submitted to *IAEE Europe, Düsseldorf* 15.03..2013

The Infrastructure Implications of the Energy Transformation in Europe until 2030/2050 - Lessons from the EMF28 Modeling Exercise

Franziska Holz [a (*)], Christian von Hirschhausen [a,b], and Pao-Yu Oei [b]

Abstract

This paper summarizes the approaches to and the implications of bottom-up infrastructure modeling in the framework of the EMF 28 model comparison „Europe 2050: The Effects of Technology Choices on EU Climate Policy“. It includes models covering all the sectors currently under scrutiny by the European Infrastructure Priorities: electricity, natural gas, and CO_2. Results suggest that while infrastructure enhancement is required to achieve the decarbonization, it may not be as critical a factor as often assumed. In the electricity sector, additional cross-border interconnection is required, but generation and the evolution of low-cost renewables weighs higher. For natural gas, the falling total consumption could be satisfied by the current infrastructure in place and even in a high-gas scenario the infrastructure implications remain manageable. Model results on the future role of Carbon Capture, Transport, and Sequestration (CCTS) vary, but most indicate that CCTS has lost its crucial role for decarbonization.

1 Introduction

The objective of this paper is to address the role of infrastructure in the transformation process in Europe on the way to a low-carbon, renewables-based system. Thus, the paper summarizes the approaches to and the implications of bottom-up infrastructure modeling in the framework on the EMF 28 model comparison „Europe 2050: The Effects of Technology Choices on EU Climate Policy“. This is a complementary effort to the top-down models presented in Knopf et al. (2013). The infrastructure subgroup was lucky to include a critical mass of infrastructure modelers, with models covering all the sectors currently under scrutiny

a: DIW Berlin (German Institute for Economic Research)
b: Berlin University of Technology, Workgroup for Economic and Infrastructure Policy
(*) corresponding author: fholz@diw.de

by the European Infrastructure Priorities: electricity, natural gas, and CO_2; in addition an exploratory effort was made to „combine“ the infrastructure analysis in a joint electricity-gas approach. In each case, we investigate what the specific role of infrastructure in the analysis is, what potential opportunities and obstacles may emerge from there, and what this implies for the respective decarbonization scenarios. In its main part, this paper provides an overview of the sectoral models and the storylines that are covered, highlighting why models may differ.

2 Infrastructure Analysis within the EMF 28 Model Comparison

The EMF 28 model comparison „The Effects of Technology Choices on EU Climate Policy“ was initiated in October 2011 at the inaugural meeting in Potsdam (Germany).The subgroup on infrastructure modeling was also set up at the inaugural meeting and defined a working agenda including the sectoral analyses and paper drafts of the individual modeling teams. Subgroup meetings were held in the EMF 28 framework in Utrecht (March 2012) and Berlin (October 2012) as well as between those meetings (March and August 2012 in Berlin). At the EMF 28 meeting in Berlin in October 2012 the final outline for the papers and the structure of the final issue were agreed upon. Additionally, regular bilateral contacts between the meetings assured coherence among the contributions.

The participants of the EMF 28 model comparison agreed on a scenario matrix that also served as reference for the infrastructure subgroup (see Table 1). It included a „Reference Scenario“ respecting the EU 2020 targets and 40% greenhouse gas reductions by 2050, and a „Mitigation 1“ scenario of an 80% reduction of GHG emissions by 2050. These reduction scenarios were crossed with technology-specific scenarios to give the matrix: scenarios EU1 and EU6 describe a default case including CCTS (carbon capture, transportation and storage) and reference assumptions on nuclear energy, energy efficiency, and renewable energies. Scenarios EU2-EU5 and EU7-EU10 perform variations on this theme, taking the 40% or 80% GHG reduction as given, respectively. It was up to the individual modelers to fill the scenarios with flesh, i.e. to provide concrete estimates for the „low-ref-opt-high“ (“low-reference-optimistic-high”) fields. All infrastructure models ran the scenarios EU1 and EU6, and most of them also ran additional scenarios, amongst them scenarios EU4/EU9 and EU5/EU10.

Table 1 EMF 28 scenario definition

Technology dimension						
		Default w CCS	**Default w/o CCS**	**Pessimistic**	**Optimistic**	**Green**
CCS		on	off	off	on	off
Nuclear energy		ref	ref	low	ref	low
Energy efficiency		ref	ref	ref	high	high
Renewable energies		ref	ref	ref	ref	opt
Policy dimension for the EU	**Policy dimension for the Rest of the World (ROW)**					
No policy baseline (no policy, also without the 2020 target)	no policy	EU11				
Reference: including the 2020 targets and 40% GHG reduction by 2050	"moderate policy" scenario ModPol; no emission trading across macroregions (but trade within macroregions e.g. within EU)	EU1	EU2	EU3	EU4	EU5
Mitigation1: 80% GHG reduction by 2050 (with Cap&Trade within the EU)	"moderate policy" scenario ModPol; no emission trading across macroregions (but trade within macroregions e.g. within EU)	EU6	EU7	EU8	EU9	EU10

3 Electricity Network Requirements: Integration of Renewables

The three electricity network models that participated in the EMF28 Subgroup on Infrastructure focus on different aspects of electricity transmission expansion, and analyze different levels of detail. Some common ground is the focus on the need to develop the North Sea region, as highlighted by all three models (LIMES: “Northern Europe”). More generally, North-South seems to be the dominant direction of expansion plans. On the contrary, the potential contribution of external regions to EU electricity supply seems to be rather modest. There is some uncertainty around absolute cost figures for transmission expansion, though overall those are modest when compared to generation investment. Moreover, the effect of transmission expansion is modest relative to total discounted system costs, but a levelizing and decreasing effect on electricity (and CO2) prices is generally found.

4 Natural Gas: The “Transformation Fuel” with Modest Infrastructure Requirements

The natural gas-only models (Global Gas Model, RAMONA) show that the European Union with its climate policy will be in competition with Asia for Russian and LNG supplies. Hence, the traditional supply picture, in which Russia plays an important role cannot be sustained and new infrastructure is needed to accommodate the imports from new suppliers from the Caspian and the North African region. This takes place despite the large pipeline investments from Russia in the last years (Nordstream, South Stream). There is little variation when introducing uncertainty on demand, as done by the RAMONA team. In contrast to the gas-only models, the Combined model assumes smaller changes to the supply structure. All models find support for some small, but decisive investments in reverse-flow capacities within the European network. These reverse-flow capacities would, especially in East Europe go opposite the traditional East-West direction. Hence, they will increase the supply diversification and supply security in East Europe by reducing the dependence from Russia. Two additional decarbonization scenarios in which the natural gas consumption in Europe does not decrease are analyzed with the Global Gas Model. While one (80% GHG emission reduction) scenario attributes a transitioning “bridge” role to natural gas (with sustained natural gas consumption only until 2030), the other one assumes a slightly increasing demand until 2050 (40% GHG emissions reduction). Comparing their results clearly shows that a sustained strong demand is needed to incentivize investments. In the “bridge” scenario, more flexible LNG imports are used during the transition period, but hardly any (pipeline) investments are carried out.

5 Carbon Capture, Transport and Storage: The North Sea Region as the Focus of Potential Action

CCTS can no longer be considered as the “silver bullet” to achieve decarbonization. While in the EMF 28 exercise most top-down models introduced CCTS, with an average share in electricity generation of about 15% in the EU6 and EU9 scenarios, the CCTSMOD model results as well as a critical view at the reality on the ground teaches us that Europe may well have live without CCTS at all. It is most plausible that CCTS will only emerge in the context of EOR, with some projects in the North Sea region at best. There may be a small number of North Sea riparian countries that develop individual projects, such as Norway, the UK, and the Netherlands. The different assessment by different models result from the use of different input data, in particular overly optimistic costs assumptions dating back to the middle of the last decade.

6 Conclusions

This paper has summarized and compared model results for analyses of the infrastructure implications of different scenarios facing the 2050 decarbonization target for the European energy sector. We focus on the three “big” infrastructures, i.e. high-voltage electricity transmission lines, natural gas pipelines (and related infrastructure like LNG terminals), and CO_2 pipelines. Our analysis summarizes work set out in the study by the Energy Modeling Forum (EMF) 28 „The Effects of Technology Choices on EU Climate Policy“, that foresees a reduction of CO_2 emissions by 40% and 80%, respectively, and combines this with several technological scenarios, which are then „translated“ via modeling work and scenario assumptions into concrete infrastructure development requirements. The strength of this approach is that it provides insights into the infrastructure aspects of decarbonization from a variety of models and on a variety of sectors. The models used in this EMF 28 subgroup represent the current state of the art modeling techniques, in particular optimization and equilibrium models.

Our main finding is that while infrastructure enhancement is required to achieve the decarbonization, it may not be as critical a factor as often assumed. In the electricity sector, additional cross-border interconnection is required, but generation and the development of low-cost renewables weigh higher. In natural gas, little new infrastructure is required when focusing on Europe, and even in a high-gas scenario the infrastructure implications remain manageable. With respect to CO_2 pipelines for Carbon Capture, Transport, and Storage (CCTS), which was until recently considered to be one of the silver bullets in the decarbonization debate, we find that only under very extreme assumptions, a European-wide network for CCTS in the EU-ETS industry and energy sectors could emerge. More likely, though, is the emergence of regionally focused connections around the North Sea, including only the riparian countries, using offshore CO_2 storage combined with Enhanced Oil Recovery (EOR).