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Necessity and impact of power-to-gas on energy transition in Germany

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Abstract

The present paper gives an outlook on a bandwidth of required installed power-to-gas capacity in the German power sector fed by 100 % renewable generation until 2050. Two scenarios were simulated to quantify cost effects of power-to-gas on the electricity system: once with, once without additional short-term flexibility options to a system using fossil natural gas as sole flexibility option instead.
As a result, at latest in 2035, power-to-gas capacity expansion has to take place to reach required installed capacities of up to 89-134 GW in 2050. Application of power-to-gas as long-term flexibility leads to cost savings of up to 11,7-19 bn Euro enabling a fully renewable system in 2050.

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Keywords: power-to-gas; energy storage; renewable energy; system costs; surplus energy; supply security; energy transition; decarbonization.

1. Introduction

Facing climate change, the German federal government made a commitment to own energy policy objectives within their coalition agreement and energy concept in 2010: greenhouse gas emissions in Germany shall be reduced by 40 %

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until 2020 and by 80-95 % until 2050 compared to the amount of 1990. Power consumption is supposed to decline by one quarter in the same period of time (10 % until 2020, 25 % until 2050) while shares of renewable energy generation ought to rise up to 80 % in 2050 (40-45 % in 2025, 55-60 % in 2035). Furthermore, the aim is to reduce the final energy consumption in the heat sector by -80 %, the one in the transport sector -40 % until 2050.

To avert dangerous consequences of climate change, these aims are not sufficient. A fully renewable power supply in the year 2050 is required and feasible [1]. Because of highest potentials and lowest costs, the main supporting columns of energy transition in Germany will be wind and solar power (photovoltaics). Therefore, one of the major tasks will be balancing the fluctuating, weather-dependent generation of wind and solar power at contemporary high-level security of supply. For this, amongst different flexibility options, energy storage becomes increasingly important. In the following, necessity and impact of power-to-gas (PtG) for energy transition in Germany [2-4] will be introduced.

2. Methodology

The need for renewable energy storage options is depending on a variety of aspects such as upcoming extensions in renewable power plant capacity, national and international grid expansion or demand side integration. Today, there are no final and reliable answers to tell how exactly the future energy system will look like. For this reason, evidence at which point of time power-to-gas is needed, only can be given throughout a range of time.

2.1. Assumptions

To determine the role of power-to-gas as energy storage option, a simplified approach is introduced: the German power supply at 100 % renewable generation in 2050 outgoing from a trend-scenario set up by the environmental organization Greenpeace e.V. (Table 1). To turn out the effect of power-to-gas on the system, its costs are calculated once with and once without power-to-gas as a flexibility and storage option while alternative flexibility options are not considered. At assumed CO_2-costs of 100 €/t CO_2 [5], coal is not profitable anymore. For this, maximum balancing costs for fluctuations in power generation (with the use of power-to-gas) become clear as a 'worst-case-scenario' [2] and can be compared to a system whose supply security is assured only by fossil natural gas. In reality, a renewable power system gets cheaper because of other flexibility options get into market which are at lower price for specific situations. This is the reason why in an extended analysis of Götz et al. [3], the effect of short-term storage respectively flexibility options were examined. There, fluctuations below two days get balanced through short-term options, for cycles above this benchmark, power-to-gas gets into action.

Table 1. Trend-scenario for a 100 % renewable power supply system in Germany on specifications of the environmental organization Greenpeace e.V. Assumptions made for generation capacity to be installed in GW, gross electricity production in TWh and full load hours (VLH) of different renewable generation capacities. As a basis of this expansion phase, the real German generation situation in 2013 is taken from AG Energiebilanzen[1)] [6] and German Ministry for Economic Affairs and Energy[2)] [7]. * Including not-appearing other sources e.g. domestic waste (difference: 5,2 TWh).

	Installed Capacity GW		Gross electricity production in TWh		Full load hours
	Trend-Scenario 100 %	(2013)	Trend-Scenario 100 %	(2013)	Trend-Scenario 100 %
Wind Onshore	131	33,66[2)]	262	49,8[1)]	2000
Wind Offshore	30	0,52[2)]	120		4000
Photovoltaics	135	35,9[2)]	135	28,3[1)]	1000
Hydro power	5,6	5,6[2)]	22,4	21,2[1)]	4000
Biomass	8,1	8,1[2)]	48,5	42,6[1)]	6000
Geothermal	3	0,031[2)]	18	0,04[2)]	6000
Sum renewable energy generation			606 TWh	147,1[1)*]	
Shares of renewable energy on gross electricity consumption in Germany			100 %	23,4 % [1)]	
Gross electricity consumption/demand			569 TWh	629 TWh [1)]	