# RECOMMENDATIONS FOR SHALE GAS CARBON FOOTPRINT ASSESSMENT

## M. HAUCK, H. DENIER VAN DER GON

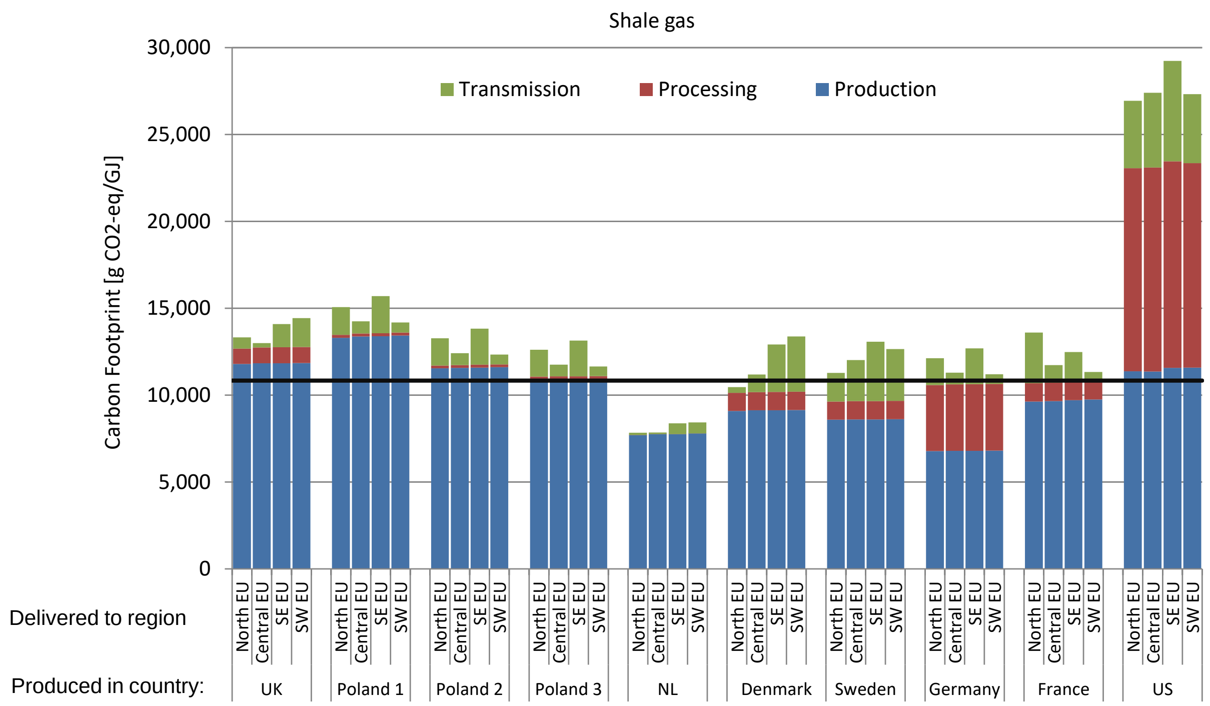



Figure 1. Carbon Footprints [$gCO_2$-eq./MJ delivered] from shale gas produced in European plays (three in Poland: Lublin, Podlasie, Baltic) and the US (horizontal countries on x-axis), delivered to four European regions ((North, Central, Southeast (SE) and Southwest (SW), vertical regions on x-axis). Contribution of life cycle stages is also shown (blue: production, red: processing, green: transmission). Horizontal black line indicates conventional gas delivered to the consumption-weighted average of all European regions.

## Background

Greenhouse gas (GHG) emissions to the atmosphere are critical to assess climate impacts of shale gas exploration and exploitation. Electricity production using (natural) gas instead of coal generally produces less carbon dioxide [IPCC, 2011]. However, the advantage of gas over coal is not undisputed, as leakage of $CH_4$ (a potent greenhouse gas) during exploitation could offset the advantage of gas over coal. The total of greenhouse gas emissions over a products life cycle, e.g. from well exploration to electricity generation from gas, is often referred to as carbon footprint (CFP). Different greenhouse gases can be compared by expressing the emissions of each gas in $CO_2$ equivalents based on their Global Warming Potentials (GWP). A proper comparison of GHG emissions between shale gas and other energy sources, specifically for Europe, will aid in assessing the carbon footprint of fuels.

## Study

A review of the existing knowledge on the carbon footprint of shale gas operations, mostly from U.S. based studies, was made. Omitting the combustion phase, that is indistinguishable for shale gas and conventional gas, most emissions arise from losses of gas during production (gas winning from wells) and preproduction (the preparation of the wells). The total production of a well is identified as one of the largest unknowns for the assessment of the carbon footprint of shale gas, as a higher production per well reduces the CFP. Next, the existing knowledge on shale gas operations in Europe was implemented in the life cycle assessment tool, GHGenius ((S&T)² Consultants Inc., 2013). GHGenius is able to estimate carbon footprints for conventional gas and oil for Europe. In M4ShaleGas we extended the tool with 8 potential European shale gas plays as production regions and extra shale gas related emission sources during production.

## Results

Per MJ delivered total GHG emissions range from 8 to 29 g $CO_2$-eq/MJ (Figure 1), consistent with the range reported in literature. Spread in carbon footprints are mainly related to differences between producing countries. The CFP of shale gas is generally higher than the average CFP from conventional gas delivered to Europe (from Europe and other countries). Total $CH_4$ leakage rate related to production ranged from 1% to 1.8% for shale gas from European regions. That is lower than the 3% often cited as being the maximum for natural gas to have a guaranteed lower carbon footprint than oil or coal. A first sensitivity analysis indicates the importance of good estimations of the fugitive emissions from hydraulic fracturing flowback and the large variation in data on production emissions. On a per kWh basis our default calculations show only small differences between carbon footprints of conventional gas and shale gas, both lower than those of oil and coal.

M4ShaleGas
Measuring, Monitoring, Mitigating, Managing the Environmental Impact of Shale Gas

# RECOMMENDATIONS FOR SHALE GAS CARBON FOOTPRINT ASSESSMENT

TNO

M. HAUCK, H. DENIER VAN DER GON

## Science-based Recommendations

Knowledge gaps remain due to lack of data from shale gas operations in Europe, most important are data on expected production ranges, dimensions of well pads and reduced emissions completions. Compulsory use of reduced emissions completions is recommended. When used for electricity generation, however, it should be kept in mind that most GHG emissions arise from combustion of shale gas, influenced by power plant efficiencies. The carbon footprint tool GHGenius adapted for shale gas can be used to estimate and compare carbon footprints from shale gas and other fossil fuels in Europe. Using (shale) gas showed an advantage in cumulative carbon footprints over other fossil fuels for a range of scenarios with upstream leakage rates of about 5% (Figure 2). However, differences between countries should be taken into account, related to the current origin of fossil energy sources and the expected development of the fossil electricity mix under a baseline scenario.

**Recommendations for further model improvement are:**

- To enable a better comparison with all fossil fuels relevant for electricity generation in Europe, GHG emissions arising from the delivery of coal to Europe should be included with more detail.
- Currently, total production per play is derived from the recoverable reserves. This could be extended by more realistic production scenarios that take into account political or economic restraints. Economic analysis or policy preferences could give insight in other possible or likely exploitation scenarios.
- Since total $CH_4$ leakage rate is a dominant parameter, more data on ranges in carbon footprints due to uncertainty in leakage rates will increase the accuracy. [Note that this will also apply to leakage of coal mine gas associated with the coal used in our comparison between coal and shale gas].
- In analogy to the US and Canada, more measurement -based data of integrated GHG losses from European oil, gas or coal exploitation areas are needed..
- Results showed that transmission emissions are generally related to transmission length. Data on pipeline length and maintenance state of the network should be improved to give more accurate estimations.

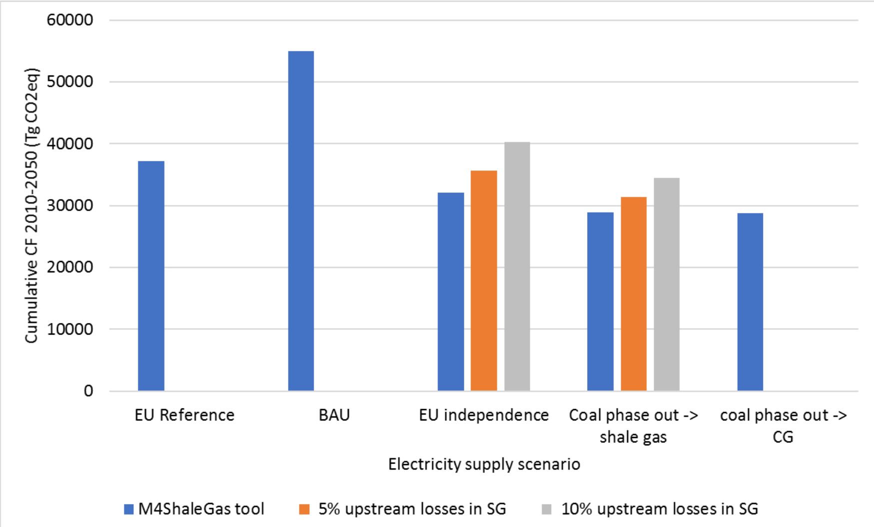
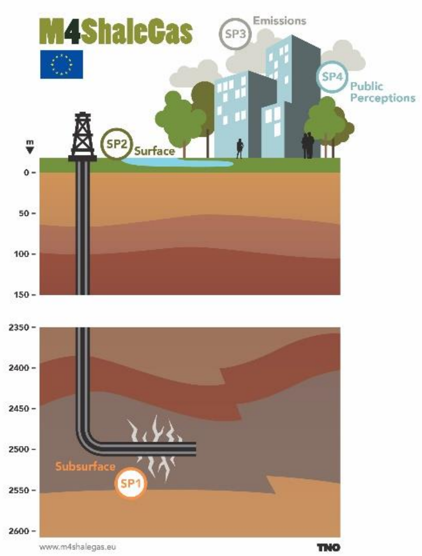



Figure 2. Cumulative Carbon Footprint for fossil electricity supply in the EU several scenarios calculated using the M4Shalegas tool: the EU reference 2016, a Business As Usual (BAU) scenario based on 2010, an independence scenario where imports get replaced by domestic shale gas, and two coal phase out scenarios, where coal gets replaced by shale gas (SG) or conventional gas (CG). Higher (5% and 10% of production) upstream losses are included for shale gas to illustrate their potential impact.

## The Project

**M4ShaleGas** examines the potential environmental impacts and risks related to **shale gas** exploration and exploitation in Europe with the goal to build a technical and social knowledge base on best practices and innovative approaches for **m**easuring, **m**onitoring, **m**itigating, and **m**anaging these impacts.




**4 sub-programs:**

- SP1-subsurface
- SP2-surface
- SP3-air emissions
- SP4-public perceptions

**Funding:**
The project that has received funding by the European Union's Horizon 2020 research and innovation programme under grant agreement number 640715.

**Horizon 2020 Topic LCE-16-2014:**
Understanding, preventing and mitigating the potential environmental impacts and risks of shale gas exploration and exploitation.

**Project duration:**
1 June 2015 – 30 November 2017

**Coordination:**

TNO



Published December 2017 by M4ShaleGas Consortium