Nuclear Energy Not CO_2-Free

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Nuclear energy is often presented as a solution for the greenhouse effect. The emissions of carbon (CO_2) would drastically decrease by using nuclear power plants. There are two arguments opposing this view. Firstly, in the current Dutch situation the reduction of CO_2–emissions will be much less as often claimed, if compared with a highly efficient combined heat and power (CHP) plant. This power station almost halves the decrease in CO_2–emissions gained by nuclear energy. And, secondly, nuclear energy it selves contributes to the greenhouse effect. Due to these two factors, the CO_2 gain by nuclear energy decreases even further and will reach zero in the long run.

Although nuclear power is often heralded as carbon-free and a beneficial replacement for coal-fired power plants, realisation of a new nuclear base load power plant may change the CO2 profile of power generation capacity in the Netherlands in a more sophisticated manner. In particular, a new nuclear power plant may directly compete with highly efficient combined heat and power (CHP) plants, which would significantly reduce the emission reduction often ascribed to nuclear power. In a new research report by CE Delft, an independent research and consultancy organisation, it is stated[1]: "In particular, a new nuclear power plant may directly compete with highly efficient combined heat and power (CHP) plants, which would significantly reduce the emission reduction often ascribed to nuclear power."
A CHP plant requires natural gas to generate electricity but produces by doing so heat.[2] A nuclear power station only generates electricity, the residual heat is not utilized but ends up in the cooling-water. Suppose that the same amount of electricity from the CHP plant is generated by a nuclear power plant. To produce a same amount of energy (heat), the nuclear power station would need an additional gas-fuelled high-efficiency industrial boiler, which also produces CO_2. De CO_2 from the nuclear power plant plus boiler is less than that of the CHP, but CE Delft calculates that the net CO_2- reduction of the nuclear power plant is approximately 56% of the emissions of the CHP plant[3]. This CHP power station therefore almost halves the CO_2 reduction of the nuclear power station.
But there is more: it is likely that a new nuclear reactor in the Netherlands will compete with CHP. Peak demand, is met by flexible (typically gas-fired) plants that have high fuel costs but low fixed costs. Assuming base load demand is met by the cheapest set of base load plants, any new plant that has lower production costs than existing ones has the potential to push the most expensive plant off the base load market. In the Dutch power market the most expensive base load plant is likely to be a CHP plant, with which a new nuclear power plant may compete directly. This means it will replace the relatively environmental friendly CHP plant and not the least environmental friendly: coal powered stations.

However, even this is not the full story. Nuclear energy in it selves also contributes to the greenhouse effect. This has to do with CO_2 that is released during the mining and processing of uranium ore, constructing, operating, maintaining and refurbishing of the nuclear power plant, waste management, dismantling of the reactor and construction of a geological repository to isolate the waste. Each process consumes fossil energy, consequently each process, except the production of electricity in the reactor itself, emits CO_2: this is called the indirect CO_2-emission of nuclear energy.

The mining and processing of uranium ore contributes most to the indirect CO_2-emission. At this moment the richer uranium ores, with an average of 0.1 per cent uranium, are mined; meaning that one kilogram of uranium is extracted from 1000 kilograms of rock. The CO_2 gain of the nuclear power station compared to a CHP plant, decreases even further by this indirect CO_2 emission. In the situation described here, the CO2 gain of a nuclear power plant compared to a CHP plant decreases from 56% to approximately 50%.[4]
There is however a limited amount of richer uranium ore. When, because of for instance the greenhouse effect, more nuclear power stations are built, one would has been forced within 10 to 15 years to mine ores with lower grades of uranium. Then much more rock has to be excavated and processed for the same amount of uranium. Because of that CO_2 emission will increase. At an ore grade of 0.02 percent the CO_2 gain of a nuclear power plant is about 38% in comparison with the CO_2 emissions of a CHP plant[5]. At ores of a lower grade than 0.0086 percent, the nuclear power plant is responsible for more CO_2 emissions than when the same amount of electricity would be produced by burning natural gas in the CHP plant and the CO_2 gain is zero.[6] [7] [8] [9] [10] [11]

Table 1:

Ore grade	***CO_2 emissions [g/kWh]***
2 %	14
0.1%	26
0.02 %	82
0.001%	210

Threshold grade 0.0086 % in scenario
Source: "Energy Balance of nuclear power generation", Oekologie Institute, November 2011, available at: http://www.ecology.at/files/berichte/E22.595.pdf

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[1] http://assets.wnf.nl/downloads/report_nuclearenergy_wnf_nov2011.pdf, Mart Bles, Maarten Afman, Jos Benner, "Nuclear energy: The difference between costs and prices", CE Delft, November 19, 2011.

[2] 13% of the generating capacity in the Nederlands are CHP-plants; source: http://www.tennet.org/images/0403-35%20KCD%20man.samenvatting_100714def_tcm41-19221.pdf, p 5.

[3] "Suppose, for example, a hypothetical CHP plant requiring 200 PJ natural gas (11.2 Mton CO_2) to generate 57 PJ electricity and 101 PJ heat (the remainder is counted as a loss). If the electricity were generated by a 2,000 MW nuclear power plant, the heat otherwise delivered by the CHP plant would now require a high-efficiency industrial boiler, burning 122 PJ of natural gas (6.3 Mton CO_2). Hence, the net effect of the nuclear power plant in terms of CO_2 emissions is a reduction of 4.9 Mton, considerably less than if a coal-fired power plant were replaced by the nuclear power plant (approximately 12.8 Mton savings). Hence, the net CO_2 reduction of the nuclear power plant is approximately 56% of the emissions of the CHP plant."; CE Delft, page 96..

[4] http://www.ecology.at/lca_nuklearindustrie.htm, http://www.ecology.at/files/berichte/E22.595.pdf, November 2011.

[5] http://www.ecology.at/lca_nuklearindustrie.htm, http://www.ecology.at/files/berichte/E22.595.pdf, November 2011.

[6] Jan Willem Storm van Leeuwen, "Energy from Uranium", Oxford Research Group, July 2006, http://www.oxfordresearchgroup.org.uk/publications/briefing_papers/energy_security_and_uranium_reserves_secure_energy_factsheet_4.; http://www.stormsmith.nl/report20050803/Chap_2.pdf.

[7] http://www.peopleplanetprofit.be/beelden/oko-institut.pdf, March 2007.

[8] Tabel: total (direct and indirect) CO_2-emission (gram/kWh)

Fuel	emission
Natural gas	448
Coal	924

Sources: Ir. Wouter Biesiot, "Kernenergie: Een Beoordeling van de Risico's van Nieuw te Bouwen en Bestaande Installaties", published by Interfacultaire Vakgroep Energie en Milieukunde van de Rijksuniversiteit Groningen, March 1992. "Energy Balance of nuclear power generation", Oekologie Institute, November 2011, available at: http://www.ecology.at/files/berichte/E22.595.pdf

[9] Mudd, G M & Diesendorf, M, 2008, Sustainability of Uranium Mining : Towards Quantifying Resources and Eco-Efficiency. Environmental Science & Technology, 42 (7), pp 2624-2630, april 2008; data from uraniummining in S-Africa en Australia give 47 to 260 gram CO_2 per kWh. .

[10] Benjamin K. Sovacool Benjamin Sovakool from the National University of Singapore has published a paper on the CO_2 emissions of nuclear power. He assessed 103 lifecycle studies of the nuclear fuel cycle. When one selects only the most methodologically rigorous studies, typical lifecycle emissions from nuclear plants appear to be about 66 gCO_2/kWh: http://www.nirs.org/climate/background/sovacool_nuclear_ghg.pdf.

[11] "Energy Balance of nuclear power generation", Oekologie Institute, November 2011, available at: http://www.ecology.at/files/berichte/E22.595.pdf