SICHERUNG DER MOBILITÄT - POLITIK UND PHYSIK IM WIDERSPRUCH?

SAVING THE MOBILITY - POLITICS AND PHYSICS IN CONTRADICTION?

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Life teaches us to choose our friends, partners and advisors wisely [figure 1]. Is the transport industry well advised to follow every current political and ecological ambition? Have those who frequently publicise their ecological demands to shape public opinion examined the effects on the environment and the welfare of the population? Have they been properly trained or simply been appointed as so-called political experts? Can we trust the ecological visions and the advocated solutions implicitly? When mobility comes under fire we should be on our guard.

The environmentalist movement emerged from a middle-class, affluent society. Puristic environmentalists (“fundamentalists”), who preached minimum consumption of all resources, and “realists”, who pursued a more moderate restructuring of society and its habits, agreed common objectives. Fundamentalists and realists were initially at odds with a public that feared losing its hard-earned status. The environmental debate largely ignored the fact that the at least 4 billion people trying to escape from poverty in the poorest developing countries had not even been included in the discussions on the division of the world’s energy resources and raw materials. The document published by the Rio Convention in 1992 (Agenda 21), which was also signed by the then chancellor of the Federal Republic of Germany, is as much well meaning and naïve as it is unrealistic [3]. Hundreds of billions of dollars were to be spent on the conservation of nature and resources. The document is defined by advice for the poorest on the efficient use of animal dung and firewood in combination with cheap fossil fuel and “renewable” energy (e.g. p. 121). It has meanwhile become clear that this has made no impression on second and third world countries, which use energy that is cheaply available to them on the world market, such as carbon dioxide and oil, to increase their prosperity [4], thereby turning them into the biggest CO\textsubscript{2} emitters [figure 2].

1 THE REORIENTATION OF ENVIRONMENTAL AWARENESS

In 1972 a study by the Club of Rome [1] on the finite supply of resources and the extrapolation of the limits of growth raised doubts in the Western industrialised world about the economies that had until that time been primarily orientated towards growth and prosperity. The disaster scenarios fuelled fears in western societies but were also met with criticism from reputable scientists, who called them “irresponsible nonsense” [2]. The ’68 protest movement sought to introduce ecological change via social and industrial structures and successfully transformed into the Green Party. Respect for our natural environment became and still is the guiding principle that every party now feels committed to.

Figure 1 Fox and goose (Source FAZ)
Since their political breakthrough in various fields some ecological initiatives have had to rely less and less on scientific facts for their alarming scenarios, which resulted, and still results, in misjudgements and scapegoat campaigns. The needless concern about the German forests was certainly well intentioned, and the Brent Spar campaigns, which were based on seriously wrong assumptions, have not particularly harmed their credibility. Yet, the dangers of deep-sea oil exploration being discussed today should have been highlighted back then. The current mistakes made by BP (Deepwater Horizon) unfortunately reconfirm that companies and their managers cannot be trusted to act environmentally responsibly per se. It took over 60 years before asbestos fibres were banned even though manufacturers knew about the carcinogenic effect of their products. As long as business does not establish self-cleaning mechanisms – something that industry associations could very well commit to – eco-NGOs continue to be absolutely essential.

Nowadays no party can afford not to take the public’s environmental concerns and worries about the future seriously. Politicians and environmentalists seek out problems, real or unprovable, such as the “climate gas” (5.2) carbon dioxide. They fuel fears and offer solutions. At the same time they now also raise our hopes that we will be able to sustain our comfortable western lifestyle. The potential eco-electorate is accordingly recruited from among the left-leaning population [5] and from among conservatives who want to safeguard their current status.

2.1 ECOLOGY AND ECONOMY

In the eighties a new ecology (the theory of household management) assumed political dominance over economics (the principles of household management). Justus von Liebig’s and Darwin’s originally neutral natural science of ecology became a positively loaded term so that ‘ecological’, and now also the prefix ‘eco’, became synonymous with environmentally compatible, clean or considerate. It is also used with ‘sound’ and ‘valid’. However, economics must not take a subordinate role to what has become a political and also ideological ecology. Economics tells us how much profit and loss is generated by ecology. In The Green Paradox the economist Hans-Werner Sinn [6] explains the Kyoto countries’ ecological misconceptions of a politically motivated restriction of the
demand for energy. This “green politics” would lead to relative reductions in energy prices on the world market, which would trigger additional demand in the countries that have not signed up to the Kyoto Protocol [cf. figure 2]. The “sustainability triangle” discussed below shows that “green politicians” are aware of the fact that ecological measures can harm prosperity and the welfare state.

2.2 SUSTAINABILITY

Sustainable development was not invented by modern ecologists but dates back to the 16th century and the aim to make optimum use of nature, e.g. woods and forests [7, 8, 9]. As late as the nineties, Konrad Ott [10] still postulated that ‘renewable, living resources must not be exploited to a greater extent than they are capable of renewing themselves’. He referred solely to biological sustainability. Today “sustainability” is demanded for practically every aspect of life.

Figure 3 Integrating triangle of sustainability

The sustainability triangle [figure 3] is supposed to permit the continuous integration of the three dimensions of sustainability, the environmental, economic and social [11]. It becomes clear that each optimum is in competition with the others.

The term sustainability still only makes sense in the context of biology when it is used to refer to the renewable that embodies a biological agenda. It does not apply to resources. Materials are subject to the principles of combinability and recyclability while elements are subject to transmutation. Energy cannot be sustainable either. It follows the laws of thermodynamics. More on this later.

There is another topic that is often ignored by modern “ecological sustainability”. When we consume resources we are supposed to think in ethical categories such as intergenerational justice. How many generations would be politically correct? Don’t our good intentions have to last until the scientific “end time”, that is, for about another two billion years when the earth will be destroyed by fire as it is enveloped by the sun? Maybe not quite as long? Perhaps one of the politicians preaching sustainability is prepared to make a firm commitment on long-term energy supplies in their election programme.

3 ENERGY POLICY

Energy policy is a central theme of the environmentalist movement and should also be an issue for centre-right and socially-oriented parties as explained below. It is likely that some environmental politicians, aware of the success of semantic shifts, have become careless. Glib, misleading “eco” word creations conceal the problems. Giving public recognition to simple laws of physics and economic and social banalities appears to be a difficult task. Perhaps
the universal benefits of physics and its branch of thermodynamics are simply being underestimated.

3.1 “ALTERNATIVE” ENERGIES

People from the Rhineland are familiar with the laws of thermodynamics without needing a degree in science. There the laws apply in a meaningful way to every aspect of the economy and society. In the vernacular the first law is expressed as Von nix kütt nix (Nothing comes from nothing) or in other words, perpetual motion of the first kind does not exist. You must have energy or money in the first place before you can consider its exploitation or lossy conversion. There is only one type of energy in physics. “Alternative energies” do not exist in physics or in real life.

3.2 “REGENERATIVE” OR “RENEWABLE” ENERGIES

The second law of thermodynamics is equally clear and comprehensible to people in the Rhineland: Wat fott es, es fott (What's gone is gone). Or, in scientific terms, there is no perpetual motion of the second kind. Those who talk about “regenerative or renewable energy” do so out of ignorance or to hoodwink the average citizen. So why is it that the Renewable Energy Sources Act (EEG) was passed on the basis of a non-existent physical effect? Ignorance? Obfuscation?

We must appeal to the scientific community and ask them to categorically avoid using manifestly manipulated physical terms such as “alternative”, “regenerative” and “renewable” energies in future.

4 MAN AS AN ENVIRONMENTAL PROBLEM

The two principal laws of thermodynamics also lead us to the recognition that as human beings we live a “parasitic” life in terms of energy. Regardless of whether we cultivate plants that biologically absorb the rays of the sun and then consume this energy in the form of food with a loss of efficiency or whether we prefer to go to the next stage of the food chain and consume animal products with further losses (cf. 4.2). We can live even more effectively and more parasitically if we use bio-energy formed over millions of years by digging up coal or extracting oil. Prosperity depends on cheap energy that is easily accessible and easy to store.

There is no doubt that prosperity for all is a noble political goal. Poverty is supposed to be eradicated throughout the world [3]. This is where knowledge of physics and the willingness to embrace new technologies are extremely useful. It isn’t energy consumption that should weigh on our conscience but waste and a lack of efficiency.

However, are the available energy and fuel supplies actually finite? Could we live a “sustainably” parasitic life? More on that later.

4.1 MOBILITY AS THE FOCUS OF “ECOLOGICAL” POLITICS

The Extra-Parliamentary Opposition, the ’68 generation, transformed into a stable group of voters in favour of an authoritarian environmental policy. They are backed by a well-supported eco-industry involving NGOs, environmental institutes, experts and specialised lawyers. They take up – almost as their unique selling point – a wide range of ecological subjects, the majority of which are also considered to be important by the general public. As fast followers the centre-right and left parties can hardly ignore these issues. The current initiatives to reduce air pollution caused by particulates and nitrogen oxides are a good example of this. The problem here is not the transport industry but the fact that European and national governments and legislators have completely failed. Air pollution limits, which have a verifiable effect on average life expectancy, are years ahead of comparatively lax vehicle emission limits. It remains to be seen whether vehicle and engine manufacturers could have addressed this imbalance through early compliance with the next statutory limits. Technically speaking, car manufacturers are beyond reproach when it comes to the introduction of catalytic converters or particulate filters. In both cases the introduction of new environmental technology was not the result of binding immission legislation or mandatory European vehicle emission limits. Voluntary introduction is possible only if customers are prepared to pay for it, and to this day there are few exceptions to this rule. In spite of all this, the German car industry was pilloried by politicians and environmental organisations. It has not been able to shake off the stigma to this day. Since the credibility of the car industry is well below that of Greenpeace any resistance to the biased treatment handed out by the parties and the media seems to have been broken.

Would the public even notice if car manufacturers correctly advertised the fact that engines equipped with modern exhaust aftertreatment are actually able to at least
partially clean the ambient air? And why aren’t we told that electric vehicles will never be able to do this? A car manufacturer from Southern Germany launched a misleading press campaign that suggested the opposite by depicting an exhaust pipe with a knot in it. The high NOₓ/NO₂ concentrations in urban areas that have been shown to cause cell damage are a different matter. Here, too, there is a huge gap between permissible emissions and immissions. The fact that this is not discussed to a greater extent by the political parties and environmental organisations may be due to the already effective CO₂ climate debate and the unavoidable CO₂ emissions from combustion engines. The combustion engine industry could avoid NOₓ levies through exhaust aftertreatment. This would not be possible in case of a CO₂ tax. The entire vehicle industry finds itself in a CO₂ climate trap. Perhaps the only means of escape is the CO₂ emission certificate malus range applied in industry. This approach is also supported by the move towards electric vehicles [figure 4], especially when strict CO₂ limits take effect.

Is this the reason why there is no resistance to a malus tax applied to those who exceed the CO₂ emission limit for fossil fuels? Or why the much higher (China) or comparable (Germany) CO₂ emissions inherent in electric transport are dismissed? Was this overlooked by the car lobbyists of the organisations? And by the suppliers as well? Is this the very reason why the future prospects for the internal combustion engine look so grim? Honi soit qui mal y pense!

4.2 CONSUMERS AND ENERGY PRICES

It needs to be said again that even those living in abject poverty in the developing countries live a parasitic life. Affluent societies obviously enjoy a more pleasant and energy-hungry life [figure 5]. As mentioned above, we consume energy in the form of food by cultivating and eating plants that grow in the soil with the aid of sunlight; or we feed these plants to animals to produce 1 kg of meat from approximately 7 kg of concentrated feed. One thing is clear, further energy losses are inevitable if we want to consume energy-rich foods to satisfy our demand for plant or meat-based energy. The eradication of poverty, an important goal of Agenda 2010, is accompanied by a rise in meat consumption and vehicle density as GNP increases [12].

Figure 4 Taxes in euro/t CO₂ w/o VAT [6] midsized car; 7l/100km; 20k km; 3,3 t CO₂; taxes € 1,090 p.a.)
Fossil fuels have been the most effective and cheapest method of generating energy (cf. 4) since time immemorial. The same applies to uranium and thorium for nuclear power stations. If you can afford the energy it is essentially possible to optimise all agricultural produce and make industrial consumer goods with the appropriate raw materials and processes. Two conclusions can be drawn here: food, raw materials, energy or their products can be expressed in terms of financial value. If one or several of these variables become more expensive the remaining disposable income is reduced. The resulting decline in prosperity and rise in poverty will sooner or later also affect the state’s budget. Over the past few years this point has been clearly illustrated by the increase in energy costs alone. We have seen a particularly rapid rise in energy taxes paid by consumers [figure 6].

The feeding-in of wind and solar power increases the price that consumers pay for their energy supply by approximately 2 cents/kWh. At present all parties impose this additional burden of approximately 10% on the population. The planned transition toward “renewable” energy will raise prices even further with the apparently inevitable changeover to a so-called ecological energy supply. No proof has yet been offered that one day in the distant future wind and solar power will cost the same as power generated by light water reactors (production costs) [14-19] or 5 to 8 cents/kWh (market costs) [20, 21]. Anyone giving incorrect information in relation to the widely varying costs will be met with incomprehension from the educated public. In addition, attention is also diverted away from the...
fact that since 1998 disposable income has already fallen by around 8 percent because of rising energy prices [figure 7].

![Graph showing possible income after deduction of energy costs in 1998 and 2009](image)

As all human life is inherently parasitic, *carpe diem* should also be understood to mean that after death and after having irretrievably converted vast amounts of energy for various purposes man should leave something behind for the benefit of nature – for the good of “sustainability”.

5 Environmental policy influences future energy and drive concepts

5.1 The first threat to combustion engines: CO\(_2\) and climate taxes

The same principle applies to both people and machines; they both require energy. If energy is available, profitable and productive time can be extended and output per time unit can be increased.

The first measure is unlikely to have much effect on employees in highly developed countries because of our social achievements. In the developing countries both variables still apply to a significant extent. We exploit each variable by outsourcing production to low-cost countries. What helps us in the western world to be productive and socially responsible is the largely optimised division of labour in our industrialised sector. Mobility and the means of communication reduce losses. Specialisation improves processes and increases capacity, which also reduces losses.

Energy sources with a high degree of enthalpy, such as petrol and diesel, and efficient combustion engines are what have made mobility, effective transport and the rational division of labour possible in the first place. Therefore we owe a great deal to mobility, especially individual transport. However, since we have access to sophisticated alternatives, including trains, aeroplanes or ships, environmental politicians can call our automotive mobility into question without running the risk of having to properly justify their claims.

We should not forget that effective protection of the environment depends on whether we are able to afford it. We will be able to afford to operate combustion engines that can clean the environment.

The cars that were our pride and joy and that promised us freedom and prosperity have become subject to a series of increasingly critical factors: oil crises, land use, harmful exhaust emissions and most recently the above-mentioned inescapable CO\(_2\) problem. Even if cheap fossil fuel made from crude oil continued to be available the combustion engine would not be able to escape “eco-politics”. In future our oil reserves could be stocked up with natural gas as a substitute fuel [figure 8]. However, the combustion of natural gas releases carbon dioxide, too, albeit to a lesser extent. Those responsible should be well aware that obstacles to mobility reduce productivity and prosperity (see figure 3).
From 2015 CO₂ emission limits for passenger cars will be 130 g/km in the EU and from 2020 this limit is anticipated to be 95 g/km. Similar limits can be expected for light and heavy commercial vehicles. This measure will not slow the rise in fossil fuel consumption [figure 9]. In fact, it is going to increase especially in the non-OECD [cf. figure 2] or non-Kyoto countries [6]. Biofuels are not a universal option as experts have been warning of competition with food crops and the effects on food prices since the early nineties.

5.2 IS CO₂ A HARMFUL CLIMATE GAS?

The vast majority of climate scientists who have published papers on this issue support the findings of the IPCC [24]. The IPCC’s climate scenarios are based on an increase in the CO₂ content in the air from 0.032% in 1960 to approximately 0.038% at present. On this basis, the IPCC concludes that temperatures will rise from 1.1 °C to 6.4 °C, i.e. to levels that are dangerous to humans, by the end of the 21st century.

Critics point out that the data that was simulated using computer models is flawed and that the various calculated forecasts were published as average results. The climate of the past millions of years is well known to geologists. Shouldn’t at least some of the known warm periods and ice ages be included in the calculations of the climate models in order to validate the simulations, which might make it possible to
extrapolate future trends? So is the work of the IPCC members nothing but a valuable intellectual exercise and not science? The reasons for these doubts are the many mutually interactive variables and imponderables that defy a scientific, reproducible, comprehensive model.

Almost all politicians, with the notable exception of the Polish Prime Minister Donald Tusk and the Czech President Václav Klaus, have decided to introduce a CO₂ tax to prevent the predicted climate catastrophe. Geology provides more reliable data: This branch of science arrives at the opposite, and this time reproducible, conclusion, that the CO₂ concentration in the air increased after the climate had changed [25]. During a beneficial warm period some one to two million years ago when the human race evolved the CO₂ content in the air was 5%.

Both camps agree from today’s initial position that we are currently going through a mini ice age, during which according to definition at least one of the earth’s poles has to be covered with ice. So with the correct scientific approach they should arrive at the same result for the past and the future.

Experts therefore anticipate the price of crude oil to rise steadily [figure 11]. This price trend inevitably raises petrol and diesel prices to the level of the currently more expensive alternative fuels or biofuels.

5.4 PLAYING POLITICS WITH ENERGY RESERVES

Figure 12 shows that even according to conservative estimates fossil fuel supplies will run out within 6 to 20 generations (reserves of approximately 300 years) based on current inevitable worldwide consumption behaviour [figure 2] [27, 28].

The interested average citizen is going to be painfully aware that details about energy reserves are clearly being used to manipulate the public. Ecologists claim that nuclear power will only be available for another 40 years while the representatives of the nuclear industry say that reserves will last 300 to 10,000 years. This would represent an energy reserve equivalent to up to 400 generations. Not quite “sustainable” but it would give us more time to develop a sensible energy policy. We should remain optimistic. The tangible economic effects of rising energy prices will encourage people to “search” for cheaper and more environmentally friendly energy.

Figure 10 Historic and future ways of oil exploitation methods [26]

5.3 THE SECOND THREAT TO COMBUSTION ENGINES: CRUDE OIL SHORTAGES AND PRICES

At some stage fossil fuel supplies from deposits that are difficult to extract, such as tar sand and oil shale, will also run out [figure 10].
Figure 11: Price trend reflects shortages of oil reserves.

5.5 NUCLEAR FUSION

A successful outcome of the international fusion experiment at ITER would make nuclear fusion, besides sun and wind, the only type of new energy source that is geared towards the earth’s life cycle. This energy source should last (see above) until the day the earth is destroyed by fire in approximately 2 billion years. The first CO$_2$-free fusion reactor is expected to go online in 2050, by which time the demand for electricity will at least have doubled. The reactor will not produce nuclear waste with a long half-life. Unfortunately, this seemingly perfect energy source arrives too late to ward off the two above-mentioned threats to the combustion engine.

So do we have no option but to accept energy price rises and a decline in our standard of living?
If in awareness of the finite nature of fossil fuels, such as coal, crude oil and natural gas, we reject nuclear energy, don’t believe in nuclear fusion and know that bio-energy is expensive does that mean that we have to hope for a miracle?
Are there ways out and solutions whose only obstacles are political and ecological interests?

6 POSSIBLE WAYS OUT OF THE CO$_2$ AND PROSPERITY TRAP?

6.1 METHANE HYDRATE?

Methane extracted from methane hydrate is an alternative fuel that has been largely unexploited so far. Vast quantities are found primarily near coastlines in the Arctic and Antarctic. At an estimated 12 billion tonnes the available quantities of methane hydrate exceed the entire fossil fuel reserve and are said to account for 50% of organic carbon. The natural release of methane into the air and the massive release predicted by geologists as a result of global warming are critical factors. The extraction facility in the Siberian methane hydrate fields in the Krasnoyarsk region is still the only industrial and commercial plant in the world. Germany is currently involved in another industrial research project.

If the assessment of the climatic effects of CO$_2$ is based on climate simulation rather than geology these gigantic reserves would be rendered virtually useless because of CO$_2$ emission limits. In fact, they would present an even greater threat than CO$_2$ itself because of the climatic effects of methane (or is this just what climatologists believe?); nor would they be “sustainable” in terms of a green ecology because even gigantic reserves are ultimately finite.
6.2 SYNTHETIC FUEL PREPARATION

6.2.1 PROCESS HEAT

Coal and lignite – even from domestic sources – can be “charged” with hydrogen to form more energy-rich hydrocarbons using known CTL processes. Worldwide coal reserves are around 1 billion tonnes. The German lignite fields contain as much energy as all the Iraqi oil fields combined. Coal is extracted in Eastern Europe, Asia, Australia and America, often in open cast mines. Instead of burning coal to generate electricity it could be used as a suitable basis for fuel. The process heat should be generated by wind, water or solar power or by transmutation (the conversion of one chemical element into another through nuclear reaction) in inherently safe high-temperature reactors (HTR) without releasing CO$_2$. This way coal could be converted into cheap designer fuels for around 50 to 60 cents per litre. The benefits are obvious; a safe fuel reserve for combustion engines that would last for the next several hundred years.

One political problem remains. The generated fuel releases CO$_2$, albeit less than fuel produced from crude oil.

6.2.3 Batteries

Electrochemical batteries

In electrochemical terms, charging batteries is a rather straightforward physicochemical process. However, combining high capacity with low weight, volume and cost is not. In this age when there is so much political hype surrounding electric vehicles, many partially contradictory papers have been published on the potential and the reality of electrochemical batteries. We should let electrochemical experts rather than professional optimists express their views on this matter.

“Chemical batteries”, a CO$_2$ recycling process

It is a well-known fact that at the appropriate temperature carbon and hydrocarbons can combust and produce thermal energy when oxygen is supplied. The end products of complete combustion in an engine or power station are carbon dioxide CO$_2$ and water H$_2$O. In the Fischer-Tropsch synthesis and the nuclear process heat method mentioned above the coal has already been “chemically charged” using an industrial process to form more energy-rich hydrocarbons. China is currently building a high-temperature reactor that was developed in Germany.

Can this be applied universally and taken to the next stage? Could the “climate gas” CO$_2$ and
water be “chemically charged” using a suitable process and the addition of energy? Perhaps even at a rich source of CO$_2$, such as the stack of a coal-fired power station? Would it make coal-fired power stations more acceptable if the CO$_2$ was part of a closed loop like biofuels? The necessary “charging energy” would have to be generated from solar (any kind), wind, water, nuclear or fusion power. This would be an environmentally friendly and CO$_2$-free method. And what would be the cost? For example, per litre of petrol?

To answer this question we developed an approximate process and system design. Our aim was not to propose the construction of a plant but to show that we can apply physics –

![Figure 13: Process scheme of CWTL-plant](image)

and in this case chemistry – to solve the two core problems of the internal combustion engine. Firstly, the problem of eco-politics, that is, fuel production that does not release new quantities of CO$_2$ (CO$_2$ recycling). Secondly, the process could also be applied sustainably. Fuel could be produced for as long as cost-effective energy was available. Consumers or transport providers could still decide what price they would be prepared to pay for petrol or diesel to use these highly ‘compact’ energy sources in cars, trucks or aeroplanes not least because of the distances they enable us to travel.

We analysed the costs of the investments, materials, energy and operation to estimate the price of the end products.

6.2.3 Process evaluation of ‘carbon dioxide & water to liquid’ (CWTL)

Figure 13 below shows a process diagram of the CWTL process (carbon dioxide & water to liquid fuel). The purpose of this process is to chemically utilise the CO$_2$ generated during coal burning as a recyclable material and (with the supply of energy) reconvert it into a source of chemical energy. The process is essentially based on a conventional coal-fired power station with a circulating fluidised bed. It deviates from the standard insofar as it is not solely being powered with atmospheric air but with a mixture of air and pure oxygen from a water electrolysis system. The main purpose of the water electrolysis system is the generation of hydrogen, which is needed to catalytically convert CO$_2$ into methanol. This slightly exothermic reaction is catalysed by CuO/ZnO/Al$_2$O$_3$ contact and occurs at approximately 250°C and 50-100 bar of pressure with a yield of 71% and a CO$_2$ conversion of 98%. However, the CO$_2$ produced in the combustion step first has to be enriched in a physical scrubber operating at approximately 80% efficiency. Finally, the methanol is catalytically converted on a ZSM-5 zeolite at 300-400°C with an 85% yield to form 49% aliphatic (non-aromatic carbon-hydrogen compounds) and 27% aromatic hydrocarbons. The process was based on a typical 300 MW coal-fired power station. Figure 14 shows all material and energy flows. The process converts approximately 92 tph of coal and produces 69 tph of petrol and almost 10 tph of an energy-rich gas mixture that is similar to natural gas. 300 MW of the released electric energy come from coal burning and approximately 15 MW from the conversion into petrol, however electrolysis uses up 1690 MW.
and CO$_2$ scrubbing consumes 5 MW so that in total the process requires approximately 1420 MW. Nonetheless, at almost 50% the process achieves a high degree of efficiency (cf. figure 15)

The reason for this good efficiency balance is the large amount of chemical energy contained in the generated fuel:

$$\eta_{\text{overall}} = \frac{\dot{m}_{\text{fuel}} \cdot \eta_{\text{chem. advance}} + \dot{m}_{\text{fuel}} \cdot \eta_{\text{thermal advance}}}{\dot{m}_{\text{fuel}}} = \frac{1245.2 \text{ MW}}{1525 \text{ MW}} = 89.3\%$$

This results in a revenue of

$$\text{Erlös} = \frac{128100 \text{ m}^3/\text{h} \cdot 1.96 \text{ kg/m}^3 \cdot 20 \text{ €/t CO}_2 \cdot 8000 \text{ h/a}}{1000 \text{ kg/t CO}_2} = 40.2 \text{ Mio €/a}$$

Accordingly, CO$_2$ recycling reduces CO2 emissions by 2 million tonnes per year.

All in all, the resulting total costs are approximately 450 million euros at an expected lifetime of 20 years and an operating time of 8,000 hours per year. The above-mentioned petrol production would result in a price of 61 cents per litre.

In relation to today’s costs for petrol made from petroleum distillate this appears to be a more than acceptable alternative, especially since it can be produced in a CO$_2$-neutral process. If one were to extrapolate this quantity of petrol produced per 300 MW coal-fired power station (550 kt p.a. of petrol) to the complete power station output in Germany (31800 MW in 2008) the resulting petrol production would cover approximately 71% of fuel consumption in Germany (based on 2005 figures).
Carbon capture storage (CCS) was developed to reduce CO$_2$ emissions into the atmosphere. The process involves concentrating the CO$_2$ emitted by a coal-fired power station and injecting it into sedimentary rocks at high pressure. The CO$_2$ displaces any seawater in the rock and remains there in a supercritical state because of the high pressure. However, the fact that a large part, in fact 40%, of the electric energy generated in the coal-fired power station has to be expended on the separation, conduction and compression of the CO$_2$ is a drawback that substantially reduces the efficiency of the power station process.

Figure 16 shows a comparison between the efficiency factors of CCS and CWTL. While the CCS process uses about 40% of the generated electric energy to simply remove CO$_2$, the CWTL process actually produces petrol at an efficiency of 50%.

Table 1: Portion of costs for the construction and operation of a CWTL plant, (lifetime 20 years, 8,000 hours per year)

| CO$_2$ scrubbing | 239 * | -803 * |
| Electrolysis | 2545 * | 7192 * |
| Methanol synthesis | 380 * | -73 * |
| MTG system | 146 * | -497 * |
| **Total** | **3310 *** | **6622 *** | **-803 *** |
| **Sum total** | **9129** |
| **per year** | **456m p.a.** |

6.2.4 COST COMPARISON OF ALTERNATIVE FUELS

Figure 17 below shows a cost comparison between the most important technologies used in the production of synthetic fuels and conventionally produced petrol and diesel. The price of the electricity used for electrolysis is a crucial factor in the calculation. Energy for the CWTL process was supplied from a nuclear power plant at a cost of 3 cents per kWh. This perfectly illustrates the fact that the amounts of energy required in everyday operations are set by political energy concepts and not by economic requirements. Of course, the CWTL process also works with wind or solar power but the effects of substantially higher cost prices make it less economic in case of wind power and unattractive in case of solar power.

If the general public knew that they could influence consumer energy prices they would doubtlessly be more interested in the underlying principles and want to have more control over the decisions.

![Figure 16: Comparison of efficiency of CCS and CWTL](image-url)
6.2.6 CONCLUSIONS:

Ethanol and BTL are associated with by far the highest production costs. BTL would in theory be able to cover between 100 and 150 percent of the fuel requirement in Germany (2005) (demand = 8.2m tonnes p.a.). This is based on BTL requiring between 2.8m ha (environmental scenario) and 4.2m ha (biomass scenario) of arable land in Germany (approx. 14m ha) for the cultivation of biomass.

Similarly, GTL would currently be able to cover 134% of demand in Germany. However, this is based on the currently available worldwide GTL production capacity.

The cost of the potentially CO₂-neutral petrol produced in a CWTL process would be similar to those of ethanol and plant oil depending on the chosen method. This makes CWTL petrol the only fuel in this comparison that has a very high calorific value and is made from regeneratively processed CO₂ and water. CWTL petrol could also be produced in large quantities at quite competitive cost.

In principle, the CWTL process would therefore make it possible to sustain combustion engine-based transport at acceptable costs.

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**Figure 17:** Production cost of fuels, energy content (Exception: natural gas: import Price)
7 SUMMARY:

A lemming bucking the trend (Source FAZ)

In the eco world knowledge and honesty may make you lonely but:

- Politics must be judged by the following: Only physical and economic truths can put us on the right ecological track.

- Ecology and economy must go hand in hand: Energy costs have a decisive impact on prosperity.

- We have to let go of “eco” terminology and errors and promote sustainable energy concepts designed to last for the lifetime of the earth.

- In principle, the CWTL process can be used to recycle CO₂ and water to form petrol.

- Combustion engine-based transport will have a future for as long as cheap electricity is available.
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