Power to Gas – an economic approach for energy storage?

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Abstract

The reduction of CO_2 emissions is clearly linked to the extension of renewable energies (RE). However, due to the volatile character of related power generation there will be an increasing mismatch between generation and demand. The storage of excess energy will become essential in the future in order to prevent increasing curtailment of wind and PV installations and to enable an economic integration of renewables into the future energy scenario.

Power to Gas as a storage option merging energy, mobility and industrial markets

It is very clear that grid extension and demand side management will come prior to energy storage. But the estimated storage demand in a 85 % RE scenario – as targeted for Germany in 2035 - will be in the multi-TWh range.

There are many concepts and technologies to store electric energy. Among the three options for large-scale storage – pumped hydro, compressed air and hydrogen – hydrogen is the only viable option to address capacities >10 GWh (fig. 1). A key component for hydrogen storage is the electrolyzer converting electrical energy into hydrogen (Power-to-Gas, P2G).

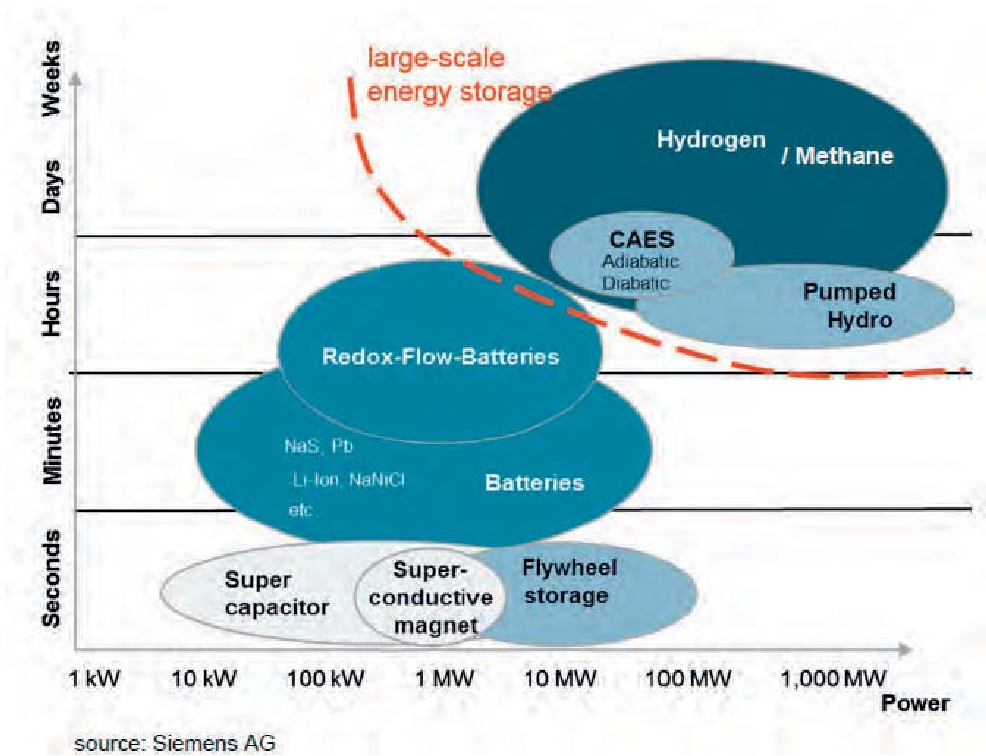

Fig. 1: Segmentation of electric energy storage technologies regarding power and discharge time

In this context 'Power-to-Gas' requires a clear definition. Some people associate this approach with the conversion of electricity to hydrogen, others with the subsequent injection of H_2 into the natural gas grid, some are including the conversion to synthetic natural gas (fig. 2). As the economy of these varying interpretations and the related business cases differ strongly, a clear definition of P2G is necessary. ‘Power-to-chemicals’ (leading to methanol, etc.) is not separately mentioned in fig. 2, it is a subsequent process to P2H.

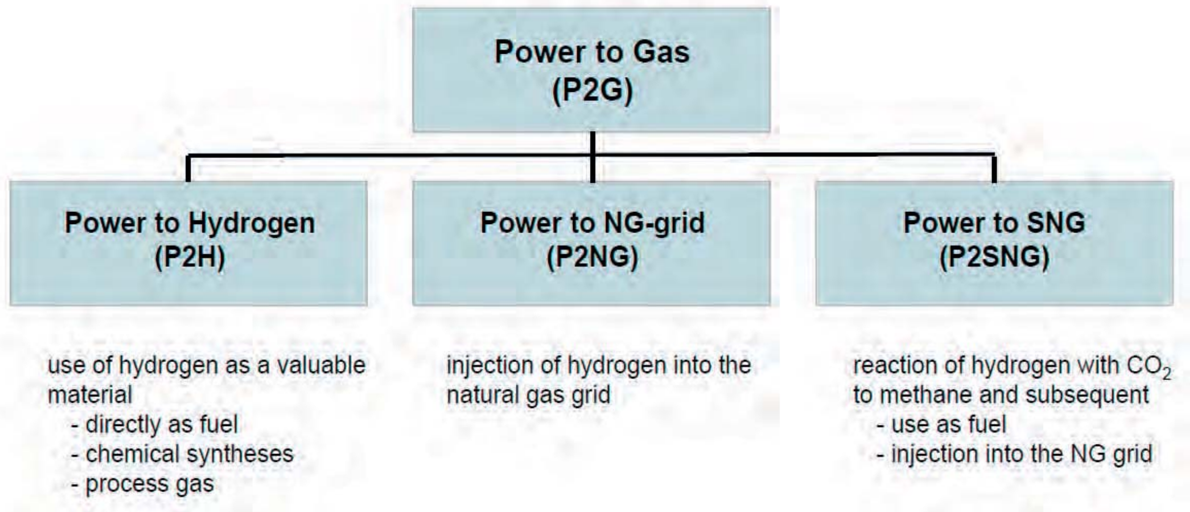

Fig. 2: Different routes of ‘Power to Gas’

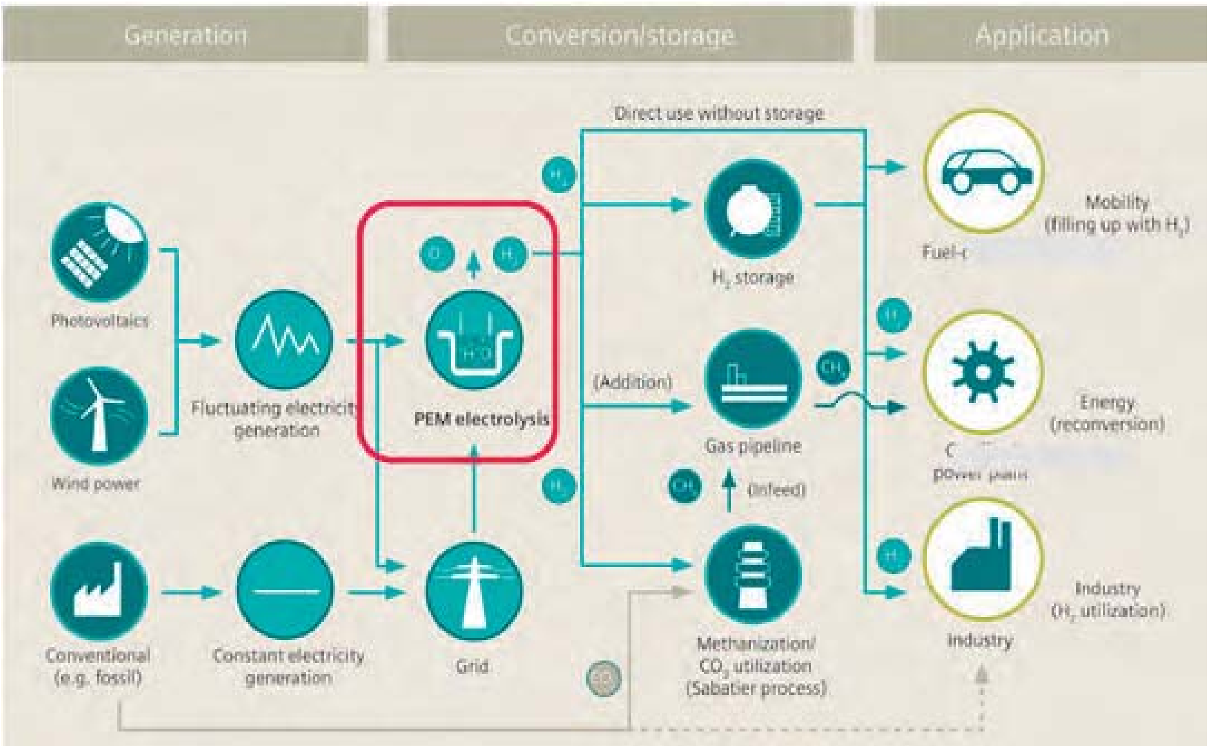

Fig. 3: The “big picture of hydrogen” – hydrogen as a multifunctional energy vector which drives the convergence between energy and industry markets

Fig. 3 illustrates the integration of electrolyzer technology into the volatile power generation and the different routes of H_2 utilization and applications. It makes clear that hydrogen enables the convergence of the energy market with the mobility and industry markets: instead of curtailing the ‘excess’ production of green electricity this electricity can be shifted to mobility or industry applications and secure CO_2-savings there.

Economic considerations

The use of hydrogen in the applications ‘mobility’, ‘industry’ and ‘energy’ follows a merit order principle. In all cases where simply heating value is required (re-electrification via gas turbines, process heat or house heating) hydrogen with respect to price competes with natural gas. A preceding conversion to SNG tightens this economic challenge due to additional conversion losses and mandatory capital investment.

Compared to re-electrification (“power to power”) the use of hydrogen in industry or mobility as a valuable material leads more easily to a positive business case.

Due to the described merit order the three use cases have different market entry points, market potential and consequently different maturity.

The question, whether P2G is economically viable depends on a number of different parameter and thus cannot be answered in one single sentence. For this reason several calculations with extreme assumptions are illustrated in the following.

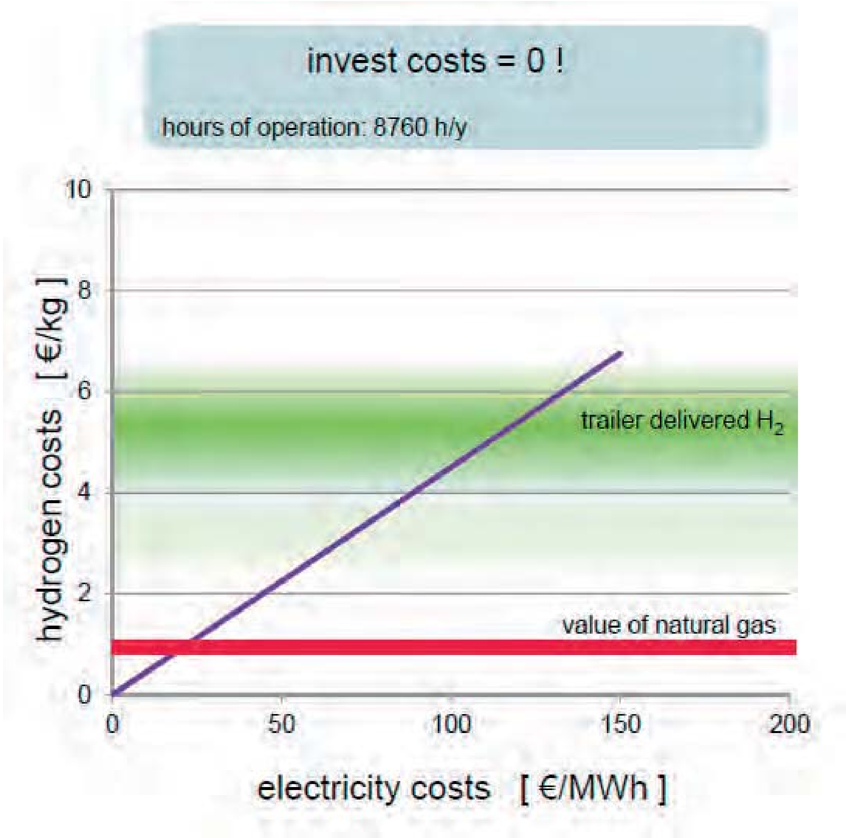

Fig. 4a: Theoretical production costs of hydrogen generated via electrolysis – main assumption: invest costs of electrolyzers are zero

Fig. 4a outlines that it is not likely that electrolytic hydrogen can compete now and in the next years with the price of conventional natural gas. For instance, even if the costs of future electrolyzer technology diminishes down to zero the electricity must be purchased at prices below 2.5 ct/kWh over the whole year to reach cost competitiveness to conventional natural gas (fig. 4a). The same figure illustrates on the other hand, that electricity can be purchased even at higher (and more realistic prices) if the competition is trailer-delivered H_2.

In a second step it was assumed that electricity costs are zero. This situation is not unlikely as curtailed electricity is already at this stage reality.

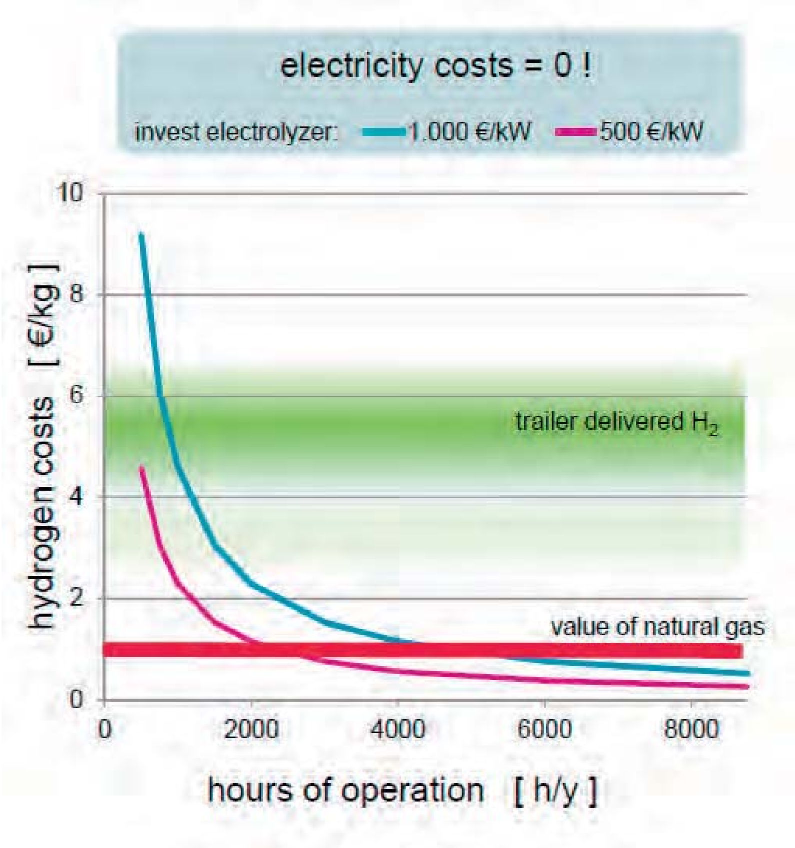

Fig. 4b: Theoretical production costs of hydrogen generated via electrolysis – main assumption here: electricity costs are zero

Fig. 4b clarifies that the utilization of the electrolyzer must be roughly above 3000 hours under these conditions to yield prices competitive to natural gas. The situation is even less stringent if the application is on-site use in the hydrogen consuming industry.

Further assumptions for the calculations (figs. 4a-4c) are as follows:

- efficiency electrolyzer system = 70 % HHV
- for figs. 4b,c: depreciation: 20y; interest rate: 5 %; maintenance: 3% of capex;
- natural gas prize: 3 ct/kWh

The assumptions used for fig. 4c are reflecting the current situation, as electricity prizes of ≤ 50 €/MWh can be found at the EEX for more than 4000 h per year.

The main key findings of graphs 4a-c outline that all applications where only the heating value is relevant – for instance the injection into the NG grid - do not reveal a positive business case (even with capex=0) under given assumptions. They further illustrate that H_2 production via electrolysis may be an attractive alternative to steam-reforming in particular when the electrolyzer system has access to “cheap” electricity. The business cases will become more attractive by additional offering of grid services (e.g. secondary control power).

But it clearly has to be pointed out that fees (grid fees and in particular the ‘EEG-Umlage’ in Germany) ruin most positive business cases. This is a general hurdle for grid-scale energy storage and will require a clear regulatory framework.

It is important to note that all price ranges given (e.g. for natural gas or H_2-delivery) are estimates. Real conditions, in particular for smaller quantities may lead to notably higher prices.

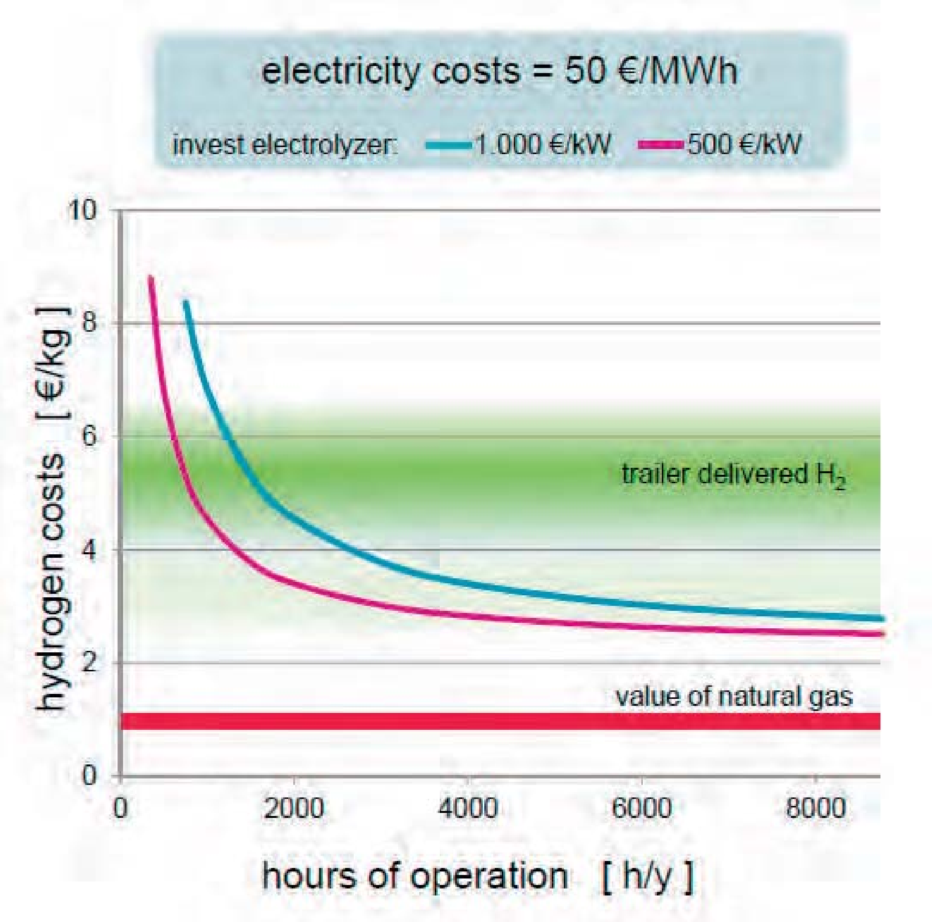

Fig. 4c: Theoretical production costs of hydrogen generated via electrolysis under reasonable assumptions for capex and opex

Outlook: the long-term perspective of P2G - Scenario 2035+:

The situation described above could consolidate the conclusion that power to SNG and H_2-injection into the NG grid does not make sense. However, the circumstances will change. The main reason is that the CO_2-reduction targets will require a link of power generation with industry and mobility. This scenario can be summarized as follows:

- CO_2 reduction targets require stringent measures in the sectors mobility, industry, power generation
- There will be a high share of renewable electricity production together with gas turbines as fast response and flexible (backup) power generation
- There will be installations of different storage options
  - thermal storage
  - pumped hydro storage
  - batteries
  - H_2 (multifunctional) as likely the only large-scale (tens of TWh) long-term storage option

In this future scenario the role of Power-to-Natural Gas or Power-to-Synthetic Natural Gas will gain increasing importance. By this means CO_2 savings will be shifted to residential heating, industrial processes and to the re-electrification in gas turbines. This will likely happen if / as soon as all opportunities to sell H_2 into mobility and industry markets are fully used and the commitment to existing CO_2 reduction targets remains valid.

However SNG as well as the injection of H2 into the NG grid has specific limitations:

- SNG in any case requires CO_2 sources near-by
- H2 addition in the NG grid is only possible up to regulatory limits.

If / as soon as the H_2 production will become too large i.e. the concentration will exceed the regulatory limits of the NG grid the combustion of pure H_2 becomes likely.

In conclusion, while the business case for the above will evolve in co-existence with other storage options, these above scenario clearly indicates, that there are a variety of technological options on a mid- and long-term perspective making thermal use of H_2 and also SNG, a reasonable approach to buffer CO_2-free energy from fluctuating renewables in the TWh-range for re-electrification and heating.

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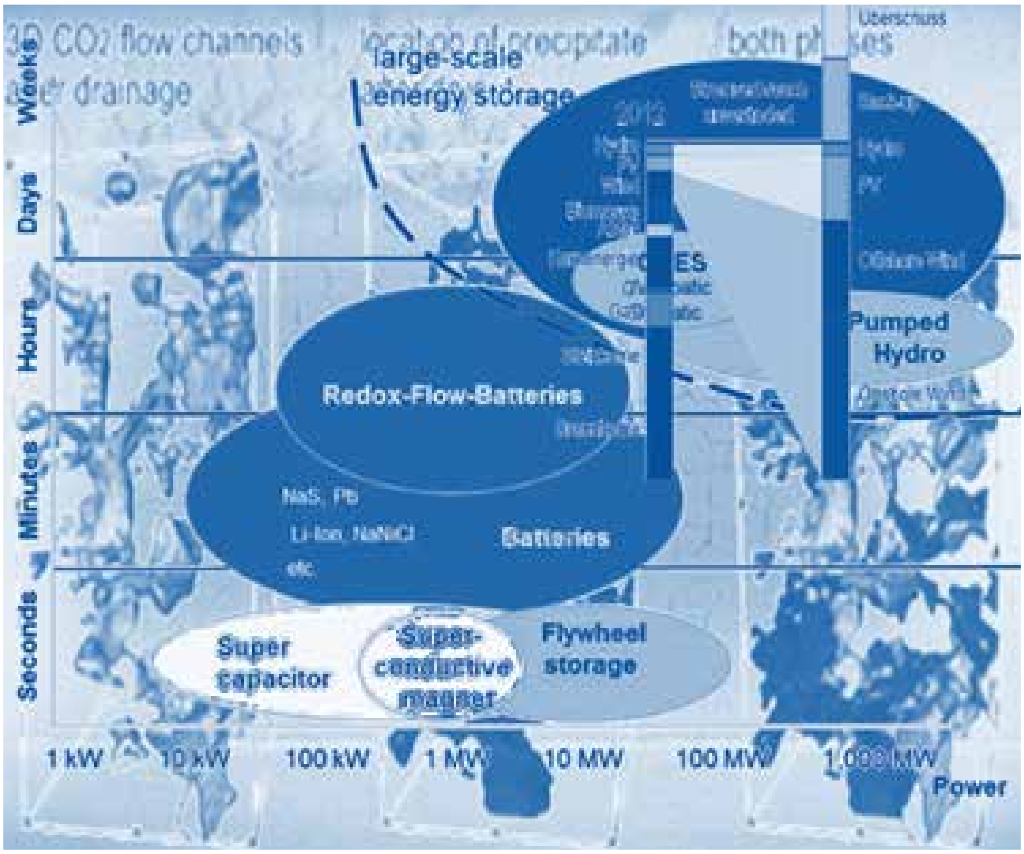

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Haupt- und Fachvorträge

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Der vorliegende Band versammelt schriftliche Ausarbeitungen von Vorträgen auf der Tagung des Arbeitskreises Energie in der Deutschen Physikalischen Gesellschaft des Jahres 2015 in den Räumen der Technischen Universität Berlin. Leider ist es nicht gelungen, von allen Vortragenden Manuskripte zu erhalten. Die Präsentationsfolien der meisten Hauptvorträge können auf der Webseite des Arbeitskreises über:

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(von dort gelangt man zum Archiv des AKE) eingesehen werden. Allen, die zu diesem Sammelband beigetragen haben, sei an dieser Stelle sehr herzlich gedankt.

Düsseldorf, im August 2015 Hardo Bruhns