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Book for reference with details and thermodynamic calculations (German): Berndt Warm, „Die kurze Endphase des Ölzeitalters: Erdöl, Autoproduktion und Thermodynamik“, ISBN-13: 978-3347487307

Calculations on the Lifetime of Vehicle and Oil production

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Foreword

Oil production and driving are connected like Siamese twins. Without fossil fuels hardly any vehicle moves. Crude oil provides the energy for propulsion. Crude oil supplies energy for oil production. And provides much of the energy to build vehicles and roads. Worldwide, almost only internal combustion engines are used for motor vehicles; the share of Electric vehicles is in the percentage range (1.4% in 2021). Siamese twins can sometimes be separated, otherwise they live and die simultaneously.

Based on openly available data on passenger car manufacturing and petroleum production the lifetimes of this twin were determined in several ways. The mathematical procedures used are standard procedures for data evaluation. The computational procedures and results are presented, but details of the calculations are not.

Procedures: (stroked are left out in short version)

~~1. from worldwide production of motor vehicles.~~

2. from the oil price

~~3. from the monthly production of passenger cars~~

~~4. from German passenger car data~~

5. from the entropy balance equation for open systems2

Prerequisite: Determination of an inflation-independent oil price

Oil production and oil prices are linked. Oil prices are quoted on the stock exchange in USD/barrel. They are subject to inflation. As a result, a price from 2010 is not directly comparable with the price in 2020; you must factor in inflation. Inflation values fluctuate from year to year and have been particularly high since 2021. Consequently, if you want to compare prices of different years, you have to assume a reference year. Using a reference year has two disadvantages:
1. it is not standardized; each author uses his own reference year.
2. it is outdated: Who is interested today in prices related to the year 2000?
An independent reference system is needed. For this, the Global Domestic Product (GDP) is used.

Dividing GDP by world primary energy consumption yields energy productivity. It is shown in figure 1. With the help of energy productivity, the price of a barrel of crude oil can be converted into the energy content of the barrel and expressed as a percentage value.

The primary energy content of a barrel of oil (=Barrel of Oil Equivalent, BOE) is 1 BOE or 1628.2 kWh. BOE is an energy unit commonly used in the oil industry. The price of a barrel of oil, which is expressed in US dollars, can be converted into a percentage of the energy of the barrel. The conversion factor for this is energy productivity in Figure 1.
The percentage is calculated using:

$$\%BOE = \frac{Price\left(\frac{USD}{bbl}\right) * 100}{EP(t) * 1628.2\ kWh}$$

Where: Price(USD/bbl): the price of crude oil in US dollars per barrel
EP(t): the value of energy productivity EP from Figure 1 for the year under consideration.
% BOE: indicates the percentage of energy content paid per barrel. Another name for %BOE is "Specific energy content in percent".

Example: The barrel of Brent costs 60 USD in 2020. EP(2020) is 0.55 USD/kWh.
Cost per Barrel= 60∗100 / 0.55∗1628.2 =6.7 %BOE.

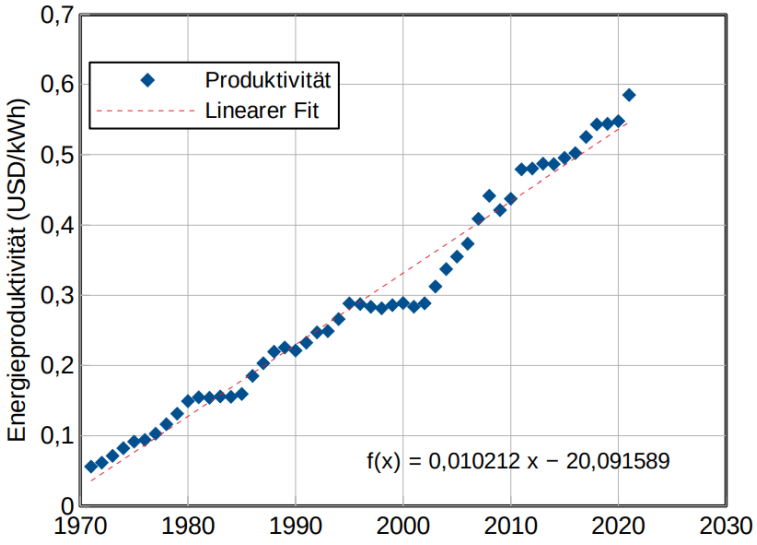


Figure 1: Energy Productivity EP(t). The value EP(t) indicates how many dollars the world economy generated per kWh of primary energy. The data on which the graph is based up to 2020 are from the World Bank. The value for 2021 is based on data from BP, Statista and other sources. For 2022, the curve is extrapolated from the 2020 and 2021 data.

The advantage of specifying in %BOE is that the values are not dependent on a reference year. The disadvantage is that values for EP(t) of the last two years have to be estimated and are only known inaccurately, since the World Bank publishes the data with a delay. Energy productivity allows money to be converted into energies in a simple way. **This is important because the economy runs on energy, not money**. This difference is trivial, but is often overlooked. Crude oil is produced with energy, not money. Money is printed by central banks, and can be created in any quantity. **Energy is finite.**

[…]

2. Lifetime determination from the oil price

Figure 5: Oil price (Brent) converted to the energy content of a barrel.
(Prices: https://www.finanzen.net/rohstoffe/oelpreis)

Around the end of 2018, the author saw that the peak oil prices were pretty much on a straight line (dashed green line in Figure 5). The straight line started in 2008 and lasted until 2021, thirteen years. The straight line drops off at 1.1%BOE/year. It wasn't until early 2021 that the oil price came back above the straight line and has been going up ever since. Just as there was an upward bounding line, there was one that bounded the oil price downward (dashed dark yellow line in Figure 5). It started in early 2016 and has been rising ever since. The two lines crossed in mid-2020, **and the author interprets the line of maxima as the maximum oil price that developed countries can afford while maintaining their lifestyles. He interprets the line of minima as the oil price that producing countries need to keep their economies running.** In mid-2019, this intersection caught the author's eye, and he expected a crisis in 2020, although it was completely unclear to him what kind of crisis it would be then. Corona he did not expect. Oil prices have been somewhat above the green line since 2021, and significantly so since 2022. First OPEC raised prices because their states' economies needed the money. Then the war in Ukraine has caused another increase. On 05.09.2022 OPEC decided to cut production because the oil price became too low for them. The inhabitants of the industrialized countries now realize that their lifestyle is at risk. The line of maxima reaches zero (0%BOE) around mid-2027. From then on, the inhabitants of the industrialized countries will no longer be able to afford oil without having to do without many things in their daily lives. The demand of oil producers will then be 13-14%BOE. These two values are incompatible.

Result: Extrapolation of oil prices shows that from 2022 onwards, the lifestyle of western civilization will degrade and that from 2027 onwards, the inhabitants of the industrialized countries will hardly be able to afford oil anymore.

[…]

5. Lifetime determination from the entropy balance equation for open systems

The Earth's crust is usually in temperature equilibrium near oil fields. Petroleum production transports heat from the earth's interior to the earth's surface. The petroleum pumped upward is replaced by water from the earth's surface, which cools the earth's interior.

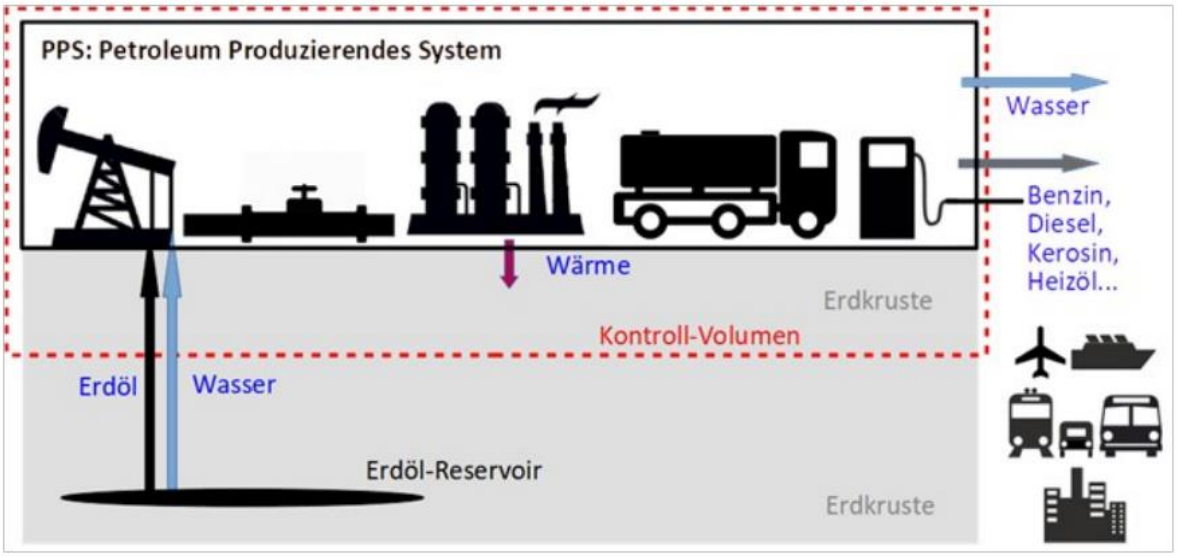


Figure 8: Sketch of the control volume for the thermodynamic calculation for oil production.

The temperature equilibrium of the earth is disturbed. According to the Second Law of Thermodynamics, the energy required to do this must be provided by the Petroleum Producing System (PPS). The PPS consists not only of the pumping equipment of the conveyors, but also includes refineries, transportation systems, fuel stations, etc. It also includes the training of the welder who makes pipes for petroleum production somewhere in the world, doctors, military personnel to secure transportation routes, and much more. Energy expenditure is calculated using the Steady State Entropy Rate Balance for Control Volumes, a mathematical formulation of the Second Law of Thermodynamics[1] for open systems. This calculation requires the definition of a control volume, which is shown in Figure 8. 10 years ago, HillsGroup[2] produced the graph (Figure 9), resulting from the calculation of the thermodynamically necessary exergy. Transformed into the SI system, Figure 10 results, showing exergy values and anergy values. Exergy is the mechanically usable portion of energy. Engines use about 20%-60% of the total energy of a fuel, depending on the design, and convert this 20%-60% into mechanical work. Anergy is the portion of energy that cannot be used and is also referred to as waste heat. The thermodynamically necessary exergy (TNE) for oil production (=change of temperature equilibrium) increases continuously over time. The distance of this curve to the theoretically or practically usable fraction is the exergy remaining for the oil user.

[1] The second law is a law of nature that is as impossible to violate as it is to fly faster than light.

[2] A former consulting group for the oil industry. The HillsGroup website no longer exists. The report "Report# HC3-433 Depletion: A determination for the world's petroleum reserve" included this graphic.

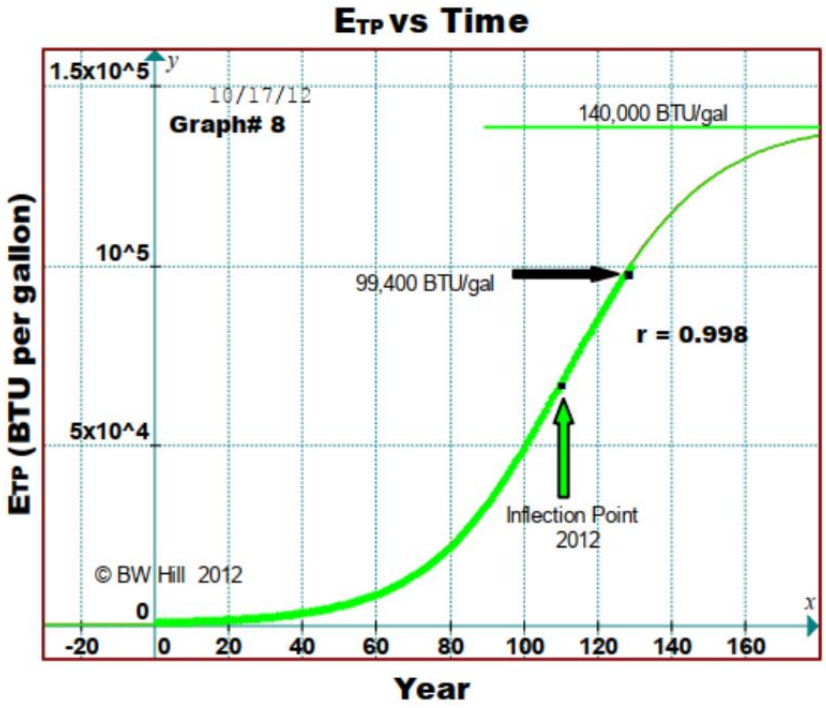
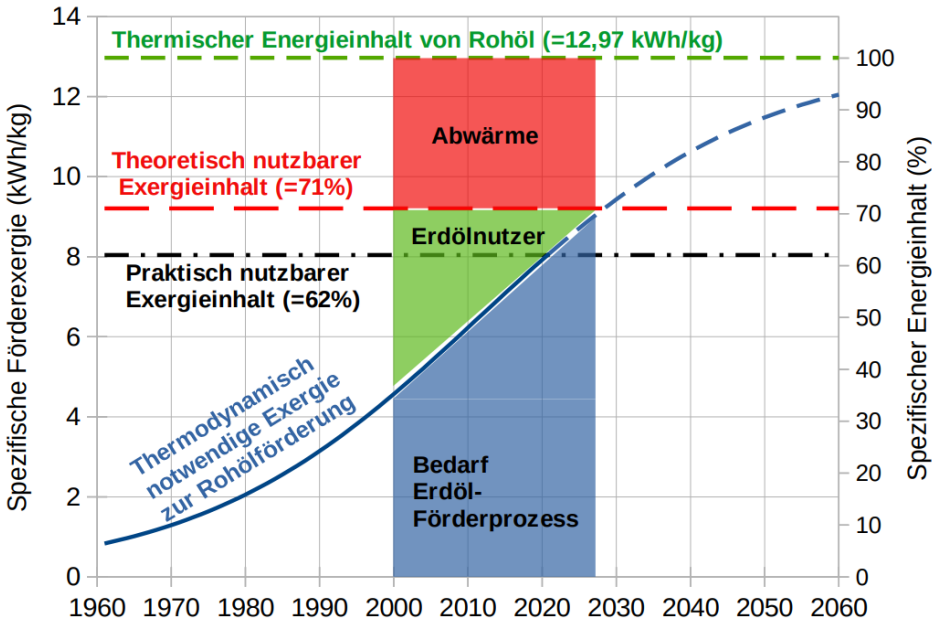


Figure 9: Exergy expenditure of oil production, calculated thermodynamically. ETP stands for Energy Total Production. The units (BTU, gallon) are from the imperial system used by oil production companies. The graph is copied from the original HillsGroup report.



Spezifische Förderexergie (kWh/kg)	Specific extraction exergy (kWh/kg)
Spezifischer Energieinhalt (%)	Specific energy content (%)
Thermischer Energieinhalt von Rohöl (12.97 kWh/kg)	Thermal energy content of crude oil
Theoretisch nutzbarer Exergieinhalt (71%)	Theoretically usable exergy content
Praktisch nutzbarer Exergieinhalt (62%)	Practically usable exergy content
Thermodynamisch notwendige Exergie zur Rohölförderung	Thermodynamically necessary exergy for crude oil extraction
Abwärme	Waste heat
Erdölnutzer	Oil usable for economy
Bedarf Erdöl-Förderprozess	Demand for crude oil extraction

Figure 10: Graph of thermodynamically determined production exergy in the SI system, including the distribution of barrel petroleum exergies to the total petroleum production process, petroleum users, and waste heat (anergy). The "smooth" curve is due to the fact that not the real oil production quantities were used, but a fit to these quantities.

The exergy required to change the temperature equilibrium increases continuously, reaching the value for the practically usable exergy content of petroleum in 2021, and the theoretically usable exergy content in about 2029. The difference in exergy between 2021 and 2029 is 9%, or 1.125%BOE/year. After subtracting the exergy required for production from the theoretically usable exergy, we obtain the exergy that can be technically used. The green triangle indicates the exergy remaining for the consumer for the relevant range from 2008 to 2027. Result: In the years 2028 - 2029, the exergy required for oil production will be higher than the exergy content of crude oil[3]. At that point, oil production no longer makes sense from an energy point of view. However, since cheaper energies than crude oil, such as gas or coal, are also used for oil production, production can still make financial sense for producers.

Comparison of the results of method 2,3 and 5

Method 2 (Figure 5): The slope of the dashed green line connecting the price maxima is -1.1%BOE/year. The line meets the zero line in 2027. In 2027, according to this diagram, a phase of continuously sharply decreasing sales begins.

Method 3 – Skipped in this translation

Method 5 (Figure 10): The slope of the extraction exergy is currently 1.25%BOE/year. The theoretically usable exergy content will be reached in 2029.

The three methods give almost the same result for the slope and end date. This accuracy is astonishing, because method 5 has two inaccuracies due to its principle: - Crude oil is produced to a large extent with other energies, e.g. from natural gas and coal. - Real efficiencies of gasoline and diesel engines are significantly below the 71 percent that can be theoretically achieved. The inaccuracies should lead to the fact that the real figures from the economy have deviations from the calculation. However, the real figures and the calculation are almost identical. The probable explanation is: Consumers pay at most as much for the oil as they themselves can earn with it. And their earnings are proportional to their share in the exergy of the barrel. Their share is the theoretically usable exergy minus the exergy used for extraction (Figure 11). Plotting the Thermodynamically Necessary Exergy (TNE) remaining for consumers for an efficiency of 69% on the oil price curve yields Figure 12, which shows a remarkable correspondence between maximum oil prices and the theoretical curve. The dashed green curve of Procedure 2 connecting the maximum values lies almost exactly on the thermodynamically calculated one. In most cases, however, less is paid than the limit allows. The very good agreement between calculation from physics and economic data demonstrates the validity of the thermodynamic calculation. It also provides an explanation why curves 1,2 and 4 have linear progressions: The underlying thermodynamic calculation results in an almost linear course of the pumping energy in the relevant period.

[3] The exergy necessary to change the temperature equilibrium is only the minimum exergy required.

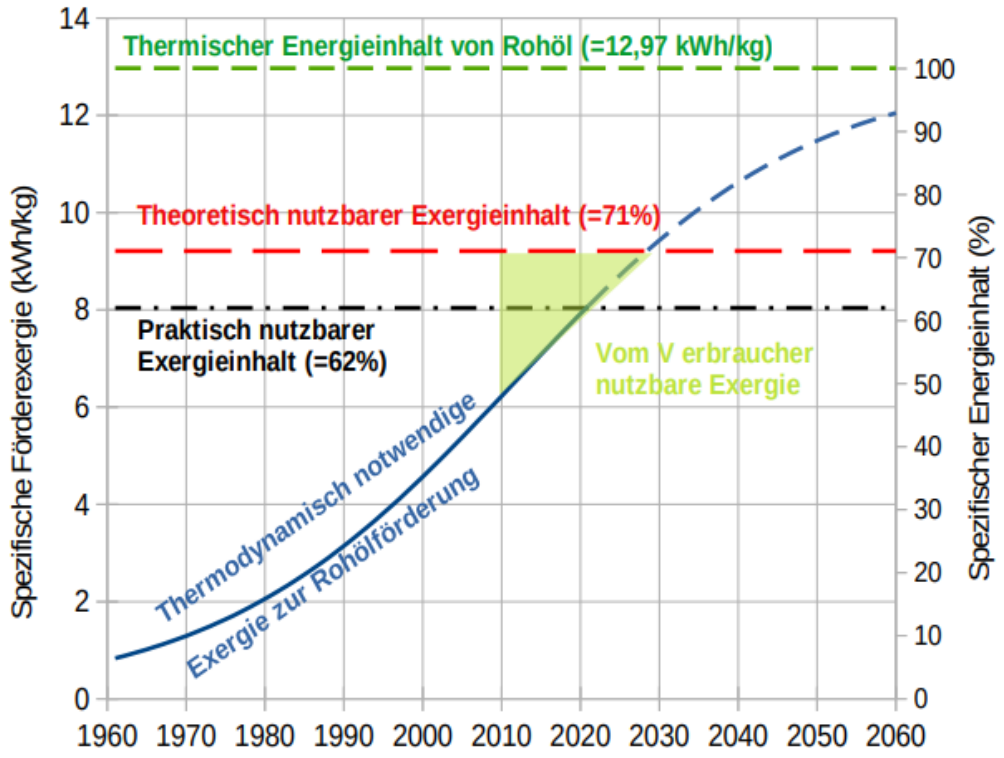


Figure 11: The light-green triangle marks the time range from 2008-2027. It shows the **exergy available for consumers**.

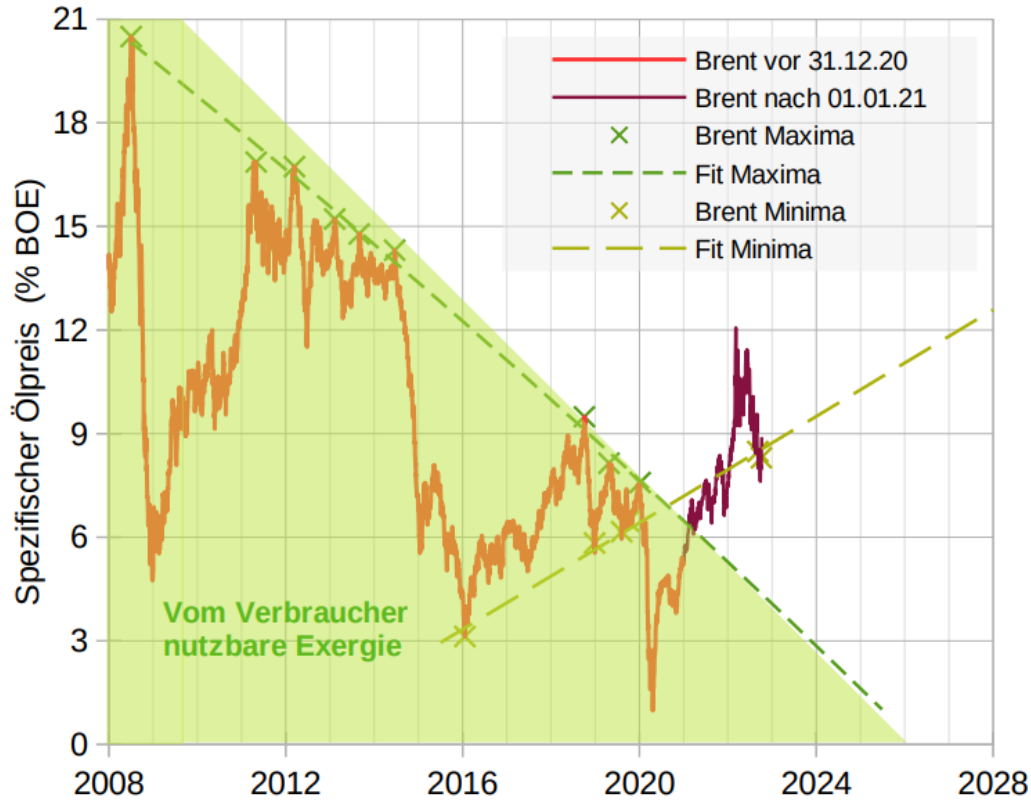


Figure 12: Real Brent oil price with maxima, as well as **residual exergy remaining for consumers** from the calculated Thermodynamically Necessary Exergy (TNE) for 69 % efficiency for the oil user. All values in % BOE.

The real price curve in Figure 12 is bifurcated, with the intersection in 2020. Before 2020, the oil price is determined by consumers, after that by oil producers. After 2020, the price of oil has risen above levels that are sustainable for consumers. Because oil producers use forms of energy such as coal and gas that cost less per GJ than petroleum, **they do not have a positive balance energetically, but they do have a positive balance financially**. The dark yellow line connecting the minima of the petroleum price indicates how much exergy the producers need. If the oil price falls near this curve, OPEC decides to cut production. The point at which the producers can no longer produce profitably depends not only on their own cost situation, but also on the coal and gas prices that will apply in the future and is difficult to estimate. In the past year, the prices of all fossil energies have risen sharply. There are clear differences between the continents, and the locally available reserves also vary widely. Europe is worst, China is best because of its coal reserves, and North America is in the middle. After 2030, oil production will be globally unprofitable and largely cease.

The price decline of crude oil from 2008 to 2020 with the extreme price increase since 2021 is an absolute alarm signal! Soon no more crude oil will be affordable, no matter for which national economy of the world!

Prediction of future oil production

Based on past car sales figures and the five methods, it is possible to make a prediction for future C & C oil production. It is expected that crude oil production will slowly decrease until 2027 because people spend their money on oil products to continue the lifestyle they are used to. They will just refrain from buying new cars. After 2027, they will be forced to give up oil products, which will become too expensive. Oil production will then decrease very rapidly.

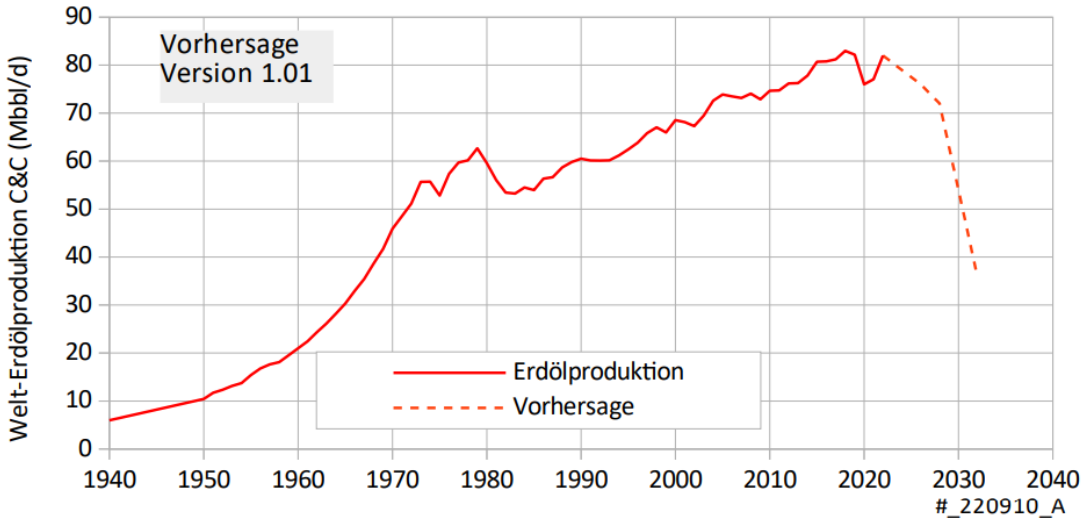


Figure 13: Prediction of Crude Oil Production

Summary

Procedures 1,2 and 4 are extrapolations of past economic data. Procedure 3 is a linkage of oil prices to passenger car production. Procedure 5 is a calculation based on a law of physics. The five calculation procedures result in:

1. end of the motor vehicle production of the world between 2031 and 2034.
2. end of the oil production in 2027.
3. strong decline of the world-wide sales of motor vehicles starting from 2027.
4. end of the German vehicle production in 2027-2028.
5. strong decline of the oil production starting from 2029.

The results are not exactly equal, but very similar in its final outcome. All five methods show that vehicle production and oil production will continue to collapse in the next few years. Vehicle production will disappear first. Oil production later, as the world's existing vehicle fleet will continue to consume oil even if no new vehicles are added. Oil production will decline slowly until 2027, then rapidly.

This means: crude oil will become extremely expensive in 2027 at the latest!