Nuclear power plant viability reports

OBJECTIVES

Two reports were commissioned into the viability of nuclear power in South Australia. Their objectives were:

1. To develop cost estimates and an initial business case for a range of the latest nuclear generation technologies likely to be commercially available for deployment in South Australia and which will already be in commercial operation elsewhere by 2030 (WSP/Parsons Brinckerhoff)
2. To quantify the relative commercial viability of integrating nuclear power generation technologies into the National Electricity Market (NEM) in South Australia, in conjunction with renewable and fossil fuel generators, in 2030 and 2050 under a variety of electricity demand and renewable generation scenarios (DGA Consulting/Carisway).

BACKGROUND

These reports aim to determine the commercial viability of nuclear power in South Australia under different wholesale electricity price forecasts and demand assumptions.

Each analysis was conducted on the basis that the global response to reducing carbon emissions to constraint global temperature rise to below 2 degrees C would underpin government policy and drive demand for low carbon energy solutions.

The baseline assumptions on what constituted strong climate action were different for each report, primarily with respect to the assumptions on carbon price and the degree of behind-the-meter storage that was installed. [1 2]

The viability of the nuclear power plant technology options identified was assessed by comparing the levelised cost of electricity (LCOE) against the levelised price of electricity (LPOE) received by the sale of electricity in the NEM over the plant's life by applying a real pre-tax weighted average cost of capital (WACC) rate of 10 per cent.[3] The net present value (NPV) and internal rate of return (IRR) were also assessed for each option assuming the same cost of capital.

The reports did not assess the viability of establishing nuclear power plants in other Australian states.

WSP/PARSONS BRINKERHOFF

South Australia's electricity market is characterised by flat grid electricity consumption and a variable demand profile. The generation mix is dominated by natural gas, wind and coal. It also currently has a high share of intermittent renewables (wind and solar photovoltaics) which is expected to rise through the increased uptake of rooftop solar PV.[4] The electricity market in South Australia requires peaking generators with fast response times to complement intermittent renewables, or the ability to import power from interstate to effectively meet electricity demand.[5]

Nuclear power plants usually operate as baseload generators. Although large plants have some load-following capability, they have relatively slow response times and are generally uneconomic in this mode of operation.[6] Small modular reactors (SMRs), on the other hand, are likely to have better load-following capabilities, and may be a better fit with the increasing renewable generation capacity in the South Australian electricity market. However, operating SMRs at reduced capacity, as with larger nuclear plants, reduces profitability.[7]

First-of-a-kind (FOAK) commercial nuclear power plants are considered inappropriate for development in South Australia due to the significantly increased technical, project and commercial risks.[8] It is assumed that a nuclear power plant considered for South Australia, would have been developed internationally to an nth-of-a-kind (NOAK) basis (that is, there is more than one operational plant), for operation by 2030.[9]

The capital costs of representative western nuclear reactor types, considered likely to be commercially available and suitable for development[10] in South Australia by 2030, were assessed. These reactor classes, types, and designers are[11]:

- light water reactors (LWR) – Westinghouse AP1000 and GE Hitachi ESBWR
- pressurised heavy water reactors (PHWR) – Atomic Energy of Canada Limited (AECL) EC6 and ACR-1000
- small modular reactors (SMR) – NuScale and B&W Bechtel mPower.

Capital costs, operating expenditure and the levelised cost of electricity (LCOE) varied significantly for the different types of reactors.[12]

The deployment timeline for a nuclear power plant to be developed in South Australia, based on a large power plant of more than 1 gigawatt electrical (GWe) is shown in Figure 1 on the following page.[13]

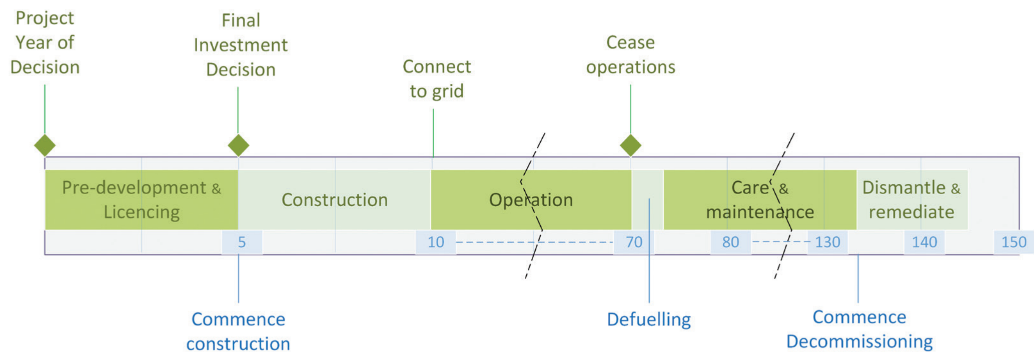

Figure 1: Assumed nuclear power plant deployment timeline

The deployment of large-scale nuclear power plants (although not SMRs) and/or the growth in renewables are likely to necessitate major electricity network development by 2030 and an increase in the export of electricity to Victoria and New South Wales.[14]

Large nuclear reactors would need to be located on the coast, due to the large quantities of cooling water required[15], while SMRs could be deployed inland, if air cooled,[16] although this would result in some degradation in performance.

DGA CONSULTING/CARISWAY

The report analysed the future generation mix available, including using separate combinations of renewable/storage technologies that could meet the South Australian system demand.[17] The technologies considered included:

- solar PV panels without storage
- solar PV paired with storage
- wind generation
- wind paired with storage
- centralised solar thermal
- vehicle to grid with electrical vehicle storage
- combined cycle gas turbine (CCGT) with carbon capture and storage (CCS)
- nuclear power
- fossil fuels.

A significant increase in wind and Photo Voltaic (PV) solar panels is anticipated, particularly with advancements in storage that will provide improved flexibility.

The analysis was based on actual 30-minute interval datasets of load by consumer categories supplied by SA Power Networks and extrapolated forward to 2030 and 2050 to predict the shape of future demand in South Australia[18], and determine that which could be supplied or exported to the NEM from either new CCGT or nuclear power plants.

Various scenarios were modelled as inputs to the comparative assessment of market entry for four generator options in South Australia for demand forecast, technology forecasts, dispatch modes, and climate change mitigation. The four generator options assessed were:

- CCGT
- CCGT with CCS
- small modular reactor nuclear – 285 MWe installed capacity
- Large Nuclear Reactor - 1125 MWe installed capacity.

The Strong Climate Action (High Storage) scenario represents the least-cost mix of generation in South Australia that meets reliability standards and the forecast level of demand determined by Ernst & Young market model incorporating Australian Energy Technology Assessment (AETA) technology learning rates and Electric Power Research Institute (EPRI) costs for technology options. The scenario assumes:

- The Climate Change Authority recommended emissions reduction target of 65 per cent below 2005 levels by 2030 is adopted.[19] For 2050, a target aimed at reducing carbon emissions to net zero is adopted (including substantial carbon permit imports).
- The demand dispatch model assumed current electricity market rules are maintained, which assumes either CCGT or nuclear are dispatched after all renewables, with nuclear operating as base-load.[20]
- There is widespread uptake of vehicle-to-grid and mass storage technologies, and distributed storage creates some firm capacity in the grid.[21]
- Average electricity demand in South Australia (and the NEM more broadly) is projected to decrease across all customer categories (except major customers), and the profile will become smoother (less variable), between now and 2030.[22]
- Rooftop solar PV is expected to reach saturation by 2028[23] (that is, 75 per cent of suitable dwellings with 3.5 kW each) at which point it will come close to meeting residential peak demand in summer but not in winter.

- South Australia has the largest installed capacity of wind generation in Australia with total installed capacity of 1,473 MW (2014).[24] Installed capacity in the state is assumed to increase under medium and high growth scenarios to 3,000 MW and 4,421 MW respectively by 2030.[25]
- Interconnector capacity to the eastern states is increased to 2,000 MW, from the current 650 MW.[26]

The capital cost and technology learning curves assumptions are:

- The capital costs of the selected nuclear power plants (that is, 285 MWe SMR and 1125 MWe LWR) were derived from the WSP/Parsons Brinckerhoff report.
- CCGT and CCS costs and learning curves were derived from previous AETA/CO2 CRC (EPRI) studies.[27]
- Renewable technologies (that is, rooftop solar PV and storage, and large-scale renewable generation capacity) were assumed to be commercially viable, with penetration rates and installed capacities estimated using costs and learning curves taken from previous Australian Energy Market Operator (AEMO)/ AETA/CSIRO studies.[28]
- Wholesale electricity price forecasts were derived from computational general equilibrium (CGE) analysis undertaken by Ernst & Young as part of a separate piece of work produced for the Commission for the Strong Climate Action (High Storage) scenario.

The viability of expanding the transmission interconnector[29] and alternatives to electricity export, including power-to-fuel systems or grid storage, was not assessed.

FINANCIAL ANALYSIS

WSP / PARSONS BRINKERHOFF

All nuclear power plant technologies are characterised by high fixed costs and relatively low variable costs. Capital cost recovery, and fixed operating and maintenance costs account for about 90 per cent of nuclear power plant LCOE.[30] The LCOE is most sensitive to capital cost and weighted average cost of capital (WACC) assumptions (an indicative commercial WACC of 10 per cent and sensitivity WACC of 7 per cent were modelled).[31]

The Strong Climate Action (Low Storage) scenario, used as the basis of viability assessments in the WSP/ Parsons Brinckerhoff report [32], is based on a carbon price that increases to $328/ tCO_2-e in 2050 and assumes the development of 1.25 GWh of behind-the-meter storage by 2050.

Under the Strong Climate Action (Low Storage) scenario, wholesale electricity prices were estimated to rise from $134/ MWh in 2030 to $253/MWh by 2050 without nuclear. The introduction of a large nuclear power plant under this scenario (in 2030) reduces wholesale electricity prices by about 23% or $30/MWh.[33]

Based on the LCOE/LPOE comparison (AUD 2015) all reactor types show a negative net present value (NPV) and, as such, are unlikely to be commercially viable in South Australia (under existing market rules) based on best-estimate cost assumptions at a commercial WACC of 10 per cent, as shown in Figure 2.[34]

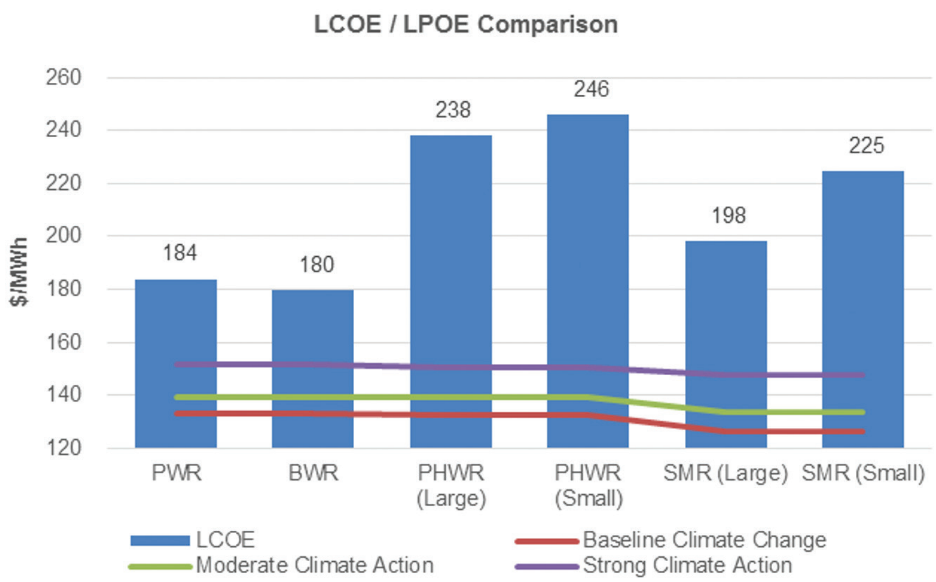

Figure 2: **Best Cost Estimate (WACC 10%)**

The estimated capital cost of the more viable nuclear power plant options are estimated to be:

- large LWR (1,125 MWe) - A$9.323bn (2014)
- 'large' SMR (2 x 180 MWe) - A$3.691bn (2014).[35]

These estimates include pre-construction, capital cost, supporting infrastructure at a greenfield site. The analyses of viability also include decommissioning costs of $0.5bn for the large LWR and $0.25bn for the "large" SMR.[36] Transmission network upgrade costs are not included in the capital cost of the nuclear power plants considered in this study but connection to the existing grid is included.

As shown in Figure 3 for large LWR plants to be potentially viable (but not PHWR or SMR options) the capital costs of the plant would need to be delivered for approximately 7 – 8 per cent less than the current best-estimate cost assumption under the Strong Climate Action (Low Storage) scenario.[37] Alternatively, as shown in Figure 4, if the project can be financed at a reduced WACC of 7 per cent or less, again under the Strong Climate Action (Low Storage) scenario, both large LWR and large SMR plants could be potentially viable.[38]

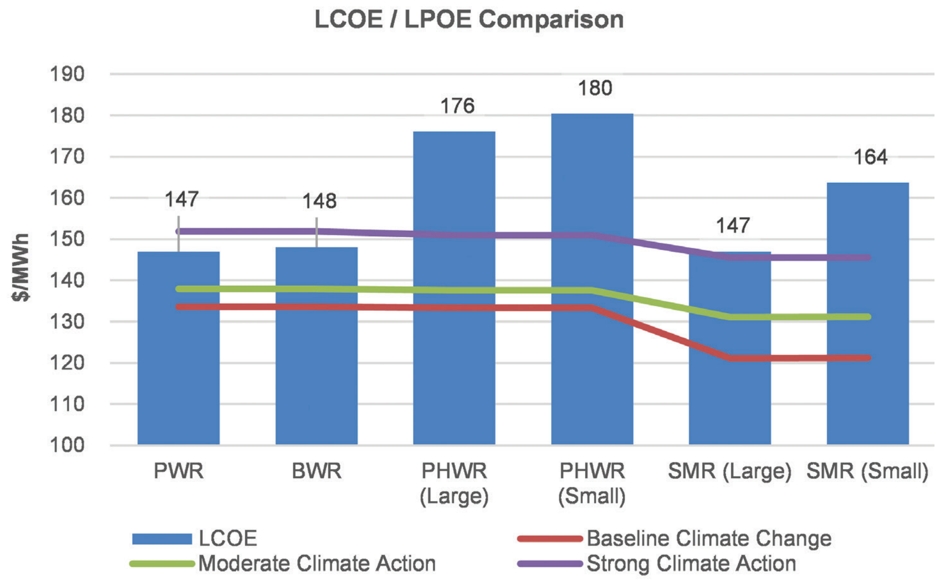

Figure 3: **Low capital cost**

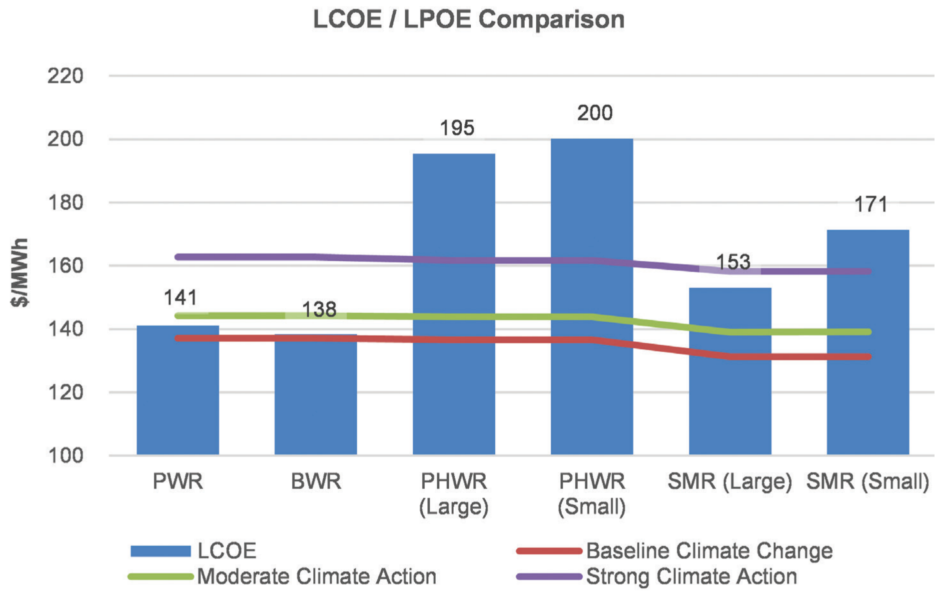

Figure 4: **Low WACC (7 per cent)**

DGA CONSULTING/CARISWAY

The expansion of interconnector capacity from 650 MW (of firm capacity expected to be available from July 2016) to 2000 MW is important to enable the export of both surplus renewable and nuclear electricity generation that may be developed in South Australia to displace fossil fuel generation capacity in the NEM.[39]

The Strong Climate Action (High Storage [40]) baseline scenario, used in the DGA Consulting/Carisway report, assumed a wholesale electricity price forecast based on a carbon price rising to $254 per tonne carbon dioxide equivalent (tCO_2-e) and the development of 2 gigawatt hours (GWh) of behind-the-meter storage by 2050.[41]

Under the Strong Climate Action (High Storage) scenario [42], approximately 29 per cent of electricity demand in South Australia in 2030 would have to be met through electricity imports or another form of firm, dispatchable generation capacity such as CCGT, nuclear, open cycle gas turbine (OCGT) or hydro. Under an alternative, High Renewables Penetration[43] generation mix scenario for South Australia, 9 per cent of electricity demand in South Australia in 2030 would still have to be met by another form of dispatchable generation.

Under the Strong Climate Action (High Storage) scenario, without the inclusion of nuclear, the wholesale price of electricity is expected to increase from $139/MWh in 2030 to $186/MWh by 2050. In 2050, wholesale electricity prices under the Strong Climate Action scenario is $24 – 31/MWh higher than the moderate climate action scenario (depending on the mechanism for climate mitigation action).[44]

The introduction of a large nuclear power plant into the South Australian region of the NEM in 2030 as a baseload plant would have an immediate impact by reducing the wholesale regional reference price of electricity in South Australia by about 24 per cent, or $33/MWh, under the Strong Climate Action (High Storage) scenario. Alternatively, the introduction of a SMR into the South Australian region of the NEM in 2030 would be expected to reduce wholesale prices by approximately 6 per cent, or $8/MWh.[45]

In comparison with nuclear, the integration of CCGT, or CCGT with CCS, does not have any impact on the wholesale price trajectory. This is because it is assumed to operate only when the wholesale price of electricity is greater than its cost of operation.

This analysis confirmed that the two nuclear options considered (large and small nuclear plants) consistently deliver strongly negative NPVs at a commercial WACC of 10 per cent under current market rules for all climate action scenarios for both the 2030 and 2050 time horizons.[46]

CCGT plants delivered positive NPV under both moderate and strong climate action scenarios for the 2030 and 2050 time horizons.

CCGT with CCS delivered a marginally positive NPV for Strong Climate Change scenario in 2030 and stronger positive NPV for all scenarios in 2050.[47]

Under all climate action scenarios, based on the NPV analysis CCGT and CCGT with CCS generation plants would be developed ahead of nuclear on a commercial basis under current market rules. However, it should be noted that:

- CCGT options will not achieve a 100 per cent decarbonisation outcome (although CCS has the prospect of reducing carbon emission intensity).[48]
- CCS is not a commercially proven technology
- the viability of CCGT options is heavily affected by changes to gas and carbon prices.[49] [50]

CONDITIONS FOR VIABILITY

Long-term revenue certainty from nuclear generation would be required in order to attract interest from private-sector equity investors and debt financiers for nuclear power plants.

Depending on the magnitude and speed of climate mitigation action taken by Australia between now and 2050, for nuclear power plants to be commercially viable in South Australia:

- the capital cost of the nuclear plants would need to decrease by at least 25 per cent from the central estimates for its cost to be competitive with electricity generation from CCGT[51],
- the cost of capital would need to decrease to 6 per cent or less assuming strong climate action (a level unlikely to be commercially available on the open market)[52], or
- A carbon price of at least $180/tCO_2$-e (AUD 2015) would be required (that is, electricity prices would need to increase significantly above that estimated under the Strong Climate Action [High Storage] Scenario).[53]

In the absence of these conditions, some form of government subsidy, guarantee and/or policy action is likely to be required for nuclear power to be developed in South Australia.

OPPORTUNITIES

If nuclear power were to be developed in South Australia:

- Excess electricity generated by large-scale nuclear power plants as baseload operation in South Australia, in conjunction with renewable sources, could be used to power other states in the NEM as aging coal-fired generators are retired in those states. This would require major upgrades to the transmission grid and interconnector capacity between states.[54]
- SMRs could supply baseload requirements to the South Australian electricity market to meet incremental growth in demand without the need for major upgrades to the transmission network.[55]

REFERENCES

[1] DGA Consulting/Carisway, *Final report for the quantitative viability analysis of electricity generation from nuclear fuels*, report prepared for the Nuclear Fuel Cycle Royal Commission, Adelaide, February 2016, available at http://nuclearrc.sa.gov.au/tentative-findings/, p. 62, section 5.2.1.

[2] WSP/Parsons Brinckerhoff, *Final report. Quantitative analysis and initial business case—establishing a nuclear power plant and systems in South Australia*, report prepared for the Nuclear Fuel Cycle Royal Commission, Adelaide, February 2016, available at http://nuclearrc.sa.gov.au/tentative-findings/, p. 79, section 7.3.2.

[3] ibid., p. 76-77, section 7.3.1.

[4] ibid., p. 61; section 7.1.1.

[5] ibid., p. 67; section 7.1.4.

[6] ibid., p. 67; section 7.1.4.

[7] ibid., p. 68; section 7.1.4.

[8] ibid., p. 10; section 3.1, para. 4.

[9] ibid., p. 10; section 3.1, para. 4.

[10] ibid., p. 10; section 3.1, para. 5.

[11] ibid., p. X; Executive Summary, Methodology.

[12] ibid., p. 84, Figure 7.19; section 7.3.3.1.

[13] ibid., p. 11, Figure 3.1; section 3.2.2 and p. 47, section 6.4.

[14] ibid., pp. 68–69, section 7.1.5.

[15] ibid., p. 42, section 6.3.3.

[16] ibid., pp. 15, section 3.3.2.3.

[17] DGA Consulting/Carisway, op. cit., p. 30, section 3.1.2.

[18] ibid., p. 17, section 1.2.1.

[19] Ernst & Young, *CGE modelling assessment*, report prepared for the Nuclear Fuel Cycle Royal Commission, Adelaide, February 2016, available at http://nuclearrc.sa.gov.au/tentative-findings/, p. 7, section 1.4.

[20] DGA Consulting/Carisway, op. cit., p. 41, section 4.2, Table 11.

[21] ibid., p. 33, section 3.2.4.

[22] Ernst & Young, op. cit., p. 56, section 5.1.

[23] DGA Consulting/Carisway, op. cit., p. 31, section 3.2.1.

[24] ibid., p. 32, section 3.2.2, Table 8.

[25] ibid., p. 36, section 3.4, Table 9.

[26] ibid., p. 36, section 3.4, Table 9.

[27] ibid., p. 40, Table 10, section 4.1 and p. 66, section 5.3.3.

[28] ibid., p. 35, section 3.4, Table 9.

[29] ibid., p. 65, section 5.2.6.

[30] WSP/Parsons Brinckerhoff, op. cit., p. 84, Figure 7.19; section 7.3.3.1.

[31] ibid., p. 87, Figure 7.23; section 7.3.3.2.

[32] ibid., pp. 80–82; section 7.3.2.

[33] ibid., p. 80, Figure 7.14; section 7.3.2.

[34] ibid., p. 85, Figure 7.20; section 7.3.3.2.

[35] ibid., p. xiii, Table ES.3, ES.5–7, Executive Summary.

[36] ibid., p. xiv, Table ES.3, ES.9, Executive Summary.

[37] ibid., p. 86, Figure 7.21 and p. 80 Figure 7.23; section 7.3.3.2.

[38] ibid., p. 87, Figure 7.23; section 7.3.3.2.

[39] DGA Consulting/Carisway, op. cit., p. 55, 57, section 4.8.

[40] ibid., p. 50. Figure 52 (represented by the base scenario throughout); section 4.6.

[41] ibid., p. 63, Table 18; section 5.2.1.

[42] ibid., p. 56, Table 15 (Base scenario); section 4.7

[43] ibid., p. 56, Table 15 (Scenario 3); section 4.7.

[44] ibid., p. 64, Table 20; section 5.2.4.

[45] ibid., p. 64, Table 20 (Base scenario); section 5.2.4.

[46] ibid., p. 73, section 6.1, Tables 35 and 36.

[47] ibid., p. 73, section 6.1, Tables 35 and 36.

[48] ibid., p. 79, section 6.6, Table 39

[49] ibid., p. 80, section 7.2.

[50] ibid., p. 94, section 9.2.5.

[51] ibid., p. 15, Executive Summary.

[52] ibid., p. 78, section 6.5.

[53] ibid., p. 15, Executive Summary

[54] ibid., p. 57, section 4.8.

[55] ibid., p. 57, section 4.8.