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Switching from coal and oil to natural gas
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Switching from coal and oil to natural gas accelerates climate change through alarming methane emissions

Thure Traber* & Hans-Josef Fell

Abstract

Natural gas is often presented as a climate-friendly alternative for the electricity and heating sectors and as a "bridging technology" with a key role on the way to a sustainable energy system. If, however, methane emissions are considered in addition to carbon dioxide emissions, it can be seen that a climate protection strategy based on natural gas has the exact opposite effect. Savings on carbon dioxide during on-site combustion are only achieved by significantly increasing the methane emissions in the entire chain. Overall, the switch from coal and oil to natural gas in power plants and heating systems even increases the greenhouse effect of energy consumption by around 40%. At the same time, this creates obstacles to renewable energy sources, prevents a sustainable, emission-free economic system and blocks effective climate protection. Despite a simultaneous commitment to Paris' climate protection targets, which are incompatible with increased natural gas use, many governments continue to support the highly climate-damaging natural gas with subsidies and indirect support measures.

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1 Introduction

The timeframe for a smooth transition to a world that prevents dangerous climate change by effectively reducing greenhouse gas (GHG) emissions to zero is closing in a few years. However, it is not only global CO₂ emissions but also rising methane emissions that are causing increasing climate damage. This fact is often downplayed by the fossil energy industry, although its growing importance is proven by scientific findings. Overall, the use of fossil raw materials is responsible for at least 60% of global greenhouse gas emissions. It is therefore essential for an effective climate policy to dismantle all fossil fuel subsidies and open the market to cheaper renewable energies.

Despite 30 years of international UN conferences and countless agreements to combat climate change, greenhouse gas emissions reached a new peak in 2018. Global warming is already at 1.1 °C (as of 2019) and we are experiencing global weather extremes and a rapid rise in sea levels. Taking into account the agreed Paris climate targets as well as these developments, an emission-free world must be achieved by 2030, and any new source of emissions is already unacceptable today. The main reason for this poor development is sticking to fossil energy carriers, i.e. mineral oil, fossil coal, and natural gas.

The remaining carbon budget of 420 gigatons set by the Intergovernmental Panel on Climate Change (IPCC) will be depleted by 2030 at the latest due to the record emissions of recent years, as long as there is no immediate reduction in emissions ¹ . It should be noted that remaining within this budget only limits global warming to 1.5 °C with a 66% probability, which alone will have catastrophic effects in large areas of the world.

¹ See Global Carbon Project, <https://www.globalcarbonproject.org/carbonbudget/>, last retrieved on 18 June 2019. Note that these budgets are about 300 GT higher than those estimated by the IPCC prior to its update in 2014.

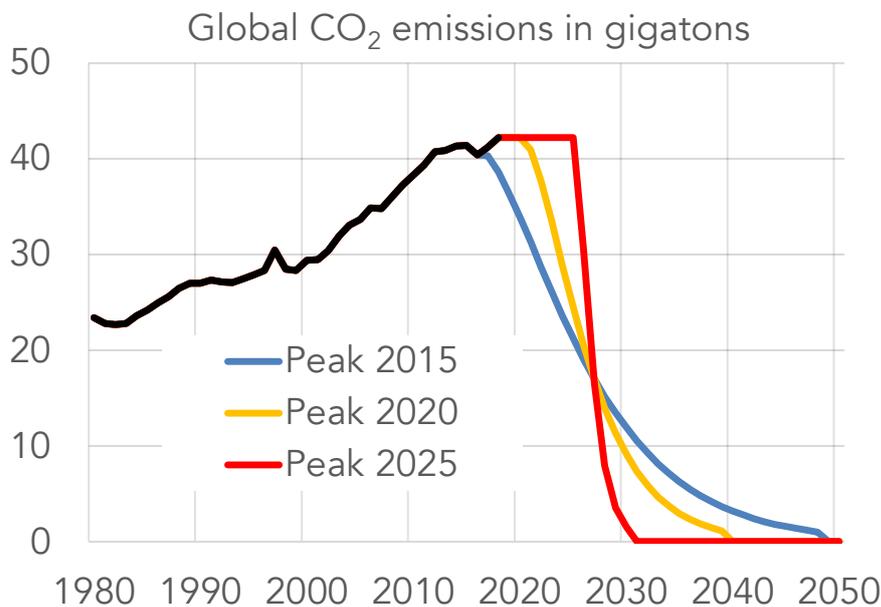


Figure 1: Global greenhouse gas emissions have to peak well before 2025. Source data from the Global Carbon Project GCP using mitigation curves after Raupach et. al (Raupach et al. 2014), own depiction.

The graph in Figure 1 above demonstrates the increasing speed of transformation necessary to reach the 1.5 °C target in respect to the start date of effective carbon dioxide reduction. If the world is not embarking on a drastic transformation pathway well before 2025, preventing the earth from entering an uncontrollable hot age becomes illusory. And natural gas plays a decisive role.

Close attention to methane emissions is not only needed due to a much faster rise of methane concentration in the atmosphere than previously projected (Broderick and Anderson 2017; M. Saunio et al. 2016), but also because of rising emissions from natural gas exploitation that are most likely the prime source of the atmospheric methane increase as recent studies reveal (Howarth 2019; Worden et al. 2017). Reflecting the findings of Howarth, Figure 2 below shows that natural gas-related methane emissions are already responsible for about 5% of all greenhouse gas emissions. In total, methane accounts for about 41% of all greenhouse gases.

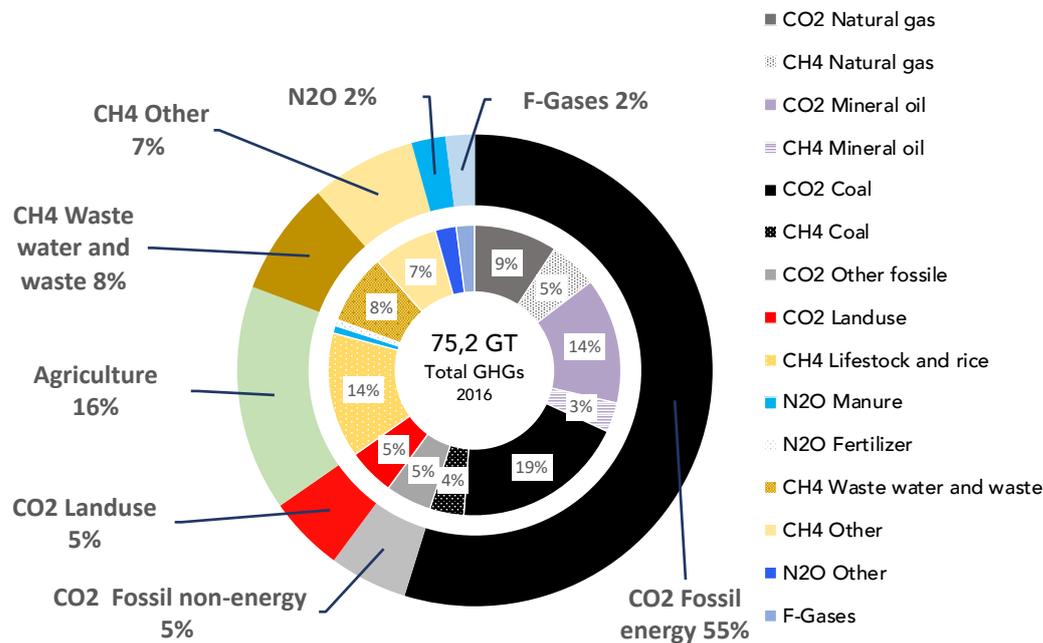


Figure 2: Shares of source-types in total GHG emissions 2016: fossil methane emissions are contributing an increasing share which is driven by natural gas use. Own calculation based on Howarth et al. and Olivier et al. (Howarth 2019; Olivier J.G.J., K.M. Schure, and J.A.H.W. Peters 2017).

Renewable energies and associated zero-emission technologies offer a cost-effective alternative and enable a comprehensive and rapid transition to a climate-friendly energy system. These are, in particular, solar and wind energy combined with battery storage, electric drives and heat pumps. The existing gas infrastructure can already be used today for biogas and green gas. This use of these cost-saving and climate-friendly opportunities requires fair cost competition and thus the immediate elimination of subsidies and reliefs for fossil fuels. This is by no means the case at the global level, as the International Monetary Fund (IMF) reports again in a recent study (Coady et al., 2019). Some countries are currently even introducing further national subsidies for fossil fuels.

In the following section, the effect of replacing coal-fired power generation and oil heating with natural gas-fired alternatives is calculated, taking into account the latest findings on methane emissions and total supply chain emissions from natural gas-based power and heat generation. Subsequently, alternatives based on renewable energies will be shown and an overview of existing and planned natural gas subsidies will be given using the example of the EU and its member states. Finally, the results are summarised, and policy recommendations are presented.

2 Greenhouse Impact of Switching to Natural Gas

A significant part of greenhouse gas emissions from natural gas is due to the intentional or unintentional escape of methane from the source to the final consumer. In the ten years from 2003 to 2012, according to a metastudy carried out by Sauniois et al. (Sauniois et al., 2016), the annual methane emissions from fossil fuels were estimated using so-called bottom-up models at about 121 terragrams (Tg), with a minimum quantity of 114 Tg. The central estimate for gas and oil was set at 79 Tg per year (Sauniois et al., 2016). However, these older estimates reflect the situation around the end of 2007 (2003-2012) and do not explain the drastic increase in methane concentration in the atmosphere over the last ten years (Worden et al. 2017).

This picture of recent developments in global total methane release into the atmosphere is at least partly explained by various studies, often with a regional focus, examining different parts of the natural gas supply chain. For example, a recent analysis of US natural gas and oil supplies, which are increasingly dominated by shale resources, supports this view (Alvarez et al. 2018). On the basis of detailed measurements, the authors conclude that methane emissions exceed the previously published data of the US Environmental Protection Agency (EPA) by about 60%. In addition to the assessment by Alvarez et al., downstream emissions from the final use of natural gas, e.g. in households, power plants and the chemical industry, must also be accounted for. A recent study by Lavoie et al. provides current evidence (Lavoie et al. 2017) showing methane leaks in US power plants of around 0.5% of the gross natural gas supply. This adds more than 10% to the methane emissions of the other parts of the energy supply chain. In addition, the natural gas distribution network is also a frequently neglected source of leaks.

The estimated downstream methane emissions often total up to 100% of the upstream methane emissions from natural gas supply i.e. up-to 2,7% of extracted gas is lost downstream (European Commission 2015; McKain et al. 2015; Nace, Plante, and Browning 2019). For comparison, by replacing electricity from coal-fired power plants with electricity from unrealistically efficient natural gas-fired power plants, Alvarez et al. argue that direct climate impacts can only be saved if the total natural gas leakage is below 3.2% (Alvarez et al. 2012).

In most cases, importing to Europe, as well as to other major importing countries such as Japan and China, involves comparably high downstream emissions, either through long-distance pipelines or LNG shipping. Both routes are often responsible for the dominant part of the emissions in the entire supply chain – particularly from distances of around 4000 kilometres. (European Commission 2015).

More consistent with the latest development of methane concentration over the last ten to fifteen years and the latest studies on fossil gas supply-side emissions are the studies by Worden and colleagues (Worden et al. 2017) and by Howarth, who also states that the supply of fossil fuels is the main driver of methane emissions, and among these the increase in shale gas production dominates (Howarth 2019).

2.1 Trivialisation of Methane Emissions from Natural Gas by the International Energy Agency (IEA)

In contrast to the latest observations, the World Energy Outlook WEO 2018 of the IEA (International Energy Agency 2018) provides a rather placating assessment of global emissions from oil and gas supply. However, there are several reasons why this IEA-created picture that natural gas in particular cannot guide effective climate policy and why emissions from the switch to natural gas are much higher. The low greenhouse gas emissions from natural gas use as suggested by the IEA can be explained by the following five problematic IEA-assumptions that are explained in detail below.

1. Allocating a level of methane emissions from fossil fuels that was representative for the decade 2003 to 2012, which neglects almost ten years of growth in natural gas use.
2. Omission of emissions from downstream methane leakages related to end-use.
3. Focusing on average, existing plants instead of the less energy efficient but more competitive future plants for natural gas power generation.
4. Assessing the climate impact of methane over a long 100-year period. This represents only one third (35%) of the climate impact of methane compared to the 20-year assessment period, which is the crucial time frame for avoiding climate tipping points.
5. Highlighting the emissions of current average natural gas when assessing the climate impact of switching from fossil-to-fossil fuels, although additional gas sources are more expensive and more polluting than average sources already in use.

The way in which the IEA presents the data plays down the risks of natural gas for the climate, providing another assessment that is biased in favour of fossil and nuclear energies and against renewable energies. This bias has already been demonstrated regularly in other IEA publications, as investigated by several studies of the Energy Watch Group on the development of fossil and nuclear reserves, their costs and the costs of renewable energies and their development (EWG 2017; Metayer, Breyer, and Fell 2015; 2015; Zittel et al. 2013; Zittel and Schindler 2007; 2006). Nonetheless, the IEA exposition is based on a comprehensive data base, which is in part also available online and serves as a starting point for the following calculations ².

2.2 Updated Methane Emissions from Natural Gas

Based on the data of the IEA, we develop a consistent picture of the emissions of additional natural gas use by successively correcting the problematic assumptions. We correct the first assumption of the IEA presentation with findings from Howarth's recent methane emission development study (Howarth, 2019), which shows an increase in fossil methane emissions of around 20% in ten years, while the IEA assigns only a 5% increase in the same decade. Taking these results into account, methane emissions from fossil fuels in 2016 amount to 136 Tg ³. Compared to WEO 2018, this calculation results in about 20% higher actual emissions from fossil fuels and about 32% higher actual emissions from natural gas. This adaptation solves the first and presumably also the second problem of the IEA presentation, since Howarth's approach also covers methane emissions from final consumption.

² See methane tracker <https://www.iea.org/weo/methane/>, last retrieved on 18 June 2019.

³ Note that this is a value well in the range of bottom-up estimates for the methane emissions of fossil fuels as between 90-137 Tg per year as reported for the year 2012 in Saunio et al. (Saunio et al., 2016). See the appendix for our assumptions and data integration method.

In order to fix the third shortcoming, we identify the most likely future energy technologies and hence evaluate global warming effects of replacing coal-based electricity and mineral oil-based heat with the most competitive natural gas power plants and heat boilers. Under the accelerated development of renewable energies, open cycle gas turbines with comparably low thermal efficiency have a competitive advantage in electricity generation as shown with electricity market models for instance in Traber (Traber 2017).

In order to fix the fourth deficiency outlined above, we base our estimation on the impact of methane emissions with a 20-year global warming horizon ⁴ since global warming and its effects are appearing faster than expected. Examples include the melting of polar ice, glaciers, and permafrost that regionally occurs more than 70 years earlier than projected by the IPCC (Farquharson et al. 2019). Thus, climate tipping points are also more endangered than previously recognized and require the focus on the prevention of current and near-term warming. Notably, the IPCC is mostly referring to values that are comparable to those used by the IEA.

Finally, we correct the problematic fifth assumption that average gas is available for new natural gas applications. However, every increase in natural gas consumption due to the conversion of coal and petroleum applications increases the existing supply and leads to increased production of the most expensive and usually dirtiest supply sources, on the contrary to the IEA assumption. These mostly consist of small onshore fields and are associated with the highest environmental impact. (Balcombe et al. 2017; Crow et al. 2019).

⁴ The global warming potential of methane expressed in CO₂ warming units used here is 85.

This results in supply chain emissions of natural gas of 0.34 tons of CO₂ equivalents per MWh for the aggregate termed “new gas” which is comparable to estimates already published in 2011 by Howarth (Howarth, Santoro, and Ingraffea 2011) for the case of shale gas ⁵. For other cases, for instance using existing conventional gas supplies that are not based on fracking and without long LNG or pipeline transports, the estimate called “average gas” in the following may be applicable.

It remains important to note that the provided estimates are still conservative in the sense that the switch towards natural gas technologies would trigger further substantial emissions due to the production and installation of new plants. In addition, the gradual depletion of efficient natural gas reserves over time further reduces economic and ecological efficiency, which is not taken into account in the following considerations. Thus, the prospective natural gas supply over the technical lifetime of power plants and heating boilers, which are typically used for several decades, will be substantially dirtier than the values featured here. New investments into renewable energies have instead a lifetime that is hardly economically restricted due to the small share of variable costs mostly consisting of operational expenditures (OPEX).

⁵ Please refer to the appendix for emissions derived on the basis of Howarth (2011), the assumed supply chain emissions and their decomposition into CO₂ and CH₄.

2.3 Additional Greenhouse Gas Emissions through “Fossil-to-Fossil” Substitution

What is to be expected for the climate if the current use of fossil fuels is replaced by additional natural gas? In order to put the latest supply chain observations into the context of potential GHG emission reduction through fuel switching from coal and mineral oil to natural gas, we assume best available technology for electricity and heat generation. We derive the related emissions and compare them with emissions from other fossil fuel alternatives that could potentially be replaced by natural gas. More precisely, we compare (a) electricity generated from natural gas in an open cycle gas turbine ⁶ with electricity generated from coal in a coal-fired power plant with a steam turbine, and (b) heat from a condensing boiler fired with either fossil gas or mineral oil.

Electricity Sector: Replacing Coal Power Plants with Natural Gas Power Plants

Figure 3 below shows the substantial negative climate effect when replacing electricity generation in existing coal-fired power plants with electricity generation in new natural gas power plants. The estimated increase of GHG emissions of this switch is +41%. While this is partly a result of the fact that new natural gas applications are sourced from rather expensive and emission-intensive resources, it also becomes clear that with the hypothetical use of global average gas, no savings can be reached either.

⁶ For details regarding technology assumptions see the appendix. We assume for our comparison a new built open cycle gas turbine (OCGT) with an efficiency degree of 38%. Other publications like (Howarth 2014), and (Heath et al. 2014) use higher efficiency degrees that are representative for combined cycle gas turbines (CCGT). However, these power plants are not competitive in many markets including Europe and have a much higher investment costs compared to open cycle gas turbines. Due to larger intermittency of renewable energy in a sustainable power system development, OCGTs lower capital costs make them more attractive in particular as complement and back-up for the electricity system. For comparison, Figure 6 of the appendix also shows for the case of switching to natural gas fired CCGT.

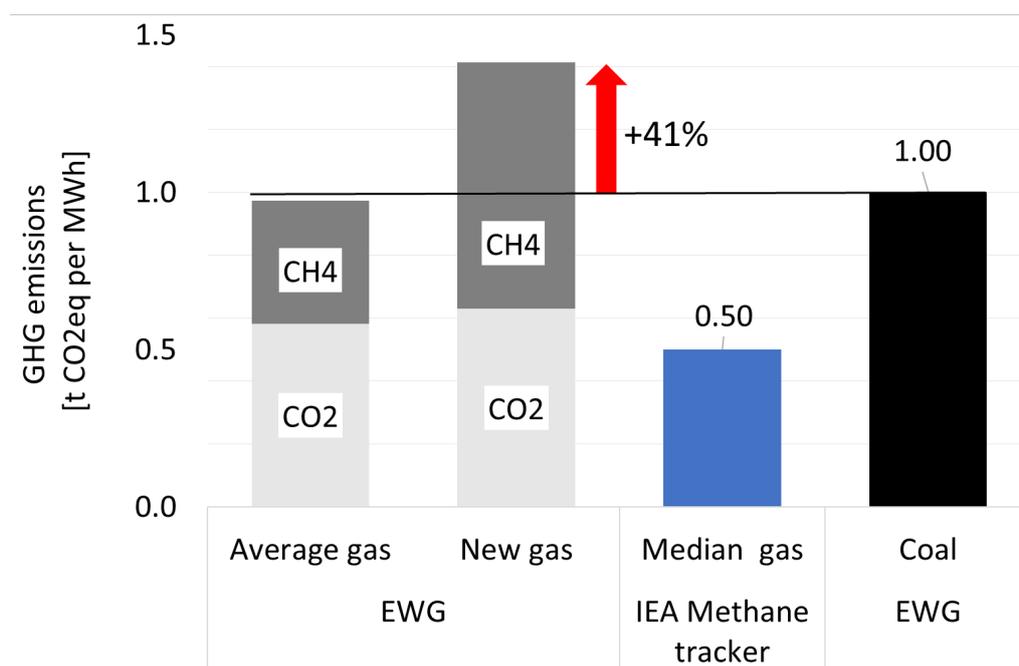


Figure 3: Greenhouse gas emissions from fossil sources and additional emissions from the switch from coal to new natural gas for electricity generation: Additional methane emissions more than offset any CO₂ savings. Source: Own calculation, IEA Methane tracker.

These results are in stark contrast with the depiction of natural gas as a bridging fuel towards a more climate-friendly energy future, as presented by the IEA in its WEO 2018 ⁷, as well as in its Methane tracker. The Methane tracker claims that “on average, coal-to-gas switching reduces emissions by 50% when producing electricity”, which can be seen in Figure 3 as the difference between coal-based electricity and the IEA's emission rating for natural gas shown in blue.

⁷ See Chapter 11 in IEA (2018).

Heating Sector: Replacement of Oil Heating Systems by Natural Gas Heating Systems

Similar conclusions are to be drawn for the heating sector as presented in Figure 4 below. Here, the replacement of mineral oil heating boilers by state-of-the-art natural gas boilers increases the GHG emissions per energy unit by 40 percent.

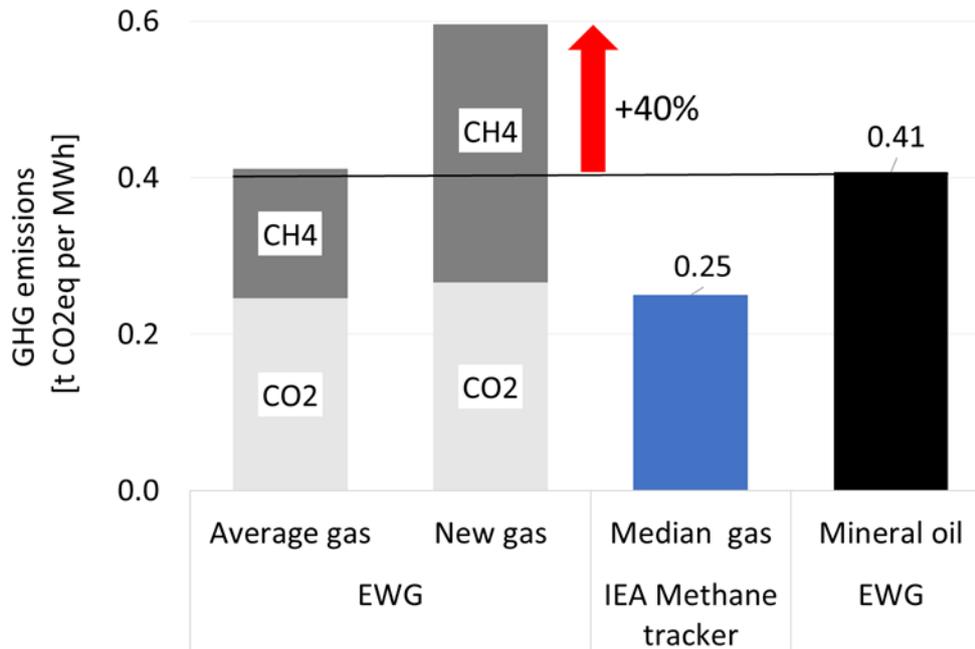


Figure 4: Greenhouse gas emissions from fossil sources and additional emissions from the switch from oil to new natural gas for heat generation: Additional methane emissions more than offset any CO₂ savings. Source: Own calculation, IEA Methane tracker.

Comparing heating emissions for natural gas, as published by the IEA, with emissions from a mineral oil boiler as depicted in Fig. 4 would falsely suggest an impressive 39% reduction from 0.41 to 0.25 tons of CO₂ equivalents per MWh. However, the IEA claims a comparatively low emission rate of coal heating of only about 0.38 tons and thus an GHG reduction of 33%. Contrary to the IEA's figures, greenhouse gas emissions rise drastically by as much as 40% due to the switch to natural gas in both the electricity and heating sectors. In addition, our calculations show that even if "average gas" is unexpectedly available – e.g. from local, easily accessible conventional, non-fracked sources – no emission savings are to be expected. Only CO₂ emissions could potentially be reduced in this way. However, the presentation of this switch as a contribution to climate protection with exclusive reference to the possible CO₂ savings is a delusion of the public, as it conceals the methane emissions that are decisive for climate change.

3 100% Renewable Energy is the only Option for a Fast-Track Transition to Zero Emissions

The rapid expansion of renewable energies to 100% worldwide is the only viable option to convert the current energy systems, which are based primarily on fossil and nuclear sources, to zero emissions quickly enough. As a large number of scientific studies have shown by now, a fast, cost-effective and largely decentralised transition to an emission-free energy sector can be achieved worldwide by 2050 or earlier. Hansen et al. provide a comprehensive overview of studies with scenarios for 100% renewable energy systems (Hansen, Breyer, and Lund 2019), while Brown et al. rebuff and invalidate alleged reliability and cost arguments (Brown et al. 2018). The studies show how a variety of cost-effective solutions will contribute to an electricity and heat provision that lead to zero emissions as part of an energy system based on 100% renewable energy sources.

Today, renewable energies can compete with nuclear and fossil fuel-based supplies on a cost basis, even when environmental damages and other costs of the conventional solutions are socialised (Teske 2019; Jacobson et al. 2015; Plessmann and Blechinger 2016). Particularly, the prospective costs of renewable energies are lower than those of fossil fuels in the G20 countries even when negative externalities are partially neglected (Ram et al. 2017).

The recent study conducted in cooperation between the Energy Watch Group and the Finish LUT University has simulated how the shift can be technically and economically realised (Ram et al. 2019). The study shows that natural gas-fired electricity and heat generation will hardly be economical from 2030.

The most cost-effective technologies to achieve zero emissions in all energy sectors are photovoltaic and wind power, followed by geothermal, hydro and solar thermal power (CSP). These technologies will dominate energy investments in the short term if adequate policies are in place. Figure 4 shows the development of global electricity generation sources under the EWG/LUT scenario, which allows emission reductions in line with the Paris Accord. The transition paths are generally characterized by a continuous reduction of all fossil-nuclear fuels including coal, natural gas, mineral oil and nuclear power, while increasing the share of renewable energies to 100%.

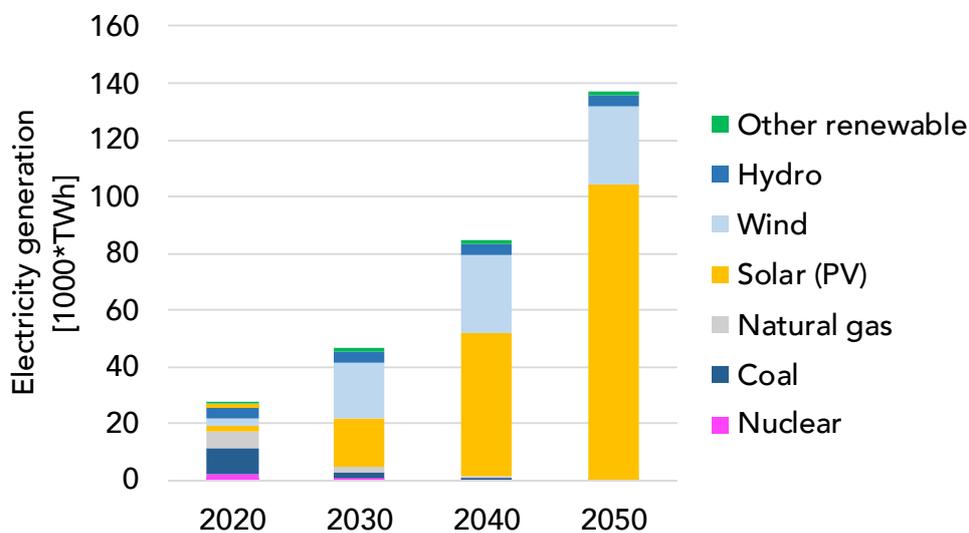


Figure 4: Development of global electricity generation according to the study by EWG/LUT: (Ram et al. 2019): Five-fold increase in global electricity generation, mainly on the basis of PV.

A broad range of technologies in the heat sector can already compete with fossil fuel-fired generation on a cost basis today. These include, in particular, heat pumps, direct electric heating, heating with biomass, and in a second stage of the energy transition heating with synthetically produced methane⁸ as shown in Figure 5, which features a cost-effective transition in the heat sector.

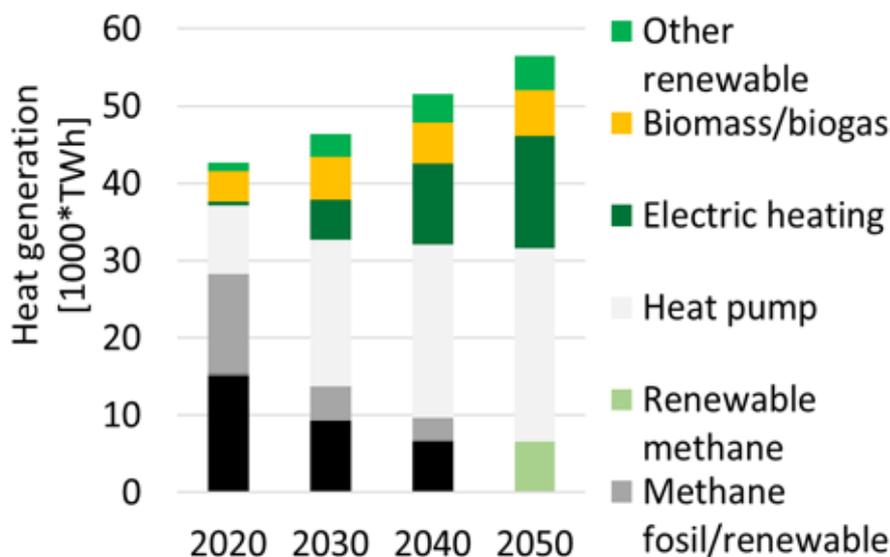


Figure 5: Development of sources of global heat generation until 2050 according to the study by EWG/LUT (Ram et al. 2019): Replacement of fossil methane and coal mainly by heat pumps and electricity heating. Heat generation from oil-fired heating systems, which still amounted to 111 TWh in 2015, is not apparent in the graph in terms of volume, but is certainly relevant to the climate, especially in Europe.

Such an integrated heat and electricity system based on renewable energy will be complemented by a range of storage technologies guaranteeing stable energy supply throughout the year. The EWG/LUT Study (Ram et al. 2019) projects a predominance of battery electric storage in concert with adiabatic compressed air storage, hydro energy storage and substantial solar thermal storage.

⁸ Note that methane transforms from a mainly fossil energy in 2020 to a renewable energy carrier produced fully on the basis of renewable electricity in 2050.

The transition towards renewable energy-based technologies outlined above requires a fast change of the capital stock in the energy system across sectors. In order to avoid stranded investments where possible, parts of the existing gas infrastructure are usable as the basis for the roll-out of green gas technologies. The following existing technologies can be rapidly deployed to play a central role:

- Methane from biogas based on organic farming,
- Methane directly from algae,
- Synthetic methane gas based on wind energy and photovoltaics in combination with direct CO₂ separation from the air,
- Hydrogen from electrolysis with photovoltaic and wind electricity,
- Hydrogen directly from algae,
- Hot air from high-temperature storage based on, e.g. liquid salt, hot stones or fluid metal charged with wind and solar energy.

From a technical perspective, renewable methane can replace natural gas in existing pipelines by up to 100%. The study shows that once we have completed the energy turnaround, the optimal use of green methane for heating purposes alone will amount to 36% of the natural gas used for this purpose in 2015. Blending hydrogen into pipeline gas in the existing pipeline infrastructure is today feasible up to around 20%. Another way to use existing energy plants is to use high-temperature storage to generate hot air, which can be used by existing gas turbines to generate electricity at times of low supply with renewable electricity.

Subject to political will and commitment, a further accelerated transition is possible on the basis of existing technologies, making all energy sectors emission-free well before 2050. Despite the enormous potential of low-cost renewable energies, however, fossil-nuclear technologies are still being pursued. Subsidies play a decisive role here.

4 New Subsidies for Natural Gas Despite Simultaneous Commitments to Subsidy Reduction

In 2009, the OECD countries announced that they would abolish subsidies, especially for fossil fuels, as this would make it possible to avoid 10% of all greenhouse gas emissions by 2050 (Belschner, Westphal, and Wissenschaft 2011). Today, the International Monetary Fund (IMF) finds in a new study (Coady et al., 2019) that in 2017 6.7% of global GDP, equivalent to about 4,6 trillion Euro (\$5.2 trillion), was still dedicated to fossil fuel subsidies. The same report uncovered that in 2015 the European Union spent about 264 billion Euro (\$289) on fossil fuel subsidies. Out of the global fossil fuel subsidies, about 10% were devoted to natural gas.

Estonia, Ireland, and Germany in particular are among the European countries planning LNG import facilities (Nace, Plante, and Browning 2019). In this context, Germany intends to grant new national subsidies for the construction of LNG terminals, similar to Finland, which is already financially supporting its LNG infrastructure. Additionally, the EU is awarding supranational grants through its "Connecting Europe Facility". Poland, Croatia, Sweden and Ireland will receive EU grants of several hundred million euros through this instrument alone to promote LNG terminals. Further subsidies from the EU flows for distribution networks that facilitate fuelling ships with LNG instead of diesel oil ⁹.

⁹ <https://www.lngworldnews.com/eu-funds-german-lng-fueling-project/>;
<http://www.foeeurope.org/EU-hitches-itself-climate-incompatible-gas-subsidies-until-2027-121218>;
<https://www.lngworldnews.com/eu-grants-funds-for-polish-lng-terminal-expansion/>;
<https://tem.fi/en/investment-support-for-lng-terminals>, last retrieved on 18 June 2019.

Germany, as one of the most recent examples, is already subsidising natural gas considerably and plans to further increase LNG support for natural gas import infrastructure, as examined in a study commissioned by the Energy Watch Group and conducted by Green Budget Europe (FÖS) in 2019^{10 11}. FÖS finds that German subsidies for natural gas amounted to at least 1.4 billion Euro¹² in 2017, with most prominent tax breaks being the energy tax on input fuel for electricity generation (1,2 billion Euro) and on fuel use for cars (180 million Euro).

This shows the absurdity of the climate and energy policy, which regularly promotes climate protection as laid out in the Paris agreement, but at the same time increases subsidies for fossil energies instead of reducing them as announced. Clearly, the subsidies for natural gas infrastructures not only constitute a significant burden to the national state budgets and taxpayers. In addition, negative consequences for investors are also to be expected. If the terminals are used, their potential economic success is fundamentally called into question by effective climate policy to address the poor climate balance. But even if the current situation is maintained, without the organisation of effective climate protection, the investments will not pay for themselves because the price of natural gas is too low. With rising prices, natural gas would ultimately become less and less competitive, as the prices for renewable energy continue to fall. From 2010 to the present, the shale gas industry already created negative cash flows of about 168 billion Euro (\$184 billion; Nace et al., 2019).

¹⁰ The study was mandated by the Energy Watch Group and released in March 2019.

¹¹ For this to happen, the government even seems to – knowingly or unknowingly – endorse or accept breaking the law. For instance, the proposed LNG-Terminal in Brunsbüttel stands in conflict with local legislation. This is supported by a recent report of Environmental Action Germany (DUH) highlighting the incompatibility with safety regulations; downloadable in German: https://www.duh.de/fileadmin/user_upload/download/Projektinformation/Energiewende/190528_DUH_Stellungnahme_ROV_Erdgasleitung_ETL_180.pdf DUH 2019, last retrieved on June 18 2019.

¹² This number does not include the indirect support of the government due to absent or incomplete internalisation of damages from fossil fuel supply and consumption.

On the export side, countries such as the USA support liquid gas supplies, especially to Europe. The US government also calls the predominantly fracked natural gas "freedom gas" or "freedom molecules"¹³. At the same time, according to studies by Howarth and colleagues (Howarth 2015; Howarth, Santoro, and Ingraffea 2011), fracking gas clearly has above average methane-intensity and, due to its supply as liquefied natural gas (LNG), counterproductive for climate protection in any case. Europe and other target regions of such LNG exports should be aware of the environmental impacts.

In addition, a subsidized switch from coal and oil to natural gas has many additional negative side effects. These are among others:

1. lower financial possibilities for investments in renewable energies, since investment funds are basically limited.
2. supply of natural gas at market-distorting low prices, which do not reveal the full economic costs of production, transport and distribution, since a part is covered by subsidies and thus reduces the market advantage of alternative, climate-neutral energy sources.
3. another chapter is added to the outdated narrative of a climate-compatible fossil-nuclear future.

¹³ See <https://www.theguardian.com/business/2019/may/29/energy-department-molecules-freedom-fossil-fuel-rebranding>, last retrieved on 18 June 2019.

5 Conclusion

Natural gas cannot contribute to the protection of the climate. Due to its high methane footprint, natural gas is not a climate-friendly alternative to other fossil energies and therefore is no bridge technology as part of a transition to a zero-emission energy system. The switch from coal and oil to natural gas does not lead to savings in greenhouse gas emissions, but increases them even further. It also hinders the urgently needed rapid deployment and expansion of emission-free renewable energies. In the public and political debate, natural gas is nevertheless often presented as a contribution to climate protection through possible CO₂ reductions. However, this view ignores unacceptably high emissions due to additional CO₂ and methane emissions from the natural gas supply chain.

Based on the IEA's latest alarming estimates, and taking into account the latest research on methane emissions from fossil fuels, this study quantifies the climate impact of fossil-fossil substitution by natural gas. The balance sheet is sobering. Instead of protecting the climate, replacing hard coal and crude oil with natural gas in the electricity and heat sectors causes a considerable additional burden on the climate of at least 40%.

In addition, natural gas investments are in competition with the ever cheaper renewable energies and therefore represent a growing risk by tying in with obsolete technologies. Tax support for these antiquated technologies creates major overall obstacles to the smooth development of a sustainable energy system. All in all, the fossil-fossil switching of the energy system to additional natural gas not only calls into question any effective climate protection, but also involves enormous economic risks.

6 Policy Recommendations

Responsible and effective climate and energy policymaking must be based on evidence supported by the latest scientific literature and must obey the precautionary principal in regard to the risk of catastrophic climate change. In the case of natural gas, emissions from natural gas supply appear to be significantly higher than in previous studies, which did not take into account scientific findings from the last five to ten years. While the IEA's World Energy Outlook acknowledges that the use of natural gas for some sources causes higher emissions than the use of coal, the IEA's and many national governments' presentation of natural gas as a necessary climate protection measure is inconsistent with the latest scientific findings. This misrepresentation continues to encourage governments around the world to give billions of euros to the fossil industry in the form of direct subsidies, tax breaks and exemptions, and support for infrastructure projects to import and export natural gas.

Rather, supporting long-lived natural gas infrastructures will generate irretrievable costs through unnecessary and climate-damaging investments and potentially lead to a lock-in situation in which natural gas is sold below its full cost. This would be another obstacle to fair competition and in particular to the development of renewable energy.

A sensible climate and energy policy for natural gas must abolish all subsidies for fossil fuels including natural gas. In addition, a moratorium on further infrastructure investments is essential, at least for certain facilities that cannot be quickly integrated into a clean, 100% renewable energy system.

The heat, electricity and transport sectors and their development without fossil emissions are of particular importance for policy-making. In the heating sector, a successful transformation is based on increasing energy efficiency through building refurbishment, the use of green electricity driven heat pumps and solar thermal collectors, as well as the conversion from fossil fuels to biomass pellets or green gas. In the electricity sector, it is crucial that the share of renewable energy sources reaches 100% and that sufficient storage capacities enable the timely phase-out of natural gas power generation. For the transport sector, a rapid transition towards electric solutions in road and rail transport must be completed based on green electricity and green gas.

In order to replace natural gas, all parts of the energy system should be converted to renewable energy sources. The existing multitude of cost-effective technologies for a 100% renewable energy system must be promoted by markets that reward their value for an energy system of the future that is compatible with climate policy goals. This applies not only to PV and wind, but also to batteries and fuels based on renewable energies and beyond that to technologies that replace fossil fuels in the transport and industrial sectors. To this end, administratively fixed feed-in tariffs should be used, such as those already being applied successfully worldwide for the transformation of the electricity sector. Feed-in tariffs should also be used to promote storage facilities and green gas.

Instead of creating new import options, the accelerated development of biogas and green gas based on green electricity not only enables rapid savings in greenhouse gas emissions, but also the elimination of fuel import dependencies and their strategic implications. For example, many countries in Central and Eastern Europe, especially Ukraine, can free themselves from their dependence on unilateral natural gas imports by developing their own local sources of biogas. The rapid implementation of strategic plans for biogas holds enormous potential, especially for energy independence.

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Appendix

Assumptions

Barrels per ton of oil equivalents	7.33
Megawatt hours per ton of oil equivalents	12
Megawatt hours energy content per barrel of oil equivalents	0.61
Degree of efficiency open cycle gas turbine	0.38
Degree of efficiency combined cycle gas turbine	0.58
Degree of efficiency natural gas condensing boiler	0.90
Degree of efficiency oil condensing boiler	0.90
Specific emissions from combustion - natural gas [kg/MWh]	200
Specific emissions from combustion - oil [kg/MWh]	266
Global warming potential of methane 20-year horizon [CO ₂ equivalents]	85
Natural gas supply chain emissions average gas (total/CH ₄)* [kg CO ₂ eq./MWh _{fuel}]	170/148
Natural gas supply chain emissions new gas (total/CH ₄)* [kg CO ₂ eq./MWh _{fuel}]	337/297

*Differences between total and CH₄ equals the CO₂ emissions.

Method of data integration

The data used for this paper adjusts IEA data published in WEO 2018 (International Energy Agency 2018) and in its Methane tracker to fit insights from latest publications in particular for methane emissions from fossil fuels (Howarth 2019). Howarth finds an increase of the global annual methane emissions from mineral oil and natural gas from 2005 to 2015 of about 19.1 Tg while the Methane tracker of the IEA reports an increase of annual emission of only 5.3 Tg in the same period. We are correcting the IEA information about natural gas emissions for the difference in emission growth assuming 1.6 Tg increase of annual emissions from mineral oil supply in the respective period and no conflict between the assignments of the emission increase by Howarth and the IEA.

This leads to an increase of natural gas emissions of 32% compared to the dataset used by the IEA resulting in an annual emission of natural gas supply of 57 Tg methane. We scale-up the information regarding natural gas supply methane emissions from the WEO 2018 by 32% throughout the paper.

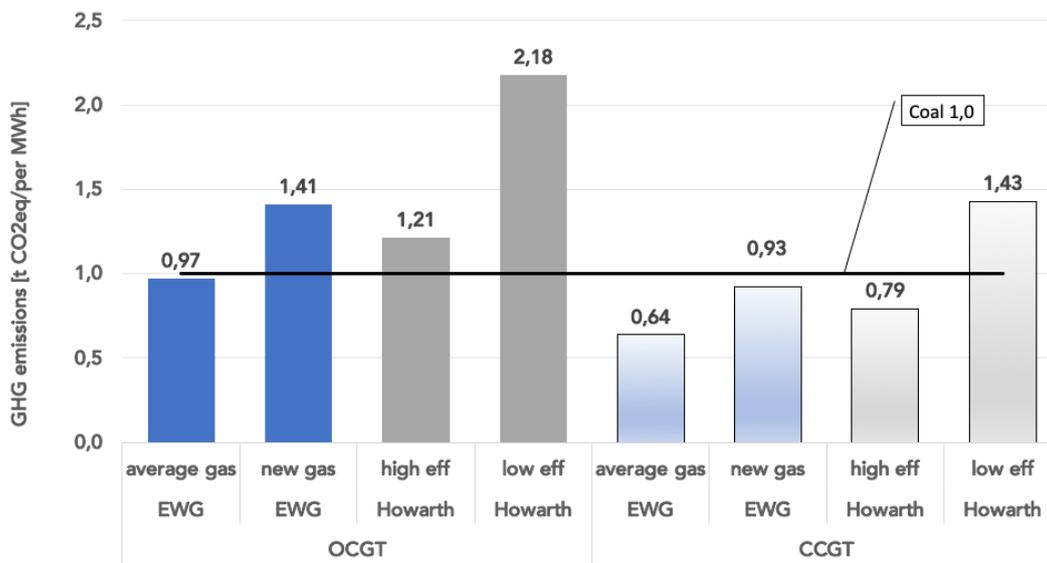


Figure 6: GHG emissions from electricity generation from natural gas based on supply chain estimates from EWG for average and new gas. Grey bars indicate resulting emissions that are based on supply chain emissions of shale gas as reported in Howarth (2011) but using our assumptions for electricity generation. The light colours on the right-hand side indicate emissions associated with expensive combined cycle power plants (CCGT) with extremely high degree of efficiency (58%) which are not competitive in Europe and most OECD-countries worldwide.