTUAL Space heating Output (kW)	Efficiency Range (%)	Efficiency Used for Tool (%)	Priority
Generic Enclosed Woodburner (pre Sept 05)	7-35	5-14	55-75	60	1
Generic Enclosed Woodchip Heater (pre Sept 05)	4-8	4-8			
Generic Woodchip Heater (post Sept 05)	7-35	5-14	65-80	65	1
Generic Woodchip Heater (post Sept 05)	4-8	4-8			
Generic Potbelly Stove	1-5	1-5	35-60	35	1
Generic Pellet Burner	6-12	6-12	75-92	75	1
Generic Soild Fuel/coal range	15-20	10-14	60	60	1
Generic Open Fire	0-4	1	0-20	15	5
Generic Multi-Fuel burner	5-23	4-13	55-75	60	1
Generic Resistance, Radiative, convective heater (default for no heating)	1-6	1-4	100	100	5
Generic Air Source Electric heat Pump	3-16	3-8	200-400	300	2
Generic Flued Gas Heater	1.5-10	4-12	60-85	80	3
Generic Unflued Gas Heater	1.5-10	1-4	80-100	80	4
Generic Diesel Boiler	5-12	5-12	65-80	75	1

Table 2: Efficiencies of Common (non-central) Space Heaters (various sources)

Central Heating Appliance Type	Appliance Efficiency	Distribution Efficiency	Efficiency Used for Tool (%)
Gas boilers (1998 or later, including LPG)			
Regular non-condensing with auto ignition	0.73	0.7	**0.51**
Regular condensing with auto ignition	0.83	0.7	**0.58**
Non-condensing combi with auto ignition	0.73	0.7	**0.51**
Condensing combi with auto ignition	0.83	0.7	**0.58**
Regular non-condensing with permanent pilot light	0.69	0.7	**0.48**
Regular condensing with permanent pilot light	0.79	0.7	**0.55**
Condensing combi with permanent pilot light	0.69	0.7	**0.48**
Gas Boilers (pre 1998 including LPG with fan assisted flue)			
High or unknown thermal capacity	0.68	0.7	**0.48**
Combi	0.7	0.7	**0.49**
Condensing Combi	0.83	0.7	**0.58**
Condensing	0.83	0.7	**0.58**
Oil Burners			
Standard oil burner pre 1985	0.65	0.6	**0.39**
Standard oil burner 1985 - 1997	0.7	0.6	**0.42**
Standard oil burner 1998 or later	0.79	0.6	**0.47**
Condensing	0.83	0.6	**0.50**
Combi, pre 1998	0.7	0.6	**0.42**
Combi 1998 or later	0.76	0.6	**0.46**
Condensing Combi	0.81	0.6	**0.49**
Range cooker boilers (oil)			
Single burner	0.6	0.6	**0.36**
Twin burner (non-condensing) pre 1998	0.7	0.6	**0.42**
Twin burner (non-condensing) 1998 or later	0.75	0.6	**0.45**
Other			
Electric resistive cental heating	1	0.95	**0.95**
Electric Ducted Heat Pump	2.5	0.95	**2.38**

Table 3: Efficiencies of Common Central Space Heaters (various sources)

5.6 Prioritisation of Heaters

If there is more than one heater in a zone they need to be prioritised so the main heater will be considered first for its rating requirements, the second heater next and so on. There were four options considered for prioritising the heaters:

1. The assessor prioritises the heaters based on what they believe is the main heater type. However, issues with this include potential bias to ensure the best outcome and the occupancy influence of this choice.

2. Prioritising on efficiency so the most efficient heater gets selected first. This would lead to homes potentially getting a higher star rating then it should as the

3. Prioritise by size of heater so the largest heater is given highest priority. Has the potential of a biased outcome especially if the largest heater is very inefficient, penalising the star rating outcome.

4. Predetermine a priority based on typical user behaviour. This would mean a standard approach across all homes and combinations of heater types would be prioritised in the same order and giving the same importance.

Option 1 would provide the most realistic outcome to the occupants usage but does not allow consistency (e.g. new occupants may have a different priority) for comparison purposes so should not be used. Options 2 and 3 will bias either efficient or large heating systems but will provide a consistent approach. Option 4 is an attempt to cross options 1 and 3 where the typical priority is preset, which incidentally will often have the largest heater as the highest priority. It is recommended option 4 be used and the priorities have been provided in Table 2.

If there are two heaters with equal priority then it is assumed they will share the load.

6. DATASET

6.1 Rating Tools

Few rating tools available take space heating appliance characteristics into account. Most rating tools tend to focus on the heating load. A variety of rating tools and simulation engines were examined, such as: Canadian HOT3000, Australian NABERS, BASIX, BERS, FirstRate, and the United Kingdom's NHER Powergen Pocket Affordable Warmth Survey (PAWS).

After an examination of the tools, it was concluded that the most comprehensive space heating rating tool was that included as part of the HOT3000 tool (see Appendix B for details). There is potential for the information used in HOT3000 to be extended and modified to include assessments of rating index as well as energy use. However, further investigation revealed that adapting it would be problematic and not very feasible. It was realised that it would be better to start from scratch with a purpose-built space heating rating tool, using energy use output from an established and recognised tool specific to Australian and New Zealand heating needs, in this case the AccuRate modelling engine. Within the Accurate energy output files, there is already robust data that a rating tool can relatively tap into. The next section gives an overview of the approach taken.

7. ACCURATE

7.1 Introduction

The approach taken in the development of this space heating tool is to achieve, as far as practicable, a tool which is able to:

- utilise the energy outputs from the AccuRate modelling engine
- ensure a seamless transfer of information between the AccuRate and the space heating tool, keeping the modifications required for AccuRate to a minimum
- represent *standardised* behaviour, so that a change in occupants would not change the results (providing the appliances used are kept constant)
- minimise the amount of additional information required from the assessor.

Currently, AccuRate produces the energy required to heat the home according to the specified temperature setpoints and defined hours of occupancy. There is currently no provision in AccuRate to specify space heating types or assess their environmental impacts as part of the overall house assessment. The space heating rating tool is designed to provide these specifications.

It should be noted that AccuRate needs to be run in its "Rating Mode" to capture all the conditioned spaces within a house, which is essential to ensure a fair rating.

7.2 Proposed Procedure

The following stepped procedure shows the process for calculating a home's yearly space heating CO_2 emission and therefore its heater star rating, from AccuRate. It is simplified for clarity. The algorithms and further detail are provided in an Excel spreadsheet – Appendix C.

STEP 1: HERS/ACCURATE MODELLING
House is modelled in HERS/AccuRate as usual, with hourly output values for (net) Energy and Power Demand for each conditioned space provided within the *energy.txt* file. The usual default values for space/zone temperature set points and times of heating are used. When modelling, each zone requires a specific name to allow heaters to be assigned (i.e. if there is more than one bedroom they will need to be assigned Bedroom 1, Bedroom 2, etc)

Additional requirements from the AccuRate are:

- yearly demand loads for each zone (see Step 3)
- climate zone (to determine which fuel CO_2 figure should be used).

STEP 2: ADDITIONAL INFORMATION
Assessor provides additional information on:

- the fixed space heating system's type, each conditioned space
- each space heater's rated peak power output (kW)
- zones that each heating system provides heat to (can be more than one zone for each heater)
- where there is more than one heating system, the priority of the systems with a main system, secondary system and so on.

STEP 3: DETERMINING HEATING SYSTEM MAXIMUM OUTPUT FOR EACH ZONE
If a heating system heats more than one zone, the peak power output of the system needs to be shared across the zones. This should be allocated proportionately based on the yearly demand loads as calculated by the AccuRate tool. This assumes the heater can effectively heat the zones it is assigned to and distribution of heat across the zones is efficient.

STEP 4: CHECKING PEAK DEMAND (HOURLY)
Determine the actual (gross) power demand (heating demand) for each zone and determine if heaters assigned to that zone can meet the heating requirements.

For each zone, for each hour, determine if the AccuRate modelled peak power demand (heating demand) is able to be met by the *fixed* heating appliances assigned to that zone, based on the heaters' maximum output possible for that zone.

The method needs to first check to see if the highest prioritised heating system's maximum output (for that zone) can meet the heating requirements. If it can, then proceed to STEP 6. If the first heater doesn't meet the heating demand of that zone, determine if the remaining heat required can be met by the next heating system's maximum output (for that zone) until all assigned heaters have been accounted for.

STEP 5: ACCOUNTING FOR PEAK ENERGY SHORTFALLS
For any shortfall in hourly energy requirements, assume that it is met by an electric (resistive type) heater with a 100% efficiency, that requires heating according to the AccuRate definitions, for every zone/space.

STEP 6: HEATING SYSTEM ANNUAL TOTAL ENERGY
For each heater, calculate the total energy supplied by that heater over the entire year for all the zones the heater is assigned, by summing hourly load requirements for that heater from the assigned zones.

Determine the energy demand for each heating system by accounting for its efficiency (i.e. COP).

This includes the additional (i.e. makeup) heating appliances where required.

STEP 7: STAR RATING
Convert this total annualised energy figure to an equivalent CO_2 emissions figure, knowing what the fuel type is (from STEP 2) and therefore its resulting carbon intensity for each heating system. Sum the CO_2 emissions for each heating system to determine the total house heating CO_2 figure. Divide this by the conditioned area, to get: *kg* $CO_2/m^2/yr$.

Covert this figure into a star rating according to the bands set, between 0 and 10.

7.3 Issue to Address

7.3.1 Emissions

The CO_2 emission figures by fuel type are listed in Table 4 below. Note that the New Zealand figures are based on the NZBCSD Emission calculator web tool. Figures for this web tool were taken directly from the Ministry of Economic Development (www.med.govt.nz/) and information from the Climate Change Office. These figures are widely used in New Zealand, including by the NZ Green Building Council (NZGBC, 2007). The Australian figures are sourced from the Australian Greenhouse Office's Factors and Methods Workbook (AGO, 2006).

Fuel Region	Electricity	Natural Gas	LPG	Coal	Diesel	Dry Wood
NZ	0.15	0.20	0.25	0.33	0.25	0.05
NSW	1.07	0.29	0.24	0.33	0.29	0.05
ACT	1.07	0.25	0.24	0.33	0.29	0.05
VIC	1.33	0.23	0.24	0.33	0.29	0.05
QLD	1.05	0.23	0.24	0.33	0.29	0.05
SA	1.04	0.26	0.24	0.33	0.29	0.05
WA (SWIS)	0.94	0.22	0.24	0.33	0.29	0.05
TAS	0.06	0	0.24	0.33	0.29	0.05
NT	0.72	0.19	0.24	0.33	0.29	0.05

Table 4: CO_2 Emissions by Fuel Type (kg CO_2/kWh)

7.3.2 Floor Normalisation

As for the AccuRate tool, there is the possibility for making it progressively harder for space heaters in larger houses to achieve higher space heating star ratings. Thus, when the CO_2 emission factor is calculated (in units of kg CO_2/m^2), larger houses are penalised in recognition of their larger absolute carbon contribution. Given that this approach has been accepted in AccuRate, it seems fair and consistent to apply it to the space heating rating tool also.

7.3.3 Charting of System Performance Distribution

The spreadsheet-based prototype space heating tool was used to calculate a limited set of data points that are shown in Figure 1. This allows the effect of the variation in kg CO_2 emissions to be shown across the main regions of interest. The figure demonstrates the performance of one selected heating system in three different house models. Further work will allow refinement and the inclusion of a variety of other heating systems as required.

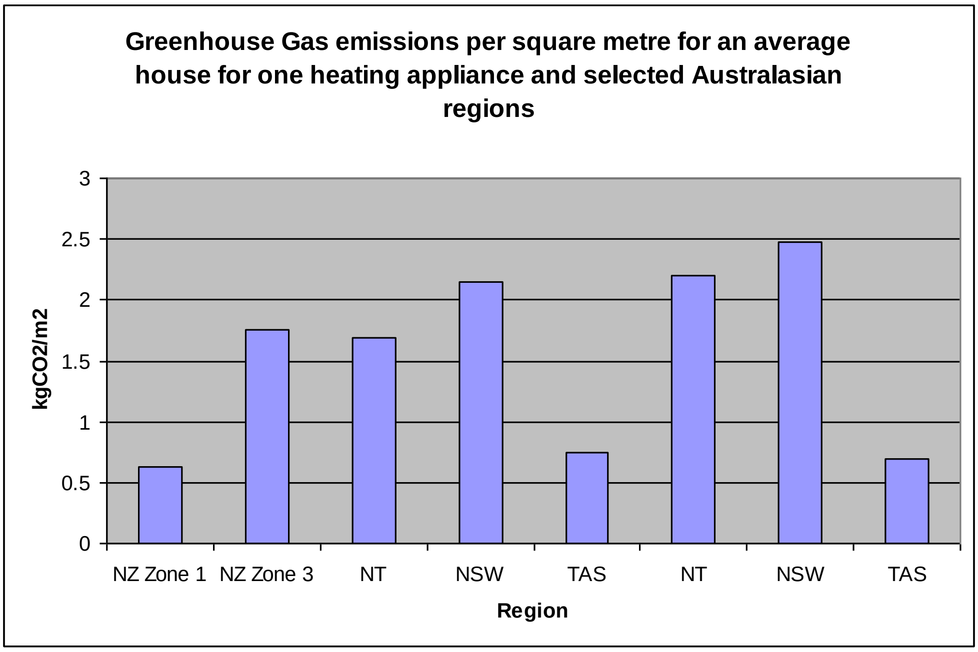


Figure 1: CO_2 emissions for one heating appliance per square metre of two different house models in three Australian climates, and one model in two New Zealand climates.

8. SUMMARY AND RECOMMENDATIONS

SUMMARY

Of all the possible environmental impact indicators, CO_2 emissions (by floor area) resulting from fuel use was established as the best proxy for gauging the environmental impact of space heating. A listing of commonly found domestic heating appliances from both Australia and New Zealand is presented, along with an average efficiency. It was found that no international space heating related tool could be found that met the Australasian requirements for adaptation, so it is proposed to develop a tool from scratch that could be used as a bolt-on tool for existing thermal modelling programs. The AccuRate modelling tool, used in both New Zealand and Australia, was seen as the most promising back-end tool given its robustness and acceptance in the marketplace. A stepped procedure is proposed to extract the appropriate AccuRate (hourly) energy output information, to determine the annual CO_2 emissions per square metre of conditioned floor area, based on space heater (fuel) types. Very little extra information is required above that necessary for a standard HERS calculation.

Graphed CO_2 emissions for each region showing the emissions from the generic heater types based on two loads 5k and 20kw are provided in Appendix D, giving a basic indication of the variability between heater types and the different fuel regions.

RECOMMENDATIONS

1. In order to determine the star ranking between zero stars (poor performance) and 10 stars (excellent performance), the distribution between the heater types must be charted for each climate zone, or at the minimum, each fuel zone. The results provided are for one heater in a living/family room in each of three different models – the average New Zealand house (2 climate zones, Auckland and Wellington), the existing AccuRate 1 storey model, and the existing AccuRate 2 storey model (3 climate zones, Alice Springs, Sydney and Tasmania). This demonstrates the difference that fuel generation methods make to CO_2 emissions per square metre. The star rating should be based on a rating of 3 for an "average" house with electric default heating for each climate zone.

2. Currently, AccuRate star ratings are based on an adjusted floor area to penalise very large houses that have a lower surface/floor area ratio. It seems sensible and reasonable to carry this approach over to the CO_2 emissions ratings for space heating.

3. Ideally, some adjustment to account for the effectiveness of heat pumps – both in terms of their overall performance and their climate sensitively-related performance – should be made. This needs to be part of a discreet study, as no recent, independent benchmarking information could be found.

4. The tool in its current form assumes that if a heater is assigned to a zone, the heat is effectively distributed to that specific zone. At this stage items such as heat transfer kits have not been accounted for. This could be considered in a further upgrade. (Note: the generic efficiency figures for central heating systems include typical transfer losses)

5. The tool does not include a de-rating for heaters that are largely oversized (which is included in the cooling scheme). There are two reasons for this: a zone may have more than one heater where the heaters collectively are oversized but they are used at different times of the year; unlike cooling there are many different fuel types and heating options with less ability to provide accurate maximum output data for some

heating types (e.g. woodburners). Until a complete database of specific information has been built up this is not recommended.

6. It is recommended that in order to increase the efficiency of the data collection of heating systems, existing links between Government Agencies are exploited to make use of existing databases of space heating systems in Australia and New Zealand.

7. It may be worth considering the presence/effectiveness of thermostats, since these are likely to alter the way people heat their spaces. Unfortunately, this issue was not investigated as part of the HEEP studies conducted by BRANZ.

8. To ensure there is consistency between assessments, it is suggested that a training guide is developed for identifying heater types and likely performance parameters. One of the better ways to achieve this is to use photo representations of the major brands and associated models.

9. The transfer of heat losses within ducts (which are usually out of the thermal envelope of the house), might need to be considered. Even in insulated ducting (which has an R value of less than 1.0), the losses are likely to be significant, especially where the temperature difference is high or the traverse long.

10. Losses due to underfloor heating systems might also be considered in future assessments.

11. As many of the product specific variables need to be standardised as possible, to ensure consistency. It is suggested that the sources for these should only rely on third party accredited testing such as that required by:

- Ministry for the Environment/Nelson/Otago Council process
- Clean Heat Project registration or approval status
- EECA Energy Rating Label holder (see www.energyrating.gov.au/)
- Solid fuel appliance certification status and expiry by Australian Home Heating Association
- or any other approved third party appliance tester

REFERENCES

Australian Greenhouse Office (AGO), 2006. Factors and Methods Workbook. Department of the Environment and Heritage, Canberra, Australia.

Environment Australia 2002, *Emissions from solid-fuel-burning appliances (wood-heaters, open fireplaces)*, Consultancy by CSIRO Atmospheric Research, authors: J. Gras, C.Meyer, I. Weeks, R. Gillett, I. Galbally, J. Todd, F. Carnovale, R. Joynt, A. Hinwood, H. Berko and S. Brown, Canberra, Australia.

Isaacs, N., Camilleri, M., French, L., Pollard, A., Saville-Smith, K., Fraser, R., and Rossouw, P., 2005. *Energy Use in New Zealand Households: Report on Year 9 of the Household Energy End-use Project (HEEP)*. BRANZ Study Report 141. BRANZ Ltd, Judgeford, New Zealand.

Isaacs N. P., Camilleri M., French L., Pollard A., Saville-Smith K., Fraser R., Rossouw P. and Jowett J., 2006. *Energy Use in New Zealand Households: Report on the Year 10 Analysis for the Household Energy End-use Project (HEEP)*. BRANZ Study Report 155. BRANZ Ltd, Judgeford, New Zealand.

Ministry for the Environment (MFE), 2005. *Detailed Study of Heating Options in New Zealand: Phase 1 Report*. Prepared by Strategic Energy and EnergyConsult for the Ministry for the Environment, Wellington, New Zealand. November 2005.. Pages 4–36.

Natural Resources Canada, Ottawa, 2002. *'HOT2000, Users manual'*, Version 8.73.

New Zealand Green Building Council. *Green Star NZ Office Design V1 Technical Manual*. 2007.

Wilkenfeld and Associates 1998, *Australia's national greenhouse gas inventory 1990 and 1995: Cross-sectoral analysis of emissions*.

APPENDIX A: SPACE HEATING IN AUSTRALIA AND NEW ZEALAND

Space heating is a large contributor to household energy use in both New Zealand and some parts of Australia.

New Zealand

In New Zealand, BRANZ's nationally representative HEEP Study of 400 houses has shown that space heating is the single largest consumer of energy in New Zealand houses, accountable for 34% of total energy use by end use, followed by water heating at 29%, as shown in Figure 2.

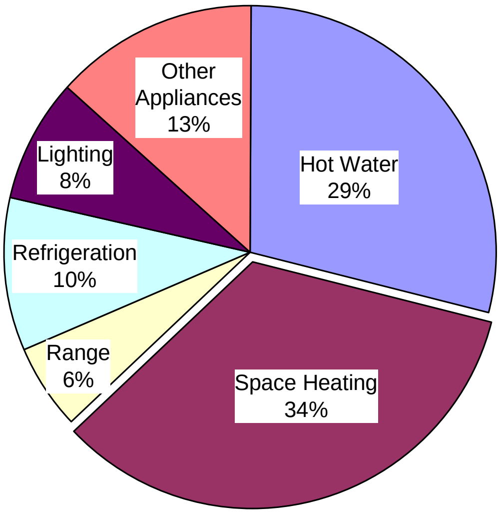


Figure 2: Total energy use by end use. Source: HEEP Year 10 Report.

On a nationwide basis, solid fuel, taking into account the efficiency of the wood-burning appliances (assumed to be 60%), was responsible for providing 45% of space heating energy in New Zealand residences, as can be seen in Figure 3. Electricity came second, providing 32% (assuming 100% efficiency) of New Zealand's residential space heating energy. Reticulated, or mains gas provided 15% (assuming 80% efficiency), while bottled LPG provided 8% (assuming 94% efficiency). It should be noted that reticulated gas is only available in the North Island of New Zealand.

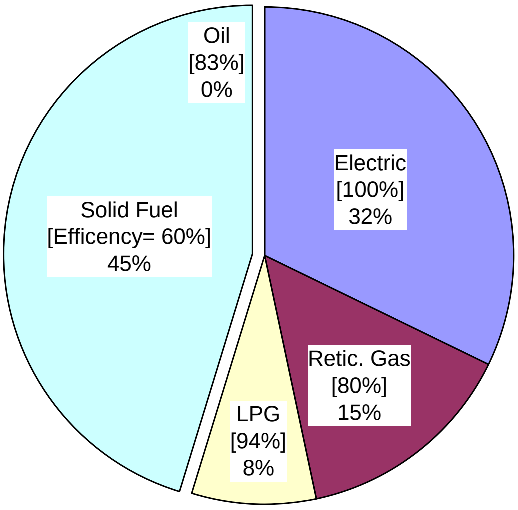


Figure 3: Space heating delivered energy by fuel. Source: Year 10 HEEP Report.

Very few New Zealand residences do not have a heater – in the HEEP study around 2.5% households said they did not own any heaters, and just under 4% said they did not use heaters anywhere in the house at any time[1].

Australia

In 1995, space heating accounted for 40% of residential energy use in Australia (Wilkenfeld & Associates, 1998). As can be seen in Figure 4, just over ¼ of Australian residences use electric space heating, while just under ¼ have no heater. More Australian residences are heated with wood than mains gas. However, LPG/bottled gas and mains gas combined heats just under ¼ of Australian residences.

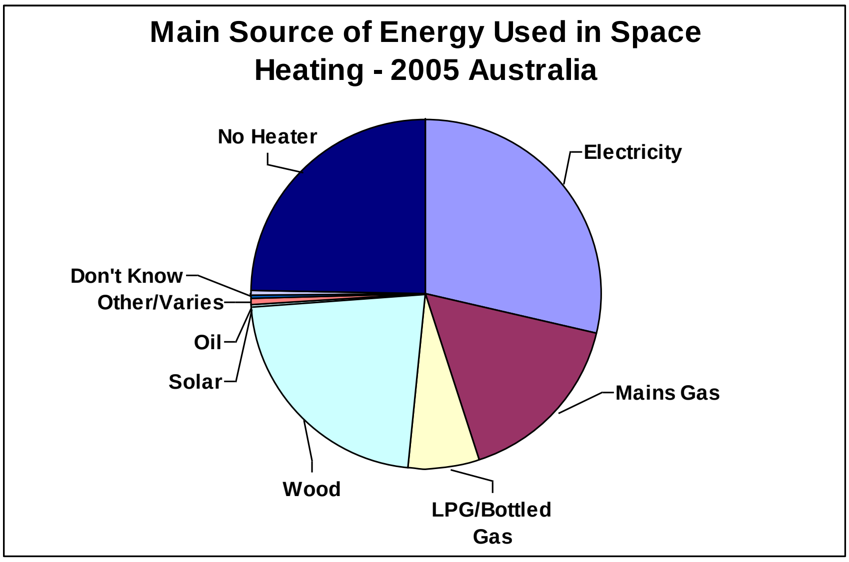


Figure 4: Fuel types used in Australia for Space Heating in 2005.

[1] Personal correspondence with Michael Camilleri, BRANZ, 14/06/2007.

The main sources of energy used for space heating varies widely across the states of Australia. More households in Queensland do not have a heater than do.

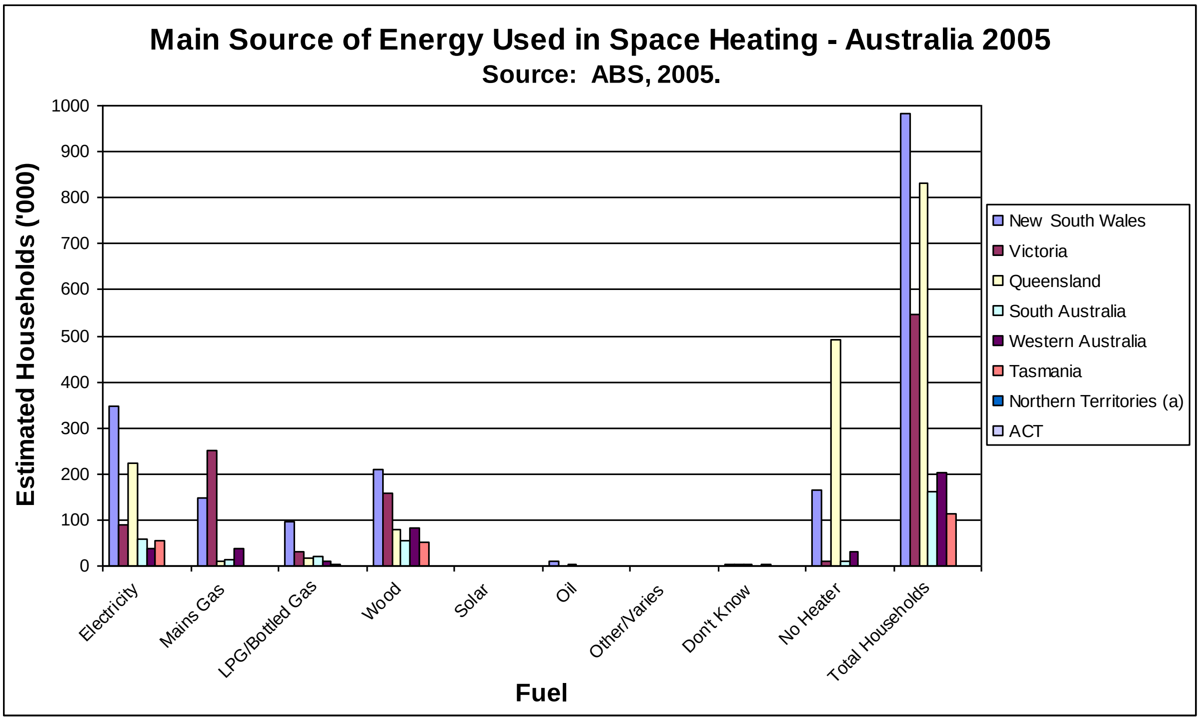


Figure 5: The main sources of energy used in space heating in Australia and its States in 2005. Source: ABS, 2005.

APPENDIX B: HOT3000 OVERVIEW

INTRODUCTION

HOT3000 stemmed from HOT-CAN, which used a monthly heat balance model, and is a new model to replace HOT2000 with its bin-based energy analysis core. HOT3000 incorporates the ESP-r energy analysis engine developed by the University of Strathclyde, with more flexibility and expandability than HOT2000's bin-based energy analysis core (Natural Resources Canada, 2007).

HOT3000 was formulated for the Canadian market to simulate the energy use of residential buildings. It was developed with support from various individuals from Government departments and the Canadian building industry. The basis for this tool has potential to be used for part of the space heating appliance rating tool. As will be discussed in depth later in this report, it will need to be expanded and changed in order to produce the desired outputs, as well as to cater for Australian and New Zealand heaters and heating patterns.

The amount of information required for the space heating section of HOT3000 is relatively extensive, and output is generated with this information along with information on the physical characteristics and properties of the building from elsewhere in the building file. Currently heating and cooling are wound up together in one section of the tool named "Heating/Cooling Systems". A list of the inputs required are listed in the table below, with each column representing one "tab" or section of the input for the Heating/Cooling Systems section input.

Tab/Section of Heating/Cooling Systems	Subsection	Item
Main	Type 1	Select: Baseboards; Furnace; Boiler; Combo heat/DHW; Fuel cell cogen system
	Type 2	Select: N/A; Air-source HP; Water-source HP; Ground Source HP; Central Air Conditioning.
	Additional	Select: Radiant Heating; Solid fuel burning; Supplementary Heating System 1; Supplementary Heating System 2
Season	Cooling	Select: Start Month; End Month; Design Month
Fans/Pumps	Heating Systems Fan/Pump	Mode; (N/A, auto, continuous, two speed, other); Fan/Pump Power (calculated; user specified); Energy Efficient Motor (select/leave blank)
	Cooling Systems Fan/Pump	Indoor Mode (auto, continuous); Fan power (calculated, user specified); Indoor fan flow rate (specify litres/second); Power (specify Watts)
Baseboard	Specifications	Output capacity (user specified, calculated); Value (kW or btu/hr); Sizing Factor (default to 1 if user specified output capacity, specify if calculated); Efficiency (overwriteable default of 100%)
	Equipment Information	User write in Manufacturer and Model
Heat Pump – Air	Equipment	Unit Function (Heating, Heating/Cooling); Cooling Type (Conventional, Economiser Control, Ventilation Control).
	Equipment Information	User writes in Manufacturer and Model
	Specifications	Capacity (specify kW or btu/hr); Heating efficiency (COP/HSPF); Cooling Efficiency (COP or SEER); Temp. Cutoff Type (Balance Point, Restricted °C, Unrestricted)
	Additional	Specify Crankcase heater; Sensible Heat Ratio; Vent Cooling Flow (if Ventilation Control Equipment selected); Economiser Control (if Economiser Control Equipment selected); Openable Window Area (%)
Heat Pump – Water Source	Equipment	Unit Function (Heating, Heating/Cooling); Cooling Type (Conventional, Economiser Control, Ventilation Control).
	Equipment Information	User writes in Manufacturer and Model
	Specifications	Capacity (specify kW or btu/hr); Heating efficiency (COP/HSPF); Cooling Efficiency (COP or SEER); Temp. Cutoff Type (Balance Point, Restricted °C, Unrestricted)
	Additional	Specify Crankcase heater; Sensible Heat Ratio; Vent Cooling Flow (if Ventilation Control Equipment selected); Economiser Control (if Economiser Control Equipment selected); Openable Window Area (%)
	Water Temperature	Use (Calculated, User Specified); Edit Temperatures (if User Specified); Average Depth (Default to 1.5 m, can be overwritten).
Heat Pump – Ground Source	Equipment	Unit Function (Heating, Heating/Cooling); Cooling Type (Conventional, Economiser Control, Ventilation Control).
	Equipment Information	User writes in Manufacturer and Model
	Specifications	Capacity (specify kW or btu/hr); Heating efficiency (COP/HSPF); Cooling Efficiency (COP or SEER); Temp. Cutoff Type (Balance Point, Restricted °C, Unrestricted)
	Additional	Specify Crankcase heater; Sensible Heat Ratio; Vent Cooling Flow (if Ventilation Control Equipment selected); Economiser Control (if Economiser Control Equipment selected); Openable Window Area (%)
	Ground Temperature	Use (Calculated, User Specified); Edit Temperatures (if User Specified); Average Depth (Default to 1.5 m, can be overwritten).
Solid Fuel		Equipment Type (N/A, Fireplace With Doors, Open Fireplace, Wood Stove, Wood/Coal Furnace); Flue Diameter. *Note: Option for 2 Solid Fuel Burners.*
Central Air Conditioning	Equipment	Cooling Type (Conventional, Economiser Control, Ventilation Control); Cooling Type (Conventional, Economiser Control, Ventilation Control); Add-On or Stand Alone.
	Equipment Information	User writes in Manufacturer and Model
	Specifications	Use (Calculated, User Specified); Sizing Factor (default to 1 if calculated, specify if 'User Specified'); Efficiency (COP or SEER).
	Additional	Specify Crankcase heater; Sensible Heat Ratio; Vent Cooling Flow (if Ventilation Control Equipment selected); Economiser Control (if Economiser Control Equipment selected); Openable Window Area (%)

Subsidiary Heating 1 & 2	Equipment	Fuel Type (Electric, Natural Gas, Oil, Propane, Mixed Wood, Hardwood, Softwood, Wood Pellets); Equipment Type (Furnace/Boiler w/spark ignition, Fireplace w/spark ignition [unsealed], Fireplace w/spark ignition [sealed], Fireplace with pilot [unsealed], Fireplace with pilot [sealed], Portable Heater [describe]).
	Equipment Information	User writes in Manufacturer, Model and Description.
	Additional	Year Made (Before 1920, 1920–29, 1930–39, 1940–49, 1950–59, 1960–69, 1970–79, 1980–89, 1990–99, 2000–); Usage (Never, 10% of time, 25% of time, 50% of time, 75% of time, Always, Specified Monthly [%], Specified Monthly [hr/day]); Location Heated (Main Floors, Basement, Exterior); Approximate Floor Area Heated (User Specifies m^2), Flue Location (Interior, Exterior); Flue Type (Brick, Brick/Tile Lined, Plastic Single Wall, Metal, Metal insulated); Diameter (100 mm Default can be overwritten); Rated Output Heating Capacity (kW, default of 2 can be overwritten); Steady State Efficiency (% default of 30 can be overwritten); Pilot Light Energy Consumption (MJ/day default of 25 can be overwritten).

To tailor the tool to Australia and New Zealand, the heating types contained within the tool would need to be modified, and certain sections added to take into account other variables needed to ascertain RATING INDEX of space heating in different climates throughout Australia and New Zealand.

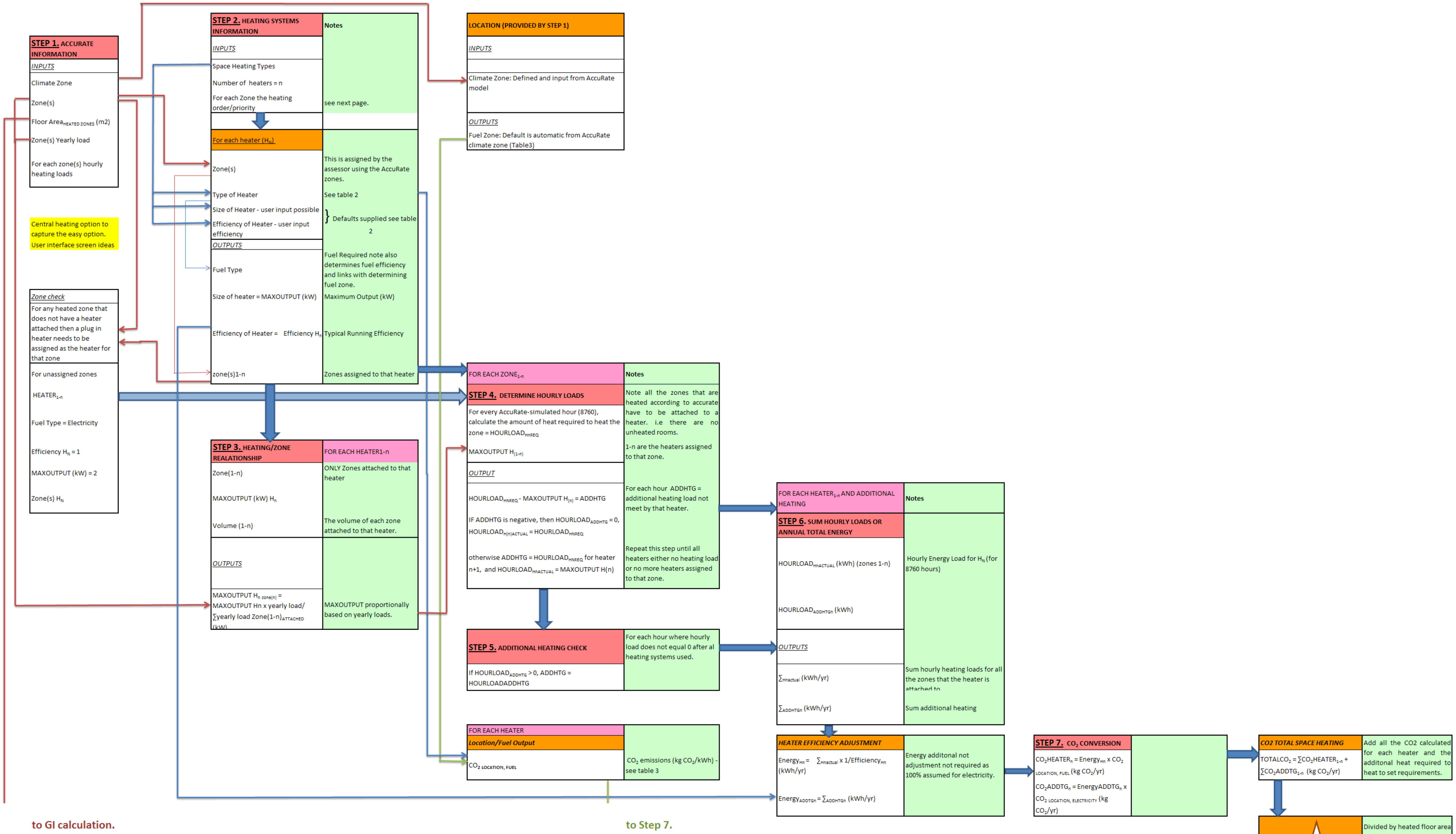
HOT3000 has limited choice in the types and numbers of heaters. Should the user be permitted to select heater fuel, certain brand and models, most of the information required could be pulled from a database and automatically selected. A generic selection could also be made, putting in generic values that can be overwritten into the project for users with information for older models or lesser known models.

The heating zones of HOT3000 assume systems are centralised, rather than allowing the ability to spot heat, as is more reflective of Australian and New Zealand homes. Users are unable to specify where heaters are located unless the heater is listed under one of the two Supplementary Heating tabs. Users should be able to allow zoning of heaters (and thereby heating set points) in accordance with Australian and New Zealand home heating patterns.

As with many of the other tools, selection criteria is often named with explanation-less technical jargon. This should be reworded or annotated with flash-up explanations for better understanding by the general public and those who are new to using the tool.

HOT3000 requires little information on solid fuel burners. For a tool used in Australia and New Zealand, this should be extended to include particulate emissions, efficiency, and fuel. This would allow the inclusion of multi-fuel burners and pellet burners.

For heat pumps and heaters with thermostats, default temperature settings should be selected to avoid occupant behaviour from influencing results.



APPENDIX C. Space Heating Tool Flow Chart

APPENDIX D: GRAPHED OUTPUTS

The following graphs show the variation in CO2 emissions across each of the New Zealand and Australian fuel regions to supply the peak heating demand with the nominated generic heater plus any required supplemental heating by a default electric heater. Emissions for an hour of peak demand at 5 kW and 20 kW are calculated. Note that the scales on the 5 and 20 kW heater graphs are different.

The solid column in each graph represents the space heating emissions from the heater named, with the outline column that extends up beyond the black column representing the emissions from the supplementary heating system (defined as a 100% efficient default electric space heater).

Three of the graphs, Western Australia, Tasmania and New Zealand, are explained below. The graphs for the other Australian states are similar to that of Western Australia, and therefore are included without individual explanation at the end of this section.

Western Australia

The first graph, for Western Australia (WA), shows that under 5 kW of peak load heating for an hour, pellet burners have amongst the least emissions of all the different heating types.

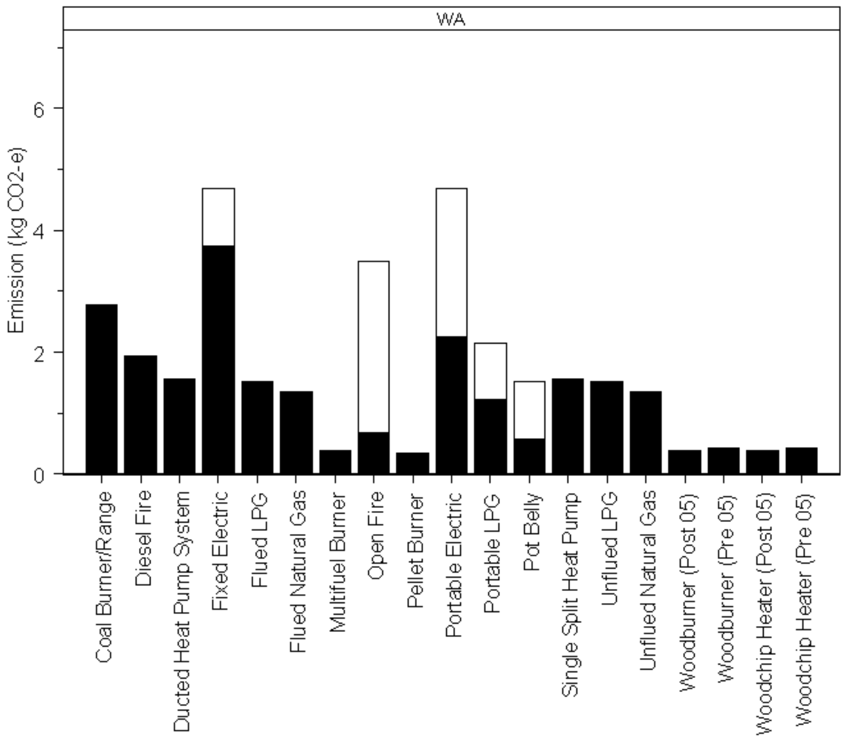


Figure 6: CO_2 emissions for the provision of 5 kW of peak-load space heating in the Western Australian fuel zone.

However, under 20 kW of peak heating load for an hour (see **Figure 6**), the emissions associated with the use of the pellet burner are higher than those of the heaters with larger outputs, such as woodburners and ducted heat pump systems.

This is due to the emissions associated with the full fuel cycle (production, transmission, distribution) of electricity for Western Australia being higher than that of wood and wood pellets, as well as the high efficiency of the ducted heat pump system. These appliances also require little default electric heating, which tends to lead to lower overall emissions.

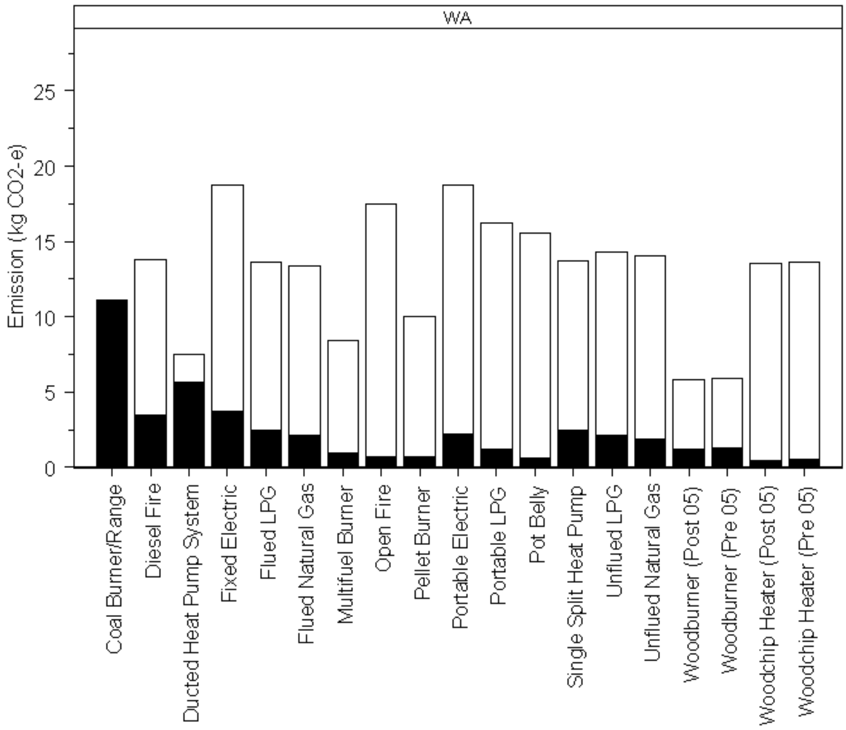


Figure 7: CO_2 emissions for the provision of 20 kW of peak-load space heating in the Western Australian fuel zone.

Tasmania

In contrast to the other Australian states, the lowest GHG emitting space heating appliances in Tasmania are electric (including single split and ducted heat pumps, followed by portable and fixed electric), at both 5 and 20 kW peak heating load, due to the dominance of hydro electricity. Coal ranges have the highest GHG emissions at both peak heating loads. Note that there is no reticulated natural gas supply in Tasmania, therefore emissions figures are not included.

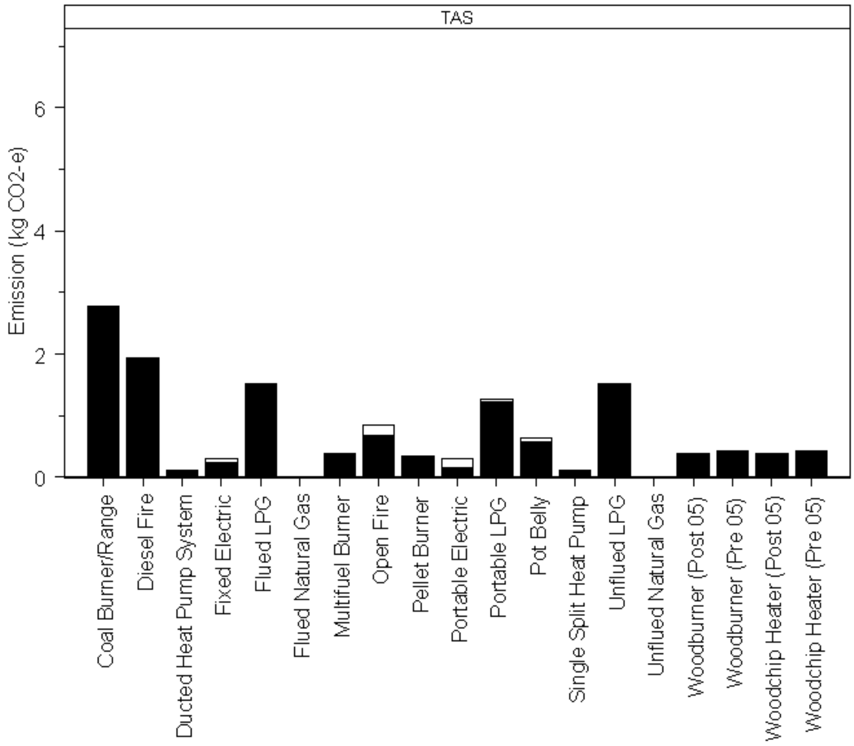


Figure 8: CO_2 emissions for the provision of 5 kW of peak-load space heating in the Tasmanian fuel zone.

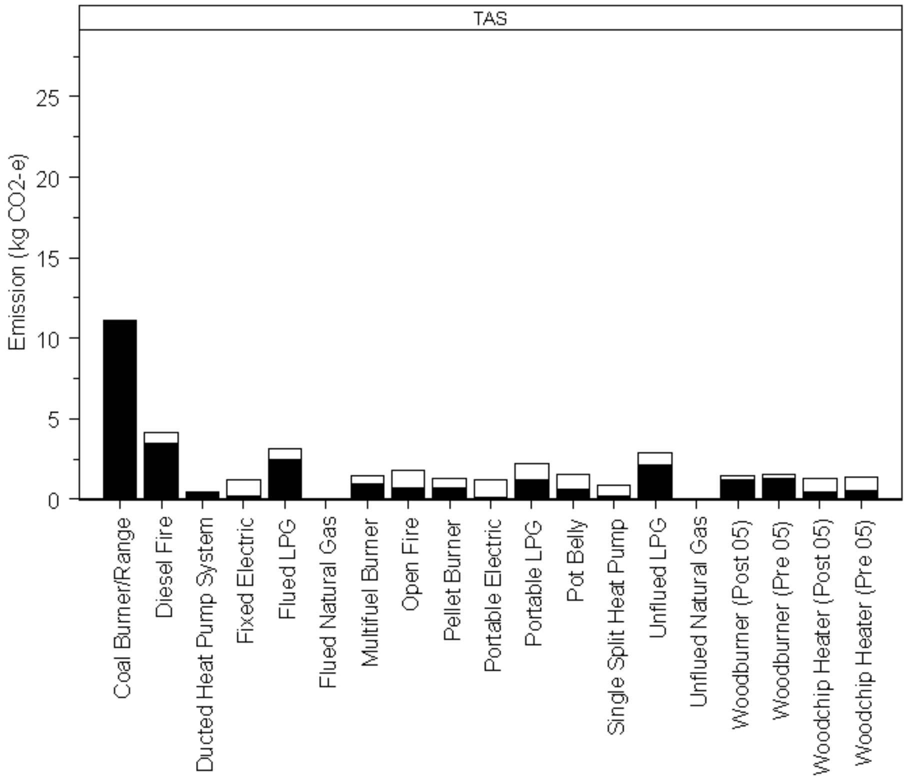


Figure 9: CO_2 emissions for the provision of 20 kW of peak-load space heating in the Tasmanian fuel zone.

New Zealand

The GHG emissions from New Zealand space heating appliances (excluding wood-fuelled) are quite different to those in Australia. Due to the use of space heating appliances when thermal power stations are used to top up supply, the marginal GHG emissions from electric space heaters are similar to that of the Northern Territories (see Figure 18 & Figure 19).

The space heating appliances with the lowest GHG emissions in New Zealand at 5 kW peak load are pellet burners, as well as woodburners and woodchip heaters installed after 2005. The highest GHG emitting appliances are fixed and portable electric, followed by open fires under both 5 and 20 kW peak heating loads.

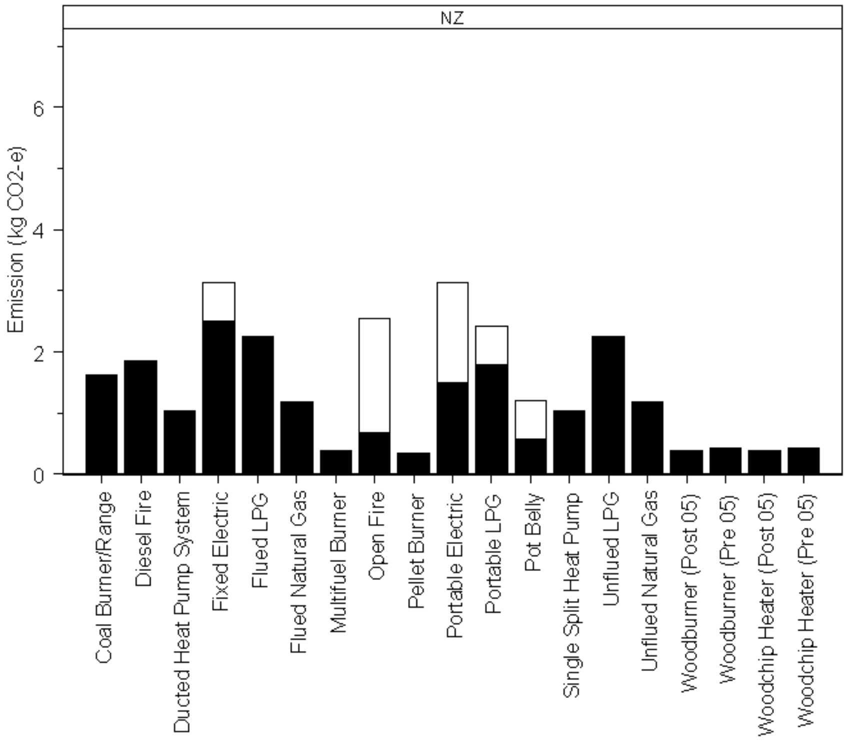


Figure 10: CO_2 emissions for the provision of 5 kW of peak-load space heating in the New Zealand fuel zone.

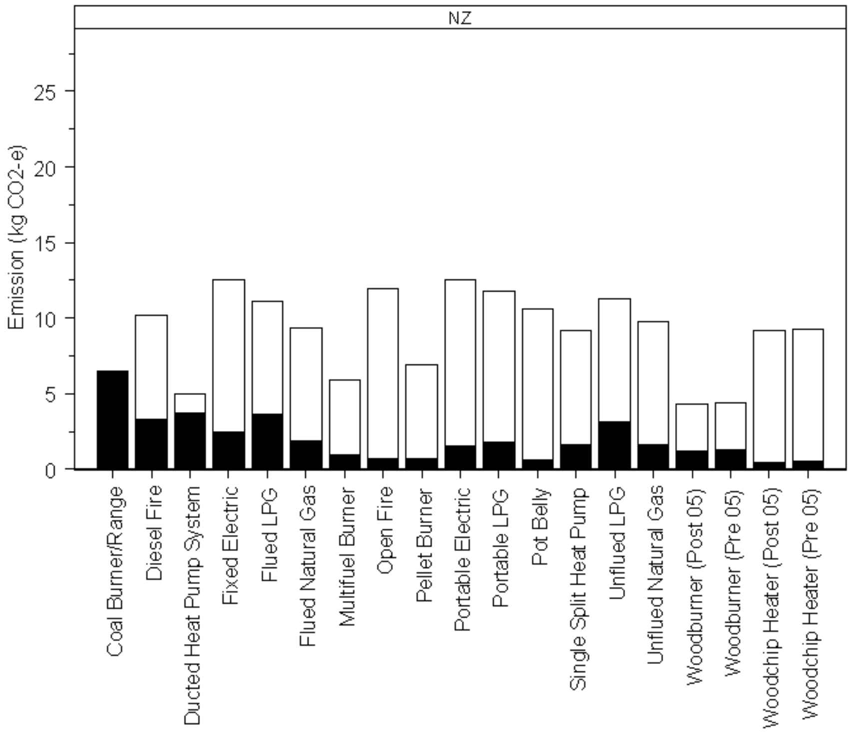


Figure 11: CO_2 emissions for the provision of 20 kW of peak-load space heating in the New Zealand fuel zone.

The space heating appliances with the lowest GHG emissions under 20 kW of peak load are woodburners, installed before or after 2005, followed by ducted heat pump systems.

Victoria

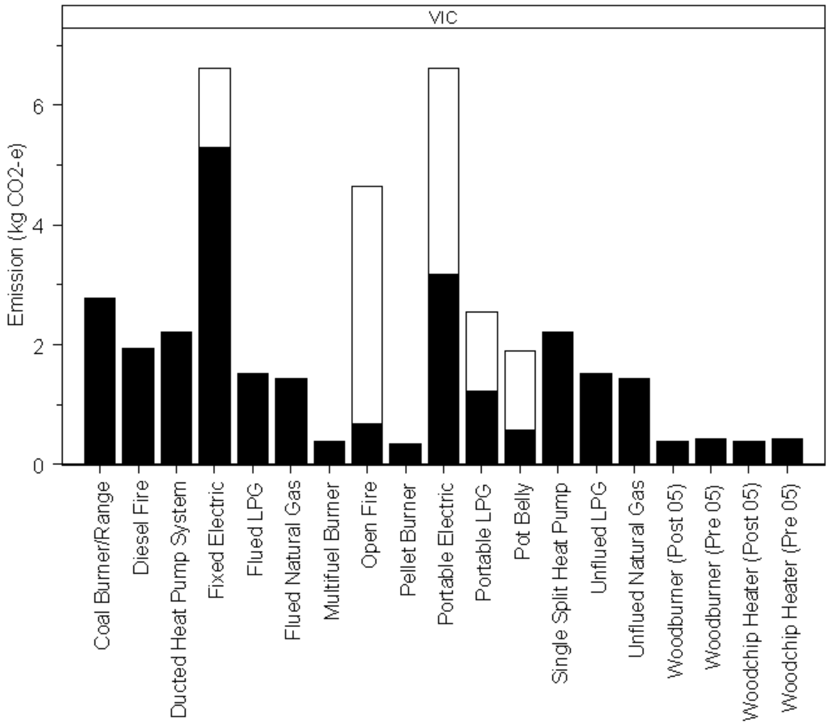


Figure 12: CO_2 emissions for the provision of 5 kW of peak-load space heating in the Victorian fuel zone.

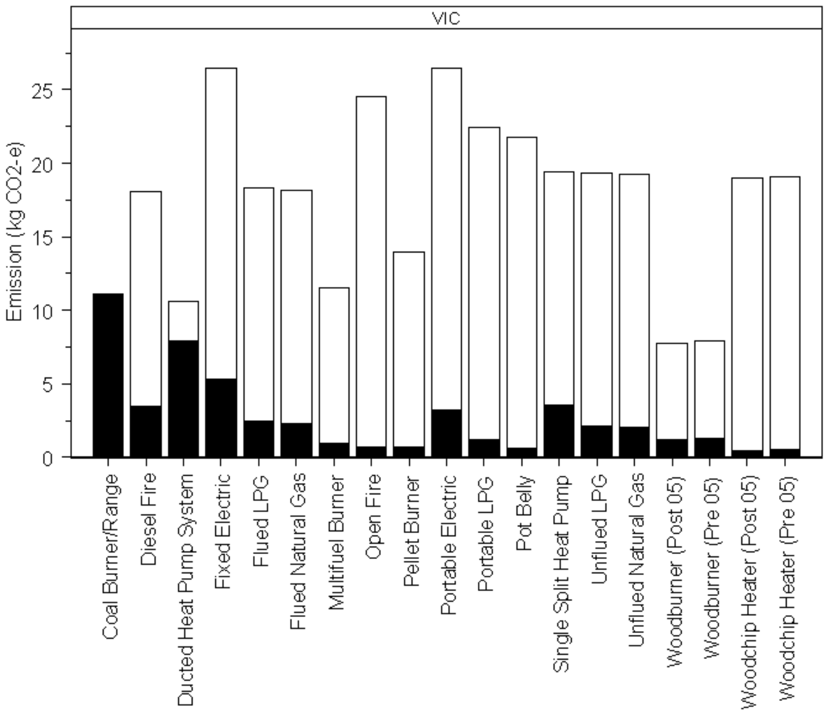


Figure 13: CO_2 emissions for the provision of 20 kW of peak-load space heating in the Victorian fuel zone.

South Australia

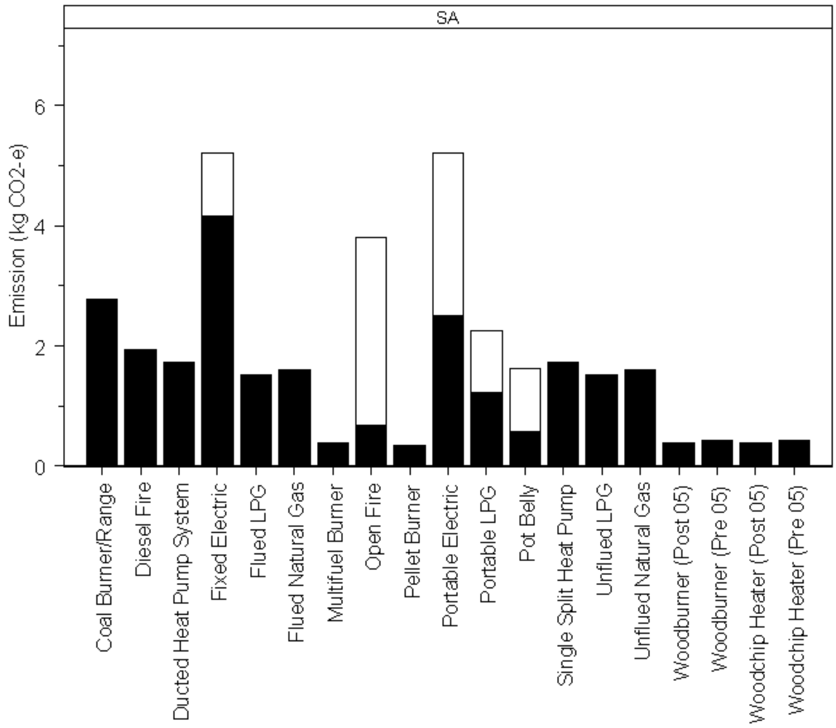


Figure 14: CO_2 emissions for the provision of 5 kW of peak-load space heating in the South Australian fuel zone.

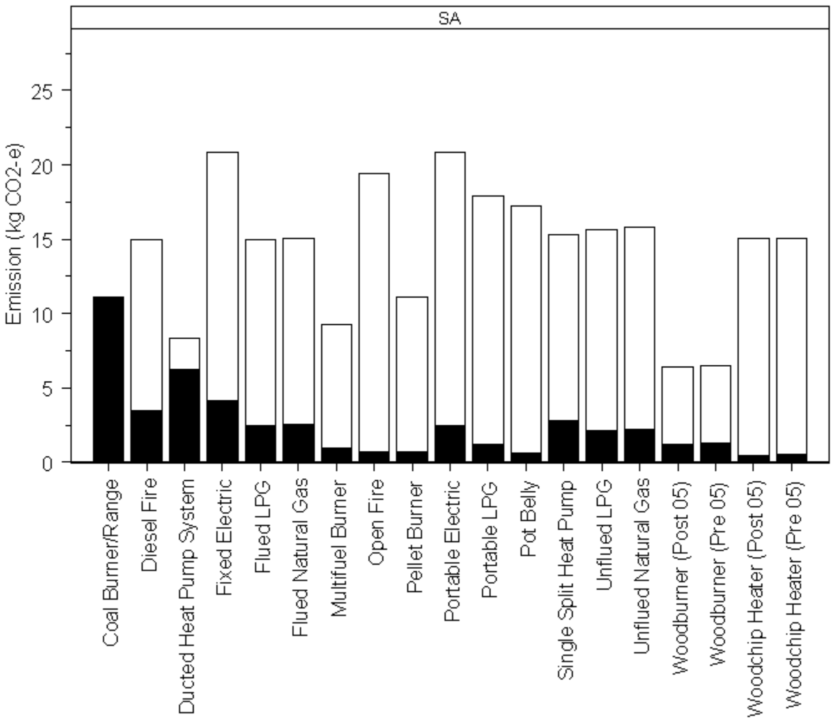


Figure 15: CO_2 emissions for the provision of 20 kW of peak-load space heating in the South Australian fuel zone.

Queensland

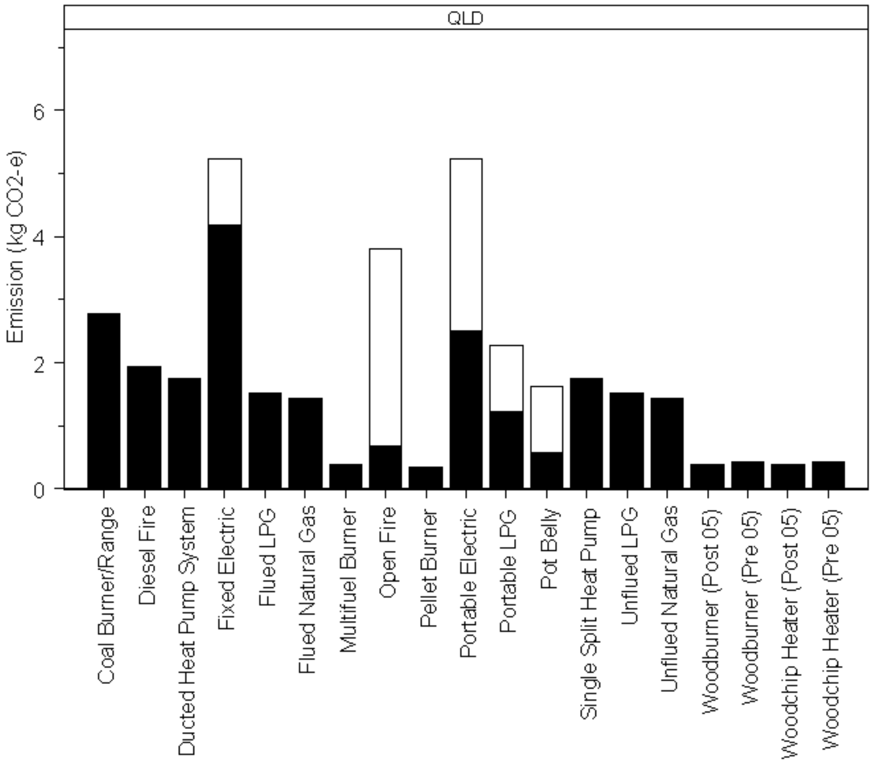
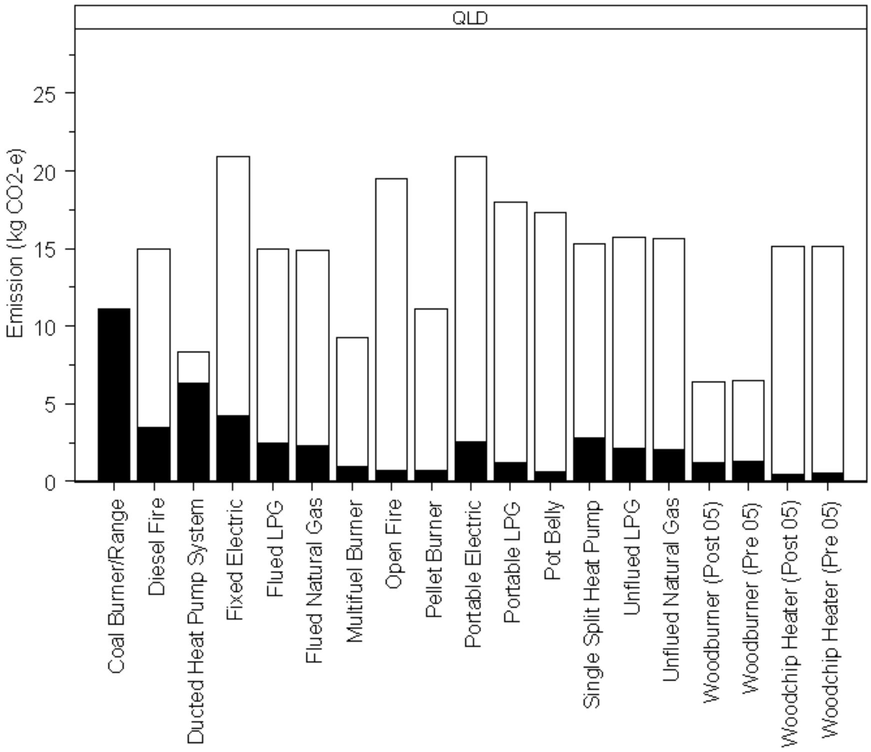


Figure 16: CO_2 emissions for the provision of 5 kW of peak-load space heating in the Queensland fuel



zone.

Figure 17: CO_2 emissions for the provision of 20 kW of peak-load space heating in the Queensland fuel zone.

Northern Territories

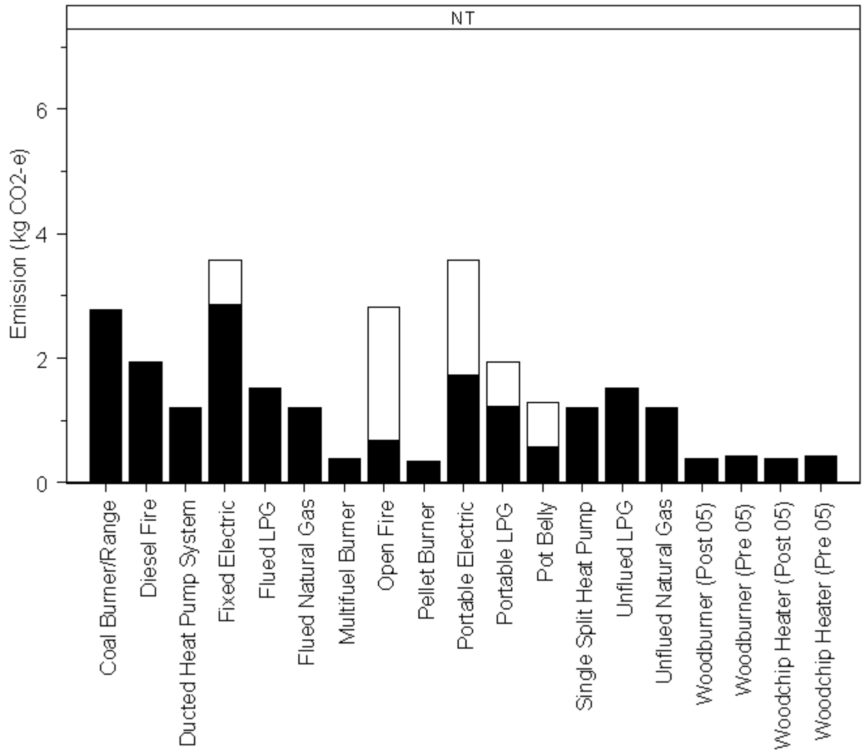


Figure 18: CO_2 emissions for the provision of 5 kW of peak-load space heating in the Northern Territories fuel zone.

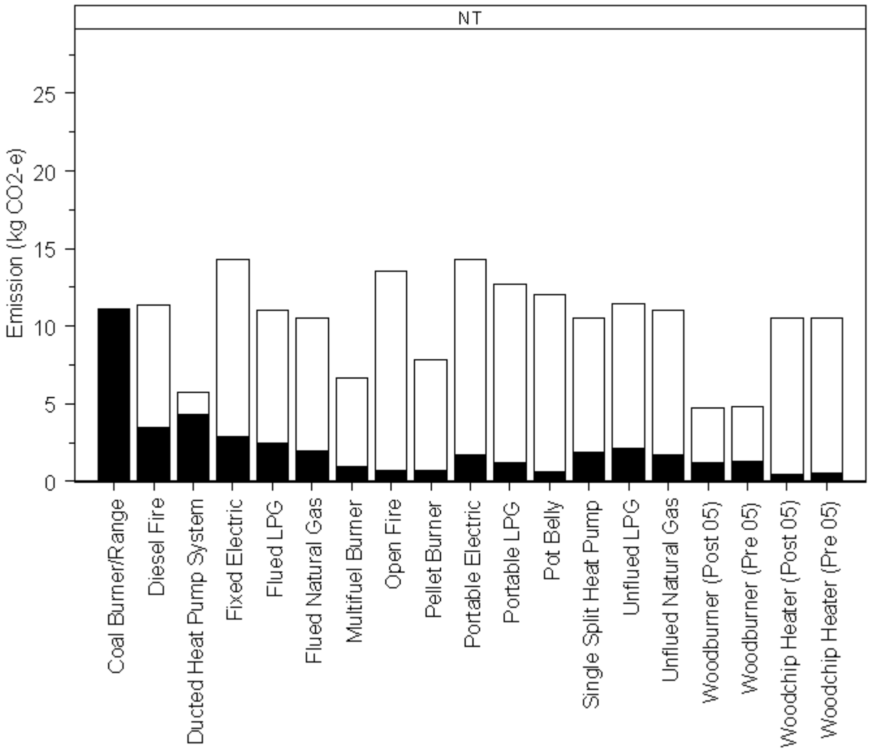


Figure 19: CO_2 emissions for the provision of 20 kW of peak-load space heating in the Northern Territories fuel zone.

New South Wales/Australian Capital Territories

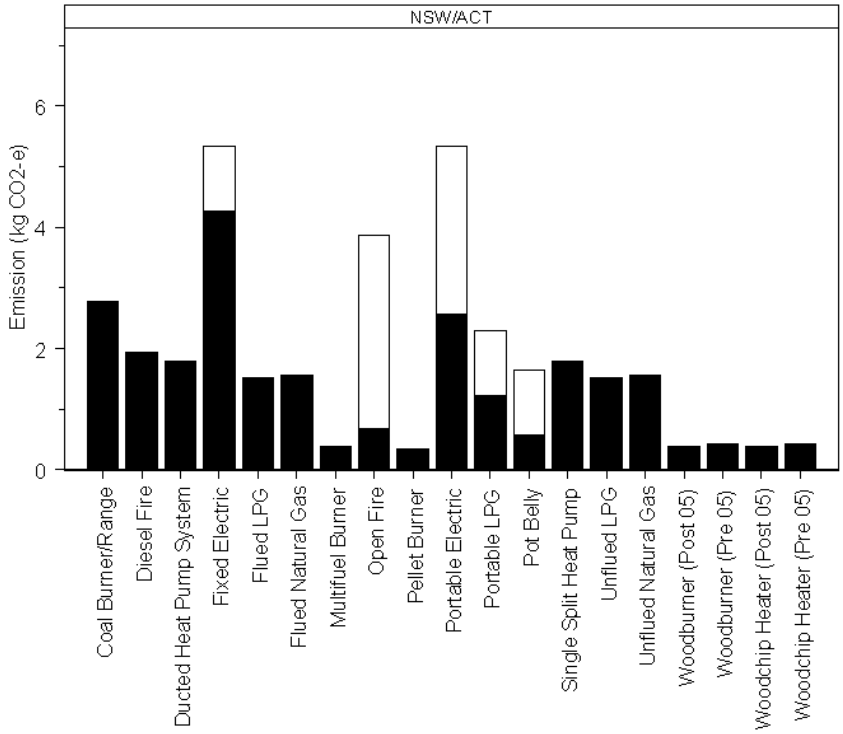


Figure 20: CO_2 emissions for the provision of 5 kW of peak-load space heating in the New South Wales/Australian Capital Territories fuel zone.

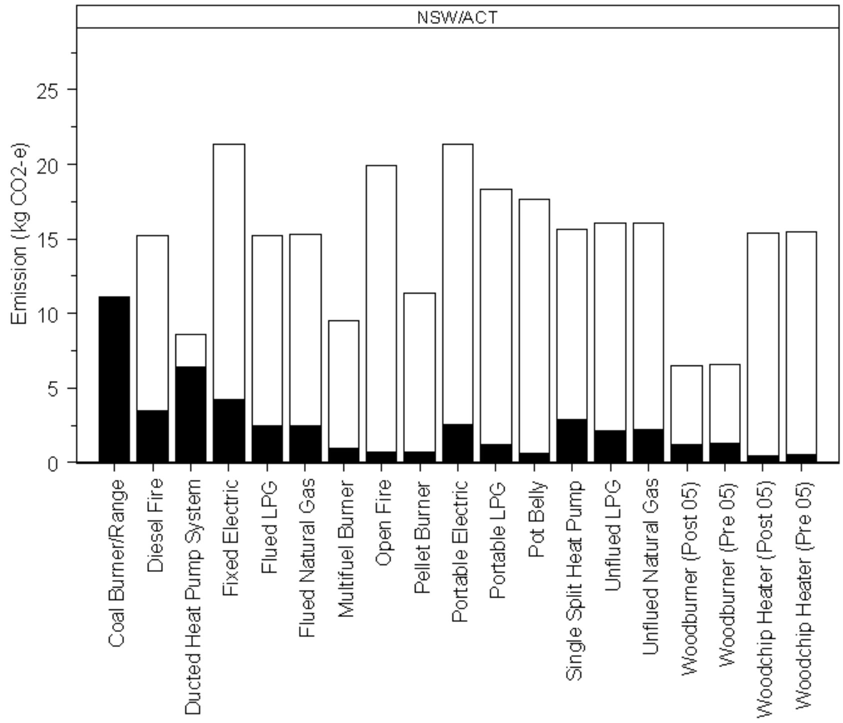


Figure 21: CO_2 emissions for the provision of 20 kW of peak-load space heating in the New South Wales/Australian Capital Territories fuel zone.