The impact of fossil fuels

Greenhouse gas emissions, environmental consequences and socio-economic effects

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Summary

This is a study examining the greenhouse gas emissions, environmental impacts and socio-economic effects of the production of conventional and non-conventional fuels and formulates both practical recommendations for climate protection measures in the transport sector and for social and environmental standards for fossil fuels.

The basis for the evaluation of greenhouse gas emissions, environmental impacts and socio-economic effects is the evaluation of predictions regarding future petroleum production. The comparison depicts a broad range of prognoses, up to 2030. In this, the International Energy Agency (IEA) does not anticipate a reduction in overall petroleum production over the next two decades, despite the strong production decline in the currently existing fields. This is because according to its estimates an additional c. 1.2 to 1.3 trillion barrels are still available. However, it is assumed by other peak oil experts that the easily extracted petroleum reserves will soon be exploited and the utilisation of difficult to access petroleum reserves is limited due to technological problems. Because of this, current estimates anticipate a reduction in global production from over 80 million barrels of petroleum daily to between 40 and 76 million by 2030.

There is no uniform definition of unconventional petroleum. This study refers to unconventional petroleum as deposits that require elaborate processing in order to attain the characteristics of crude oil. According to this definition, unconventional petroleum includes Bitumen or raw oil from tar sand, extra heavy oil and pyrolysis or crude oil made from oil shale. In addition, synthetic fuels made of natural gas (GTL) and coal (CTL) are included as unconventional fuels. In short, it can be said that at the present time unconventional fossil fuels represent approximately 5% of global petroleum production.

However, we can assume a strong increase in the production of unconventional fuels, since, particularly in developing and emerging countries, a powerful increase in mobility resulting in up to three times current capacities is to be expected. This will lead to a corresponding increase in demand. The transport sector's share in total petroleum consumption will rise from a current rate of 52% to 57% by 2030.

In regard to greenhouse gas emissions, it is important to recall that the CO_2 emissions of unconventional fuels are up to two and a half times higher than fuels made from conventional petroleum. Fuels made from coal and oil shale perform the worst in this. But emissions from conventional petroleum can also rise by up to 50% due to increasingly elaborate extraction technologies and processing, deeper deposits, high gas flaring and stricter fuel norms.

The range of greenhouse gas emissions from conventional fossil fuels shows that the EU reference value for diesel and motor petrol, at 302 g CO_{2eq}/kWh and a diesel reference value of GEMIS 4.5 at 313 g CO_{2eq}/kWh, has been set too low. Working from this, the current German average value for diesel fuel would have to lie between 335 and 360 g CO_{2eq}/kWh.

In 2008, global petroleum production and utilisation resulted in greenhouse gas emissions ranging from 13.5 to 15 billion t CO_{2eq}. Petroleum emissions thus correlate to the approximate scale of global greenhouse gas emissions from coal use, namely from 14 to 15 billion t CO_2. However, the comparison of pure combustion emissions of 10.8 billion t for petroleum and 12.6 billion t for coal leads to underestimating of the climate balance in the petroleum sector.

The comparison of the greenhouse gas balances of various fossil fuels with their production costs reveals no direct correlation between the level of the greenhouse gases and the production costs. The most expensive fuels are oil shale, CTL and GTL: the greenhouse gas balances of these, however, differ greatly. Underground coal gasification, one of the fuels with the highest level of emission, entails considerably lower production costs.

Analysis of socio-economic effects reveals that particularly those states rich in resources are affected by strongly negative social and economic impacts in regard to such areas as child mortality, life expectancy or average incomes. When evaluating studies on environmental impacts, it is important to note that all petroleum extraction methods have massive negative environmental effects on human beings and the natural assets of air, soil, water etc.

In two exemplary scenarios, 'constant demand for fuels' and 'growing demand for fuels', it becomes clear that, even if demand remains constant, a considerable rise in greenhouse gas emissions from 8 to 10 billion t/CO_2 can be anticipated in the transport sector. The growing demand for fuel would lead to an increase in emissions from approximately 5 billion t CO_2, 60% more than today. This worsening is particularly due to the increasing quantities of unconventional fuels. But the CO_2 emissions from conventional fuels are rising, even though in both scenarios their production will sink from 79 to 71 million barrels per day by 2030.

In the transport sector, promising political framework conditions do not exist for climate protection. A follow-up agreement to the Kyoto Protocol and the measures, to some extent merely national or regional, that have been taken for CO_2 reduction, will by no means be sufficient to stop the increase in greenhouse gases from fossil fuels. Only massive expansion in the area of sustainable biofuels, the quickest possible introduction of renewable electro-mobility, increased efficiency in motor technology and the expansion of local public transportation and rail transport can lead to CO_2 reductions.

The potential calculations in this study show that half of today's global fuel consumption could be covered by biofuels provided that a quarter of the globally degraded surfaces were to be utilised. Even with rising demand, this quantity of biofuel is sufficient to provide a complete substitute for the growing quantities of unconventional fuels.

Due to the massive negative socio-economic and environmental effects, the study recommends social and environmental standards not only on the basis of self-commitments on the part of the petroleum industry but also by the placing of globally binding, verifiable standards upon the petroleum industry.

List of Abbreviations:

API: American Petroleum Institute = Specific volumes of crude oil

ASPO: Association for the Study of Peak Oil & Gas

BGR: Bundesanstalt für Geowissenschaften und Rohstoffe (Federal Institute for Geosciences and Natural Resources)

CBM: Coalbed methane

CDM: Clean development mechanism

CHOPS: Cold heavy oil production with sand

CTL: Coal to liquid process for the manufacturing of liquid fuel from coal

CSS process: Cyclic steam stimulation

EIA: Energy Information Administration of the US Government

EID: Erdöl-/Energie-Informationsdienst (Petroleum/Energy Information Service)

EPA: United States Environmental Protection Agency

EOR: Enhanced oil recovery

EUROPIA: European Petroleum Industry Association

EWG: Energy Watch Group

GTL: Gas to liquid process for the manufacturing of liquid fuel from natural gas or other gases

JI: Joint Implementation

IEA: International Energy Agency

LNG: Liquid natural gas

NETL: National Energy Technology Laboratory

NGL: Natural gas liquids from natural gas production

OECD: Organisation for Economic Co-operation and Development

OPEC: Organization of Petroleum Exporting Countries

PAH: Polyaromatic hydrocarbons

SAGD process: Steam assisted gravity drainage

TEOR: Thermal Enhanced Recovery – Enhanced extraction methods with steam injection

THAI process: Toe-to-heel air injection

UCG: Underground coal gasification

Vapex process: Vapour extraction

WBGU: German Advisory Council on Global Change

WEO: World Energy Outlook

WEC: World Energy Council

WOR: Water to oil ratio – Ratio of water consumption to petroleum production

WTW emissions: Well-to-wheel emissions: Greenhouse gas balance encompassing all process steps and fuel combustion

WTT emissions: Well-to-tank emissions: Greenhouse gas balance encompassing all process steps up to the fuel tank

1 Introduction

In the coming years, the production of so-called unconventional fuels, e.g. from tar sand and extra heavy oil, will achieve greater global significance. Their production has been subject to heavy criticism in the current discussion due to their presumably higher greenhouse gas emissions. However, the public has so far ignored two important aspects:

Already the production of conventional fuels has frequently resulted in a drastic rise in emissions from greenhouse gases as well as disastrous environmental impacts. At the same time, profound social effects can be observed in the producing countries, which are occasioning almost irresolvable problems in those states affected.

The production of unconventional fuels leads to strongly elevated greenhouse gas emissions as well as environmental damage, both of which have profound impacts on the respective ecosystems.

The German Renewable Energy Federation (BEE) and the Association of the German Biofuel Industry (VDB) have used this fact as an opportunity to raise awareness of the problems of fossil fuel production with its own study, 'Greenhouse gas emissions, environmental impacts and socio-economic effects of conventional and unconventional fuels'.

The study will first examine both the issue of peak oil, one being discussed in academia, and the future production of fuels from unconventional petroleum production. In a second step, the study will compare the greenhouse gas emissions and production costs of fossil fuels. In a third step, it will present the socio-economic effects and the environmental impacts of unconventional and conventional fuels. In the last chapter, the study will assess the impacts of unconventional fuels on the long-term development of greenhouse gas emissions in the transportation sector and possible substitution effects through biofuels. In conclusion, recommendations for the limitation of greenhouse gas emissions and for social and environmental standards for fossil fuels are to be offered.

2 Projection of petroleum production to 2030

2.1 Development of petroleum production to 2008

Global petroleum production has increased tenfold over the past 60 years (see Illustration 1, Development of petroleum production, 1925-2005). However, between 2005 and 2008 petroleum production rose by just 1%.[1]

[1] EIA 2009

Approximately 70 million barrels of conventional petroleum are being produced per day. [2] In addition to this are approximately 10 million barrels of liquid hydrocarbons from natural gas production (NGL) and approximately 1.7 million barrels of unconventional fuels from tar sand, natural gas (GTL), coal (CTL) and chemical additives[3] (see Illustration 14). The following illustration shows the high proportion of super-giant oil fields in total output.

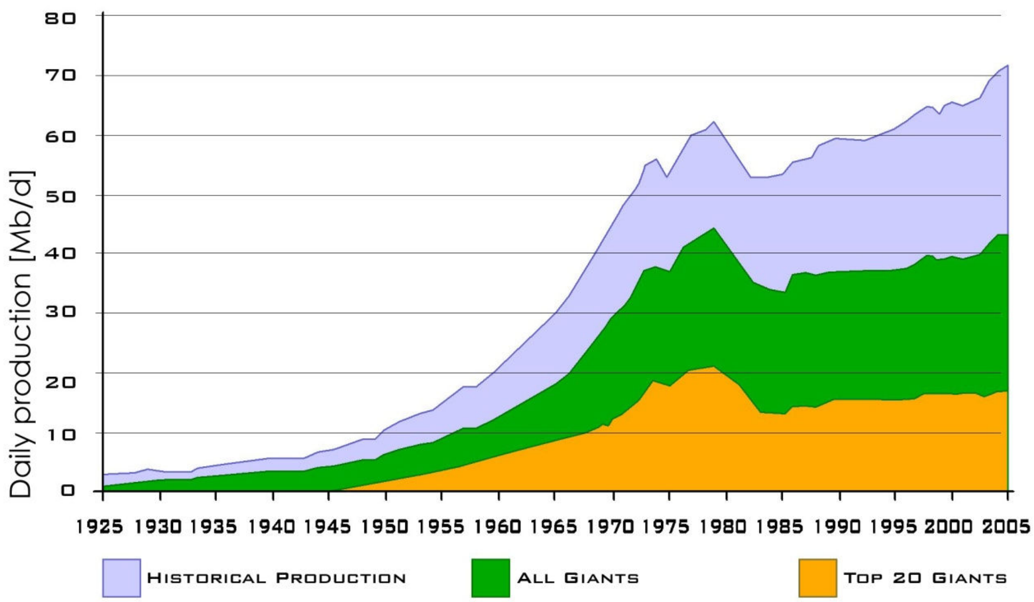

Illustration 1: Development of petroleum production, 1925-2005[4]

2.2 Development of production declines in current oil fields

Across the globe, evidence is mounting that the production of conventional petroleum will soon reach its peak. The IEA is also warning about future supply bottlenecks as production in oil fields that have already passed their production peak (post-peak fields) is already in sharp decline. [5] According to the analyses of the IEA, the average global annual production decline in post-peak oil fields amounts to 6.7%.[6]

Rates of production decline have risen sharply in recent decades since production in post-peak oil fields is dropping more quickly than in those from older deposits: According to the analysis of the IEA, post-peak fields that began production before 1970 display a production decline rate of under 4 %/a, whereas fields opened up after 2000 display a more than three times higher rate of decline.

This development can be traced to a number of factors:

[2] Incl. Extra heavy oils. Definition of extra heavy oil Table 2. Own estimate according to IEA 2008a and EIA 2009.
[3] For example MTBE
[4] Höök, Hirsch and Aleklett 2009
[5] IEA 2008a, Connor 2009, Birol 2009.
[6] IEA 2008a.

Technological development: technologies are increasingly being used to raise the degree of oil recovery, i.e. the exploitation of the fields. The more intensively oil recovery technologies are employed, the more sharply production sinks after the production peak.[7] The enhanced oil recovery (EOR) technologies include thermal processes such as steam injection, the injection of gases (nitrogen, CO_2) and the use of chemicals to lower the petroleum's viscosity.**[8]** Globally, between 3% and 4% of all petroleum is produced using EOR technologies.[9]

Oil recovery technologies are used with particular intensity in offshore fields in order to achieve a high degree of oil recovery as quickly as possible (up to 66%). This means that high offshore investments can be recouped in a short time. One example of extreme exploitation is the Canterell offshore field in Mexico. The intensive use of various oil recovery technologies has led to a situation where production has declined, from a peak production in 2003, by 20% in just 5 years.[10] The share of offshore petroleum production has continually increased over recent decades.[11]

The growing significance of small fields: the share of super-giant and giant fields[12] in overall petroleum production has dropped from over 70% to under 60% in the last 30 years.[13] This is due to the fact that the number of new giant oil fields has declined sharply since the 1960s. For example, the amount of petroleum from super-giant oil fields found in the 1990s amounts to only 1/10 of the volume of the super-giant new discoveries of the 1960s[14] (see Illustration 2). Thus global production is strongly dependent on old giant and super-giant fields that were discovered before 1970 and which still contribute more than a third of total output[15] (see Illustration 1 and Illustration 3). By contrast, the few giant fields that have started production this decade produce approximately one percent of global petroleum production. The production decline of small post-peak fields is higher than from large deposits because small fields can be exploited more quickly than large ones, as fewer drillings are necessary.[16] Just how strongly size impacts the annual decline in production is revealed by the IEA's evaluation of the post-peak fields. According to estimates by the IEA, the rate of decline among the 70,000 small fields globally is even higher than that seen in the giant fields.

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[7] Höök, Hirsch and Aleklett 2009, IEA 2008a, Schindler and Zittel 2008, Campell 2009
[8] IEA 2008a.
[9] BGR 2009.
[10] Höök, Hirsch and Aleklett 2009, IEA 2008a,
[11] IEA 2008a.
[12] According to the classification of the IEA, a super-giant field has more than 5 billion barrels in oil reserves, a giant has from 500 million to 5 billion, a large field has over 100 million and a small field has less than 100 million barrels.
[13] Own calculation according to Höök, Hirsch and Aleklett 2009, IEA 2008a.
[14] Höök, Hirsch and Aleklett 2009
[15] Own calculation according to IEA 2008a.
[16] Höök, Hirsch and Aleklett 2009

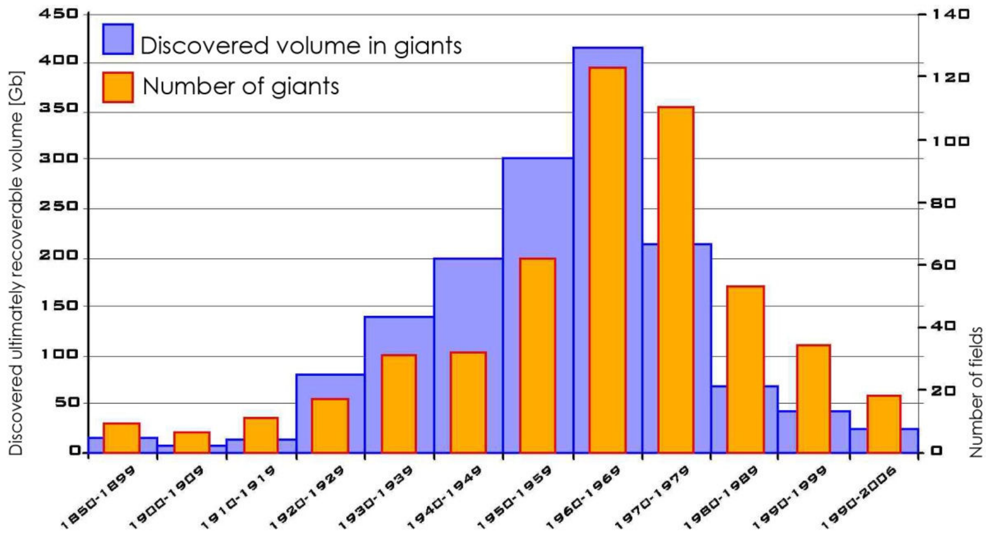

Illustration 2: Development of super-giant oil discoveries[17]

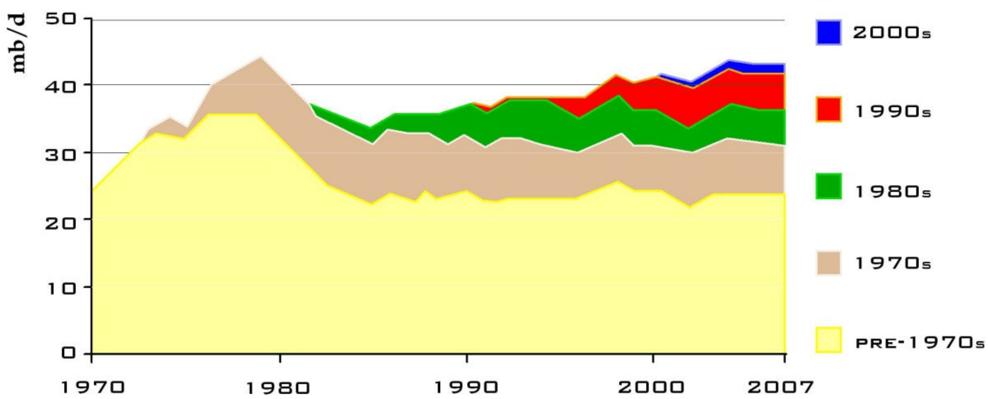

Illustration 3: Development of petroleum production in super-giant oil fields[18]

The development of the production decline rate is of great significance for future petroleum production. Today, over 60% of giant petroleum production comes from deposits that have already passed their production peaks. If this trend continues, a share of 80% of total output on the part of the giants will result (see Illustration 4). For this reason, there will be more and more super-giant oil fields with declining exploitation in the future. This development is highly probable, since today 20% of global petroleum production comes from giants that are more than 50 years old and super-giant new discoveries are becoming increasingly rare.[19] Due to the increased use of oil recovery technologies, Höök, Hirsch and Aleklett anticipate an increased decline in production among the giants, which will enter a post-peak phase in the future.[20.] The IEA likewise anticipates an increase in the future rate of production decline.[21.]

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[17] Höök, Hirsch and Aleklett 2009, IEA 2008a,
[18] IEA 2008a.
[19] Own calculation according to IEA 2008a.
[20] Höök, Hirsch and Aleklett 2009
[21] IEA 2008a.

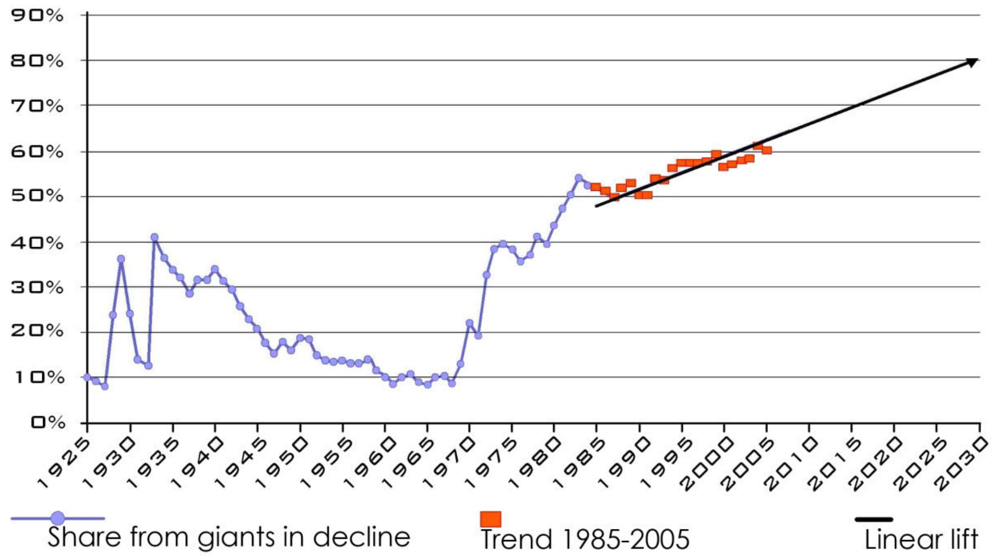

Illustration 4: Share of declining oil fields in total giant petroleum production[22]

2.3 Projections of future petroleum production

Due to the manner in which the production decline rate is developing, the IEA anticipates a powerful decline in production in all oil fields from 70 million barrels/day in 2007 to 27.1 million barrels in 2030 (see Illustration 5).

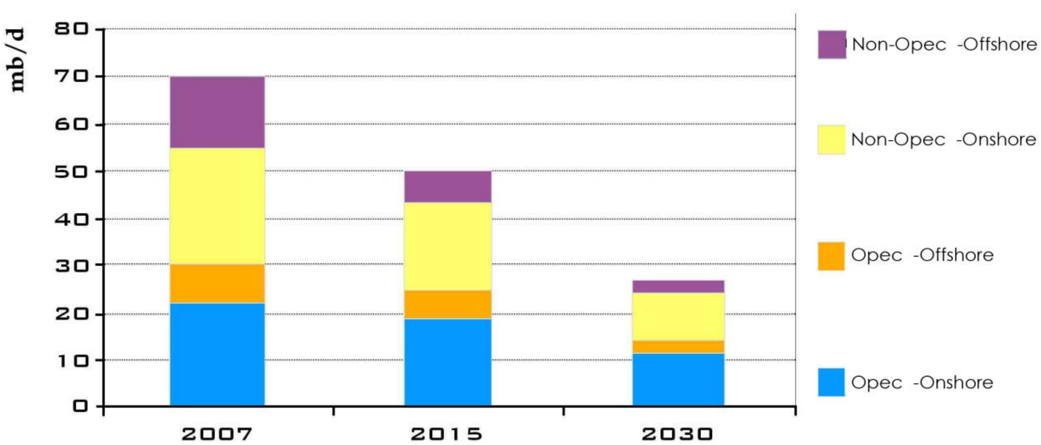

Illustration 5: Development of petroleum production in current fields[23]

[22] Höök, Hirsch and Aleklett 2009
[23] IEA 2008a.

Despite the strong production decline in currently existing fields, the IEA anticipates no decline in total petroleum production in the next two decades since according to its calculations there are still proven petroleum reserves available of approximately 1.2 to 1.3 trillion barrels.

According to the IEA's calculations, the decline of current fields can be balanced out by the following developments and an increase in total fossil fuels by one quarter, i.e. an increase to 103.8 million barrels/day, can be achieved by 2030[24] (see Illustration 6):

Developing previously discovered fields: Production from new fields that have already been discovered but not yet developed will rise to 29 million barrels/day by 2020 and then drop to 23 million barrels/day by 2030. OPEC offshore deposits and non-OPEC offshore deposits will provide the largest contribution with a maximum amount of 20 million barrels/day.

New discoveries: Production from new fields that have not yet been discovered will rise to 19 million barrels by 2030. Here, OPEC onshore deposits and non-OPEC offshore deposits will once again make the largest contribution with a maximum amount of 15 million barrels/day.

Natural gas liquids (NGL) from natural gas production: NGL production will double by 2030 up to 20 million barrels (15 million barrels of petroleum equivalents). [25] 80% of this increase will come from the OPEC states, particularly from the Middle East. OPEC's NGL production will triple by 2030.

Enhanced oil recovery: Production with EOR technologies will rise from 2.5 million barrels/day to 6.4 million barrels/day in 2030. CO_2 injection will provide the largest share. In 2030, 70% of EOR production will occur in four countries: the USA, Saudi Arabia, China and Kuwait.

Unconventional fossil fuels: The production of unconventional fossil fuels will increase nearly fivefold by 2030 to reach almost 9 million barrels/day. Fuels from tar sands in Canada will provide the largest contribution in 2030, amounting to nearly 6 million barrels/day.

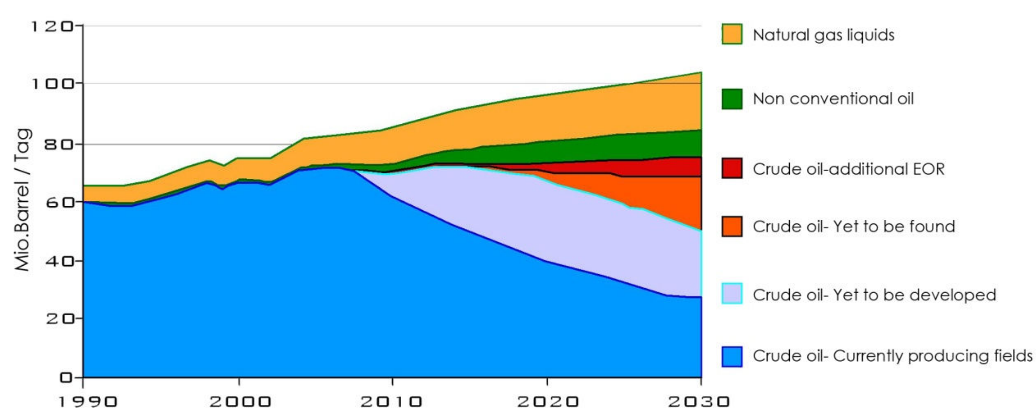

Illustration 6: Global petroleum production in the reference scenario of the 2008 WEO[26]

[24] IEA 2008a.
[25] Aleklett 2009.
[26] IEA 2008a.

The increase to over 100 million barrels/day by 2030 can only be realised with investments in excess of 8 billion dollars. Due to this, the IEA sees great risks arising if the OPEC states do not sufficiently invest to balance out the decline in current fields. If the necessary investments to develop new capacities are not made, the organisation is warning of supply bottlenecks in the coming years.[27]

In contrast to the IEA, peak oil experts do not see any possibility for balancing future production decline with high investments in new production capacities. [28] According to their calculations, the easily extractable petroleum reserves will soon be exploited. The use of hard to access oil deposits and unconventional fossil fuels will be restricted by technological problems. That is why they are predicting a decline in global production of between 39 and 76 million barrels of fossil fuels by 2030.[29] This results in a difference of up to 60 million barrels from the IEA's predictions. According to studies by peak oil experts, the potential from previously undeveloped or undiscovered oil fields, NGL, EOR and unconventional fuels is considerably lower than the predictions of the IEA and other institutions, such as the EIA or BGR.

Development of previously discovered fields: Peak oil experts assess global petroleum reserves as considerably lower than the IEA and other institutions such as OPEC, BGR and WEC do. [30] The most important reason for this is the different evaluation of the OPEC reserves. Between 1985 and 1990, the most important OPEC countries approximately doubled their reserve figures without, within this time period, announcing any new discoveries. The most important reason for this upgrading of the reserves was probably the incentive for OPEC members to implement higher production quotas via the stating of higher reserves [31] (see Illustration 7 und Table 1).

As such, according to Campbell and Bakhtiari, actual OPEC reserves are only about half as large as the official statistics claim. These results are supported by studies undertaken by Simmons in Saudi Arabia and comments from the employees of state-run petroleum companies in Kuwait and Saudi Arabia.[32]

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[27] IEA 2008a, Connor 2009
[28] Aleklett 2009, Schindler and Zittel 2008, Campell 2009, Höök, Hirsch and Aleklett 2009
[29] Aleklett 2009, Schindler and Zittel 2008, Campell 2009,
[30] Schindler and Zittel 2008, BGR 2009, IEA 2008a.
[31] Schindler and Zittel 2008, Campell 2009
[32] ASPO 2006 a,b., Schindler and Zittel 2008, Campell 2009.

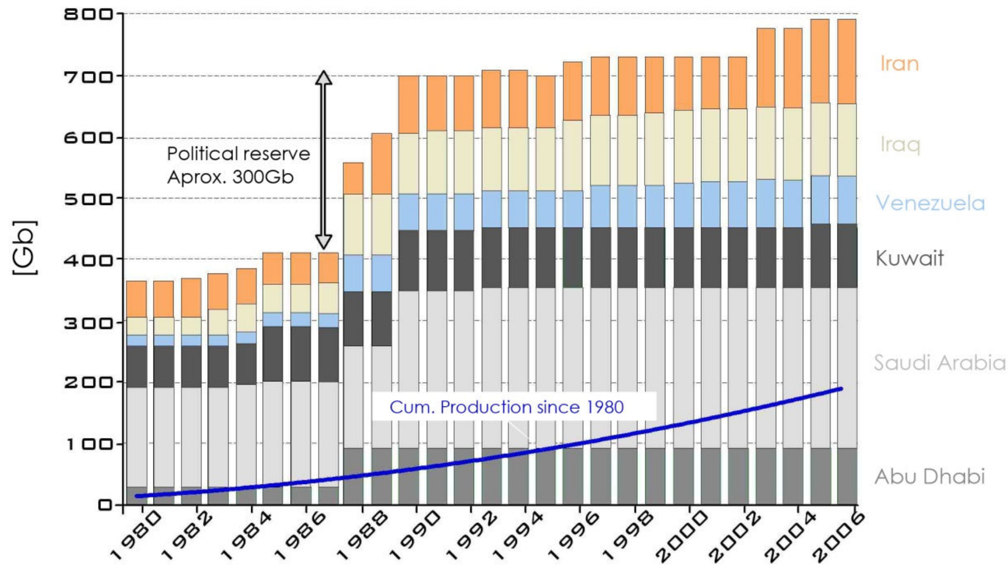


Illustration 7: Development of proven petroleum reserves in the OPEC countries[33]

Bill. barrels	Abu Dhabi	Iran	Iraq	Kuwait	Saudi Arabien	Venezuela
1970	12	70	32	67	129	14
1980	28	58	31	65	163	18
1984	30	51	43	64	166	25
1985	31	49	45	90	169	26
1987	31	49	47	92	167	25
1988	92	93	100	92	167	56
1990	92	93	100	92	258	59
2008	92	136	115	102	264	99

Table 1: Development of OPEC petroleum reserves[34]

New discoveries: New discoveries have declined sharply worldwide since the 1960s. Since most regions with oil deposits have been very closely examined, a continuation of this trend is highly realistic and super-giant new discoveries are unlikely. (see Illustration 8)

[33] Schindler and Zittel 2008
[34] Campell 2009.

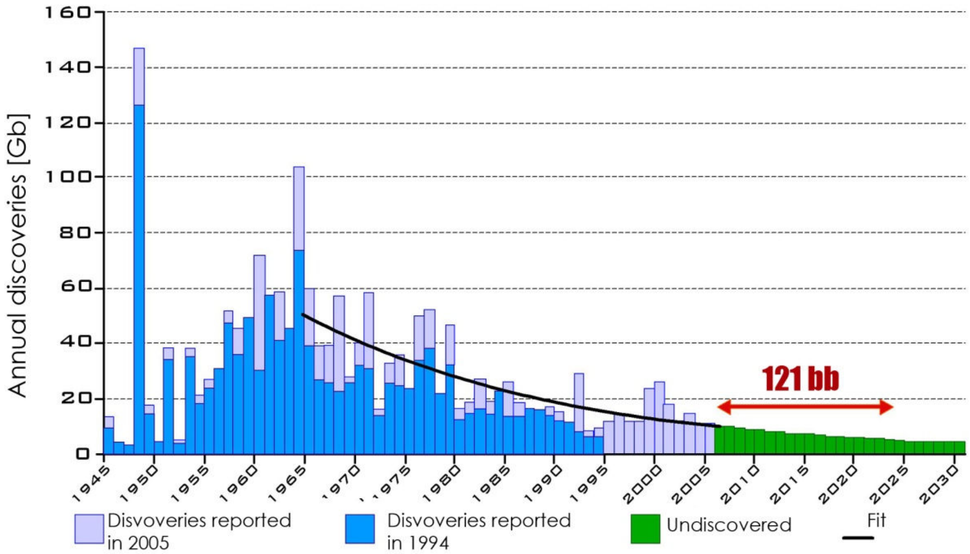


Illustration 8: Development and forecast of petroleum discoveries[35]

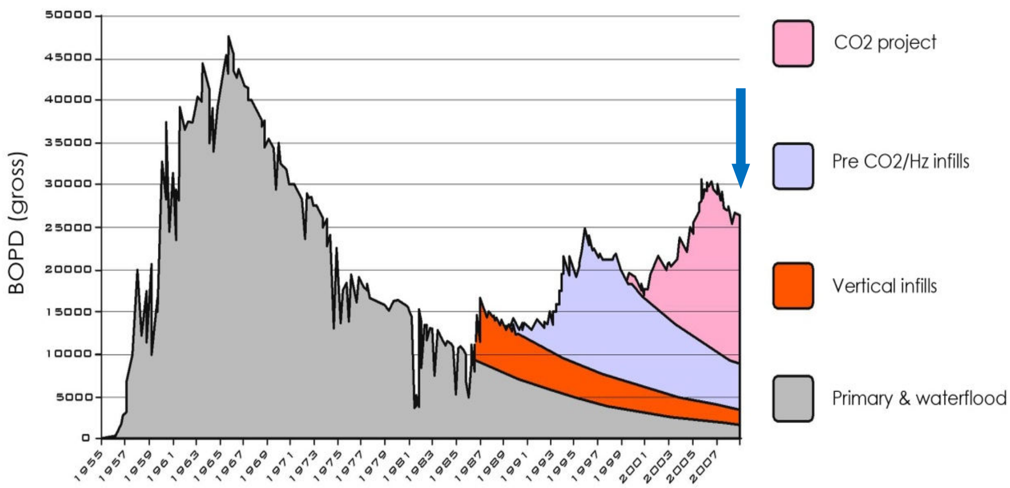
Natural gas liquids (NGL) from natural gas production: According to Likvern, the IEA's NGL forecast is unrealistic since the IEA's assumptions regarding the NGL share in the total amount of natural gas are much too high. [36]

Enhanced oil recovery: According to Schindler and Zittel, enhanced oil recovery technologies cannot halt the global production decline. Despite decades of use, EOR technologies could not prevent the production decline in the USA and in the North Sea fields. While enhanced oil recovery technologies can, as shown above, increase the exploitation rate to over 60%, production then suffers an even sharper subsequent fall.[37]

In the Weyburn field, it is expected that, by 2030, cumulative output can be increased up to a third via the usage of CO_2 injections. [38] However, current production data reveals that petroleum production has been declining sharply since as early as 2006 (see Illustration 9). The use of EOR in the Yates field shows that the application of hot steam and chemicals could only briefly halt the decline in production (see Illustration 10).

In the USA, despite the growing use of CO_2 EOR, total EOR production has been dwindling since 2000. This is due to the steep decline in the use of thermal processes (s. Illustration 11)[39].

[35] Aleklett 2009.
[36] Likvern 2008.
[37] Schindler and Zittel 2008.
[38] IEA 2009.
[39] Demchuk 2009.



Illstration 9: Development of petroleum production in the Weyburn field, Canada[40]

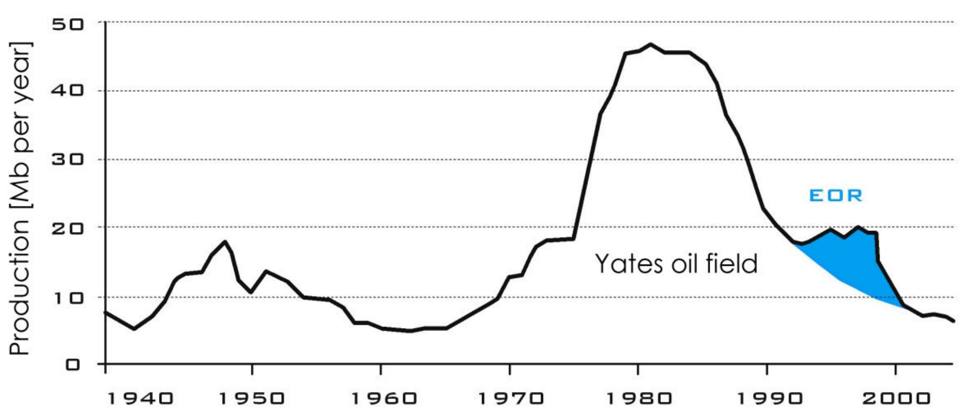


Illustration 10: Development of petroleum production in the Yates field, USA[41]

[40] Demchuk 2008.
[41] Schindler and Zittel 2008

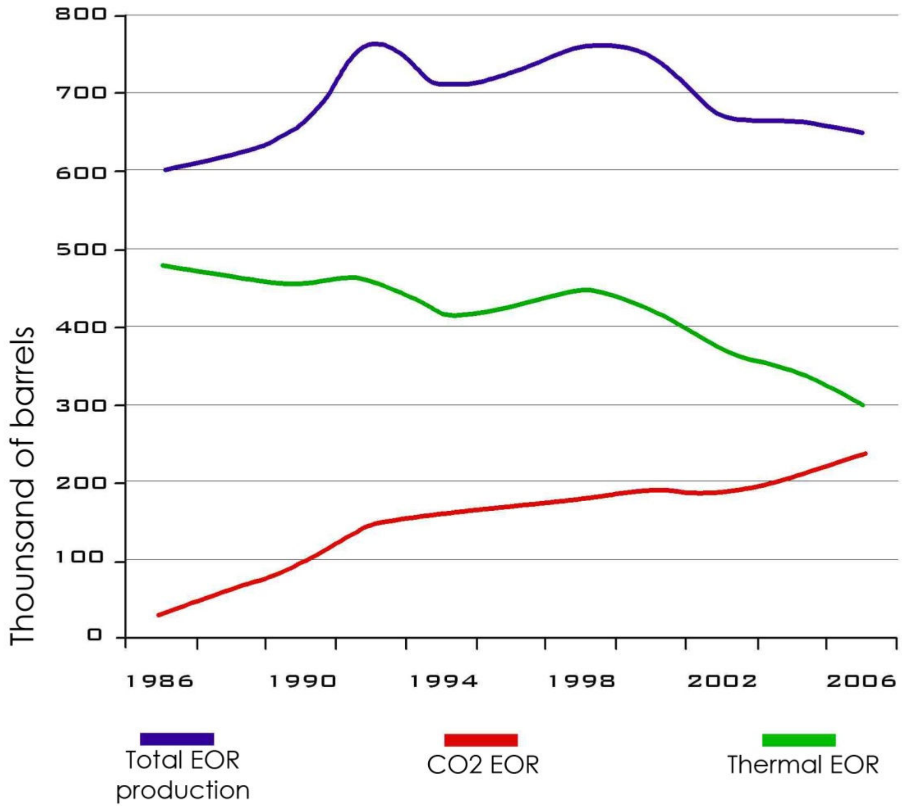


Illustration 11: Development in EOR production in the USA[42]

The IEA anticipates that the injection of CO_2 will provide the greatest contribution to the total EOR production of 6.4 million barrels/day in 2030. However, this requires vast quantities of CO_2. For example, in order to produce 3 million barrels/day through CO_2 EOR it is necessary to produce over 400 million t of CO_2, which corresponds to the CO_2 separation of more than 50 1,000 MW CCS power stations. It is highly uncertain whether CCS power plants can be built in this quantity and size over the coming years. In addition, the safe storage of CO_2 in petroleum deposits has not yet been scientifically proven. The costs of CO_2 EOR processes (CO_2 separation, transport and injection) represent a vast hurdle for the further development of these technologies. [43]

2.4 Development of the demand for fuels

A strong increase in global mobility is anticipated, particularly in the developing and emerging countries. According to the World Business Council for Sustainable Development, global mobility needs will triple by 2050. [44]

Today, 52% of total petroleum production is already used in transportation. By 2030 this share is expected to increase to 57%.[45].

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[42] Demchuk 2009
[43] Cohen 2006, Statoil Hydro 2008. Demchuk 2009.
[44] World Business Council for Sustainable Development 2004

3 Unconventional fossil fuels

3.1 Definition of unconventional fossil fuels

There is no uniform definition of unconventional fossil fuels as a raw material. A broad interpretation of the term unconventional oils encompasses all deposits that are only able to be produced with elaborate input. Alongside tar sands, extra heavy oil and oil shale, said definition further includes deep sea and Arctic petroleum deposits. Like the BGR and Meyer-Renschhausen, this study employs a more precise definition and only refers to unconventional petroleum as those deposits that are costly to develop in order to attain the characteristics of crude oil. According to this definition, unconventional petroleum includes bitumen or crude oil from tar sands, extra heavy oil and pyrolysis or crude oil made from oil shale. Extra heavy oil has a density of over 1 g/cm³ (or less than 10° API).[46] This study also refers to synthetic fuels made from natural gas (GTL) and coal (CTL) as unconventional fossil fuels. It will illustrate the extraction technologies of the various unconventional fossil fuels in chapter 3.4.

3.2 Raw material deposits for unconventional fossil fuels

The following chapter describes raw material sources for unconventional fossil fuels.

3.2.1 Unconventional petroleum

According to estimates, the total amount of tar sand, extra heavy oil and oil shale deposits (in-place quantity) amounts to between 6.6 and 9 trillion barrels (see Illustration 12). A quarter of this can be extracted using technical means.[47] Future extractable unconventional petroleum resources are more than twice as high as conventional petroleum reserves.

The maximum estimates of the quantities of tar sand, extra heavy oil and oil shale deposits in-place are approximately equal, at c. 3 trillion barrels each.[48]. However, the extractable quantities vary widely due to their differently high recoverability factors. With 400 billion barrels, only half as much extra heavy oil as tar sand can be produced.

More than 60% of global deposits of unconventional petroleum are located in North and South America: tar sand in Canada, extra heavy oil in Venezuela and oil shale in the USA. Additional super-giant deposits are located in Russia (oil sands and oil shale), Kazakhstan (oil shale) and in the Middle East (extra heavy oil). There are also a number of giant oil shale deposits in the Republic of Congo, Brazil, Italy, Morocco, Jordan, Australia, Estonia, China, Israel, Thailand and Canada.[49]

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[45] IEA 2008a.
[46] Meyer-Renschausen 2007, BGR 2009.
[47] IEA 2008a.
[48] IEA 2008a, BGR 2009, Meyer-Renschhausen 2007. Data on the distribution of global tar sand deposits vary sharply. Meyer and Attanasi evaluate the in-place oil sand quantities in Nigeria at over 400 billion barrels, which is a factor of 100 greater than that of the BGR. Quoted in Meyer-Renschhausen.
[49] BGR 2009.

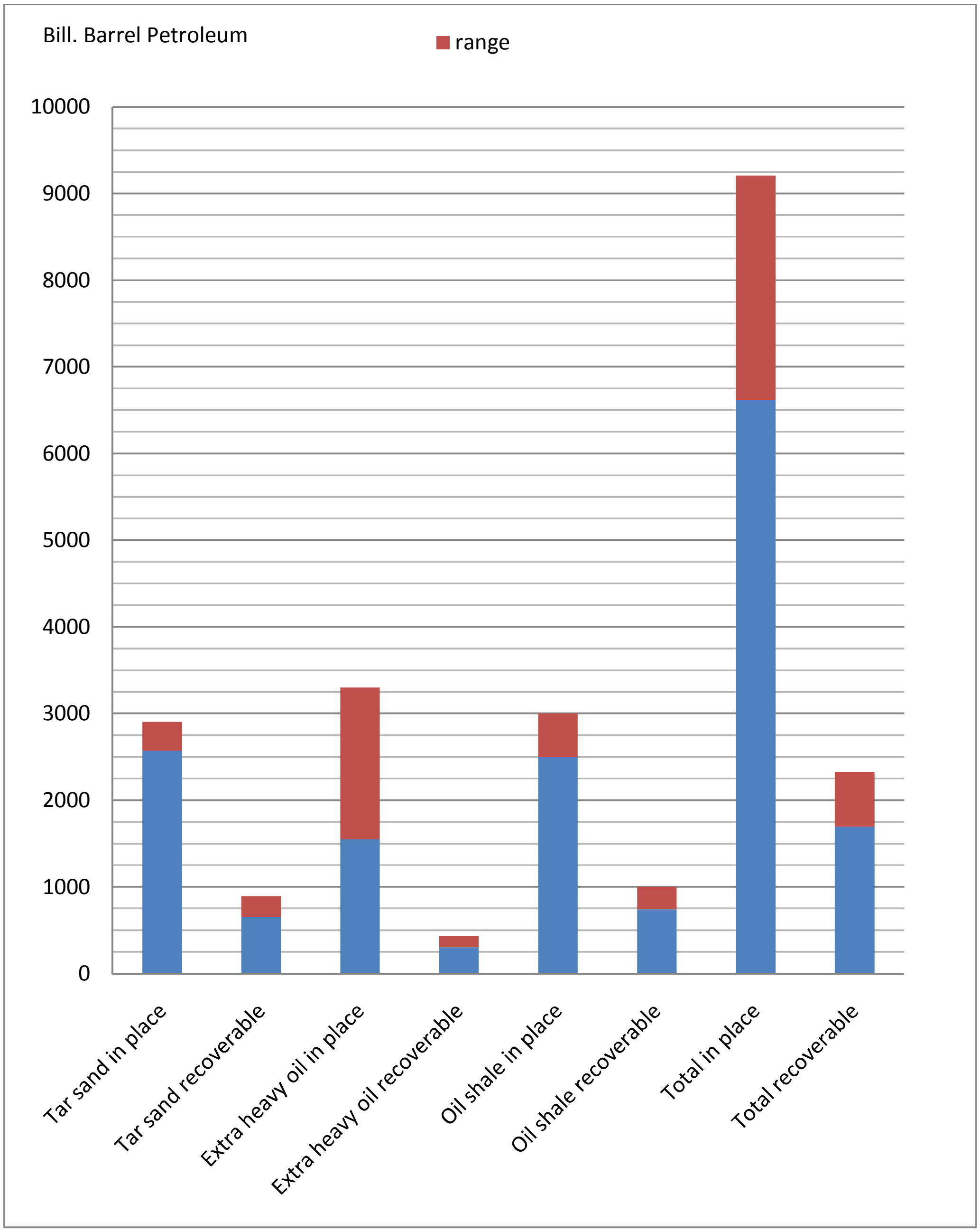

Illustration 12: Global deposits of unconventional petroleum[50]

[50] Own calculation according to IEA 2008a, BGR 2009, Meyer-Renschhausen 2007

3.2.2 CTL and GTL (CTL - Coal to Liquid, GTL - Gas to Liquid)

Alongside oil sands, extra heavy oils and oil shale, coal and natural gas represent further important raw materials.

Coal has a share of over 75% in global fossil energy deposits. The BGR estimates total coal resources at around 21 trillion t, including 16.4 trillion t hard coal and 4.4 trillion t soft brown coal.[51]

Natural gas forms a more than 20% share of global fossil deposits. However, conventional natural gas has a mere 8% share in the total natural gas resources of 3,000 trillion m³ (see Illustration 13). Gas hydrate represents the largest gas quantities with 1,000 trillion m³[52] along with natural gas in aquifers with 800 trillion m³, although its extracability is still very uncertain.[53] The production of natural gas from dense reservoirs and coal deposits will become increasingly important globally and is already widespread in the USA. Over the last ten years, the share of unconventional natural gas in total production in the USA has risen from 28% to 46%.[54] The extraction of shale gas in the USA has even tripled during this period.

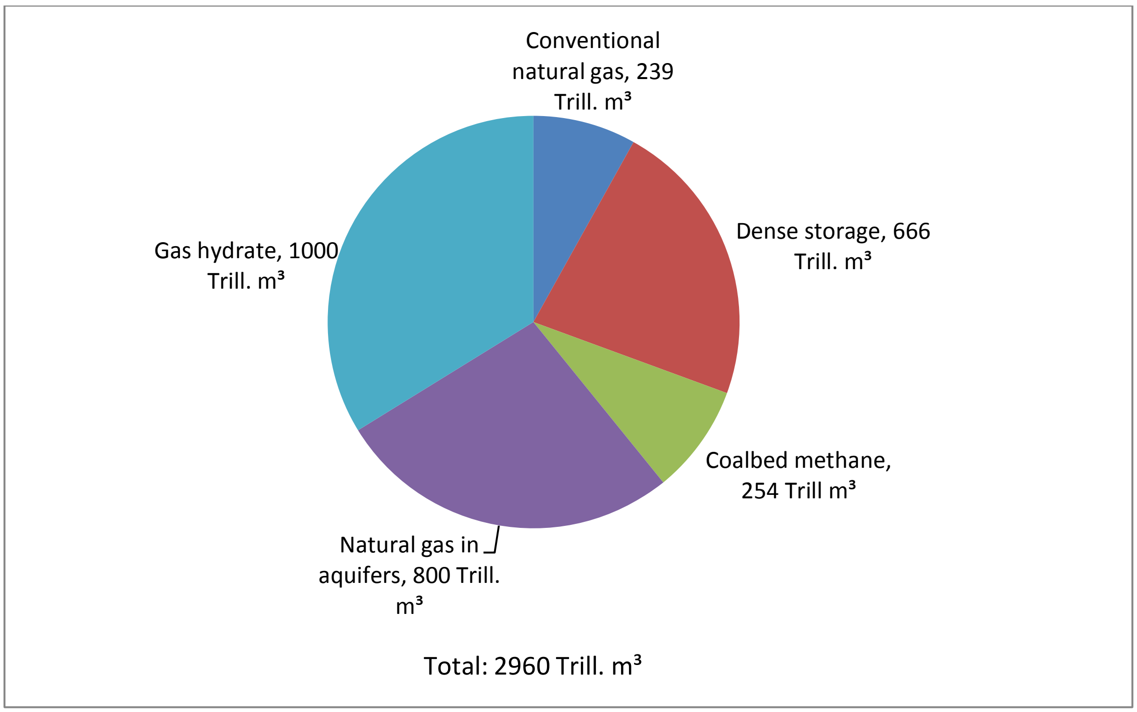

Illustration 13: Global conventional and unconventional natural gas deposits[55]

[51] BGR 2009.
[52] Global data on stored natural gas quantities in gas hydrates show a broad range, between 1,000 and 120,000 billion m³. BGR 2009.
[53] BGR 2009.
[54] This includes 68 % tight gas (gas from sandstone), 21 % coal bed methane and 11 % shale gas (Gas from argillaceous rock) NCI 2008.
[55] BGR 2009

3.3 Current production of unconventional fossil fuels

Unconventional fossil fuels currently make up approximately 5% of total global fuel production. In 2007, the total production of unconventional fossil fuels in 2007 amounted to 182.5 million t, the largest share of which was fuel production of 93 million t of extra heavy oils and 77 million t of bitumen from tar sand (see Illustration 14). So far, annual production of CTL, at 8.7 million t, GTL at 2.9 million t and shale oil at 0.9 million t has been considerably lower.[56] Compared to 2000, the production of unconventional fossil fuels has tripled.[57] Tar sand extraction is occurring only in Canada and extra heavy oil extraction is mostly occurring in Venezuela, Great Britain and Azerbaidjan.[58] Outside of Germany, CTL has so far only been produced in South Africa. GTL is currently being produced in South Africa, Malaysia and Qatar.[59] Oil shale is being processed into fuels in Estonia, China and Brazil.[60]

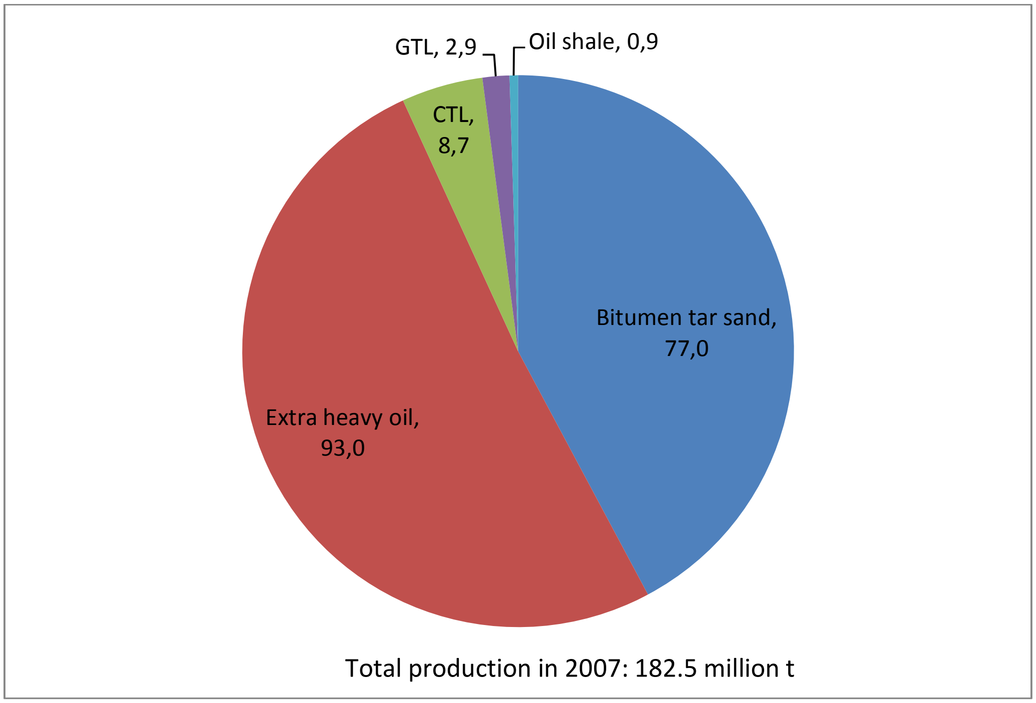

Illustration 14: Production of unconventional fossil fuels in million t in 2007[61]

3.4 Unconventional fossil fuels – description of technologies

The following chapter presents the various technologies used in the extraction of unconventional fuels. The production of tar sands is presented in more detail than the other fuel categories since, together with extra heavy oil, it represents the most important current

[56] Bitumen, extra heavy oils, CTL and oil shale according to BGR 2009, GTL according to IEA 2008a.
[57] Own calculation according to BGR 2009.
[58] BGR 2009.
[59] BGR 2009.
[60] IEA 2008a.
[61] BGR 2009.

and future unconventional fuel. In the meantime, processes for tar sand extraction have also proved effective in the production of extra heavy oil. The description of tar sand technologies is based on statements from Meyer-Renschhausen and the BGR raw materials report.[62].

3.4.1 Extraction of fuels from tar sand

3.4.1.1 Characteristics of tar sand

Oil sands are mixtures of bitumen,[63] water, sand and clay. The weight component of bitumen varies between 1 and 8%, with the average at 12%.
Bitumen is a highly viscuous form of petroleum with an API[64] of under 10° (see Table 2). Like extra heavy and heavy oil, bitumen is a degraded form of oil. In bitumen the degree of degradation, i.e. the reduction of volatile components, is highly advanced. [65]

Light oil	30°-40° API
Medium heavy oil	20°-30° API
Heavily oil	10°-20° API
Extra heavy oil and natural bitumen (tar sand)	below 10° API

Table 2: Classification of crude oil according to weight[66]

3.4.1.2 Tar sand extraction in open-cast mines

Currently, the extraction of fuels from tar sand is taking place only in Canada. Around 60% of global tar sand resources are located in the Canadian province of Alberta (see Illustration 15). Currently, the extraction of tar sand in open-cast mines of a depth reaching to 75 m is most common. [67] However, in future, the share of in-situ processes will increase, since 93% of Canada's tar sand reserves are at a level deeper than 75 m.

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[62] Meyer-Renschhausen 2007, BGR 2009
[63] Bitumen consists mainly of long-chain hydrocarbons. Bitumen is a thermoplastic substance, i.e. its viscosity is temperature-sensitive: it becomes brittle when cooled, but when it is heated it passes smoothly continuously through all states, from firm (glass-like) to viscous to thin.
[64] API: American Petroleum Institute= specific volume of crude oil
[65] Meyer-Renschhausen 2007, BGR 2009.
[66] API American Petroleum Institute= specific volume of crude oil
[67] Woynillowicz et al. 2005 and Greenpeace 2008.

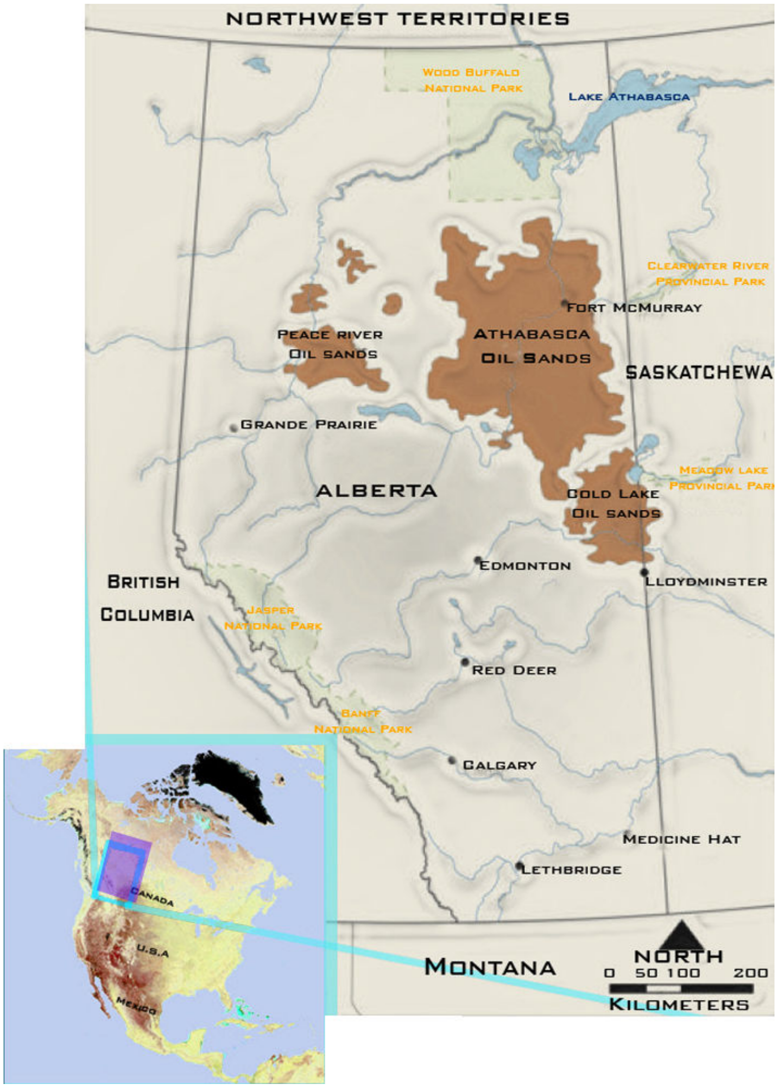

Illustration 15: Location of tar sand deposits in Canada. Own presentation, source: The University of British Columbia.[68]

Process steps in open-cast mining:

The extraction of tar sand in surface mining consists of the following process steps (see Illustration 16):

- The topsoil is removed and deposited onto heaps.
- A 40 to 60 m thick tar sand layer is removed using bucket diggers and is transported to the crusher in dump trucks.

[68] www.forestry.ubc.ca

- In the crusher, the material is pulverised and conditioned for further transport to the extraction facility.
- The tar sands are washed in hot water. This results in a foamy mixture of water, bitumen and fine materials. Increasingly, cold water processes are being utilised in order to lower operating costs.
- A solvent is added to aid the separation of the bitumen.
- The waste mixture of water and sand is channeled into sedimentation ponds.
- The waste water is recycled and the separated sand is used to refill the excavation pit following the end of the excavation process. This sometimes occurs 30 years after the start of production.
- Finally, the stored topsoil is replaced following the end of the excavation process and replanted.

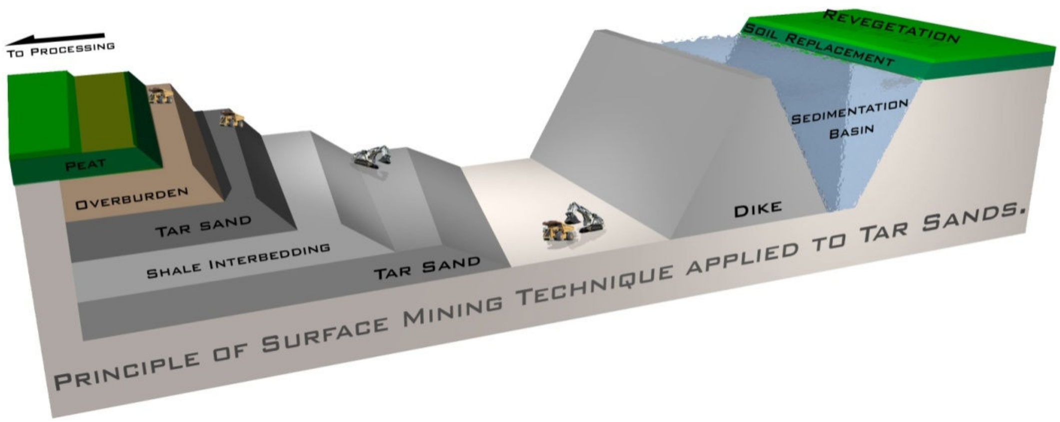

Illustration 16: Diagram of tar sand extraction in surface mines. Own presentation, source: Total.[69]

Advantages of surface mining:

- High degree of oil recovery (91%)
- Low energy consumption

[69] Total 2007.

Disadvantages of surface mining:

- Intense landscape intervention
- Large boreal forest areas are cleared and large quantities of earth are moved. Since Canada's boreal coniferous forest contains 22% of global stored carbon in terrestrial ecosystems (boreal coniferous forests store twice as much carbon as rainforests), large amounts of carbon can be released through tar sand extraction.[70]
- Methane emissions can develop in the sludge settling ponds used in tar sand processing.
- Up to 4.5 litres of water are required to produce one liter of fuel from tar sand, and up to 6 litres of poisonous sludge can develop. This sludge must then be deposited in settling ponds. The total area of settling ponds used in current tar sand extraction in Canada amounts to approximately 50 km^2. All steps of the process of tar sand processing lead to severe disruptions in and environmental pollution of water bodies (rivers, groundwater, lakes and marshes).[71]
- Alongside CO_2 emissions, additional large quantities of other air pollutants are emitted during the numerous steps of the process of tar sand production.

3.4.1.3 In situ tar sand extraction

Around 90% of tar sand deposits are located deeper than 75 m. They must therefore be extracted using in situ procedures.[72] There are thermal, non-thermal, chemical and physical in situ procedures (see Table 3).

Thermal in situ procedures	Non-thermal, chemical and physical procedures
CSS	VAPEX
SAGD	CHOPS
THAI	

Table 3: Overview of in situ procedures in tar sand extraction

[70] International Boreal Conservation Campaign 2008 und 2009. Woods Hole Research Center, 2007.
[71] Pembina Institute 2009
[72] Woynillowicz et al. 2005 and Greenpeace 2008.

3.4.1.3.1 CSS procedure (Cyclic Steam Stimulation)

Using the CCS procedure (cyclic steam stimulation) it is possible to extract tar sand deposited on a deeper level. The procedure reduces the viscosity of the bitumen by injecting hot steam (300° C). Through weeks of high steam pressure of up to 11,000 kilopascal, interfering rock layers are crushed, achieving an unhindered flow of bitumen. The liquified bitumen, along with the water, is then pumped upward.

Benefits of the CSS procedure:

- Extraction of deeper tar sand deposits
- Breaks up interfering rock layers
- Less clearing of forest areas and lower landscape impact than in surface mining

Disadvantages of the CSS procedure:

- Low degree of oil extraction: up to 40%
- Steam injection with high pressure and high temperatures means high energy and water consumption
- SOR (steam-to-oil ratio, i.e. the number barrels of water needed to produce one barrel of bitumen) of a typical CSS project: 3.5 (3.5 l water for 1 l petroleum)
- High CO_2 emissions due to large natural gas consumption

3.4.1.3.2 SAGD process (Steam-Assisted Gravity Drainage)

The SAGD procedure (steam assisted gravity damage) allows for continuous in situ bitumen extraction. Two horizontal parallel pipes are used (see Illustration 17). The upper pipe conducts steam into the tar sand layer and frees the bitumen from the surrounding sand. Due to its higher specific weight, the bitumen flows downward and is pumped out separately through the production pipe.

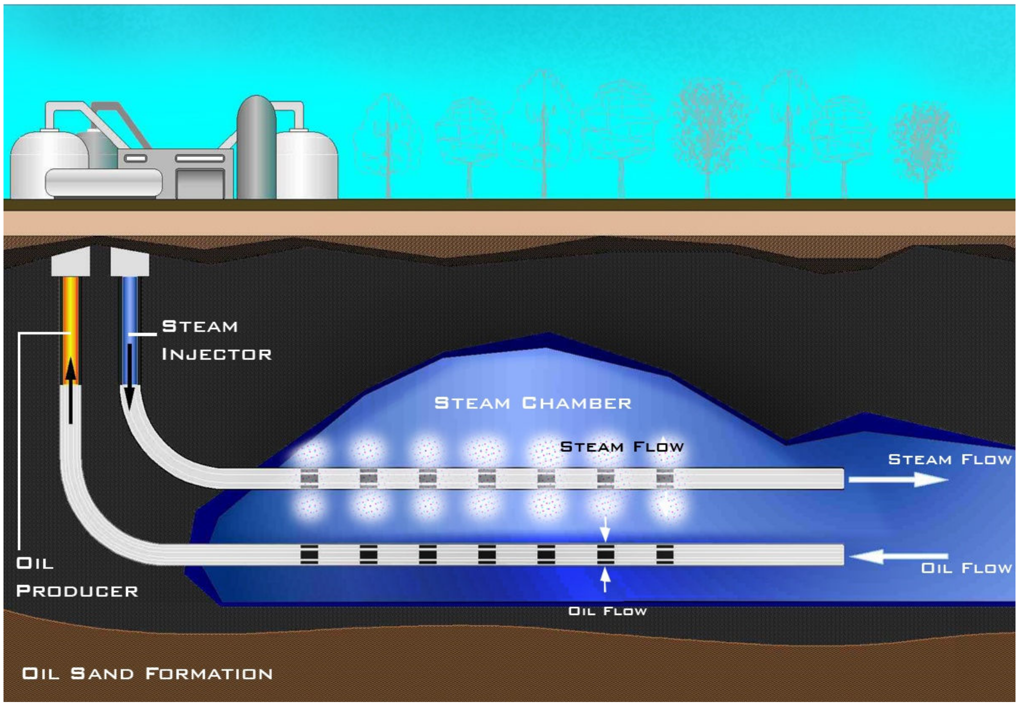

Illustration 17: The SAGD procedure. Own presentation, source: National Energy Board Canada.[73]

Advantages of SAGD procedure:

- Extraction of deeper tar sand deposits
- Continuous bitumen extraction
- Less clearing of forest areas and lower landscape impact than in surface mining

Disadvantages of the SAGD procedure:

- Since the steam is introduced at lower pressure, it is not sufficient to break the overlaying rock formations. Thus some oil deposits cannot be reached.
- The degree of oil extraction is lower than in surface mining (40%-60%)
- Water consumption is extremely high (SOR: 3-8).
- High CO_2 emissions due to large natural gas consumption
- While natural gas can be substituted by MSAR (Multiphase superfine atomised residue) as a low-calorific heating gas for the upgrading process, the use of primary energy is not reduced since 15%-18% of the extracted bitumen is needed for MSAR production. The

[73] www.neb.gc.ca.

combustion of MSAR is linked to high emissions of pollutants (sulphur compounds, particles and nitrogen oxides)

3.4.1.3.3 THAI procedure (Toe-to-Heel Injection)

In the THAI procedure (toe-to-heel injection), a portion of the tar sand is ignited underground in order to liquify the bitumen. THAI technology is still in the testing phase. Air is blown into the tar sand deposit through a verticle injection, creating a flame front where a portion of the bitumen is coked. The coking process forms gases with a temperature of 300°-600° C that reduce the viscosity of the bitumen. Using gravity, the bitumen flows to the production pipe beneath the flame front and is pumped to the surface along with the accumulating gases. Illustration 18: Diagram of the THAI procedure. Own presentation, source: Greaves[74].

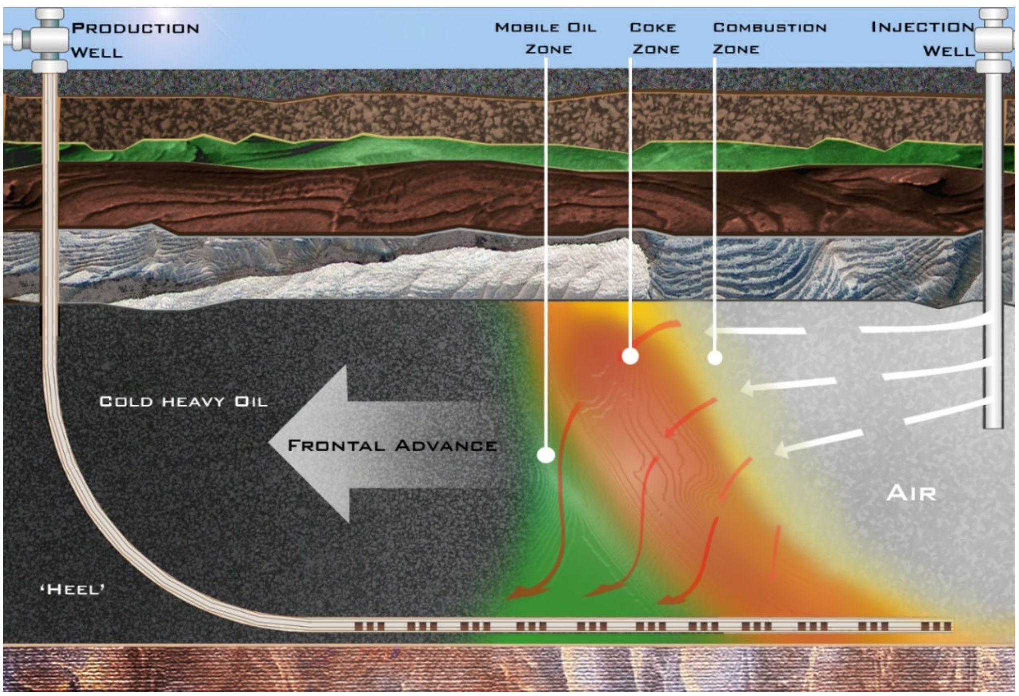

Illustration 18: Diagram of the THAI procedure

Advantages of the THAI procedure:

- The degree of oil recovery (80%) is considerably higher than in other in situ procedures
- Lower water and natural gas input
- The coking provides for a partial upgrading of the bitumen since heavy components remain in the deposit

[74] Greaves 2006.

- Enhanced cost-effectiveness through lower natural gas input

Disadvantages of THAI procedure:

Comparatively high CO_2 emissions through partial combustion of bitumen in the deposit

3.4.1.3.4 Vapex procedure

Like the SAGD technology, the Vapex procedure (vapour extraction) uses two parallel horizontal conduits. Instead of hot steam, however, it pumps gasiform solvents (propane, ethane or butane) into the tar sand deposit. The bitumen becomes liquid through the solvent without additional heat. This procedure is still in the development stage.

Advantages of the Vapex procedure:

- Substituting hot steam with solvents can considerably reduce energy input and dependence on natural gas prices
- Capital costs are lower than the case of thermal in situ procedure, as no steam producing and water processing facilities are necessary
- Operating costs are only half as high as in the SAGD procedure due to reduced energy and water input
- The light hydrocarbon compounds are upgraded via the use of solvents. This already causes an upgrading[75] of the bitumen within the deposit
- The procedure can also be used with moderately thick oil sand deposits as well as other deposits that are unsuitable for thermal procedures.[76]

Disadvantages of the Vapex procedure:

- The degree of oil recovery is lower compared to the thermal in situ procedure
- The yield per production facility is lower than the case of the thermal in situ procedure
- The procedure is not yet technically mature

[75] 'Upgrading' is the process used to transform bitumen into synthetic crude oil. Long-chain hydrocarbons are split through high temperatures, catalysts and added hydrogen (in order to increase the hydrogen-to-carbon ratio). During the upgrading, the bitumen is also freed from sulphur.

[76] For example, oil sand deposits may not be suitable for thermal procedures due to high water saturation, low porosity or low thermal conductivity.

3.4.1.3.5 CHOPS procedure (Cold Heavy Oil Production with Sand)

Tar sand deposits with lower viscosity can also be extracted using the CHOPS procedure. Via this technology, oil is extracted together with the sand without added heat and is only separated from the sand above ground.

Advantages of the CHOPS procedure:

- Lower energy input, resulting in lower production costs and CO_2 emissions
- The substratum becomes more porous due to the sand-oil production, thus increasing the yield of the subsequent thermal oil recovery procedure

Disadvantages of the CHOPS procedure:

- Can only be used on tar sand deposits with low viscosity and not on pure bitumen deposits
- The extracted sand must be disposed off along with the accumulating pollutants in an environmentally friendly manner

3.4.1.4 Concluding assessment of all in situ procedures compared with surface mining

Surface destruction from in situ procedures is lower than in surface mining. However, here too, large boreal coniferous forest areas need to be cleared for the infrastructure of the drilling work, petroleum transportation and processing. Conservative estimates predict a 10% forest clearance rate for tar sand surfaces in future in situ extraction.[77]

3.4.1.5 Bitumen upgrading (refining)

Bitumen is used to manufacture two products that are similar to conventional petroleum

1. **Diluted natural bitumen (‘blended bitumen’):**

   The bitumen is diluted with light hydrocarbon compounds. However, the final product has a reduced market value, since very few refineries can process it.

2. **Synthetic bitumen**

   The sulphur compounds, heavy metals and heavy carbon-rich compounds contained in the bitumen are separated. A hydrotreating procedure enriches the petroleum with

[77] Schneider & Dyer 2006.

hydrogen. As the final product is better suited to refineries, it has a higher market value. However, a great deal of energy is required for the refining process, particularly for the manufacture of the hydrogen.

3.4.2 Extracting fuel from extra heavy oil

The extraction of extra heavy oil[78] currently relies on the same in situ procedures as those used in tar sand extraction. Compared to bitumen, extra heavy oil has a lower viscosity and is thus easier to produce. [79] In Venezuela, the country with the largest extra heavy oil reserves in the world (approximately 50%), the high reservoir temperatures (at an average of 50°) also increase the flowability of the extra heavy oil. However, the exploitation rate from cold production is, at 8%-12%, very low.

Compared to the country's total extractable petroleum resources, which amount to 300 billion barrels, Venezuela's current extra heavy oil production of approximately 0.6 million barrels per day (220 million barrels annually) is very small. [80] However, Venezuela's extra heavy oil production will increase sharply over the next ten years. Thanks to Chinese and Russian investment, production will be increased by 0.9 million barrels/day by 2012. [81] In addition, the Venezuelan government has invited tenders for three projects in the Carabobo field with 0.4 million barrels per day each. Analysts expect these to begin production in 5 years. [82] As a result of the planned projects, Venezuela's extra heavy oil production will quadruple to 2.7 million barrels. This development stands in powerful contrast to EWG estimates, which state that Venezuela's extra heavy oil production will not expand until 2030. [83]

3.4.3 Extracting fuels from oil shale

Oil shale is a crude petroleum bedrock that has not yet completed the geological development necessary to form petroleum. The organic material contained in oil shale, called kerogen, differs from conventional petroleum through its higher content of oxygen compounds. [84]

The extraction of fuels from oil shale is extremely elaborate, as the organic material is enclosed within the pores of the rock in fine-grained form and can only be extracted through thermal treatment. Although oil shale has been mined and processed for more than 160 years, its economic use has only been possible through financial and political support. [85] Today, oil shale is only extracted in large quantities in Estonia, the Leningrad Basin, southern China and Brazil.

[78] Definition of extra heavy oil see Table 2
[79] BGR 2009.
[80] Technically extractable quantity of petroleum from total extra heavy oil resources (c. 20 % of the in-place quantity)
[81] AFP 2009a.
[82] Reuters 2009.
[83] Cf. Schindler and Zittel 2008.
[84] BGR 2009.
[85] Porath 1999.

However, fuels from oil shale are only produced in small quantities in these countries. [86] Experts anticipate more than 10 years of development time is required before the first large-scale industrial production of fuel from oil shale can be expected. [87] So far, oil shale has only been extracted using surface and deep mining. In situ procedures are still in the research and pilot phase.

In mining procedures, the rock containing oil shale is blasted, removed and crushed. Afterwards, the material can either be burned to produce electricity, as in Estonia, or else processed into higher quality hydrocarbons through coking or carbonisation. To this end, carbonisation reactors, so-called retorts, are used with downstream distillation facilities. Through carbonisation, the oil shale is heated to 300° to 500° and the kerogen is transformed into a gaseous mixture that is condensed into pyrolysis oil through cooling.[88]

In the in situ procedures, the oil shale in the deposit is carbonised and the carbonisation gases pumped out. There are various procedures for in situ carbonisation, including experiments in the USA involving heating of the rock via electricity.

3.4.4 Extracting fuels from coal and natural gas (CTL: coal to liquid, GTL: gas to liquid)

Just like tar sand and oil shale, coal can also be extracted using mining and in situ procedures and processed into fuels. In mining procedures, coal is extracted from deep or surface mines and then transformed into liquid fuels in several procedural steps. The gasification of coal and liquification using the Fischer-Tropf (FT) procedure have already been in use for more than 80 years.

CTL technology was primarily developed in South Africa, and fuel production from coal began in 1955. Current production amounts to 150,000 barrels/day. [89]

Direct liquefaction is a further possible means of manufacturing fuels from coal. One example of this is the Bergius-Pier procedure. In this procedure, coal is hydrated into fuels using high pressure and catalysts. [90] The greenhouse gas emissions of the entire procedural chain roughly correspond to the balance resultant from the gasification and Fischer-Tropsch procedures. [91] At the end of the 2008, the first direct liquefaction facility to be constructed worldwide after the Second World War was opened in China.[92]

Coal can also be extracted without mining procedures if the coal is gasified in situ, namely within the deposit (UCG: underground coal gasification). The UCG operates in a manner similar

[86] BGR 2009.
[87] Bartis 2006.
[88] BGR 2009.
[89] BGR 2009.
[90] Behrendt, F. et al. 2006
[91] America's Energy Future Panel on Alternative Liquid Transportation Fuels, National Academy of Sciences, National Academy of Engineering and National Research Council 2009.
[92] IEA 2008a.

to the THAI in situ procedure for the production of tar sand. The coal is ignited using a blend of oxygen and steam that is then pumped into the coal seam by means of boreholes (see Illustration 19 and Illustration 20). The gas accumulated below ground is transported to the earth's surface through a vertical borehole. The gas, possessing a fuel value of approximately 3 kWh/m³, contains approximately 32 % hydrogen, 17 % methane, 16 % carbon monoxide and 35 % carbon dioxide.[93]

The UCG procedure is not a new technology but was used in the former Soviet Union for over 50 years.[94] One facility is still in operation. Global interest in the UCG procedure has increased in recent years.[95] Several pilot projects are underway in Australia, China, South Africa, Russia and Canada. Additional projects are being planned in India, the USA, Vietnam and New Zealand.[96] The projects are primarily designed for the generation of electricity. So far, only Linc Energy in Australia (GTL) and the Hebei Xin'ao Group in China (methanol) are pursuing plans for fuel production from UCG gas.[97] In Germany, 2008, the Rheinisch-Westfälische Technische Hochschule Aachen began a UCG research project in order to examine geological and technological aspects of the procedure and the CO_2 storage capacity of the burned out seams.[98]

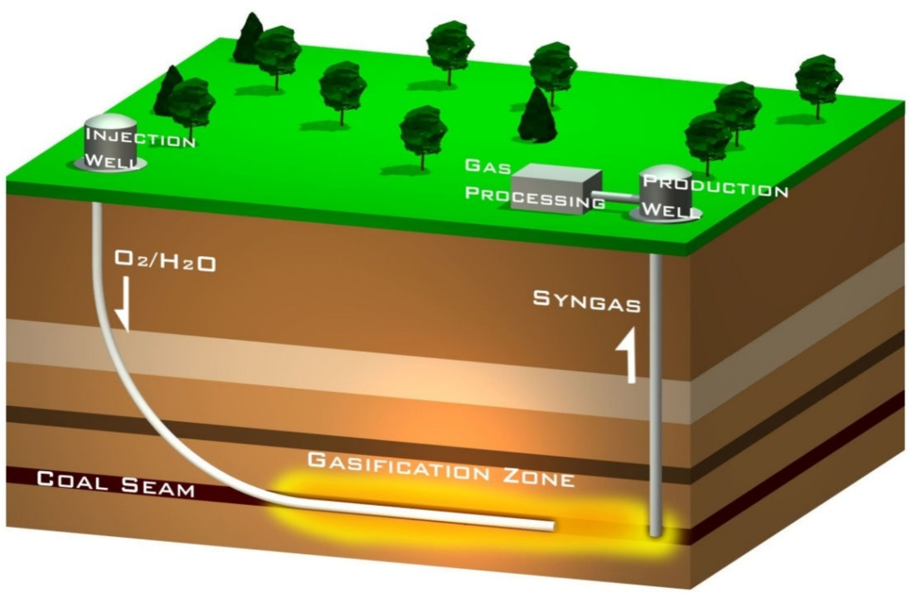

Illustration 19: Process diagram of in situ coal gasification. Own presentation, source: Kempka et al. 2009[99].

[93] Courtney 2008.
[94] Shafirovich et al. 2008. Kempka et al. 2009.
[95] Lawrence Livermore National Laboratory 2007.
[96] Shafirovich et al. 2008. UCG Partnership 2009. http://www.ucgp.com/
[97] Linc Energy 2009. Shafirovich et al. 2008
[98] Rheinisch-Westfälische Technische Hochschule Aachen 2008.
[99] Kempka et al. 2009.

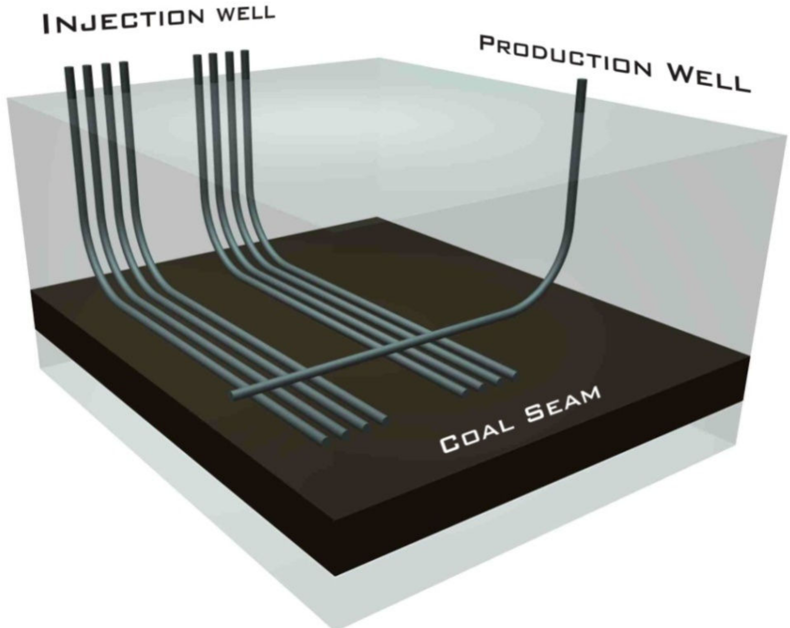

Illustration 20: Sequence of injection and production drillings for in situ coal gasification. Own presentation, source: Kempka et al. 2009[100]

In situ procedures like UCG profit from advanced developments in drilling technology for the extraction of unconventional natural gas, which are primarily taking place in the USA[101] (see chapter 3.2.2). These experiences and technological advances are improving the underground gasification of coal and making it possible to reach coal at depths of more than 1,000 m. [102]
The Fischer-Tropsch (FT) procedure is also used to liquefy natural gas. The global GTL production of 50,000 barrels/day occurs primarily at three facilities: Sasol in South Africa, Shell in Malaysia and Oryx in Qatar.[103]

4 Greenhouse gas emissions from fossil fuels

4.1 Greenhouse gas emissions from unconventional fossil fuels

The comparison of the greenhouse gas balances of various fossil fuels shows that emissions from unconventional fuels are up to two and half times higher than those of conventional fuels (s. Illustration 21 and Table 4).[104] Fuels made from coal display the worst results. GTL from synthetic gas from underground coal gasification shows the worst climate balance at nearly 830 g CO_{2eq}/kWh.

[100] Kempka et al. 2009.
[101] cf. BGR 2009.
[102] Nucoal 2009 http://www.nucoalenergy.ca/news/109/
[103] IEA 2008a.
[104] The German diesel value of GEMIS 4.5 serves as a reference value.

Compared to conventional fuels, the production of fuels from oil shale leads to levels of greenhouse gas emission between 30% and 70% higher. [105] The greenhouse balance of in situ procedures that produce fuels from oil shale with lower temperatures is comparable to tar sand extraction. Since there is little large-scale application, there is still a lack of available data for calculating the greenhouse balances of oil shale processing. The emissions will depend strongly on the oil content of the sedimentary rock, which varies between 2.5% and 41% globally. Moreover, [106] the carbonate composition of the matrix influences CO_2 emissions. [107] According to a study by Sundquist and Miller, process temperatures in fuel manufacture from oil shale amounting to between 700° and 1,100° degrees can entirely disintegrate the carbonated matrix and lead to extremely high CO_2 emissions of between 880 und 1,400 g CO_{2eq}/kWh fuel. [108]

The use of oil shale for electricity generation in Estonia highlights the problems resulting from high carbonate removal. Compared with electricity from coal, modern-day shale combustion in Estonia leads to 60% CO_2 emissions (1,600 g CO_{2eq}/kWh).[109] Yet even with the implementation of the most modern technologies, oil shale processing also leads to emissions up to 75% higher than those of conventional petroleum.

The comparison of GTL fuel from conventional natural gas with GTL from natural gas in the USA reveals how strongly the greenhouse gas balance depends on GTL from the upstream chain. Due to the high proportion of unconventional natural gas in the USA (tight gas, shale gas, coal bed methane), the greenhouse gas balance displays a fall of 33% in comparison with conventional petroleum. By contrast, GLT fuel from conventional natural gas leads to emissions only 13% higher.

[105] Brandt 2007a,b,c.
[106] Porath 1999.
[107] Sato & Enomoto 1998.
[108] Sundquist & Miller 1980. The matrix is rich in carbonaceous minerals such as calcium carbonate.
[109] European Academies Science Advisory Council 2007.

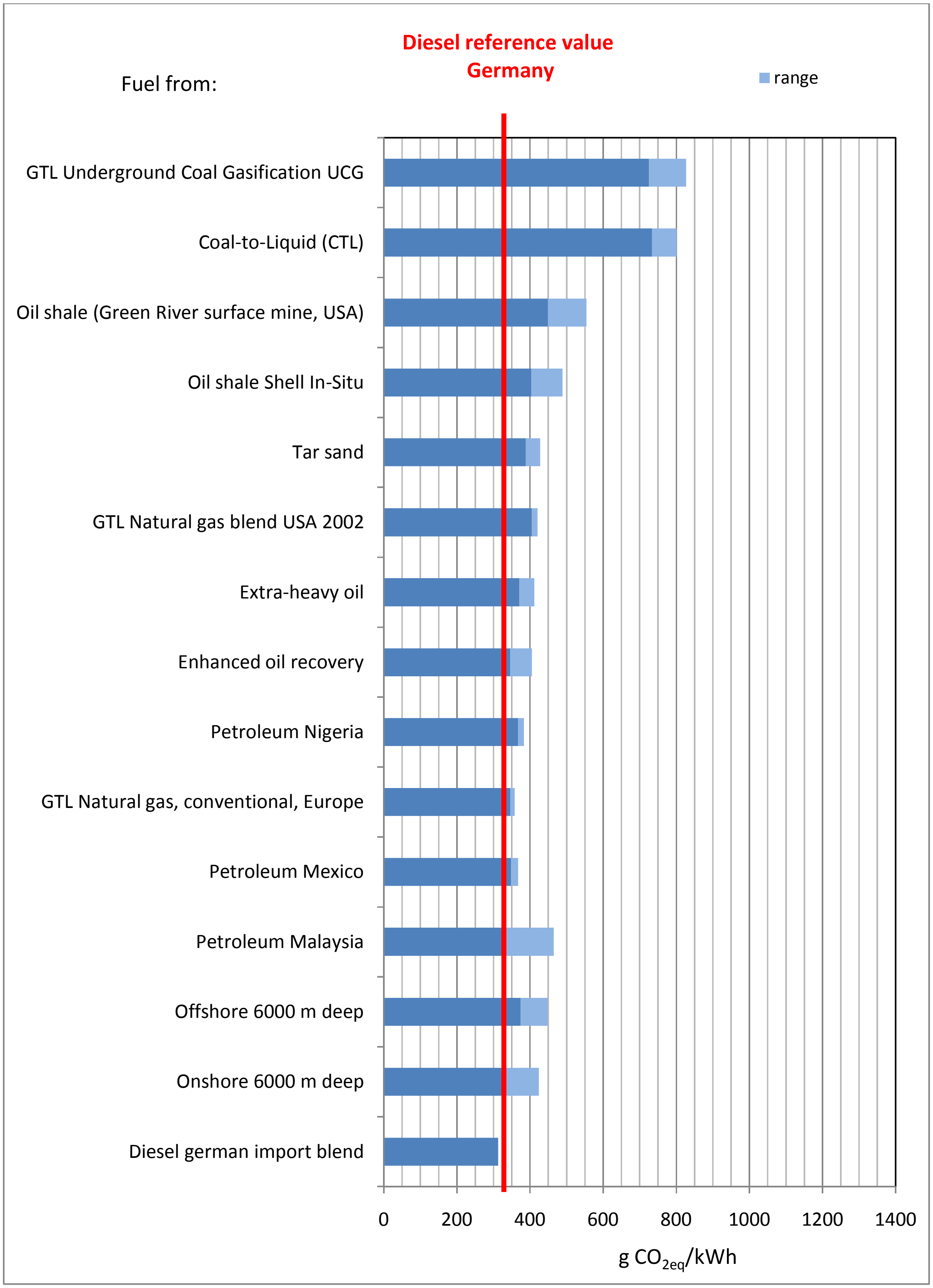

Illustration 21: Green house gas emissions of fossil fuels (WTW). Source: own calculation.

	(g CO_{2eq}/kWh)		Difference to diesel reference value, Germany (GEMIS 4.5)	
Fuels from:	min.	max.	min.	max.
GTL Underground Coal Gasification UCG[110]	775	827	+132%	+164%
Coal-to-Liquid (CTL)[111]	734	802	+134%	+156%
Oil shale (Green River surface mine, USA)[112]	449	554	+43%	+77%
Oil shale, Shell, in situ[113]	404	488	+29%	+56%
Tar sand[114]	388	428	+24%	+37%
GTL natural gas blend, USA 2002[115]	405	421	+29%	+34%
Extra heavy oil[116]	371	411	+18%	+31%
Enhanced oil recovery[117]	346	405	+11%	+29%
GTL natural gas, conventional, Europe[118]	346	358	+11%	+14%
Petroleum Nigeria[119]	367	383	+17%	+22 %
Petroleum Mexico[120]	348	368	+11%	+14%
Petroleum Malaysia[121]	328	465	+5%	+49%
Onshore, 6,000 m deep[122]	332	424	+6 %	+345%
Offshore, 6,000 m deep[123]	374	449	+20%	+43%
Reference value: Diesel German import blend [124]	313			

Table 4: Greenhouse gas emissions from fossil fuels (Well to Wheel – WTW-Emissions). Source: own calculation.

110 Own calculation according to CONCAWE, EUCAR and European Commission Joint Research Centre 2008, Courtney 2008, Armendariz 2009.
111 CONCAWE, EUCAR and European Commission Joint Research Centre 2008
112 Brandt 2007b,c.
113 Brandt 2007a,b 2008c.
114 Farell & Brandt 2006.
115 Own calculation according to CONCAWE, EUCAR and European Commission Joint Research Centre 2008, NETL 2008.
116 NETL 2009b.
117 Farell & Brandt 2006.
118 CONCAWE, EUCAR and European Commission Joint Research Centre 2008
119 NETL 2009b
120 NETL 2009b
121 Own calculation according to Talisman 2008 and NETL-Baseline. Due to the elevated share of CO2 in the accompanying gas (159 g CO2eq/kWh), the greenhouse gas emissions from the Talisman petroleum production in Malaysia are more than five times higher than the UK Talisman emissions.
122 Keesom et al. 2009. Estimated water to oil ration (WOR) 25:1.
123 Keesom et al. 2009. Estimated WOR 25:1.
124 GEMIS 4.5

4.2 Greenhouse gas emissions from conventional fossil fuels

The comparison of the various balances shows that the range of greenhouse balances of conventional fuels is immense. It is influenced by the following parameters:

- Oil field depth
- Water to oil ratio (WOR): Proportion of water in extracted oil
- Use of improved production technologies
- Flaring of accompanying gas
- Venting of unburned accompanying gas
- Viscosity of petroleum
- Sulphur content of petroleum

4.2.1 Oil field depth and water to oil ratio (WOR)

As oil fields become deeper, yielding a greater water to oil ratio, the greenhouse gas emissions from petroleum production also increase. In 2009, Jacobs Consultancy published a study outlining the impacts of various oil production parameters on the emissions balance. [125] The results of the analysis of the parameters of depth and the water to oil ratio are depicted in Illustration 22 and Illustration 23. Illustration 22 shows that, with a 0% water content (WOR 0:1) greater petroleum deposit depth has little impact on emissions. However, the increasing water content of the extracted petroleum indicates significant differences. For example, with a water to oil ratio of 10:1, the greenhouse gas emissions from petroleum production in a 6,000 m deep field are twice as high as those in a 1,500 m deep field. The impact of the WOR increase develops at the same ratio:

- In a 1,500 m deep field, emissions double through an increased water to oil ratio of 0:1 to 10:1.
- In a 6,000 m deep field, emissions increase fourfold with the same deterioriation of the water to oil ratio.

Illustration 23 shows how the emissions from pumping, water injection, water processing and other energy consumption rise through increased depth and the increasing water to oil ratio. For a comparison of the greenhouse gas balances of various fossil fuels (Illustration 21 and Table 4), an offshore field with a depth of 6,000 m and a water to oil ratio of 25:1 is depicted. The emissions for both examples are as much as 34% and 42% higher than the German diesel reference value from GEMIS.

[125] Keesom et al. 2009

However, the greenhouse gas emissions from onshore and offshore fields has the potential to increase even more since the sample fields do not have the most extreme parameters. With a depth of more than 10,000 m, Chevron's Tahiti field in the Gulf of Mexico is currently the deepest developed offshore oil deposit. BP's latest discovery in the Gulf of Mexico, the Tiber field, is in fact 10,700 m deep. [126] The Tupi field off the coast of Brazil is located at a depth of 7,000 m.

The water to oil ratio can rise to 50:1. [127] Many older oil fields are liable to have a WOR surpassing 20:1. [128] When calculating both sample fields, this study did not take into consideration further parameters, such as the increase in accompanying gas and the share of CO_2 in the accompanying gas. [129]

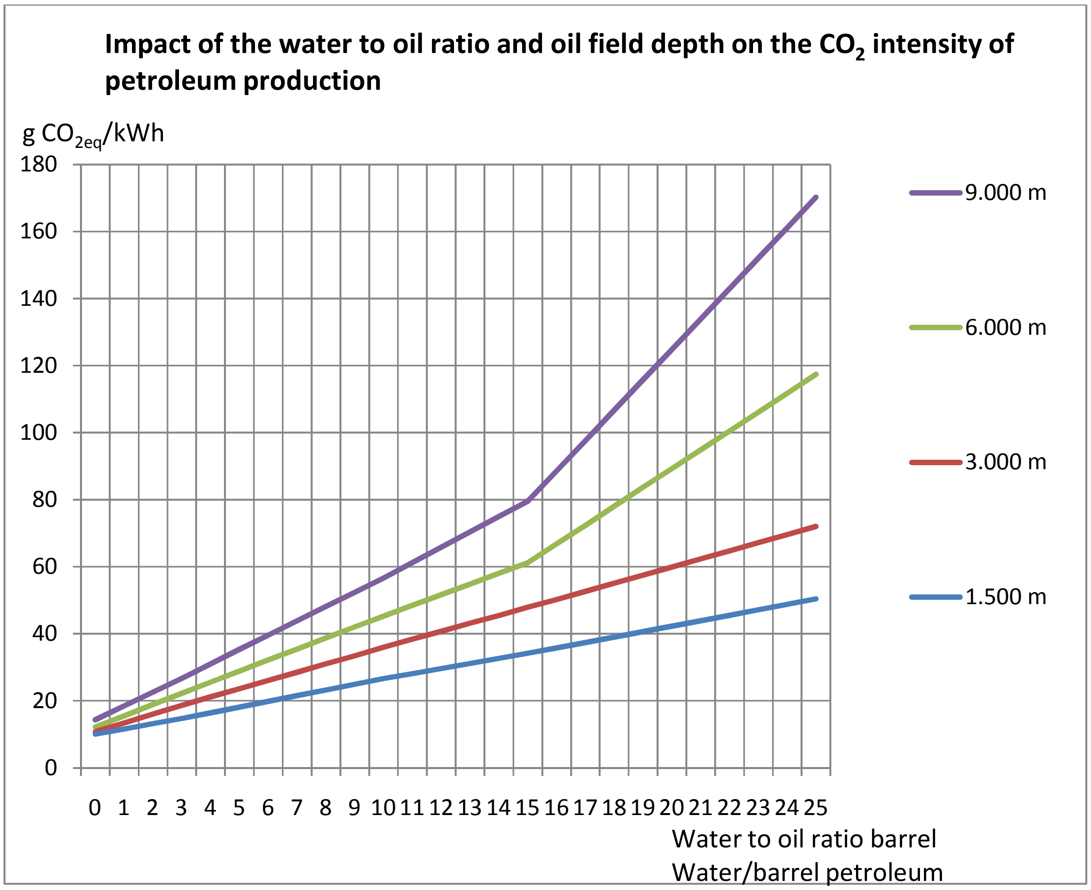

Illustration 22: Impact of the water to oil ratio and oil field depth on the CO_2 intensity of petroleum production. Own calculation according to Keesom et al.[130]

[126] BP 2009c.
[127] Maersk Oil 2008.
[128] Keesom et al. 2008
[129] Ibid. 2008, Talisman 2008. Due to the share of CO2 in the accompanying gas (159 g CO2eq/kWh), the greenhouse gas emissions from Talisman petroleum production in Malaysia are five times higher than UK emissions.
[130] Keesom et al. 2008

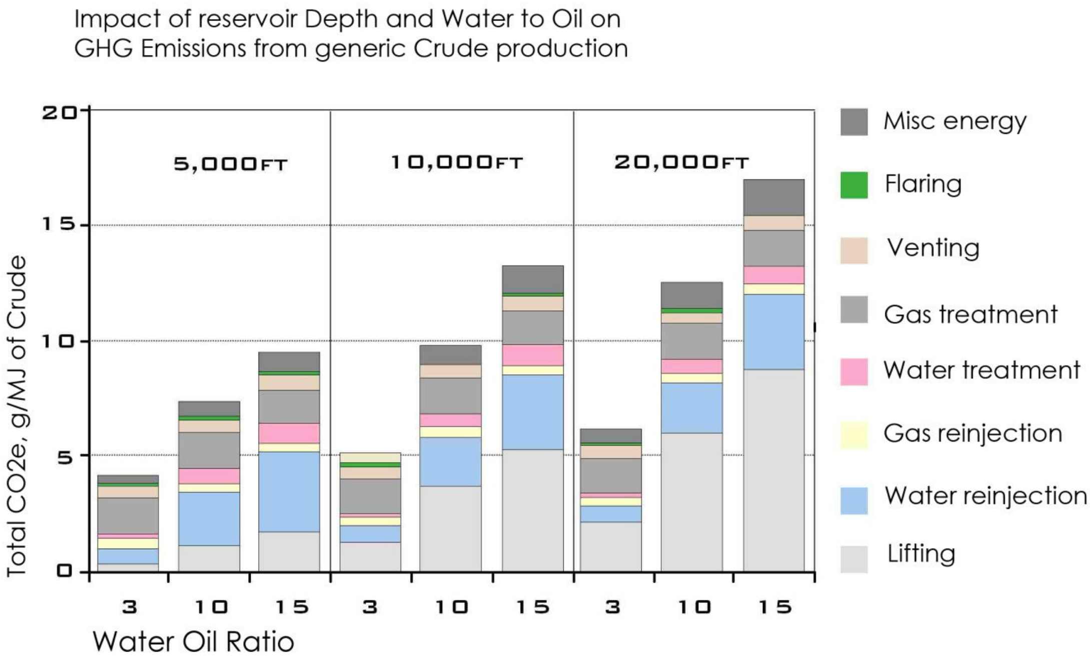

Illustration 23: Specific greenhouse gas emissions of petroleum production with varying water to oil ratios and oil field depths. Own presentation according to Keesom et al.[131]

In the future, deep-sea drilling will grow in importance, as indicated by the recent petroleum discoveries in the Gulf of Mexico and off the shores of Brazil and Africa. Offshore oil fields already contribute one third of global petroleum production. [132] According to Llewelyn, 15% of them are deep-sea deposits. [133] The exploitation of deep-sea fields entails vast technical challenges, e.g. the penetration of a nearly 2,000 m thick layer of salt in the Tupi field.
Yet onshore drillings are also becoming deeper. For example, in Russia the average drilling depth has doubled since 1960, now reaching 3,000 to 4,000 m. In the future, depths of 5,000 to 6,000 m can be expected. [134] According to IHS and Credit Suisse, around 30% of remaining global oil reserves are located at a depth greater than 3,000 m. [135]

The water to oil ratio will also continue to deteriorate worldwide, as, the older the field, the greater the decline of production amounts and the greater the proportion of water rises. [136] In Canada, for example, the WOR of petroleum production in the province of Alberta has risen sharply in recent years and increased from 11.6 to 14.8 between 2000 and 2003 alone. [137]

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[131] Keesom et al. 2008.
[132] IEA 2008a.
[133] Llewelyn quoted in Chang 2007. David Llewelyn is a petroleum expert from Crondall Energy Consultants
[134] Matveichuk 2005.
[135] Sandrea & Sandrea 2007
[136] Maersk Oil 2008.
[137] Hawkins and Singhal 2004.

4.2.2 Use of enhanced recovery technologies

As has already been described in chapter 2.2, enhanced oil recovery (EOR) methods are used to increase the exploitation rate of the oil fields. The following table shows that the emissions from petroleum production triple through the use of water and gas injection and even increase more than fourfold using steam injection. Applied to the WTW emissions, the findings of Farell & Brandt 2006 indicate an increase of up to 30% compared to the German diesel reference value (see Illustration 21and Table 4[138]).

Greenhouse gas emissions	Primary production methods	Water injection	Gas injection	Steam injection (TEOR)
g CO_{2eq}/kWh	15.52	20.45	46.3	68.00

Table 5: Comparison of greenhouse gas emissions from various production methods. Own calculation according to CARB [139]

As the proportion of oil fields in total production continues to rise (see chapter 2.3), the significance of enhanced recovery technologies will increase in the future. With this, the energy required for the production of petroleum will likewise continue to increase. For this reason, CERA (Cambridge Energy Research Associates) call petroleum production in fields that have already passed their peak an 'energy intensity dilemma'. [140] One example of how the specific greenhouse gas emissions from petroleum production in declining fields will develop in the future can be seen in the University of Calgary's forecast for Canada. By 2020, the university's energy experts anticipate a tripling of carbon intensity from the production of light and medium-heavy petroleum types in Canada compared with the average emission values of 2000. [141]

The increase of the greenhouse gas intensity of oil fields is already clearly visible in the North Sea. The greenhouse gas emissions from Talisman petroleum production in Great Britain have risen by 60% to 30 g CO_{2eq}/kWh in the past 5 years. [142] The development of BP in the North Sea is very similar: the greenhouse gas intensity of the BP North Sea fields also increased by almost 60% from 2004 to 2008 (Illustration 24 und Illustration 25).[143]

When indirect effects are also taken into consideration, it is possible to note an 80% increase in specific emissions from North Sea petroleum over the past 4 to 5 years: [144] If we assume that a large portion of greenhouse gas emissions can be traced to the energy supply of the oil platforms, substitution effects must be included in the calculation. The natural gas consumed on the platforms can no longer be fed into the British natural gas grid and must therefore be replaced with imported liquefied natural gas (LNG). As a result, the greenhouse gas calculations for petroleum have to bring into consideration not only the pure combustion emissions from natural gas but also the upstream emissions of LNG use.

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[138] Farell & Brandt 2006. On EOR energy consumption, see also Petroleum Economist 2009, IEA 2008a. BGR 2009.
[139] CARB 2009.
[140] Markwell 2009.
[141] Timilsina 2006.
[142] Talisman 2009.
[143]Own calculation according to BP North Sea 2009, BP 2009b and European Commission 2009.
[144] Own calculation according to BP North Sea 2009,BP 2009b and European Commission 2009.

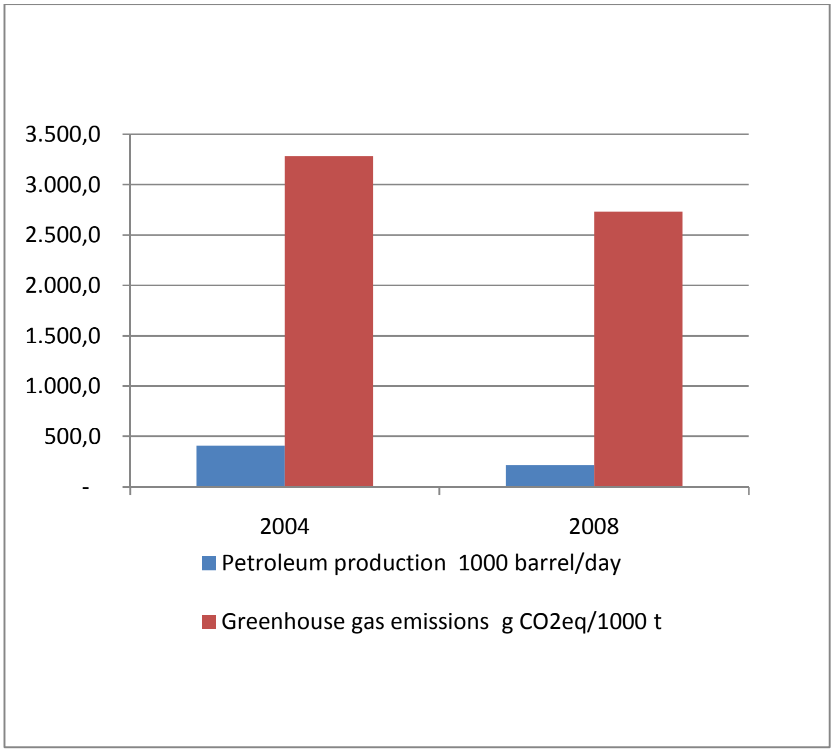

Illustration 24: Development of petroleum production and the greenhouse gas emissions from BP petroleum production in the North Sea[145]

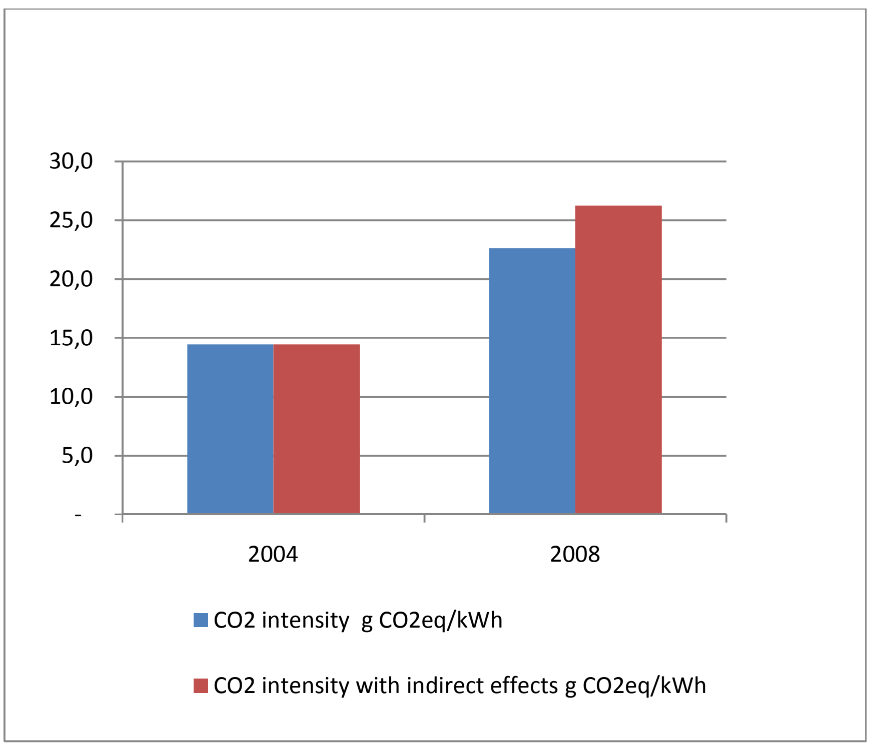

Illustration 25: Development of CO_2 intensity of BP petroleum production in the North Sea[146]

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145 Own calculation according to BP North Sea 2009, BP 2009b and European Commission 2009.
146 Own calculation according to BP North Sea 2009, BP 2009b and European Commission 2009.

4.2.3 Flaring of accompanying gas, venting of unburned accompanying gas

The flaring of accompanying gas and the venting of unburned accompanying gas leads to extremely high greenhouse gas emissions the world over. According to a study by the World Bank, approximately 150 billion m³ of accompanying gas is burned off globally, leading to emissions of 400 million t of CO_2. [147] As stated in the World Bank's report, global flaring quantities have scarcely changed in the past 15 years. [148] Although several countries have shown progress, flaring quantities in other countries, such as Russia, have increased sharply. Further increases can be observed in other regions. For example, the specific flaring quantities amassed by BP in the North Sea have increased by around 70% in the past 4 years. [149] Total BP flaring quantities have increased by 25% globally in the past 4 years. [150]

With 16.8 billion m³, Nigeria flares the second-largest quantity of accompanying gas after Russia. [151] This amount corresponds to 15% of annual natural gas consumption in Germany. The flaring quantities in Nigeria lead to 20% higher emissions in comparison with the German diesel reference value (see Illustration 21 and Table 4).

The flaring quantities are joined by the global quantities of unburned vented natural gas, which, according to EPA estimates, produce approximately 60 million t CO_{2eq}. [152] However, according to BGR and Jacobs Consultancy, global venting quantities have scarcely been ascertained. When studying accompanying gas, for example, it is essential to take the varying compositions into consideration. [153] Thus the high proportion of CO_2 in accompanying gas leads to extremely high emissions, as at the Talisman oil field in Malaysia, whose greenhouse gas balance is even worse than that of tar sands (see Illustration 21 and Table 4). [154] Alongside Malaysia, petroleum deposits in Thailand, Indonesia, Vietnam and China have high CO_2 quantities that are normally vented. [155]

Moreover, when calculating methane emissions, it is important to consider the upstream chain of the natural gas that is used for petroleum extraction and processing. Using the USA's CH_4 baseline data for diesel fuel, this results in projected annual greenhouse gas emissions of around 400 million t CO_{2eq}. [156]

The following table shows how the different venting assumptions and calculation methodologies (NETL baseline and Jacobs Consultancy) impact the balance of diesel from Russia compared with various reference values in Germany, the EU and the USA.

[147] BGR 2009.
[148] Elvidge et al. 2007.
[149] BP North Sea 2009.
[150] BP 2009e.
[151] BGR 2009.
[152] EPA 2006.
[153] Keesom et al. 2008
[154] Talisman 2009
[155] Ibid. 2009
[156] NETL 2009b.

	Source	WTW greenhouse gas emissions g CO_{2eq}/kWh fuel
EU default value diesel/petrol	EU Commission EU-EE Guideline	301.68
Germany diesel fuel	GEMIS 4.5	313.02
USA baseline diesel fuel	NETL	328.44
Russia diesel fuel: medium venting quantities	Own calculation according to NETL Baseline, World Bank (Flaring), Öko-Institut (venting)	347.63
Russia diesel fuel: high venting quantities	Own calculation according to NETL-Baseline, World Bank (Flaring), NETL (venting)	363.39
Russia Diesel fuel: medium venting quantities	Own calculation according to Jacobs (Arab Medium), World Bank (Flaring), Ökoinstitut (venting)	375.95
Russia diesel fuel: high venting quantities	Own calculation according to Jacobs (Arab Medium), World Bank (Flaring), NETL (venting)	391.71

Table 6: Comparison of greenhouse gas emissions from diesel fuel from Russia with various reference values[157]

4.2.4 Viscosity and sulphur content of petroleum

The following illustration shows how sharply greenhouse gas emissions increase due to increased weight (i.e. declining API values – see Chapter 3.4.1.1) and rising sulphur content.

[157] GEMIS 4.5,UBA 2009, NETL 2009b. Keesom et al. 2009. Methodology for calculating WTW emissions from diesel from Russia: For the calculation of all WTW emissions without flaring and venting, the values of the US reference value from NETL and the values for Arab Medium from Jacobs Consultancy were used. The API and sulphur values of average oil input in US refineries and from Arab Medium are approximately equivalent to the qualities of REBCO petroleum (Russian Export Blend Crude Oil). USA average: 30.2 API, 1.5 % sulphur, Arab Medium: 31.1 API, 2.6 % sulphur, REBCO: 31-32 API, 1.2 % sulphur. For flaring quantities, the 2007 World Bank values were used. The basis for calculating the average venting quantities (CH4 losses through leakage and flaring) are the assumptions of the Öko-Institut with a venting-to-flaring ratio of 1:30. The basis for calculating the high venting quantities are NETL's assumptions for Nigeria with a venting-to-flaring ratio of around 1:10.

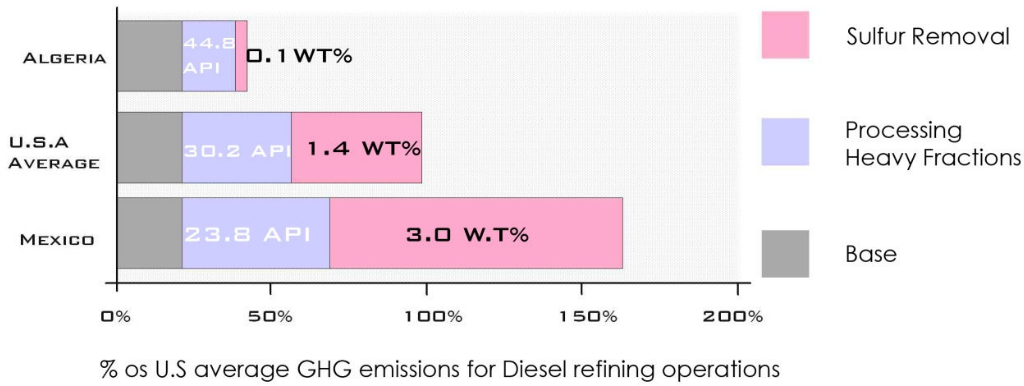

Illustration 26: Impact of weight and sulphur content of petroleum: deviation of the average greenhouse gas emissions of diesel fuel in the USA by percentage.[158]

The greenhouse gas balance in petroleum from Mexico indicates that heavy oil production and processing leads to emission increases of up to 16% compared to the German diesel reference value (see Illustration 21 und Table 4). Greenhouse gas emissions from the extraction and processing of heavy oils will continue to rise:

- In global petroleum production, the proportion of heavy, sulphurous crude oils is growing and that of the lighter, low-sulphur types, [159] which currently make up just 20% of global production, is declining. [160]

- Due to increased global demands on fuel quality (e.g. the reduction of sulphur and polyaromatic hydrocarbons [PAK]), energy expenditures and emissions for petroleum refining are rising. [161] According to EUROPIA, CO_2 emissions from European refineries will rise by 50% in order to reduce the sulphur content of diesel and to cover the growing European demand for diesel. [162] In other regions as well, strict fuel directives are leading to increased greenhouse gas emissions. For example, Szklo and Schaeffer[163] anticipate a 30% increase of CO_2 emissions in the Brazilian refineries through the attempt to maintain the new sulphur emission thresholds.

- The growing share of heavy and sulphurous crude oils will further increase the tendency towards the usage of hydrogen in petroleum processing. The largest global share of hydrogen is currently being manufactured through the reformation of hydrocarbons, particularly from natural gas. A higher natural gas demand via the petroleum industry will increase the greenhouse gas emissions from natural gas production:
    - The production of unconventional natural gas will intensify.

[158] Keesom et al. 2009. WT: sulphur content.
[159] EID 2006, Greaves 2006.
[160] Wood 2007
[161] Szklo and Schaeffer 2006.
[162] Euractiv 2008.
[163] Szklo and Schaeffer2006.

- The production of LNG will gain further incentives. Through liquefaction, transport and regasification, the CO_2 emissions from LNG will rise from 220 to as much as 340 CO_{2eq}/kWh.[164]
- Methane leakage from natural gas production will rise further through increased natural gas production. According to EPA estimates, the natural gas sector is already leading to methane emissions of nearly one billion t CO_{2eq}. Due to increasing natural gas demand, the EPA anticipates an increase in annual emissions by 54% to 1.5 billion t CO_{2eq} by 2020. [165]

- The substitution of sulphur-rich heavy oil for the generation of electricity through other energy sources, such as natural gas or renewable energies, will further increase the demand for heavy and sour crude oils for usage in the transportation sector. [166]

4.2.5 Impacts of the results on the German reference value and on global petroleum production emissions

The range of greenhouse gas emissions from conventional fossil fuels as depicted in chapter 4.2 shows that the EU reference value for diesel fuel and petrol, at 302 g CO_{2eq}/kWh and the diesel reference value of GEMIS 4.5 at 313 g CO_{2eq}/kWh, has been set too low. In Germany, nearly 50% of the petroleum is imported from those countries having the world's highest flaring quantities, such as Russia, Kazakhstan, Nigeria and Angola. Moreover, 25%, at continually rising levels of greenhouse gas emissions, comes from the North Sea. For this reason, the current German average value for diesel fuel has been placed at between 335 and 360 g CO_{2eq}/kWh.[167]

For global petroleum production and use, the range of greenhouse gas emissions as presented in chapter 4.2 amounted to between 13.5 and 15 billion t CO_{2eq} in 2008. [168] Emissions from petroleum are thus approximately equal to the global greenhouse gas emissions from coal use of between 14 and 15 billion t CO_2.[169] The comparison with pure combustion emissions of 10.8 billion t for petroleum and 12.6 billion t for coal leads to underestimating of the climate balance in the petroleum sector. [170]

[164] With respect to the total life cycle of gas use from production to combustion.
[165] EPA 2006.
[166] Gtai 2009
[167] Lower value calculated with NETL figures and upper value calculated with Jacobs Consultancy results. GEMIS 4.5,UBA 2009, NETL 2009b. Keesom et al. 2009.
[168] Lower value calculated with NETL figures and upper value calculated with Jacobs Consultancy results. GEMIS 4.5,UBA 2009, NETL 2009b. Keesom et al. 2009
[169] Own calculation according to Ökoinstitut 2007 and IEA 2008b
[170] IEA 2009. BP 2009f.

5 Production costs of fossil fuels

The production costs for fossil fuels have risen sharply over the past 10 years. Costs for the generation of petroleum from tar sand have more than quadrupled and costs for deep-sea oil have increased more than sevenfold. [171] In its International Energy Outlook of 1998, the EIA (Energy Information Administration) in the USA regarded a petroleum price of 30 dollars/barrel as sufficient for the cost-effective production of 2 trillion barrels of unconventional petroleum in 2020. [172] However, in 2008, the IEA was citing production costs of up to 120 dollars/barrel for unconventional petroleum. [173]

The range of production costs for conventional and unconventional fossil fuels is vast. Illustration 27 shows that CTL, GTL from natural gas and fuels from oil shale represent the most expensive fossil fuels at production costs of up to 120 dollars/barrel. By contrast, fuel from tar sand, bitumen from Venezuela and GTL from UCG synthetic gas have lower maximum production costs of up to 70 dollars/barrel. The production of these unconventional fuels remains below the highest costs for enhanced oil recovery from existing oil fields and for Arctic oil. The maximum production costs for deep-sea oil are approximately as high as those for producing GTL from UCG synthetic gas.

[171] IEA 1998, IEA 2008a
[172] EIA 1998
[173] IEA 2008a

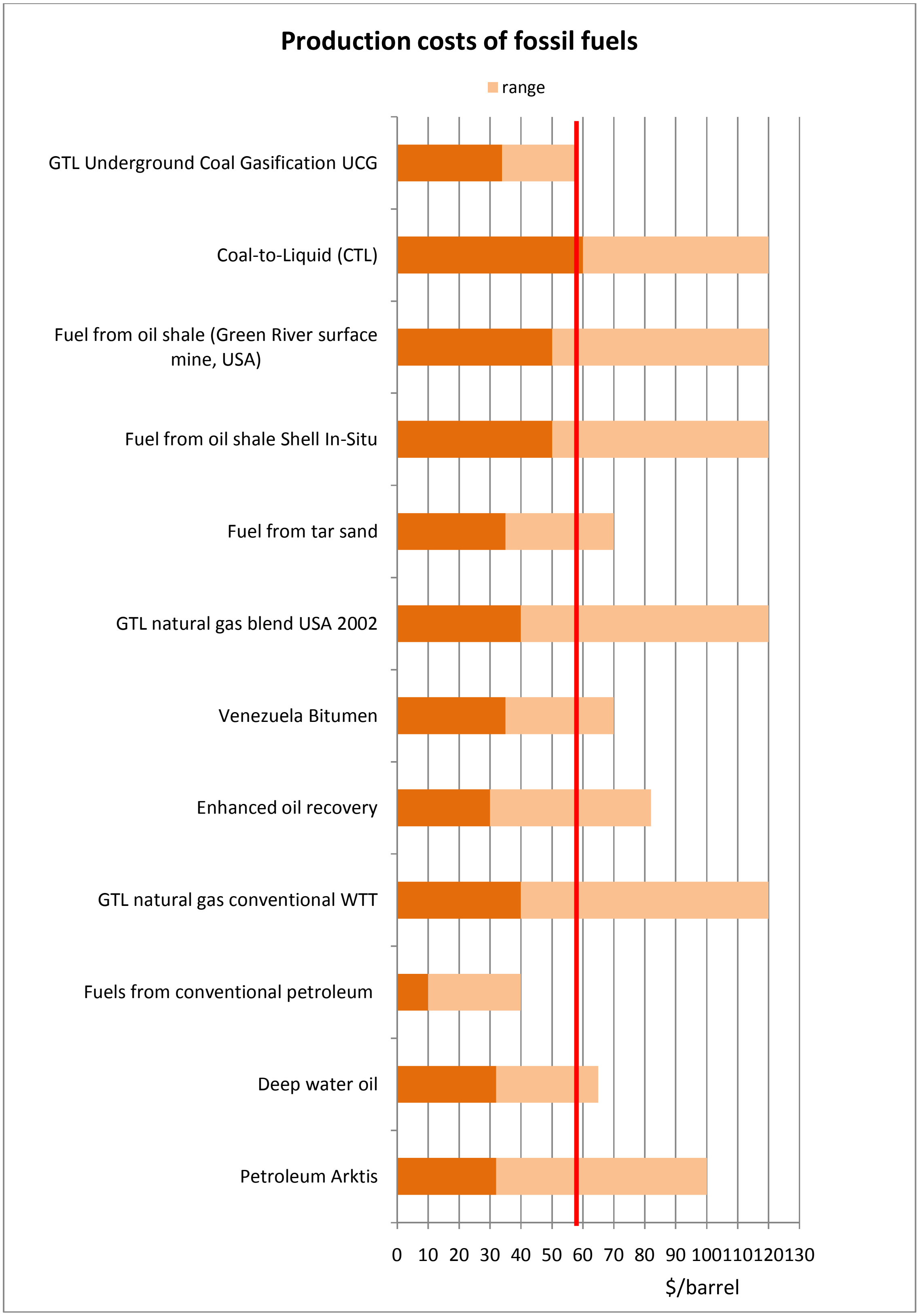

Illustration 27: Production costs of fossil fuels[174]

[174] Sources: IEA 2008a, Bartis et al. 2008, Department of the Interior 2008, FEV & WI 2008, Courtney 2008, *Rahman 2008*, Linc Energy 2009, BGR 2009.

The following factors have been causing both the sharp rise in production costs over the past 10 years and their broad range:

- The geological, geographical and chemical properties of the resource deposits greatly influence material and energy requirements for the extraction and processing of the raw materials:
  - The depth and location of the resources (offshore or onshore, infrastructure: transportation and pipeline networks)
  - The geological structure of the raw material deposits
  - The characteristics of the surrounding rock
  - The chemical structure of the hydrocarbons
- The amount of return anticipated has a strong influence on the total investment costs. For example, according to a RAND study, CTL with an internal interest rate of 10% is already cost-effective starting at 55 dollars/barrel. However, with an internal interest rate of 14%, it only starts to become cost-effective at 70 dollars/barrel. [175]
- Production costs are steadily rising:[176]
  - The number of drilling rigs per quantity of petroleum has risen sharply over recent decades[177]
  - There is a constant need for deeper digging
  - The average quantity of crude oil per field is declining. For this reason, more and more fields need to be developed in order to maintain the same quantity of raw material production
  - Elaborate technologies are needed for the manufacture of unconventional fossil fuels. The effort and expenses for the processing of coal and oil shale into fuels is still higher than that for oil extraction from tar sands.[178]
- Material costs have risen rapidly over the past 10 years. Between 2000 and 2008, for example, costs per drilling rig rose 120%.[179]

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[175] Bartis et al. 2008: Reference-case CTL plant costs. High CTL plant cost case: 10 % internal interest rate: 65 dollars/barrel. 14 % internal interest rate: 90 dollars/barrel
[176] Cf. IEA 2008a
[177] IEA 2008a
[178] CONCAWE, EUCAR and European Commission Joint Research Centre 2008, Brandt 2007b, Meyer-Renschhausen 2007. Tar sands contain bitumen, which is a degraded form of petroleum. The liquid hydrocarbon contained in oil shale, so-called kerogen, is a pre-stage of petroleum. That is why the effort involved in manufacturing fuels from kerogen is higher than from bitumen.
[179] IEA 2008a.

- Energy costs particularly influence the costs of fuels that require high energy input for the conversion process, e.g. CTL, GTL and fuels made from oil shale and tar sand. The following factors must be taken into consideration:
    - The extraction and mining costs of fuel vary sharply: for example, the extraction of sweet gas in Adu Dhabi costs between 0.3 and 0.5 $ct/kWh, while the extraction of sour gas costs 1.7 $ct/kWh. The average gas extraction costs in the USA amount to 1 $ct/kWh,[180] with shale gas production costs between 1.4 and 1.7 $ct/kWh.
    - The market price of the raw material: if the raw materials for energy can also be used to manufacture fuel in other sectors (electricity and heat generation, the chemical industry), then it is essential to consider not only the extraction costs of the raw material but also its market price. The examples of GTL and CTL make it particularly clear how the market price of the energy source impacts upon total costs.
    - GTL: When the pure production costs are included in the calculation, GTL (e.g. in Abu Dhabi) costs only 30 dollars/barrel. [181] By contrast, in the average import costs[182] for gas in Germany, GTL production costs were more than three times higher in 2008 (95 dollars/barrel).
    - In the natural gas market, the growing significance of liquefied natural gas (LNG) is complicating the realisation of GTL projects. LNG capacity increased more than sixfold between 2003 and 2009 and now stands at over 300 billion m³.[183] Indeed , the capacity of the loading terminals amounts to twice that of the liquefaction facilities. [184]
    - Globally, LNG already makes up a quarter of all natural gas traded across borders . [185] The IEA anticipates a further 50% increase in global LNG capacity by 2013. [186] In contrast to LNG, current GTL production is very low. Only around 5 billion m³ of natural gas was processed to GTL in 2008, which is less than 2% of the current LNG quantity. [187] Although the quantity of natural gas used for GTL will increase tenfold according to IEA estimates, this quantity will remain very small compared to LNG. The reasons given by the IEA include high investment needs, greater technological demands and greater input of energy[188] compared to LNG. [189]

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[180] CERA 2004
[181] Own calculation according to CONCAWE, EUCAR and European Commission Joint Research Centre 2008 and FEV & WI 2008.
[182] Border-crossing costs
[183] Own calculation according to BGR 2009, IEA 2008a, IEA 2003
[184] Platts 2008
[185] BGR 2009
[186] IEA 2009
[187] IEA 2008a
[188] GTL: 1,4-1,7:1; LNG: 1,25:1
[189] Cf. *Rahman 2008.*

GTL from UCG synthetic gas (underground coal gasification) is the most inexpensive unconventional fuel, provided only the extraction costs are included in the calculation (cf. Illustration 2).[190]

CTL: The raw material costs for CTL, for example, when based on the average price of coal in the USA in 2007 (26 dollars/t), stood at 12 dollars/barrel, and when correlated with the average German import price (150 dollars/t) in 2008, they stood at 60 dollars/barrel. The high raw material costs in Germany would push CTL costs to over 115 dollars/barrel. [191]

In addition to possible alternative uses, the market price also strongly depends on the raw material's transportability. [192] Only anthracite, the form of coal with the highest carbon content, and bituminous coals are to be transported over extended distances. By contrast, the transport of lignite and sub-bituminous coal is not cost-effective due to the lower energy content of these coal types.

- The use of large quantities of externally generated energy: for example, in situ procedures that extract bitumen from tar sands using hot steam cost 50% more when the gas price triples. [193] (This is assuming US gas prices will rise from the current level – the summer of 2009: 1.37 $ct/kWh – back to the level of the summer of 2008, 4.8 $ct/kWh).

  The costs of energy-intensive conversion processes using internal heat input, i.e. that use energy from the same raw material, can be reduced. One example is the toe-to-heel injection procedure (THAI), which burns a portion of the tar sand underground in order to liquefy the bitumen[194] (see chapter 3.4.1.3).

6 Comparison of greenhouse gas emissions and production costs of fossil fuels

The comparison of the greenhouse gas balances of various fossil fuels with their production costs shows that there is no direct correlation between the level of greenhouse gas emissions and production costs. Although fuels made from coal and oil shale are among the most expensive unconventional fuels, and also have the highest emissions, the maximum production costs for GTL, the unconventional fuel with the best climate balance, are located in the same range. In contrast, GTL from synthetic gas or underground gasification shows almost the

[190] Actually, the market price of hydrogen-rich synthetic gas (more than 30% hydrogen, over 15% methane) must be taken into consideration, since it can also be used to generate electricity and heat and for the manufacture of chemical products (e.g. fertiliser).

[191] Own calculation according to Bartis et al. 2008 – at an internal interest rate of 10 %

[192] According to the International Classification of in-Seam Coals (UN-ECE 1998), coal is divided into the following categories: soft brown coal, sub-bituminous coal, bituminous coal and anthracite. Source: BGR 2009. The degree of coalification ranges from soft brown coal to anthracite. The degree of coalification is the degree of transformation from plant-based substances into coal. As coalification increases, the coal becomes richer in carbon and weaker in volatile components. The degree of coalification depends on the coal's age and its external formation conditions (pressure, temperature). Source: http://www.steinkohle-portal.de.

[193] Own calculation according to Bartis et al. 2008.

[194] Meyer-Renschhausen 2007.

highest emissions but also represents the unconventional fuel with the lowest production costs.

Although the UCG-GTL procedure, like CTL and GTL, requires the highest energy input of all the unconventional fuels, its raw material and investment costs are lower:

- The market price for synthetic gas from underground gasification is low in remote regions without potential alternatives to use in the electricity, heat and chemical sectors. The synthetic gas would first have to be transformed into methane in order to use the existing infrastructure, or else a new pipeline infrastructure would have to be built for hydrogen transport. Thus, without alternatives to use , it is possible to assume that the raw material costs for the UCG-GTL procedure would be the production costs for synthetic gas, namely 0.6 to 1.5 ct/kWh. [195]

- The investment costs for the UCG-GTL procedure are considerably lower than for CTL since the gasification occurs underground and thus no elaborate coal gasification facilities need to be built. According to information from the Australian firm of Linc Energy, the investment costs for a UCG-GTL facility per barrel/day amount to less than 25,000 dollars, i.e. only a third of a CTL facility. [196]

With tar sand as well, the reduction of energy costs can lead to higher greenhouse gas emissions:

- Reduction of externally generated heat with natural gas through the toe-to-heel injection procedure (THAI), whereby a portion of the tar sand is burnt underground in order to liquefy the bitumen. [197]

- Substitution of natural gas for electricity, steam and hydrogen production with bitumen, which is transformed into a low calorific, synthetic heating gas. (Upgrading with integrated heating gas production by Nexen and Opti). [198]

- Substitution of natural gas for electricity, steam and hydrogen production with unconventional natural gases or synthetic gas. For example, the firm of Ego Exergy is planning an underground gasification project in Canada in order to supply the tar sand extraction and processing with electricity, steam and hydrogen. [199] The use of USG synthetic gas instead of natural gas would increase the WTW emissions from fuels made of tar sand by 20%.[200]

In the coming years, the development of tar sand extraction is expected to slow due to elevated raw material and investment costs in addition to other restraining factors. In the following, we present the development of the various procedures for unconventional fuels:

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[195] Courtney 2008
[196] Linc Energy 2008. www.lincenergy.com.au/pdf/analyst-10.pdf*. CTL-Kosten: IEA 2008a.*
[197] Meyer-Renschhausen 2007
[198] Meyer-Renschhausen 2007.
[199] http://www.cigionline.org/articles/2009/05/clean-coal-go-underground-alberta
[200] Own calculation according to Meyer-Renschhausen 2007, CONCAWE, EUCAR and European Commission Joint Research Centre 2008, Courtney 2008, Armendariz 2009.

- **Tar sands:** The energy, material and personnel costs for tar sand extraction have risen sharply in recent years. In Canada, tar sand extraction and processing consumed approximately 10 billion m³ of natural gas in 2007. Presumably, natural gas needs will rise to 26 billion m³ by 2017. [201] In situ procedures will gain in importance for tar sand extraction since the potential for extraction through mining is limited. But in situ always entails a higher energy input. [202] That is why the use of procedures such as THAI technology is necessary in order to reduce natural gas consumption.

  Due to the increased costs, the low petroleum price and growing resistance among the population, a somewhat lower increase in Canadian tar sand production is expected by 2015 than previously forecasted (80% instead of 110% growth compared to 2007). So far, other countries with large tar sand deposits, such as Russia, Kazakhstan and the USA have only carried out pilot projects and have no large-scale concrete extraction plans. In the Republic of Congo, the Italian firm of ENI has reserved the mining rights but has not yet started production. [203]

- **Extra heavy oil:** With approximately 240 t extra heavy oil, Venezuela has uncoventional petroleum deposits comparable in size to those of Canada. Even so, experts anticipate a slow expansion of extra heavy oil production in Venezuela due to government restrictions. [204] The EIA, for example, predicts that Venezuelan extra heavy oil production will only rise from a level of 25 million t today (0.6 million barrels/day) to 50 million t (1.2 million barrels/day) in 2030. [205]

- **GTL and CTL:** While GTL and CTL production is almost technically mature, the high price of raw materials is hindering its expansion. CTL also involves considerably higher investment costs than GTL.

- **Oil shale:** The extraction of fuels from oil shale, as described in chapter 3.4.3, is a highly elaborate process. That is why experts expect that more than 10 years will be needed before the first industrial-scale fuel production from oil shale can begin. [206] In situ procedures for oil shale mining are extremely expensive due to the high investment and energy costs and the low exploitation rate. On this ground, Brandt regards surface mining as more likely option for large-scale oil shale projects. [207] Surface mining procedures will lead to higher greenhouse gas emissions than in situ technologies. [208]

[201] BGR 2009.
[202] Meyer-Renschhausen 2007.
[203] BGR 2009.
[204] EWG 2008. EIA 2009.
[205] EIA 2009.
[206] Bartis 2006.
[207] Brandt 2007b. NCI 2008
[208] Brandt 2007b,c. cf. Illustration und Table 1.

- **GTL from UCG synthetic gas:** GTL from synthetic gas manufactured by underground coal gasification (UCG) has the lowest production costs of all unconventional fuels due to its lower raw material and investment costs. If the industrial-scale production of GTL from UCG glas is successful, this will mean the availability of a technology which, together with the use of tar sand, will allow for the production of vast quantities of unconventional fossil fuels at lower costs than EOR, deep-sea and Arctic oil. However, the WTW emissions will increase immensely. While UCG producers are promoting the CCS option, it has not yet been proven whether it will be possible to sequester vast quantities of CO_2. Without CCS, GTL made from UCG leads to emissions 2.5 times higher than those from conventional fossil fuels.

  Underground gasification will primarily be used for electricity generation over the coming years. However, due to the large global coal deposits that are suitable for UCG, no raw material bottlenecks are to be anticipated, as would be the case for natural gas production. Raw material bottlenecks could lead to competition over use for electricity, heating and fuel production.

- **Coal-bed methane (CBM)** is also an alternative gas for the GTL process. With the UCG procedure, however, 300 to 400 times more energy can be extracted from a tonne of coal by means of CBM. This is due to the very low methane content per kg of coal. [209] Due to the considerably lower gas exploitation rate in comparison with the UCG procedure, it is anticipated that in future CBM will continue to be used primarily in the electricity and heating market and not for GTL production.

The comparison of greenhouse gas emissions with production costs also shows that the moment of peak oil production plays only a qualified role in the development of unconventional fuels. What is extremely important, however, is the IEA estimate in the current World Energy Outlook, which states that the age of cheap petroleum is finally at an end. In order to compensate for the rapid production decline in post-peak fields, vast sums must be invested in order to find new fields and to increase the exploitation of the old ones. The most recent petroleum price decline shows that many projects in the petroleum sector were halted again once the price dipped below 80-100 dollars/barrel. [210] Due to technological advances with regard to unconventional fossil fuels, it will be less expensive in the medium term to produce fuels from tar sand, coal or oil shale than to extract petroleum from a depth of 8,000 m or from the Arctic, or else to raise the exploitation rates of old fields using highly elaborate methods.

[209] Homer-Dixon & Friedmann 2009. Methane is present in coal deposits in very small concentrations.
[210] Petroleum Economist 2008.

7 Analysis of the environmental impacts and socio-economic effects of conventional and unconventional fossil fuels

7.1 Methodological approach

In contrast to greenhouse gas emissions, there are few studies with scientific pretensions that analyse the environmental impacts and socio-economic effects of conventional and unconventional fossil fuels. Non-governmental organisations in particular have conducted studies on regional conflicts. However, there are scarcely any reports examining impact on a global level. As a result, this study can only selectively describe the environmental impacts and socio-economic effects on the basis of examples taken from individual countries. The selection of the countries is based on the following criteria:

- Availability of information
- Consequences of the impacts and effects described here
- Future significance of these countries to the production of fossil fuels

Based on these criteria, the report focuses on impacts from the production of fossil fuels in Nigeria, Angola, Ecuador and Canada. It presents the environmental impacts and socio-economic effects of the petroleum industry in three crucial regions:

- Africa: Petroleum production on the African continent is particularly conflict-laden. Africa has become increasingly important for the global petroleum supply over the past 10 years. Africa's growing significance in the global petroleum market is evidenced by the great interest many countries and international petroleum corporations are currently showing in the continent.
- The Amazon: Petroleum production in the Amazon basin is particularly problematic due to the high biodiversity and conflicts with the indigenous population. As a result of dwindling global petroleum deposits, pressure is increasing to further exploit the Amazon oil fields.
- Canada: The impacts from tar sand mining in Canada highlight the consequences of producing unconventional fuels.
- The effects and impacts described here apply not only to the countries under study but also highlight the consequences that the production of fossil fuels have on the development of states.

Due to the issue's complexity, the environmental impacts and socio-economic effects in many other global regions, such as Russia and Alaska, cannot be examined in this study. Nor has it the Arctic been examined, although the environmental threats to this region are particularly grave due to future petroleum production there. Moreover, the environmental impacts of petroleum production arising from many individual emitters, e.g. drilling platforms, petroleum refineries and catastrophic events such as tanker accidents have not been included.

The complex impacts of military conflicts on petroleum production can also be presented only very briefly within the framework of this study.

This list of consequences left unanalysed highlights the great need for future studies on this issue.

7.2 Evaluation of studies on the socio-economic effects of conventional petroleum

Countries that are rich in natural resources are often regarded as financially wealthy countries. This includes countries that profit by petroleum exports. However, if one evaluates these countries according to certain indicators, then the negative social and economic impacts of petroleum production in many of the countries become impossible to ignore. Scholars frequently use the terms 'resource curse[211] '[212]or 'oil curse' to describe this phenomenon. [213] Studies have shown that oil-rich countries grow more slowly when compared to non-oil producing countries. They are more authoritarian and prone to conflict, and also occupy the lowest berths in the Transparency International Corruption Index. [214] Countries that depend on oil exports belong to the states displaying the most economic problems. [215]

The petroleum boom of the 1970s brought the petroleum-producing developing countries vast wealth and rapid economic growth. Nevertheless, over the next 30 years, many of these countries suffered from gigantic foreign debts, high unemployment and stagnating or declining economies. In 2005, at least half of the OPEC members were poorer than 30 years earlier. [216] Table 7 assesses petroleum-exporting countries according to the indicators of the United Nations' Human Development Index (HDI), the Corruption Index of Transparency International, infant mortality per 1,000 births, life expectancy as well as the proportion of the population earning less than 1 USD per day.

It is readily apparent that many of these countries score very negatively in this assessment.

Two examples:

Angola: Although Angola is the second largest petroleum-producing country south of the Sahara, on a global scale the child mortality in this country is surpassed only by that of Sierra Leone.[217]

Equatorial Guinea: Despite a daily production of 420,000 barrels of petroleum and an average annual per capita income of 8,510 USD, this country is in the lower third of the HDI ranking.

[211] Auty 1993
[212] Sachs and Warner 1995
[213] Ross 2008
[214] Shaxson 2007, Karl 2007
[215] Catholic Relief Services 2003
[216] Ross 2008
[217] Fischer Almanach 2009.

Between 1990 and 2000, the country even dropped 10 levels in the index.[218] It is regarded as one of the world's most corrupt countries and has one of the highest child mortality rates.

Country	Petroleum production (in barrels/day) 2008 [219]	HDI Development Index (for 177 countries) 2007 [220]	Corruption Index (for 180 countries) 2008 [221]	Child mortality (per 1,000 live births) 2006 [222]	Life expectancy in years 2006 [223]	Percentage of population living on less than 1 USD/day[224]
Russia	9,886,000	67	147	16	66	below 2 [225]
Iran	4,325,000	94	141	34	71	below 2
Nigeria	2,170,000	158	121	191	47	70.8[226]
Angola	1,875,000	162	158	260	42	54.3[227]
Kazakhstan	1,554,000	73	145	29	66	3.1[228]
Azerbaijan	914,000	98	158	88	72	3.7 [229]
Colombia	618,000	75	70	21	73	7 [230]
Ecuador	514,000	89	151	24	75	17.7 [231]
Sudan	480,000	147	175	89	58	90
Equatorial Guinea	361,000	127	171	206	51	Unknown
Rep. Congo	249,000	139	158	126	55	54.1
Gabon	235,000	119	96	91	57	4.8 [232]
Turkmenistan	205,000	109	166	51	63	24.8 [233]
As a comparison:						
USA	7,760,000	12	20	8	78	
Germany	75,000	22	14	4	79	

Table 7: Development indicators for petroleum-exporting developing countries

[218] Shaxson 2007
[219] BP 2009a
[220] Fischer Weltalmanach 2009
[221] Transparency International 2008
[222] Fischer Weltalmanach 2009
[223] Fischer Weltalmanach 2009
[224] UNDP 2009
[225] with less than 2 USD per day= 12.1 %, less than 4 USD = 56.7 %
[226] With less than 2 USD per Tag= 92.4 %
[227] With less than 2 USD per Tag= 70.2 %
[228] With less than 2 USD per Tag= 16.%, less than 4 USD = 56.7 %
[229] With less than 2 USD per Tag= 33.4 %, less than 4 USD = 85.9 %
[230] With less than 2 USD per Tag = 17.8 %. Percent below national poverty level = 64 %
[231] With less than 2 USD per day = 40.8 %
[232] With less than 2 USD per day= 19.6 %
[233] With less than 4 USD per day= 79.4 %

But what are the causes of this paradox whereby on the one hand countries take in vast income from petroleum exports while on the other hand they suffer from social and economic decline? A number of effects play a role:

7.2.1 The Dutch Disease[234]

The economic syndrome known as the Dutch Disease became evident in the 1960s when vast natural gas deposits were discovered in the Netherlands off the North Sea coast. This is an effect where national economies that successfully export a raw material may experience an economic decline due to developments in the exchange rate. The chain of activities develops as follows: Due to petroleum exports, a great deal of money flows into the national economy, leading to overvaluing of currency and price rises. Local products such as agricultural or industrial goods become more expensive and thus less competitive compared to imported goods. Local production of these goods is no longer cost-effective. The products' export figures decline and the country loses its agricultural and industrial foundation. It becomes dependent on the petroleum sector and is thus subject to price fluctuations in the international markets. The consequence of this process is that a small group of people becomes rich while the majority is affected by unemployment and poverty. [235]

Example:

Nigeria: Before the 1970s petroleum boom, Nigeria was the world's second-largest cocoa producer, with agriculture accounting for approximately 75% of exports. In the years 1975-78 alone, the cultivated agricultural surface declined by 60%. Millions of Nigerians lost their livelihood. In 1970, 19 million Nigerians were living below the poverty level. Today, petroleum accounts for 97% of Nigeria's exports. Despite 400 billion USD in petroleum income so far, 90 million people are living below the poverty level. [236] The number of people living in poverty has increased nearly twice as quickly than population growth over the past three decades. Poverty in Nigeria primarily results from the detachment of the petroleum industry from the local economy. 95% of state petroleum income flows into the tills of the Nigerian government, whereas the local population in the petroleum-producing region gains no share of the income. The petroleum industry creates few jobs and the few that do develop are filled by highly qualified foreigners. [237]

[234] Dichtl and Issing 1993
[235] Shaxson 2007
[236] Sala-i-Martin and Subramanian 2003
[237] Adams, Osho and Coleman 2008

7.2.2 The rentier state effect

States whose income largely flows in from the outside on the basis of available raw materials without the presence of internal production and investment activities inside the country are called rentier states. They are largely independent of internal tax revenues.

Examples:

Whereas in Germany taxes and levies account for 36.4% of the gross domestic product (GDP), with an average 37.4% among the OECD states, in **Kuwait** they amount to just 3.4% of GDP and in the **United Arab Emirates** just 1.8%. In Arab states without petroleum deposits, the average tax rate stood at 17% in 2002. In the Arab petroleum-producing countries the figure was at 5%. In their book 'Schwarzbuch Öl', ('The Black Oil Book'), Seifert and Werner state that 'the low tax rates provide Arab citizens with no incentives to challenge what their governments are doing with their petroleum'. At the same time, by distributing money, governments promote patronage and clientelism, thus reducing the need to provide their citizens with democratic rights. [238]

7.2.3 Off-budget petroleum revenues

At the same time, these rents frequently do not flow into government budgets but are rather off-budget revenues that frequently enter the country via illegal accounts. Control over financial currents through the central budget is further complicated, increasing the opportunities for corruption. [239]

Example:
The US State Department has written that **Angola**'s wealth lies in the hands of a small elite that frequently exploits government positions in order to enrich itself, and that corruption is occurring on all levels. [240] According to a report by Human Rights Watch, in the period between 1997 and 2002, the equivalent of 4.2 billion USD in oil revenues disappeared. [241] However, since no data has been published on state oil revenues, the Angolan population has no information basis upon which to demand an explanation of the misuse of funds. When BP fulfilled the requirements for transparent corporate policy and sought to publish its payments to the government, Angola threatened the petroleum group with expulsion from the country. Upon this, BP refrained from revealing the figures. [242]

Many petroleum-producing countries, particularly in Africa, are also dictatorships. The list of countries that have successfully transformed themselves into democracies in recent years does not include a single petroleum-exporting country.[243]

[238] Seifert and Werner 2007, Karl 2007
[239] Heilbrunn 2004
[240] Catholic Relief Services 2003
[241] Human Rights Watch 2004
[242] Misereor 2006
[243] Heilbrunn 2004

7.2.4 Foreign debt

Despite their revenues from petroleum exports, many of these countries are deeply in debt. Amongst the reasons for this are volatile petroleum prices. In times of high petroleum prices, the petroleum-producing countries became creditworthy. They accepted money and frequently financed vanity projects instead of investing these funds in education and healthcare.

Example:

Ecuador: Petroleum has been produced in Ecuador since 1967. As early as 1981, the country's foreign debt had reached 22 times the level of 1971. In terms of dollars, this amounted to 5,870 million USD, i.e. 42% of the gross domestic product. [244] For the first time, debt servicing was higher than export revenues. In the 1990s, the mountain of debt reached the level of the gross national product. At the same time, however, the share of budgetary expenditures dropped from 21.3 in 1986 to 13% in 1996, just as the index for military expenditures rose by a third. In 1999 the International Monetary Fund declared Ecuador to be unworthy of credit. [245] At the present time, debt servicing amounts to nearly half of state revenue and thus more than the revenue from petroleum exports. [246]

7.2.5 Military conflicts/civil wars

In a study[247] published in 2000, Collier and Hoeffler determined that countries dependent on petroleum and raw material exports are much more likely (23%) to experience a civil war than countries that do not export raw materials (0.5%). These numbers refer to a 5-year period. The same authors additionally determined that the risk of a civil war in an average developing country is at 14%. If a developing country has a high share of raw material exports (over 30%) the risk of a civil war rises to 22%. If petroleum is the main export commodity, then the risk of civil war increases by 40%.

[244] Acosta 2003
[245] Acosta 2003
[246] Mierkes
[247] Collier and Hoeffler 2000

7.3 Evaluation of studies on the environmental impacts of conventional and unconventional petroleum

This study presents the environmental impacts of conventional and unconventional petroleum using the examples of petroleum production in Ecuador and Nigeria as well as tar sand extraction in Canada.

7.3.1 Description of production areas

Ecuador: In Ecuador's Amazon region, more than 300,000 barrels of oil are produced daily from more than 300 boreholes. At the same time, the area is among the most species-rich regions in the world. The combined volume of the concession areas adds up to 10 million ha. Thus most of the Ecuadoran Amazon is either directly or indirectly impacted upon by petroleum production activities. The activities of the petroleum companies mainly affect indigenous territory, since 90 of the oil concessions have been distributed there. The indigenous population residing there is being directly confronted with a form of high tech industrialisation that represents a radical break from their traditional lifestyles and economic situation. [248]

Nigeria: Like the Amazon region in Ecuador, the Niger Delta represents a unique ecosystem: it is one of the largest wetlands in the world, with an area of 26,000 km^2, a catchment basin of 2.23 million km^2 and an annual discharge of 180 billion m^3. The principal feature of the Niger Delta is the dynamic balance between flooding, erosion and sedimentary deposits, which has shaped and reshaped the delta throughout its existence and provided it with fertile soil for agricultural production. The delta consists of coastline sand islands, mangroves, freshwater swamp forests and lowland rainforests. [249]

Canada

The tar sand deposits of Canada are located beneath an area of 15 million ha of boreal coniferous forest: 22% of the globally stored carbon in terrestrial ecosystems is located in boreal coniferous forests.[250] Each hectare of boreal coniferous forest contains more than twice as much carbon than the same area in a tropical rainforest (460 t). [251] 84% of this is stored in the soil. [252] The forest and soil area above the tar sand deposits in Canada stores up to 7 billion t of carbon. [253] Canada's boreal coniferous forest is also one of the largest remaining contiguous forest areas in the world and furthermore provides vital habitats for many

[248] Feldt 2001
[249] Steyn 2003
[250] International Boreal Conservation Campaign 2008 und 2009.
[251] Woods Hole Research Center 2007.
[252] Greenpeace 2008
[253] Own calculation according to Woods Hole Research Center 2007, International Boreal Conservation Campaign 2008.

threatened animal species. [254] Between 20 and 170 million birds breed every year in the boreal coniferous forest of the tar sand deposit alone. [255]

7.3.2 Environmental impacts: air / atmosphere

Ecuador: One of the largest problems is the flaring of non-commercially used accompanying gas, which is usually burned on site. Only 12% to 15% of the resulting gas quantity is sent to Quito through the Shushufindi pipeline and the rest is burned. In the burning process, CO_2 , nitrogen and sulphur compounds are released along with heavy metals, hydrocarbons and soot. According to conservative estimates, 2 million m^3 of gas is burned daily. [256] Biologists repeatedly point out that aside from polluting the air and rainwater, the flaring also leads to the extermination of countless rare insects.

Nigeria: After Russia, Nigeria flares the world's second largest quantity of accompanying gas (16.8 billion m^3).[257] This amount corresponds to 15% of Germany's annual natural gas consumption. Although petroleum companies in Nigeria also use natural gas for commercial purposes, they prefer natural gas extraction from deposits where it is located in isolation. This is justified by the high costs for the processing and transport of accompanying gas. Gas flaring in Nigeria is also extremely incomplete and emits vast amounts of methane. [258]

Canada: Tar sand extraction is the fastest growing source of greenhouse gases in Canada. Emissions from mining and processing are estimated at approximately 40 million t for 2007. These emissions are mainly attributable to high natural gas consumption for production and processing. It is estimated that in 2012 the tar sand industry will consume as much natural gas as all Canadian households combined. The additional gas needs require new pipelines and drilling in nature reserves, such as the Mackenzie Valley. [259]

Tar sand mining also has an influence on Canada's policy of approving a national limit on greenhouse gas emissions. Since the government has not set any real maximum limit for greenhouse gases from tar sand mining, it is difficult for it to demand such measures from the rest of Canadian industry.

Alongside greenhouse gas emissions, there are other serious air pollutant emissions as well. The Canadian environment ministry estimates that tar sand production emits 158,000 t of sulphur oxide and 76,000 t of nitrogen oxide annually. [260] The tar sand industry's own studies show that the emissions guidelines of the Canadian provinces cannot be fulfilled. [261] As they can be spread for many thousands of kilometres, the air pollutant emissions from tar sand processing cause nationwide damage. For example, in one town in Saskatchewan, 200 km from

[254] International Boreal Conservation Campaign 2008
[255] Wells et al. 2008.
[256] Feldt 2001
[257] BGR 2009
[258] NETL 2009b
[259] Canadian National Energy Board 2007
[260] Wilderness Committee 2008
[261] ibid. 2008.

the tar sand projects, precipitation has become considerably more acidic over the past 12 years: from a pH value of 5.3 to 4.1. Normal precipitation has a pH value of 5.6. In 2005 the environmental authority in the Province of Saskatchewan installed a network of 10 monitoring stations in the northwest of the province in the vicinity of the tar sand extraction area and determined an increase in the air's nitrogen content. In rivers and lakes acidification promotes the transformation of mercury into the more dangerous form of methyl mercury, which can be absorbed by fish and thus enter the food chain. [262]

In addition, the tar sand industry emits vast amounts of pollutants that cause reproduction and development toxicity, e.g. through the Suncor Energy refinery.[263]

7.3.3 Environmental impact: Destruction of the forest

Ecuador: The development of the production areas for the supply and transport of heavy machines is leading to vast forest clearings. The building and expansion of roads has the greatest negative impact. The route must be deforested and additional wood must be cut to reinforce the roads. However, the construction of camps, platforms for test drilling, oil rigs and pipelines as well as new landing areas for helicopters entail additional surface consumption at the forest's expense.

At the same time, the development of the production area has led to indirect consequences, namely new settlement. Since 1972, the start of the petroleum boom in Ecuador, more than 1 million farmers have moved from the highlands into the lowland regions. This has led to additional forest cutting and demands for surface areas.[264]

Nor have protection measures necessarily led to a halt to clearings. Despite intervention on the part of the environmental ministry in Ecuador, large portions of the Yasuni National Park and the Cuyabeno Reserve have been given over to petroleum production.

Canada: The development of tar sand mining in Canada is having a disastrous influence on Alberta's boreal coniferous forest, one of the world's largest carbon reservoirs and the habitat of the Canadian caribou and lynx, as well as billions of songbirds. The Canadian caribou, a threatened species, is a major indicator of the health of boreal ecosystems since it requires vast areas of untouched forest in order to survive. In the East Side Athabasca Range, which covers more than 3.6 million ha of forest area, caribou stock has declined by around 50% over the past 10 years due to tar sand mining and other industrial activities. [265] Government and industry studies anticipate that caribou numbers will continue to decline in a business-as-usual tar sand scenario. Unless measures are undertaken to protect the boreal coniferous forest, the Canadian caribou will become entirely extinct in this region. [266] Tar sand mining also negatively influences birds, martens and lynxes. The population of several bird species has already

[262] Maqsood et al, 2008
[263] Ecojustice 2007
[264] Feldt 2001
[265] Athabasca Landscape Team 2008.
[266] Schneider & Dyer 2006

declined by 80% in some areas. Moreover, bird species dependent on older forests, such as the black-throated green warbler, could decline by 60% over the coming years. [267]

Although in situ mining does not require the same degree of deforestation as surface mining, the network of paths, boreholes and pipelines fragment natural habitats and damages aquatic ecosystems.[268]

7.3.4 Environmental impact: water / groundwater

Ecuador: Together with petroleum and gas, petroleum production also uncovers so-called formation water, which contains heavy metals and toxic salts. An environmentally sound disposal would mean pumping this water back into the borehole. Companies frequently fail to do this for reason of cost. Instead, the formation water is stored in tailing ponds.
For example, Texaco has been accused of channelling around 70 million m³ of untreated toxic wastewater into over 900 tailing ponds between 1964 and 1990, and with this causing the contamination of rivers and groundwater.[269] A lawsuit before a US court in New York filed by settlers and dependents from indigenous communities asking for compensation and damages has yet to be ruled on. The reason for this is Texaco's repeated attempt to avoid the court case by means of out of court settlements and payments. [270] Texaco claims to have repaired the environmental damage done. However, independent studies made of 45 allegedly rehabilitated areas on behalf of the New York court have shown that all of these areas show TPH (total petroleum hydrocarbon) values several thousand times higher than normal. [271]
Experts estimate that Chevron, which took over Texaco in 2001, could be made responsible for environmental and health damages of up to 27 billion USD. This sum would be many times higher than the 4 billion dollars that Exxon Mobil paid for a tanker accident in Alaska in 1989. [272]

Canada: Two thirds of the water taken from the Athabasca River is used for tar sand mining. The current projects have licences to use more than 550 Mio. m^3 of fresh water from the Athabasca basin annually. That is enough to provide water of a city of 3 million people for an entire year. In 2007 the oil sand industry in Canada used 129 million m^3 of water. [273]
Since there are no restrictions on water use along the Lower Athabasca River, tar sand mining leads to very low water levels as well as to a decline in fish populations. [274]

Tar sand mining procedures: During tar sand mining, toxic wastewater, which is channelled into open ponds or deep wells, contaminates the surface and ground water. High concentrations of arsenic and other metals have been found in the delta of the Athabasca River. The delta forms part of the Wood Buffalo National Park and is one of the world's most

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[267] Wilderness Committee 2008
[268] Schneider & Dyer 2006
[269] Smith and Gullo 2008. Palmer 2009.
[270] Feldt 2001
[271] Palmer 2009.
[272] AFP 2009b; Smith and Gullo 2008. Palmer 2009.
[273] Pembina Institute 2009
[274] ibid.

important wetlands. Approximately 1.8 million m^3 of toxic mud accumulates there annually. In June 2008, 720 million m^3 of mud was contained in the tailing ponds. [275]

The wastewater tailing ponds for tar sand mining cover more than 130 km^2 of surface area. The toxic contents of the basins represent a constant threat to the region's inhabitants as well as to flora and fauna. Birds must constantly be kept away from the tailing ponds using special devices and scarecrows, given that they would otherwise die in them. [276]

According to a new study, 11 million litres of contaminated water flow out of the tailing ponds every day. In addition, many tailing ponds have been built directly alongside the Athabasca River. A breach in a tailing pond's wall would have an even greater impact on the ecosystem than the 1989 Exxon Valdez disaster in, when 40.9 million litres of petroleum leaked onto the Alaskan coast, contaminated 1,100 km of coastline and killed 36,000 birds. [277]
Mining procedures for oil sand extraction require 2-4.5 litres of water to produce a single litre of petroleum.

Tar sand mining damages not only the wetlands in the extraction area but also the surrounding ecosystems to such a degree that the groundwater level is lowered across a large area. Wetlands play a central ecological role in the boreal coniferous forest, both as a water filtration system and as a carbon reservoir. [278] It is impossible to reconstitute these ecosystems. A large portion of the untouched landscape in the tar sand region in Alberta is covered with wetlands.

Tar sand in situ procedures: Most in situ projects in the Athabasca River basin utilise groundwater. Some projects recycle up to 90% of the water. When recycled or salt water (from deeper aquifers) is used, it has to be desalinated before it can be used for steam production. The waste materials from desalination and other treatment processes may be pumped into disposal wells in deep formations or else into the soil. [279] Salts and other wastes can enter the surrounding aquifers.

In addition, nitrogen oxide and sulphur dioxide emissions raise the acidity level of the soil and water in the tar sand mining region and the surrounding regions. [280]
Intended for the end of the oil sand projects by the oil sand companies are end pit lakes, serving to deposit the remaining wastewater. End pit lakes have not yet been tested as long-term deposits for tar sand wastewater. There is no evidence that these lakes will be suitable when it comes to providing ecosystems with permanent protection from pollutants. [281]

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[275] ibid.
[276] ibid.
[277] ibid.
[278] ibid.
[279] Pembina 2006, p. 104
[280] Pembina 2009, p. 25
[281] Pembina 200, p. 41

7.3.5 Environmental impact: soil

Ecuador: 97% of Ecuadoran petroleum comes from the Amazon region and is pumped to the Pacific port of Esmeralda via a 500 km long pipeline, the SOTE. The SOTE, which was built by Texaco, crosses over the two Cordillera mountain chains on its way to the Pacific. Because of active volcanoes, up to 4,000 m high slopes and strong rainfalls, the Cordilleras are strongly threatened by erosion. The SOTE is constantly damaged by landslides and requires continuous repairs. Due to frequent leaks, up to 160,000 litres of oil enter surface water bodies and seep away. [282]

Environmental activists call the OCP (Oleoducto de crudos pesados, i.e. pipeline for heavy oils), a new pipeline that was built from the Amazon to the Pacific coast, Oleoducto de Contaminación y Pobreza (pipeline for contamination and poverty). The OCP is operated by a consortium of international petroleum companies including EnCana (Canada) Repsol-YPF (Spain), Pecom Energia (Argentina), Occidental Petroleum (USA), ENI-AGIP (Italy), Techint (Argentina) and Perenco (Great Britain). The pipeline's lenders include 16 European and American financial institutions, one of which is the Westdeutsche Landesbank. [283]

Like the SOTE, the OCP, which is designed to double oil production in the Amazon and which Ecuador hopes will increase its oil revenues and reduce its debts, is causing significant environmental damage. [284] The OCP was built very quickly in just 2 years and has been in operation since 2003. It extends over a distance of 500 km between Lago Agrio (Amazonia) and the port of Esmeralda on the Pacific and must therefore cross the Andes mountain chain. The OCP passes across 94 tectonic rifts and instable páramos, along 6 active volcanoes and through rainforests and 11 nature reserves, forests and national parks. In 2008, 2,500 barrels of crude oil spilled from the OCP into the Yasuní National Park . On 25.02.2009 there was a new leak – this time it amounted to 14,000 barrels of crude oil – in the Cayambe-Coca nature reserve, the country's largest sanctuary (400,000 ha) with also its largest biodiversity (more than 1,300 animal species). [285] The petroleum leak led to the contamination of several rivers over a length of more than 500 km along with the adjoining forests. It also contaminated the water sources of the town of Coca and its 30,000 inhabitants. [286] The Ecuadoran environment ministry (MAE) has reported on environmental damage in four nature reserves, including the Sumaco-Napo-Galeras National Park and the Cayambe-Coca nature reserve. According to the Confederación de Nacionalidades Indígenas del Ecuador (Conaie), dead fish and snakes were even found in Aguarico in the province of Orellana, 500 km distant from the leak. The Ecuadoran environment ministry has filed suit against OCP Ecuador S.A., the pipeline's operator, because of intentional or negligent offences. [287] Among other things, the ministry claims that the control mechanism only reacted 7 minutes after the leak and that its employees were provided with insufficient information on emergency measures. Moreover, the ministry is of the opinion that the system lacked retention dams. The lawsuit of 28.02.2009, which was introduced

[282] Mirkes 2003.
[283] Kneidinger 2003.
[284] Acción Ecológica 2003
[285] Prensa Indígena 22/03/2009
[286] El Comercio. 2009
[287] El Universario 2009.

together with the environmental office of the petroleum and mining ministry, demands the distribution of emergency plans for immediate crude oil recovery, the complete cleanup of the affected region and compensation to the affected inhabitants. Even so, two weeks subsequent to the accident, OCP Ecuador had still not produced any emergency plans.

7.3.6 Environmental impact: increased risk of disease – Ecuador

Near the oil fields that were formerly operated by Texaco and that have been continued by the state-owned Petroecuador, it has been shown that the local population is being exposed to elevated health risks. For example, a survey by the Centro de Derechos Económicos y Sociales shows that the risk from cancer, damage to the central nervous system and disabilities among newborns has increased. [288] In cooperation with other international institutions, the Instituto de Epidemiología y Salud Comunitaria, 'Manuel Amunarriz', has conducted a number of studies indicating a strong risk of cancer, including childhood leukaemia, uterine and breast cancer among women, stomach, skin, lymph node and prostate cancer among men as well as spontaneous miscarriages and birth defects. [289] It is estimated that approximately 4,200 m^3 of mud, sullage etc. per borehole develop due to improper handling. Precise data on the chemical composition of these drilling wastes are not available for Ecuador. They also vary from borehole to borehole, but nearly always contain toxic compounds made up of aluminium, antimony, nickel, zinc, benzene, naphthalene, phenanthrene along with sodium and chlorides. These waste products are temporarily stored in collecting basins. If they are not effectively protected from precipitation they can overflow following tropic rainfalls, which has frequently occurred in the past and contributes significantly to the contamination of ground water and surface water as well as of the soil.

Nigeria: Gas flaring often occurs very close to local populations. Frequently, there is a lack of suitable enclosures for the protection of the inhabitants who are constantly exposed to great heat while pursuing their normal activities.[290]

Vast quantities of toxic chemicals are released through flaring, including nitrogen dioxide, sulphur dioxide, volatile organic compounds such as benzene, toluene, xylene and hydrogen sulphide along with such carcinogenic substances as benzo(a)pyren and dioxin. Persons exposed to such substances may suffer from a number of respiratory ailments that appear among many children in the Niger Delta, although there are no studies done on the subject. These chemicals can exacerbate asthma and cause breathing difficulties, pains and chronic bronchitis. Benzene, for example, can cause leukaemia and blood disorders. [291]

Canada: Tar sand use leads to increased rates of rare cancer types as well as thyroid problems and immune deficiencies among the local population in the mining areas. Toxic substances

[288] IESR 1994, quoted in Feldt, 2001
[289] Instituto de Epidemiología y Salud Comunitaria 'Manuel Amunarriz' 2000, 2002; Hurtig and San Sebastián; San Sebastián, Armstrong and Stephens 2001
[290] FOE 2004.
[291] Environmental Rights Action, Friends of the Earth Nigeria, 2005, p. 24

have been found in the water of nearby rivers and lakes: high concentrations of arsenic, mercury and polycyclic aromatic hydrocarbons (PAKs). [292]

In addition, sudden steam releases from in situ projects, so-called blowouts, threaten the population's health. In the case of a blowout, the residents of the affected areas must be evacuated or remain in rooms whose doors and windows have taped off or else sealed with damp cloths until the chemicals dissolve in the air. [293]

7.4 Concluding assessment of the environmental impacts and socio-economic effects of petroleum production

Chapters 7.2 and 7.3 presented the environmental impacts and socio-economic effects of petroleum production largely on the basis of national examples. The question is whether the results from this country analysis are representative of petroleum production as a whole. The countries studied within the framework of this study represent a relatively small portion of global petroleum production. The list of unanalysed impacts also shows that the consequences of petroleum production go far beyond the results of this study. It is also to be expected that the negative environmental impacts and socio-economic effects of conventional and unconventional fossil fuels will continue to increase in the future:

- Africa's significance for global petroleum production is growing while the problems of the existing petroleum-producing countries have not been solved and further politically unstable petroleum-producing countries are being added.
- Tar sand mining and the production of extra heavy oil will continue to increase. Without the creation of alternatives, fuels from oil shale and coal will be added, with considerable environmental effects.
- Petroleum production is becoming increasingly difficult: deeper and deeper deposits and oil fields in remote regions, such as the Arctic, need to be developed. More elaborate technical measures increase environmental risks as shown by the most recent, a leak in a deep sea drilling off the Australian coast. [294] A tanker or pipeline accident in the ecologically sensitive Arctic would lead to an environmental disaster with irreparable damage.

A study published in june 2009 by the auditing firm of PricewaterhouseCoopers and oekom research AG, [295] one of the leading rating agencies in the field of sustainable investment, shows that the results from the country analysis in this study are not isolated examples but can be applied to the global situation of the petroleum and gas economy. In their study, PricewaterhouseCoopers and oekom research AG examined the way companies pay attention to social and environmental issues. They analysed whether companies have formulated

[292] Timoney 2007
[293] Wilderness Committee 2008
[294] The Australian 2009. So far, 2 months following the accident, all attempts at stopping the leak have failed.
[295] oekom research AG, PricewaterHouseCooper, 2009

appropriate standards and implemented measures to implement these standards. In addition, they examined actual compliance with these standards. They based their analysis on 825 companies from 38 countries. In the process, they either completely or largely covered the globally most important stock indexes, for example 100% of the DAX 30 companies and 75% of the companies listed in the MSCI World. They also examined such blocks of themes as human rights, environmental standards as well as transparency and corruption.

For example, in the field of human rights it was discovered that there is a difference between human rights policies developed by the companies and their actual implementation. Two industries stood out as being particularly problematic: the petroleum and gas economy, as well as mining. For example, the human rights policies of the petroleum and gas industries received the best evaluation. At the same time, however, 21.1% of the companies stood out due to human rights violations. These frequently were land use conflicts, such as expulsions and expropriations as well as the use of force by security personnel.

Massive environmental violations on the part of petroleum and gas companies were also discovered in the category of environmental standards, e.g. in the area of petroleum production and petroleum transport using pipelines and ships. The leaks in the pipelines that Shell operates in the Niger Delta were listed as an example.

In the area of transparency and corruption, general transparency regarding payments to governments was evaluated. On a scale from 0 (very low transparency) to 100 (very high transparency) the petroleum and gas industries had the best results, but at 34.33% this result was very modest. In the area of corruption, the companies in the petroleum industry analysed by oekom research revealed a wide incidence of corruption at 18.2%.

The research results of this study, which are supported by PricewaterhouseCoopers und oekom research AG reveal the great need for action, one which is presented in more detail in chapter 8.4.

8 Summary evaluation of results and recommended action

8.1 Impact of the extraction of unconventional petroleum on the long-term development of greenhouse gas emissions

Due to the complexity of the technical problems, environmental problems and also the socio-economic effects described here, forecasts for the development of greenhouse gas emissions from unconventional fuels are difficult to make (see chapters 6 and 7). [296] However, in order to describe a trend, we will describe two development scenarios. The results serve as a prediction on how CO_2 emissions might develop if the decline of conventional fuels is compensated for by

[296] The environmental impacts of tar sand mining can, for example, exacerbate conflicts with the local population and environmental groups and thus made further use of tar sand more difficult.

unconventional fossil fuels. We are looking at just those emissions from petroleum used in the transport sector and that represent around half of total petroleum consumption. [297] For further transport development, we are using the IEA's estimate that the share of petroleum in the transport sector will increase to 60% of total consumption by 2030. [298]

It is not only forecasts for the development of unconventional fuels that are difficult. Assessments of the future production of conventional petroleum are also highly uncertain. Chapter 2.3 shows the high variety of the forecasts made by the various institutions. The varying estimates for petroleum production in 2030 diverge from one another by more than 30 million barrels/day. [299] The estimate of the greenhouse gas balances of the various fuel types is also difficult since the range of balances is so large (see Table 8). Future CO_2 emissions from conventional fossil fuels are influenced by many factors, including extraction costs, the depth of the deposits, the share of heavy oil, the sulphur content, the flaring of accompanying gas, the EOR technologies and the development of fuel thresholds for sulphur and other pollutants. For this reason, these scenarios represent a theoretical observation, which, however, serves to illustrate the growing CO_2 problem in the transport sector.

The scenarios are based on the following assumptions:

- In both scenarios, the total production of conventional fuels will decline from 79 million barrels/day in 2007 to 71 million barrels/day in 2030. [300] These figures are based on an estimate by the University of Uppsala (see Tables 10 and 11 in the appendix). The Uppsala figures represent an intermediate scenario of future petroleum production and are more than 30 million barrels/day higher than the EWG forecast. [301]

- In the 'constant demand' scenario, we assume that total production will remain constant until 2030.

- In the 'growing demand' scenario, however, the total production of 84.4 million barrels/day will rise to a total production of 105 million barrels/day. [302] These figures are based on data from IEA 2008a as well as new IEA estimates for 2009/10. [303]

- In both scenarios the decline of conventional and unconventional fossil fuels is balanced out (see Illustration 28 and Illustration 30). In the case of unconventional petroleum, our figures are based on our own estimates, which consider resource management and technological development and assume the presence of large state incentive and research programmes. For these scenarios, we assume that, due to technological progress, inhibiting factors such as high energy costs can be eliminated. The further development of in situ procedures, in particular, e.g. the THAI procedure for tar sand

[297] IEA 2008a
[298] IEA 2008a
[299] Forecast for conventional petroleum in 2030: EWG: ca. 34 million barrels/day. Uppsala World Energy Outlook 2008: 66.7 million barrels/day. EWG 2008, Aleklett 2009
[300] Aleklett 2009 incl. NGL. NGL amounts are calculated as per IEA 2008a, e.g. the volume and not the energy content, as with Aleklett, is considered. NGL has a c. 75% lower energy content per volume than petroleum.
[301] Sorell et al. 2009.
[302] Incl. NGL and production increases.
[303] IEA 2008a, IEA 2009

mining and underground gasification for CTL production, will make the production of vast quantities of unconventional fuels possible. Oil shale extraction will also profit from the development of in situ procedures.

- Among the unconventional fuels, tar sands from Canada and extra heavy oil from Venezuela are displaying the fastest growth as the technical procedures necessary for them are already mature. Recent Chinese and Russian investments in Venezuela show how quickly production in Venezuela can be expanded.

- For the development of the greenhouse gas balances of unconventional fuels, we are assuming medium emission values (see Table 8). We are using highly optimistic values for the mining and processing of oil shale. Emissions from fuel production from oil shale may end up being considerably higher if high processing temperatures dissolve the carbonised accompanying matrix (see chapter 4). The tar sand balance values now include greenhouse gas emissions through indirect land use effects.

- We assume that the greenhouse gas balances of conventional fossil fuels will continue to deteriorate since the efforts required for production and processing will rise due to the following factors (see Table 8):

    - The increasing depth of the deposits
    - The growing share of heavy oil and/or the declining average API value
    - The increasing sulphur content
    - The stricter fuel thresholds for sulphur and other pollutants and the resulting greater efforts needed for refining
    - The increasing application of EOR technologies in order to enhance the exploitation of the oil fields

  We anticipate that stricter fuel thresholds for sulphur and other pollutants will compensate for future increases in efficiency. In addition, lower flaring rates due to upstream emissions in the future will balance out growing natural gas consumption (methane leakage) in the petroleum sector.

  In presenting both the THG emissions of conventional fossil fuels and unconventional fuels we have used the values in Table 4 (see Table 4 and Table 8).

Emissions g CO_{2eq}/kWh			
	2007	2020	2030
Tar sands	408	408	408
Extra heavy oil	391	391	391
CTL	802	802	802
GTL	358	358	358
Fuel from oil shale	877	521	521
Old oil fields	329	350	370
Onshore development		350	370
Offshore development		360	380
Onshore new discoveries		360	380
Offshore discoveries		370	390
EOR		375	375
NGL	325	333	341

Table 8: Development of specific greenhouse gas emissions of conventional and unconventional fuels until 2030 (own calculation)

8.1.1 Scenario: Growing demand

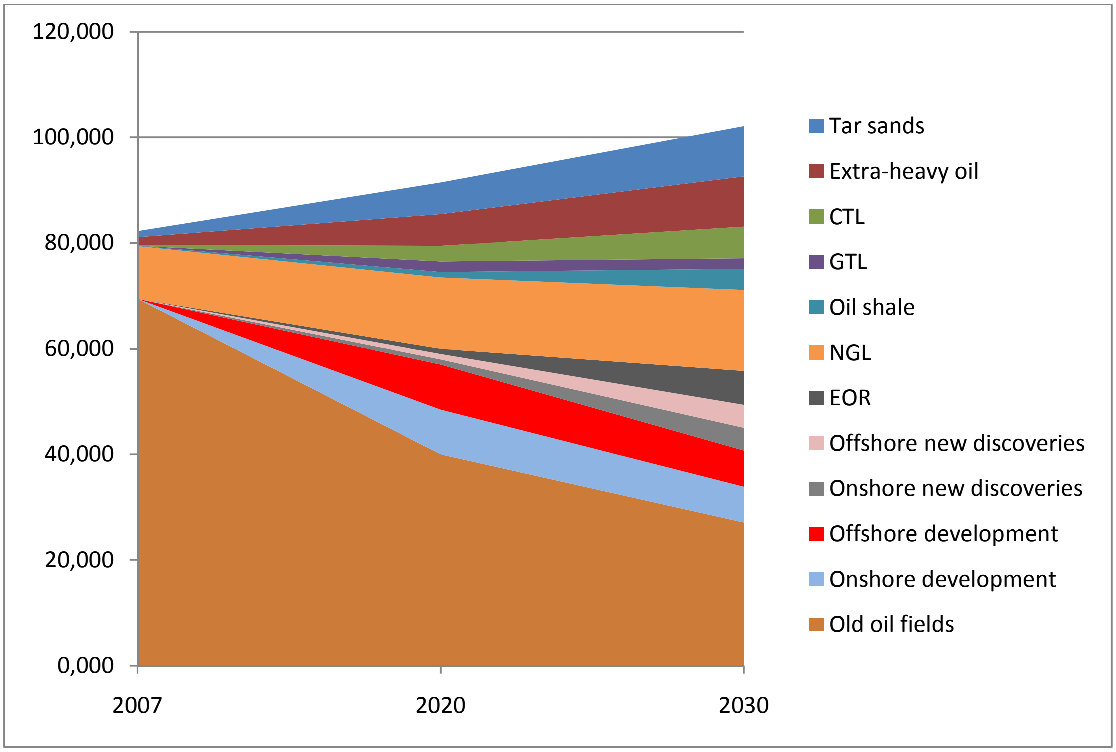

Illustration 28: Development of fuel production in the 'growing demand' scenario. Cf. Table 10 in appendix.

In Illustration 28, we depict the development of fuel production on the basis of our assumptions. Illustration 29 makes it clear how, as a worst-case scenario, the share of conventional and unconventional fuels could change over the coming years. This has a considerable impact on the CO_2 balancing of fuels. Total CO_2 emissions in the transport sector will grow from 8 billion t CO_2 in 2007 to 13.2 billion t CO_2 in 2030. This enormous growth, one of more than 5 billion t CO_2, can be attrributed almost entirely to the growth of unconventional fuels. CTL and tar sand mining have the greatest share. However, GTL, extra heavy oil and fuels from oil shale also have a considerable share in CO_2 emissions.

Despite production declines, greenhouse gas emissions from conventional fuels will also increase from 67.6 to 8.2 billion t CO_2 by 2030. The average WTW (well-to-wheel) emissions (incl. combustion in vehicles) of conventional fuels will rise by 12% from 328 to 368 g CO_{2eq}/kWh due to the factors outlined above. The WTT (well-to-tank) emissions (without combustion in vehicles) will rise by 64% to 103 g CO_{2eq}/kWh.

In the 'growing demand' scenario, the average WTW emissions from all fossil fuels will rise by 23% to 407 g CO_2/kWh. In this way, the WTT emissions will rise by 100% to 142 g CO_{2eq}/kWh.

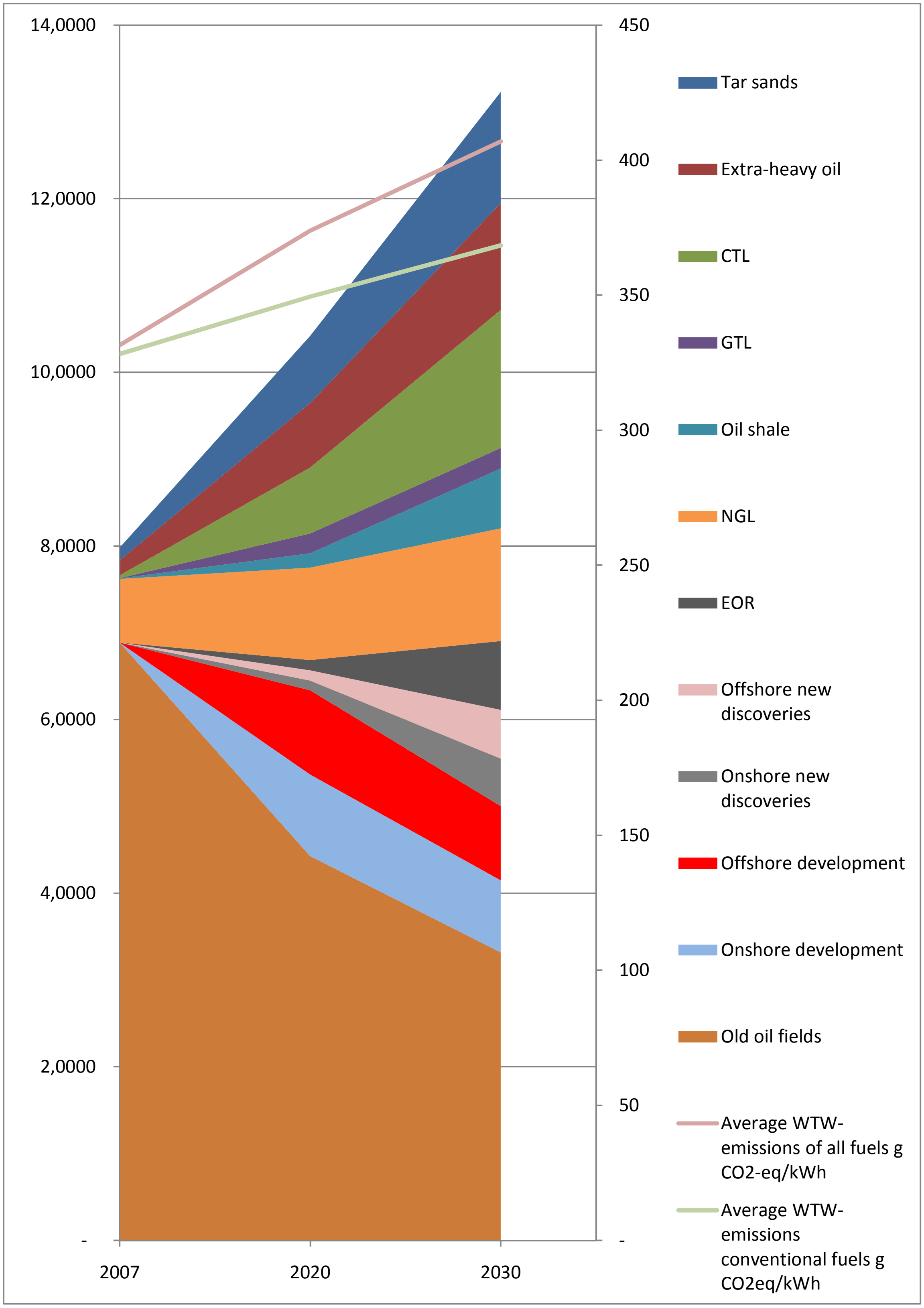

Illustration 29: Development of greenhouse gas emissions from all conventional and unconventional fuels in the 'growing demand' scenario.

8.1.2 Scenario: Constant demand

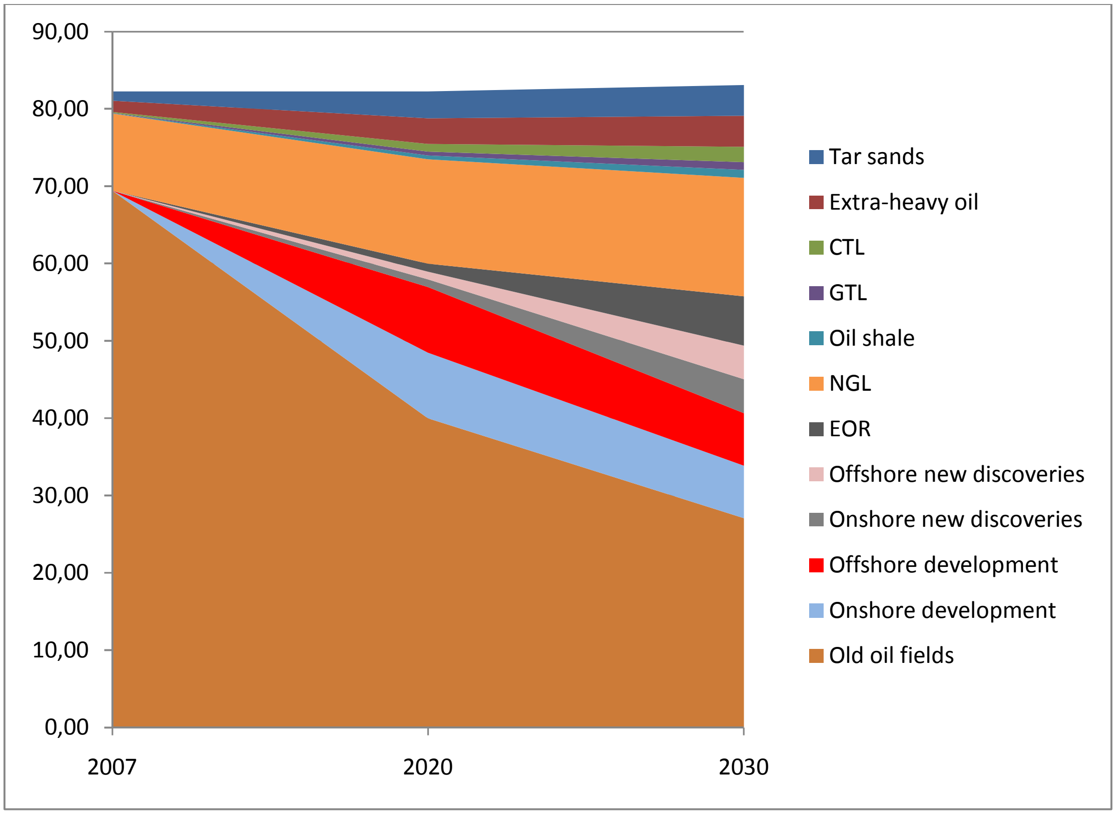

Illustration 30: Development of fuel production in the 'Constant demand' scenario. Cf. Table 11 in appendix.

The 'constant demand' scenario is depicted in Illustration 30 and Illustration 31. In this scenario too, there is an increase of CO_2 emissions by 2 billion t CO_2 through the increased use of unconventional fuels, particularly through tar sand mining, CTL and extra heavy oil production (see Illustration 31). The greenhouse gas emissions from conventional fuels are developing as shown in the 'growing demand' scenario, as we are in both scenarios assuming an equally large production of conventional fuels.

In the 'constant demand' scenario the average WTW emissions from all fossil fuels increase by 16% to 384 g CO_2/kWh. In this way, the WTT emissions rise by 80% to 119 g CO_2/kWh.

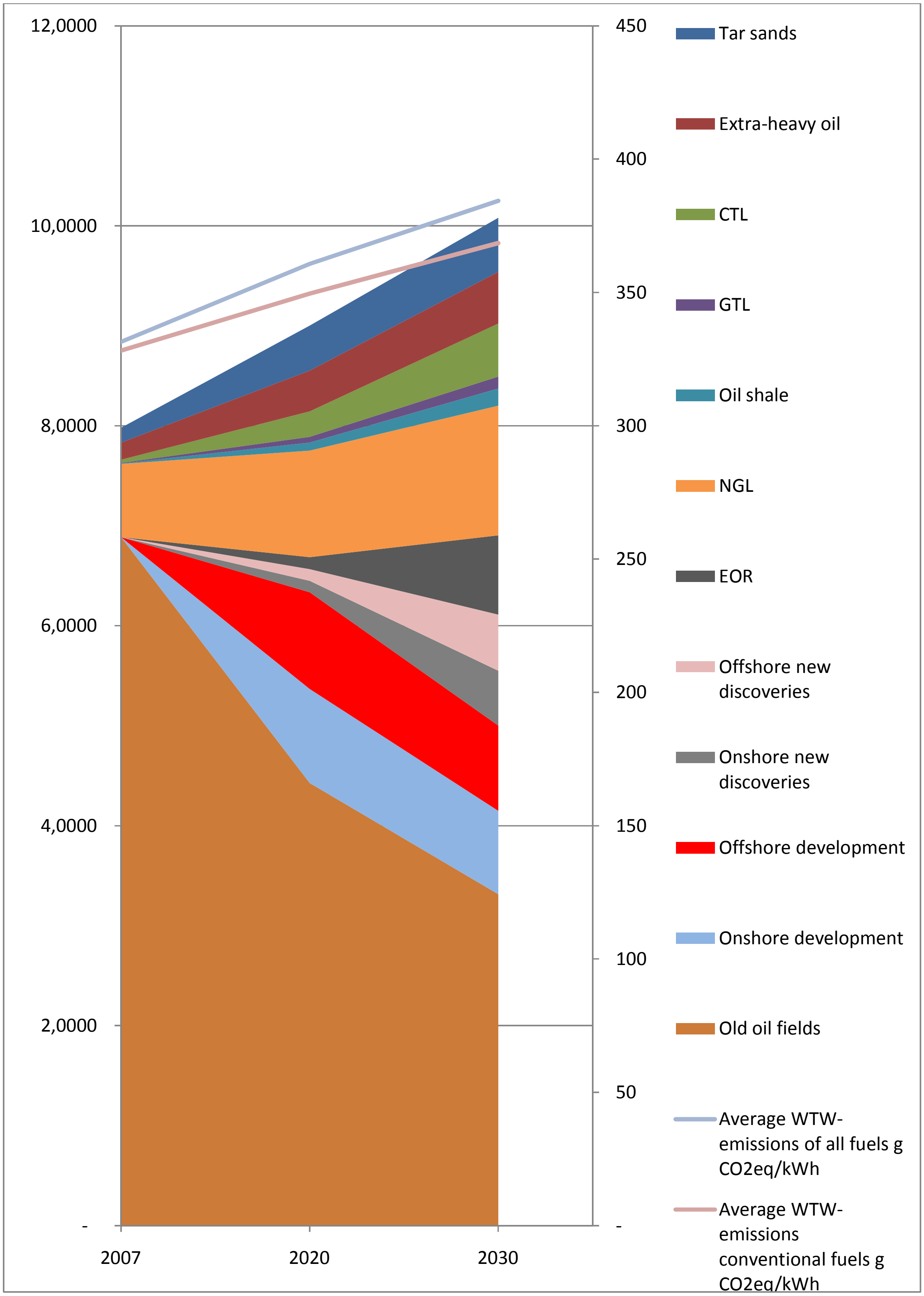

Illustration 31: Development of greenhouse gas emissions from all conventional and unconventional fuels in the ‘constant demand’ scenario

8.2 Substitution effects of marginal oil through biofuels

In the following chapter we describe global possibilities for the use of biofuels to replace fossil fuels.

There are considerable global possibilities for the production of biofuels on degraded surfaces. According to surveys by the FAO, more than 3.4 billion ha globally are degraded surfaces. [304] This represents 40% of global farm, meadow and forest surfaces (cf. Illustration 32).

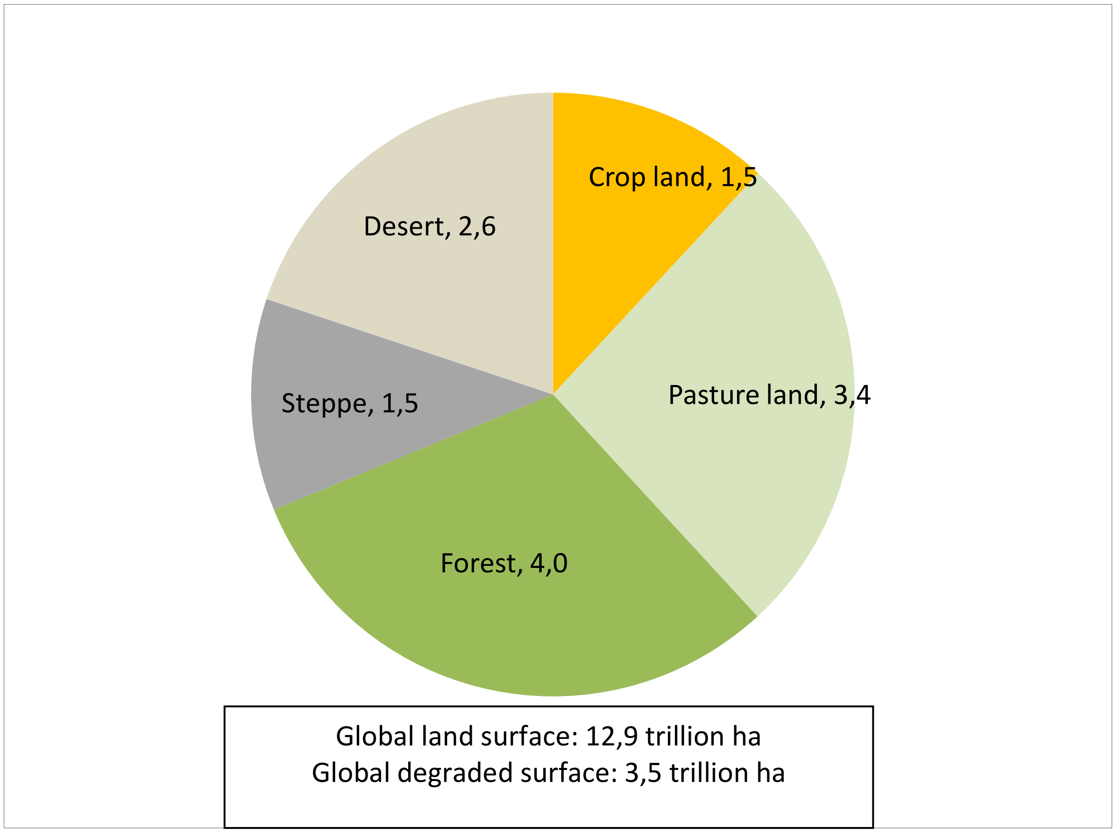

Illustration 32: Global land use in billion ha[305]

A large portion of the degraded surfaces could be used for biofuel production since the global potential for yield increase shows that an additional expansion of agricultural surfaces is not necessary to cover the future global need for foodstuffs.

- The increase of grain production by 50% to 100% by 2030 on existing agricultural areas is realistic since the current average global yield (3 t/ha) represents less than half of the yield found in Germany and other European countries. [306] Research projects such as the SAFE World Research Project show it to be possible to achieve large yield

[304] Quoted in: Metzger & Hüttermann 2008.
[305] Metzger & Hüttermann 2008
[306] Current grain yields according to USDA 2008.

increases in the tropics using improved and sustainable cultivation methods without the intensive use of synthetic fertilisers and pesticides. [307]

- The potential for yield increase is very high, particularly in the tropics. For example, the average agricultural production per hectare in Africa amounts to only one third of the average world level. [308]

Research projects show that yields can be increased especially through increases in the proportion of carbon in the soil (through humus or charcoal). [309] These results counteract the fears of the German Advisory Council on Climate Change (WBGU) that increases in agricultural production always lead to increased greenhouse gas emissions and negative environmental effects.

The following example shows that bioenergy can provide an immense contribution to the global energy supply if half the degraded soils (1.75 billion ha) would be used to grow energy plants:

- An average plant oil and/or ethanol yield of 1.2 t crude oil equivalent on a quarter of the area (0.9 billion ha) could cover half of current global fuel consumption.
- On another quarter, rapidly growing trees with an annual increase of 10 t dry mass could cover more than a third of current primary energy consumption for electricity and heat generation.

This calculation represents a highly conservative estimate of biomass yields since the current maximum plant oil yields amount to over 5 t crude oil equivalent (see Table 9), with ethanol yields amounting to over 4 t crude oil equivalent and the growth rates for fast growing trees in the temperate zones amounting to up to 20 t dry mass/ha and up to 30 t dry mass/ha in dry tropical forests. [310] Studies in Mexico also show that very high bioenergy yields are not restricted to the moist tropics. Attempts to cultivate agaves with a very high sugar content under semiarid conditions have resulted in ethanol yields of over 7,000 litres/ha (i.e. over 3.5 t crude oil equivalent). [311]

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[307] Pretty and Hine 2001
[308] Lahl 2008. cf. USDA 2008.
[309] Lal 2001, 2006, 2009. Woolf 2008. Lehmann et al. 2003, 2006, Lehmann 2006. Research requirements for the use of charcoal (biochar) are still immense. But there are already many research and pilot projects underway around the globe that are designed to increase yields with biochar and other techniques. But so far, it has not been possible to duplicate the qualities of the Terra Preta soils in the Amazon region using these measures, since they have maintained high fertility for many thousands of years. This has permitted intensive agricultural use with high yields despite the intensive tropical erosion process.
[310] Worldwatch Institute 2006. Metzger & Hüttermann 2008.
[311] Vélez 2008, Burger 2008.

Oil plants/oilseed	Yield t crude oil equiv. /ha/a
False flax (mixed cultivation with grain)	0,4
Soy	0.4
Hazelnuts	0.4
Mustard seed	0.4
Sesame	0.5
Safflower	0.6
Tung oil tree	0.7
Cocoa tree	0.8
Peanuts	0.8
Olive tree	0.9
Moringa tree	0.9
Piassava palm	1
Spurge plant	1
Castor-oil plant	1.1
Bacuri tree	1.1
Rapeseed	1.2
Pecan tree	1.3
Babassu palm	1.4
Jatropha	1.4
Sunflowers	1.6
Jojoba tree	1.8
Brazil nut tree	1.8
Avocado	2
Oiticia tree	2.2
Buriti palm	2.4
Pequi tree	2.8
Macauba palm	3.4
Pongamia palm	3.7
Oil palm	4.4
Coconut	5.3

Table 9: Oil plant yields[312].

In addition, it is important to utilise the vast potential of salty surfaces with salt-tolerant plants (halophytes) for bioenergy production. According to Lahl, approximately 50 million ha of coastal areas are suitable for saline agriculture using seawater irrigation. [313]

[312] NCAT (National Center for Appropriate Technology) 2002, Pingel 2008, Bundesverband Pflanzenöle 2009. The values represent yields at good locations

[313] Lahl 2008

8.3 Evaluation of the framing political conditions for the limitation of greenhouse gas emissions for fossil fuels

As shown in chapter 8.1.2, even a constant demand for fuels in a 'business as usual' scenario will lead to an increase in greenhouse gases from fossil fuels. Massive changes would be necessary to even prevent an increase from 8 to 10 billion t/CO_2 by 2030.

The political circumstances for this are proving difficult to create:

On the international level, there is currently a standstill in the realm of international climate conferences. The negotiations on a post-Kyoto Protocol have come to a halt. There has not yet been an agreement between the industrialised nations and the emerging and developing countries on CO_2 reduction goals and their distribution. For this reason, a press release by Germanwatch from 14/08/2009 refers to conditions that could jeopardise a far-reaching climate agreement.[314] According to Germanwatch, the petroleum-exporting countries are playing a particularly active role in undermining the entire negotiations process.

Yet even under the currently valid reduction goals of the Kyoto Protocol, the transport sector plays virtually no role at all. For example, the EU emissions trading system does not include the transport sector. An EU directive inclusive of aviation will not come into effect until 2012, and it only applies to operators whose aircraft take off and land within the European Union.
The political discussion regularly calls for introducing a tax on kerosene consumption; no such tax is in sight.

An extension of emission trading to shipping traffic is being discussed without, until now, any results. The issue of shipping traffic is complicated by the fact that the decision of the International Maritime Organisation (IMO) to ban sulphur from shipping in April 2008 will lead to a considerable increase in CO_2 emissions. The background: The transformation of previously utilised sulphurous heavy oil in refineries into lighter fractions requires a great deal of energy. Concawe, the research centre of the European petroleum industry,[315] assumes that this will increase greenhouse gas emissions from refineries by a third.

Projects in the transport sector are extremely underrepresented within the framework of the flexible mechanisms of the Kyoto Protocol, Clean Development Mechanism (CDM) and Joint Implementation (JI).[316] This is explained by the great complexity, the high costs and long implementation phases of such projects. The calculation of CO_2 reductions presents particular difficulties.

The EU energy package of early 2007 called, in addition to for 20% goals for renewable energies and energy efficiency, a separate development goal of 10% for renewable energies in the transport sector.

[314] Germanwatch, 14/08/2009
[315] Schlandt 2009
[316] Grütter 2008

The EU Commission's initial plans for the introduction of fleet targets for new vehicles of 120/130 g by 2012 have been scaled down to a gradual introduction by 2015. However, it still hopes to reach a target of 95 g CO_2 by 2020.

A CO_2-based vehicle tax is being discussed on the EU level and is supported by the EU environmental ministers. The current Swedish EU Council Presidency has spoken out in favour of its introduction and would like to implement it during the current term.

On the national level in Germany, a CO_2-based vehicle tax for new vehicles has been in place since 1 July 2009. According to this regulation, cars with up to 120g CO_2 emissions are tax-exempt until 2011 and cars with up to 95g CO2 emissions will be tax-exempt starting in 2014. In June 2009, a new law came into being in Germany that makes changes to the production of biofuels. According to the law, the share of biofuels in the total fuel market will retroactively drop from 6.25% to 5.25% as of 1 January 2009 and remain frozen at 6.25% from 2010 to 2014. The original law had called for increasing the mandatory quota annually in order to achieve a value of 8% in 2015. This alteration means that the original climate protection targets in the fuel sector have been significantly weakened.

The German government would like to give the topic of electromobility a stronger push with its National Development Plan for Electromobility. The political discussion is still in the starting phase. The goal is to put a million electric cars onto the German market by 2020. The topic of electromobility is also increasingly being discussed in Japan and the USA.
Japanese manufacturers have made the greatest advances in the development of vehicles with electric propulsion. But some German companies (BMW and Daimler) have also announced their intention to put electrically-powered urban vehicles onto the market.

Conclusion:

No internationally coordinated strategy to reduce CO_2 emissions in the transport sector is visible. Individual measures of the kind that have been suggested at the European level and implemented in several countries do not go nearly far enough when it comes to achieving an effective reduction of CO_2 in fossil fuels. In addition, there is a danger that national or European measures will not reduce the global amount of CO_2 emissions but merely displace them by using CO_2-poorer, lighter fuels in Europe while other countries are forced to use fuels made from heavy oil, oil shale, tar sand and coal. [317] That is why global CO_2 reduction goals must be implemented along the same lines as CO_2 reduction goals in the areas of electricity and heat.

8.4 Recommended action: Social and environmental standards for fossil petroleum

For several weeks now, the draft of a biofuel sustainability directive has been available. It will come into effect on 1 January 2010. The background for this directive is the national implementation of the European sustainability directives as defined in the Directive on the

[317] cf. Reilly 2007.

Promotion of the Use of Energy from Renewable Sources (RED) and the introduction of sustainability criteria for the production and utilisation of biomass.

There are no efforts to formulate compulsory sustainability criteria for the production of fossil fuels. All that has been presented in this area so far has been voluntary principles or voluntary initiatives without any legally binding provisions. The following four initiatives are presented as examples: [318]

Voluntary Principles on Security and Human Rights: These voluntary principles were established in 2000 following a meeting of representatives from the foreign ministries of the USA and Great Britain as well as from petroleum, mining and energy companies along with various non-governmental organisations, following accusations against Exxon and BP human rights violations by their security forces in Colombia and Indonesia. The principles are intended to guarantee security and protection during the mining of raw materials and ensure that human rights and human freedoms are respected. According to the memorandum from the Heinrich Böll Foundation, there is scarcely any information as to the effectiveness of the initiative, as no criteria for membership exists as well as no procedure for ascertaining whether these principles are being adhered to. In the meantime, numerous NGOs have threatened to abandon this initiative.

UN Global Compact: The Global Compact derives from an initiative by former UN General Secretary Kofi Annan from 1999. It is based on ten principles in the areas of human rights, labour, the environment and the fight against corruption. The Global Compact provides companies with a springboard for learning where they can become acquainted with and practice optimal behaviours. However, as there are no binding measures in place, it fails when companies do not observe the 10 principles.

OECD Guidelines for Multinational Enterprises: These guidelines contain principles for social and environmental standards, compliance with the rules and tax regulations of the host country and measures to combat corruption. While these principles are voluntary, they entail the formal possibility for appeal. In addition, OECD members commit themselves to establishing a contact point where complaints can be submitted. For example, the UN Expert Panel on '*Illegal Exploitation of Natural Resources and other Forms of Wealth in the DR Congo*' has made these principles the basis of its report in order to present public evidence whenever companies violate international law and fail to observe OECD guidelines. The report aroused a controversial discussion due to the absence of clear evidence of the companies' participation in the guideline violations. This showed that the indicators and procedures of the OECD guidelines are not clear enough to provide clear proof of the participation of those companies that were involved in the conflicts.

Extractive Industries Transparency Initiative (EITI): The target of this initiative is transparency on revenues from the raw materials industry. EITI is a purely voluntary commitment. The 'Publish What You Pay' campaign by international NGOs goes further. While it supports the

[318] Heinrich Böll Stiftung 2007

EITI initiative, it goes further by demanding a binding disclosure of taxes, levies, licensing fees and other payments. Over the coming years, these initiatives will have the opportunity to show their effectiveness.

In addition, the study by PricewaterhouseCoopers and oekom research AG (see chapter 7.4) shows that the standards formulated by companies and their actual implementation deviate from one another, e.g. in the areas of human rights policy and environmental impacts.

Conclusion: Sustainability standards should also be implemented for fossil fuels. For example, the European Parliament has presented preliminary initiatives to hold those companies whose overseas activities lead to environmental damage and human right violations more liable for their actions than has previously been the case. A potentially willingly partner might be the European Coalition of Corporate Justice (ECCJ), a network of 250 European NGOs that are demanding the introduction of direct liability for companies.

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12 Appendix

Development of fuel production in the 'growing demand' scenario

Million barrels/day			
	2007	**2020**	**2030**
Tar sands	1.20	6.00	9.50
Extra heavy oil	1.46	6	9.5
CTL	0.14	3	6
GTL	0.05	2	2
Oil shale	0.01	1	4
Unconventional total	**2.85**	**18.00**	**31.00**
Old oil fields	69.448	40.00	27.1
Onshore development		8.50	6.8
Offshore development		8.50	6.8
Onshore new discoveries		1.00	4.35
Offshore new discoveries		1.00	4.35
EOR		1.00	6.40
NGL	10.00	13.5	15.33
Total production	**82.30**	**91.50**	**102.13**
Gains in production	2.1	2.4	2.6
Total production	84.40	94	105

Table 10: Development of fuel production in the 'growing demand' scenario

Development of fuel production in the 'constant demand' scenario

Million barrels/day			
	2007	2020	2030
Tar sands	1.2	3.50	4.00
Extra heavy oil	1.46	3.3	4
CTL	0.14	1	1.7
GTL	0.05	0.5	0.8
Oil shale	0.01	0.5	0.7
Unconventional total	**2.85**	**8.80**	**11.20**
Old oil fields	69.45	40.00	27.1
Onshore development		8.50	6.8
Offshore development		8.50	6.8
New discoveries Onshore		1.00	4.35
New discoveries offshore		1.00	4.35
EOR		1	6.4
NGL	10	13.5	15.33
Total production	**82.3**	**82.30**	**82.33**
Gains in production	2.1	2.1	2.1
Total production	84.40	84.40	84.43
Total conventional	79	74	71

Table 11: Development of fuel production in the 'constant demand' scenario