GREENPEACE

DECENTRALISING SCOTTISH ENERGY: CLEANER, CHEAPER, MORE SECURE ENERGY FOR THE 21ST CENTURY

APPLICATION OF THE WADE ECONOMIC MODEL TO SCOTLAND

ABOUT WADE

WADE is a non-profit research and advocacy organisation that was established in June 2002 to accelerate the worldwide deployment of decentralised energy (DE) systems. WADE is now backed by national cogeneration and DE organisations, and DE companies and providers, as well as a number of national governments. In total, WADE's direct and indirect membership support includes over 200 organisations and corporations around the world.

DE technologies encompass the following types of energy generation system that produce heat and electricity at, or close to, the point of consumption, including:

- high-efficiency cogeneration/combined heat and power;
- on-site renewable energy systems; and
- energy recycling systems, including the use of waste gases, waste heat and pressure drops to generate electricity on-site.

WADE classifies such systems as DE regardless of project size, fuel or technology, or of whether the system is on-grid or off-grid.

WADE believes that the wider use of DE holds the key to bringing about the cost-effective modernisation and development of the world's electricity systems. With inefficient central power systems holding a 93% share of the world's electricity generation and with the DE share at only 7% WADE's mission is to bring about the doubling of this share to 14% by 2012. A more cost-effective, sustainable and robust electricity system will emerge as the share of DE increases.

The economic modelling work underlying this report was undertaken by Sytze Dijkstra, Research Executive, WADE, who can be contacted at sytze.dijkstra@localpower.org

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GREENPEACE FOREWORD

As this report goes to print, Scotland is heading towards the polling booth. The findings herein and the issue of energy are more pertinent than ever in this evolving political landscape. While this report comes at a key time, its findings have lasting relevance to the energy pathway that Scotland and the UK take together. The pathway that Scotland chooses to follow, whether centralised or decentralised, will have a lasting impact on energy security, fuel consumption, carbon emissions and the impact of renewable technology development. This report's findings show that the decentralised approach combined with large scale renewables delivers the best outcomes across the board.

Scotland is assuming ever-greater importance in the UK energy debate. Its renewable energy potential - wind, wave and tidal - are the envy of the rest of the EU. Scotland will also have a big say in whether the UK will build a new set of nuclear power stations. Given the shortage of sites at which new nuclear power might conceivably be politically acceptable, the Hunterston and Torness locations will be a critical part of a programme of new build; the economics of nuclear dictate that a series of stations is required rather than just one or two. Thus, Scotland has a pivotal position in approving or vetoing a nuclear renaissance.

The failure of the UK Government to consult properly over the possibility of constructing new nuclear power means that a full and proper consultation must take place; and in the words of the Judge finding against the Government's process, consultation should in this case be "extended to the adult population of the United Kingdom". Most people in Scotland oppose the building of further nuclear power stations, for well-rehearsed but valid reasons – nuclear waste, terrorism, safety and proliferation to name just a few – and most of the Scottish parties reflect that view. Of the parties likely to hold power in the Scottish Assembly, only the Labour party remains equivocal about building new nuclear reactors. The SNP, Liberal Democrats and Greens have all ruled them out.

Some opinions may even see new nuclear power stations as inevitable given the planned closure of many thermal power stations over the next 20 years. Some may see new nuclear power as essential if we are to combat the twin threats of climate change and worries over security of gas supply.

In fact, as this study shows, these challenges are met better by a rethinking of Scotland's energy system, in decentralising power generation in order to allow the heat normally wasted in thermal power stations to be used in providing the hot water and heating needed in buildings. Our current electricity system depends on thermal power stations, which generally throw away about two-thirds of the energy put into them, via cooling towers and cooling water. UK-wide this waste heat is enough to provide the heating and hot water requirements for all the buildings in the country. In a climate-constrained world, such wastage is unsupportable.

Decentralised energy and combined heat and power plants utilise this 'waste' heat properly and effectively. Moreover, producing power closer to its point of use means less investment (and thus cost savings) on the transmission and distribution grids. These grids are likely to make up around half of the cost of infrastructure renewal over the next 25 years, according to the International Energy Agency[1]. Furthermore, a decentralised electricity grid facilitates contributions from a diverse range of renewable energy, including biomass, solar, micro-wind and heat pumps. And local power and heat production can provide much cheaper heating to address Scotland's fuel-poverty problem, as has been seen at the Stockethill project in Aberdeen[2].

Scotland is highly-suited to a renewably supported but decentralised grid system. Its renewable energy is well-known, but it has a relatively high heat demand from buildings that require local heating – buildings that could harness the by-product of electricity generation from gas or oil. The economic model put together for Greenpeace by the World Alliance for Decentralised Energy (WADE) shows what is possible. This model has been used by the UK Foreign and Commonwealth Office as well as the European Commission and governments or agencies in Germany and Canada (see page 9). It shows that decentralising power generation in Scotland over the next 20 years delivers a saving of 8% on both CO2 emissions and on gas use compared with a scenario in which a continuation of centralised power and the renewal of nuclear reactors is relied upon – and all at a lower cost.

Even higher levels of renewable generation do not affect decentralisation as a viable route to lowering climate impact, and at better costs than business as usual. The Model demonstrates that even if you accept the risks of accidents, terrorism, proliferation and nuclear waste associated with new nuclear power stations, it isn't the best option. Scotland can meet its energy needs, prolong the life of its gas reserves and even increase its renewable energy exports to England by a combination of decentralised power and large-scale transmission-connected renewable power developments. Details of the scenarios used are given in the body of the report.

The Scottish Labour party has not ruled out a new nuclear build programme. But the WADE research turns this 'pragmatic' policy on its head. Why support a more expensive, dirtier and less secure system of delivering power, when alternatives provide a better deal without having to worry about the thorny issues of waste and terrorism? Wind power provides better jobs and higher return on investment than nuclear power and decentralised energy means many more skilled jobs in communities throughout the country.

With the next UK prime minister likely to be a Scot, and with its unique renewable resource, Scotland is in an unparalleled position to influence energy policy not just in the UK but Europe-wide. Greenpeace takes the view, and we believe this research makes clear, that an energy efficient, renewable and decentralised energy system is Scotland's best option.

Dr Doug Parr, Chief Scientist. Greenpeace

Acknowledgements
Greenpeace would like to thank Carlo Rossini, Marcus Newborough and Maf Smith for their helpful comments on the input assumptions of the scenarios.

1. International Energy Agency. World Energy Outlook, 2006.
2. www.aberdeencity.gov.uk/ACCI/web/site/CouncilNews/pr/pr_city_turned_on.asp accessed 16 March 2007

1. EXECUTIVE SUMMARY

1.1 MAIN FINDING

Decentralised energy (DE) can meet Scotland's future electricity demand at lower cost than traditional centralised generation (CG)

The reasons for this are: that DE reduces transmission and distribution (T&D) network costs, while avoiding power losses in the network; and that decentralised combined heat and power (CHP) systems have a higher overall efficiency than CG by virtue of waste heat utilisation (see Figure 1). This efficiency advantage is particularly important in Scotland where the demand for heat is higher than for the UK in general.

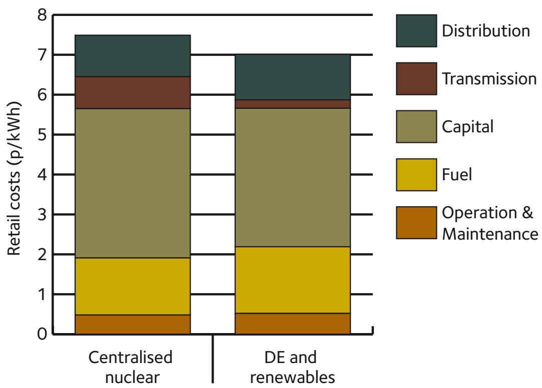

Figure 1. Retail costs in 2024 – baseline scenarios (see section 3.2)

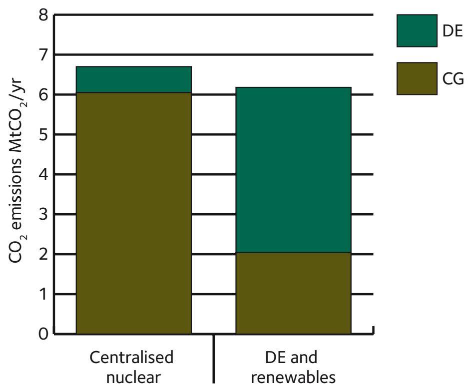

Figure 2. CO_2 emissions in 2024 – baseline scenarios (see section 3.2)

1.2 ADDITIONAL FINDINGS

Finding 1: Decentralising the electricity supply system offers a cheaper and more effective way to reduce CO_2 emissions than nuclear power

An energy future that combines DE generation with a 40% share of renewables (centralised and decentralised), such as wind, wave and tidal power, promises to be more cost-effective in reducing electricity sector CO_2 emissions in Scotland than a centralised system in which retiring nuclear capacity starts to be replaced. The CO_2 emissions in the DE scenario are 6.18 $MtCO_2$/yr, 8% lower than in the centralised scenario. A decentralised scenario in which half of Scotland's electricity demand in 2024 is met through renewable sources would reduce CO_2 emissions even further to 5.47 $MtCO_2$/yr, and would still be cheaper than the centralised baseline.

Finding 2: DE systems reduce gas consumption and dependency on imported gas

The amount of gas needed to meet future electricity demand is 8% lower in a decentralised scenario than in a centralised scenario when we compare the baseline centralised nuclear scenario with the baseline decentralised and renewable energy scenario, as defined in section 3.2. DE gas use is more efficient than centralised gas plants, delivering more energy overall from less fuel because both heat and electricity are used. This lower gas consumption will slow the depletion of Scottish reserves thereby reducing the potential dependency on imports in the future.

Finding 3: DE and renewables buffer the impact of possible fossil fuel price rises on electricity costs for consumers

Fuel prices are a major factor in determining the delivered cost benefit of DE, but even in a high fuel price scenario DE would remain cheaper than the centralised alternative until the end of 2024. A DE system could therefore help address fuel-poverty in Scotland.

Finding 4: DE could help cushion investment costs for the required electricity network upgrades and additions in Scotland

Projections by the International Energy Agency indicate that more than half of the total electricity sector investment over the next 25 years is expected to be in networks[1]. Uncertainties about the necessary upgrades and investment required would influence the capital costs and delivered electricity costs in Scotland but, even so, in all scenarios analysed, the costs for a decentralised system are lower than those for a centralised system.

Finding 5: Demand growth trends are highly significant in determining future costs and CO_2 emissions

Slowing the demand growth will reduce the amount of electricity needing to be generated to meet Scotland's demand. This reduced demand then translates into cost savings both in terms of spend on infrastructure and in terms of retail cost to the consumer. Halting demand growth in Scotland will also cut CO_2 emissions considerably.

1.3 EXPLANATION OF THE FINDINGS

The reasons for the superior outcomes promised by DE compared with CG are threefold.

Firstly, generating electricity near the point of use reduces the extent and capacity of network required and avoids network losses, thereby reducing the T&D costs associated with centralised power plants. This is particularly important in the light of findings from the International Energy Agency that most new investment in the electricity sector over the next 25 years will be in T&D facilities. Network investment is particularly important in Scotland because there is great potential for renewable energy generation in the North West of the country. However, any power generated here would need to be transmitted to satisfy the demand of those in geographically distant locations in the Central Belt and further south. The T&D network in Scotland can integrate 4.8 GW of additional renewables without any additional investment[2] (meeting about 30% of total electricity demand); but achieving the 40% renewable energy target set by the Scottish Executive, as well as allowing export to England, will require substantial investment in the network. Furthermore, as in the rest of the UK, the T&D network in Scotland is ageing and will need replacing within the next 10 to 20 years. Generating electricity close to the point of use reduces the loads carried by transmission networks, so that fewer upgrades and additions are required.

Secondly, the fuel efficiency of DE is generally higher than that of CG, because localised generation allows for the use of both the heat and the electricity outputs of the process. The potential for using the heat output of electricity generation with CHP in Scotland is considerable – Scotland uses 14.3% of the UK's heat demand but has only 8.5% of its population. Altogether, DE requires less generation capacity and uses less fuel to meet the same level of energy demand.

Thirdly, DE requires less redundancy (back-up capacity) than CG because, unlike a system consisting of a few large power plants, a system of many small generators is less vulnerable to the outage of a single generator. As a result, the required back-up capacity safety margins for DE capacity are smaller than those for CG. The WADE Model takes this into account, and estimates less additional back-up generation and T&D capacity for DE than for CG.

2. THE WADE ECONOMIC MODEL

The purpose of the WADE Economic Model is to calculate the economic and environmental impacts of meeting incremental electricity demand growth with varying mixes of centralised generation (CG) and decentralised energy (DE). With changed input assumptions, the Model can be adapted to any country, region or city in the world. Starting with generating capacity for the current or a recent year, together with estimates of plant retirement rates and demand growth, the Model estimates the capacity growth required to meet assumed demand increases, using a specified mix of capacity types over a 20-year period.

The Model's data inputs are detailed and extensive, requiring comprehensive information on a range of factors including:

- existing generating capacity and power output by technology type;
- pollutant emissions by technology type;
- heat production, fuel consumption and load factor[3] by technology type;
- capital and investment costs of generating capacity and T&D by technology type;
- operation and maintenance (O&M) and fuel costs by technology type;
- overall and peak demand growth for the system;
- estimates of future capacity retirement by technology type in five-year steps; and
- estimates of future proportion of capacity installed by technology type in five-year steps.

Annexes to the report can be found at www.greenpeace.org.uk/climate/wadescotland/annexes. The completed input sheet for the Scotland baseline scenarios set out in section 3.2 can be found in Annex A, with the sources for the inputs in Annex B. Annex C contains the assumptions used for each generation portfolio that were run for the purposes of this study.

The Model's outputs are:

- total capital costs (covering investment in generation capacity and T&D) over 20 years;
- retail cost (T&D amortisation + generation plant amortisation + O&M + fuel costs) in year 20 of electricity supplied by new generating plant;
- CO_2 emissions in year 20 from existing (that is, prior to year 1) and new generating plant;
- fuel consumption according to fuel type in year 20 by existing and new generating plant; and
- generation from new capacity in year 20 by generation type.

The Model projects new generation and T&D capacity needed to meet incremental demand over 20 years, covering scenarios ranging from 0% DE and 100% CG to 100% DE and 0% CG. The Model also enables users to run any number of scenarios: for example, scenarios that favour certain technologies, involve changes in fuel prices or aim to meet specific environmental goals. A number of such scenarios were created for the application of the Model to Scotland, as described in this report.

The Model takes into account many real but little-understood features of electricity system operation – such as the significant impact of peak-time network losses on the amount of CG required to meet new demand. For example, assuming peak T&D losses of 15%, new demand of 1 MW could be met only by adding 1.18 MW of new CG.

For a full explanation of the WADE Economic Model, please consult the description available online at www.localpower.org.

To date, in addition to the UK, the WADE Economic Model has been run for:

- Brazil
- the European Union (funded by the EU DG-FER programme)
- Ireland (funded by the Irish Government)
- Ontario (funded by the Canadian Federal Government)
- the City of Calgary (funded by the Canadian Federal Government)
- Thailand (funded by the EU COGEN-3 programme)
- Australia
- the USA
- China (funded by the UK Foreign and Commonwealth Office)
- Sri Lanka (funded by the EC Small Projects Facility)
- the world

Of these, the main Model outputs for China, the European Union, Ontario, the UK, Sri Lanka and the world are publicly available. Results for the USA are also publicly available, along with a paper explaining their derivation and significance. For more information on these results or the WADE Economic Model, please contact WADE.

3. MODELLING SCENARIOS USED FOR APPLICATION OF THE WADE ECONOMIC MODEL TO SCOTLAND

3.1 INTRODUCTION

This section describes the scenarios that have been used to compare the impacts of adding new generation capacity in Scotland either through DE or through CG, in terms of costs, CO_2 emissions, and fuel use and dependency. The Annexes give a more detailed overview of the assumptions made and show the exact inputs used in the different scenarios. Annexes to the report can be found at www.greenpeace.org.uk/climate/wadescotland/annexes.

The following points apply to all scenarios used.

- Analysis covered a 20-year period, with 2004 as the base year – the last year for which full datasets were available.
- 2004 installed capacity and generation inputs were based on DTI data and the Scottish Energy Study.
- DEFRA CO_2 emission factors were used.
- Cost inputs were checked against DTI data and other independent sources. If contradictory data were found, the sensitivity of the results to different figures was analysed, and the inputs were chosen so as not to favour DE.
- Fuel price increases were set at 0.5–3% per year (the rate of growth depending on the fuel; coal price rises at 0.5% per year being lower than gas price rises at 3% per year) compounded over the whole 20 years, except in the fuel price sensitivity scenarios where these assumed rates are varied.
- Retirement of existing capacity was based on the Scottish Energy Study.
- System properties and energy losses were based on reasonable and generally accepted averages.
- All scenarios meet the Scottish Executive's target of generating 40% of electricity from renewable resources by 2020.
- The centralised nuclear baseline scenario and the CG case of each sensitivity scenario represent 100% investment in new centralised energy capacity. The DE and renewables baseline scenario and the DE case of each sensitivity scenario represents a split in future investment of 65% in decentralised energy sources, and 35% in centralised energy sources, all of the latter being renewable.[4] The exact mix of energy sources assumed to form the new generation plant in the CG and DE cases differs throughout the scenarios.
- CO_2 emission costs from the EU Emissions Trading Scheme were not included.
- Costs of decommissioning and management of nuclear waste were not included.
- The export of electricity from Scotland to England is assumed to increase to 9,750 GWh/yr by 2024, representing 18% of total generation[5].
- Transmission network investment costs for CG are £250 to £400 per kW added capacity, based on data from the DTI Transmission Issues Working Group. DE technologies are assumed to have no transmission requirements, because they are connected directly to the distribution network.
- Distribution network investment costs for CG and DE are £350 per kW added capacity, based on International Energy Agency projections for distribution network investment relative to transmission network investment.

3.2 BASELINE SCENARIOS

The analysis compared two alternative 20-year electricity generation baseline scenarios: the centralised generation (CG) baseline scenario and the decentralised energy (DE) baseline scenario. The input assumptions and parameters for these are shown in Table 1. All inputs and sources used are available in Annexes A and B.

3.3 THE GREENPEACE SCENARIO

Scotland's potential for renewable electricity generation is among the highest in Europe. This gives Scotland the opportunity to take a leading role in developing renewable sources and establishing a clean energy system. This is recognised by the Scottish Executive, which has set itself the target of supplying 40% of Scotland's electricity from renewables by 2020. This target is expected to be achieved, and most experts agree that it would be possible to meet 54% of electricity demand from renewables in 2020, particularly using onshore and offshore wind, wave and tidal energy[6]. This 54% target reflects anticipated build and is limited by policy, regulation and market barriers, rather than technical potential.

The Greenpeace scenario represents a different approach to meeting future electricity needs, while reducing CO_2 emissions drastically. It is a scenario that demands 50% renewables and was developed both to reflect Scotland's large potential for renewable energy and to show a radical reduction of carbon emissions compared with that in the baseline DE/renewables case.

The Greenpeace scenario uses the following inputs:

- demand growth: 0.8%;
- share of DE: CG case: 100% CG; DE case: 55% of new generation capacity decentralised, with 45% from centralised renewables;
- new generation capacity: 45% centralised renewables, mostly onshore wind, wave and tidal, as well as biomass and offshore wind energy. The decentralised generation mix includes more renewable biomass CHP and on-site wind power than the DE/Renewables baseline, and less gas-CHP and gas micro-CHP;
- final share of renewables generation: 50%; and
- final installed CHP capacity: 0.41 GWe (CG case) to 3.82 GWe (DE case).

Table 1. Overview of the centralised nuclear and DE/renewables scenarios

Scenario	Centralised nuclear	DE/renewables
Demand growth	Total load: 0.8%, Peak load: 0.8%	Total load: 0.8%, Peak load: 0.8%
New generation capacity: transmission/distribution modality	100% CG	65% DE, 35% CG
New generation capacity: generation technology mix	Initially mostly gas-fired combined cycle gas turbine (CCGT), with a substantial amount of onshore wind power. One new nuclear power station is to be built by 2024 to replace Hunterston B. Offshore wind and wave energy are introduced rapidly after 2010 to help meet Scotland's 40% renewable target.	The 65% DE share is initially mostly gas CHP, but other technologies, including micro-CHP, biomass CHP and on-site wind, are gradually introduced, to replace gas CHP. CG technologies are all renewable, starting with onshore wind and then increasing shares of wave and offshore wind energy.
Final renewable share of generation	40% (currently 13%)	42% (currently 13%)
Final installed CHP capacity[7]	0.41 GWe (currently 0.77 GWe)	5.07 GWe (currently 0.77 GWe)

3.4 SENSITIVITY ANALYSIS

Various departures from the baseline scenarios were considered to take into account the uncertainty of future projections. This helped to explore the impact on the outputs of varying several key starting assumptions. In particular, the sensitivity of the results to fuel price trends was analysed, as well as the effects of different levels of network investment and changes in electricity demand growth. This led to the following five sensitivity scenarios:

- a low fuel price scenario;
- a high fuel price scenario;
- a T&D investment sensitivity scenario;
- a high demand growth scenario; and
- a zero demand growth scenario.

3.4.1 FUEL PRICE SENSITIVITY SCENARIOS

Fossil-fuel prices have been rising since 2003 and this trend is expected to continue, giving rise to levels of uncertainty regarding fuel prices. The CG and DE baseline scenarios already take this into account by assuming annual compounded fuel price increases ranging from 0.5% to 3% per year. Currently, the Scottish electricity system generates more than half of its electricity in centralised gas- and coal-fired power plants (19% and 32% of total electricity generation, respectively). And, as much of the existing capacity will remain in operation over the next 20 years, it is worth exploring the impacts of different fossil-fuel price trends.

Two fossil-fuel price scenarios were analysed:

- *Low fuel price scenario*: price trends are half those of the baseline scenario for both the CG and the DE cases. In this scenario, annual fuel price increases range from 0.25% to 1.5% over the 20 years.
- *High fuel price scenario*: price trends are double those of the baseline scenario for both the CG and the DE cases. In this scenario, annual fuel price increases range from 1% to 6% over the 20 years.

3.4.2 T&D INVESTMENT SENSITIVITY SCENARIO

T&D network capacity constraints and upgrades are an important issue to consider in Scotland's future electricity supply. Network issues are threefold.

- Firstly, developing Scotland's large potential for renewable sources, such as wind and wave energy, will require the creation of transmission capacity to deliver the electricity to where it is needed. Current estimates indicate that renewable capacity generating up to 30% of Scotland's demand can be integrated into the existing network, mostly onshore wind, biomass and small hydropower in the Central Belt and South West of Scotland. This threshold is expected to be reached in 2010. Beyond that, upgrades and investment in the grid would be required to connect large onshore and offshore wind schemes in the North and West of the country.
- Secondly, enabling Scotland to export the electricity generated from its renewable sources to England will require investment to upgrade and expand the interconnector across the border. As thermal plants in Scotland are closed and more renewable generation becomes operational, the electricity flow across the border is expected to become more dynamic, requiring a more flexible connection.
- Thirdly, the electricity network is ageing. Most of its capacity was built in the 1960s and 1970s, since when there has been long-term underinvestment. Consequently, much of the existing infrastructure needs replacing within the next 10 to 20 years.

Globally over half of electricity sector investment is expected to be in T&D networks[8]. In Scotland, substantial investment is needed, too, to meet future demand and realise the country's potential for renewables. Network operators and electricity companies would be responsible for any investment in networks and so high investment costs would be reflected in higher electricity prices, which would affect consumers directly. The exact scale of investment needed depends on the amount, type and location of new generation capacity developed, so the exact cost implications are yet unclear.

The T&D investment sensitivity analysis aimed to assess the impact of the extent and timing of network upgrades and additions over the next 20 years. Two different sensitivity scenarios were developed: one looking at the network costs per unit additional capacity and one using the same unit cost, but delaying network investment until 2012 (see Table 2).

3.4.3 DEMAND GROWTH SENSITIVITIES SCENARIOS

Electricity demand in Scotland is projected to grow by 0.8% per year, but there is some uncertainty in these projections. Recent DTI data show that demand has been growing more rapidly since 2002[9], while at the same time there are calls to reduce demand growth to curb CO_2 emissions. Two demand growth sensitivity scenarios were therefore developed:

- *Zero demand growth scenario*: annual average demand growth and peak demand growth of 0% over a 20-year period.
- *High demand growth scenario*: annual average demand growth and peak demand growth of 1.6% over a 20-year period.

Table 2. T&D Investment scenarios

Scenario	Transmission capacity costs (£/kW)	Distribution capacity costs (£/kW)	Period of investment
Baseline	250–400	350	2005–24
T&D costs x 1.5	375–600	525	2005–24
Delayed investment	250–400	350	2012–24

WADE, 2007.

- *T&D costs x 1.5*: this scenario aims to evaluate uncertainties in costs for alleviating local grid constraints and replacing ageing capacity.
- *Delayed investment*: this scenario aims to reflect the capacity to integrate 4.8 GWe from renewable generation into the existing network until 2010, after which investment for network expansion would be required to make sure that electricity can be delivered safely and reliably to users.

4. MAIN FINDINGS FROM APPLICATION OF THE WADE ECONOMIC MODEL TO SCOTLAND

This section discusses the outputs of the WADE Economic Model for the different scenarios described above. It presents and compares the data for capital costs, retail cost, CO_2 emissions and fuel use. Annex D shows the complete results[10].

It should be borne in mind that the Model compares scenarios that consider the impacts of the way in which new generation capacity is developed – on either a centralised or a decentralised model. In all scenarios, some existing generating plants remain in operation in 20 years' time, emphasising the long timeframe of infrastructure change.

4.1 EXAMINATION OF BASELINE SCENARIOS

Main finding: DE can meet Scotland's future electricity demand at lower cost than traditional CG

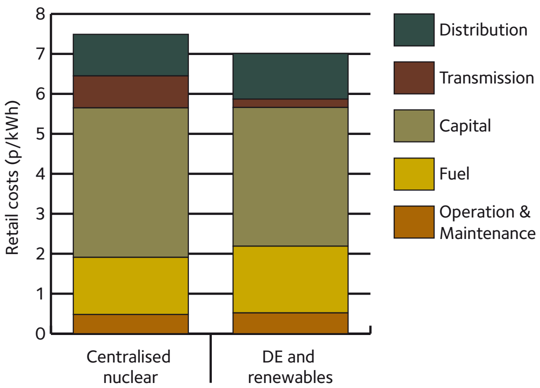

Figure 3: Retail costs in 2024 – baseline scenarios (see section 3.2)

Figure 3 shows that the cost of electricity to consumers is lower in the DE baseline scenario than in the CG scenario. The cost advantage of DE reflects the lower level of T&D investment along with a higher overall fuel efficiency. The DE scenario is more fuel efficient as it generates energy near the point of use, so not only requires a less extensive T&D network but also cuts energy losses from the network.

The electricity cost reductions that DE could deliver are particularly important in Scotland, because many people face fuel-poverty[11] as a result of the cold climate and recent increases in fossil-fuel prices.

The cost outputs for the centralised nuclear and the DE/renewables scenarios are given in Table 3. It shows that the capital costs of the two are similar, while the DE/renewables scenario has a lower retail cost compared with the centralised nuclear scenario, as mentioned above.

Figure 3 shows that the distribution network costs for the DE scenario are higher than those for the CG scenario, but the DE transmission costs are considerably lower. The reason for this difference is that DE requires less transmission infrastructure than CG. DE generators are usually connected directly to the local distribution network, rather than to the transmission network, like centralised power plants. By delivering electricity locally, rather than transmitting it over long distances through the national grid, DE reduces transmission investment costs in three ways.

Table 3. Cost outputs for 2005–24 – baseline scenarios (see section 3.2)

	Centralised nuclear	DE renewables	DE savings	% change
Total capital costs, 2004–24 (capacity + T&D) (£bn)	17.8	15.9	1.8	10%
2024 retail costs (p/kWh)	7.48	7.02	0.46	6%

- Firstly, new DE capacity connected to the distribution network does not require any expansion in the transmission capacity to deliver electricity to consumers; although additional distribution capacity may be required. New centralised plants require expansion of both the transmission network and the distribution network to supply electricity to users.
- Secondly, much existing T&D capacity will need replacing within 10 to 20 years. In a centralised generation system both the transmission and the distribution networks would need upgrading, while in a decentralised system some of the transmission upgrades could be avoided by meeting demand locally.
- Thirdly, flow patterns of electricity in Scotland are expected to change considerably with the shutdown of large nuclear and coal-fired plants and the increasing share of renewable energies. This means that the power loads on different parts of the transmission system will be different from those for which they were originally designed. In distribution networks, on the other hand, the power load required is mostly determined by the local demand, so that changes are likely to be much smaller. Delivering electricity directly to distribution networks through DE is therefore likely to reduce the number of necessary upgrades in the transmission network.

The differences between CG and DE explain the lower transmission investment costs for DE. However, the DE scenario still requires some investment in transmission (see Figure 3), because:

- new transmission capacity will be needed to deliver the electricity from renewable sources in the North and West of Scotland to consumers elsewhere in the country; and
- an upgrade of the interconnector to England will be necessary to allow Scotland to participate in the UK electricity market and deal with increasingly dynamic power flows across the border.

Additional finding 1: Decentralising the electricity supply system offers a cheaper and more effective way to reduce CO_2 emissions than nuclear power

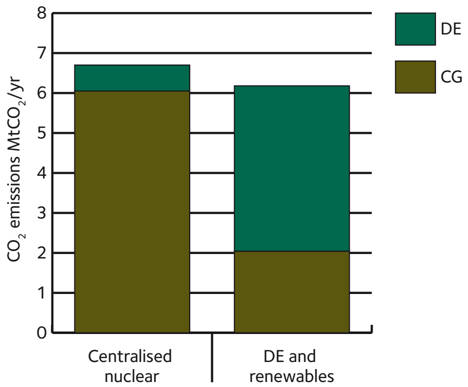

Figure 4. CO_2 emissions in 2024 – baseline scenarios (see section 3.2)

As can be seen in Figure 4, decentralising electricity generation clearly reduces CO_2 emissions. A combination of DE and renewables can reduce Scotland's CO_2 emissions from power generation by 8% more, and at a lower cost, than a centralised system in which nuclear power plants are replaced. Even though the CG scenario (which also meets the Scottish Executive's renewable energy target of 40% of total generation by 2020) cuts CO_2 emissions by 10 $MtCO_2$/yr compared with 2004, the DE scenario delivers an extra 0.52 $MtCO_2$/yr saving by 2024.

As mentioned already, DE reduces CO_2 emissions because it uses primary energy more efficiently than CG, by utilising the heat output of the generation process and avoiding transmission losses. Consequently, less fossil fuel needs to be burned to meet the same energy demand.

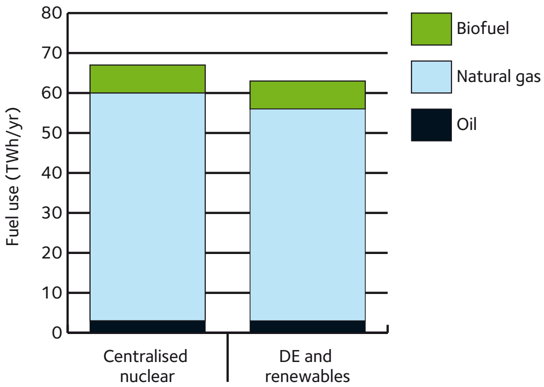

Figure 5: Total fuel use in 2024 by fuel type – baseline scenarios (see section 3.2)

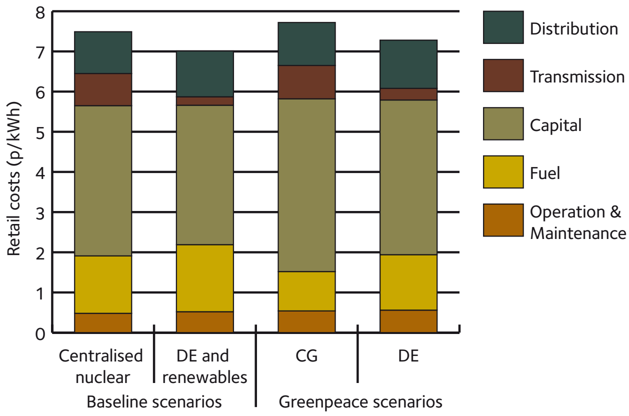

Figure 6: Retail costs in 2024 – baseline and Greenpeace scenarios

Additional finding 2: DE systems reduce gas consumption and dependency on imported gas

In addition to reducing CO_2 emissions at a lower retail cost, the DE/renewables scenario also reduces fuel consumption, as Figure 5 shows. The higher fuel efficiency of DE generation compared with CG also results in a reduction of the total natural gas use for meeting electricity demand in Scotland. Natural gas use in the DE baseline scenario is 8% lower than in the CG baseline case, while total fuel use is 7% lower. The reduced consumption of the DE/renewables scenario, in turn, would reduce dependency of gas imports.

4.2 THE GREENPEACE SCENARIO

The following section presents the results of the Greenpeace scenario in which half of all electricity generation in Scotland in 2024 is from renewable sources. This scenario offers a powerful way of reducing the environmental impacts of future electricity use. The results show that there is the potential for yet more cost-effective CO_2 emission reductions, compared with the centralised nuclear scenario.

Figure 6 presents the retail costs and Table 4 the cost outputs, including capital costs. Even though the retail costs of meeting half of Scotland's electricity generation by DE/renewables in 2024 is 0.27 p/kWh higher than for the DE baselines scenario (see Figure 6), it is still 0.19 p/kWh lower than the CG baseline case, which also meets the current 40% target.

Within the Greenpeace scenario, DE is considerably cheaper than CG, particularly in terms of capital costs. Furthermore, retail costs of the DE scenario are almost 6% lower, compared with a centralised scenario.

The Greenpeace scenario confirms that there is ample potential for cost-effective renewable energy generation in Scotland beyond the current 40% target of the Scottish Executive, especially when combined with decentralised energy generation.

Table 4. Cost outputs for the Greenpeace scenario and baseline scenarios for 2005–24

	Baseline scenarios		Greenpeace scenarios	
	CG	DE	CG	DE
Capital costs (capacity + T&D) (£bn)	17.8	15.9	19.7	17.7
Retail costs (p/kWh)	7.48	7.02	7.72	7.29

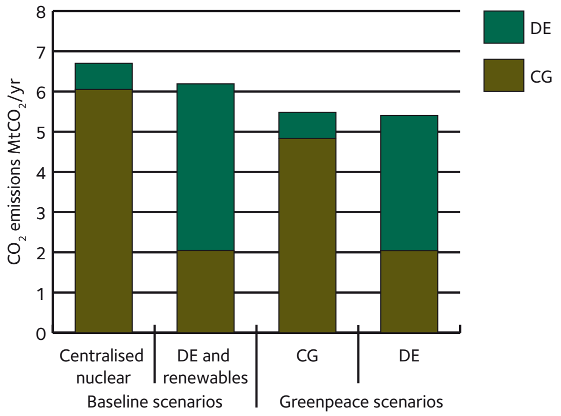

Figure 7: CO_2 emissions in 2024 – baseline and Greenpeace scenarios

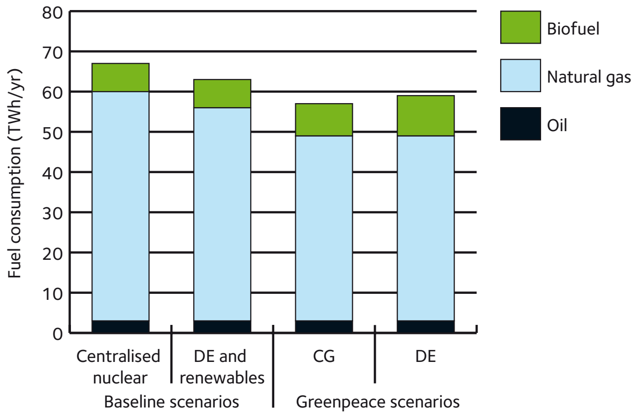

Figure 8: Total fuel use in 2024 by fuel type – baseline and Greenpeace scenarios

Figure 7 shows the CO_2 emission benefits of the Greenpeace scenario. The graph shows that the Greenpeace scenario reduces CO_2 emissions considerably compared with the baseline scenarios. Power industry CO_2 emissions are 13% lower when comparing the DE case with the DE baseline and 19% lower compared with the CG baseline. Within the Greenpeace scenarios, emissions are 70,000 tonnes CO_2 a year lower in the DE case than in the CG case.

Figure 8 shows that the Greenpeace scenario also cuts fuel consumption, and thereby reduces reliance on foreign imports of fossil fuels, including natural gas. Natural gas use for the Greenpeace DE case is 11.5 TWh/yr lower than in the centralised nuclear baseline scenario – a reduction of 20%. The natural gas consumption in both the Greenpeace scenarios is exactly the same.

4.3 SENSITIVITY MODELLING

This section explores the effect of several parameters on the cost, emissions and fuel consumption advantages of DE. Factors considered are:

- the impacts of changes in fuel prices on retail cost;
- the effects of T&D network investment requirements on capital and delivered energy costs; and
- the implications of demand growth for costs and CO_2 emissions.

4.3.1 THE IMPACT OF FUEL PRICES ON THE COSTS OF MEETING DEMAND TO 2024

Additional finding 3: DE and renewables buffer the impact of possible fossil-fuel price rises on electricity costs for consumers

The sensitivity analysis on fuel costs showed that the retail electricity costs of both the CG and the DE baseline scenarios were affected by fossil-fuel price rises, but the decentralised alternative was cheaper in all scenarios evaluated. The effect of fossil-fuel price trends on electricity costs in Scotland is expected to be small compared with the UK as a whole: tripling fuel prices, for example, over 20 years instead of doubling them in the baseline scenarios would lead only to a 7% rise (0.51 p/kWh) delivered electricity price. Since 2003 domestic consumers in the UK have seen the average annual electricity bill rise by 30% so a 7% increase over 20 years is relatively small.

The reason for the small effect of fossil-fuel prices on electricity prices in this analysis is the result of the high level of renewable electricity generation in Scotland. With a target of 40% of electricity being generated from renewable sources by 2020, the contribution of fossil-fired generation in Scotland is likely to decrease so that fossil-fuel prices become less significant in determining electricity prices. High levels of renewable sources of energy can be seen as ‘insurance’ against fuel price rises.

4.3.2 THE IMPACTS OF T&D NETWORK INVESTMENT COSTS

Additional finding 4: DE could help cushion the investment costs for necessary electricity network upgrades and additions in Scotland

The impact of changes in T&D investment costs is larger for CG than for DE generation in all scenarios modelled, because DE requires less network capacity to deliver energy to consumers and is, therefore, less affected by cost uncertainties. Consequently, DE can help cushion the effects of the substantial network investment required in Scotland over the next 20 years.

This study evaluated the impact of varying both the amount and the timing of T&D network investment in Scotland and Table 5 details the results.

- In the scenario in which the network investment is increased by 50% (T&D costs x 1.5), there is an 18% rise in total capital costs for a centralised system and a 15% increase for a DE system, compared with the baseline scenarios. Even though there are rises in retail electricity costs – of 0.70 p/kWh in the CG case and 0.67 p/kWh in the DE case – the total electricity costs in the DE case are still lower than those of the centralised nuclear baseline.
- Delaying investment in T&D safety margin capacity until 2012, so that any excess capacity is reduced as new generators connect to the network, would reduce the total capital costs for a centralised system by 2.25%. Both capital investment costs and retail costs would still be greater for the CG scenario than in the DE baseline (Table 5). Delaying network investment may seem an attractive option in Scotland because 30% of planned renewable capacity can be integrated into the existing network. However, such an approach ignores the need for replacing ageing infrastructure, planned expansion of the interconnector to England and the value of promoting exploitation of those highly renewable resources further from the Central Belt.

Network investments in Scotland are paid for by network operating companies, which recover their costs from network users through network charging. Ofgem, the national regulator, regulates these prices so that they reflect the required investment for network upgrades and additions. Electricity companies, using the network, incorporate network charges in the electricity prices for consumers, to help to recoup their costs. The National Grid Company operates the GB-wide transmission network, while distribution networks are operated on a local basis. Consequently, the costs of transmission networks in Scotland are currently spread over all GB network users and customers, whereas distribution investment is generally paid for only by the local users. So, although transmission and distribution investment affect Scottish electricity prices they do so in different ways.

Table 5. The impact of amount and timing of T&D investment on capital and retail cost outputs

Scenario	Capital investment costs		CO_2 emissions	
	Capital costs (£bn)	Retail costs (p/kWh)	Capital costs (£bn)	Retail costs (p/kWh)
Baseline	17.8	7.70	15.9	7.02
T&D costs x 1.5	21.0	8.40	18.3	7.69
Delayed investment	17.4	7.38	15.7	6.94

Table 6. The impact of annual demand growth on capital costs and CO_2 emissions from 2004 to 2024 – baseline scenarios

Scenario	Capital investment costs		CO_2 emissions	
	CG	DE	CG	DE
Constant electricity demand (zero growth)	-16%	-18%	-12%	-11%
1.6% annual demand growth	+19%	+20%	+14%	+12%

4.3.3 THE IMPACT OF DEMAND GROWTH ON COSTS AND CO_2 EMISSIONS FROM ELECTRICITY GENERATION

Additional finding 5: Demand growth trends are highly significant in determining future costs and CO_2 emissions

Changes in the future annual electricity demand growth in Scotland will have a strong effect on the costs and CO_2 emissions from electricity generation (see Table 6). These results emphasise the importance of energy-efficiency measures and demand-side management to reduce Scotland's CO_2 emissions.

5. CONCLUSIONS

5.1 MAIN CONCLUSION

Conclusion 1: Decentralised energy is more cost-effective in reducing Scotland's CO_2 emissions than centralised generation including a nuclear component and reduces reliance on fossil fuels

Lower T&D requirements and higher generation efficiency are the reasons for the benefits of DE, since it leads to reduced energy losses as well as cutting total infrastructure costs.

5.2 ADDITIONAL CONCLUSIONS

Conclusion 2: Decentralising the energy system could reduce Scotland's CO_2 emissions from electricity generation by 8% more than a centralised scenario with new nuclear generation by 2024

Changing to a scenario where 65% of all new generation capacity is decentralised would reduce Scotland's CO_2 emissions by an additional 0.52 $MtCO_2$/yr compared with a scenario where all new capacity was centralised and one of the retiring nuclear power plants would be replaced. Both scenarios meet the Scottish Executive's target of 40% renewable electricity generation by the year 2020.

Conclusion 3: A scenario where 65% of new generation capacity is decentralised lowers the retail cost of electricity by 6% compared with a scenario where all new capacity is centralised and a retiring nuclear power plant would be replaced by 2024

The retail electricity costs of the DE baseline scenario is 0.46 p/kWh lower than that of the baseline centralised nuclear scenario. DE could thereby help address fuel-poverty in Scotland.

Conclusion 4: DE reduces reliance on fossil fuels

Fossil fuel consumption was lower for the DE case in all scenarios analysed except for the Greenpeace scenario where the difference was negligible. For natural gas consumption, the DE scenario delivers lower consumption under all circumstances except the Greenpeace scenarios where gas consumption for both DE and CG is the same. A DE system has a high overall efficiency as it generates more energy from the same amount of natural gas consumed. This efficiency advantage means that dependency on foreign gas imports is generally lower in the DE scenario.

Conclusion 5: Meeting half of Scotland's electricity demand in 2024 through renewables in a decentralised, high-renewable energy system could reduce CO_2 emissions by 19% more than the centralised baseline scenario

Scotland could reduce CO_2 emissions from electricity generation by an additional 1.3 $MtCO_2$/yr in a decentralised high-renewable scenario, relative to the centralised baseline. This option is also more cost-effective than a purely centralised high-renewable scenario, lowering retail electricity costs by 6%.

Conclusions 6: The most effective way to reduce costs and CO_2 emissions of electricity generation in Scotland is by reducing or preventing demand growth

Demand growth trends were the most important factor analysed in determining the costs and CO_2 emissions of electricity generation over the next 20 years. Fuel prices and T&D investment requirements also affected the cost results of the modelling. In all sensitivity scenarios considered, DE proved cheaper and more cost-effective than centralised generation.

ENDNOTES

1 International Energy Agency, World Energy Outlook, 2006.

2 Forum for Renewable Energy Development in Scotland (FREDS), Scotland's Renewable Energy Potential: Realising the 2020 Target, 2005.

3 The load factor describes the ratio (expressed as a percentage) of the net amount of energy generated by a power plant compared to the net amount, which it could have generated if it were constantly operating at its full rated output capacity.

4 A scenario in which all new generation capacity built was decentralised, would have even larger cost benefits than the 65%/35% scenario.

5 Scottish Renewables, Delivering the New Generation of Energy, 2006.

6 Scottish Renewable Forum, Delivering the New Generation of Energy, 2006.

7 Capacity of CHP falls in the centralised nuclear scenario because of retirement of existing plant over the 20-year period.

8 International Energy Agency, World Energy Outlook, 2006.

9 DTI, Regional Energy Consumption Statistics, http://www.dti.gov.uk/energy/statistics/regional/index.html

10 See www.greenpeace.org.uk/climate/wadescotland/annexes

11 Fuel poverty in Scotland fell during the period 1996-2002, but rose again from 2003 to 2004, due to higher fuel prices (Energy Action Scotland, 2006).

Greenpeace's clean energy campaign is committed to halting climate change caused by burning oil, coal and gas. We champion a clean energy future in which the quality of life of all peoples is improved through the environmentally responsible and socially just provision of heating, light and transport.

We promote scientific and technical innovations that advance the goals of renewable energy, clean fuel and energy efficiency.

We investigate and expose the corporate powers and governments that stand in the way of international action to halt global warming and who drive continued dependence on dirty, dangerous sources of energy, including nuclear power.

GREENPEACE

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