Final Report

GEMS Data Modelling Project 2022

Prepared for:

Department of Climate Change, Energy, the Environment and Water

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Executive Summary

The objective of this project is to provide technical advice to support the Department's development and implementation of data sourcing and modelling, in order to capture past trends and predict future trends relating to the Greenhouse Energy Minimum Standards (GEMS), appliance energy efficiency, and associated carbon emissions reductions (referred to as emissions in this report).

The purpose of the report is to provide the Department with a summary and details on the modelling approaches adopted for the project and modelling results of the energy, emission and cost saving achieved by GEMS activities. The report describes:

- Overview of the methodology
- GEMS products covered and prioritised products included in the modelling
- Specific modelling approach and data/sources used for modelling the energy use and savings of the priority products
- The total energy, emission and cost savings aggregated over the priority products calculated for 2021/22.

This work covers all existing GEMS products, both residential and commercial, though the project focused on modelling the energy saving from the six product categories which appeared to produce the vast majority (97%) of the total estimated energy savings. These categories consisted of air conditioners, lighting, refrigerators and freezers, televisions, electric storage hot water, and motors. Consideration was also given to having the modelling capacity to include additional products as others are added to regulated product categories in the future.

The method of estimating the impact of a policy implementation used consisted of comparing the actual outcome to an alternative of a hypothetical, no policy implementation, which is a well-established method of estimating policy impacts. The hypothetical, no policy alternative is often called the counterfactual or baseline hypothesis. The use of the counterfactual measurement approach was applied to determine the impact of GEMS by modelling the energy use of individual products under two sets of conditions and to then calculate the savings by comparing the energy used under the different conditions. The two sets of conditions were:

- Actual: the actual energy characteristics for specified products in the given period as recorded by GEMS registrations and reflecting the actual market conditions that occurred after the GEMS regulations were introduced
- Counterfactual: the assumed energy characteristics for specified products in the given period as estimated from preceding market trends or other information, assuming the GEMS MEPS or labelling had not been introduced.

The counterfactual efficiency for Residential and Residential/Business[1] products needed to be determined for each product. It was found that the Regulatory Impact Statement (RIS) developed before a product was regulated was usually the best source of pre-intervention energy efficiency and

[1] Business is taken to refer to non-residential sectors, including the commercial and industrial sectors.

energy use, and also of existing (i.e. no GEMS regulation) trends/RIS projections in energy efficiency improvements for the product.

There were three main data gaps that impacted on the modelling, relating to lack of data in the following:

- Product sales by brand and model
- Pre-GEMS intervention average product efficiency and efficiency trends.
- Measurement of product labelling (ERL) impacts on consumer purchase behaviour.

The modelling outputs and impact estimates were calculated based on two counterfactual scenarios which were established for the each of GEMS product categories. The two scenarios were:

- **Savings 1 Scenario - Lower Efficiency Improvement**: This scenario assumed there would be minimal efficiency gain without GEMS interventions, with the level of improvement reflecting what has been used in RIS and previous impact analyses. This scenario results in savings estimates that are higher, as the difference between the poorer product efficiency under the scenario and the efficiency after GEMS is greater.
- **Savings 2 Scenario - Higher Efficiency Improvement**: This scenario assumes international or market-specific trends in product efficiency will have affected and increased efficiency trends over time without the GEMS interventions. This scenario results in savings estimates that are lower, as the difference between the slightly higher product efficiency under the scenario and the efficiency after GEMS is lower.

The spreadsheet enables the calculation of Annual energy consumption and energy savings, which were then used to calculate:

  - Annual emissions produced and emissions savings
  - Annual energy costs to the consumer and cost savings

The six product categories modelled represent the vast majority, approximately 97%, of the energy savings from the GEMS program according to the previous Department modelling.

Summary of Modelling Outputs

For 2021-22 the energy and emission savings from GEMS interventions were found to be:

- Energy savings estimated as being between 5,425GWh (Savings 2 scenario) to 8,306GWh (Savings 1 scenario)
- Emissions reductions estimated as being between 4,134 kt CO_2-e (Savings 2 scenario) to 6331 kt CO_2-e (Savings 1 scenario)
- Savings from air conditioners and from refrigerators and freezers were the biggest contributors to the total savings.

The modelling was used to forecast future energy and emission reductions stemming from existing GEMS interventions and the annual energy saving benefits from the GEMS Program for the years 2021, 2030 and 2040. These estimates and forecasts are shown in the following table. The forecasts show energy savings from GEMS impacts will increase over time, but emission savings will decrease. This is due to the declining emissions intensity of Australia's electricity grid as more renewable energy

generation is installed and higher emission electricity generation is retired, reducing the emission impact of GEMS energy savings.

Table 1: Summary of annual energy savings and emission reductions by scenario in 2021, 2030, 2040

Indicator	Scenario	2021	2030	2040
Energy Savings (GWh)	Sav.1	8,306	10,730	12,357
Energy Savings (GWh)	Sav.2	5,425	6,402	6,339
Emissions reduction (kt CO2-e)	Sav.1	6,331	2,914	1,484
Emissions reduction (kt CO2-e)	Sav.2	4,134	1,754	771

The cumulative benefits of GEMS over varying time periods were calculated from the annual impacts and are shown below. The results again show that GEMS has an increasing impact on energy savings in the future, but its emissions impact declines.

Table 2: Cumulative energy and emission savings over various time periods

Type of Savings		Historical		Future	
	Scenario	22 Years 2000 - 2021	10 years 2012 -2021	10 years: 2021 - 2030	20 years 2021 - 2040
Energy (TWh)	Sav.1	85	67	95	212
Energy (TWh)	Sav.2	60	45	59	124
Emissions (Mt CO_2-e)	Sav.1	78	60	49	70
Emissions (Mt CO_2-e)	Sav.2	55	40	31	43

The energy savings benefits from GEMS can be measured as energy cost savings and treated as a benefit to the economy. In 2021-22 the GEMS program is estimated to have saved Australian households and businesses between $1.3 billion (Savings 2 scenario) and over $2 billion (Savings 1 scenario) in avoided energy costs. For this report, the energy cost savings are based on energy tariffs by state, in present value 2021 dollars.

Cumulative energy cost savings also predict the GEMS interventions will continue to produce energy cost savings into the future, as shown in the table below.

Table 3: Cumulative energy cost savings over various time periods ($B)

	Historical		Future 10 years: 2021 - 2030	
Scenario	22 Years 2000 - 2021	10 years 2012 -2021	Constant prices	30% price increase
Sav.1	21	18	23	29
Sav.2	14	12	15	18

1. Introduction

Objective of project

The objective of this project is to provide technical advice to support the Department's development and implementation of data sourcing and modelling, in order to capture past trends and predict future trends relating to the Greenhouse Energy Minimum Standards (GEMS), appliance energy efficiency, and associated carbon emissions reductions (referred to as emissions in this report). The data sourcing and modelling also forms an input into the annual E3 Achievements report on the GEMS program report to be released early in 2023.

The project includes:

1. Identification and sourcing of suitable data, with input and provision of some datasets by the Department where appropriate.
2. Data collated and provided in Microsoft Excel.
3. Modelling and outputs describing relevant appliance/equipment energy efficiency outcomes, and how these are estimated to contribute to Australian emissions reductions and energy cost savings to the Australian economy.
4. Report on the data and model provided, including sourcing of data, processes to update data, assumptions and adjustments made in developing the model, and a manual/operating procedure describing development and use of the model.

This work covers all existing GEMS products, both residential and business, though the project focused on modelling the energy saving from the six product categories which appeared to produce the vast majority of the estimated total energy savings. These categories consisted of air conditioners, lighting, refrigerators and freezers, televisions, electric storage hot water, and motors. Consideration was also given to having the modelling capacity to include additional products as others are added to regulated product categories in the future.

Background

Over the last decade, the Department and its predecessors have utilised energy efficiency, technical characteristics, energy consumption and trend data associated with the GEMS regulated products to:

- Investigate and identify policy options for improving the energy efficiency and reducing greenhouse gas emissions of products
- Prepare Regulatory Impact Statements (RIS) for policy options
- Assess sector wide historical energy end use consumption and future trends in the stationary energy use sector
- Evaluate the impact of current energy efficiency policy options

These activities have relied upon researching, collating and analysing GEMS product data held in the registration database including data concerning:

- Energy efficiency (various metrics)
- Energy label attributes or performance measures related to MEPS levels
- Output or size
- Product categories/sub-categories.

The collection and analysis of GEMS product registration data is relatively informative but its usefulness is limited as it only explains what specific models are on the market and the timing of their release to the market, but not the number of products sold or installed. Further information on the sales[2] or installation of models in Australia (by state) has been purchased by the Department to enable the matching of sales to model characteristics. This analysis has enabled historical sales-weighted product technical characteristics to be developed for several products covered by GEMS (and earlier state-based MEPS and labelling regulations).

Sales and sales-weighted efficiency, size and other technical characteristics are a key input into estimates of energy consumption by appliances and equipment in Australia. They provide inputs for stock models which estimate the energy consumption of many products and enable trends to be determined that help estimate future changes in energy consumption.

The collection, analysis and modelling of these data for the Department have been initiated in the past for policy analysis, RIS and baseline studies at various times and usually for a particular product (e.g. TVs, Refrigerators, AC, etc). The knowledge and skills to complete these data analysis tasks are usually sourced from consultants, with some transfer of the outputs and models to Department staff. However, the Department now wishes to obtain the data and modelling resources which will enable them to estimate energy and emission savings in future years.

The current project therefore requires:

- Identifying and accessing GEMS and other data sources which can be used for modelling GEMS impacts and energy efficiency achievements
- Developing a model/models which can be used to estimate energy efficiency and emissions trends and GEMS achievements
- Documenting the assumptions and data sources used in the modelling, so energy efficiency and emissions impacts can be modelled in the future in a consistent manner by Department officials.

Purpose of this Report

The purpose of the report is to provide the Department with a summary and details on the modelling approaches adopted for the project and modelling results of the energy, emission and cost saving achieved by GEMS activities. The report describes:

[2] GfK has been contracted by the Department or E3 members to provide sales by model, state and year for several GEMS product categories in the last three decades. Gfk no longer collects sales data, except for TVs. This lack of data is addressed in the RBS2.0 Methodology report (EnergyConsult, 2020)

- Overview of the methodology
- GEMS products covered and prioritised products included in the modelling
- Specific modelling approach and data/sources used for modelling the energy use and savings of the priority products
- The total energy, emission and cost savings aggregated over the priority products calculated for 2021/22.

Further instructions, models and modelling outputs are provided separately to the Department.

Overview of methodology

The methodological challenge in determining the impact of a regulatory change, like the introduction of GEMS regulations, is that we cannot directly compare what did occur under GEMS regulations to what did not occur. We can measure what actually happened after GEMS regulations were introduced, but we have to make assumptions about what might have happened if GEMS regulations were not introduced in order to form and estimate a hypothetical non-GEMS alternative. However, if we make those assumptions and estimate the alternative outcome, we can then compare the actual to the hypothetical alternative to estimate the impact of GEMS.

This method of estimating the impact of a policy implementation by comparing the actual outcome to an alternative of no policy implementation is a well-established method of estimating policy impacts. The hypothetical, no policy alternative is often called the counterfactual or baseline hypothesis. This approach to evaluating the impact of GEMS regulations has previously been used for evaluating the impact of air conditioning (EnergyConsult, 2010) and refrigerator/freezer (EES, 2010) MEPS/ERL regulation.

The use of the counterfactual measurement approach was applied to determine the impact of GEMS by modelling the energy use of individual products under two sets of conditions and to then calculate the savings by comparing the energy used under the different conditions. The two sets of conditions were:

- Actual: the actual energy characteristics for specified products in the given period as recorded by GEMS registrations and reflecting the actual market conditions that occurred after the GEMS regulations were introduced
- Counterfactual: the assumed energy characteristics for specified products in the given period as estimated from preceding market trends or other information, assuming the GEMS MEPS or labelling had not been introduced.

The actual energy consumption of products can be estimated from information on the energy consumption and efficiency of the products in the market, and recorded in the GEMS registration database, combined with information on product usage and sales. The information can be used to create models that use a bottom-up and data driven approach to determine the energy use of the products. This involves using detailed annual sales data to develop stock models for each product. These stock models contain the stock number of each variation of product in each year where GEMS data was available and also contained the relevant product characteristics for each year, obtained by linking the GEMS data on each product with annual model sales data. The stock numbers and product

characteristics data can then be combined with product usage information to calculate energy use for each product.

This modelling approach was used to estimate the actual energy use of residential products, as the required information was already contained in the Residential Baseline Study (RBS) model and the RBS (EnergyConsult, 2020) could be utilised to provide high-quality estimates of energy use and emissions created by the relevant products for a given year. Similar models also exist for business products where Regulatory Impact Statements (RIS) have been developed to evaluate and justify the introduction of GEMS regulations for the products.

The estimating of energy consumption for a specific product under the counterfactual scenario was more complex as it involves developing alternative hypotheses and the assumptions that would support them. The processes involved included:

- Determining what the energy efficiency and energy consumption characteristics of the product were before the GEMS intervention occurred[3]
- Estimating how these energy characteristics would have changed over time, if the GEMS intervention had not occurred, and then projecting what the product energy characteristics would be in the time period being considered
- Combining the projected energy characteristics with information on product usage and actual sales to determine the counterfactual energy consumption and emissions.

Projecting what the product energy characteristics would be under the counterfactual scenario involved making assumptions about product changes. These varied with the product: some products are mainly imported and so their performance will be driven by international trends, some are affected by rapid technology changes, and others are stable technologies and are not exposed to international markets.

Generally, we assumed that for products exposed to international trends or technological change, e.g. air conditioners, product efficiency will improve over time even without GEMS intervention. In such cases we have assumed the energy efficiency characteristics of products entering the market improve at a greater than zero rate, for example, of 0.5% and 1.0% pa under potential high and lower counterfactual scenarios[4]. For products that had stable technologies and are not exposed to international markets, e.g. electric storage water heaters, we have assumed no 'baseline' efficiency improvements under the counterfactual scenarios.

For residential products, projecting the product energy and emissions impacts under the counterfactual scenario was undertaken with the RBS model, using its policy scenario facilities. This ensured that information on product usage and sales used in the counterfactual estimation matches that used for the actual energy use modelling.

Alternatively, if access to the product's RIS analysis was available, this was used for business products or when the RIS modelling was more sophisticated than the RBS modelling, as the more effective

[3] In some cases the GEMS MEPS/labelling followed on from previous State regulation of the product, in which case consideration of the situation before the State intervention was necessary.

[4] The percentage improvements in the scenarios can vary from 0.5% and 1.0% depending on the product.

method to determine energy savings. The RIS analyses were first updated with currently available data, e.g. annual product sales and efficiency, before being used for energy saving estimation.

The modelling approaches used are described in more detail in the following section.

2. GEMS products coverage and modelling approaches used

The products covered by GEMS MEPS or labelling regulation are shown in Table 4. There are 30 products linked to 24 current GEMS determinations, but a number of these 'products' are sub-categories of product categories covered by a single determination. When sub-categories are excluded, there are 19 product categories that are or have been covered by a GEMS MEPS or Energy Rating Label (ERL) intervention. The majority of these products are residential products, though most of these products can be used in both the residential and business sectors. The energy saving arising from the GEMS regulation on these residential products was estimated primarily using the RBS model.

A small number of products are used exclusively in the business sector and their impacts were assessed using separate modelling.

Table 4 summarises the following:

- GEMS product category and subcategory, as broad categories have interventions at the subcategory level at different times
- The sector applicable
- The MEPS and Energy Rating Label (ERL) intervention date.

Table 5 summarises:

- Energy savings over a two-year period (2019/21, 2020/21) summed from the Department's previous modelling spreadsheet[5] (DISER, 2017).
- Modelling framework for this project.

[5] The modelling assumptions used for the previous model were not available to be compared with the assumptions and inputs used for this project.

Table 4: GEMS product categories, subcategories, GEMS intervention dates

			Interventions (year)							
GEMS Product Category	**Subcategory**	**Sector**	**MEPS**				**ERL**			
Air conditioners	Single phase	All	2004	2006, 2007	2010	2011	1987	2001	2010	2020
Air conditioners	Three phase	BUS	2001	2007		2011	NA			
Air conditioners	Above 65 kW	BUS	2022				NA			
Air conditioners	Single duct & portable	RES	2020				2020			
Computers		All	2013				NA			
Computer monitors		All	2013				2013			
External power supplies		All	2008							
Lighting	Incandescent	All	2009				NA			
Lighting	Fluorescent lamps	BUS	2005				NA			
Lighting	Fluorescent ballast	BUS	2003				NA			
Lighting	CFL	RES	2010				NA			
Lighting	ELV converters	RES	2010				NA			
Lighting	LED, MVH/LVH	All	2023?							
Refrigerators & freezers	Refrigerators	RES	1999	2005	2021		1986	2000	2010	2021
Refrigerators & freezers	Freezers	RES	1999	2005	2021		1986	2000	2010	2021
Dishwashers		RES					1988	2000		
Clothes washers		RES					1990	2000		
Clothes dryers		RES	2012				1990	2000	2015	
Set-top boxes	Free-to-air	RES	2009				NA			
Set-top boxes	Subscription (pay) TV	RES	Voluntary (2010)				NA			
Televisions		RES	2009	2013			2009	2013		
Gas water heaters	Storage	RES	2013				No GEMS			
Gas water heaters	Instantaneous	RES	2013				No GEMS			
Electric storage water heaters	Large	RES	1999				NA			
Electric storage water heaters	Small	RES	2005				NA			
Pool pumps		RES	2022				2022			
Refrigerated cabinets	Display cabinets	BUS	2003	2021			NA			
Refrigerated cabinets	Storage cabinets	BUS	2021				NA			
Distribution transformers		BUS	2004				NA			
Electric motors		BUS	2001	2006			NA			
CCACs		BUS	2009				NA			
Chillers		BUS	2009				NA			

Sources:

RIS 2010 National Legislation for Appliance and Equipment Minimum Energy Performance Standards (MEPS) and Energy Labelling, Table 10 Products and measures covered by E3 Program, (DCCEE, 2010)

E3 Program Impact Projections March 2014 Table 1 Products and measures covered by E3 Program Projections (E3, 2014)

Retrospective Review of the E3 Program (E3, 2011b)Table 3 - Energy Efficiency Measures for Air Conditioners, Table 2 - Energy Efficiency Measures for Refrigerators and Freezers

Review of Residential Appliance Energy Labelling (SEC, 1991).

The Department has previously undertaken modelling of the energy and emissions savings that have occurred from the GEMS regulation of the GEMS covered products. The energy savings for the

different product categories are shown in Table 5. It shows there are 19 product categories covered by GEMS, but that only eight of these product categories provided 99.4% of the previously estimated energy saved from the GEMS program during the years 2019-2021.

Table 5: GEMS product categories and percentage of total previous (2019-2021) energy savings estimates

GEMS Product Category	Subcategory	Total Energy Saving 2019-21 (GWh)	% total	Model Framework
Air conditioners	Total	1,315	**8.5%**	AC RIS (2017)
Computers		0	0.0%	NA
Computer monitors		0	0.0%	NA
External power supplies		2	0.0%	NA
Lighting	Total	5,112	**32.9%**	RBS
Refrigerators & freezers	Refrigerators	5,781	**37.2%**	RBS
Refrigerators & freezers	Freezers	1,048	**6.7%**	RBS
Dishwashers		0	0.0%	RBS
Clothes washers		334	**2.1%**	RBS
Clothes dryers		0	0.0%	RBS
Set-top boxes	Free-to-air	0	0.0%	NA
Televisions		1,072	**6.9%**	RBS
Gas water heaters	Storage	62	0.4%	RBS
Gas water heaters	Instantaneous	0	0.0%	RBS
Electric storage water heaters	Total	654	**4.2%**	RBS
Pool pumps		NA		RBS
Refrigerated cabinets	Display cabinets	23	0.1%	RC RIS (2017)
Distribution transformers		0	0.0%	NA
Electric motors		63	**0.4%**	Motors RIS (2022)
CCACs		73	**0.5%**	CCAC RIS (2016)
Chillers		2	0.0%	Chillers RIS (2016)

Total (GWh)	15,542	100%
Total (Mt CO_2-e)	12.87	

Source: Previous Department modelling (DISER, 2017) for energy savings.

Note: Product subcategories have been aggregated to a total for the energy end-use (e.g. lighting, air conditioners), as the Department spreadsheet did not separate savings by subcategory.

Due to the minimal energy and emissions savings that were estimated to have been provided by the other 11 product categories, the current project focused on estimating the energy saving from the nine product categories which produced 99% of the total energy savings. These consist of:

- Air conditioners
- Lighting
- Refrigerators and freezers
- Television
- Electric storage hot water

- Motors
- Clothes washers
- Close Control Air Conditioners (CCACs).

Further research into the modelling requirements and current usage of clothes washers and close control air conditioners found that the low energy savings from these products and complexity of modelling the savings did not warrant modelling their energy saving impacts. (See details in Clothes washers and Close Control Air Conditioners). The remaining six product categories accounted for 97% of the previously estimated energy saved from the GEMS program during the years 2019-2021.

The RBS model and its policy modelling facilities were used to model the energy savings from most of these product categories. In addition, the models prepared for the RIS analyses for Motors and Air Conditioners were used for these product categories. The modelling approaches are listed in Table 5.

Also, there are possibly impacts in 2021-22 due to new products being regulated, including:

- Pool pumps (Oct 2022, Determination 2021)
- Refrigerated display and storage cabinets (May 2021, Determination 2020).

The impacts of these products were not modelled as our initial estimation of the magnitude of the impacts from MEPS on these products suggests they would not have significant impacts on the total energy savings from GEMS regulations during the 2021-22 period. These products can be included in future versions of the impact estimates.

3. Modelling energy, cost savings & emissions impacts for products

Overview of product modelling

The goals of the modelling were to produce estimates of the following:

- National energy savings in 2021/22 due to the GEMS program
- Emission savings, to be derived from the energy saving estimates
- Energy cost savings, to be derived from the energy saving estimates.

The modelling approach that was used for the majority of residential products covered by GEMS was to use the RBS to determine both actual and counterfactual energy consumption for the products.

The underlying Energy Consumption formula used in the RBS is:

- Unit Energy Consumption (UEC) = average energy efficiency x average size x average usage for a product.

Total Annual Energy Consumption (AEC) then equals product numbers multiplied by UEC. However, as average energy consumption varies by year, the total energy used in a given year is determined by:

- UEC (year1)* product number (sold year1) + UEC (year2)* product number (sold year2) + UEC (year3)* product number (sold year3) + etc.

To keep track of these variables, and to also calculate stock declines from each year, the RBS uses large stock models driven by the actual and forecast product sales in each year from 2000-2040. Forecast savings may be utilised in the final model, however the initial focus is on current year impacts.

The RBS therefore contains the modelling requirements needed to calculate actual energy requirement in any given year, using its detailed data on product stock numbers and energy characteristics. The RBS modelling also had the capability to be revised to model the counterfactual scenario, by changing the average energy efficiency of products sold in all relevant years, which in turn changes the UEC for the products in all those years. The model could then be used to calculate counterfactual total energy consumption and emissions.

Alternatively, some GEMS interventions have led to changes in the technology of the products that are sold in the market, e.g. the phase out of incandescent lamps that increased the proportion of CFL lamps sold. These changes in the mix of product technologies were also modelled by the RBS, so again it was used to determine the counterfactual scenario impacts of relevant products.

The energy saving estimates derived from the RBS were converted into estimates of:

- Energy cost savings: by multiplying the energy savings by the energy tariff for the relevant fuel and region.
- Emissions savings: by multiplying the energy savings by the greenhouse emissions factor for the relevant fuel and region.

For some of the GEMS products the RBS will not be an appropriate modelling tool to determine their energy savings, such as for business products, and instead relevant RIS models will be used. These RIS models were used to develop the forecasts of the energy saving used in the original RIS developed as part of the process of the products being regulated. The RIS models used a similar underlying logic and analysis to the RBS model but contain analyses specific to the relevant product. These RIS models were updated and modified to provide estimates of energy savings.

Limitations

Forecasts

The main focus of the project was to model and develop estimates of the energy savings for the 2021-22 year, with energy cost savings and emission savings derived from these. However, the RBS model also contains projections of product sales, UEC, efficiency trends etc which can also be used to forecast estimates of energy savings in future years, till 2040. These estimates of future energy savings are reported, but the accuracy of these estimates will be less than for the 2021-22 year and will become less accurate the more years into the future the estimate refers to.

Total energy savings

As described in the Assumptions section, the modelling of the impact of MEPS/ERL assumes no impacts occurred prior to 1999, but in practice State based MEPS and ERL programs were introduced from the mid-1980's. This means that the estimates of cumulative total energy savings from GEMS may slightly underestimate the total energy savings, due to the limitations of the modelling.

Business energy savings

Some products are treated in the RBS modelling as residential products, even though they are used in both the residential and business sectors. They are modelled as residential products as the energy use of some products, such as lighting, is largely driven by sales and appliance usage that occurs in the residential sector. The RBS model contains data on the sale of such products to both residential and business sectors, but it only models the energy use of these products in the residential sector.

This means that when the RBS is used to estimate the energy savings from GEMS impacts on such products, it will not capture the energy savings that may occur from the product units used in the business sector. As generally 90% or more of these residential/business products are sold to the residential sector, the underestimation of energy savings from GEMS interventions is relatively minor.

In theory the energy savings from the business sector could also be modelled and estimated, but in practice the lack of data on product usage and lack of consistency in usage across businesses would make building the required modelling complex and its accuracy problematic.

Data parameters, assumptions, sources and gaps

Data and parameters needed for each product

The counterfactual efficiency for included products needed to be determined for each product. It was found that the RIS developed before a product was regulated was often the best source of pre-intervention energy efficiency and energy use, and also of existing (i.e. no GEMS regulation) trends/RIS projections in energy efficiency improvements for the product. The RIS documents sometimes stated the assumed business as usual (BAU) or baseline annual efficiency changes. However, these specific assumptions were more often found in the cost benefit analysis (CBA) spreadsheets, so these spreadsheets were sourced wherever possible.

Assumptions

The year in which the first MEPS/ERL interventions of a product were initiated varies with products, and in many cases, this occurred at the State level before the national GEMS Legislation was enacted. Previous evaluations of the impact of the GEMS program have assumed that the impact of the GEMS program on a product begins from the year in which a MEPS or ERL intervention is introduced, or in some cases is announced, for the product. This means the counterfactual efficiency trends are also assumed to start in that year.

The current modelling of the impacts of GEMS on products used the initial intervention dates that have previously been used for the GEMS impact evaluations. These dates correspond to when the State/GEMS first impact on the products in the market, so they reflect when regulation first impacted on the market. Using these dates also promotes consistency between the current modelling and previous evaluations. To simplify the modelling and to use conservative assumptions about the impact duration of GEMS/MEPS interventions, no interventions are assumed to have occurred prior to 1999.

Data Gaps

There were three main data gaps that impacted on the modelling, relating to lack of data in the following:

- Product sales by brand and model
- Pre-GEMS intervention average product efficiency and efficiency trends
- Measurement of product labelling (ERL) impacts on consumer purchase behaviour.

Product sales by brand and model

To accurately estimate the energy impact of products, it was necessary to know in detail the sales numbers by product brand and model to determine the average energy efficiency and energy usage characteristics of a product. This information was previously collected by market research firms (e.g. GfK), but no longer is. Australian import data can sometimes provide total sales data, but not the detailed breakdown necessary to determine energy characteristics.

When sales weighted average efficiency could not be calculated, due to lack of data on sales by product brand and model, GEMS registration data was used to develop brand/model weighted

averages. Previous analyses of sales weighted average efficiency compared to brand/model weighted average efficiency had found that for some products the brand/model weighted average efficiency was a good approximation for sales weighted average efficiency (EES, 2010; EnergyConsult, 2010).

Pre-GEMS intervention data

As part of preparing a RIS before GEMS regulations are introduced, data will have been collected on the energy characteristics of products and energy efficiency trends for the products. Sometimes this information is reported in the RIS, but at other times the data is used to develop the cost benefit analyses for the RIS and this detailed information is not available or documented. This means unless the original cost benefit analyses have been made available to the Department and kept, it is not possible to know what the pre-intervention characteristics were and what these should be under the counterfactual scenario.

When this situation occurred for a product, estimates of the pre-intervention energy characteristics were assessed using whatever alternative information sources are available, and assumptions are made and documented. For residential products, the RBS was generally used as the source of pre-intervention energy characteristics data, while RISs were used for business products.

Product labelling (ERL) versus MEPS impacts data

It is recognised that the introduction of product labelling will have contributed to the increasing efficiency of labelled products, but it is not possible with the data available to distinguish the impact of such labelling from the impact on products when MEPS have also been introduced. Quantitative research on the impact of ERLs on consumer purchase decisions and resulting impacts on sales by product efficiency would be required and has not been undertaken. Consequently, the modelling undertaken estimates the total GEMS impact on energy saving for the relevant products but does not attempt to separate the impacts from MEPS and ERL components of GEMS interventions.

Selecting counterfactual scenarios

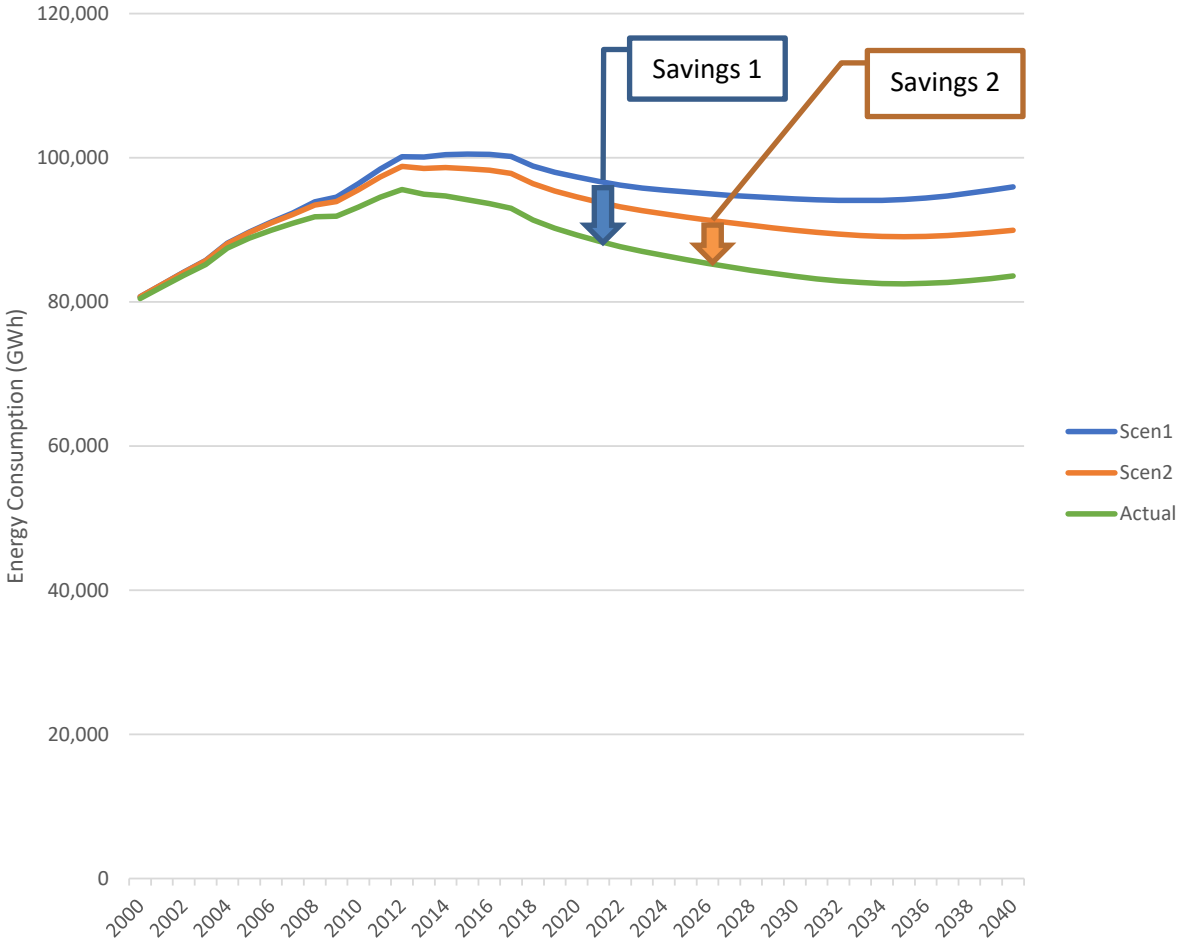
The modelling required the selection of a counterfactual scenarios to evaluate the energy savings. As there is uncertainty in determining or estimating what the change in product efficiency would have been if the GEMS interventions were not implemented, two counterfactual scenarios were established for the each of GEMS product categories. The two scenarios were:

- **Savings 1 Scenario - Lower Efficiency Improvement**: This scenario assumed there would be minimal efficiency gain without GEMS interventions, with the level of improvement reflecting what has been used in RIS and previous impact analyses. This scenario results in savings estimates that are higher, as the difference between the poorer product efficiency under the scenario and the efficiency after GEMS is greater.
- **Savings 2 Scenario - Higher Efficiency Improvement**: This scenario assumes international or market-specific trends in product efficiency will have affected and increased efficiency trends over time without the GEMS interventions. This scenario results in savings estimates that are lower, as the difference between the slightly higher product efficiency under the scenario and the efficiency after GEMS is lower.

Both counterfactual scenarios were estimated as conservatively as possible for each product, i.e. they did not assume zero efficiency improvement unless it was justified for that specific product. The estimated energy savings were the difference in energy consumption under the counterfactual scenario compared to the Actual scenario.

The energy savings were labelled as Savings 1 and Savings 2 in the data model, corresponding to the counterfactual Scenario 1 and Scenario 2. The differences between Savings 1 and 2 is illustrated in Figure 1.

Figure 1: Annual energy consumption for modelled GEMS categories by year for Actual, Scenario 1 and Scenario 2



Specific modelling approach for included products

For each of the GEMS product categories, this section outlines the key considerations for modelling the impacts of the interventions, including the chosen modelling framework, the period to be evaluated and interventions, data requirements, and sources for the actual and counterfactual scenarios.

For some of the product categories or product sub-categories, modelling was not undertaken, due to the decision that there was likely to be insufficient energy savings. For these products, a section on the assessment of the likely energy savings and describing why modelling was not undertaken is provided (see Product categories/subcategories not included in modelled savings).

Air conditioners

Air conditioners required the evaluation of the impacts of MEPS/ERL from 2004, as products will be impacted and still in service from the MEPS/ERL interventions in 2004, 2006, 2007, 2010, and 2011, as well as the GEMS Determination in 2019.

Modelling framework: The RIS CBA model (E3, 2011a, 2018) prepared by EnergyConsult was used. Details of the modelling include:

- The Air Conditioner RIS (E3, 2018) CBA modelling used includes all categories of products currently regulated in the GEMS Determination (2019)
- There was significant complexity with the categorisation of products by the past regulations, as both size (kW capacity) and power supply (single-phase vs three-phase) were used to distinguish between applicable MEPS/ERL. The RIS CBA model included separation of these categories
- This model was updated with GfK sales data to 2017-18, and used to produce estimates for the RBS2.0[6], including the forecast trends to 2020 and further to 2040. The trends in efficiency and sales were considered likely to be valid for the period 2021-22, which is the year where GEMS energy saving impacts are being estimated
- It included the business and residential sectors
- The model has been adjusted to enable a counterfactual scenario to be tested and compared to the actual product trend line, enabling comparison of Annual Energy Consumption (AEC), Unit Energy Consumption (UEC), efficiency and size for products.

Period evaluated and Interventions:

- Starting from 2005 (MEPS were introduced in 2004, 2006, 2007 and 2011, and ERL in 1987, 2001, 2010 and 2020)
- The starting point of 2005 was chosen as a conservative starting point and to simplify the modelling. The MEPS 2004 had a small impact compared to the MEPS 2006-7 impact on efficiency, and then followed by the ERL 2010 rescale. The impacts of the 1987 and 2001 ERLs were considered to be small and were not separately modelled (EnergyConsult, 2010).

[6] The updated version of the RBS was completed in 2022, this version was called RBS2.0 (EnergyConsult, 2020)

- Some categories of AC products were impacted by MEPS in later years (multi-split AC and portable AC) which is accounted for in the modelling.

Data Requirements:

- Actual scenario:
  - Sales data by model number (from GfK sales for non-ducted splits) was included
  - Model-weighted GEMS registration data was used for ducted categories of products.
- Counterfactual scenario:
  - Examined the past evaluations of air conditioners (EnergyConsult, 2010) and RIS (E3, 2009a, 2011a) to determine the baseline efficiency improvements.

Counterfactual scenarios modelled:

- Scenario 1, Lower Improvement in efficiency: The general efficiency improvement of 0.5% p.a. was used starting from 2005
- Scenario 2, Higher Improvement: The general efficiency improvement of 1.0% p.a. was used starting from 2005
- In both scenarios, the efficiency improvement for non-ducted air conditioners (<10kW) was set at 1.0% pa due to the rapid increase in efficiency of these products over the period to 2015. This results in a more conservative estimate of the savings.

Figure 2 and Figure 3 below shows an example of AC product efficiency over time versus the counterfactual baseline. Similar charts are available for different AC products.

Figure 2: AC Ducted EER (cooling) Actual trend versus Counterfactual baseline (0.5% improvement p.a.)

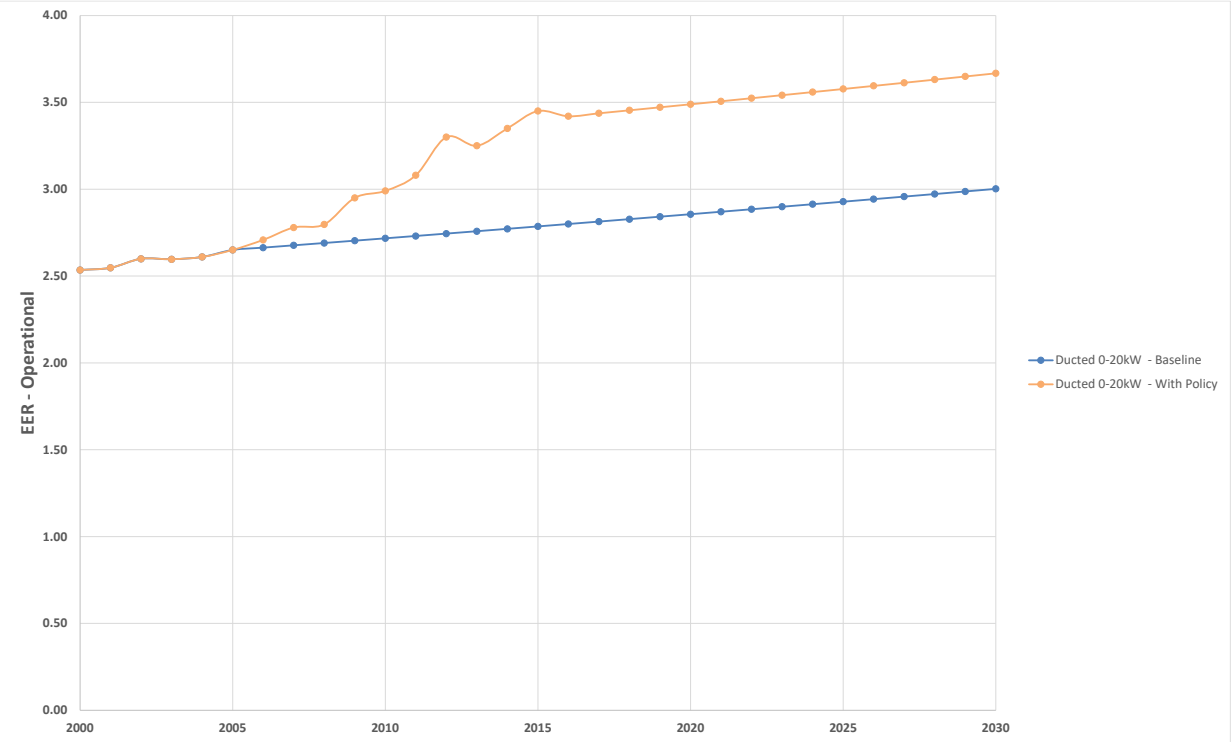
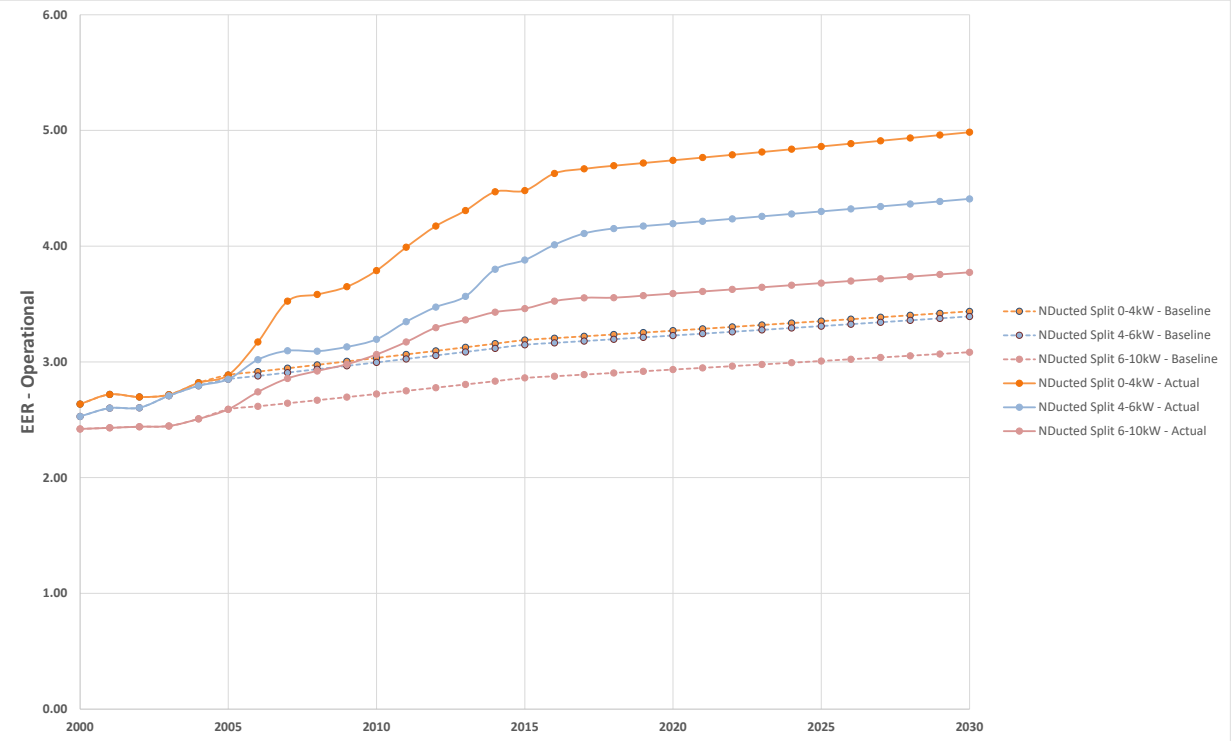


Figure 3: AC non-ducted EER (cooling) Actual trend versus Counterfactual baseline (1.0% to 2015 then 0.5% improvement p.a.)



Lighting

Lighting interventions cover multiple subcategories and sectors.

Subcategory	MEPS year
Fluorescent Ballast	2003
Fluorescent Lamps	2005
Incandescent	2009
CFL	2010
ELV converters	2010

Notes: CFL = Compact Fluorescent Lamps, ELV converters = Extra Low Voltage converters.

Modelling framework: RBS2.0 Module for Incandescent, CFL and ELV converters was used. Details of the approach included:

- For Fluorescent lamps and ballasts, a modified RBS Module was considered, however, the savings estimates were considered insignificant
- The required data and assumptions were populated from past RIS and import data
- Discussion with Beletich Associates was used to determine the availability and suitability of previous and current RIS CBA modelling

In summary, the lighting product interventions selected for evaluation of the impacts were the Incandescent (2009) and ELV converters (2010) interventions. The Fluorescent Lamps (2005) and

Ballasts (2003) interventions are not evaluated, as the market for these products has diminished. The CFL MEPS (2010) established a technical performance standard, not minimum energy performance standards (see page 28).

The establishment of modelling parameters for these interventions considered the following issues:

- Incandescent (2009) – Small savings occurred but diminishing. The phase out (MEPS) was implemented in 2009, leading to replacement of most incandescent lamps with either CFLs or mains voltage halogen (MVH) lamps. The Decision RIS (E3, 2009b) states that the baseline assumes "*There is no significant development of LED or other new technologies that would significantly reduce the cost of more efficient lamps*"(p80) and that "*The baseline scenario assumes that lamp densities and types are frozen at the 2005 levels, which means that energy consumption grows in proportion to population*" (p81)
  - The RIS baseline was not considered to be realistic for the purposes of this evaluation of impacts, given neither of the two assumptions described above to justify the baseline proved to be valid
  - There was significant impact by state (particularly Victorian) programs to replace CFLs with LEDs.
- ELV converters (2010) – Some further savings occurring, due to the slow replacement of ELVC in the stock. However, many ELV converters would have been replaced when LEDs were installed:
  - Decision RIS (E3, 2009b) estimated increasing annual replacement of non-GEMS compliant stock of up to 12% pa by 2019 (p82)
  - Consideration was given to the rapid change to LEDs in the counterfactual scenario, which increased the efficiency of lamps (reducing ELVC savings) and the complete replacement of ELV lamps with LEDs (including the ELVC).

Modelling framework: RBS2.0 model (EnergyConsult, 2020)

- The RBS model includes sales data (estimated from imports) and sales projections
- This model was updated with import data to 2020 and used to produce estimates for the RBS2.0, including the forecast trends to 2020 and further to 2040. The trends in efficiency and sales are likely to be valid for the period 2021-22 which is the year where GEMS energy saving impacts are being estimated
- It includes sales to both business and residential sectors but only utilises residential sales (which constitute ~90% of total sales) for calculating energy use and energy savings
- The model enables counterfactual scenarios to be tested and compared to the actual product trend line, enabling comparison of Unit Energy Consumption for products.

Period evaluated and Interventions:

- Starting from 2008 (Incandescent MEPS) and 2011 (ELV converters MEPS was implemented in Nov 2010).

Data required for modelling:

- Actual scenario:
  - Average efficiency and size were included in the RBS2.0 and used as the inputs for calculation of energy consumption

    - Examined the IEA 4E benchmarking report (IEA, 2015).
- Counterfactual scenario:
    - Examined the Lighting Decision RIS (E3, 2009b). The sales of CFLs and mains voltage halogen lamps (as replacements of incandescent) was modelled in the RIS. It assumed that replacement lamps would be 50% MVH and 50% CFLs under the MEPS. The baseline scenario assumed that lamp densities and types are frozen at the 2005 levels (p 81). This assumption was considered highly unrealistic for the purposes of establishing a counterfactual scenario, as it suggested that will be no changes in the share of CFLs of sales without the MEPS. A more realistic baseline was used for the evaluation of the impacts, based on the changes in the sales of CFLs compared to the actual scenario.

Counterfactual scenarios modelled:

- Incandescent (based on sales of CFLs):
    - Scenario 1, Lower improvement in efficiency: The counterfactual sales of CFLs were set to 50% lower than the Actual from 2008 to 2021
    - Scenario 2, Higher improvement in efficiency: The counterfactual sales of CFLs were set to 25% lower than the Actual from 2008 to 2021.
- ELV converters (applying to the combined efficiency of ELV converter and the lamp):
    - Scenario 1, Lower improvement in efficiency: The counterfactual efficiency improvement of 0.5% p.a. was used starting from 2011
    - Scenario 2, Higher improvement in efficiency: The counterfactual efficiency improvement of 1.5% p.a. was used starting from 2011.

Fridges & Freezers

Refrigerators and freezers required evaluation of the impacts of MEPS/ERL from 2005, as products will be impacted and still in service from the MEPS/ERL interventions in 2005 and 2010, as well as the GEMS Determination in 2019.

Modelling framework: RBS2.0 model (EnergyConsult, 2020)

- The RBS model included sales data (matched with GEMS registration data) and projections.
- This model was updated with GfK sales data to 2017-18 and used to produce estimates for the RBS2.0, including the forecast trends to 2020 and further to 2040. The trends in efficiency and sales were considered likely to be valid for the period 2021/22 which is the year where GEMS energy saving impacts are being estimated
- It included sales to both business and residential sectors but only utilises residential sales (~95% of total sales) for calculating energy use and energy savings
- The model enabled counterfactual scenarios to be tested and compared to the actual product trend line, enabling comparison of Unit Energy Consumption for products.

Period evaluated and Interventions:

- Starting from 2004 (MEPS 2005, ERL 2010, MEPS/ERL 2021)

- The evaluation of impacts could have been set for years earlier than 2005, as the MEPS (1999) and ERL re-scale (2000) were observed to affect efficiency from 1997 for some product categories. However, a conservative starting point for the calculation of impacts (of 2005) was chosen to avoid over estimating the effects of the early regulation
- The impacts of the GEMS Determination in 2019 were considered likely to occur earlier than the 2021 date of implementation, due to the published notifications and RIS. This was captured in the modelling.

Data Requirements:

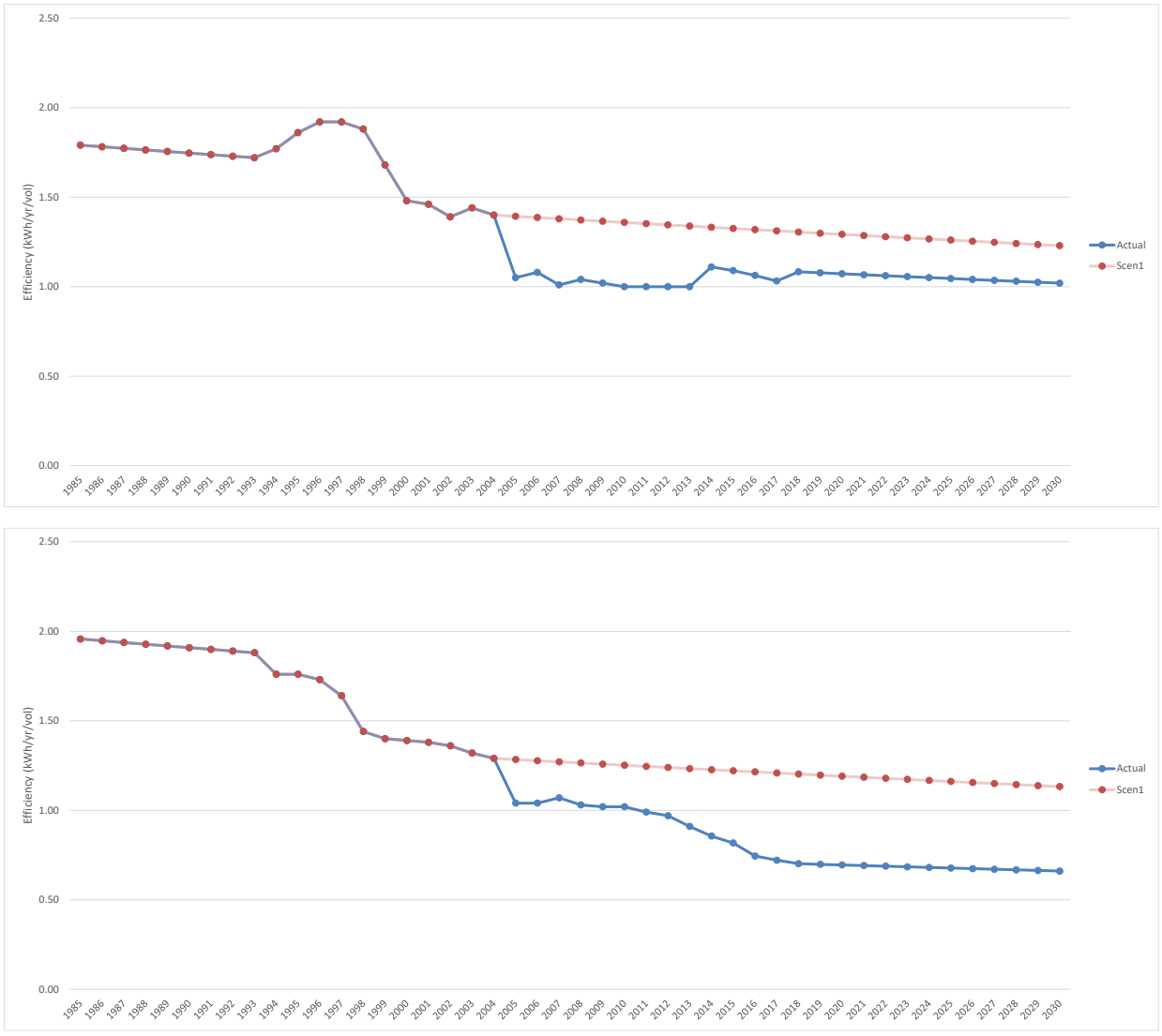
- Actual scenario:
  - Average efficiency and size from sales weighted data (GfK and matched to GEMS model) were included in the RBS2.0 and used as the inputs for calculation of energy consumption.
- Counterfactual scenario:
  - Examining the *Evaluation of Energy Efficiency Policy Measures For Household Refrigeration In Australia Use* (EES, 2010), the efficiency change was estimated at 1% pa without any interventions.
  - The 2001 RIS (AGO, 2001a), BAU projected for 2005 MEPS intervention, the 2008 RIS BAU historical and projected for the 2010 intervention, and the 2017 RIS BAU historical and projected for the 2021 intervention were all examined. These studies reported finding a baseline efficiency improvement of between 0.5% and 1.0% pa.

Counterfactual scenarios modelled:

  - Scenario 1, Lower improvement in efficiency: The counterfactual efficiency improvement of 0.5% p.a. was used starting from 2004
  - Scenario 2, Higher improvement in efficiency: The counterfactual efficiency improvement of 1.0% p.a. was used starting from 2004
- The counterfactual scenario using an efficiency improvement of 0.5% p.a. was most consistent with the analysis of pre-intervention trends ((E3, 2008), Table 39).

Figure 4 below shows an example of actual refrigerator product efficiency over time versus the counterfactual baseline. Similar charts can be produced for different refrigerator and freezer products.

Figure 4: RF1 and RF5B refrigerator efficiency (kWh/yr/litre of volume) Actual trend versus Counterfactual baseline (0.5% improvement p.a.)



Televisions

TVs required evaluation of the impacts of MEPS/ERL from 2009, as products will be impacted and still in service from the MEPS/ERL interventions in 2009 and 2013.

Modelling framework: RBS2.0 model (EnergyConsult, 2020) was used. The details of the modelling include:

- The RBS model included sales data (matched with GEMS registration data) and projections
- This model was updated with GfK sales data to 2020 and used to produce estimates for the RBS2.0, including the forecast trends to 2040. The trends in efficiency and sales were

considered likely to be valid for the period 2021/22 which is the year where GEMS energy saving impacts are being estimated

- It included sales to both business and residential sectors but only utilises residential sales (~95% of total sales) for calculating energy use and energy savings.
- The model enabled counterfactual scenarios to be tested and compared to the actual product trend line, enabling comparison of Annual Energy Consumption (AEC), Unit Energy Consumption (UEC), efficiency and size for products.

Period evaluated and interventions:

- Starting from 2009 (MEPS/ERL 2009, MEPS/ERL 2013).

Data Requirements:

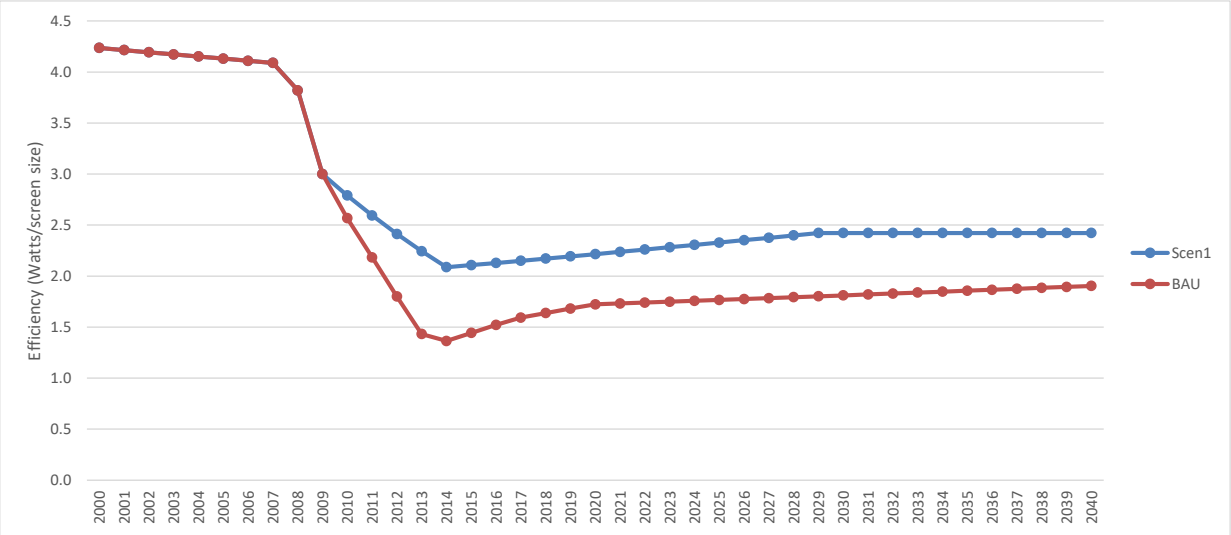
- Actual scenario:
  - Sales data matched to GEMS registration model ID were included in the RBS2.0.
- Counterfactual scenario:
  - The RIS for TVs (DEWHA, 2009) modelled LCD TVs efficiency improvement at a rate of 1% pa under the BAU scenario from 2010 to 2030. This relatively small efficiency improvement appeared to be unrealistic considering that MEPS was implemented in 2009, when the technological efficiency improvements of LCD screens and the reduction in uptake of plasma screens (which had much higher energy consumption) was accelerating worldwide. The assumption that a substantial efficiency improvement under the counterfactual scenario was considered to be more realistic and representative of the market changes that would have occurred.

Counterfactual scenarios modelled:

- This is an unusual product situation as television energy efficiency declined from around 2015, see Figure 5, rather than 'improved' as it does for most products. This decline was due to technology changes, such as the increase in sales of televisions with higher screen resolution. . A decrease in efficiency was included in both scenarios to reflect what occurred post 2015
- Scenario 1, Lower improvement in efficiency: The counterfactual efficiency improvement of 7.0% p.a. between 2010 and 2015 followed by a decrease of 1% p.a. from 2016 (consistent with the Actual scenario)
- Scenario 2, Higher improvement in efficiency: The counterfactual efficiency improvement of 10.0% p.a. between 2010 and 2015 followed by a decrease of 1% p.a. from 2016 (consistent with the Actual scenario).

Figure 5 below shows an example of TV product efficiency over time versus the counterfactual BAU baseline. Similar charts can be produced for different products.

Figure 5: LCD TV efficiency (W/inches screen size) trend versus Counterfactual baseline (7% improvement p.a. 2010-2015)



Electric storage hot waters

Electric storage water heaters required the evaluation of the impacts of MEPS from mid 1990s, as the baseline efficiency for these products in the counterfactual was estimated to be unchanged if the MEPS intervention in 1999/2005 did not occur.

Modelling framework: RBS2.0 model (EnergyConsult, 2020)

- The RBS model included estimated sales data and projections
- This model was updated with estimated sales data to 2020 and used to produce estimates for the RBS2.0, including the forecast trends to 2040. The trends in efficiency and sales were considered likely to be valid for the period 2021/22 which is the year where GEMS energy saving impacts are being estimated
- It included sales to both business and residential sectors but only utilising residential sales (~90% of total sales) for calculating energy use and energy savings
- The model enabled counterfactual scenarios to be tested and compared to the actual product trend line, enabling comparison of Unit Energy Consumption for products.

Period evaluated and Interventions:

- Starting from 1999 (MEPS 1999/2005).

Data Requirements:

- Actual scenario:
  - Estimated sales are included in the RBS2.0. Efficiency is the model average measured heat losses from the GEMS registration data.

- Counterfactual scenario:
    - The scenarios considered the projected efficiency trends documented in the 1990s (SEC, 1993) and the efficiency trends projected for 1999 intervention[7].

Counterfactual scenarios modelled:

- Scenario 1, Lower improvement in efficiency: The counterfactual efficiency improvement of 0.1% p.a. was used starting from 1999 (2005 for small)
- Scenario 2, Higher improvement in efficiency: The counterfactual efficiency improvement of 0.5% p.a. was used starting from 1999 (2005 for small).

The lower efficiency improvement (0.1%) was selected as evidence from the E3 (see below) and the GEMS registrations show little or no improvement in heat losses for electric storage water heaters.

> *"For products that are not subject to continuous technology improvement due to global market competition, increases in energy efficiency may not actually occur at all in the absence of MEPS. For example, electric storage water heaters are all built to the same maximum heat loss levels in the Australian Standard, and may never have increased in efficiency had not MEPS raised that standard."* Page 12 Retrospective Review of the E3 Program, E3, March 2011 (E3, 2011b).

Motors

Three-phase electric motors required evaluation of the impacts of MEPS from the early 2000s, as products will be impacted and still in service from the MEPS interventions in 2001 and 2006.

Modelling framework: The RIS model (E3, 2022a) prepared by EnergyConsult (2019-2022) was used and details of the approach are as follows:

- The unpublished motors RIS (E3, 2022a) CBA modelling included all categories of products currently regulated
- The RIS CBA model included separation of all categories of motors
- This model was updated with AU sales data to 2020, including the forecast trends to 2021 and further to 2040. The trends in efficiency and sales were considered likely to be valid for the period 2021/22 which is the year where GEMS energy saving impacts are being estimated
- It was only applicable to the business sector, which is realistic as three phase motors are very rarely used in the domestic sector.
- The model can enable a counterfactual scenario.

Period evaluated and Interventions:

- Starting from 2000 (MEPS 2001, 2006).

Data Requirements:

- Actual scenario:

[7] EnergyConsult understands the MEPS was implemented without a national RIS, however a 1993 study has some data which was used to support the MEPS

- Sales data (import data and surveys of suppliers) and efficiency (surveys) were included.

- Counterfactual scenario:
  - Examined the RIS (AGO, 2000, 2003a).

Counterfactual scenarios modelled:

- Scenario 1, Lower improvement in efficiency: The counterfactual efficiency improvement of 0 to 0.39% p.a. (depending on the category) was used starting from 2000
- Scenario 2, Higher improvement in efficiency: The counterfactual efficiency improvement of 0.1 to 0.50% p.a. was used starting from 2000.

Product categories/subcategories not included in modelled savings

As previously mentioned, the two product categories Clothes Washers and Close Control Air Conditioners were initially chosen as being worth modelling but later were excluded from the modelling of energy savings. The previously estimated energy saved from the GEMS program during the years 2019-2021 suggested the two products groups were contributing significantly to the total energy savings from GEMS, hence worth modelling, but they were later excluded from the modelling as evidence suggested they produced insignificant savings, as explained in the sections below.

Some sub-categories of Lighting were also not modelled, as research suggested they produced insignificant savings, as explained in the section below.

Lighting Sub-categories

The assessment of the likely savings still occurring from these interventions considered the following issues:

- CFL (2010) – no energy savings from the MEPS, technical performance MEPS only
- Fluorescent Lamps (2005) – No further savings occurring. The Decision RIS (AGO, 2003b), provides three baseline scenarios. The scenario that more closely aligns with the market changes (scenario M2) shows all impacts would be completed by 2020.
  - There are likely to be impacts still occurring from the MEPS, but only residual stock installed up to 2012 (using the M2 MEPS assumptions in the RIS (AGO, 2003b)), when the MEPS assumes no more halophosphate lamps remain in the stock
  - The increased up-take of LEDs was not considered by the 2003 RIS (understandably, as this RIS was prepared years before linear LED technology was commercialised) and this change to the market has led to rapid transition to more efficient lamps and fixtures (without the need for a ballast)
- Fluorescent Ballast (2003) – Some further savings appear to be occurring. The RIS (AGO, 2001b) projects that the BAU sales for non-complying ballasts would be between 70 and 80% of the market from 2003 to 2015 (p42). This BAU assumption was reviewed, as it was likely to be unrealistic, due to;

- Findings from a review of GEMS Determinations for fluorescent ballasts (E3, 2022b)
- The market has almost totally transitioned to electronic ballasts(E3, 2022b)
- Residual stock of MEPS-compliant ballasts will be impacted by the market transition to linear LEDs.

Clothes washers

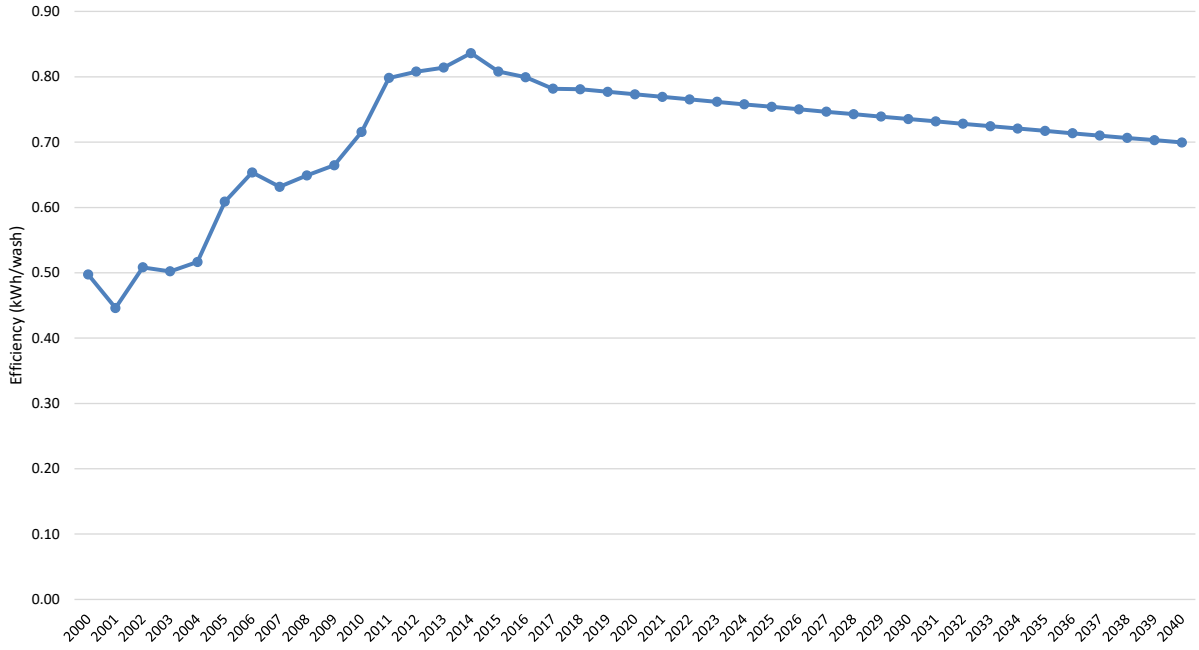
Clothes washers initially appeared to require evaluation of the impacts of ERL from mid 2000s, as products will be impacted and still in service from the ERL intervention in 2000. However, due to the modelling complexity and likely small energy savings (if any), clothes washers energy savings are not evaluated for this project. The reasons are discussed below.

The actual scenario (EnergyConsult, 2020) showed an annual increase in electricity use for clothes washers over the period of evaluation. Figure 6 shows the annual average energy (electricity) per cycle has increased from 0.5 kWh/cycle in the early 2000s to 0.8 kWh/cycle in 2016 and a slight decrease to 0.78 kWh/cycle in 2018. This increase is due to the higher electricity consumption of front loaders which are increasing in market share and the stock of appliances. Front loading (FL) clothes washers use less water than top loaders (TL) but have heating elements that heat the cold water to the desired temperature (even for cold wash, where the unit often heats the cold water to 20 - 30 degrees). They also have longer cycle times (on average 4 hours). The vast majority of Australian washing is cold wash (70% in 2005) (ABS, 2005).

The ERL awards higher stars to FL clothes washers due to their reduced water use and is measured using the warm wash programme. The counterfactual scenario change in efficiency is difficult to estimate as there has been an increasing market share of FL clothes washers, which could be attributed to several factors, including the ERL, water use labelling and consumer preferences.

The energy savings from reduced water and energy for warm wash may be considered, but as top loaders are typically dual connect (hot and cold water) the savings are the difference from reduced hot water heater energy consumption (mostly TL) vs the smaller heated water energy consumption of the more efficient clothes washer (mostly FL). This complicates the energy savings/costs estimate, as the hot water system savings are different in each state (due to differences in hot water energy sources) and energy cost savings. It is therefore considered that energy savings estimates are not easily undertaken for this product and are likely to be very small and therefore not included in the current GEMS impact estimates.

Figure 6: Average efficiency of clothes washers (kWh/cycle)



Close Control Air Conditioners

Close control air conditioning (CCAC) MEPS was implemented in 2009, and targets air conditioning used in computer rooms, telecommunications and small-scale data centres. The market for these products has changed enormously over the last decade, with the major expansion of large data centres impacting on the market for CCAC. The data centre market typically utilises central chilled water systems for controlling temperature/humidity in these buildings, which is outside the scope of the GEMS CCAC regulations. For this reason, and the lower level of savings calculated by the previous Department modelling (0.5%), close control air conditioning was not included in the current estimates.

4. Modelling outputs and impact estimates

Introduction to Modelling Outputs

The estimated savings were modelled with two counterfactual scenarios, as previously discussed, reflecting two levels of annual energy efficiency improvement. Global inputs are emissions factors and energy prices by fuel, state and year.

The modelling outputs are provided to the model users via a summary spreadsheet that contains a database of product annual energy consumption, with the following characteristics:

- Scenario name
- State
- Category
- Group
- Product
- Year
- Energy

The spreadsheet enables the calculation of:

- Annual emissions produced and savings
- Annual energy consumption and savings
- Annual energy costs to the consumer and savings.

The spreadsheet outputs are available by scenario (Savings 1, Savings 2), State (or national), category/group/product and by year (historical or projected to 2040).

In the following section of this report, the total energy, emission and cost savings from GEMS interventions are documented. These totals are based on the combined savings from the following product categories which were modelled:

- Air Conditioners
- Refrigerators and Freezers
- Televisions
- Lighting
- Electric Motors
- Electric Storage Water Heaters

These product categories represent the vast majority, approximately 97%, of the energy savings from the GEMS program according to the previous Department modelling. It is worth noting that the lighting product category was previously estimated by the Department to account for 32% of the program savings, but due to a review of the modelling assumptions (page 20), in the current modelling it was found to contribute a significantly lower proportion of the program's total savings.

Energy saving and emissions reduction benefits for 2021-2022

For 2021-22 the energy and emission savings from GEMS interventions were found to be:

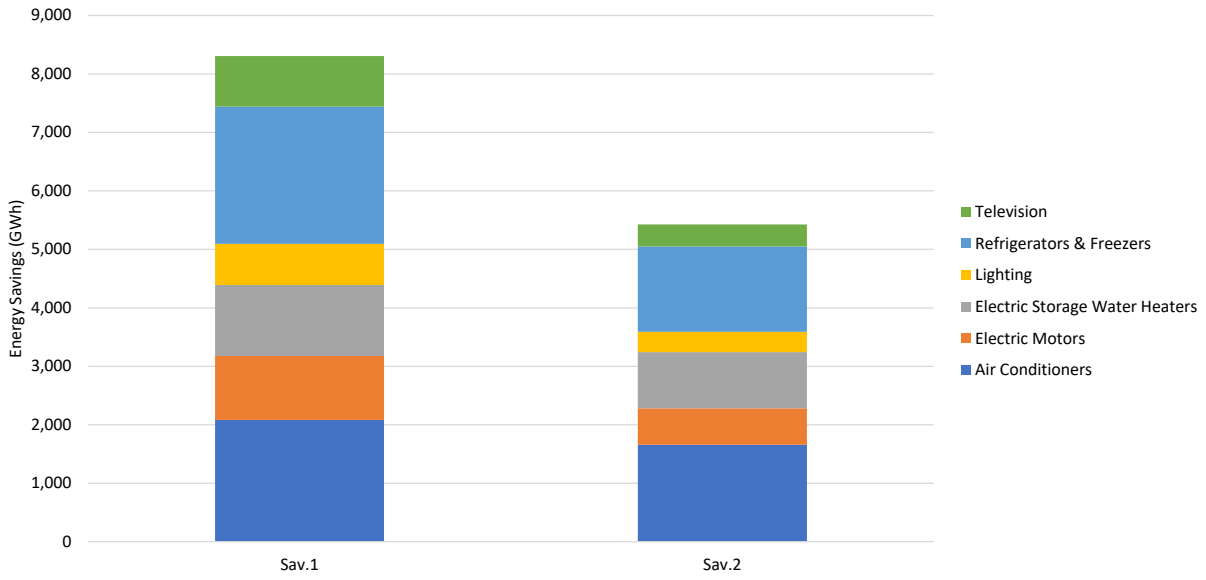
- Energy savings estimated as being between 5,425GWh (saving 2 scenario) to 8,306GWh (saving 1 scenario)
- Emissions reductions estimated as being between 4,134 kt CO_2-e (saving 2 scenario) to 6331 kt CO_2-e (saving 1 scenario).
- Savings from air conditioners and from refrigerators and freezers were the biggest contributors to the total savings.

The breakdown of the estimated energy savings (in GWh) by product category for 2021-22 is shown in Table 6 and Figure 7.

Table 6: Energy savings by category in 2021-22 (GWh)

Scenario	Air Conditioners	Electric Motors	Electric Storage Water Heaters	Lighting	Refrigerators & Freezers	Television	Grand Total
Sav.1	2,082	1,095	1,217	703	2,347	862	8,306
Sav.2	1,659	622	961	350	1,459	373	5,425

Figure 7: Energy savings by category (GWh) in 2021-22

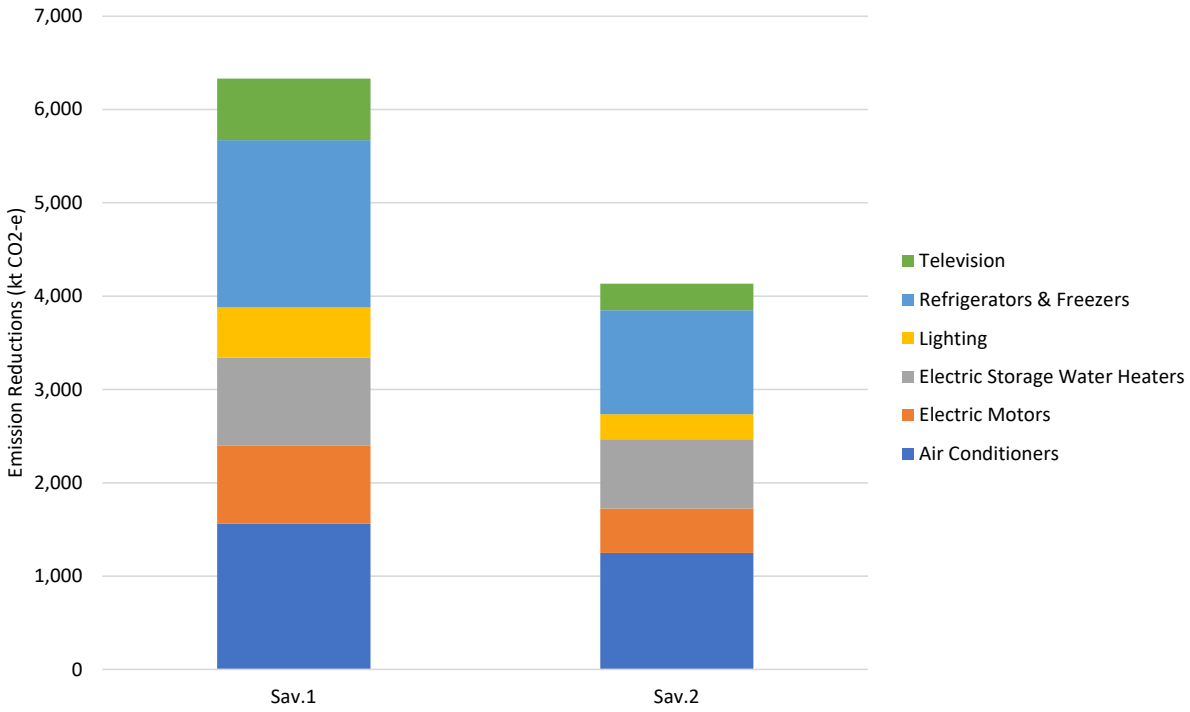


The breakdown of the estimated emission savings (in kt CO_2-e) by product category for 2021-22 are shown in Table 7 and Figure 8 for each scenario modelled.

Table 7: Emissions reductions by category in 2021-22 (kt CO_2-e)

Scenario	Air Conditioners	Electric Motors	Electric Storage Water Heaters	Lighting	Refrigerators & Freezers	Television	Grand Total
Sav.1	1,564	838	940	536	1,793	659	6,331
Sav.2	1,248	477	743	267	1,114	285	4,134

Figure 8: Emissions reductions by category in 2021-22 (kt CO_2-e)



Energy saving and emissions reduction benefits of the GEMS Program

Projected Annual Savings

The models were used to forecast future energy and emission reductions stemming from existing GEMS interventions and the annual energy saving benefits from the GEMS Program for the years 2021, 2030 and 2040. These estimates and forecasts are shown in the following table.

Table 8: Summary of annual energy savings and emission reductions by scenario in 2021, 2030, 2040

Indicator	Scenario	2021	2030	2040
Energy Savings (GWh)	Sav.1	8,306	10,730	12,357
Energy Savings (GWh)	Sav.2	5,425	6,402	6,339
Emissions reduction (kt CO2-e)	Sav.1	6,331	2,914	1,484
Emissions reduction (kt CO2-e)	Sav.2	4,134	1,754	771

The forecasts above show energy savings from GEMS impacts will increase over time, but emission savings will decrease. This is due to the declining emissions intensity of Australia's electricity grid as more renewable energy generation is installed and higher emission electricity generation is retired, reducing the emission impact of GEMS energy savings.

More detailed breakdowns of the estimated historical and projected energy savings of the GEMS program by product category are shown in Figure 9 (PJ) and Figure 10 (GWh) for Savings 1 scenario, and Figure 11 (PJ) and Figure 12 (GWh) for Savings 2 scenario.

Figure 9: Energy savings by category and year for Savings 1 (PJ)

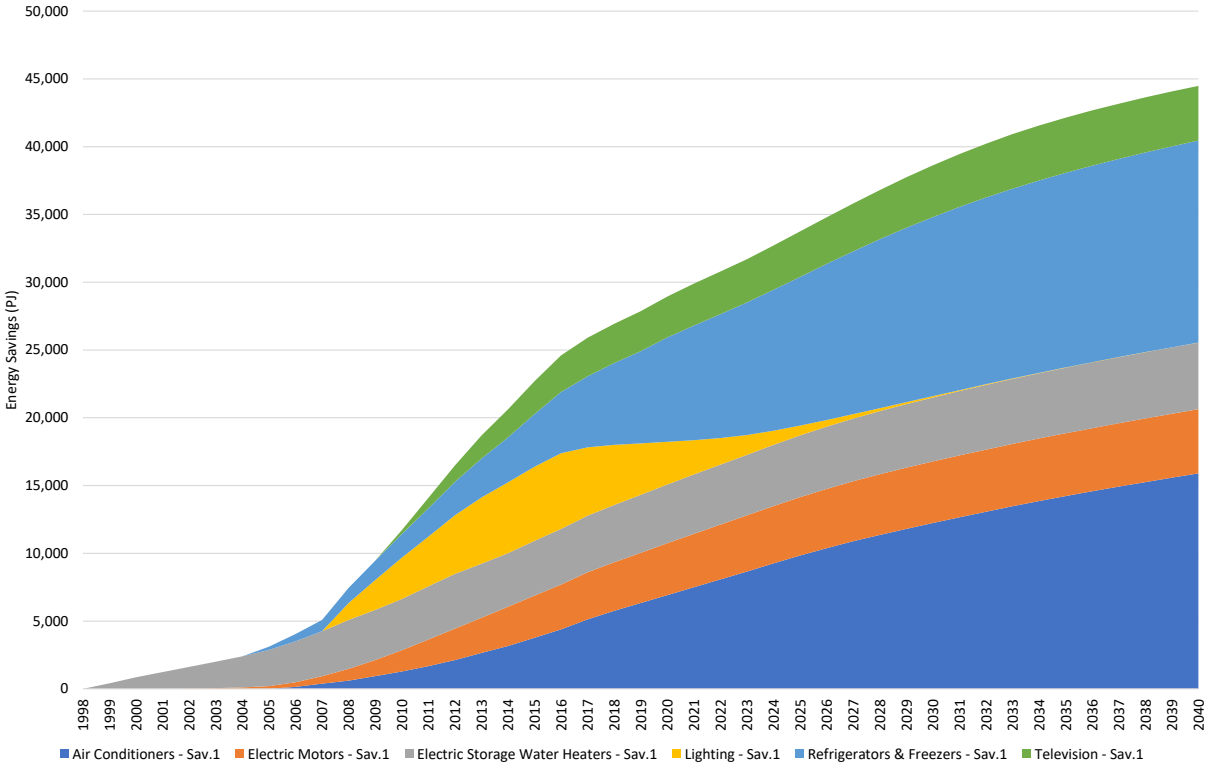


Figure 10: Energy savings by category and year for Savings 1 (GWh)

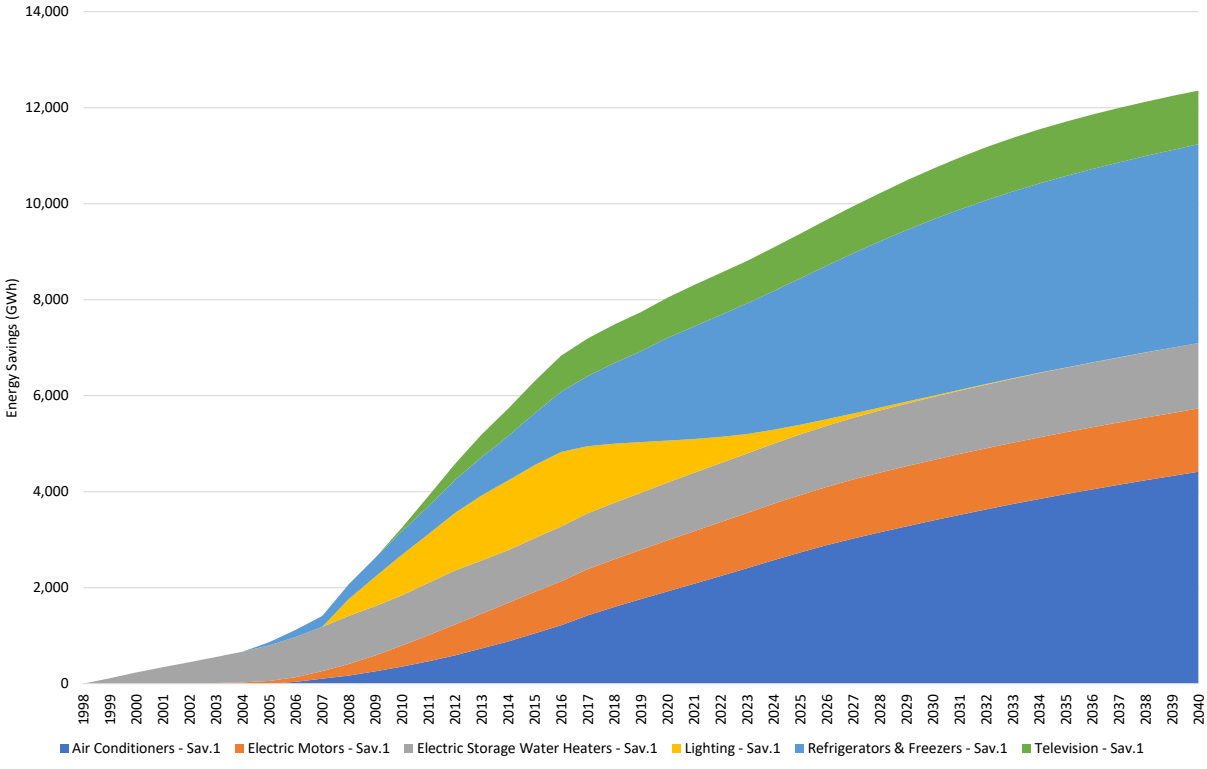


Figure 11: Energy savings by category and year for Savings 2 (PJ)

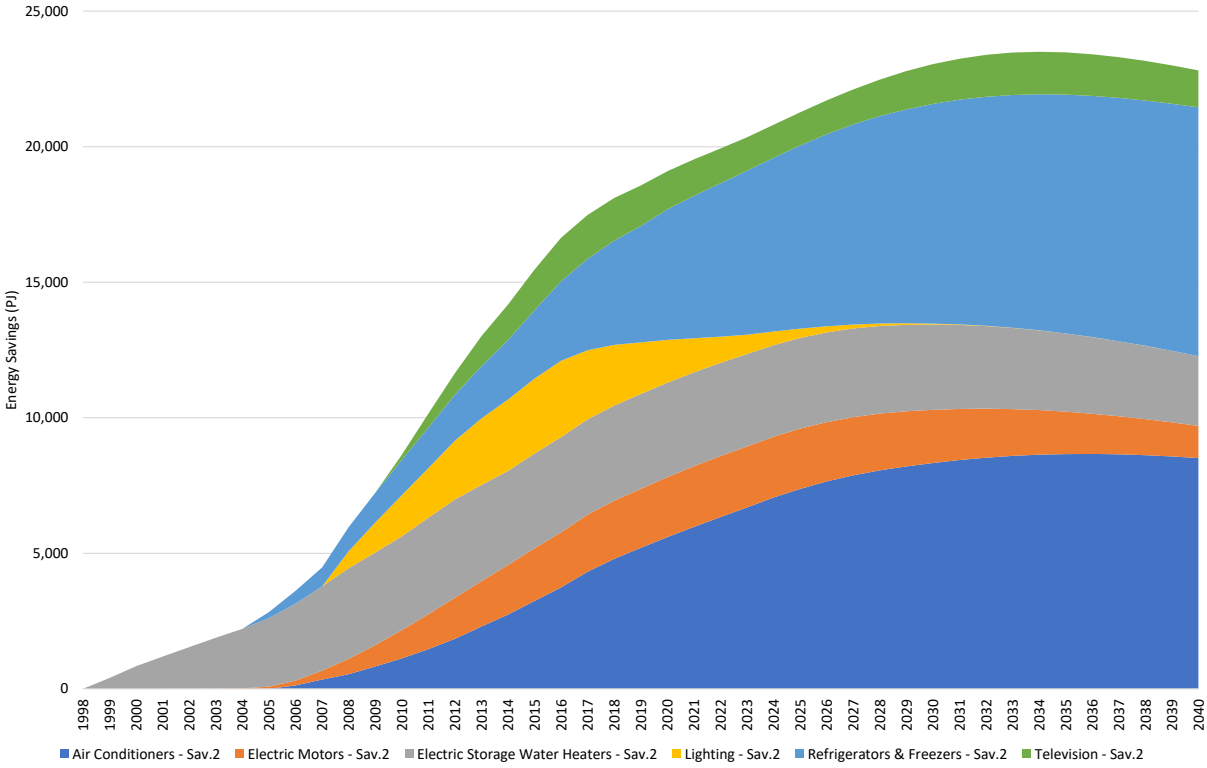
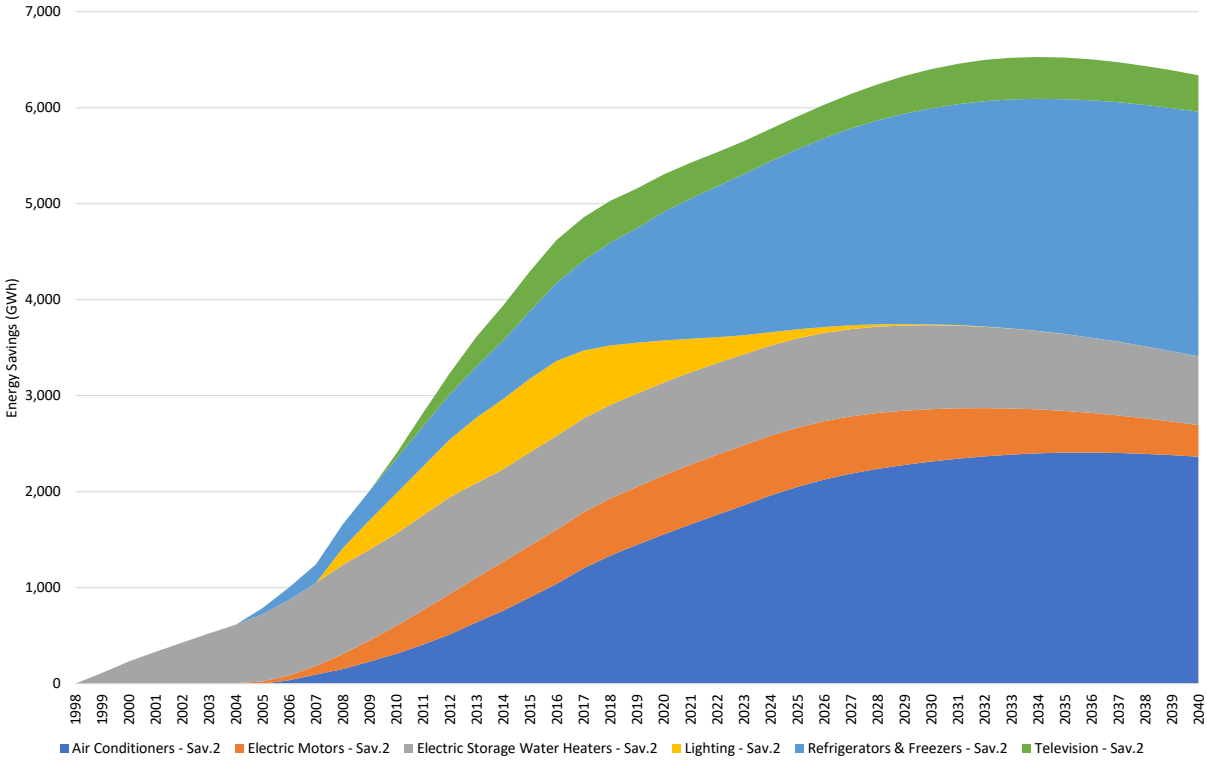


Figure 12: Energy savings by category and year for Savings 2 (GWh)



More detailed breakdowns of the estimated historical and projected emissions reductions of the GEMS program by product category are shown in Figure 13 (Savings 1) and Figure 14 (Savings 2).

Figure 13: Emission reductions by category and year for Savings 1 (kt CO_2-e)

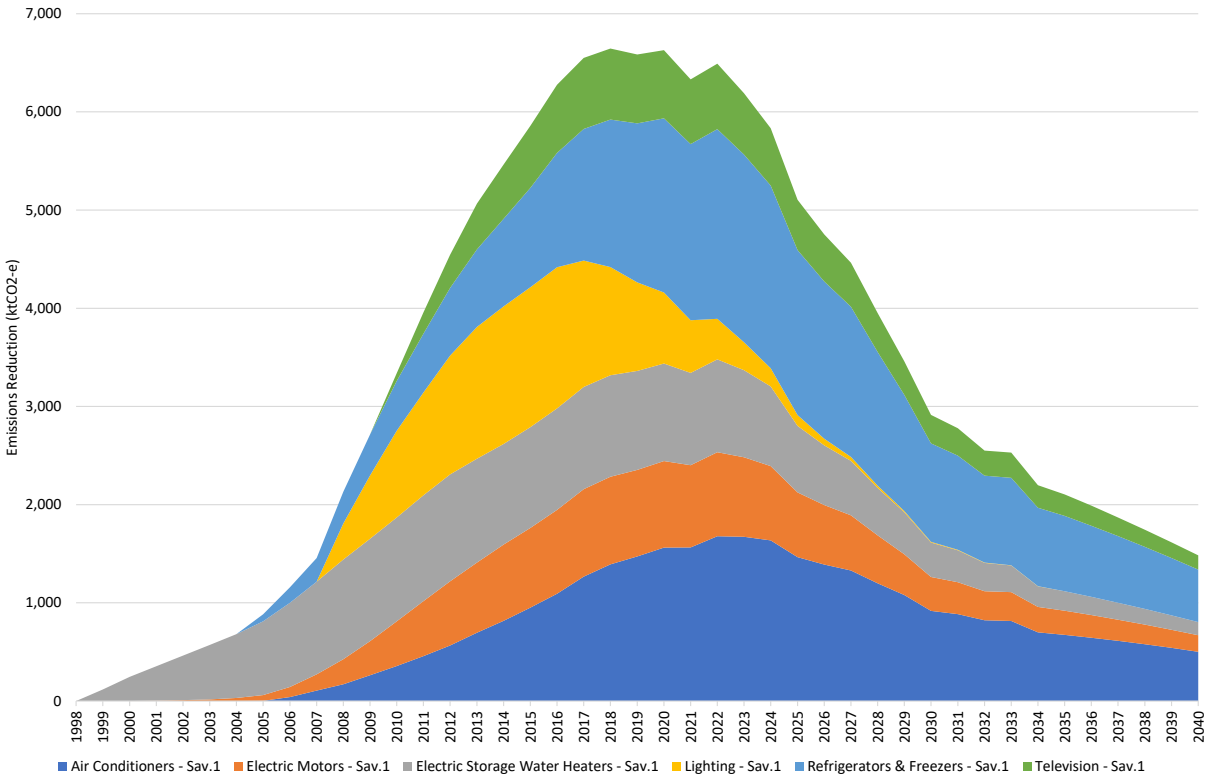
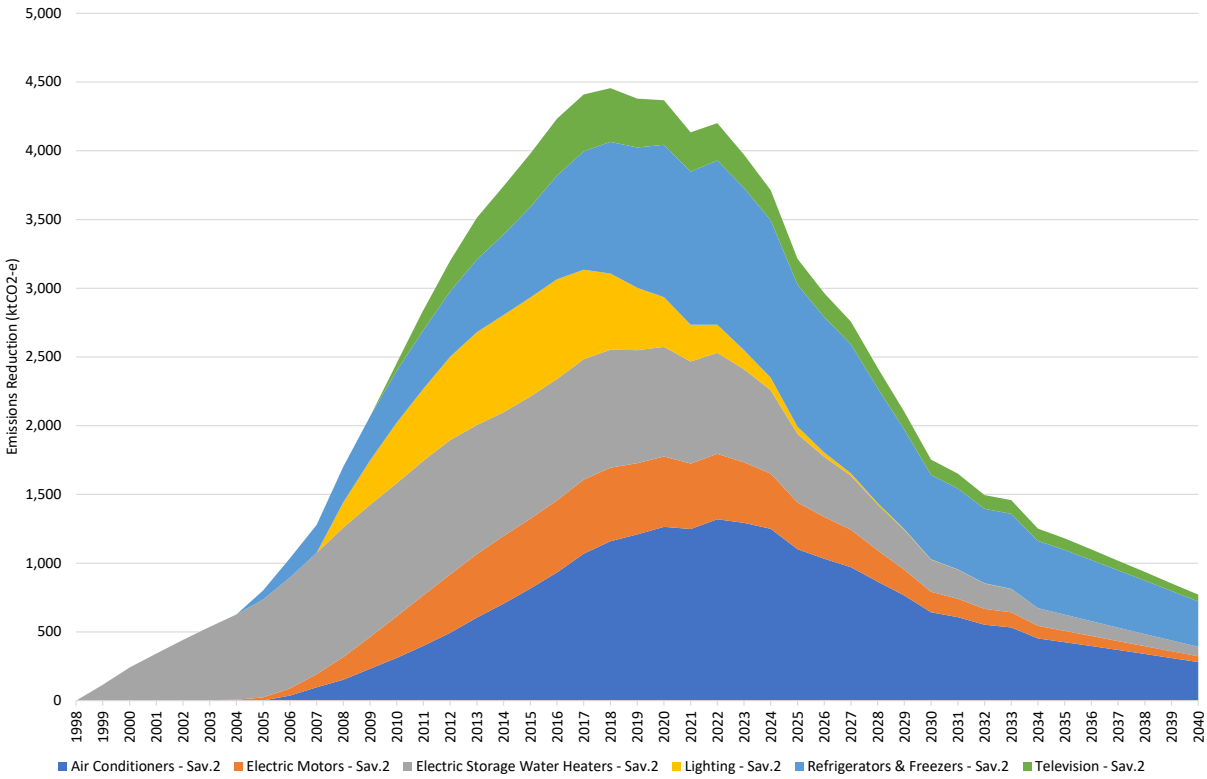
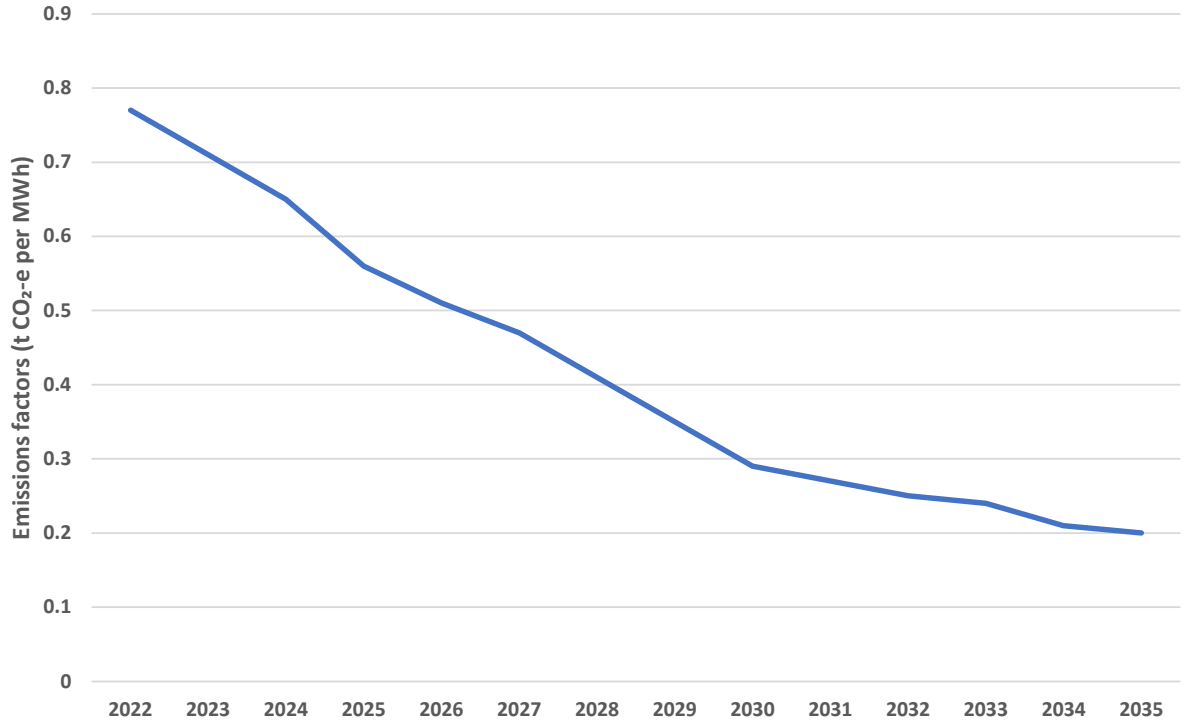


Figure 14: Emission reductions by category and year for Savings 2 (kt CO_2-e)



Both Figure 13 and Figure 14 show a rapid decrease in emissions from 2018. The reason for the rapid decrease is that the emissions intensity of the Australian electricity grid began to decrease around 2018 and continues to decrease as more renewable energy (solar, wind, etc) is utilised and higher emission electricity generation is retired (such as coal fired power stations). The reduction in emission factors (that is the amount of GHG emissions per MWh of energy generated) is shown in Figure 15, from the recently published Australian Emissions Projections (DCCEEW, 2022a). The reduction in emission intensity is higher than the increase in projected energy savings (see Figure 10) from the GEMS program, which results in declining emissions reductions. Historical emission factors by state were obtained from the National Greenhouse Accounts Factors (DISER, 2021; DCCEEW, 2022b).

Figure 15: Emissions factors for Australia's electricity grid, scope 2+3 (tonnes CO_2-e per MWh)



Cumulative Benefits from GEMS

The cumulative benefits of GEMS over varying time periods can be calculated from the annual impacts. The estimated cumulative energy savings (TWh) over different periods of time are shown in Table 9.

Table 9: Cumulative energy savings over various time periods (TWh)

	Historical		Future	
Scenario	**22 Years 2000 - 2021**	**10 years 2012 -2021**	**10 years: 2021 - 2030**	**20 years 2021 - 2040**
Sav.1	85	67	95	212
Sav.2	60	45	59	124

The estimated cumulative GHG emission reductions (Mt CO_2-e) over different periods of time are shown in Table 10.

Table 10: Cumulative emission reductions savings over various time periods (Mt CO_2-e)

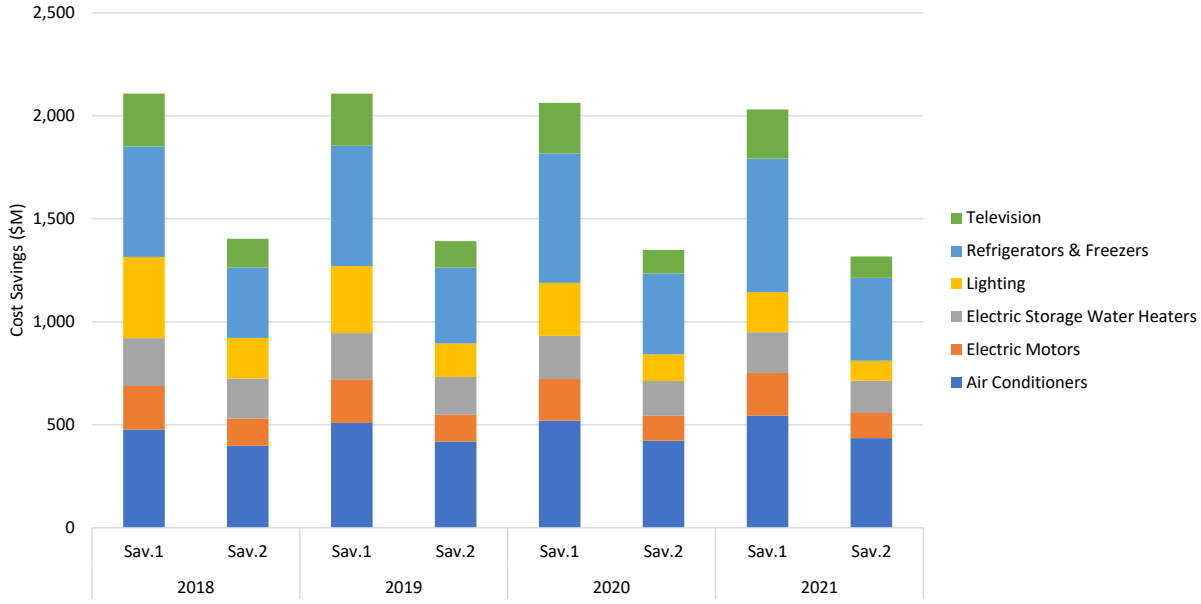
	Historical		Future	
Scenario	**22 Years 2000 - 2021**	**10 years 2012 -2021**	**10 years: 2021 - 2030**	**20 years 2021 - 2040**
Sav.1	78	60	49	70
Sav.2	55	40	31	43

Cost Saving Benefits of the GEMS Program

The energy savings benefits from GEMS can be measured as energy cost savings and treated as a benefit to the economy. In 2021-22 the GEMS program is estimated to have saved Australian households and businesses between $1.3 billion (Savings 2 scenario) and over $2 billion (Savings 1 scenario) in avoided energy costs.

A more detailed breakdown of these cost savings is shown in Figure 16. Note, for this report, the energy cost savings are based on energy tariffs by state, in present value 2021 dollars. Energy tariffs by state and consumer type were obtained from various sources (AEMO, 2017; ACCC, 2022) and used to calculate the total energy savings.

Figure 16: Annual energy cost reductions by scenario, category and selected years



The historical and projected future savings were also calculated and are shown in Table 11. This shows energy cost savings from GEMS impact are increasing.

Table 11: Cumulative energy cost savings over various time periods ($Billion, 2021 present value dollars)

	Historical		Future 10 years: 2021 - 2030	
Scenario	**22 Years 2000 - 2021**	**10 years 2012 -2021**	**Constant prices**	**30% price increase**
Sav.1	21	18	23	29
Sav.2	14	12	15	18

Figure 17: Annual energy cost reductions by savings scenario and future energy prices

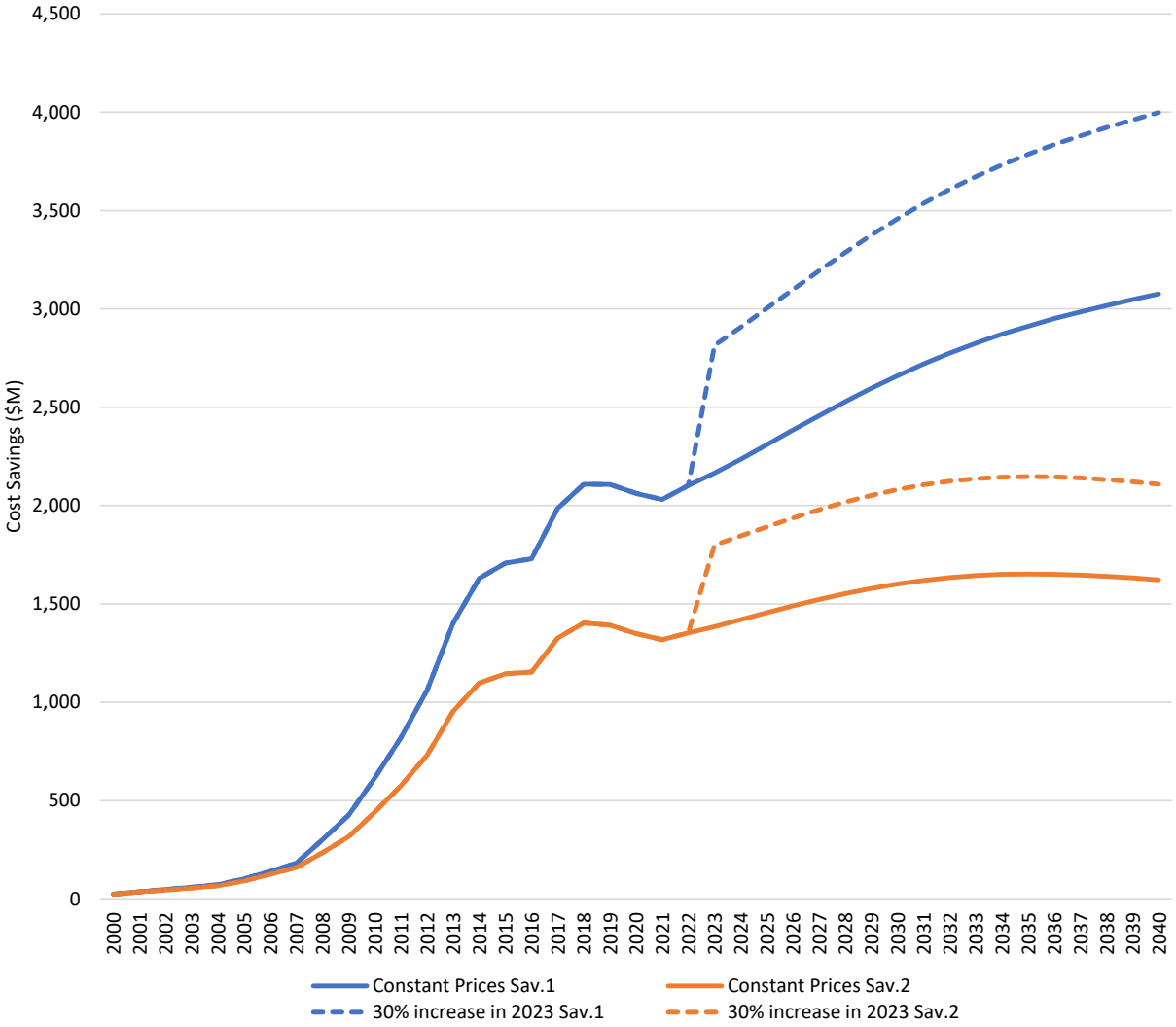


Figure 17 shows the estimated energy savings by year for the GEMS program over the modelling period. The figure shows two future energy price assumptions:

- Constant energy prices from 2023 onwards
- An increase of 30% in 2023 and held constant for future years.

The decline in cost savings from 2018 to 2021 is due to the general decline in energy prices over this period, while in 2022 prices have increased. Projected energy prices are held constant at 2022 values, which is a conservative assumption.

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