Sectoral Integration
An important aspect of "Energiewende 2.0"

Dr.-Ing. Ulrich Bünger
Ludwig-Bölkow-Systemtechnik GmbH, Ottobrunn

EVS 30 / F-Cell, Session "The role of hydrogen and fuel cells in the energy economy"
Stuttgart, 9-11 October 2017

Outline

ludwig bölkow
systemtechnik

- About LBST
- Terminology
- Challenges of future German energy transition
- Sectoral duties in fulfilling EU's climate policy goals
  - Power sector
  - Mobility sector
  - (Chemical-) industry sector
  - Households sector
- Synergies from sectoral integration
- Conclusions

Outline

ludwig bölkow systemtechnik

- About LBST
- Terminology
- Challenges of future German energy transition
- Sectoral duties in fulfilling EU's climate policy goals
  - Power sector
  - Mobility sector
  - (Chemical-) industry sector
  - Households sector
- Synergies from sectoral integration
- Conclusions

Ludwig-Bölkow-Systemtechnik GmbH (LBST)

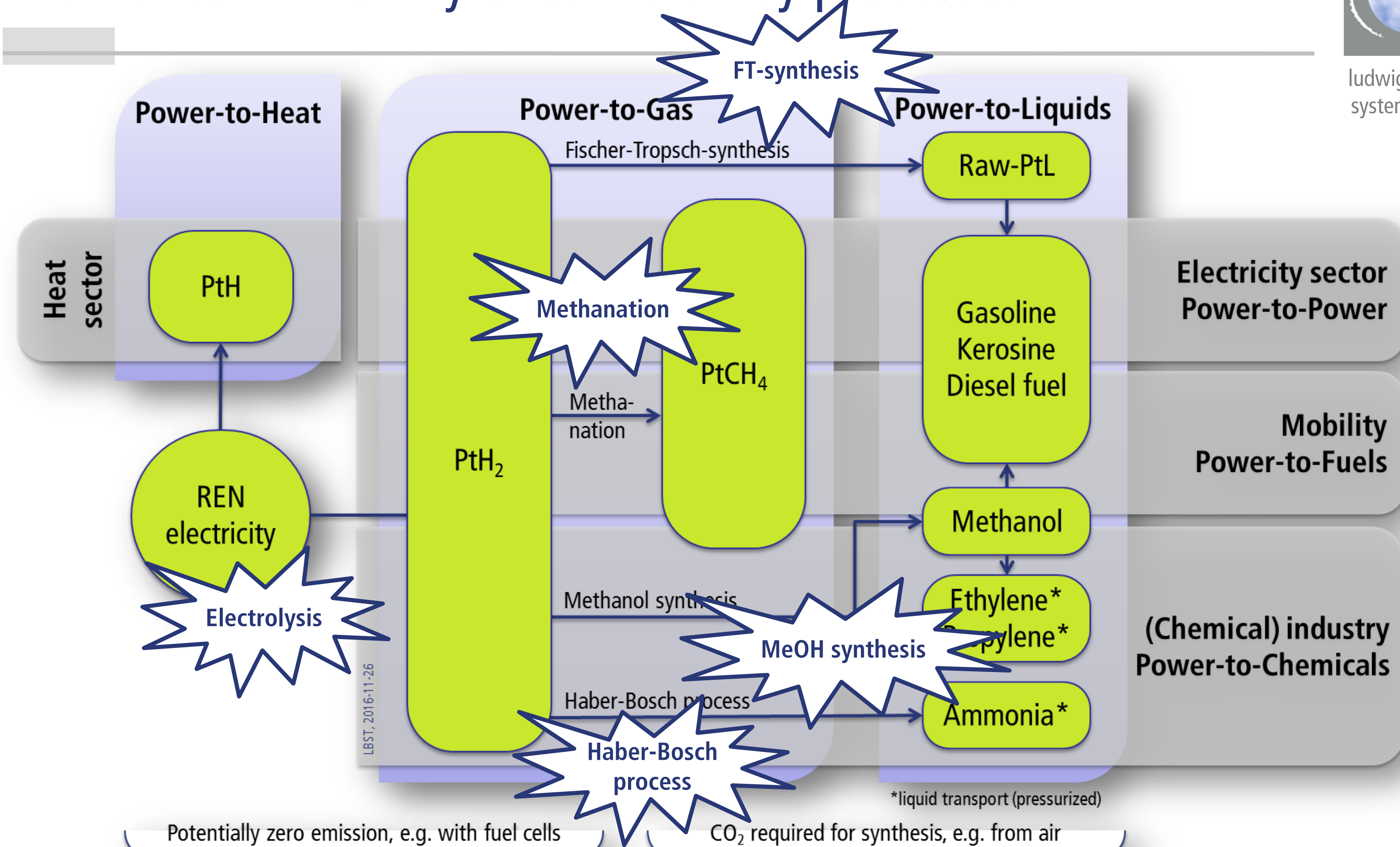
- Independent experts for sustainable energy and mobility since more than 30 years
- Renewable energies, fuels, hydrogen, infrastructure
- Feasibility and sustainability studies, technology based strategic consulting, energy concepts
- Rigorous systems approach – thinking beyond sectoral borders

Outline

ludwig bölkow
systemtechnik

- About LBST
- Terminology
- Challenges of future German energy transition
- Sectoral duties in fulfilling EU's climate policy goals
  - Power sector
  - Mobility sector
  - (Chemical-) industry sector
  - Households sector
- Synergies from sectoral integration
- Conclusions

Power-to-X – family of terms & key processes



Source: U. Bünger, J. Michalski, P. Schmidt, W. Weindorf, Ludwig-Bölkow-Systemtechnik (LBST): Wasserstoff – Schlüsselelement von Power-to-X, Chapter 16 in Springer book „Wasserstoff", 9/2017

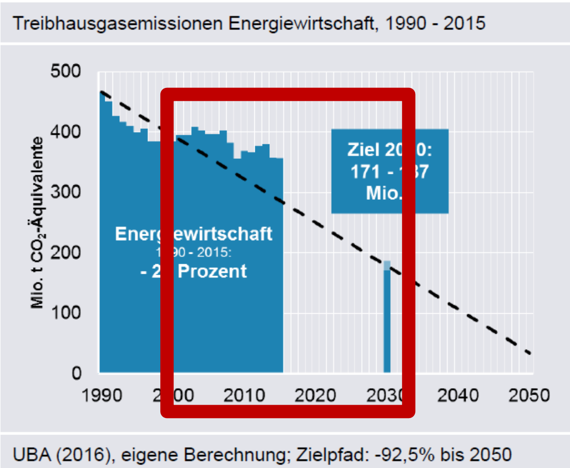
Outline

ludwig bölkow
systemtechnik

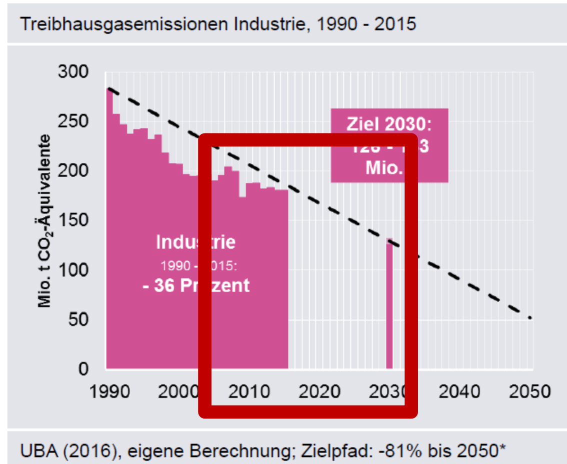
- About LBST
- Terminology
- Challenges of future German energy transition
- Sectoral duties in fulfilling EU's climate policy goals
  - Power sector
  - Mobility sector
  - (Chemical-) industry sector
  - Households sector
- Synergies from sectoral integration
- Conclusions

Sectoral CO_2-emission reduction targets for Germany

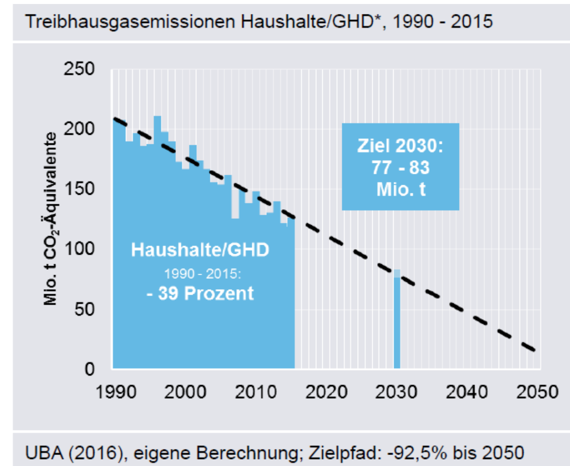
Power generation (Target: -92.5%)



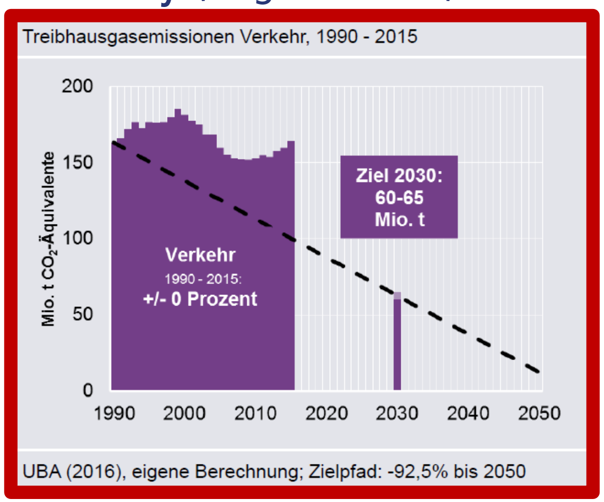
Industry (Target: -81%)



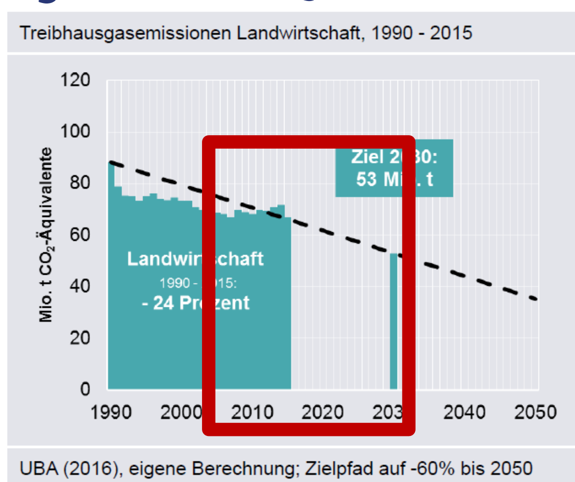
Households/Trade (Target: -92.5%)



Mobility (Target: -92.5%)



Agriculture (Target: -60%)



- Power generation, mobility and industry facing challenges
- Ambitious and short-term strategies across all sectors needed

Source: Agora Energiewende, 09/2016

Outline

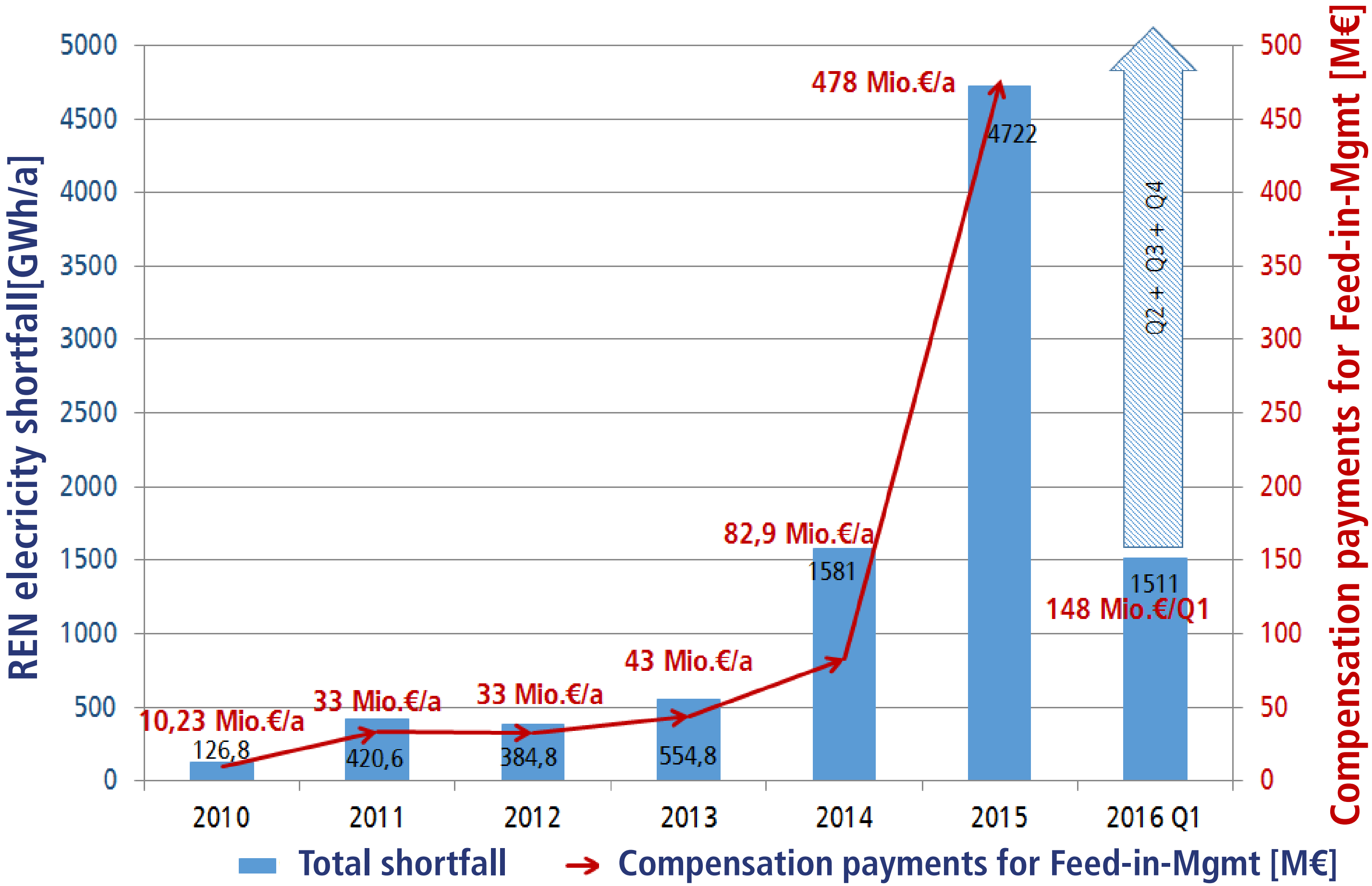
ludwig bölkow systemtechnik

- About LBST
- Terminology
- Challenges of future German energy transition
- Sectoral duties in fulfilling EU's climate policy goals
  - Power sector
  - Mobility sector
  - (Chemical-) industry sector
  - Households sector
- Synergies from sectoral integration
- Conclusions

Feed-in Mgmt*: REN electricity shortfalls / compensation

ludwig bölkow systemtechnik

Shut-down of REN electricity plants in Germany increased significantly until 2016



- Rapid growth of curtailed REN "surplus" electricity
- But, quantities limited to produce H_2 at large (1.6% of all electricity generated in 2015)

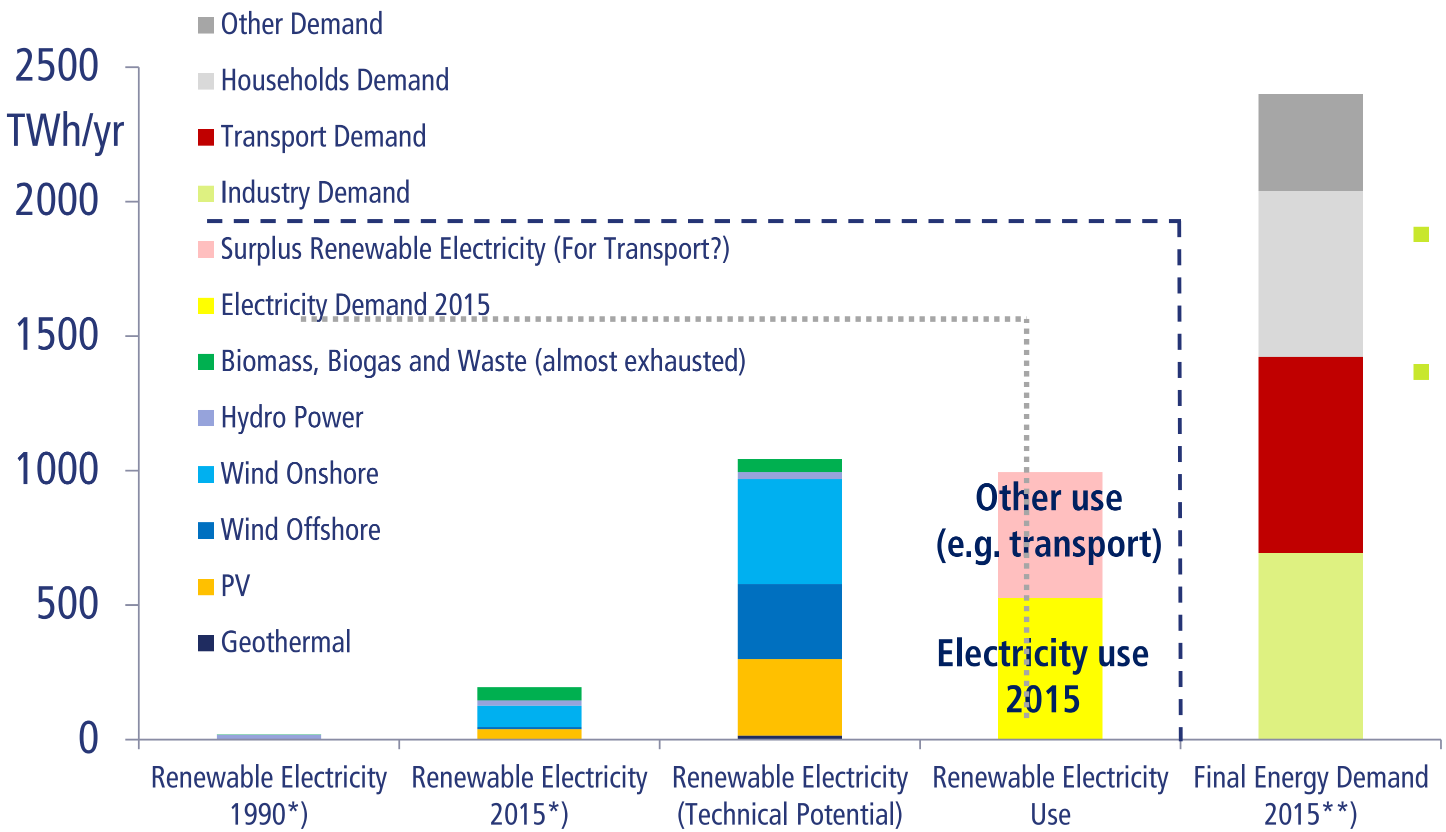
Source: LBST 2017

* German term: „EinsMan"

REN potential vs end energy consumption for Germany

ludwig bölkow
systemtechnik

- End energy use today ca. 500 TWh/yr, REN electricity potential ca. 1.000* TWh/yr



*) AGEE 2016: Energie in Zahlen 2015
**) BMWI 2016: Energiedaten 2015

- REN electricity potential is limited
- System change from fossil fuels to renewable electricity required

* conservative estimate

Source: Potentials: as shown; potential estimates: LBST, (previous graph: diamonds); consumption statistics: [BMWI 2015], [AGEE 2015]

Outline

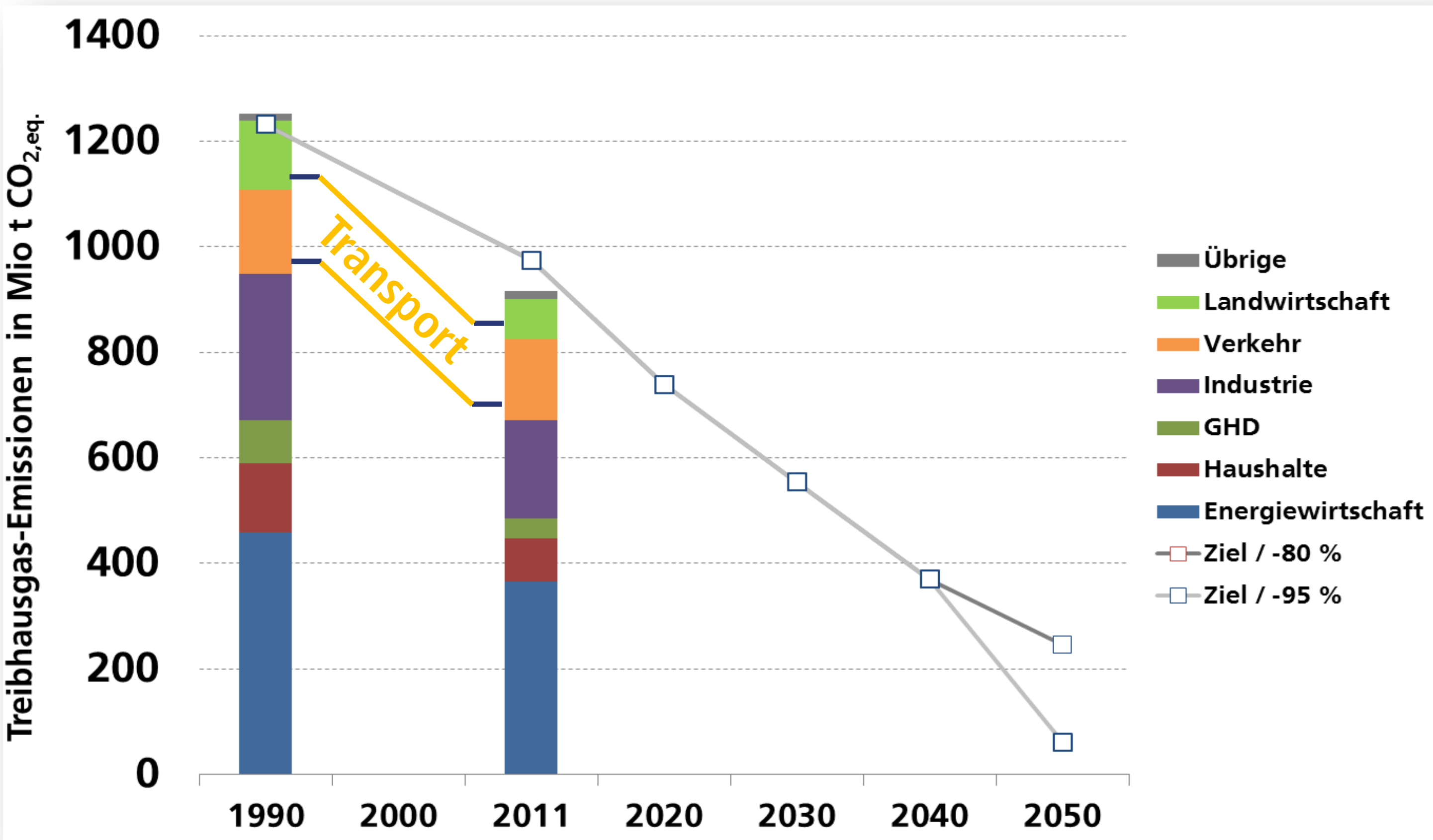
ludwig bölkow
systemtechnik

- About LBST
- Terminology
- Challenges of future German energy transition
- Sectoral duties in fulfilling EU's climate policy goals
  - Power sector
  - Mobility sector
  - (Chemical-) industry sector
  - Households sector
- Synergies from sectoral integration
- Conclusions

Challenges & opportunities for mobility sector

- Instead of contributing to GHG emission reduction (2020: -10%; 2050: -40%) German mobility sector has increased them by 1% until 2013 (base year 2005)

Failure to reduce GHG-emissions must be compensated by all other sectors

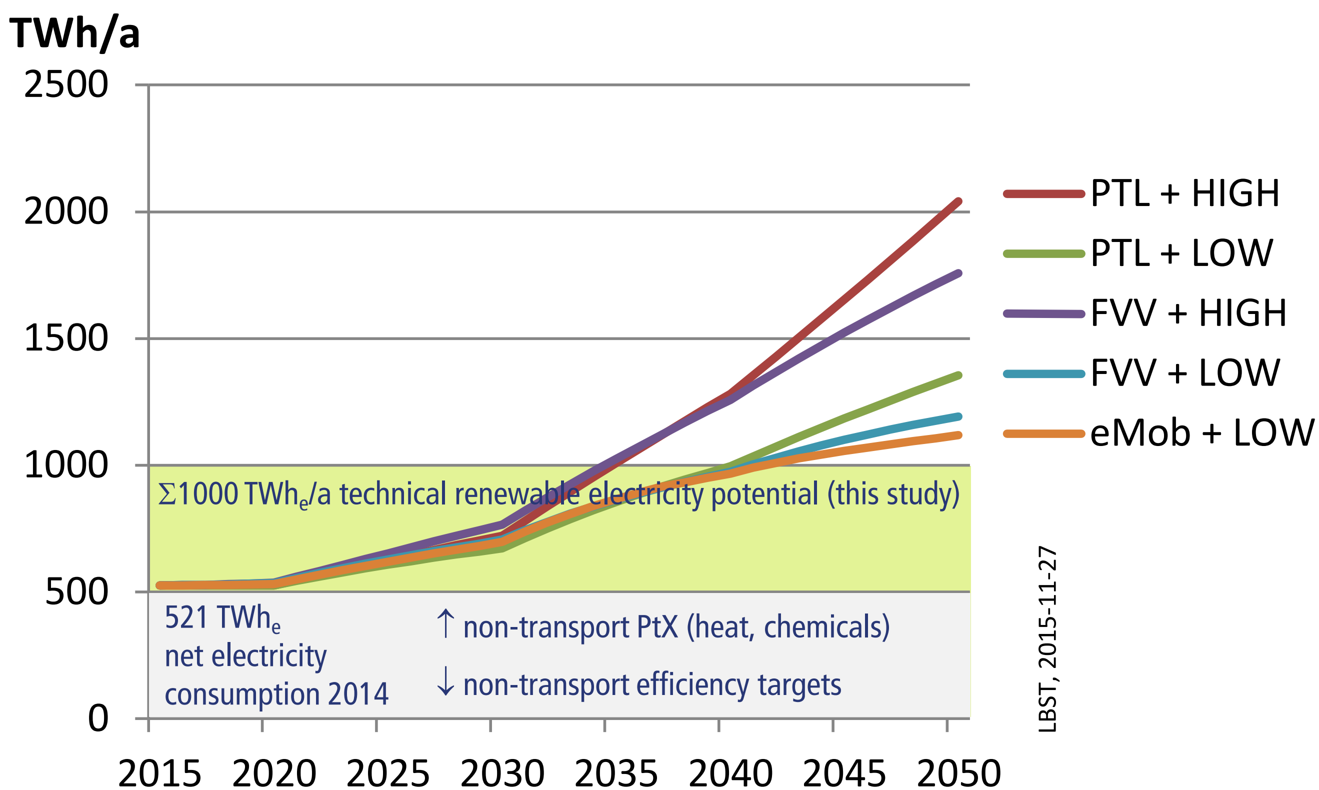


Source: FhG-ISE, 2015

Potential electricity demand for e-mobility Germany*

ludwig bölkow systemtechnik

- Electricity demand could surpass today's total demand by factor 2 - 4:
  potentially causing electricity imports



* Road, air and rail transport, w/o international maritime transport

Source: „Renewables in Transport 2050 – Focus Germany", LBST study LBST for Forschungsvereinigung Verbrennungskraftmaschinen e.V. (FVV), 2016

Fresh competition from abroad (CHN, JP, KO)

ludwig bölkow
systemtechnik

All pictures and information on this side concerning the Chinese FC strategy to be downloaded from:

http://www.iphe.net/docs/Meetings/SC26/Workshop/Session1/IPHE%20Forum%20Gwangju%20Session%201%20FCEVs%20-%20China.pdf

- Recently established FC development ventures
- Production space: 12,000 m² (W*B: 120*100 m)
- Annual FC manufacturing capacity:
  6,000 - 20,000 (1 - 3 shifts)
- Annual FC module production: 4,500 (15 kW each)
- Start of production: 1 July 2017
- Also mass production of battery city buses 100.000 pa

!

Source Prof. Dr. Zhixiang Liu, Southwest University, IPHE-Forum, Gwangju, South Korea, 02.11.2016

Outline

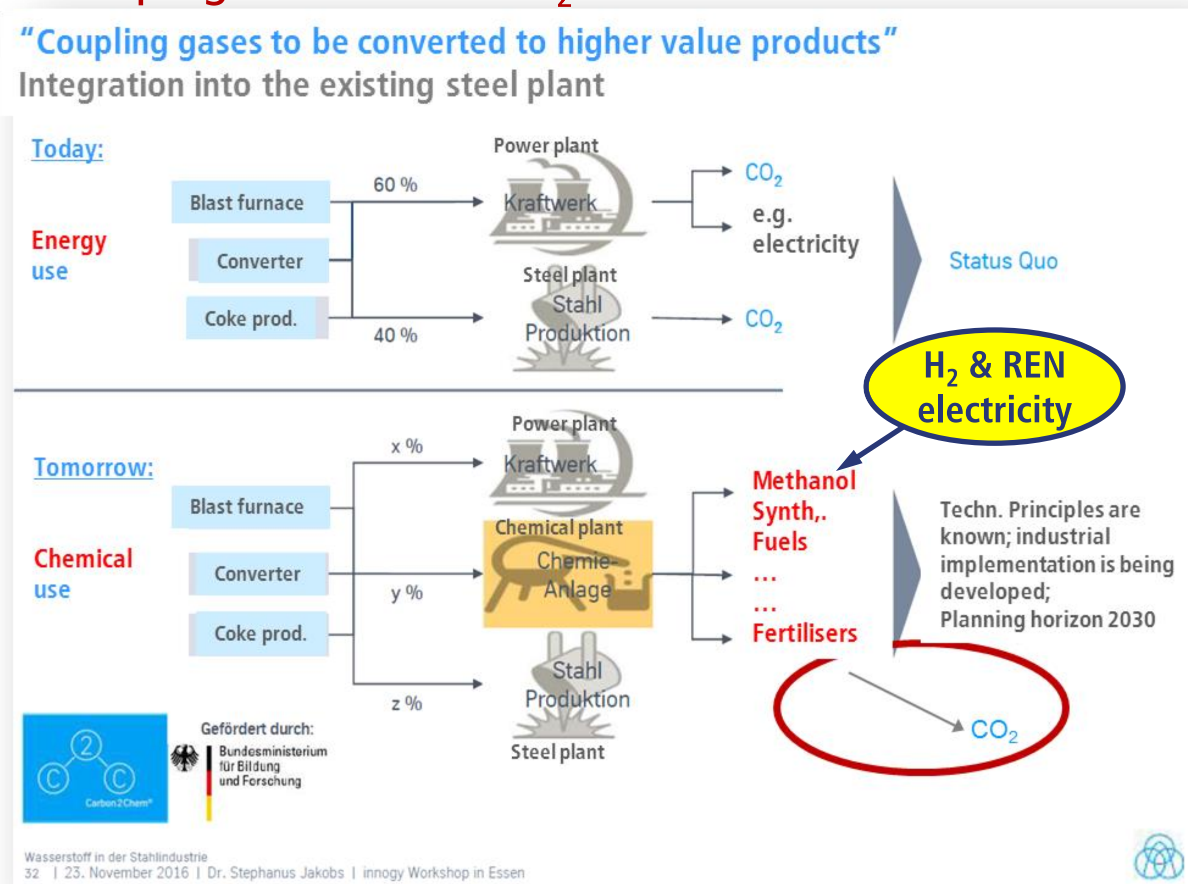
ludwig bölkow
systemtechnik

- About LBST
- Terminology
- Challenges of future German energy transition
- Sectoral duties in fulfilling EU's climate policy goals
  - Power sector
  - Mobility sector
  - (Chemical-) industry sector
  - Households sector
- Synergies from sectoral integration
- Conclusions

Carbon2Chem – CO_2-efficiency strategy

ludwig bölkow
systemtechnik

- Carbon2Chem program will increase CO_2-efficiency by REN electricity
  but is no program towards CO_2-avoidance



Direct CO_2-emissions

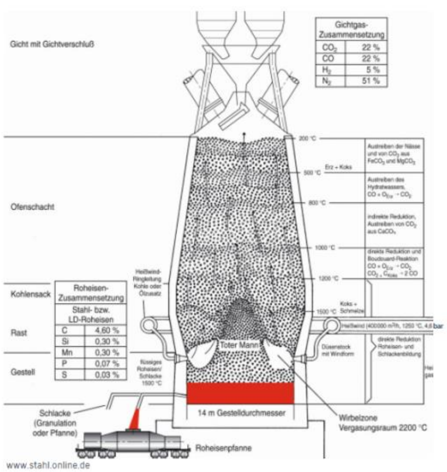
2nd life CO_2-emissions
(through REN electricity & H_2)

Source: St. Jakobs: Wasserstoff in der Stahlindustrie – Erzeugungs- und Einsatzmöglichkeiten in der Zukunft, thyssenkrupp, H_2-Congress Berlin, 2016

Vision to reduce CO_2-emissions in steel making in Germany

- Steel industry can replace blast furnaces by direct reduction plants (DRI):
  - furnaces factor ~10 smaller (economy of scale ↓)
  - practical expertise yet to be developed
- Annual H_2 demand ca. 2.4 Mton or 130 TWh/a electricity to replace all coal & coke:
  - Significant H_2 demand comprising 2-3 times total German annual H_2 production and annual GHG reduction of ca. 66 $Mton_{CO2\text{-}equiv.}$

Use of carbon as reducing agent in blast furnaces



Der Hochofenprozess

Wesentliche Teil-Reaktionen:

Eingesetzter Koks bzw. Einblaskohle:

$C + O_2 \rightarrow CO_2$ exotherm

Boudouard-Gleichgewicht:

$CO_2 + C \rightleftharpoons 2\,CO$ f(T, P); endotherm

‚Indirekte Reduktion' des Eisenoxids:

$Fe_2O_3 + 3\,CO \rightarrow 2\,Fe + 3\,CO_2$

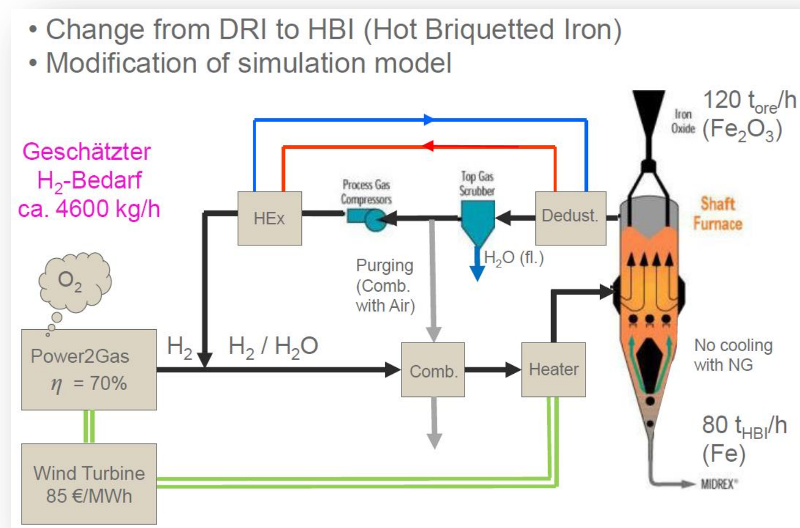
Gesamtreaktion:

$Fe_2O_3 + 2\,C \rightarrow 2\,Fe + CO + CO_2$

Untergeordnete Reaktion der Feuchte der eingesetzten Materialien mit Kohlenstoff:

$H_2O + C \rightarrow H_2 + CO$ (Wassergas-Reaktion)

MIDREX plant scheme in H_2-operation mode



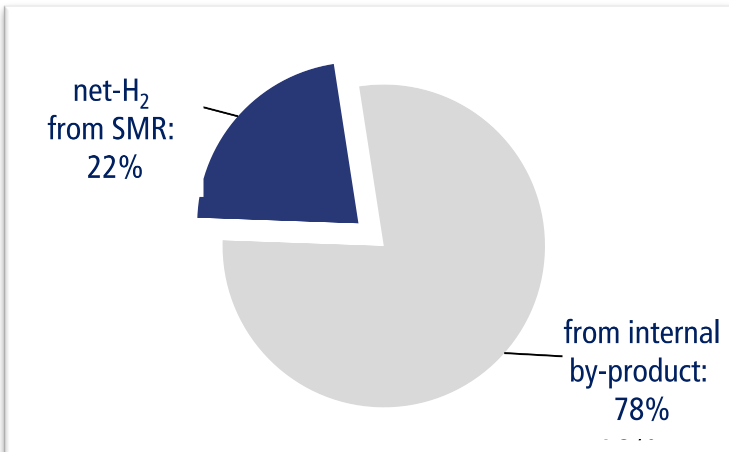
Source: LBST based on St. Jacobs: Wasserstoff in der Stahlindustrie – Erzeugungs- und Einsatzmöglichkeiten in der Zukunft, thyssenkrupp, H_2-Congress Berlin, 2016 sowie M. Höller, vormals ArcelorMittal, Hamburg, 2016

Entry strategy to introduce REN-H_2 in refinery industry

ludwig bölkow systemtechnik

H_2-use in refineries today

- H_2-demand in today's refineries partially covered by internal by-product sources; net H_2-demand provided by steam methane reforming of natural gas (SMR)
- SMR-H_2 in German refineries is energetically equivalent to ca. 0.4-1.0% of fuels produced



Substitution of natural gas

- 100% substitution of natural gas in German refineries requires: ca. 150,000 t H_2/Jahr
- Implied additional electricity demand: ca. 8.3 TWh/year
- GHG-emission reduction potential: ca. 1.6 Mton$_{CO2\text{-}equiv.}$/year (incl. reduced provision of natural gas)
- Meaningful introduction strategy, i.e. to commercialize electrolysis as key technology, however, only minor and medium-term CO_2-emission reduction potential

Source: LBST based on own studies, 2016

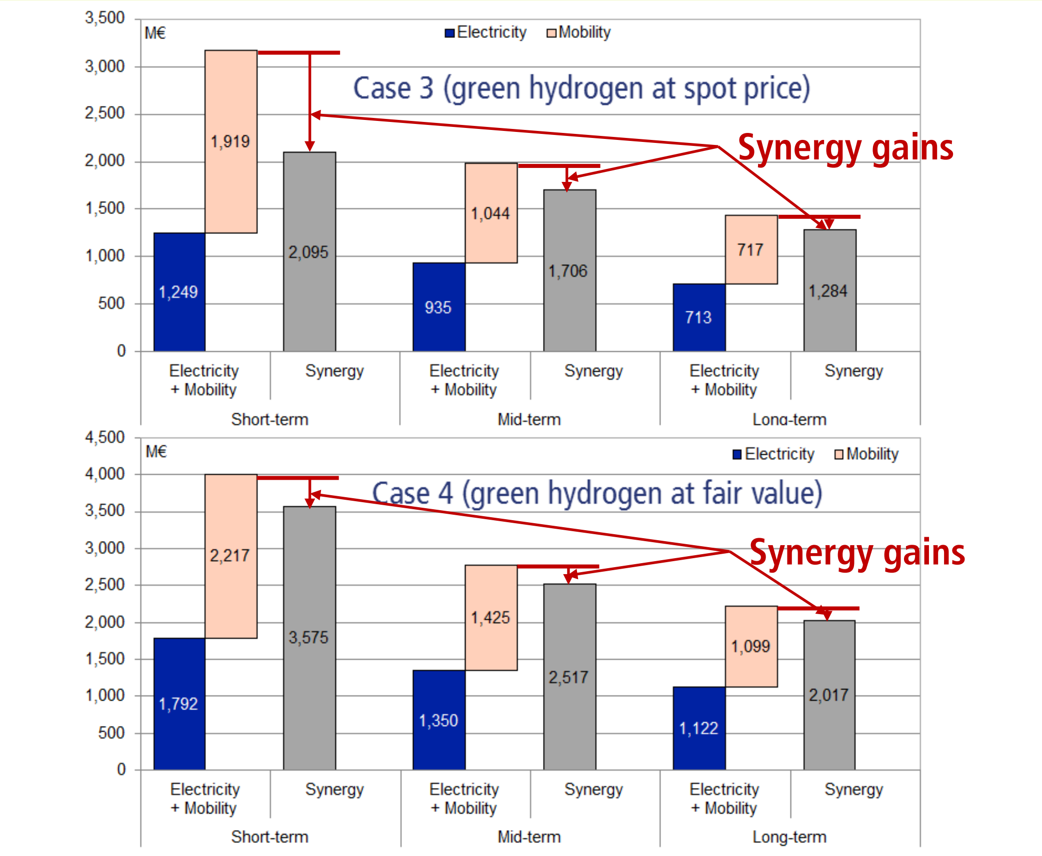
Outline

- About LBST
- Terminology
- Challenges of future German energy transition
- Sectoral duties in fulfilling EU's climate policy goals
  - Power sector
  - Mobility sector
  - (Chemical-) industry sector
  - Households sector
- **Synergies from sectoral integration**
- Conclusions

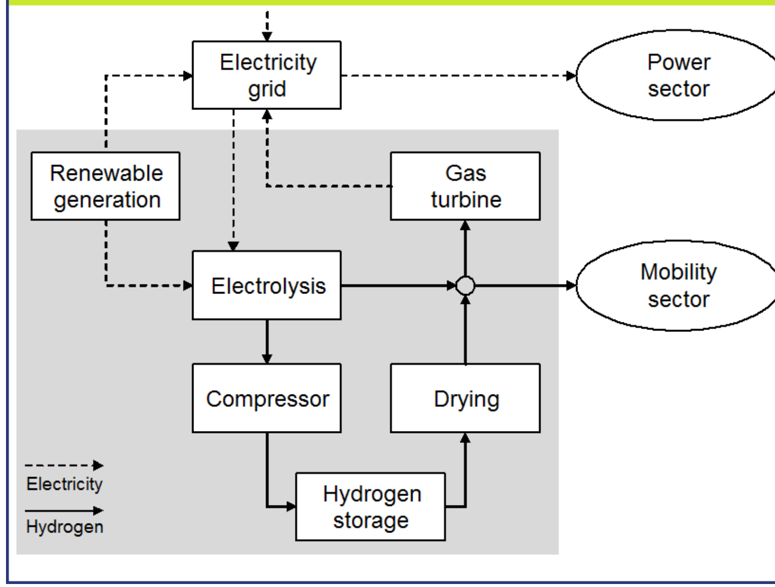
Economic synergies

ludwig bölkow systemtechnik

Discounted net expenditures in Case 3 and 4



System boundaries



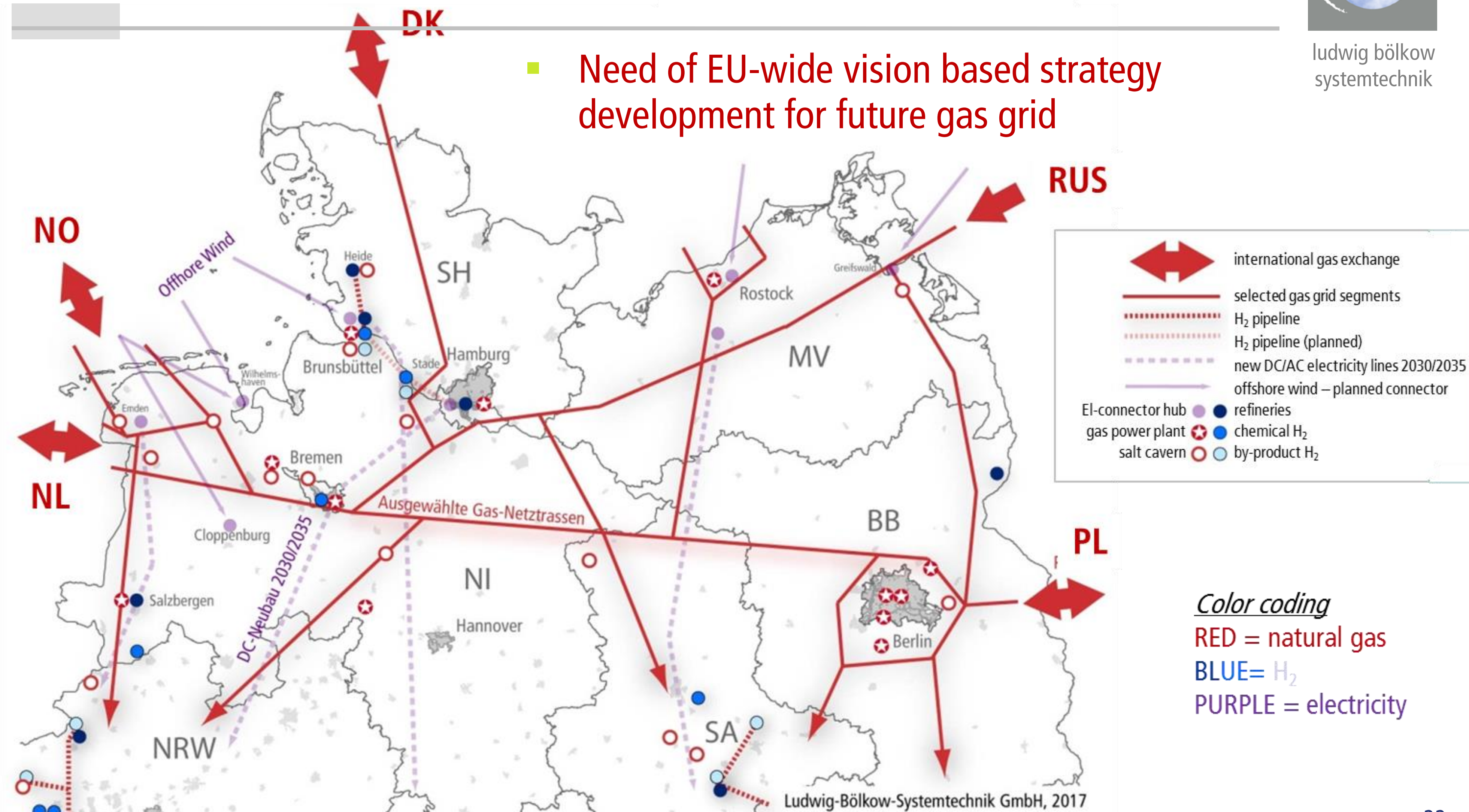
- Synergies from co-use by improved capacity utilization (all processes such as electrolysers)
- Improved utilization of intermittent electricity
- BUT: advantages shrink over time
- No synergies for "grey hydrogen"

Source: J. Michalski: The Role of Energy Storage Technologies for the Integration of Renewable Electricity into the German Energy System". PhD thesis, Technische Universität München, December 2016.

Gas grid development needs global intersectoral strategy

ludwig bölkow systemtechnik

- Need of EU-wide vision based strategy development for future gas grid



Color coding

RED = natural gas

BLUE= H_2

PURPLE = electricity

Source: U. Bünger: Aufbau Wasserstoffinfrastruktur in Norddeutschland - Strategische Herausforderungen und Marktentwicklungsoptionen, Die Westküste – Europas Energieregion der Zukunft, Entwicklungsagentur Heide, Heide/Holstein, 24 April 2017.

Outline

ludwig bölkow
systemtechnik

- About LBST
- Terminology
- Challenges of future German energy transition
- Sectoral duties in fulfilling EU's climate policy goals
  - Power sector
  - Mobility sector
  - (Chemical-) industry sector
  - Households sector
- Synergies from sectoral integration
- Conclusions

Conclusions

- *Sektorkopplung* synonymous for intersectoral integration of energy infrastructures
- Sectoral integration as set of 2nd stage measures extending "Energiewende" from electricity to all energy end-use sectors, in fulfillment of political GHG-emission targets
- Ambitious transition in all energy sectors for next 33 years to begin immediately
- E-mobility as strategy for road&rail transport; for air&maritime transport even vision lacks
- Carbon2Chem as early concept for (chemical) industry, yet w/o concise 2050 strategy
- Electricity to dominate domestic energy provision (wind, PV), complemented by biomass, BUT „all electric world" unrealistic and expensive (resource and acceptance barriers)
- Global Germany energy supply exclusively from domestic REN only possible with highly ambitious structural measures, efficiency gains or consequent energy savings
- Alternatives are REN-imports from eastern Europe, MENA-countries or Scandinavia
- Import options via electricity (HVDC) or easily transportable /storable energy carriers (PtX; which paves the way for hydrogen as universal energy carrier next to electricity)

→ Need for urgent and ambitious measures requires improved public communication

Contact

ludwig bölkow systemtechnik

Dr. Ulrich Bünger, MSc.
+49/89/608110-42
ulrich.buenger@lbst.de

Ludwig-Bölkow-Systemtechnik GmbH
Daimlerstr. 15
85521 München/Ottobrunn/Germany

Web: http://www.lbst.de