Shale Gas Analysis for Committee on Climate Change

July 2016

Description of Method and Scope

In this report, the TIAM-Grantham energy system model (see Box 1), is used to consider the impact of a 'dash for gas' in Western Europe on global energy supply and emissions, and builds upon analysis carried out as part of the AVOID2 project [1]. Cost-supply data for conventional gas is taken from analysis carried out by the European Commission's Joint Research Centre [2], and lie in the mid-range of other cost-supply estimates [3], [4]. Cost-supply data for shale gas in Western Europe are based upon the optimistic assumption (in the 2012 version of the ETSAP-TIAM model) of shale gas extraction costs in all regions falling from values based on McGlade's 2013 assessment [4] to meet extraction costs in the least expensive global regions by 2020. Other assessments are less optimistic about future shale gas costs [2], [5].

Box 1. TIAM-Grantham

TIAM-Grantham is the Grantham Institute, Imperial College London's version of the ETSAP-TIAM model, which is the global, 15-region incarnation of the TIMES model generator [6], [7], as developed and maintained by the Energy Technology Systems Analysis Programme (ETSAP). The model is a linear programming tool representing in rich resource and technological detail all elements of the reference energy system (RES) for each region represented, mapping energy commodity flows all the way from their extraction and refining to their distribution and end-use. TIAM has the ability to optimise the energy system for given climate constraints through either minimising the total discounted energy system cost over a given time-horizon, or through maximising total producer and consumer welfare when (optionally) accounting for elastic demand responses to energy prices. In the latter case, the model is solved as a partial equilibrium. There is no linkage to a macroeconomic model to observe full equilibrium impacts of changes in energy prices. The model uses exogenous inputs of factors such as GDP, population, household size and sectoral output shares to project future energy service demands across the agricultural, commercial, industrial, residential and transport sectors in each region. Energy system data such as technology costs, resource supply curves and annual resource availability are also input into the model. In solving, the model allows trade in energy commodities between regions.

In this analysis, the TIAM-Grantham integrated assessment model is used to calculate a cost-optimised energy system pathway to 2100. First, this is with no shale gas availability, under a global constraint on CO_2 from fossil fuel combustion and industrial processes, of 1,340 $GtCO_2$ over the course of the 21st century (which gives a 50% likelihood of keeping 2100 temperature change below 2°C compared to pre-industrial levels, in line with previous AVOID 2 analysis [8]). An additional pathway is considered with a tighter global constraint on CO_2 from fossil fuel combustion and industrial processes, of 940 $GtCO_2$ over the course of the 21st century (which gives a 50% likelihood of keeping 2100 temperature change below 1.75°C, close to the limit of lowest temperature rise achievable using TIAM-Grantham). These emissions constraints allow for the meeting of the weak end of Cancun pledges to 2020, and then global coordinated mitigation action thereafter, in order to meet the 21st century cumulative CO_2 constraints [8].

Global carbon prices from these initial runs are extracted, and used in follow-up runs to reflect the same level of climate ambition, but while still allowing emissions to vary. These follow-up runs calculate a cost optimised energy system pathway to 2100 with forced extraction of all but the most expensive 20% of shale gas in Western Europe between 2020 and 2050 (to represent a "dash for gas" in Western Europe). The impact of this additional gas supply on global energy supply mix, and global emissions are assessed.

It should be noted that whilst this report focuses on the impact of shale gas on energy supply mix and CO_2 emissions in a cost-optimal energy system, there exist a number of other concerns surrounding shale gas which should be considered in a full assessment of its impacts. These include challenges associated with reduction of fugitive emissions of methane,[1] and the potential for significant increase in global warming impact if regulation is not effective in reducing leakage rates [1], [9]–[11], the possible impact of hydraulic fracturing to surface water [12], air, and land [13], local opposition in some communities [14], and the challenge of ensuring sufficient information collection, access, and dissemination to support evidence-based shale gas policies [15].

Primary Energy Supply

Figure 1 shows the proportion of global energy demand supplied by a range of sources in energy system pathways with no shale gas consistent with 2°C and 1.75°C global temperature rise. In both pathways, the share of coal in the energy supply mix rapidly declines from 2020, when global coordinated mitigation efforts begin, concomitant with an increased share of gas and renewables in the energy mix. The share of renewables in the energy mix continues to grow up to 2100, whilst gas usage peaks in 2030, and slowly declines to 2100. The share of oil in global energy supply steadily declines to 2100, and the share of nuclear power remains small and near constant at 2-3% of global energy demand. In the pathway with no shale gas consistent with 2°C, 83,000 exajoules (EJ) are used

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[1] The modelling uses a global CO_2 budget that allows for emissions of non-CO2 greenhouse gases in limiting warming to the specified levels. However, additional unconventional gas production that is forced in does not assume any associated methane emissions. . Effectively the analysis assumes that any methane from the fossil fuel energy system is the same in the shale and non-shale cases. The fugitive methane emissions associated with shale gas extraction represents an area of active research and analysis. Possible global warming implications of these emissions are modelled in detail in reference [1].

between 2012 and 2100. Owing to demand elasticity, 0.49% less energy is consumed over the same period in the corresponding 1.75C pathway.

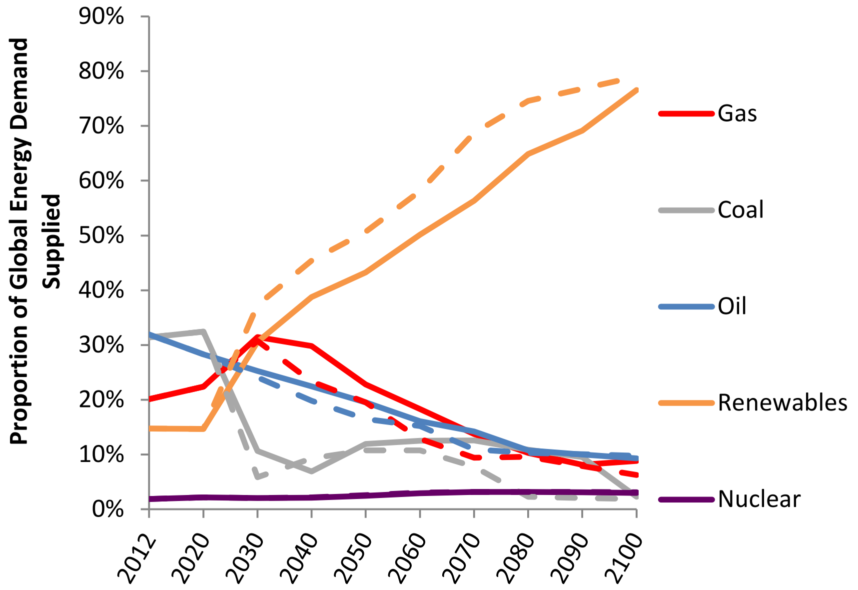

Figure 1: Proportion of global energy demand supplied by a range of sources, in pathways consistent with global warming of (solid lines) 2°C, and (dashed lines) 1.75°C.

Impact of 'Dash for Shale Gas' in Western Europe on Global Energy Mix

Figure 2 shows the forced shale gas supply profile in Western Europe associated with a 'dash for shale gas' pathway, as a proportion of global energy demand. In both temperature pathways, this forced supply peaks at 2.6% of global energy demand in 2030, before falling to close to zero in 2050. In both cases, total energy consumption is higher by 0.04% with forced extraction of shale gas.

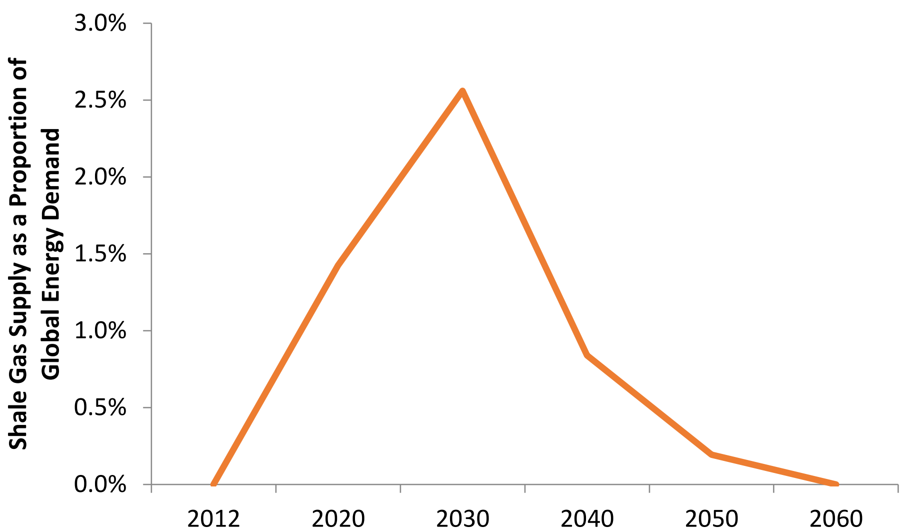

Figure 2: Forced shale gas supply from Western Europe.

Figure 3 shows the change in supply from a range of sources resulting from the forced extraction of shale gas in a scenario with identical carbon prices to the initial 2°C and 1.75°C pathways without shale gas. In Figure 3(a), this is shown as a proportion of global energy demand, and in Figure 3(b) as a proportion of the forced shale gas supply during this period. The extraction of (predominantly less expensive) natural gas declines significantly during the period of forced shale gas extraction, such that in 2030 (at peak shale gas supply) the increase in gas usage is a small proportion of the gas forced onto the system (5% in the 2°C pathway, and 11% in the 1.75°C pathway).

Gas usage in 2040 increases more significantly with forced shale gas extraction, to 60% and 50% of the forced on gas supply in 2°C and 1.75°C pathways, respectively. Overall, gas usage in 2°C and 1.75°C pathways is respectively 0.63% and 0.74% higher with a "dash for shale gas". This increased gas usage predominantly displaces oil in the 2°C pathway (where cumulative oil usage is 0.20% lower throughout over the model run with shale gas, whilst coal usage is lower by only 0.11%), but displaces coal usage in the 1.75°C pathway (where cumulative coal usage is 0.25% lower throughout over the model run with shale gas, but oil usage is identical in both runs). This is likely to be the result of the higher greenhouse gas emissions intensity of coal than gas, resulting in a higher cost associated with coal in the 1.75°C pathway in which carbon taxes are higher. In both temperature pathways, the share of demand met by renewables is slightly lower throughout the 'dash for shale gas' run (0.09% and 0.05% less energy from renewables over the entire model run in 2C and 1.75°C model runs respectively.

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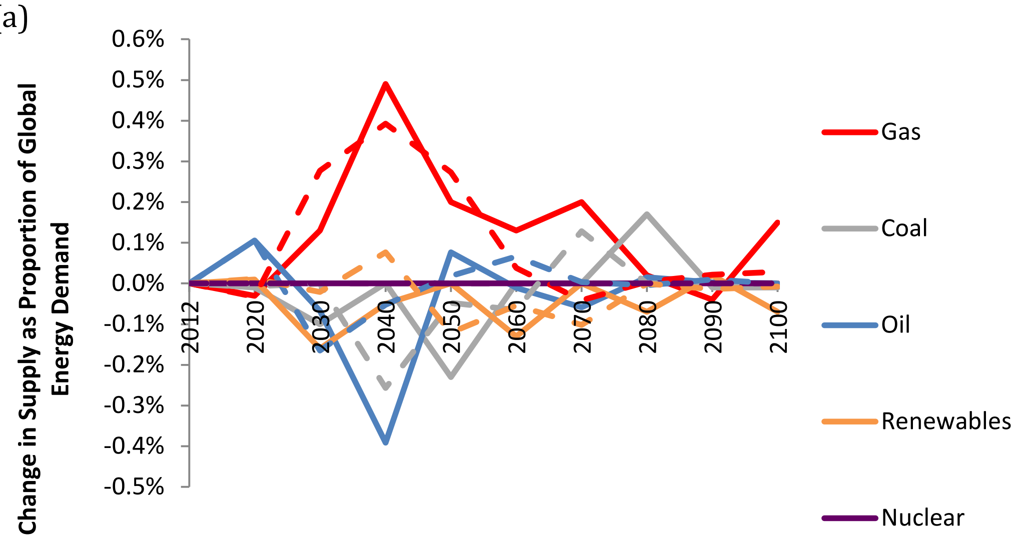
(a)



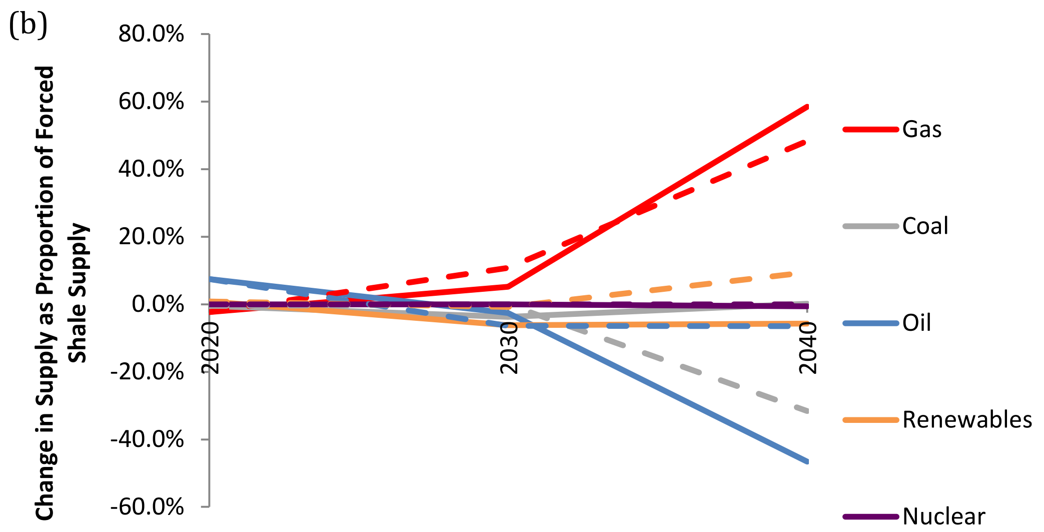


Figure 3: Impact of forced shale gas on global energy supply (a) as a proportion of global energy demand, and (b) as a proportion of forced shale gas supply, in pathways consistent with global warming of (solid lines) 2°C, and (dashed lines) 1.75°C.

Impact of 'Dash for Shale Gas' in Western Europe on Global Energy Mix

Figure 4(a) shows the emissions profile of the initial 2°C and 1.75°C pathways without shale gas (indistinguishable by eye from the 'dash for shale gas' pathways.) Emissions peak in 2020 when global coordinated climate action begins, and decline steadily to reach negative emissions in the period 2070-2080 in the 2°C pathway, and 2050-2060 in the 1.75°C pathway.

Figure 4(b) shows the contribution of the forced shale gas extraction to global emissions, alongside the change in global emissions between the pathways with and without a dash for shale gas. Under both temperature constraints, the decline in supply from other carbon-intensive fuels, alongside an increasing deployment of gas turbines with carbon capture and storage, results in similar emissions profile during the period of forced shale gas extraction to that in the pathways without shale gas. Total CO_2 emissions up to 2100 are close to identical with and without shale gas (0.03% higher and 0.29% lower in the 'dash for shale gas' pathways associated with 2°C and 1.75°C temperature rise, respectively), implying that shale gas is not significantly displacing emissions from more carbon intensive fuels.

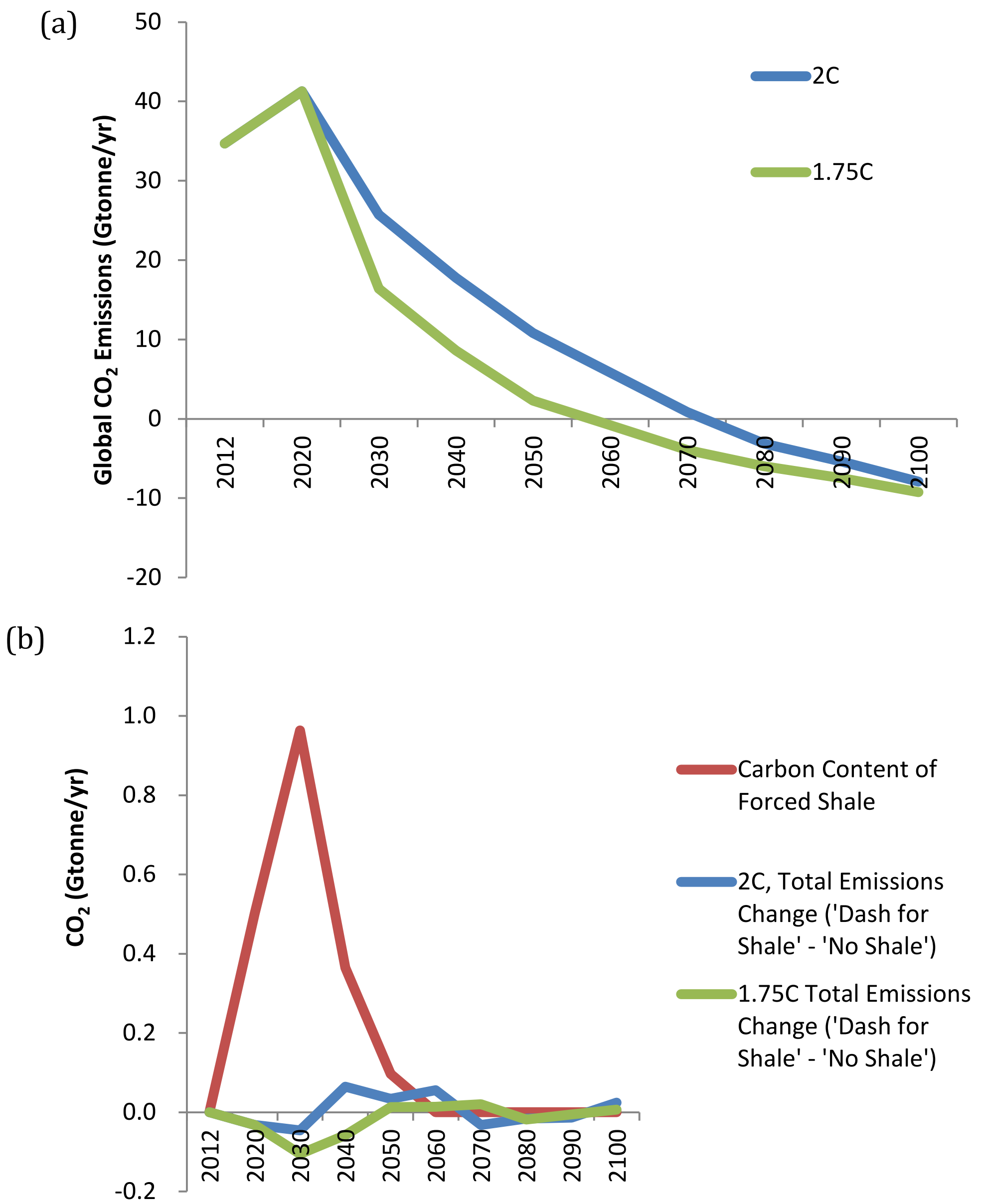


Figure 4: (a) Annual emissions in 2°C and 1.75°C consistent pathways with no shale gas, and (b) carbon content of forced shale gas, and change in total annual emissions in pathways with shale gas.

Carbon Capture and Storage

In all pathways considered here, carbon capture and storage (CCS) is deployed on a significant scale following the start of global mitigation action in 2020, on biofuels, gas turbines, and in steel and cement production (Figure 5). A range of fuels are used in steel production. Cumulatively over the period during which CCS is deployed (2030 – 2100), coal constitutes the majority of carbon content of steel fuelstock (75% in 2°C and 68% in 1.75°C pathways), with oil and LPG together constituting most of the remainder (15-16% in 2°C and 30% in 1.75°C pathways) and only a small share from natural gas (6% in 2°C and 2% in 1.75°C pathways).

In the 2°C pathway without shale gas, 1600 $GtCO_2$ is stored by 2100 (62% from biofuels, 19% from steel production, 14% from cement production, and 6% from gas turbines). The total quantity of CO_2 stored is near identical (0.04% higher) in the 2°C pathway with shale gas.

In the 1.75°C pathway without shale gas, 4.6% less CO_2 is stored by 2100 than in the 2°C pathway, but the breakdown of sources differs significantly, with 11% more CO_2 captured from biomass, and 51% more from gas turbines, but 39% less from steel, and 50% less from cement production.

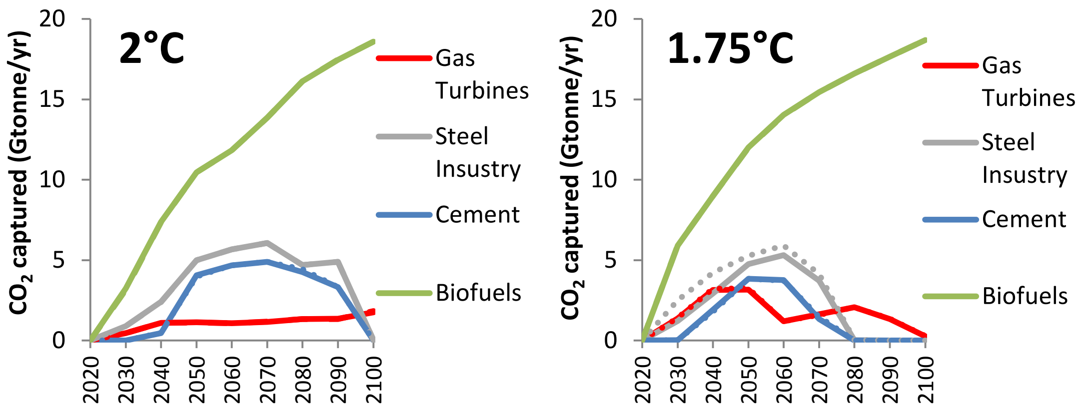


Figure 5: CO_2 captured per year from a range of sources in (a) 2°C, and (b) 1.75°C pathways; (solid lines) with no shale gas, and (dashed lines) with forced shale gas extraction.

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