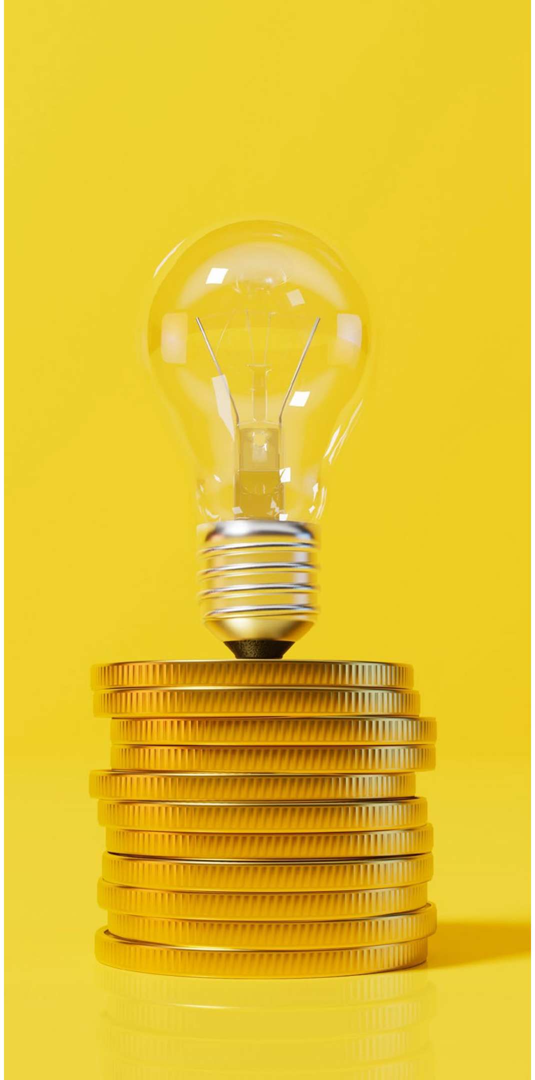

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Energy supply, economics and transition

Energy economics

Professor Philippe Thalmann

Oil and gas companies approve $50 billion of major projects that undermine climate targets and risk shareholder returns 05 September 2019

No major oil company invests to support Paris goals of keeping well below...

READ MORE >

Carbon Tracker Initiative

Decarbonisation, stranded assets, carbon bubble

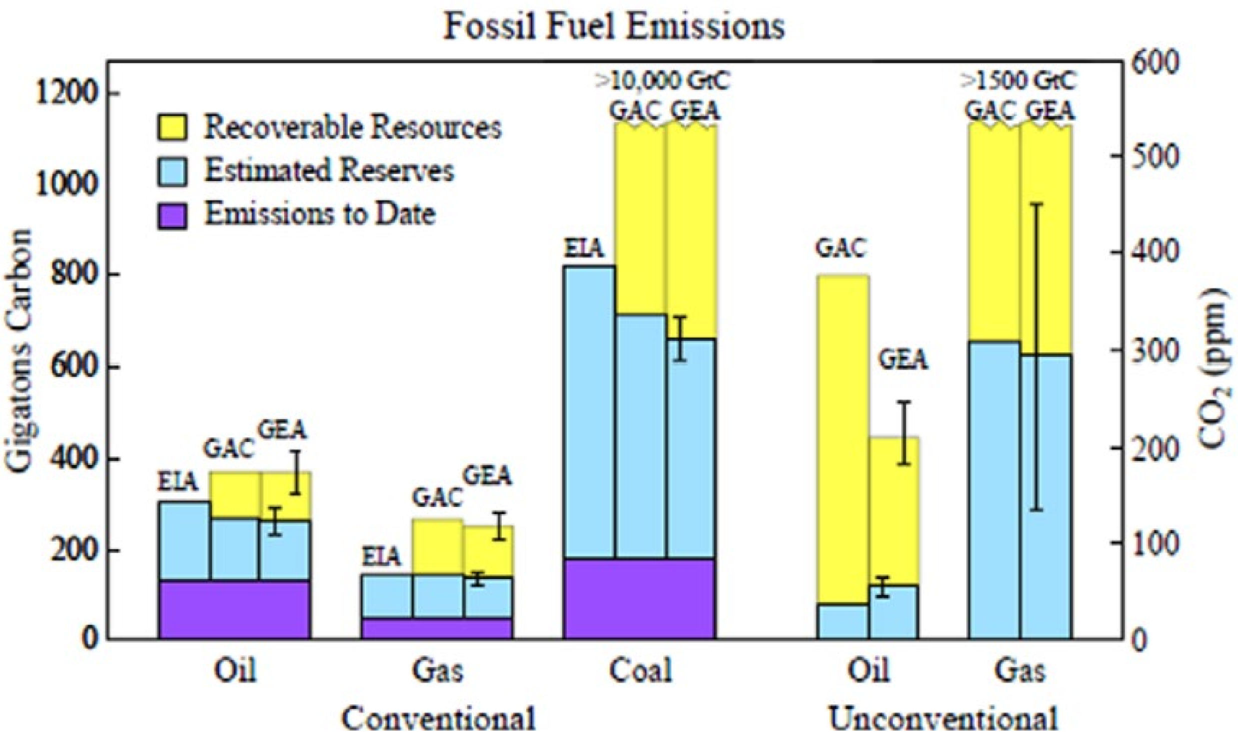
Unburnable carbon – the study* that shook the financial markets

The situation in 2012:

- Fossil energy companies have valued on the stock market the equivalent of 762 GtCO_2 of exploited and exploitable reserves
- The other owners own 3x more
- Total budget compatible with **+2°**: approx. 1000 GtCO_2, i.e. approx. 250 GtCO_2 for listed companies (1/4)
- Total budget compatible with **+1.5°**: approx. 420 GtCO_2, i.e. approx. 105 GtCO_2 for listed companies (1/4)
- Equity value of these companies: US$ 4,000 billion (about 10% or world stock market); debts: US$ 1,270 billion (2012) → *carbon bubble*
- And they keep investing → future *stranded assets*

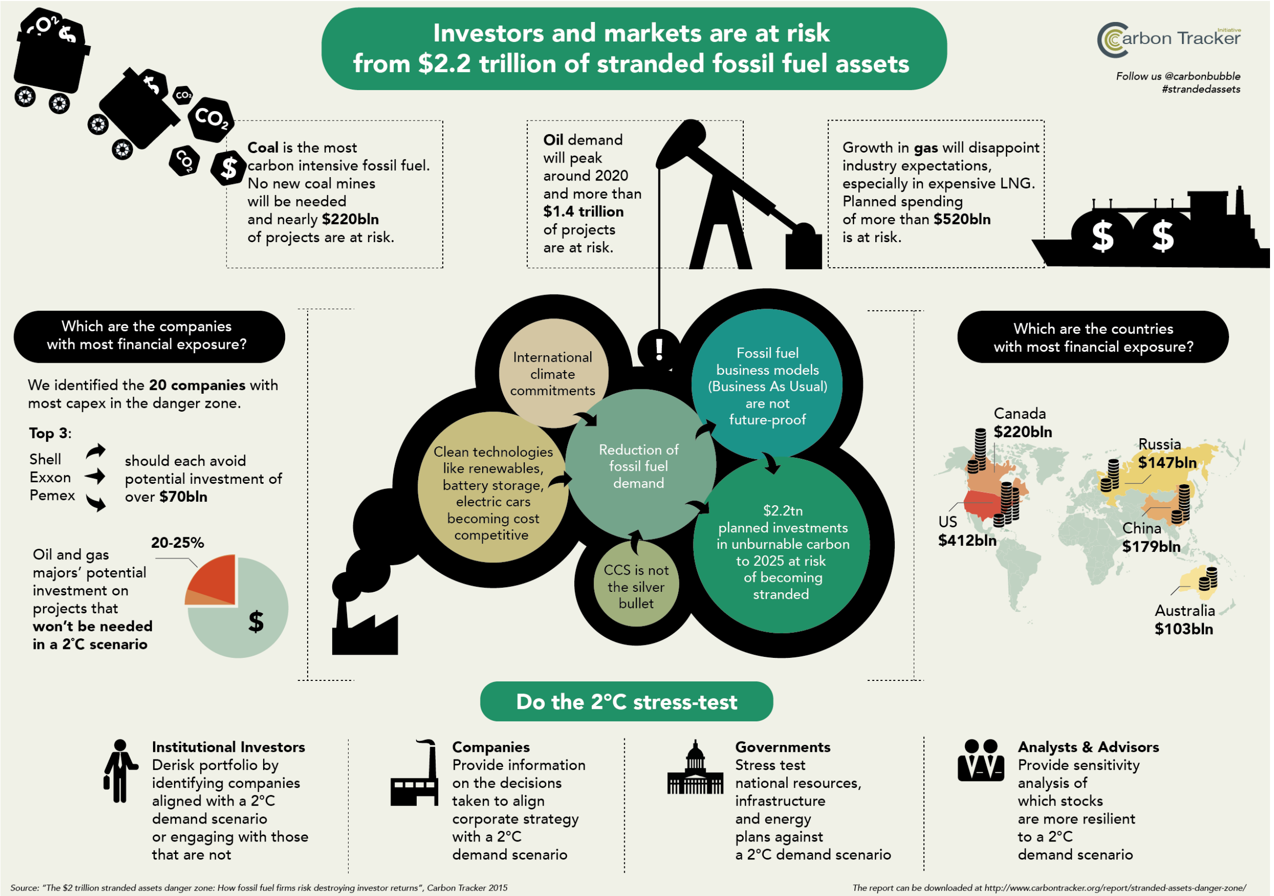
*Carbon Tracker Initiative, "Unburnable carbon 2013"

Unrecoverable reserves and resources



James Hansen, Pushker Kharecha and Makiko Sato (2013), Climate forcing growth rates: doubling down on our Faustian bargain", Environ. Res. Lett. 8 011006. EIA = Energy Information Administration, GAC = German Advisory Council, GEA = Global Energy Assessment; left scale = carbon content, right scale = corresponding increase in CO_2 concentration

Great risk of stranding ongoing investments



$2.2 trillion is about the GDP of Brazil or Italy…

Some oil giants temporarily recognized that some of their assets were stranded

TOTAL

TOTAL ADR | $37.04 | -3.28%
NEW YORK | 07/31/2020 | 11h01

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Home > *Short term price revision and Climate Ambition: Total announces exceptional 8 B$ asset impairments including 7 B$ in Canadian oil sands*

SHORT TERM PRICE REVISION AND CLIMATE AMBITION: TOTAL ANNOUNCES EXCEPTIONAL 8 B$ ASSET IMPAIRMENTS INCLUDING 7 B$ IN CANADIAN OIL SANDS

"As a result of short-term price revision, Total recognizes in the 2nd quarter 2020 an exceptional asset impairment charge of 2.6 B$, mainly on Canadian oil sands assets for 1.5 B$ and LNG assets in Australia for 0.8 B$, both being giant projects with high construction costs." "In addition, in line with its new Climate Ambition announced on May 5, 2020, which aims at carbon neutrality, Total has reviewed its oil assets that can be qualified as “stranded”, meaning with reserves beyond 20 years and high production costs, whose overall reserves may therefore not be produced by 2050. The only projects identified in this category are the Canadian oil sands projects Fort Hills and Surmont." "This leads to an additional exceptional asset impairment of 5.5 B$."

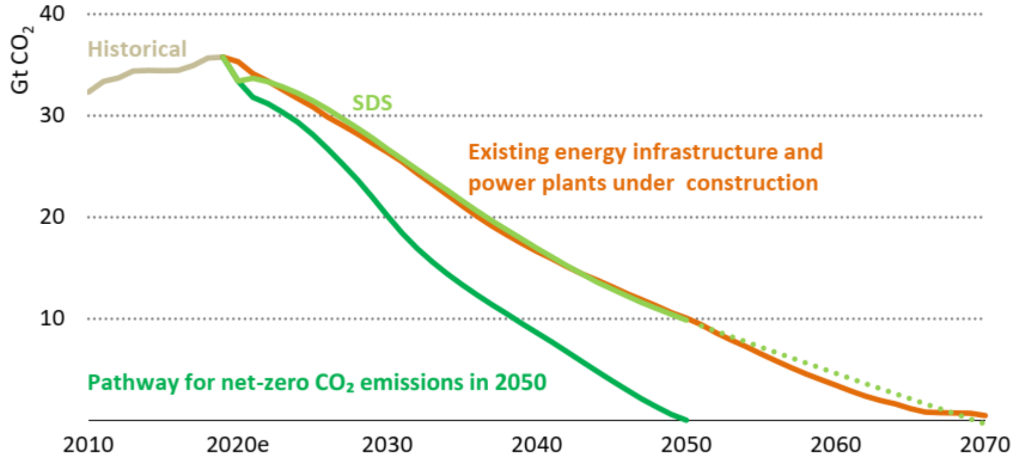
More assets that need to be ‘stranded’

- Power plants burning coal, gas or other fossil fuels that are in place (2017) will emit some 300 $GtCO_2$ until the end of their economic life
- These plants are responsible for some 38% of global emissions.
- By granting them 38% of the budget compatible with +1.5° (420 $GtCO_2$), they can still emit 160 $GtCO_2$
- So, almost half of the current plants should be shut down now, or all of them should be shut down halfway through their useful lives, or all of them should halve their output.
- In any case, the construction of such plants should be stopped.
- Plants under construction or planned will add some 270 $GtCO_2$

Reference: Pfeiffer, A., Hepburn, C. J., Vogt-Schilb, A. and Caldecott, B. (2018) ‘Committed emissions from existing and planned power plants and asset stranding required to meet the Paris Agreement’, Environmental Research Letters. Oxford, UK, 13(054019).

Reorient investments to make them climate compatible

Figure 3.8 ▷ **Historical and projected CO_2 emissions from energy infrastructure in use and power plants under construction operated in line with past practice**



CO_2 emissions from continued use of existing energy infrastructure and power plants under construction would lead to a global average temperature rise of around 1.65 °C by 2070

Note: 2020e = estimated values for 2020.

102 World Energy Outlook 2020 | **Sustainable recovery**

Orange: all of the fossil energy infrastructure that exists today or is under construction is used in a similar way as in the past until the end of its lifetime; none is added

Light green: Sustainable development scenario SDS, which considers all sources of CO_2; the existing fossil energy infrastructure must reduce its emissions faster than business as usual

Dark green: global CO_2 emissions on track for net zero by 2050

The only investment in fossil infrastructure compatible with the international climate agreements is investment to make it less polluting. Investment into creating new fossil infrastructure or expanding the existing infrastructure is not

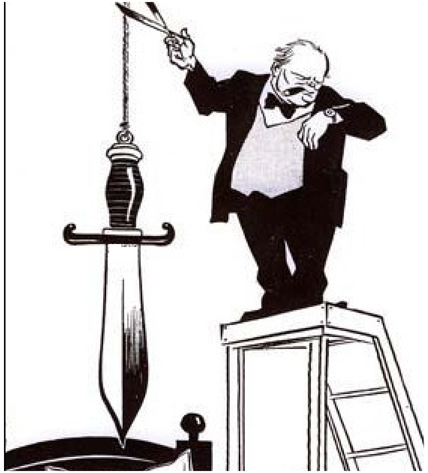
Technological and financial lock-in effects

Several factors make it more expensive to transition away from fossil energy:

- Recent investments in the fossil energy extraction infrastructure: drilling platforms, mines, pipelines, refineries, …
- Recent investments in fossil energy using infrastructure: coal-fired power plants, fossil-based heating systems, airplanes, ICE cars and trucks, …
- Long-term delivery contracts, Energy Charter Treaty *(next slide)*
- Businesses and manpower invested in activities related to fossil energy

Related concept: path dependency

A perverse form of lock-in



- Fossil-friendly governments sign long-term contracts with fossil fuel companies with large damage clauses in case of early shut-down
- Fossil fuel companies sue governments when these threaten to shut down their activities

Germany's RWE uses Energy Charter Treaty to challenge Dutch coal phase-out

By Kira Taylor | EURACTIV.com

5 févr. 2021 (updated: 8 févr. 2021)

https://www.euractiv.com/section/energy/news/germanys-rwe-uses-energy-charter-treaty-to-challenge-dutch-coal-phase-out/

The Energy Charter Treaty (ECT) is an international agreement that allows energy companies to sue states before international arbitration courts for billions of Euros of compensation when their policy measures could impact the expected incomes from investments these companies have made. The treaty was signed by 54 states in 1994 to protect Western companies investing in former Soviet Union states, but today ¾ of ECT cases are by EU companies against EU states and their climate policies. Companies can obtain compensation not just for their (depreciated) investment, but for all future expected profits.

For more info and examples: https://www.investigate-europe.eu/en/2021/ect/

Financial impacts of decarbonisation in Switzerland

Philippe Thalmann

	2018	2019	2020	2021	2022	2023
Spending for final energy consumption	27.3	27.2	24.1	27.3	33.2	36.4
./. Electricity, wood, distance heating	-10.5	-10.5	-10.5	-11.3	-13.3	-17.9
Spending for final fossil energy consumption	16.9	16.7	13.6	16.0	19.9	18.5
./. Mineral oil taxes	-4.6	-4.6	-4.2	-4.6	-4.4	-4.3
./. CO_2 levy	-1.1	-1.3	-1.3	-1.2	-1.3	-0.9
./. VAT*	-1.2	-1.2	-1.0	-1.1	-1.4	-1.3
Net-of-taxes spending for final fossil energy consumption	10.0	9.7	7.1	9.1	12.7	11.9
./. Imports of final energy	-7.2	-7.3	-4.0	-6.0	-11.1	-10.3
Net domestic income from the sale of fossil energy*	2.8	2.4	3.1	3.1	1.7	1.5

*estimation

Figures in CHF billions from the SFOE (Global Energy Statistics), the FFA and the Federal Customs Administration

Lessons learned

- Energy should be carbon-free by 2050
- Total fossil energy reserves (in the process of or near exploitation) far exceed the quantities that can still be burnt
- This puts a large volume of investments at risk: *stranded assets*
- Companies holding these assets are overvalued: *carbon bubble*
- Coal is particularly concerned, including coal power plants
- The first step is to stop investing in developing new fossil energy sources and (power) plants using them
- Even in countries not producing fossil energy, there are high financial stakes

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Quick introduction to financial calculation

Rate or return and interest rate

Investor invests sum S_0 now; his investment is worth S_1 after 1 year

$S_1 = S_0(1+r^*)$, r^* is the **rate of return** on this investment

Ex post calculation of $r^* = S_1/S_0 - 1$

Consider an alternative investment promising **rate of interest** i:

$S_0 \rightarrow S_1 = S_0(1+i)$

This could be a bank account, a loan, a bond…

Arbitrage: r = i + p, where r is required rate of return for an investment and p is an interest premium for differences in risk and liquidity

Compounding and discounting

What is the investor's willingness to pay today for a sum S_1 he will get in one year?

S_0 such that anticipated $r^* = r$, i.e., such that $S_1/S_0 - 1 = r$, or $S_0(1+r) = S_1$, or $S_0 = S_1/(1+r)$

$S_0 \rightarrow S_1 = S_0(1+r)$ **compounding**

$S_1 \rightarrow S_0 = S_1/(1+r)$ **discounting**, r is **discount rate**

Compounding and discounting over 2 years

Philippe Thalmann

Investor invests sum S_0 now; his investment is worth S_2 after 2 years

Consider investment with known interest rate:

$S_0 \rightarrow S_1 = S_0(1+i) \rightarrow S_2 = S_1(1+i) = S_0(1+i)^2$

Interest on interest: **compound interest** (assuming **reinvestment**)

Similarly for investor's investment:

$S_0 \rightarrow S_2 = S_0(1+r^*)^2 \rightarrow r^* = (S_2/S_0)^{1/2} - 1$

$S_0 \rightarrow S_2 = S_0(1+r)^2$ compounding

$S_2 \rightarrow S_0 = S_2/(1+r)^2$ discounting

Compounding and discounting over n years

Philippe Thalmann

Investor invests sum S_0 now; his investment is worth S_n after n years

$$S_0 \rightarrow S_n = S_0(1+r^*)^n \rightarrow r^* = (S_n/S_0)^{1/n} - 1$$

$S_0 \rightarrow S_n = S_0(1+r)^n$ compounding

$S_n \rightarrow S_0 = S_n/(1+r)^n$ discounting

Flow of payments, cash flow

Investor anticipates payments of D_1 in one year, D_2 in two years, D_3 in three years, etc., until D_n in n years

D could be dividends, coupons, repayments, products of asset sales…

Willingness to pay now for this stream of (expected) payments, with a required rate of return = r:

$S_0 = D_1/(1+r) + D_2/(1+r)^2 + D_3/(1+r)^3 + \ldots + D_n/(1+r)^n$

This is called **discounted cash flow** (DCF) and S_0 is the **present value** of this cash flow

Share values and NPV

$S_0 = D_1/(1+r) + D_2/(1+r)^2 + D_3/(1+r)^3 + \ldots + D_n/(1+r)^n$

S_0 could be the value of a share; the last payment could include a repayment

If the investor had to invest I_0 to generate payments of D_1 to D_n, then this is the **net present value** (**NPV**) of this investment:

$NPV = -I_0 + D_1/(1+r) + D_2/(1+r)^2 + D_3/(1+r)^3 + \ldots + D_n/(1+r)^n$

Internal rate of return

$$NPV = -I_0 + D_1/(1+r) + D_2/(1+r)^2 + D_3/(1+r)^3 + \ldots + D_n/(1+r)^n$$

For all regular investments, there is a discount rate r* such that NPV = 0; this is the **internal rate of return**

The larger is r, the smaller is the NPV; if NPV > 0, a larger discount rate would bring it down to 0

NPV < = > 0 means that the investment I_0 yields a rate of return r* smaller than, equal to or larger than r

Payback period

$$NPV = -I_0 + D_1/(1+r) + D_2/(1+r)^2 + D_3/(1+r)^3 + \ldots + D_n/(1+r)^n$$

For all regular investments, there is a number of years n* of positive incomes that makes the NPV reach 0; this is the **payback period**

If $r = 0$ and D were constant, $n^* = I_0/D$

If an investment can be exploited for less (more) than n* years, $r^* < r$ ($r^* > r$)

If the physical lifetime of the asset < n*, it cannot generate r

Stranded assets are assets that stop generating income before n*

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Applications related to energy

Carbon bubble

Assume required rate of return r = 6%

Years	Payment	Payment discounted to now
1	10	9.43
2	11	9.79
3	12	10.08
4	213	168.72
		198.02

Years	Payment	Payment discounted to now
1	10	9.43
2	9	8.01
3	8	6.72
4	27	21.39
		45.55

If investors anticipate rising incomes, they are willing to pay much more for shares of, say, a fossil energy company, than if they anticipate shrinking incomes and a low resale value

When will the carbon bubble burst?

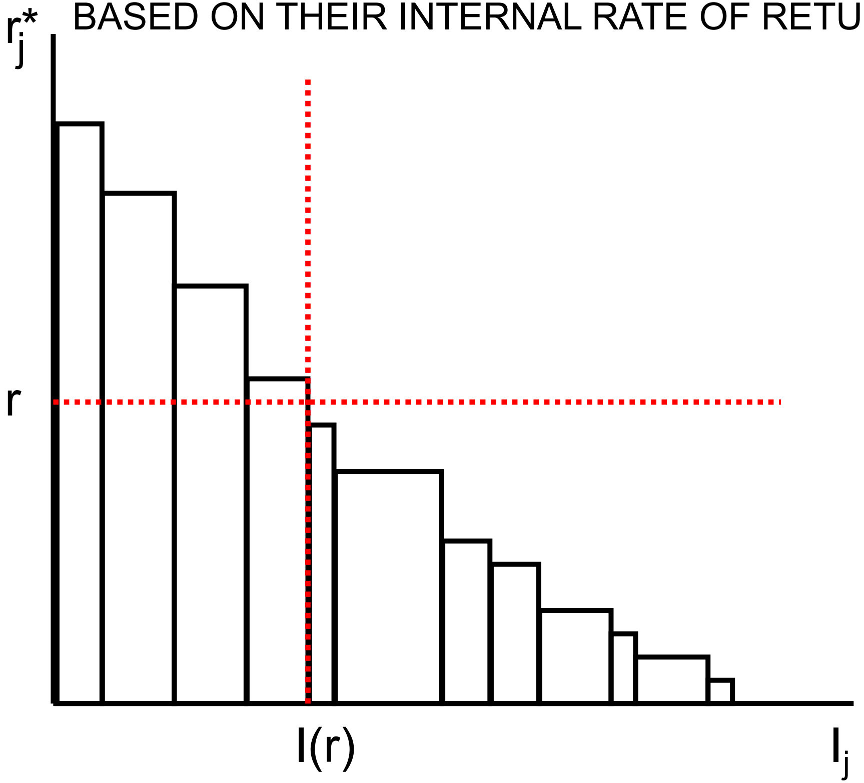
- The price of shares, of oil or any other company, depends on buyers' willingness to pay for them, which is high as long as…
  - buyers anticipate profits (in fact dividends)
  - buyers' trust that they can sell their shares at a good price when they want
- The price of shares of oil companies will come tumbling down when these two connected conditions are no longer valid
- The price can come down very fast, because holders need to sell fast, before the price drops, causing the price drop, encouraging more holders to sell, further deflating the price, confirming anticipations of dropping prices, etc.

When will the bubble burst?

- Why would investors no longer expect profits?
  - Regulation forces oil companies to keep the oil in the ground
  - Regulation reduces demand for oil, bringing its price down
  - Taxes put a wedge between buyers' and sellers' price, pushing the latter down
  - Alternative energy sources become cheaper
- Important: it all depends on expectations…

Hurdle rate

RANKING OF INVESTMENT PROJECTS
BASED ON THEIR INTERNAL RATE OF RETURN



- The **hurdle rate** is the required rate of return for this type of investment
- I(r) is the amount that can be invested with (expected) IRR greater than hurdle rate r
- Anything that lowers the hurdle rate or raises the IRR of projects triggers more investment

Philippe Thalmann

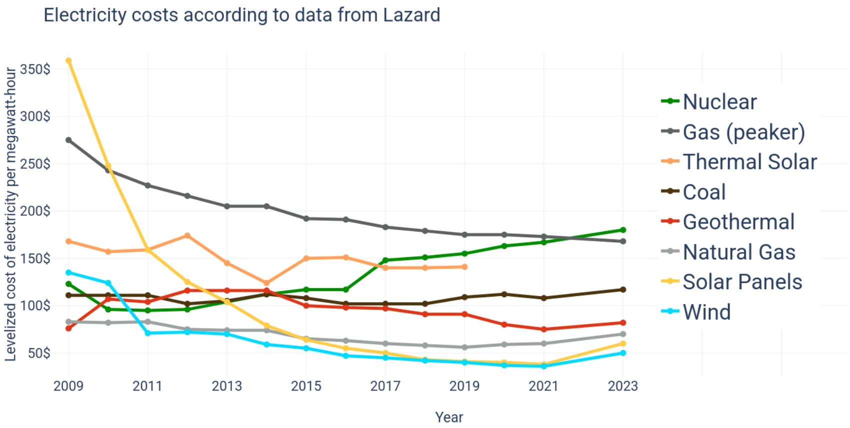
Payback period for BE car compared to ICE

Philippe Thalmann

		Discount rate:	4.0%			
	ICE - BE	Sum of payments	Discount years	Discount factor	Present value	**NPV**
Net acquisition cost	-5 850 €	-5 850 €	0	1.00	-5 850 €	-5 850 €
Running costs year 1	1 089 €	-4 761 €	0.5	0.98	1 068 €	-4 782 €
Running costs year 2	1 089 €	-3 672 €	1.5	0.94	1 027 €	-3 755 €
Running costs year 3	1 089 €	-2 583 €	2.5	0.91	987 €	-2 768 €
Running costs year 4	1 089 €	-1 494 €	3.5	0.87	949 €	-1 819 €
Running costs year 5	1 089 €	- 405 €	4.5	0.84	913 €	- 906 €
Running costs year 6	1 089 €	**684 €**	5.5	0.81	878 €	- 28 €
Running costs year 7	1 089 €	1 773 €	6.5	0.77	844 €	**816 €**
Running costs year 8	1 089 €	2 862 €	7.5	0.75	811 €	1 627 €

- The NPV in the last column is the present value of all 'payments' up to that year
- The NPV turns positive in year 7, i.e., the BE is the better choice for a user who plans to use her car for 7 years at least
- Without discounting, payback period = 6 years

Levelized cost of electricity (LCOE)



Cash flow of power generation unit

- Consider a power generation unit with initial investment cost C_0 (CAPEX), recurring annual operating costs C_t (OPEX), generating quantity Q_t of electricity per year over n years (lifetime); V_n is scrap value at end of life
- Suppose that p is the constant unit price at which the electricity can be sold
- Cash flow: $-C_0$, pQ_1-C_1, pQ_2-C_2, …, $pQ_n-C_n+V_n$

LCOE defined

Cash flow: $-C_0$, pQ_1-C_1, pQ_2-C_2, …, $pQ_n-C_n+V_n$

$$NPV = -C_0 + \frac{pQ_1-C_1}{1+r} + \frac{pQ_2-C_2}{(1+r)^2} + \ldots + \frac{pQ_n-C_n+V_n}{(1+r)^n}$$

NPV = 0 if:

$$C_0 + \frac{C_1}{1+r} + \frac{C_n}{(1+r)^2} + \ldots + \frac{C_n-V_n}{(1+r)^n} = \frac{pQ_1}{1+r} + \frac{pQ_2}{(1+r)^2} + \ldots + \frac{pQ_n}{(1+r)^n}$$

Equivalently:

$$p = \frac{C_0 + C_1/(1+r) + C_2/(1+r)^2 + \ldots + (Cn - V_n)/(1+r)^n}{Q_1/(1+r) + Q_2/(1+r)^2 + \ldots + Q_n/(1+r)^n}$$

p is the **levelized cost of electricity** for this power generation unit

LCOE reformulated

LCOE per kWh produced, when all costs are expressed per MW capacity:

$$\text{LCOE} = \frac{C_0 + \sum_{t=1}^{n} \frac{C_t}{(1+r)^t} - \frac{V_n}{(1+r)^n}}{8760 \times \sum_{t=1}^{n} \frac{\text{Capacity Factor}}{(1+r)^t}}$$

The **capacity factor** is the ratio of actual electricity generation to theoretical capacity; it depends on the mode of operation, exposition, etc.

Capital recovery factor

$$\text{LCOE} = \frac{C_0 + \sum_{t=1}^{n} \frac{C_t}{(1+r)^t} - \frac{V_n}{(1+r)^n}}{8760 \times \sum_{t=1}^{n} \frac{\text{Capacity Factor}}{(1+r)^t}}$$

Using the fact that, for constant Z:

$$\sum_{t=1}^{n} \frac{Z}{(1+r)^t} = Z \times \frac{1-(1+r)^{-n}}{r} = \frac{Z}{CRF} \quad \text{with} \quad CRF = \frac{r(1+r)^n}{(1+r)^n - 1}$$

CRF is the **capital recovery factor**

It can be used to compute the present value of a constant stream of annuities, or to compute the constant annuities whose present value is equal to some present amount

When $n \rightarrow \infty$, $CRF \rightarrow r$

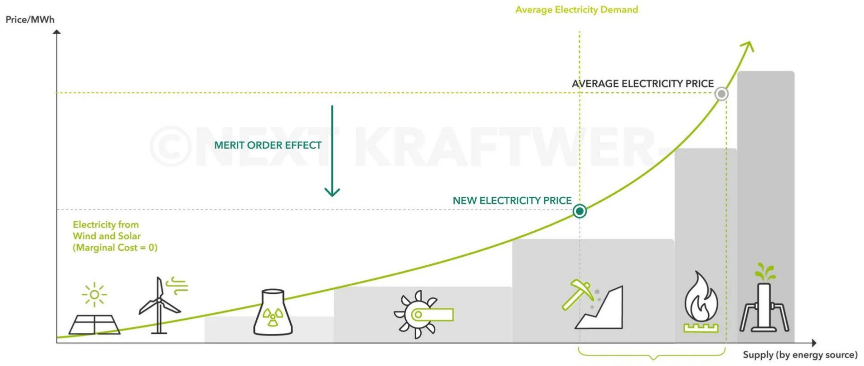
LCOE simplified

$$\text{LCOE} = \frac{C_0 + \sum_{t=1}^{n} \frac{C}{(1+r)^t} - \frac{V_n}{(1+r)^n}}{8760 \times \sum_{t=1}^{n} \frac{\text{Capacity Factor}}{(1+r)^t}} = \frac{C_0 - \frac{V_n}{(1+r)^n} + \frac{\text{OPEX}}{\text{CRF}}}{8760 \times \frac{\text{Capacity Factor}}{\text{CRF}}}$$

$$\text{LCOE} = \frac{\text{nCAPEX} \times \text{CRF} + \text{OPEX}}{8760 \times \text{Capacity Factor}}$$

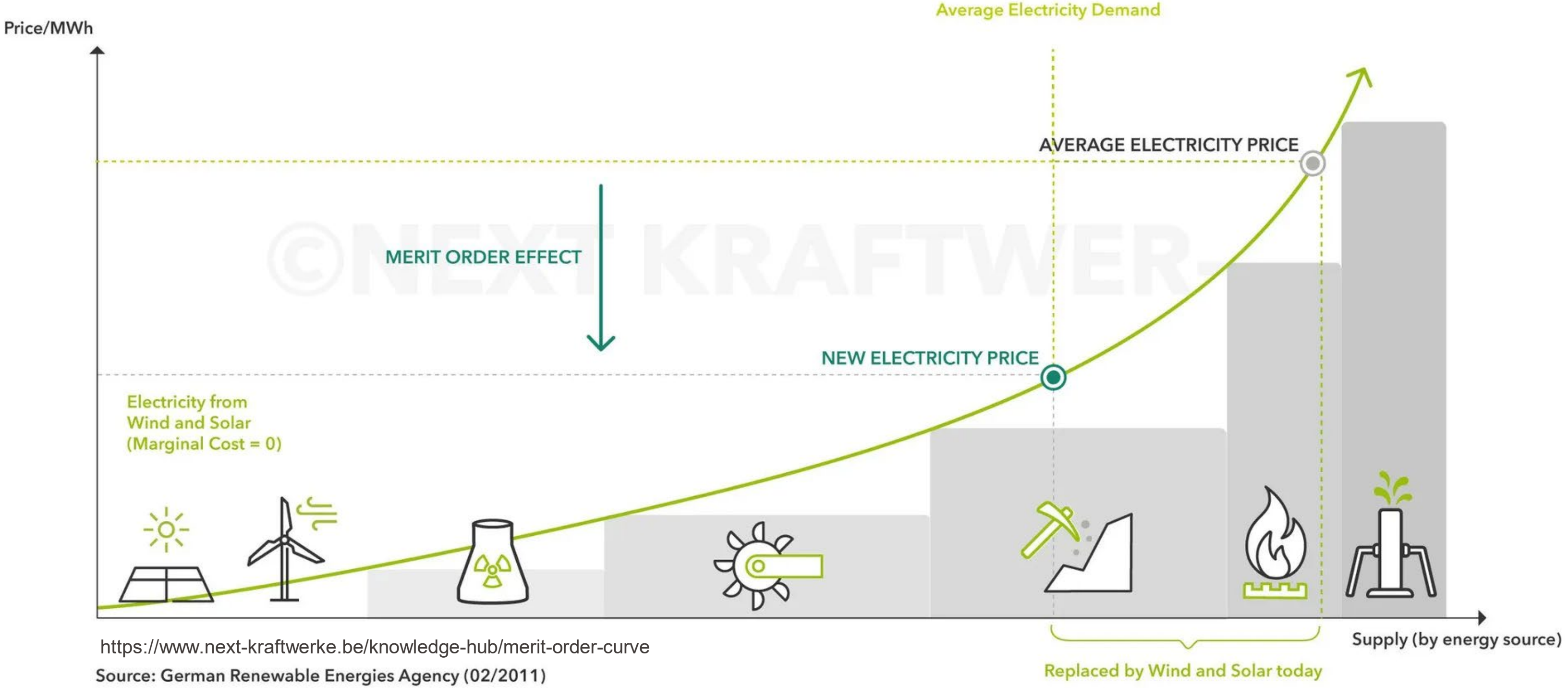
Where nCAPEX is initial capital expenditure minus present value of scrap value; the CRF converts this into an equivalent annuity

Merit order curve for electricity supply



Source: German Renewable Energies Agency (02/2011)

Merit order curve for electricity supply



https://www.next-kraftwerke.be/knowledge-hub/merit-order-curve

Source: German Renewable Energies Agency (02/2011)

With wind and solar today, the marginal cost = price is that of coal on this illustrative (German) market
Without wind and solar, demand would require gas, which would push the price higher