Optimal dynamic stochastic infrastructure planning and operation

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A case study for the CCS technology[1]

Joachim Geske[2]

The unprecedented worldwide tendency to convert energy systems towards sustainability is accompanied by the introduction of technologies such as renewable energy sources. Decisions for the integration in existing energy systems and efficient operation of these technologies include its spatial allocation. Some of the new technologies and the ongoing international integration of resource markets (LNG) are expected to require the addition of long distance transport facilities for resources, energy and byproducts of energy conversion. Therefore the planning of efficient new and the efficient extension of existing infrastructures currently gain importance. A further inherent requirement for long-term efficiency is the ability of infrastructures to be adapted to demand and supply dynamics that result from stepwise construction or structural changes. This aspect has a closed relation to the sustainability of infrastructures itself.

We propose an operational definition of a spatially and dynamically efficient transport infrastructures that minimizes variable operating and fixed investment cost to meet dynamics of demand, supply and capacity constraints. It can be deduced for the case of a new CCS infrastructure from MIT (2006), ISGS (2005) and Kobos et al. (2007) that neither the consideration of variable and fixed cost nor the spatial static optimization approach is standard in literature.

We dynamize the approach of Middleton et al. (2007) who are the first to consider fixed and variable cost in a static optimization context. The numerical solution of our model as mixed integer program represents a cost optimal grid. It enables the consideration of dynamic capacity constraints of sources and sinks. Therefore an optimal resource exploitation problem is included. Furthermore questions concerning the weighting of short-term flexibility versus long-term stability can be addressed. Another application is definition of an optimal extension of an existing net. The overall methodology is applicable to any transport media.

A key finding of the optimization approach is that sharing edges of distinct source-target paths in a transport infrastructure enables a cost reduction that overrides possible path length increases. That means e.g. that bundling of sources and sinks results in increasing returns of the infrastructure. The dynamization further reveals that bundling can take place for different points in time and therefore offers further efficiency potential.

In a case study we present aspects of the approach for the complete new construction of a CCS transport infrastructure in Europe.

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[2] Forschungszentrum Jülich, Institute of Energy Research – Systems Analysis and Technology Evaluation, Germany j.geske@fz-juelich.de for the 9th Conference on Applied Infrastructure Research ("INFRADAY"), "Sustainable Infrastructure – Theoretical and Policy Challenges", Berlin, 8-9 October, 2010

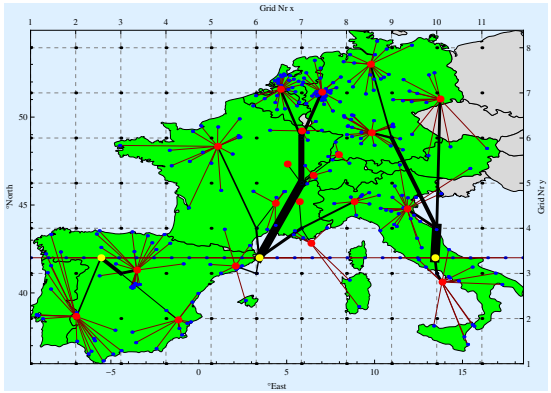

Figure 1: Example of a pan-European cost-minimizing CCS Infrastructure (Dummy sinks)

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