# 10. Scenarios for a clean energy future in 2040

## 10.1. Scenario results: changes in greenhouse gas emissions from stationary energy

### Baseline – Scenario 1

In the Baseline Scenario for 2040, as shown in Table 10.1, total demand for primary energy in stationary consumption is 33% higher than in 2001, while $CO_2$ emissions are 21% higher. It will be noted that these increases are significantly less than the 57% increase in final energy demand.

Primary energy demand grows more slowly than final energy demand because of significant increases in the efficiency of electricity generation, arising both from expected improvements within technologies (coal fired generation) and a shift toward inherently more efficient technologies and fuels (natural gas, cogeneration). The efficiency of other energy production and processing also increases.

The slower growth in emissions is attributed to these factors, plus a greater use of zero and low emission energy sources in both direct combustion and electricity generation.

However, while these relatively modest increases may seem encouraging, relative to growth rates of recent years, they still represent a major increase in Australia's greenhouse gas emissions above 2001 levels. In absolute terms it is an increase of 48 Mt of $CO_2$.

**Table 10.1: 2040 Baseline – Scenario 1 compared with 2001**

| | **Increase in 2040 relative to 2001** | |
|---|---|---|
| | **Energy** | **$CO_2$ emissions** |
| Final energy demand | 57% | *na* |
| Primary energy: | | |
| Electricity generation | 26% | 14% |
| All other stationary energy use | 42% | 37% |
| Total stationary energy | 33% | 21% |

### Clean Energy – Scenario 2

The overall result of our principal Clean Energy – Scenario 2 for 2040 is that $CO_2$ emissions are reduced to 130.9 Mt in 2040, compared with 261.7 Mt in 2001. This is a reduction of exactly 50% below stationary energy emissions in 2001 and roughly 35% below stationary energy emissions in 1990. Compared with the Baseline Scenario 1, the decrease in emissions is 59%. These comparisons are shown in Tables 10.2 and 10.3 respectively. The Tables show primary energy demand and associated emissions separated into two components:

- primary energy demand and $CO_2$ emissions related to electricity generation, and

- primary energy demand and $CO_2$ emissions related to all other stationary energy activities.

Figures 9.1 to 9.4 graph the absolute numbers for primary energy demand and greenhouse gas emissions in two different formats, again with emissions divided between the two major components. It can be seen very clearly that the adoption of zero and low emission energy supply technologies, and in particular the replacement of coal combustion for electricity generation with other generation technologies, makes a very large contribution to the reduction in emissions achieved in the Clean Energy Scenario.

Another way of understanding this is by noting that final demand for electricity and final demand by all other fuels are higher in the 2040 Clean Energy Scenario than in 2001 by almost the same amount – respectively 24.3% and 25.5%, giving the overall average of 25%. However, while emissions associated with electricity generation fall by 78%, those associated with all other fuels rise by 12%. This difference arises for two reasons. Firstly, because low-cost renewable energy can make a much larger contribution to the supply mix for electricity than to all other fuels, for which useful energy is provided directly by combustion at the point of use.

**Table 10.2: 2040 Clean Energy – Scenario 2 compared with Baseline – Scenario 1**

| | **Decrease: Clean Energy relative to Baseline** | |
|---|---|---|
| | **Energy** | **Greenhouse emissions** |
| Final energy demand | -20% | *na* |
| Primary energy: | | |
| Electricity generation | -43% | -81% |
| All other stationary energy use | -14% | -18% |
| Total stationary energy | -30% | -59% |

**Table 10.3: 2040 Clean Energy – Scenario 2 compared with 2001**

| | **Decrease: Clean Energy relative to Baseline** | |
|---|---|---|
| | **Energy** | **Greenhouse emissions** |
| Final energy demand | +25% | *na* |
| Primary energy: | | |
| Electricity generation | -27% | -78% |
| All other stationary energy use | +21% | +12% |
| Total stationary energy | -8% | -50% |

To understand the difference between Scenarios 1 and 2 it is important to note that the share of electricity in final energy demand is 38.5% in Scenario 1 but only 34.4% in Scenario 2, which is marginally less than the 2001 level of 34.7%. The difference between the two Scenarios is caused by the fact that end use efficiency increases are greatest in the electricity intensive Commercial/Services and Residential sectors. Since the losses inherent in thermal electricity generation account for most of the difference between final and primary energy demand, a fall in the electricity share of final demand brings a disproportionate fall in primary energy demand, and in greenhouse emissions, all else being equal. This effect demonstrates how important the realisation of full energy efficiency potential is to the final outcome.

The different processes at work can also be understood by comparing increases between 2001 to 2040 for Clean Energy – Scenario 2 in the following sequence.

| | | |
|---|---|---|
| GDP | +140% | |
| Baseline final energy demand | +57% | reduction caused by sectoral shifts within the economy and endogenous changes towards more efficient energy technologies |
| Medium Efficiency final energy demand | +25% | reduction caused by enhanced end use energy efficiency |
| Primary energy demand | -8% | reduction caused by 1) fall in the share of electricity in final demand, as a result of greater efficiency gains in the previous step in the electricity intensive Commercial/Services and Residential sectors, 2) adoption of cogeneration and other more energy efficient technologies for electricity generation and other energy supply, and 3) shift away from combustion based generation technologies |
| Greenhouse gas emissions | -50% | reduction caused by shift away from coal and towards low and zero emission fuels and technologies in electricity generation and other energy supply |

It is clear that each stage contributes significantly to achieving the final Clean Energy Future:

- changes to the Australian economy that are already in train or can be expected to occur;
- enhanced energy efficiency that is economically beneficial but will require policy initiatives for its realisation, noting that energy efficiency increases in the Residential and Commercial/Services sectors bring further gains in reducing primary energy requirements because of the electricity intensiveness of these sectors;
- adoption of cogeneration and other more energy efficient technologies in energy supply, also requiring policy action; and
- replacement of high emission, mainly coal based energy supply technologies with low and zero emission technologies and fuels, which again will require the adoption and implementation of appropriate policies by governments.

### Other low emission futures: Scenarios 3 and 4

Scenario 3 is identical with Scenario 2 except that coal fired power stations have been entirely phased out by 2040, while demand for all forms of energy is the same as in Scenario 2. The total emission reduction, relative to 2001, becomes 54.7% instead of 50%, and relative to 1990 is 40% instead of 36%. The emission reduction resulting from electricity generation is 84.6%, while that from all other energy sources remains unchanged, as shown in Figures 10.1 to 10.4.

In Scenario 4, energy demand is at the higher Baseline level, with final demand for stationary energy reaching 157% of the 2001 level by 2040, rather than the 125% of Scenarios 2 and 3. In view of growing international concern about climate change, and the cost effectiveness of a higher level of end use energy efficiency, such a large increase in demand seems an unlikely scenario. It is included here as a basis for comparison, and because it demonstrates the crucial role that enhanced energy efficiency will have if a clean energy future is to be achieved.

With the same energy supply mix as Scenario 3, $CO_2$ emissions in Scenario 4 in 2040 from electricity and stationary energy are 76% and 42% below the 2001 level, respectively. In this case wind energy generation becomes 247 PJ (69 TWh) and capacity is 26 GW, a more formidable challenge than the 182 PJ (50.5 TWh) and 19 GW required for Scenarios 2 and 3. Bioenergy generation becomes 1,044 PJ and its land requirements are 1.1 Mha, which is still less than the current area of plantation forest.

Changes in $CO_2$ emissions in all three scenarios are set out in Table 10.4.

**Table 10.4:Change in $CO_2$ in 2040 for Scenarios 2, 3 and 4, relative to 2001**

| Scenario and Description | | From electricity | From all other stationary energy | From all stationary energy |
|---|---|---|---|---|
| 2 | Clean Energy Future | -78% | +12% | -50% |
| 3 | Clean Energy Future plus zero coal in electricity | -85% | +12% | -55% |
| 4 | Baseline energy demand, energy supply as in Scenario 3 | -76% | +34% | -42% |

**Fig. 10.1: CO2 emissions from electricity generation and all other stationary energy consumption in 2001 and all 2040 Scenarios**

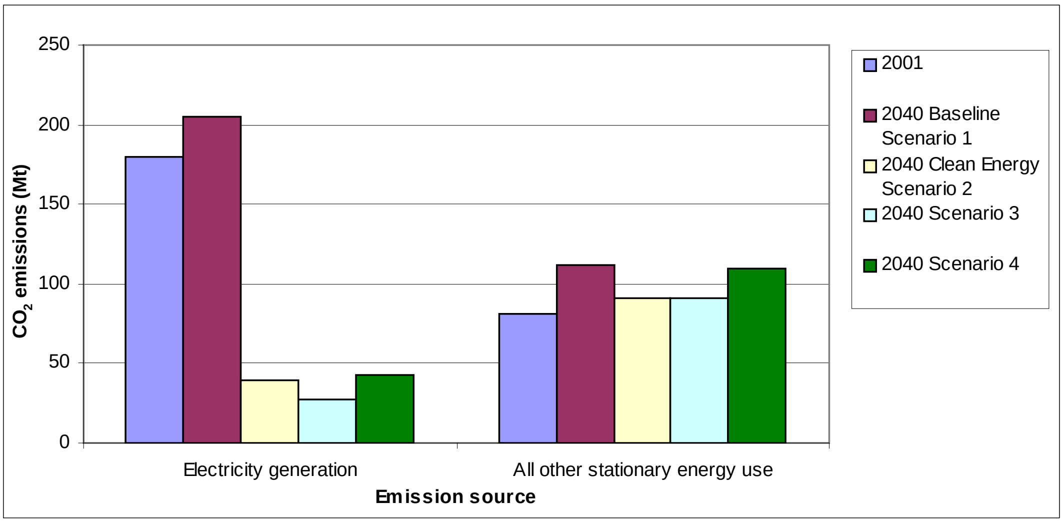



**Fig. 10.2: Composition of total $CO_2$ emissions from stationary energy in 2001 and all 2040 Scenarios**

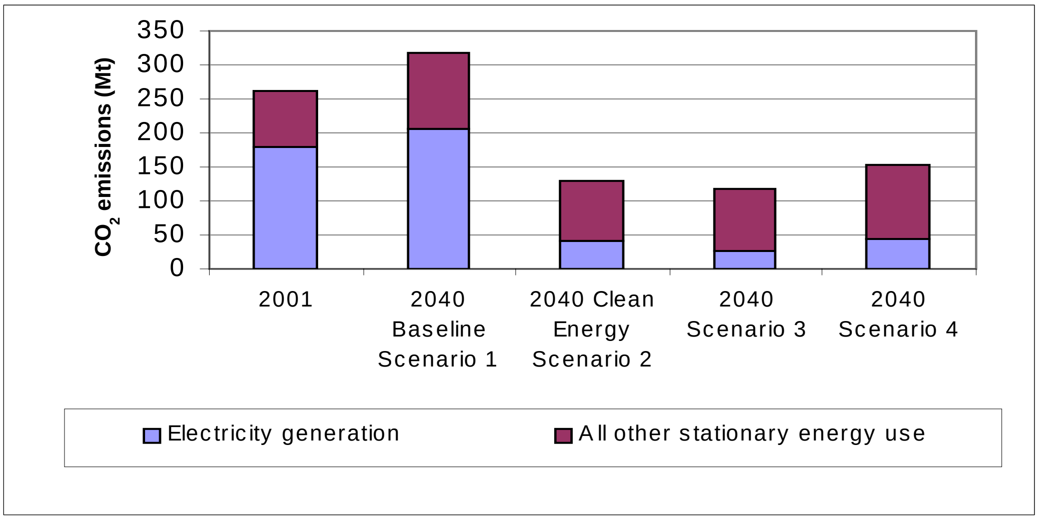


**Fig. 10.3: Primary energy demand from electricity generation and all other stationary energy consumption in 2001 and all 2040 Scenarios**

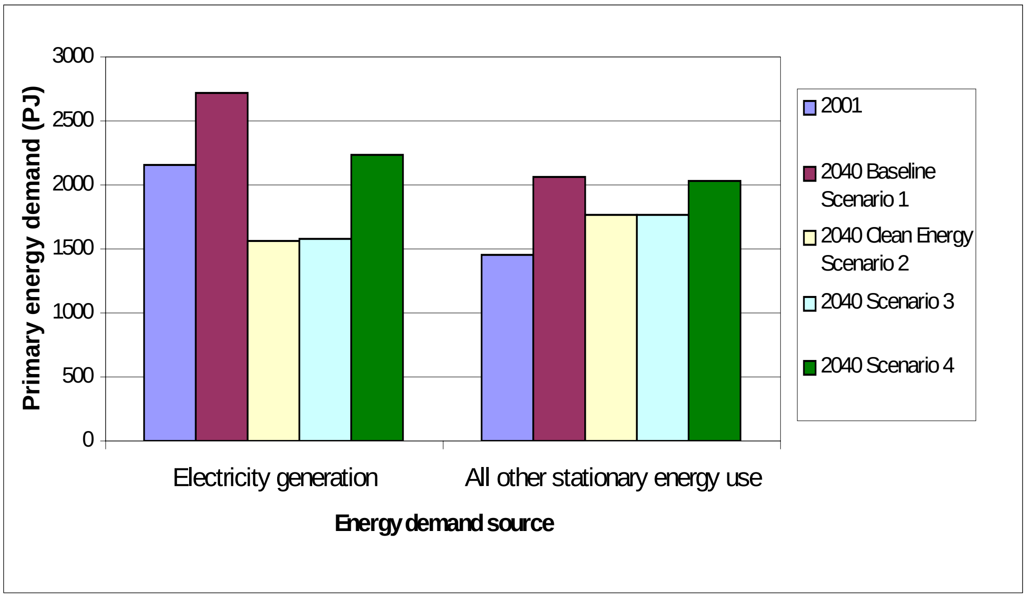
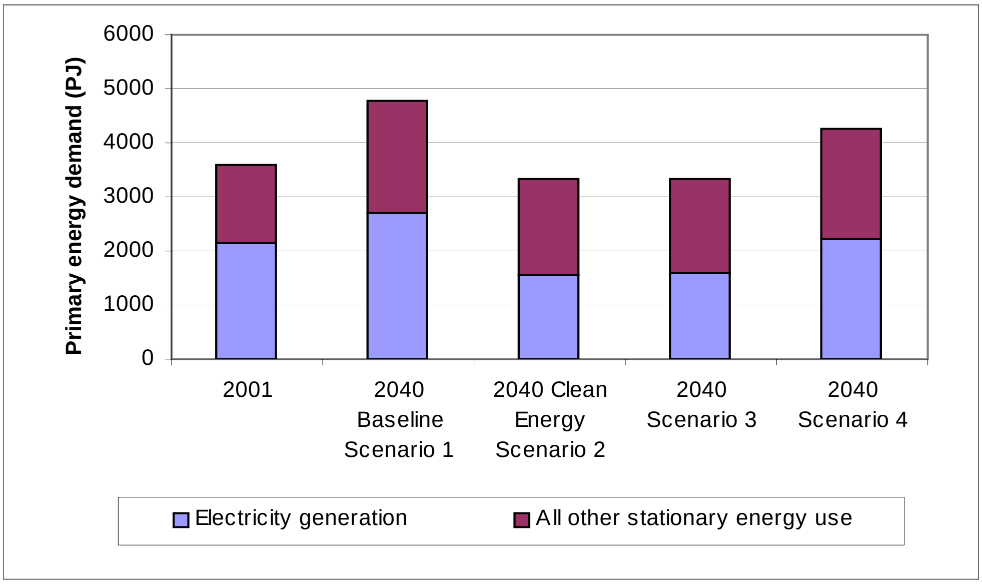



**Fig. 10.4: Composition of total primary energy demand from stationary energy in 2001 and all 2040 Scenarios**




## 10.2 Costs of the various scenarios

This report does not attempt to provide a full economic analysis of the 2040 scenarios. Indeed, as discussed in Section 2.1, we believe that this would be inappropriate for a time so far in the future, and we question the validity of the most commonly used integrated energy/macroeconomic models under these circumstances. Furthermore, there are some very large uncertainties, most notably the prices of fossil fuels and the extent of international and national constraints on greenhouse gas emissions in the long-term future. There can be little doubt that oil will be scarcer and more expensive in 2040 than it is today and that this will drive up the prices of Australia's LNG and coal exports. This in turn will draw up the prices of domestic natural gas and black coal that are capable of being exported. The extent of these increases cannot be predicted. Therefore, we do not think that a detailed attempt to evaluate the costs and economic benefits of a 'business-as-usual' scenario would be a meaningful exercise. Neither cost-benefit analysis nor the standard type of macroeconomic modelling seems appropriate.

The uncertainty about these key input cost parameters also calls into question the value of applying very detailed and complex energy system costing models, at least in the first instance. As a first step in analysing the economics of our scenarios, we offer here approximate estimates of the cost of electricity generation in the Baseline scenario (Scenario 1) and the Clean Energy scenarios (Scenarios 2 and 3), making several different but plausible alternative assumptions in each case. While this does not provide a complete economic assessment of the impact of Clean Energy scenarios, it serves to highlight the impact on electricity costs of different assumptions about fuel prices, electricity demand and supply mix.

The method of funding our Clean Energy Scenarios (see Section 10.3) can be summarised as follows:

> *In the cases where the fossil-fuelled scenarios are clearly more expensive than the Clean Energy Scenario, there are no costs to fund.*
>
> *In the cases where the fossil-fuelled scenarios are approximately the same cost or cheaper than the Clean Energy Scenario, the economic savings made by efficient energy use, together with the transfer of a fraction of the existing 'perverse' subsidies to the production and use of fossil fuels*[1]*, pay for the additional costs of clean energy supply.*

The cost estimates have been constructed on the basis of levelised costs in 2040, using a real discount rate of 8%. Because of the complexities involved, we have not attempted to estimate the costs of transmission and distribution.

The following further simplifications and assumptions are adopted.

- Electricity prices in $/MWh are average long-run prices, not short-run marginal. In other words they comprise the annualised capital, fuel, operation and maintenance costs.[2]

- Since the future costs of hydro and petroleum are uncertain and are the same in all scenarios, they have been omitted from the costings.

- For simplicity we do not consider the fuel costs of peak-load plant, which are small when spread over a year.

- Also for simplicity, it is assumed that, in the Clean Energy scenarios, solar electricity is peak-load costing $20/MWh more than conventional (hydro+gas

[1] See Section 10.3.
[2] Note that $10/MWh = 1 c/kWh.

turbine) peak-load generation. It is further assumed that in the Baseline scenario the very small quantity of solar electricity costs the same as conventional peak-load.

- We examine the Baseline scenario (i.e. Scenario 1) with four different sets of fossil fuel prices. These four cases A-D all have the same electricity generation (352 TWh including cogeneration) and fuel mixes in 2040.

- In Baseline Cases A-D we assume (as ABARE does to 2020) that the proportion of electricity generated from natural gas increases steadily. The result is that, in all our fossil fuel cases, by 2040 67% of total electricity generation (including cogeneration) comes from coal and 16% from natural gas.

- The Clean Energy scenarios all have the same electricity generation (255 TWh including cogeneration) in 2040. Scenarios 2 and 2a have the same low coal contribution (just under 9%), but different fossil fuel prices, while Scenario 3 has zero coal.

- For cogeneration, it is assumed that the electricity cost equals the grid electricity cost for that fuel. (Sales of useful heat are assumed to offset any higher price of cogenerated electricity compared with conventional fossil fuelled grid electricity.).

- Coal-fired power stations are retired at the ends of the operating lifetimes that they can reach without a major refurbishment. This lifetime is taken to be 35 years.

### Baseline Case A

In this case it is assumed that national policy will require the greenhouse gas emission intensity of coal-fired power stations in 2040 to be less than or equal to that of the best practice combined cycle natural gas power station in 2001, i.e. about 0.34 Mt $CO_2$ emitted per TWh of electricity sent out.[3] Since the newest coal-burning technologies of 2003, such as ultra-supercritical boilers, have much higher emissions than this target, IGCC with geosequestration of $CO_2$ from both coal- and gas-fired power stations would seem to be the main option to explore. Therefore, the price of coal-fired electricity is likely to be around 10 c/kWh at the point of generation (see Section 8.4). Allowing 1 c/kWh for the additional cost of electricity generated from natural gas transmitted by pipeline to the eastern States from the North-West Shelf, the price of combined cycle gas-fired electricity with geosequestration is assumed to be around 7 c/kWh.

### Baseline Case B

We assume no geosequestration, but rather that a carbon tax is placed on fossil fuels equivalent to their quantifiable external costs. As set out in Appendix A, we take the ExternE results for the costs of greenhouse gas emissions plus one-quarter of ExternE's air pollution costs for each of coal-fired and natural gas-fired electricity, and add them to the 2001 generation costs. The result is that electricity from coal is priced at 9.25 c/kWh and electricity from natural gas 7.0 c/kWh.

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[3] Such a policy would greatly reduce emissions for electricity generation, but not to the levels in our Clean Energy Scenarios.

### Baseline Case C

We assume no geosequestration, but rather that the price of coal-fired electricity has risen from its present range of 3.6-4.0 to 5.0 c/kWh (2001 value) and that the price of base-load natural gas-fired electricity has risen from around 4 c/kWh to 5.0 c/kWh. For NSW this is approximately equivalent to assuming that the cost of steaming coal doubles to about $2/GJ and that the cost of natural gas increases from $3/GJ to $4/GJ. For the purpose of comparison, we assume that these fossil fuel prices apply to both the Clean Energy scenario and to this fossil scenario.

### Baseline Case D

As in Case C, but no significant increase in the cost of coal- and gas-fired electricity, which is held at 4 c/kWh for each. We compare Case D with a version of the Clean Energy Scenario (Scenario 2A) that has the same fossil fuel prices as Case D.

## Clean Energy Scenarios

Our estimate of the costs is based on the following additional assumptions:

- Efficient energy use measures and solar hot water are implemented to the extent that they are cost effective over the lifetimes of the building, appliance or equipment concerned. Therefore, there are no net costs of efficient energy use (see Section 6.8). However, there are up-front costs. Because there are so many different technologies in third category, their average cost will be estimated as an output of the costs of energy supply in Table 10.5.

- Medium efficiency of energy use reduces demand for stationary energy in 2040 by 20%, as derived in Chapter 6. Further cost-effective reductions may be possible, although they are not considered in this study.

- The indirect economic benefits of efficient energy use that must be considered here include a reduction in the generation, transmission and distribution infrastructure required for 2040, as estimated below. This benefit will be offset to some extent by the costs of the energy efficiency measures, additional transmission and distribution costs of a more distributed electricity supply system and by the increase in peak-load gas turbine capacity required to back up wind power. These costs are very difficult to estimate accurately. For a first approximation we assume that the additional transmission and distribution costs of the centralised fossil fuel and more distributed Clean Energy scenarios are approximately equal. Because we expect most of the efficient energy use measures to pay for themselves within 8-10 years (compare Ministerial Council on Energy, 2003), the Clean Energy scenarios offer additional economic savings because they substitute for new power stations with lifetimes of 35-40 years. However, we do not attempt to calculate them, beyond suggesting that their magnitude is of the order of $10 billion.

- The price of renewable energy technologies, except for biomass, is as given in Column 3 of Table 7.3.

- Specifically, for the 65 TWh (234 PJ) of biomass energy (final consumption) required for Scenario 2, it is assumed that 15 TWh comes from bagasse and sugar-cane 'trash' at a generation cost of 5 c/kWh; 39 TWh from wheat stubble at the generation cost of 6 c/kWh; 10 TWh from forest residues also costing 6 c/kWh, and the remaining 1 TWh from oil mallee and other eucalyptus crops with multiple economic benefits that reduce the cost of electricity to 7 c/kWh.

- For the 77.4 TWh (343 PJ) of biomass energy (final consumption) required for Scenario 3, it is assumed that 15 TWh comes from bagasse and sugar-cane 'trash' at a generation cost of 5 c/kWh; 39 TWh from wheat stubble at the generation cost of 6 c/kWh; 10 TWh from forest residues also costing 6 c/kWh, and the remaining 13.4 TWh from oil mallee and other eucalyptus crops with multiple economic benefits that reduce the cost of electricity to 7 c/kWh.

- For direct solar electricity, we assume that the additional cost is 2 c/kWh above the average peak-load price paid by consumers.

## Indicative comparison of costs

Based on these assumptions, Table 10.5 shows the results of our estimates of the relative costs of four different cases for electricity generation:

**Table 10.5: Cost of Baseline Scenario, Cases A-D, and Clean Energy scenarios with various fuel prices in 2040**

| **Scenario** | **Electricity demand, 2040 (TWh)** | **Coal electricity price, 2040** ($/MWh) | **Natural gas electricity price** ($/MWh) | **Wind electricity price, 2040** ($/MWh) | **Solar electricity price, 2040** ($/MWh) | **Total cost of electricity 2040** ($ billion) | **Average cost of electricity**[a] ($/MWh) |
|---|---|---|---|---|---|---|---|
| 1: Cost A | 352 | 100 | 70 | 55 | Extra 20 | 29.5 | 90 |
| 1: Cost B | 352 | 92.5 | 70 | 55 | Extra 20 | 27.7 | 84 |
| 1: Cost C | 352 | 50 | 50 | 55 | Extra 20 | 16.4 | 50 |
| 1: Cost D | 352 | 40 | 40 | 55 | Extra 20 | 13.2 | 40 |
| 2: Cost C | 255 | 50 | 50 | 55 | Extra 20 | 12.2 | 54 |
| 2: Cost D | 255 | 40 | 40 | 55 | Extra 20 | 11.1 | 50 |
| 3: Cost C | 255 | N/A | 50 | 55 | Extra 20 | 12.3 | 56 |

Notes:

a. This equals the total cost in billions of dollars (Column 7) divided by the energy generated by the sources considered here. The latter is equal to the total demand (Column 2) minus the generation from hydro and oil (not shown).
For other assumptions, see text.

The results are encouraging. Although the cost of electricity expressed in dollars per MWh (see Column 8 of Table 10.5) is lowest in Baseline Case D, there are fewer megawatt-hours generated in the Clean Energy scenarios. As a result, the total costs in billions of dollars of the Clean Energy scenarios are less than or approximately equal to those of all the Baseline scenario cases, even Baseline Case D with low-cost coal and gas. It appears that the only way the Baseline energy supply could compete with our Clean Energy scenarios would be to adopt an important component of the latter scenarios, namely, to implement Medium Efficiency energy use. In practice, this option seems very unlikely, since cheap fossil fuels discourage the efficient use of energy.

The calculation is now refined by including the average costs of efficient energy use, which are derived as an output of Table 10.5. For fuel cost combination D, the difference in the total cost of electricity in 2040 between Scenarios 1 and 2 is $(13.2 - 11.1) billion = $2.1 billion. The difference in demand is (352 – 255) TWh = 97 TWh. Therefore, the breakeven cost of efficient energy use is $2100/97 MWh = $21.6/MWh. In other words, so long as the cost of efficient energy use is less than $21.6/MWh saved, Scenario 2 (Clean Energy) is less expensive than Scenario 1 (Baseline). Similarly, for the fuel cost combination C, the breakeven cost of efficient energy use is $43.3/MWh saved. In other words, in Case C efficient energy use could make a much greater, cost-effective contribution to the Clean Energy scenarios. In Cases A and B, efficient energy use would be competing with the costs of wind power and biomass electricity.

Including part of the environmental and health costs of the fossil fuel scenarios, either by using the IEA estimates of the costs of geosequestration of $CO_2$ (Baseline Case A) or by using the ExternE estimates of the external costs of fossil fuels (Baseline Case B), makes the Baseline cases much dearer than our Clean Energy Scenario.

## 10.3 Paying for cleaner energy scenarios

Any additional costs of the Cleaner Energy Scenario could be readily paid out of the existing financial subsidies to the production and use of fossil fuels. A recent estimate of the minimum level of these subsidies is $6.5 billion p.a. (Riedy and Diesendorf, 2003). These subsidies include:

- electricity price subsidies to aluminium smelting;
- tax benefits for salary packaging motor vehicles;
- Greenhouse Gas Abatement Program (which goes mostly to fossil fuels);
- fuel excise reduction;
- fuel sales grants scheme;
- automotive industry support;
- land for roads and car parking;
- reduced import duty on 4WDs;
- inappropriate company tax concessions;
- R&D support for fossil fuels;
- non-recovery of government agency costs (e.g. AGSO, DITR, various State departments).

Subsequently this work has been extended by Riedy (2003), who has calculated additional subsidies that lift the total to $9 billion per year. Riedy has classified the subsidies into ‘positive’, ‘negative’ and ‘perverse’ subsidies. The latter category comprises subsidies that are both economically inefficient and environmentally damaging. Such subsidies amount to $5.2 billion per year. A small fraction of these could be used on a temporary basis to speed up the transition to a 50% reduction in $CO_2$ emissions from stationary energy.

Finally, it is important to realise that the macroeconomic benefits of increasing energy efficiency are conceptually identical to the macroeconomic benefits of increasing labour market efficiency. While the latter has been the objective of government policy in Australia for over 15 years, the former is generally seen as a peripheral problem to be pursued primarily for environmental reasons. In fact, minimising the amount of energy required to produce a given level of output is as economically beneficial as minimising the amount of labour or capital input. Reducing energy consumption per unit of output will free up resources, particularly resources that would otherwise be directed towards energy generation and distribution, that can be directed towards more productive purposes.