
KIVI
Engineering Society
Understanding the costs of New Nuclear Power, the Large Light-Water Reactor and the Small Modular Reactor
Mario van der Borst, October 23th, 2020
Understanding the costs of nuclear power 23OCT2020
Koninklijk Instituut Van Ingenieurs

Some newspaper headings

Nuclear plant nears completion after huge delays (Financial Times 2017)

Areva, the French reactor manufacturer, began building Olkiluoto in 2005 with a target for completion by 2009 at a cost of €3.2bn. The latest timetable would see it open almost a decade late at the end of 2018 and nearly three times over budget at €8.5bn.

France's Areva to pay $554 million to settle Finnish reactor dispute (Reuters 2018)

France's Areva SA settled a long-running dispute with Finland's Teollisuuden Voima (TVO) by agreeing to pay 450 million euros ($554 million) for cost overruns and delays at a nuclear reactor it is building with Germany's Siemens.

Progress Nuclear New Build Projects

Project2010	Type	Rated power MWe	First concrete	Original COD	Scheduled COD	Reported
OL3 Finland	EPR-1	1600	12/8/2005	2009	2/2022	28/8/2020
Flamanville 3	EPR-1	1630	4/12/2007	2012	2024	2/4/2020
Vogtle 3 USA	AP1000	1117	12/3/2013	2017	11/2021	11/9/2020
Vogtle 4 USA	AP1000	1117	19/11/2013	2018	11/2022	11/9/2020
VC Summer 2	AP1000	1117	9/3/2013	2017	Cancelled 2017	31/12/2017
VC Summer 3	AP1000	1117	4/11/2013	2018	Cancelled 2017	31/12/2017
Hinkley Point C1	EPR-1	1750	11/12/2018	2023	2025	2/6/2020
Hinkley Point C2	EPR-1	1750	12/12/2019	2024	2026	2/6/2020
Barakah 1 UAE	APR1400	1345	19/7/2012	2017	19/8/2020	Grid conn.
Barakah 2 UAE	APR1400	1345	16/4/2013	2018	2020	19/3/2019
Barakah 3 UAE	APR1400	1345	24/9/2014	2019	2020	19/3/2019
Barakah 4 UAE	APR1400	1345	30/7/2015	2020	2021	19/3/2019
Taishan 1	EPR-1	1750	10/2009	2015	2018	1/11/2019
Taishan 2	EPR-1	1750	2010	2016	2019	1/11/2019

In the near future will new nuclear stay this expensive?

- Lessons are shared and learned. The FOAK risks will decrease.
- Reactor designs are more complex as in the old days and new codes & standards are expensive to be applied.
- Now designs and codes & standards are rationalised, reducing the overnight capital costs.
- SMR's are under development, to enhance safety and reduce investment risks

In this paper we assume a NOAK status for the nuclear plants and a moderate rate of cost decrease for the VRE plamts.

About the capacity factor

Capacity Factor

- The net capacity factor is the unitless ratio of an **actual electrical energy output** over a given period of time to the maximum (name plate) possible electrical energy output over that period. (CF)
- Power may be or not be delivered.
- Also Load factor (beschikbaar)

→ Powerplant Organisation

Utilisation Rate

- The ratio **delivered power over a certain period**, divided by the available power over that period. (UR)
- The delivered of the power is dependent on grid/market conditions.
- Also Curtailment Rate

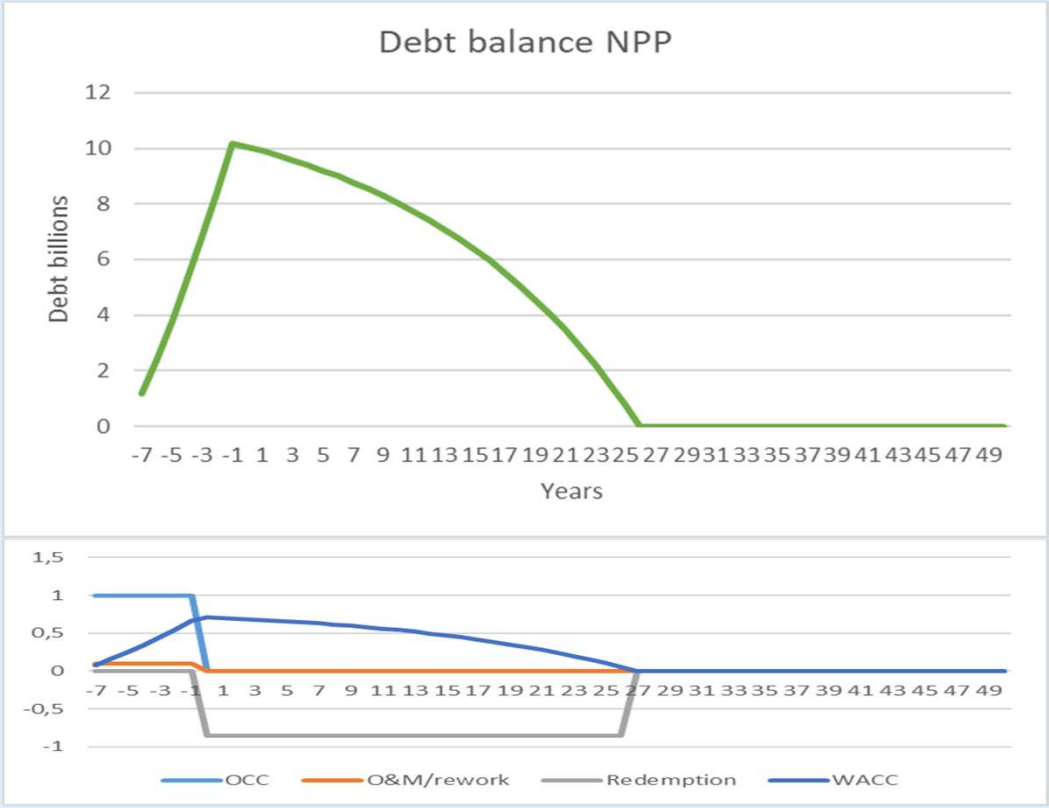
→ Grid Market

Total Capacity Factor

- The Total Capacity Factor is the unitless ratio of an actual deducted electrical energy output over a given period of time to the maximum (name plate) possible electrical energy output over that period.
- TCF=CF * UR

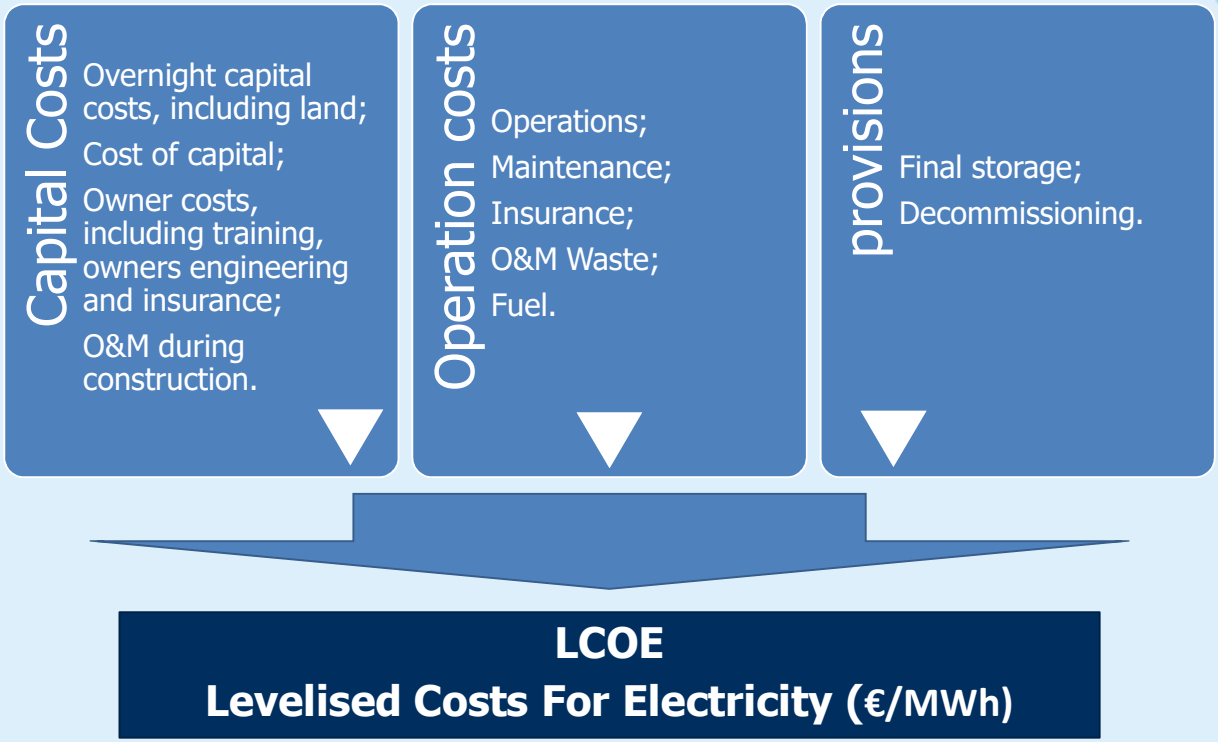
→ Total

The debt balance over the years



OCC: 7 Billion
WACC: 7%
Rework: 10%
Redemption period: 25y

Breakdown of the costs; understanding of the words



LCOE Levelised Costs For Electricity (€/MWh)

LCOE: measure of the overall competitiveness of different generating technologies. (Net present value method)

$$LCOE = \frac{\sum \frac{(I_t + M_t + F_t)}{(1 + r)^t}}{\sum \frac{E_t}{(1 + r)^t}}$$

$$LCOE = \frac{\text{NPV of Total Costs Over Lifetime}}{\text{NPV of Electrical Energy Produced Over Lifetime}}$$

INCLUDES:
- Overnight capital costs
- Financing costs
- Insurances, taxes
- Fuel costs
- Fixed operation & maintenance (O&M)
- Variable O&M (dependent on MWh's)
- Decommissioning
- Waste management
- Predicted capacity factor (incl. utilisation)
- WACC (interest rate)

NOT INCLUDED:
- System costs (Grid, market, grid-balance)
- External costs (Social, Environmental)

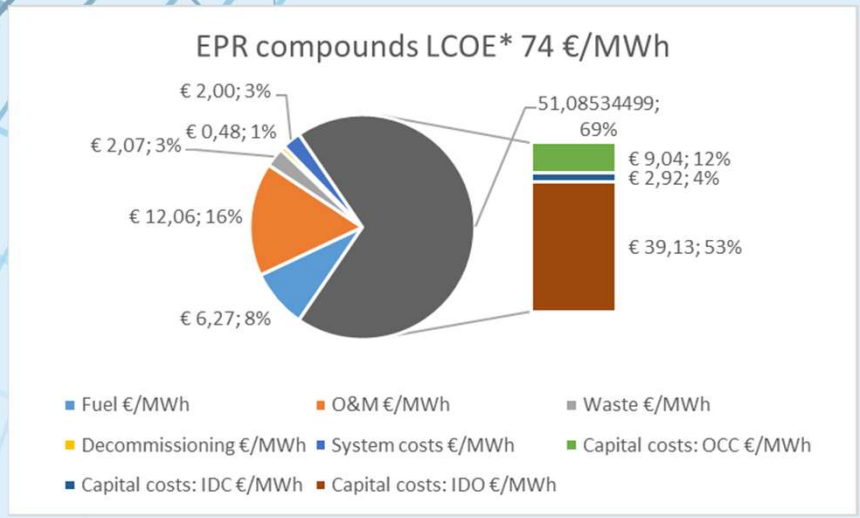
LCOE*: Adjusted LCOE
Definition introduced by IEA (2015)

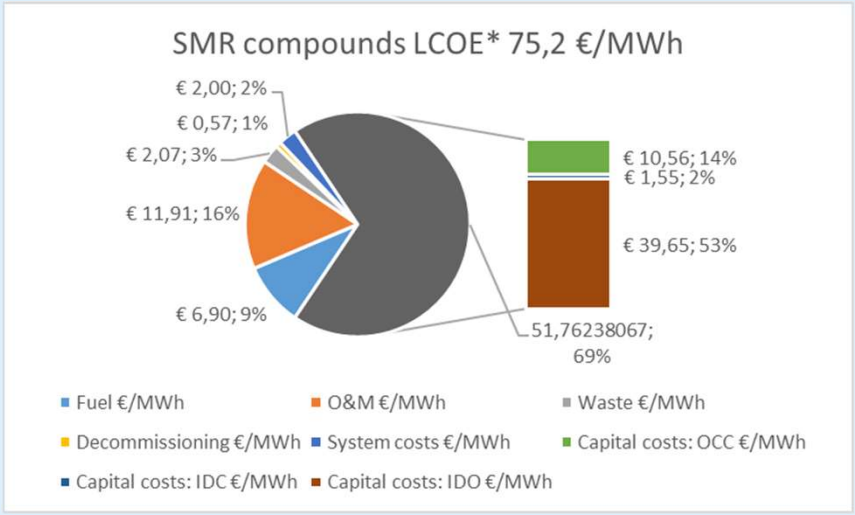
Does include system costs!

Data input used

EPR	SMR	Solar/wind
•IEA •NEA •SFEN •WNA	•NuScale •EFWG •Rolls Royce •NEA	•Alg. Rekenkamer •Frauenhofer •Irena

Nuclear LCOE* for the year 2040





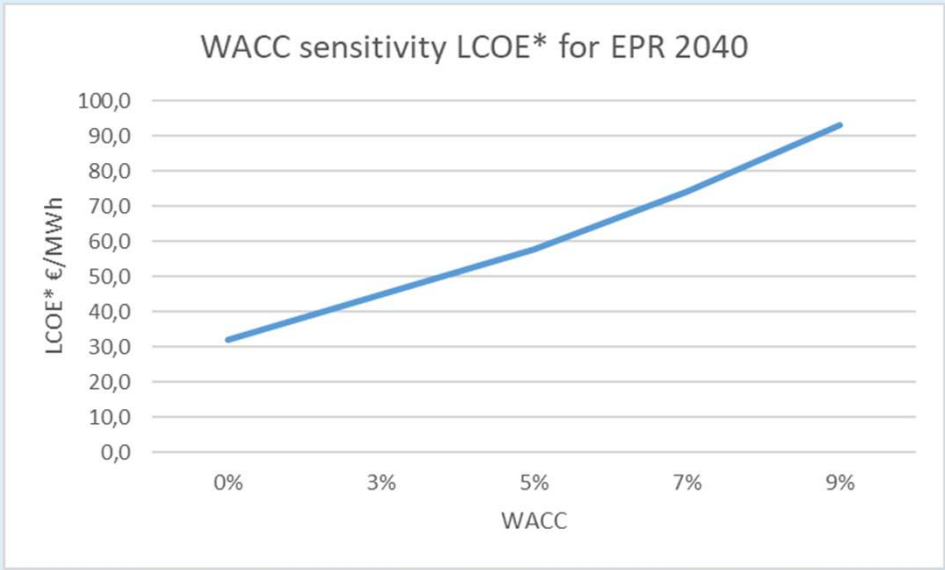
OCC: 7,335 Billion
WACC: 7%
Power: 1630 MWe
Life Time: 60y

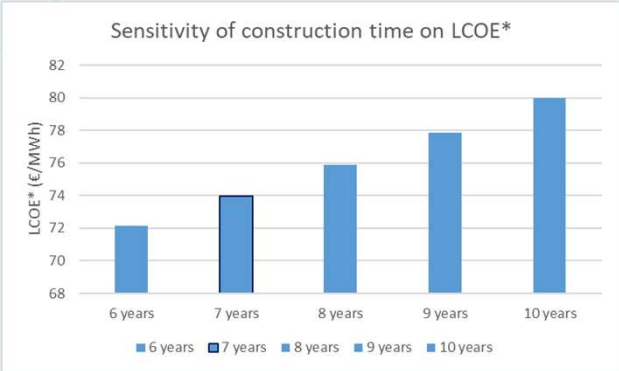
NOAK

At 100% utilisation

OCC: 1,000 Billion
WACC: 7%
Power: 200 MWe
Life Time: 60y

Most important LEVER for costs is WACC, because cost increases by delays is WACC too.





How to support the first nuclear new build projects?

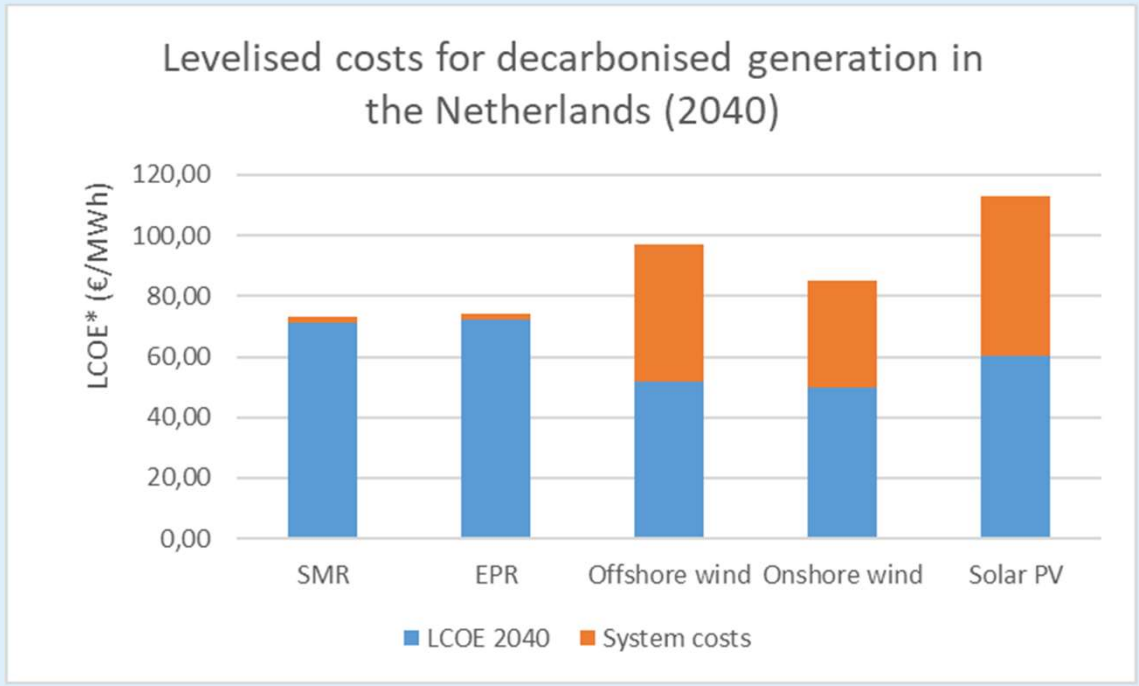
1st nuclear projects require financing support

- Governmental risksharing, resulting in a lower WACC,
- Contract for difference
- Delivery of a cheap state loan
- Utilisation guarantee

No subsidies Offshore Wind?

- Government is paying for siting and licensing
- No fee calculated for the lease of the lot
- Offshore grid connection paid by government
- Guaranteed fee for the delivered power

Comparison LCOE* of different CO2-free electricity generation types for the year 2040



Nuclear

- Lifetime 60Y
- WACC 7%

VRE

- Lifetime 25Y
- WACC 4,3%

Grounds for the major uncertainties in future LCOE* assessments

Nuclear plants

- Time needed to resolve FOAK problems
- Lack of investors, leading to higher WACC

VRE plants

- Can the trend of cost reduction be maintained
- Sparse land. Cost of land-use likely to rise
- Deeper sea locations

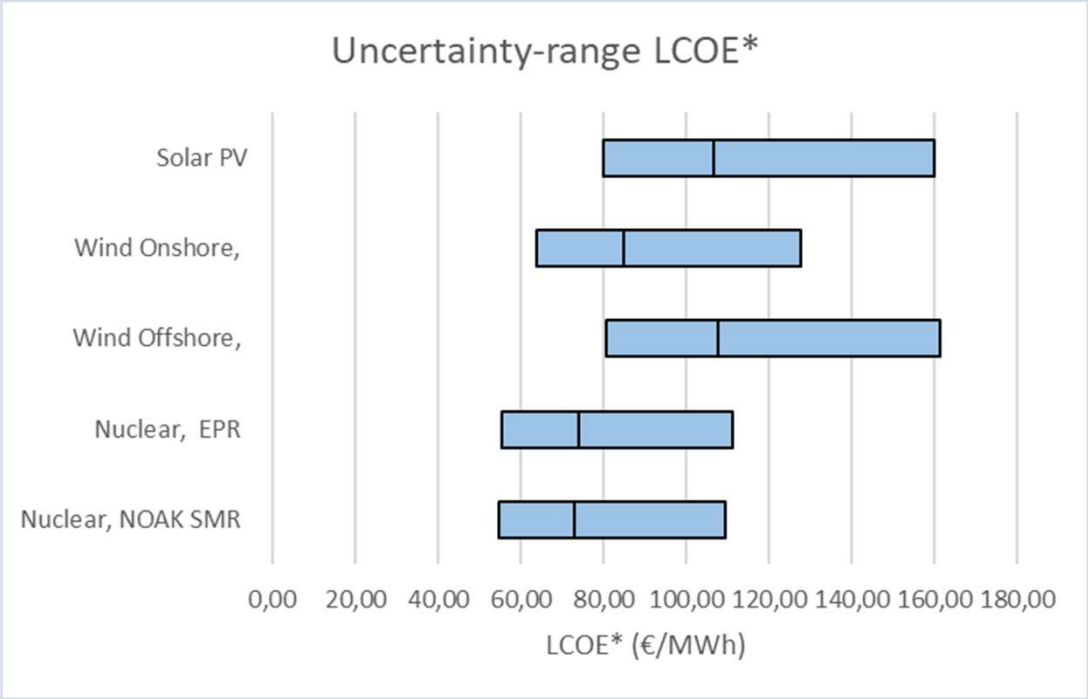
System costs

- The costs to create a stable grid, without access to hydro-power is costly.
- The possible cost reduction developments of battery and hydrogen (hydrolysis, storage, generation) are very difficult to predict

Utilisation

- In a reliable grid system, sufficient curtailment is required, resulting in lower utilisation factors (UF).
- A Merit Order model, to predict the future UF for the different generation types cannot work when most of the generators are of the zero marginal cost type.

Uncertainty ranges of the same LCOE* assessment



Conclusion

- Corrected for system costs, nuclear can more than compete with VRE's, and could be successfully deployed to maintain a stable and reliable grid.
- The future costs of nuclear energy are relatively uncertain, but the same can be said about renewable energy. Nuclear can complement renewable sources, because it is dispatchable.
- New nuclear power plants would be best economically deployed while operating between 75 and 95% capacity in a base load mode, making the rest of the capacity available to support medium and long term grid needs and to produce green hydrogen.
- Increasing difficulties in financing the construction of large GEN III reactors, coupled with the need for more low-carbon dispatchable generation, is driving policy and investor interest in SMRs. This type of nuclear reactor could be more easily financed, because of it's modular design and smaller construction times.
- The first NNB projects will require financing support in terms of guarantees, as those available to the VRE's.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