“Discounted Carbon Flow” analysis of Nuclear Fission versus Wind Turbine electricity production

vs.

A comparative example to illustrate the analysis technique

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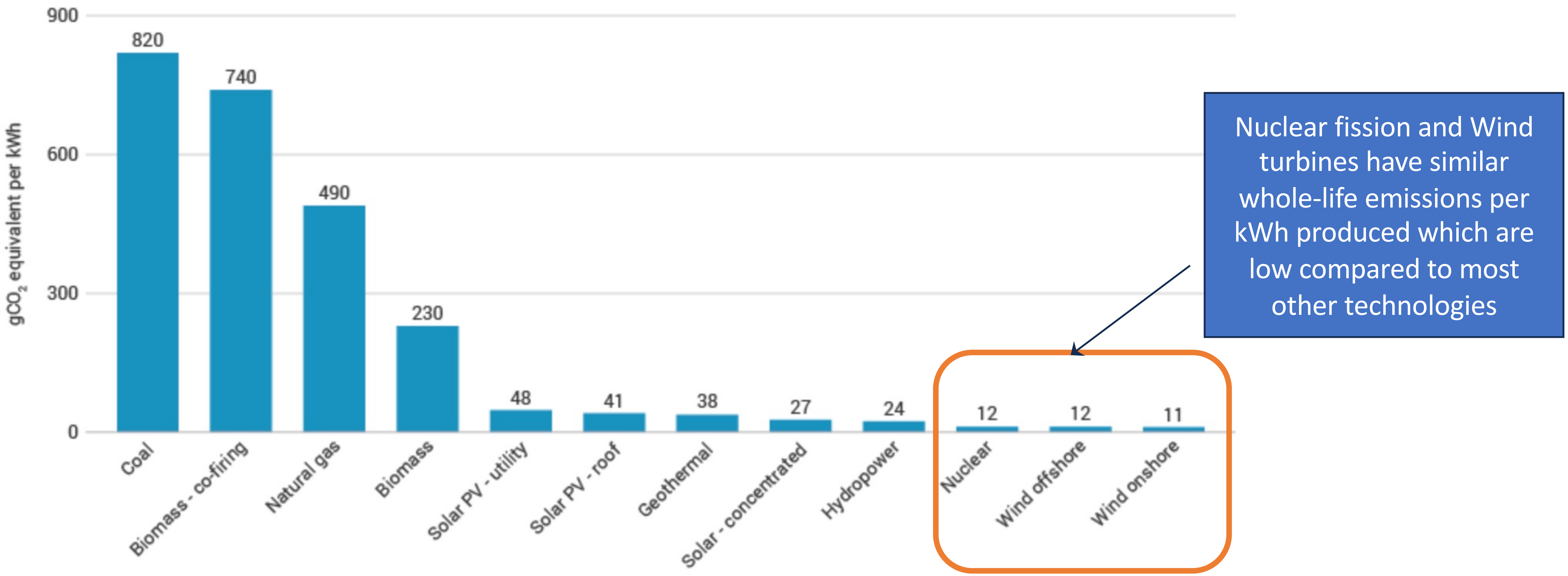
Introduction

- The intention of this document is to illustrate a “**Discounted Carbon Flow**” technique for comparing sustainable investments, by seeking to look from an environmental impact perspective.
- The examples compared are **Nuclear** fission and **Wind** turbine based electrical power production – which are claimed to have similar whole-life emissions per kWh of energy produced.
- This analysis is not intended to ”put down” nuclear technology (as this is in any case preferable to the alternative of fossil fuel-based production).
- The analysis is based on “**Discounted Cash Flow**” techniques that are already routinely applied in financial investment analysis and widely understood in the Project Management community.
- Focus is on the Paris Agreement target of NetZero Greenhouse Gas (GHG) emissions by 2050 - hence the analysis considers benefits up to 2050.

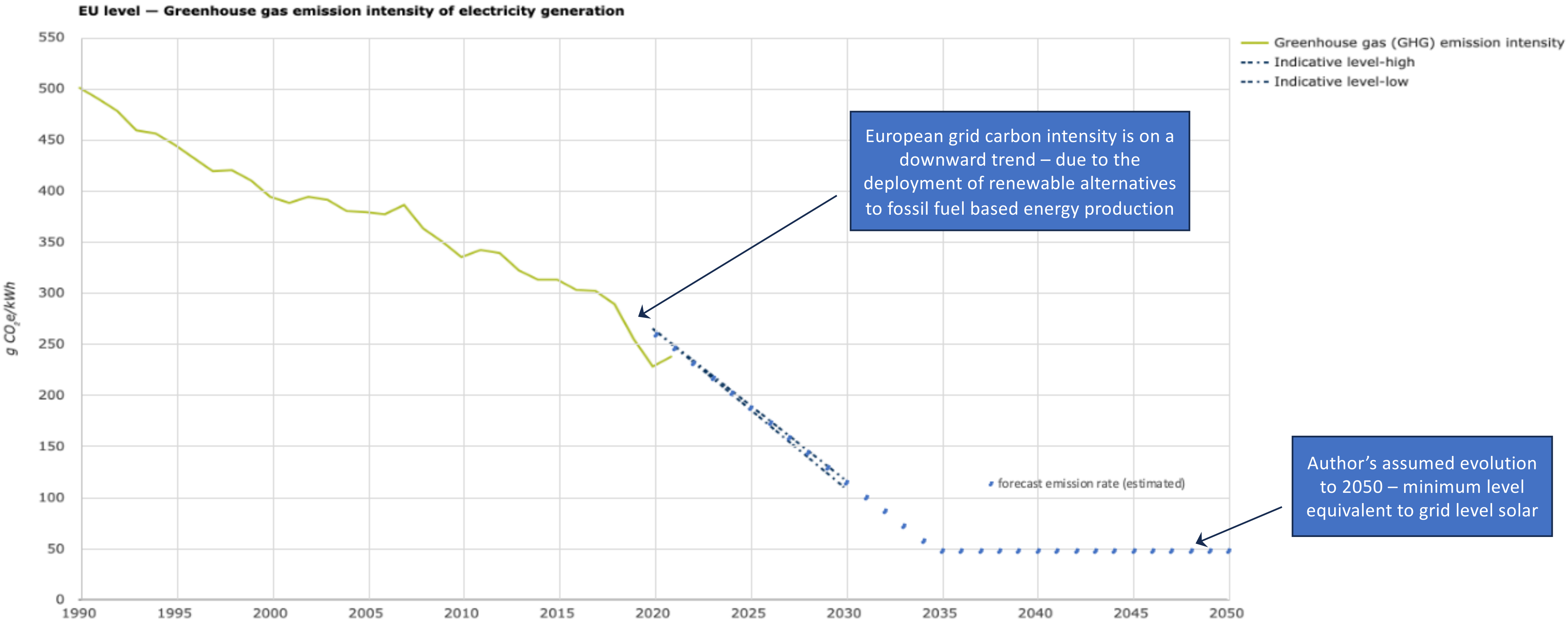
Life-cycle emissions comparison – World Nuclear Association / IPCC



Average life-cycle carbon dioxide-equivalent emissions for different electricity generators (Source: IPCC)

https://world-nuclear.org/nuclear-essentials/how-can-nuclear-combat-climate-change.aspx

Assumed evolution of grid carbon intensity



https://www.eea.europa.eu/

Other Assumptions

	Nuclear Fission Scenario		Wind Turbine Scenario	
Parameter	Value	Comment / reference	Value	Comment / reference
Construction start	2024	https://en.wikipedia.org/wiki/Sizewell_C_nuclear_power_station	2025	Assumption - additional year of pre-planning vs nuclear scenario.
Construction & commissioning duration	9– 12 years *(10 assumed)*	https://en.wikipedia.org/wiki/Sizewell_C_nuclear_power_station	10 years	Aligned to Nuclear production scenario. Assuming 10% of capacity deployed per year.
Production power	3.26 GW	https://en.wikipedia.org/wiki/Sizewell_C_nuclear_power_station	12.52 GW	Calculation, based on 2 lines below
Production rate once operational	99%	Author's assumption – to allow some time for annual maintenance	25.8%	Calculation, based on example in: "How Bad Are Bananas? – The Carbon Footprint of Everything" Mike Berners-Lee, p 152 - reference [3]
Annual production	28,291 GWh / year	Calculation, based on 2 lines above.	28,291 GWh / year	Aligned to Nuclear production scenario
Expected lifetime	over 50 years	https://en.wikipedia.org/wiki/Sizewell_C_nuclear_power_station	20 years	Likely to be pessimistic (could easily be extended to 25 yr through maintenance)
Assumed CO2e intensity over lifetime	12 gCO2e per kWh	https://world-nuclear.org/nuclear-essentials/how-can-nuclear-combat-climate-change.aspx - reference [1]	12 gCO2e per kWh	Aligned to Nuclear production scenario. Note that this is a pessimistic view – it's likely that <8 gCO2/kWh could be achieved (*see "How Bad Are Bananas?" Mike Berners-Lee, p 152*) – reference [3]
Assumed portion of embodied emissions incurred during construction	50%	Author's assumption – taking into account that some of the emissions will be associated with nuclear fuel supply & disposal	99%	Author's assumption – taking into account that some maintenance activity (with associated emissions) will be required during lifetime

“Discounted Carbon Flow” analysis

- When considering financial investments – Discounted Cash Flow (DCF) analysis is typically applied
- For explanation of the technique see [5] : https://en.wikipedia.org/wiki/Discounted_cash_flow
- The underlying principle is “Time Value of Money”:

  “€1 today is worth more than €1 next year”

- A Discount Rate is applied to reflect this – e.g. 10% per annum
- A corresponding environmental measure could be “Time Value of CO2e saved”:

  “1 TCO2e saved today is more beneficial than 1 TCO2e saved next year”

- The Internal Rate of Return (IRR) is the value of the Discount Rate that leads to a Net Present Value (NPV) of zero:
  - If the IRR is higher than the Discount Rate, the project has positive NPV (and is generally “worth doing”)
  - If the IRR is lower than the Discount Rate, the project has negative NPV (and is generally “not worth doing”)
- What ”discount” rate to apply for “Discounted Carbon Flow”?

What “Carbon Discount Rate” to apply?

Financial:

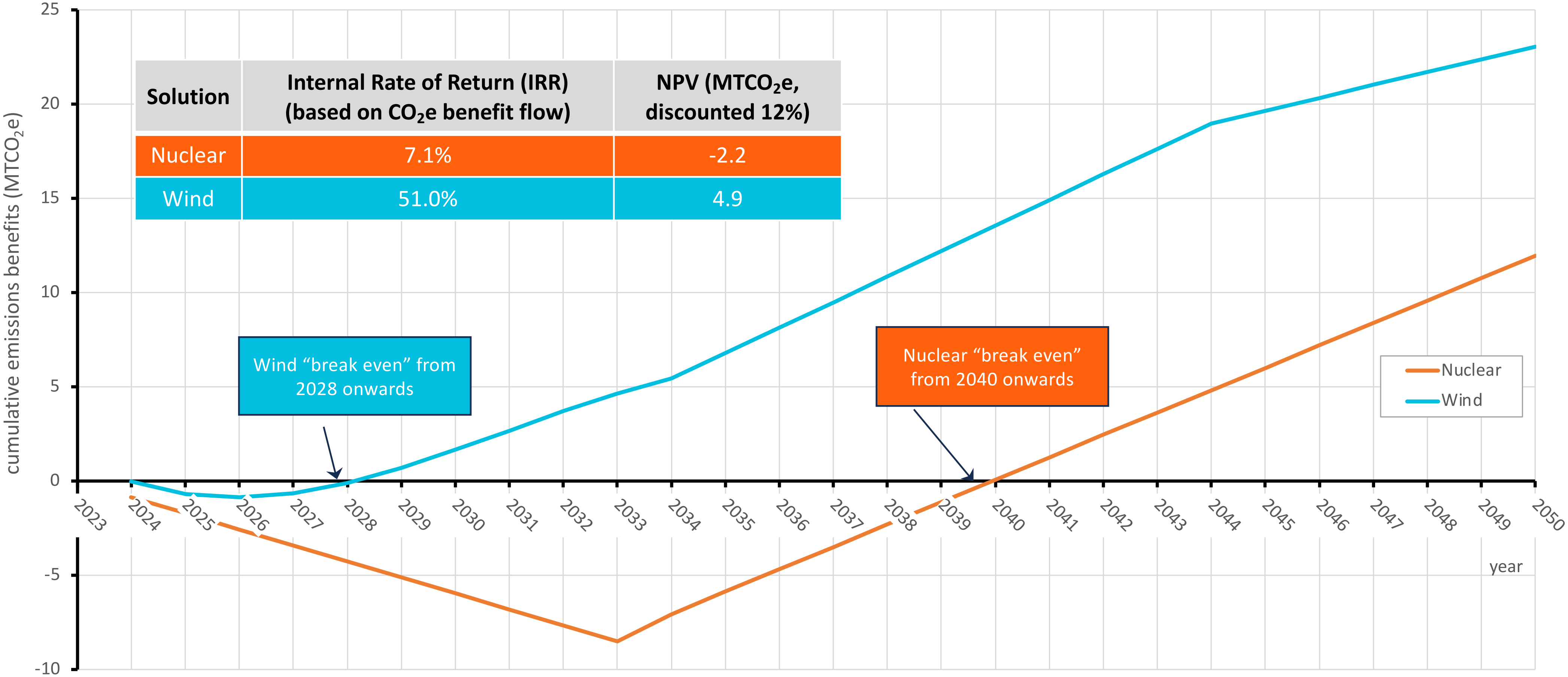
- In Discounted Cash Flow, a discount (or investment “hurdle” rate) of 8% to 10% is typically applied in assessing a project’s business case.
- Such a rate reflects that a business is “taking a risk” in approving the project, so the business expects the project to deliver a rate or return at least in line with “putting the money in the bank” and 10% is (generally) a good bank interest rate (dependent on status of financial markets).

Carbon:

- The key question to answer is: ***“what is the relative benefit of saving 1 T CO2e emissions today, compared to doing that a year from now?”***
- This is a complex question, as we increasingly start to see “positive feedback” effects (such as global warming driving increases in forest fires which in turn release additional CO2, which leads to more global warming, same for continental ice sheet albedo effect, etc. etc.)
- To get to a scientifically justified answer, complex climate modelling would be needed, with associated consumption of human and computing resources (which also lead to further CO2 emissions) and delay in drawing a conclusion. Also, let’s recall that we only seek an indicative benchmark (after all financial markets are also complex, but a financial discount rate is still taken as a benchmark target).
- To simplify this choice, the proposed approach is to take the Paris agreement targets as our driver.
We need to have eliminated net CO2 emissions by 2050 and halved CO2 emissions by 2030.
- On this basis, it is proposed that we should set the discount rate to a value where the value of reducing emissions in 2030 is 50% of what it is in 2024 – a period of 6 years.
- This corresponds to an **annualised discount rate around 12%** (actually 12.25% but a rounded value is proposed for convenience).
- **A discount rate of 12% leads to a cumulative discount factor around 50% by 2030 and 95% by 2050 – broadly aligning to Paris Agreement targets.**
- *Note 12% is a proposed rate for projects where implementation starts in 2024 (for projects starting after 2024, see later slide.)*

Comparing Nuclear & Wind solutions

Solution	Internal Rate of Return (IRR) (based on CO_2e benefit flow)	NPV ($MTCO_2$e, discounted 12%)
Nuclear	7.1%	-2.2
Wind	51.0%	4.9



“Carbon investment discount rate” evolution

Project Implementation start date	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Years to 2030	10	9	8	7	6	5	4	3	2	1
Target reduction by 2030	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%
Discount rate (annualised) to meet target	**7.2%**	**8.0%**	**9.1%**	**10.4%**	**12.2%**	**14.9%**	**18.9%**	**26.0%**	**41.4%**	**100.0%**

- **The target hurdle rate for project implementations starting in 2024 is 12 %**
- As each year passes, the “hurdle rate” becomes higher to be able to meet the Paris Agreement targets.
- This means any projects with “modest” CO2e IRR should start as soon as possible (otherwise they will not be justifiable versus the goals of the Paris Agreement.)
- A large-scale Nuclear fission project (such as Sizewell ”C”) has probably missed the opportunity to make a positive contribution towards the Paris Agreement targets, as the IRR is calculated to be only 7.1%. (The above table indicates it would have been better to have started in 2020 when the target Discount rate would have been 7.2%)
- However, a Wind turbine project (with IRR of 51%) could still make a positive impact even if implemented only in 2028.
- In any case, projects should be targeted that maximise the delivery of CO2e emission benefits (those with high CO2e IRR.)

Very brief review of other sources

- I have tried to find other references to the technique of "Discounted Carbon Flow" – and not found many.
- Discounted Cash Flow is well documented on Wikipedia [5] but there is no similar coverage of "Discounted Carbon Flow".
- The best example I have found is from Marc Guibert in his article "Time value of carbon and 'discounted carbon flow' (DCF)" [6]
- Marc looks at the data of the IPCC Assessment Report (AR5 2013) for various Representative Concentration Pathways (RCP) and by considering the remaining carbon budget associated with each RCP, proposed a Discount Factor range. Note that this is not the latest Assessment report (AR6 synthesis published in 2023).
- Marc's conclusion is that "*If humanity wants to keep the projected increase in global temperature below 2 degrees C by year 2100 , the carbon discount rate cannot not be less than 8.4% and may be as high as 28.0% (if global emissions finally peak in 2025).*
- Marc's analysis is based on a more thorough mathematical treatment than my more "rule of thumb" approach - however I think it supports my proposed Discount Rate of 12% for projects starting in 2024 (and rising as time passes).
- In discussions with numerous carbon accounting experts, I have surprisingly discovered that "Discounted Carbon Flow" as I have described is not generally applied. Instead, organisations use carbon offsetting calculations, to determine a financial equivalent value of the carbon cost of their project, and then proceed with project justifications based on a financial view of the project NPV and IRR etc. To my mind, this approach is based on the view that financial economics prevail. I would prefer to see "carbon economics" considered *at least* alongside "financial economics" when justifying a project; especially if the project relates to sustainability.

Benefits of applying ”Discounted Carbon Flow” method

- For the specific example considered, 2.2 M Tonnes CO2e negative benefit (of the Nuclear fission scenario) is transformed into 4.9 M Tonnes CO2e positive benefit (for the Wind turbine scenario), **a positive difference of 7.1 M TCO2e.**
- The relatively poor performance of Nuclear fission vs Wind turbines is largely due to long construction period and then competing with lower grid emission rates when production comes on-line.
- This analysis suggests that if Nuclear fission technology is to have a beneficial future role, then accelerated planning / construction periods will be required to deliver early benefits (substantially before 2050).
- Beyond this specific example, the method could be applied as a general, quantified, Portfolio Management tool – with a focus on maximising benefits leading to net-zero emissions by 2050.
- Independently of quantifying the CO2e benefits, the method illustrates the importance of acting quickly in order to deliver net-zero by 2050.
- Of course, projects need to be financed, and as such IRR (€, $) and NPV (€, $) need to be considered.
- My proposal is that the parallel metrics of IRR (TCO2e) and NPV (TCO2e) should, also be considered to gain a complete and balanced view if the investment case.
- Then we can leverage all of the accumulated experience in the financial DCF metrics also to consider the climate case for the investment.

Notes of the approach to this example

1. This document is intended as an example of a Project investment case technique. To illustrate the technique, I attempted to use a topical and ”real world” example of the kind of decision that could be supported by the technique
2. Of course, a complex project (such as the implementation of a nuclear power station) would need to consider many factors that are not available to the author. Hence, I have followed publicly available information to develop Nuclear & Wind modelling assumptions
3. I have taken lifetime emissions assumptions from data published by the World Nuclear Association reference [1] – but note that lifetime emissions from wind turbines have probably reduced relative to WNA assumptions.
4. The benefits of low-emission production for both the Nuclear and Wind scenarios are calculated by comparing the difference against the existing grid emissions – due to the ease of access to data, I have taken Europe-wide averages (rather than UK specific) – reference [2]
5. Note that I have considered only the “Carbon Economic Case”, if have not considered the “Financial Economic Case” (or “Business Case”) that would result from a similar “Discounted Cash Flow” analysis.
6. The example analysis focuses only on energy <u>production</u> – the energy <u>storage</u> required for continuity of Wind turbine power and the energy <u>transmission</u> from an inherently centralised Nuclear facility are <u>not</u> considered here.

References / links used in this example

Ref	Author / Source	Title	Link
1	World Nuclear Association	How can nuclear combat climate change?	https://world-nuclear.org/nuclear-essentials/how-can-nuclear-combat-climate-change.aspx
2	European Environment Agency	Greenhouse gas emission intensity of electricity generation	https://www.eea.europa.eu/data-and-maps/daviz/co2-emission-intensity-13#tab-googlechartid_chart_11
3	Mike Berners-Lee	How Bad Are Bananas? – The Carbon Footprint of Everything	https://howbadarebananas.com/ (2020 edition, page 152)
4	Wikipedia	Sizewell C nuclear power station	https://en.wikipedia.org/wiki/Sizewell_C_nuclear_power_station
5	Wikipedia	Discounted Cash Flow	https://en.wikipedia.org/wiki/Discounted_cash_flow
6	Marc Guibert / BXVentures	Time value of carbon and 'discounted carbon flow' (DCF)	https://www.linkedin.com/pulse/time-value-carbon-discounted-flow-dcf-marc-guilbert-ph-d-/
7	Trevion	Trevion 100% Green Energy provider – wind turbine image.	https://trevion.be/

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