HOW MUCH CAN NUCLEAR ENERGY DO ABOUT GLOBAL WARMING ?

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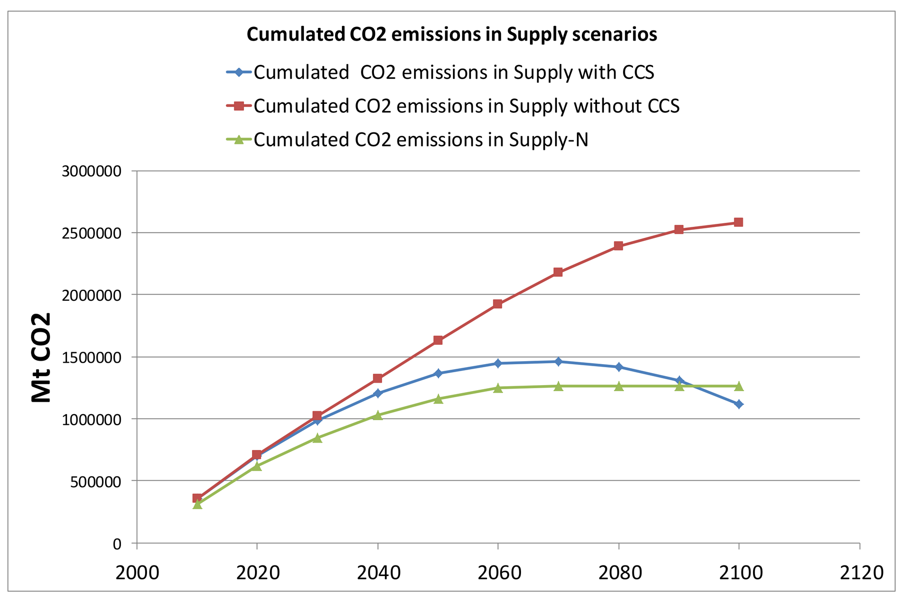
Association « Sauvons le Climat » (Save the Climate) Further details:
http://www.sauvonsleclimat.org/images/articles/pdf_files/climat-energie/Enforced%20nuclear-GEA.pdf

CARBON CAPTURE IN IPCC SCENARIOS

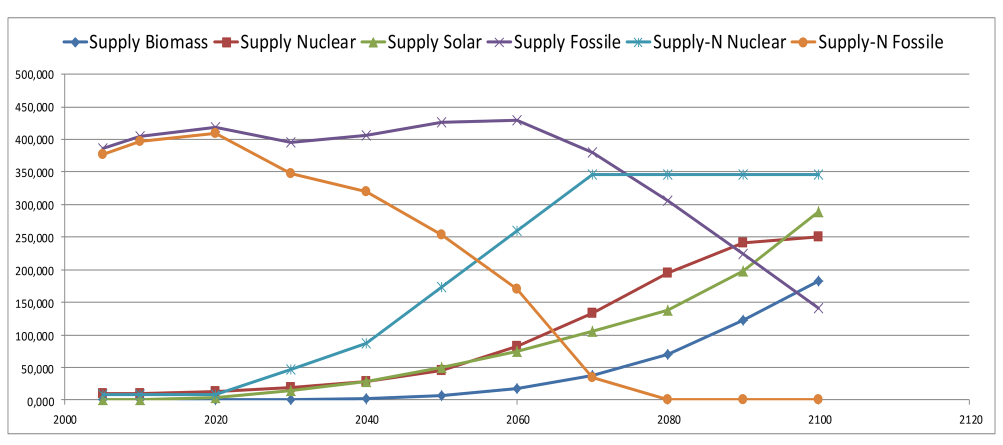
The reference IPCC scenarios consistent with a global mean surface temperature increase below 2 degrees (RCP 2.6) above pre-industrial level rely on massive capture and storage of Carbon dioxide (CCS), up to 50 billion tons per year toward the end of the century, while present knowledge of this process is limited to a few experiments at the million tons level. Since such objective may seem optimistic, it is wise to examine the consequences of a failure to develop CCS at the required level.
The present work explores the possibility to limit global warming without CCS or drastic decrease of energy consumption. It proposes to start the strong development of nuclear energy as soon as 2020 rather than 2060 as in the case of the MESSAGE "Supply" scenario. This corresponds to our Supply-N scenario.

CO_2 EMISSIONS



This figure shows that the early development of nuclear energy allows an emission trajectory compatible with RCP 2.6 without resorting to CCS

ENERGY MIX



Comparison of main components of the energy mix for the MESSAGE Supply and Supply-N scenarios. The biomass and solar contributions are the same for the Supply and Supply-N scenarios. Nuclear energy contributes approximately 50% of the Total Energy Supply for the Supply-N scenario and 30% for the Supply scenario

Plutonium breeding

Typical Plutonium core inventory is 4 tons/Gwe
However, at present, another 4 tons are present in the processing cycle. This leads to a total inventory of FBR of 8 tons/Gwe. It is too high to allow the required FBR construction rate. Using the Integrated Fast Reactor technique, the inventory might be reduced to 5,5 tons/Gwe. If such a significant decrease of the plutonium total inventory of FBR appears not feasible, an alternative would be to include more CANDUs in the slow neutrons reactors fleet. The proportion of CANDUs in the nuclear fleet depends on the performances of the fuel reprocessing of PWR or CANDU. With 4 years reprocessing times (from fuel extraction to fuel reinsertion) the proportion of CANDUs should reach 50%. For reprocessing time of 1.5 year CANDUs are not required. The Table summarizes the equivalence between reprocessing times and CANDUs' proportion..

Total Pu inventory.GWe tons	5,5	6	7	8
Proportion of CANDUs in the thermal fleet %	50	37	14	0

FOSSIL vs NUCLEAR

These figures compare the electricity production by nuclear (top) and fossil fuel (bottom) for the "Supply" and "Supply-N" scenarios.

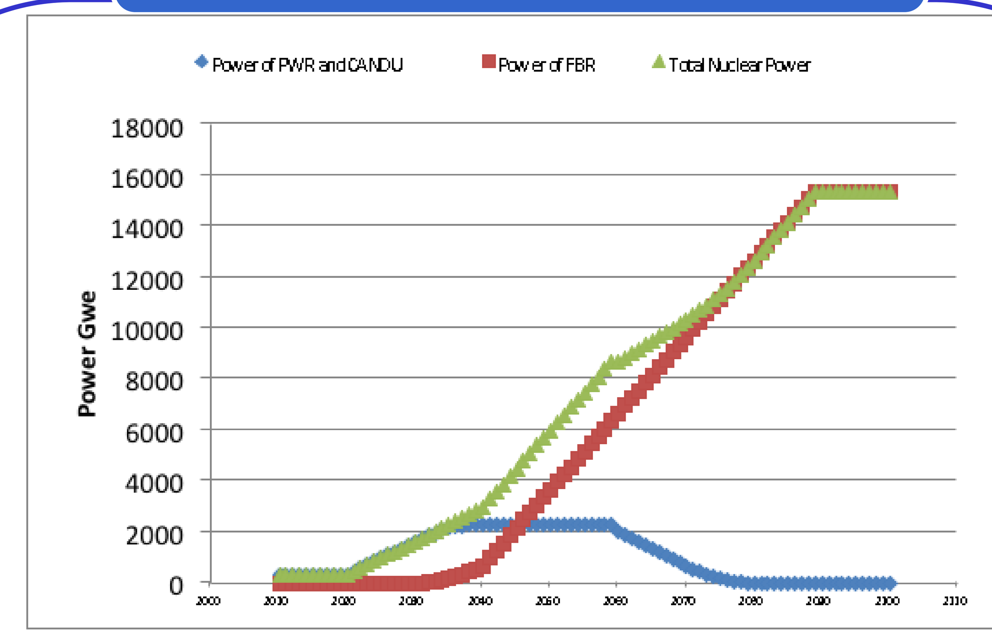
NUCLEAR RISKS

In the mind of many who remember Chernobyl and Fukushima, nuclear energy is the most deadly of all. However cold minded estimations such as those carried out in the frame of the ExternE program of the UE do not support such beliefs. Table 3 which was established by Forbes shows that it is one of the less, if not the less deadly technique for producing electricity. Indeed, coal, which is the primary method to generate electricity currently, has many detrimental impacts on air pollution and health

Technique	Number of deaths per 1000 TWh
Coal (world)	170000
Coal (China)	280000
Coal (US)	15000
Oil	36000
Natural gas	4000
Biomass	24000
Solar PV	440
Wind	150
Hydroelectricity	1400
Nuclear	90

Table 3: Number of deaths for 1000 TWh final energy production for different techniques. For nuclear energy casualties related to Chernobyl and Fukushima are included. Data from Forbes

NUCLEAR DEVELOPMENT



The scenario Supply-N assumes a nuclear production of 100 000 TWh in 2100 corresponding to a nuclear power around 16 000 GWe. PWR reactors require 120 tons of Natural Uranium per GWe annually. Annual Uranium consumption would then be about 1.4 million tons. The Nuclear Energy Agency gives an estimate for "classical" reserves around 16 million tons. Thus, Fast Breeder Reactors (FBR) are needed. In 2100 the Plutonium inventory would amount to 65 000 tons. Building 16 000 GWe breeding power in 50 years implies a building rate of 320 Gwe/yr, requiring, annually, between 1 800 and 2 500 tons of plutonium, depending on the amount of plutonium in the cycle. PWR and FBR produce annually 0,25 and CANDU 6 tons of Plutonium per GW. The figure above shows how such a development of nuclear energy might take place. Thermal reactors (PWR and CANDU) start the program both for energy production and building up the plutonium inventory necessary for the FBR.

NUCLEAR WASTES

One might think that, multiplying nuclear power by 30 would multiply the volume of nuclear wastes accordingly. Fortunately, it is not so. Indeed, the reprocessing extracts uranium and plutonium isotopes from the used fuels, and reduces the waste volume by two orders of magnitude. Besides, if, as proven possible, minor actinides are also extracted the radiotoxicity of the wastes after 100 years will also be divided by almost 100. Therefore, the needs for waste disposal for 20000 fast breeder reactors might be less than for the present 500 thermal reactors.

COSTS

Costs of new reactors vary very much from 7200 $/kW for the EPR being built at Olkiluoto to 4000 $/kW for Watts Bar 2 to 2800 $/kW for Hongshane 4 (CPR 1000). China foresees 2000 $/kW which might decrease to 1600 $/kW.
For FBR reactors we estimate an investment cost of 4000$/kW. Table 4 gives an estimate of electricity costs for various techniques

Techniques	OCDE (US$ / MWh)	China (US$ /MWh)
Nuclear	50-82	30-36
Coal with CCS	85	(54)
Coal without CCS	54	34
Wind on shore	90-146	51-86
Wind off shore	138-188	?
Photovoltaic	287-410	123-186

Table 4: Levelized costs of electricity for OECD countries and China. For FBR reactors our estimate is 80 $/MWh (ref:OECD).

CONCLUSIONS

An accelerated development of nuclear electricity production as soon as 2020 would significantly reduce the constraints to stabilize the world temperature below the 2° target. The unproven CO_2 CCS technique might prove unnecessary. The constraints on the development of expensive and intermittent renewable electricity techniques might also be lessened.
Relying on breeding with improved reprocessing techniques and (or) increasing the contribution of CANDU reactors permits a nuclear power of 16 000 GWe before 2100. Nuclear production would then generate close to 60% of the final energy consumption, to be complemented by renewable energies. The risks associated to climate change and fossil use are much larger than those from the nuclear electricity production.