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GIS-based analysis of hydrogen pipeline infrastructure for different supply and demand options

15/02/2012 | Sylvestre Baufumé, Thomas Grube, Fabian Grüger, Dennis Krieg, Jochen Linssen, Michael Weber, Jürgen-Friedrich Hake, Detlef Stolten

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Content

- General Presentation
- Hydrogen demand
- Hydrogen transport
- Hydrogen production
- Results
- Conclusions and discussion

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Methodological approach

Hydrogen for transport application – Scenarios for Germany 2050

- High penetration of hydrogen-fuelled vehicles
- Hydrogen delivered to consumers in conventional fuelling stations
- Central hydrogen production:
  - Water electrolysis using wind generated electricity and/or
  - Gasification of domestic lignite
- Gaseous hydrogen transport per pipelines

➡ **New pipeline network to be built**

➡ **Preliminary layout and costing required**

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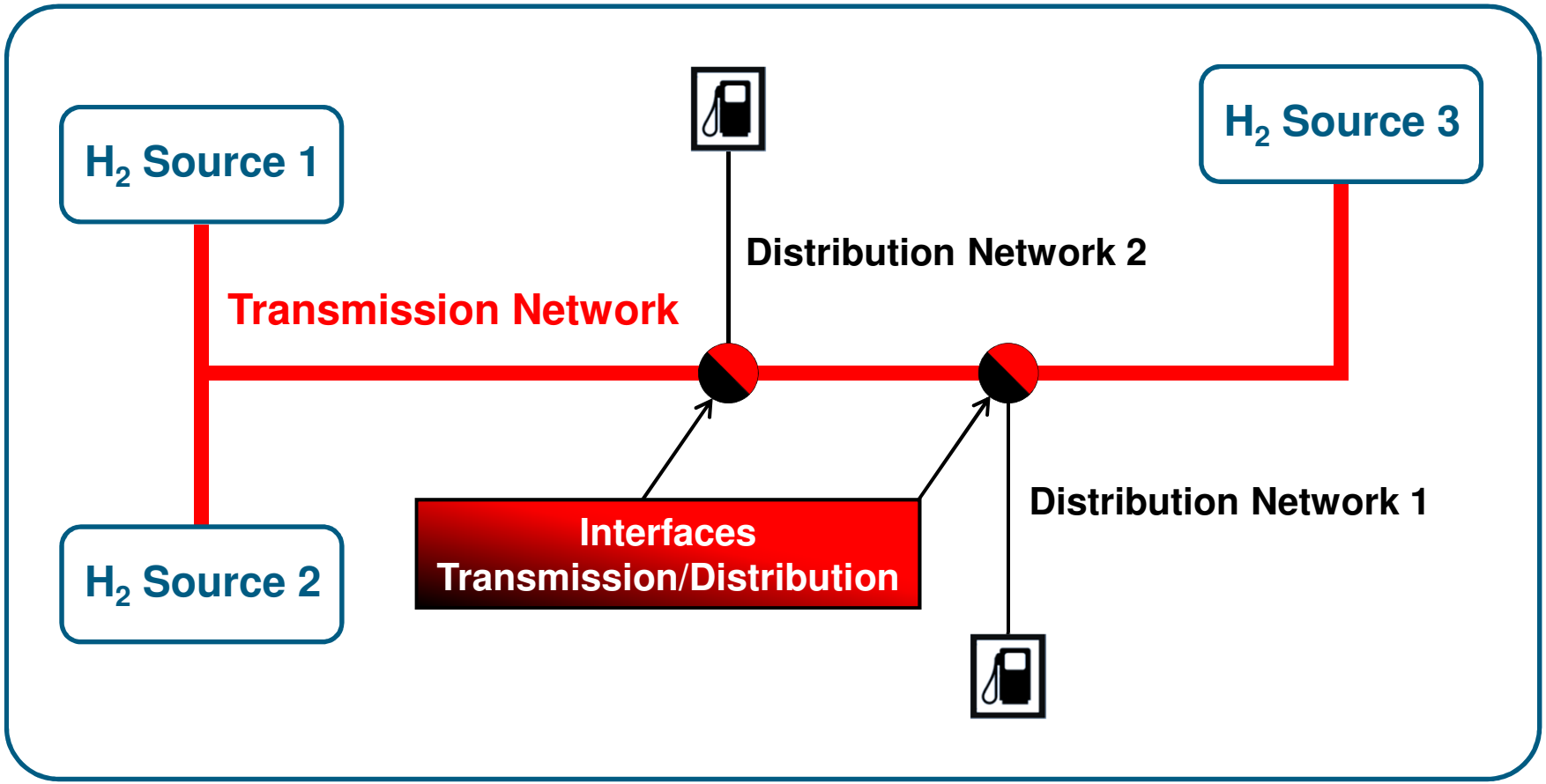
System and model



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Assumed H_2-vehicle fleet and consumption

H_2 Vehicles		H_2 Utilisation	
Type -	Market Share [%]	Annual average mileage [km/year]	Average specific consumption [MJ/km]
Passenger Vehicles	73	11,400	0.85
Light Duty Vehicles	55	18,500	2.30
Buses	74	50,000	10.30

→ **4.3 million tons H_2/year**

Averaged characteristics of the fleet described in [BMVBS, 2009]

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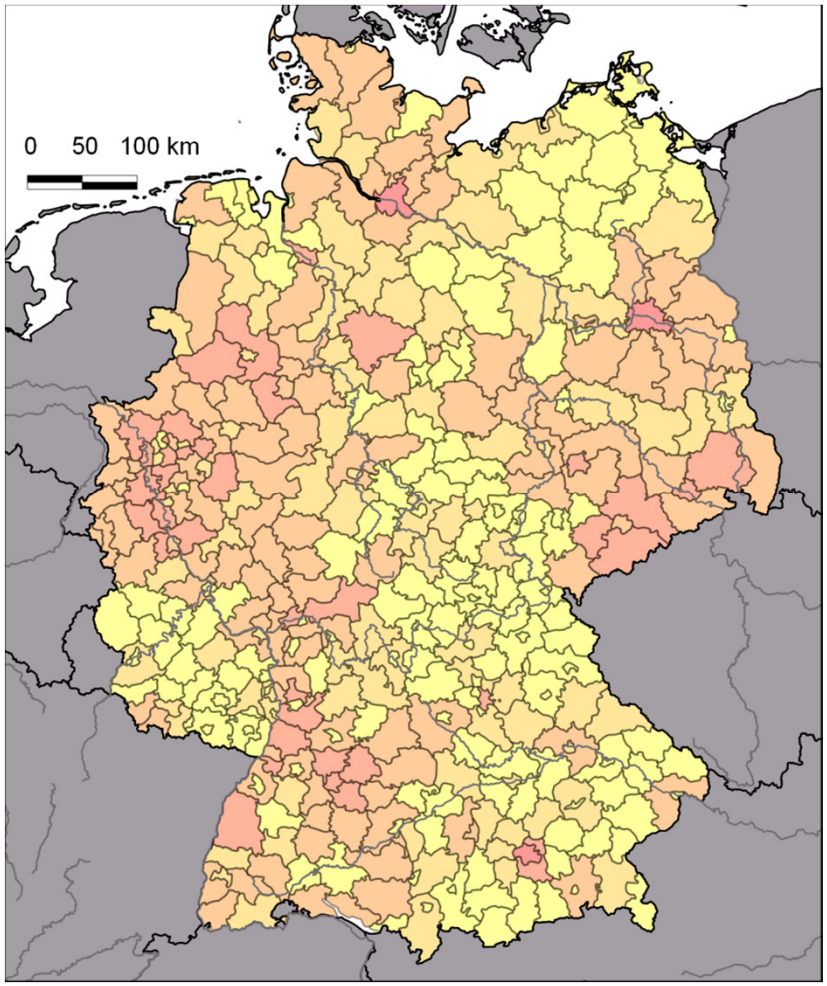
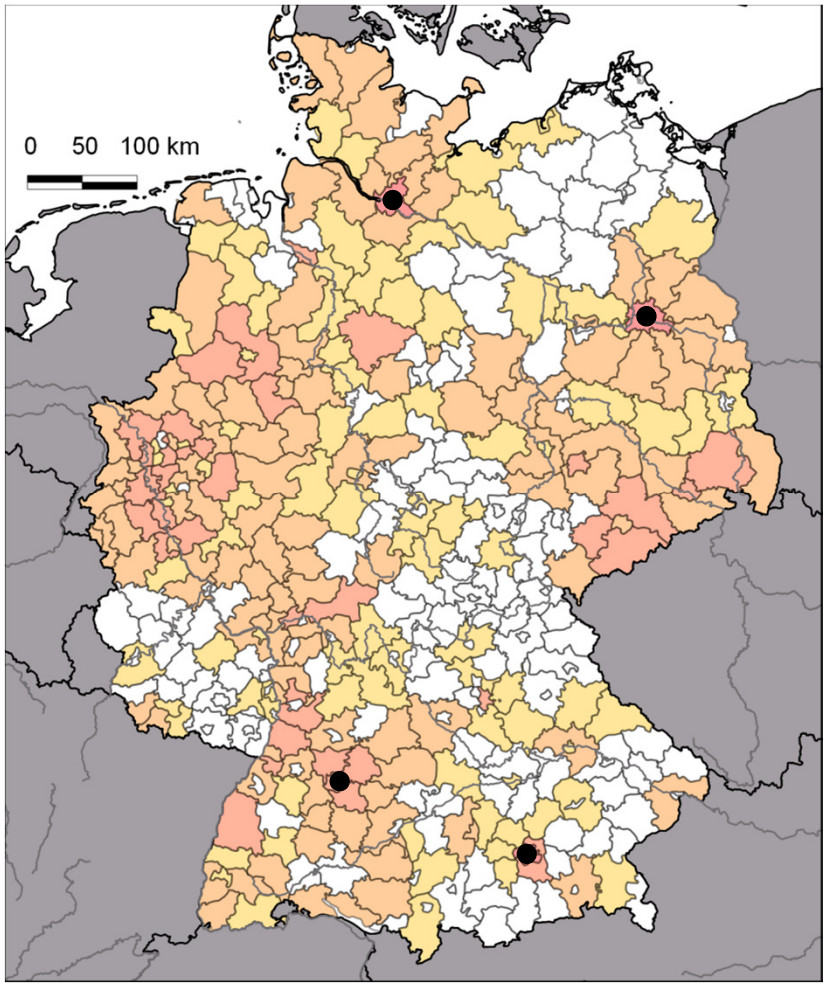
Regional distribution (All districts)



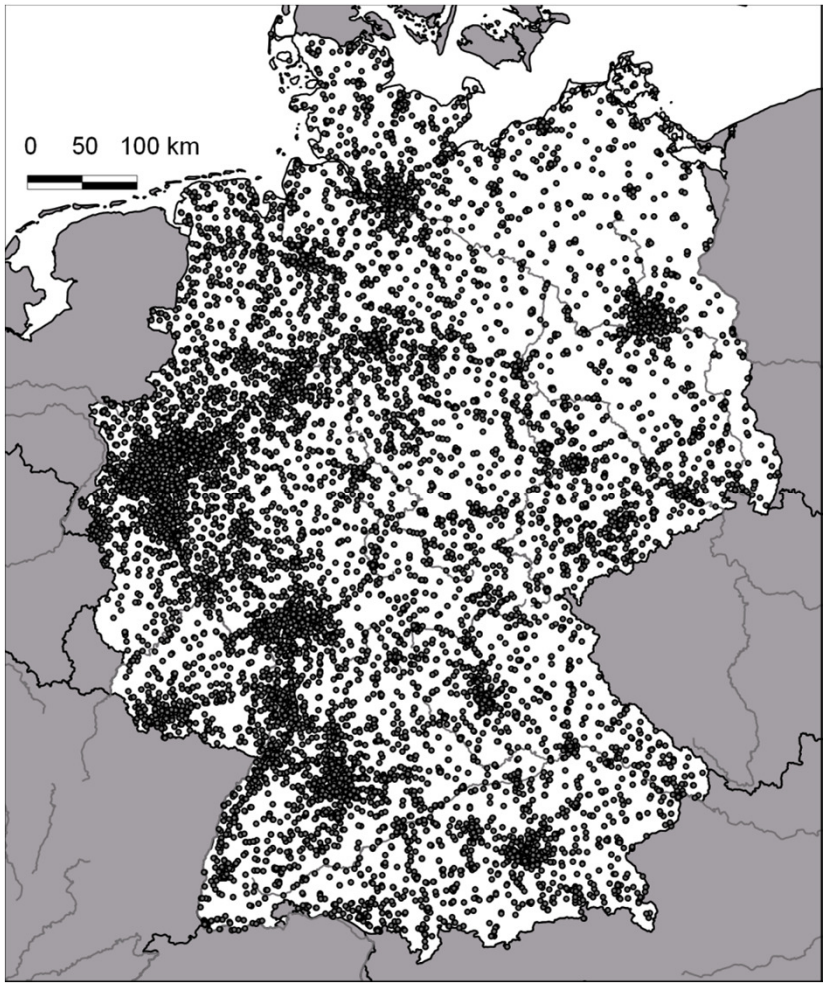
- Assuming current distribution unchanged for Passenger Vehicles, Light Duty Vehicles and Buses

Regional distribution (Demand > 8,000 tons H_2/year)



- Assuming current distribution unchanged for Passenger Vehicles, Light Duty Vehicles and Buses
- Berlin, Hamburg, Stuttgart and Munich first

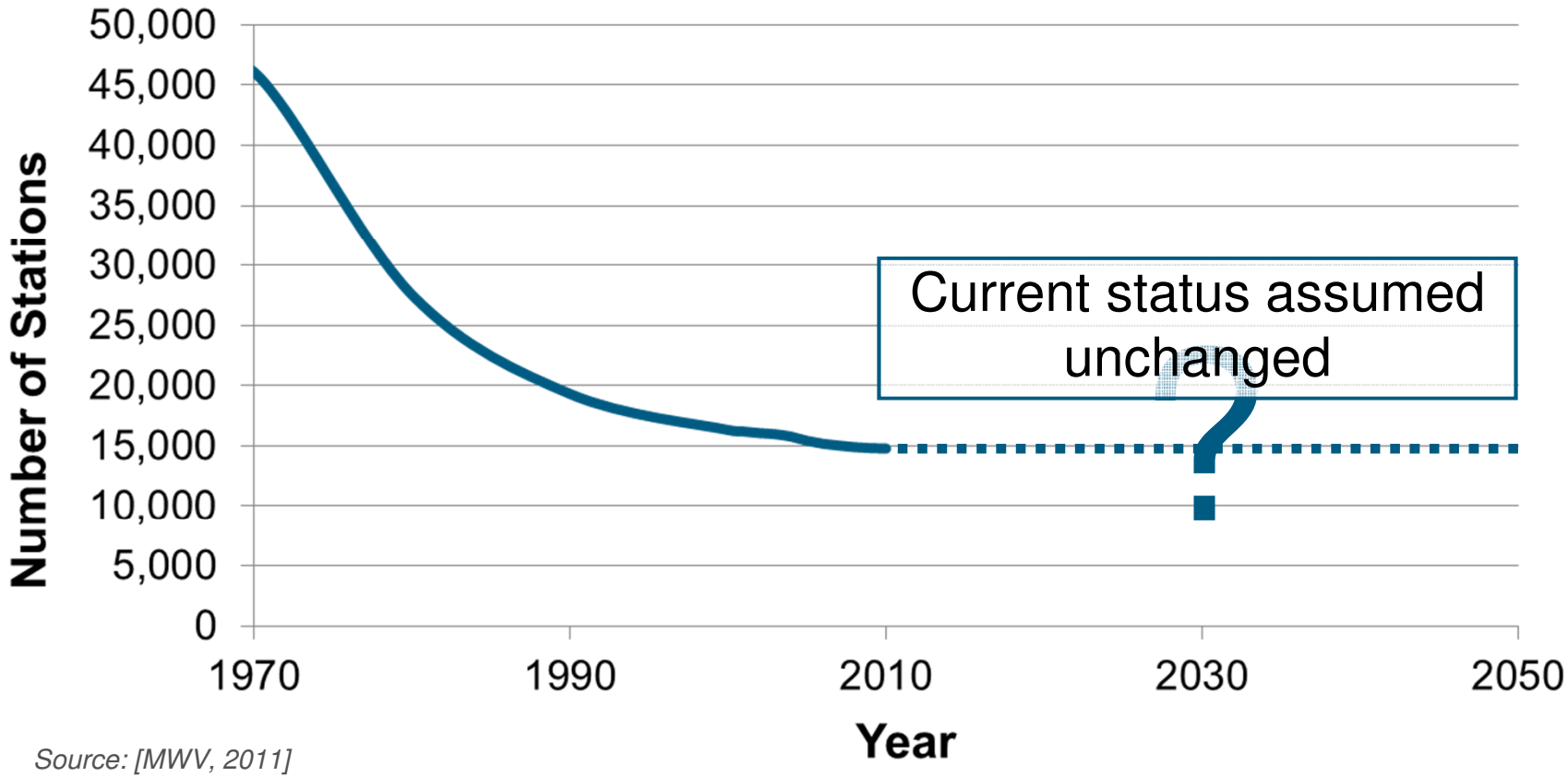
Refuelling stations – Current Situation



Approx. 12,000 stations identified and geo-localised:

- 81% of the 14,782 referred in [EID, 2010]
- 88% of the fuel delivered when reflecting market shares

Refuelling stations – Future evolution ?



Source: [MWV, 2011]

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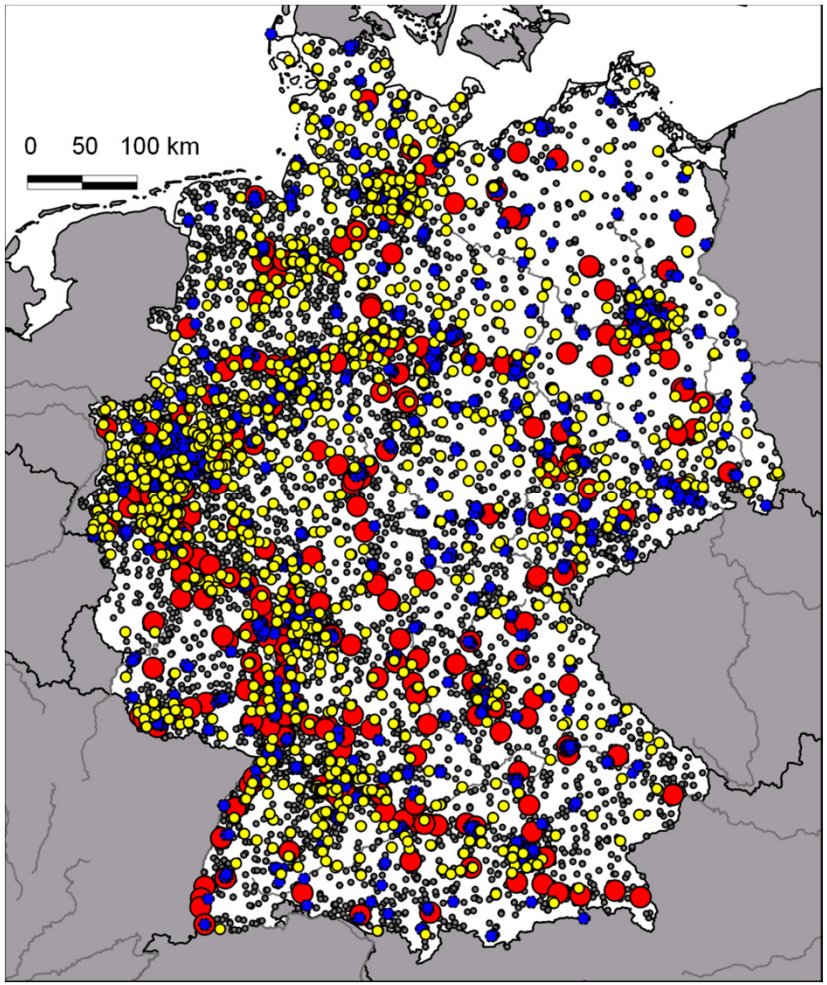
Refuelling stations – Networking sequence



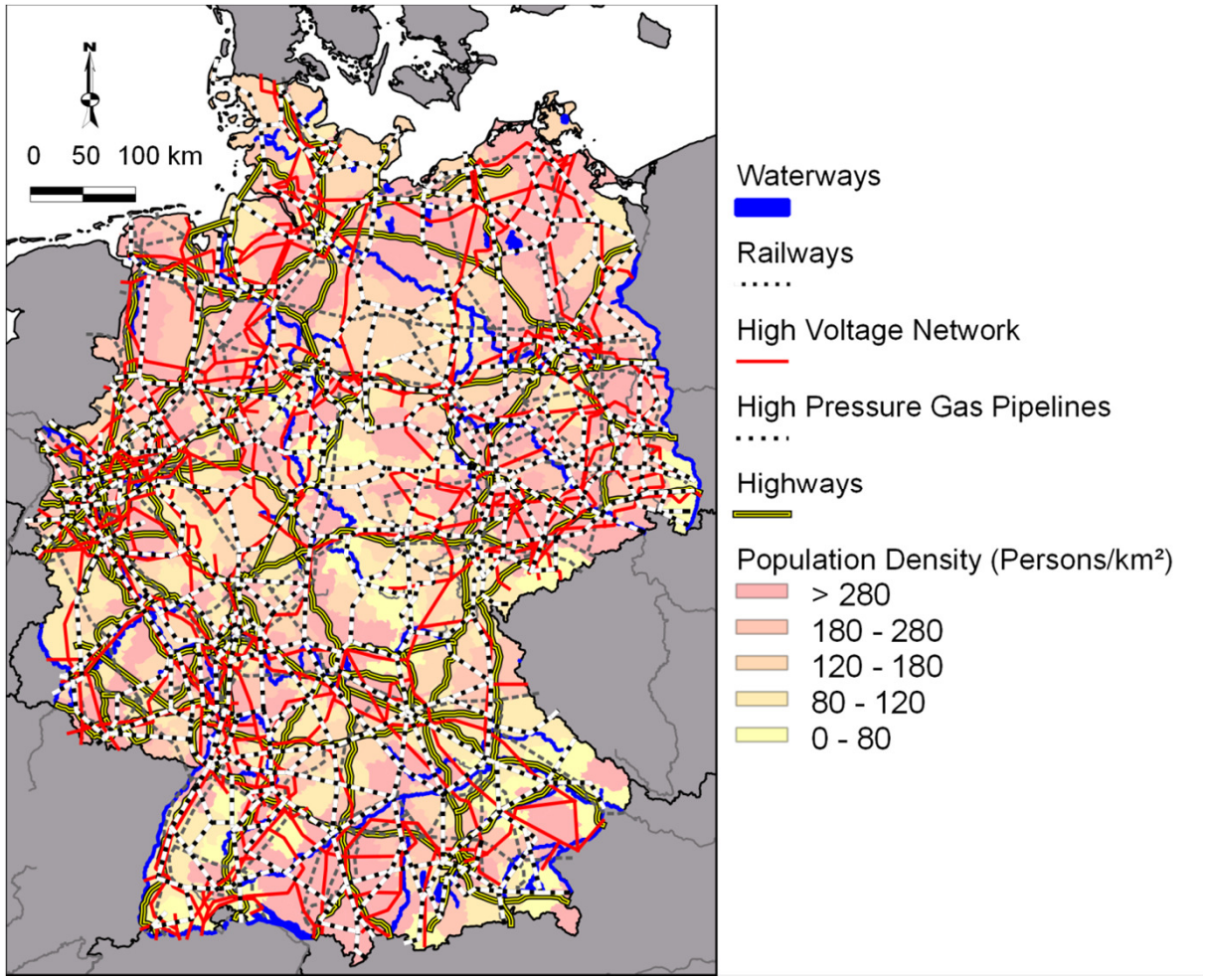
1) Motorway stations

2) Dense urban area stations

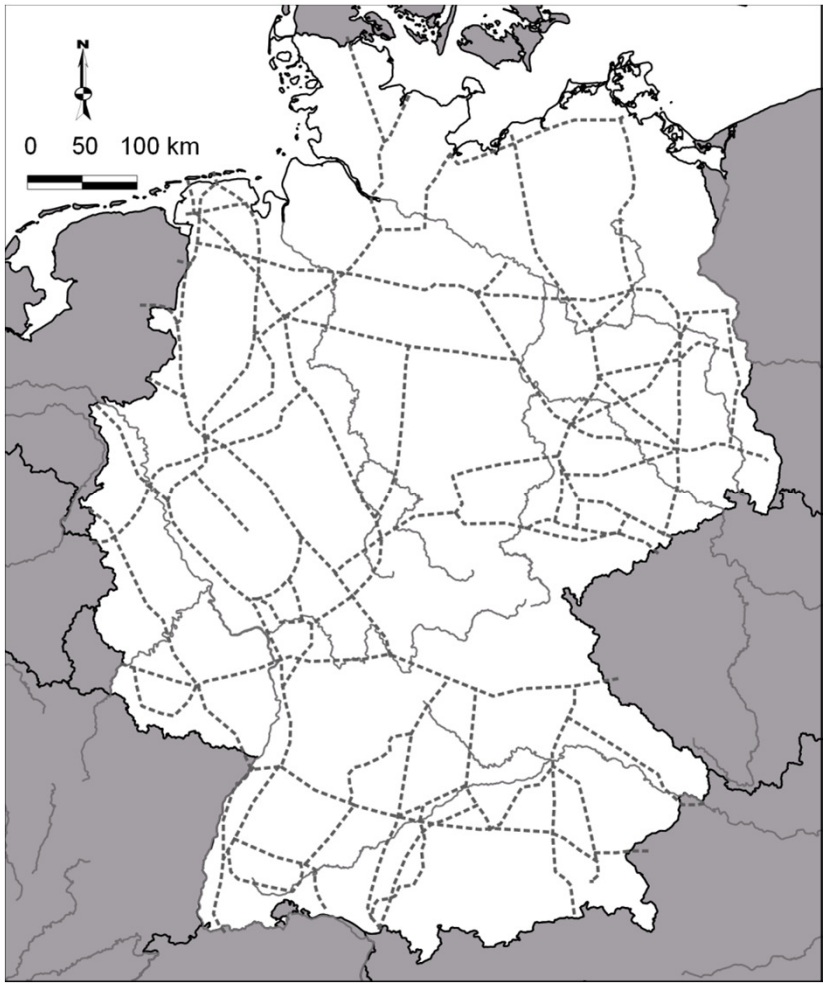
3) Urban area stations

4) Rural area stations

New infrastructure restricted by existing ones



New infrastructure might follow existing ones

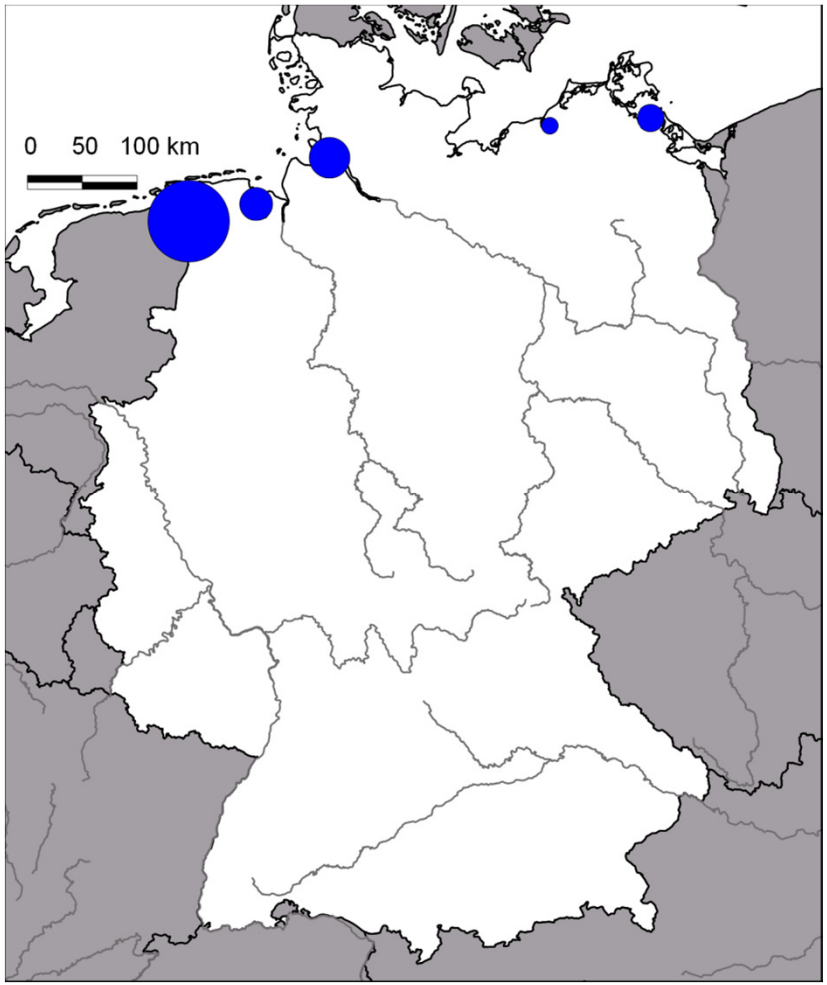


Building a new long distance transmission pipeline network would need to accommodate pre-existing conditions:

- Find new corridors or
- Follow existing corridors

➢ For this study, we assume that the new H_2 transmission network will often follow the existing high pressure Natural Gas grid

Water electrolysis – Offshore wind

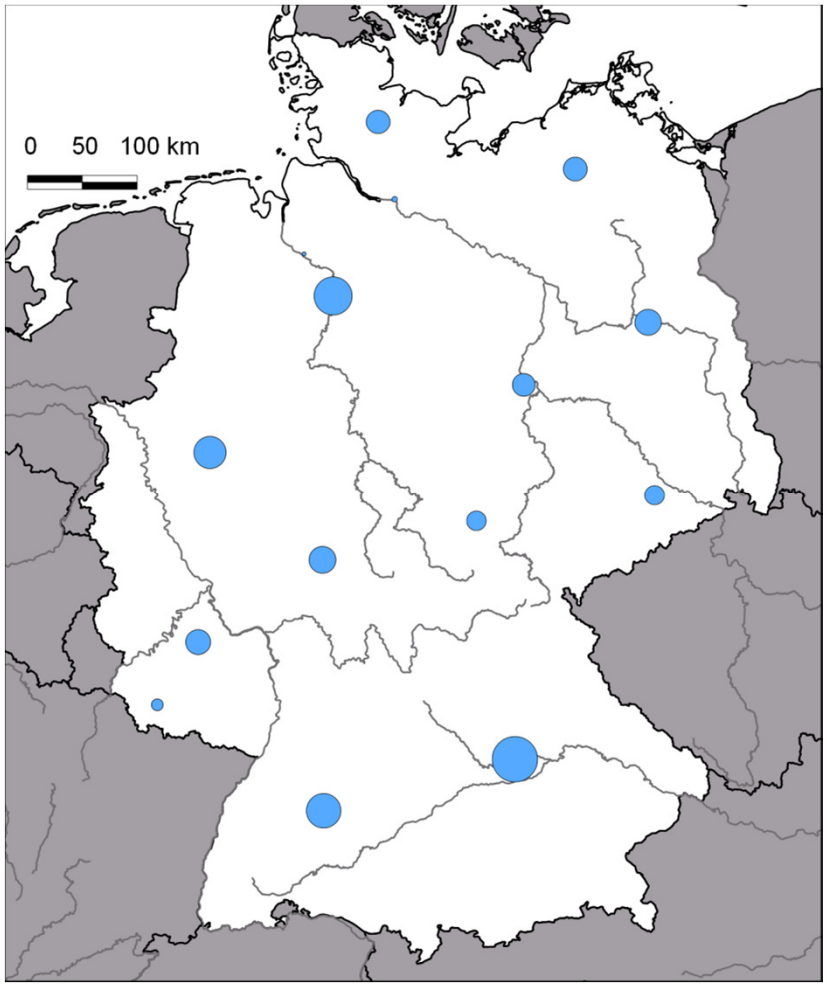


- Assuming hydrogen production proportional to the cumulated power of projects in the permitting process as listed in [DENA, 2011] (~ 51 GW_e)

Hydrogen production (kt/year)

- 1,400
- 400
- 200
- 100
- 50

Water electrolysis – Onshore wind

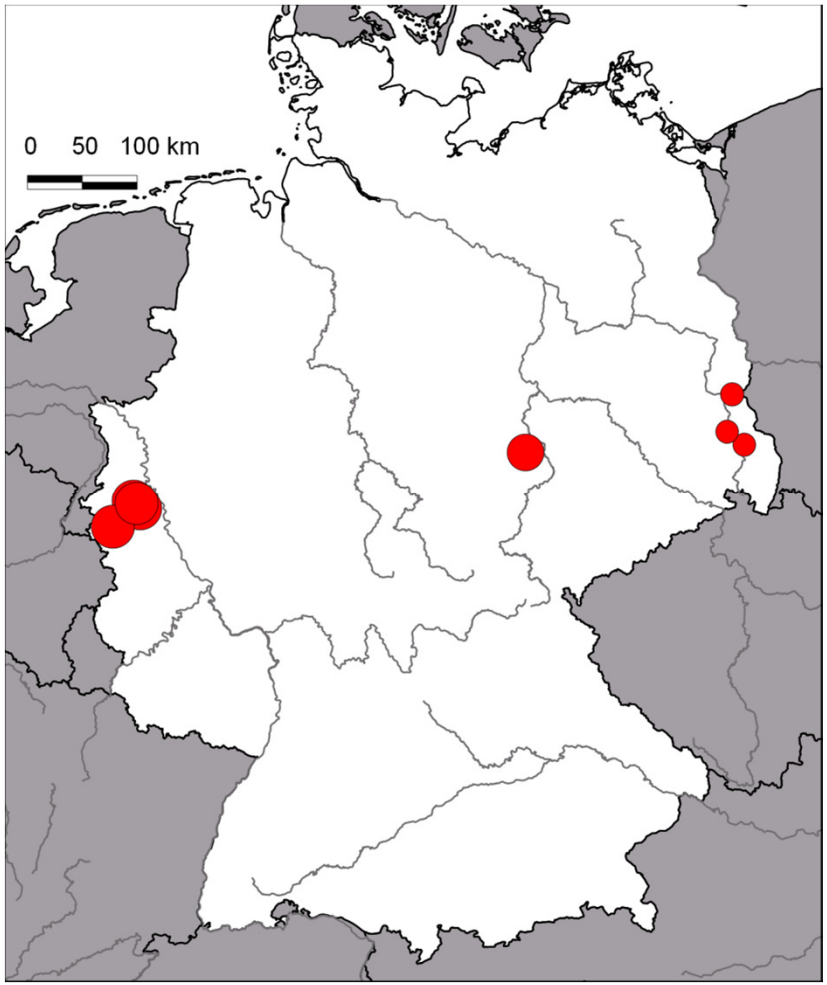


- Assuming hydrogen production proportional to the potential wind energy production in each German state as estimated in [BWE, 2011] (~ 200 TWh_e/year)

Hydrogen production (kt/year)

- 1,400
- 400
- 200
- 100
- 50

Gasification of domestic lignite



- Assuming hydrogen production proportional to the German domestic lignite reserves as estimated in [DEBRIV, 2011]

Hydrogen production (kt/year)

- 1,400
- 400
- 200
- 100
- 50

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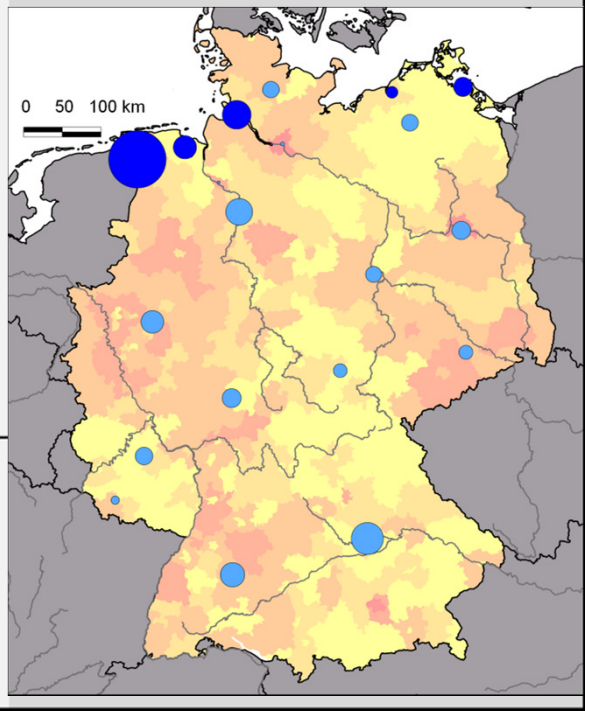
Definition of scenarios – Naming convention

H_2 Demand	H_2 Production: Electrolysis with **offshore** wind generated electricity: **50%**; Electrolysis with **onshore** wind generated electricity: **50%**
All districts	A-100%
Districts with demand > 8000 t/year	A-8000



Scenario names

Definition of scenarios – Naming convention

H_2 Demand	H_2 Production: Electrolysis with **offshore** wind generated electricity: **50%**; Electrolysis with **onshore** wind generated electricity: **50%**
All districts	A-100%
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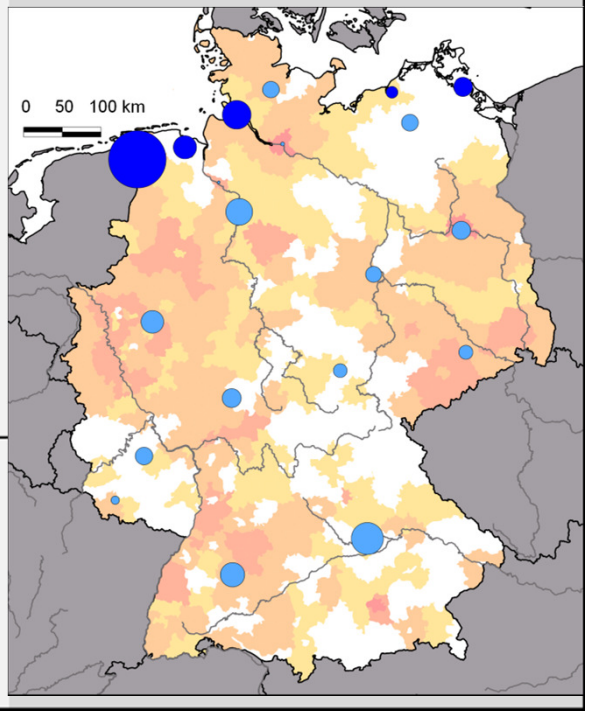
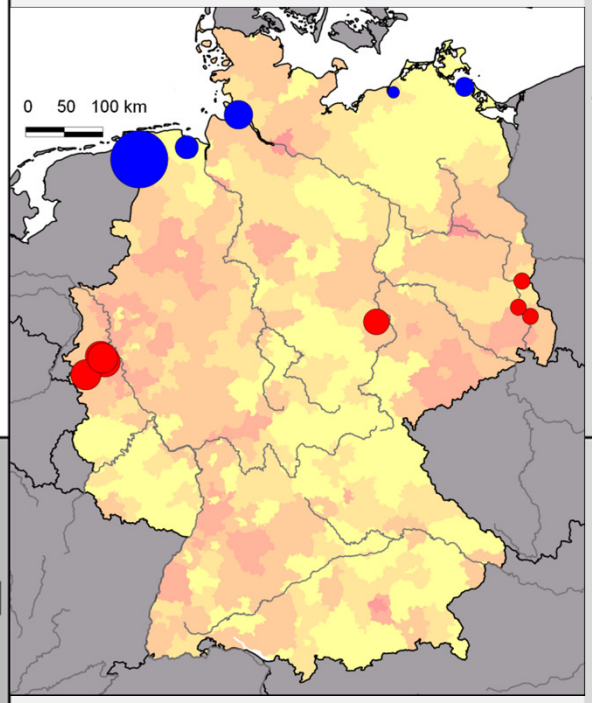
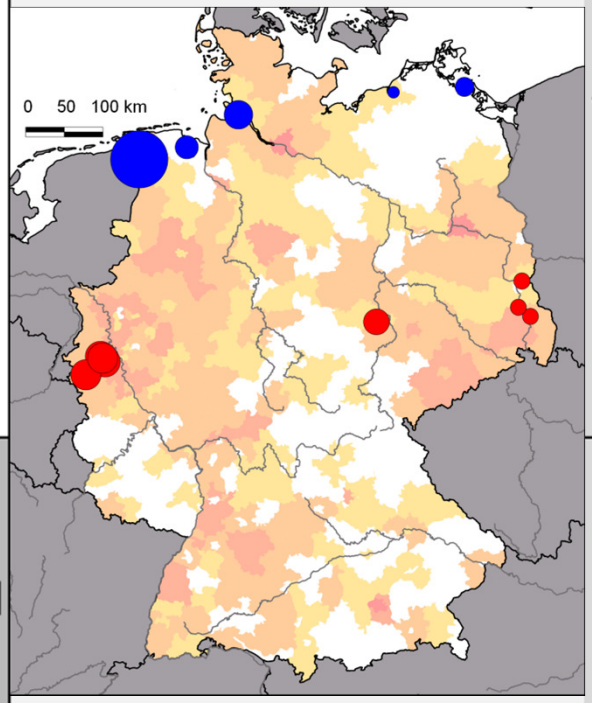


Scenario names

Definition of scenarios – Naming convention

	H_2 Production	
H_2 Demand		Electrolysis with **offshore** wind generated electricity: **50%** **Gasification of domestic lignite: 50%**
All districts		B-100%
Districts with demand > 8000 t/year		B-8000
	Scenario names	

Definition of scenarios – Naming convention

	H_2 Production	
H_2 Demand		Electrolysis with **offshore** wind generated electricity: **50%** **Gasification of domestic lignite: 50%**
All districts		B-100%
Districts with demand > 8000 t/year		B-8000
	Scenario names	

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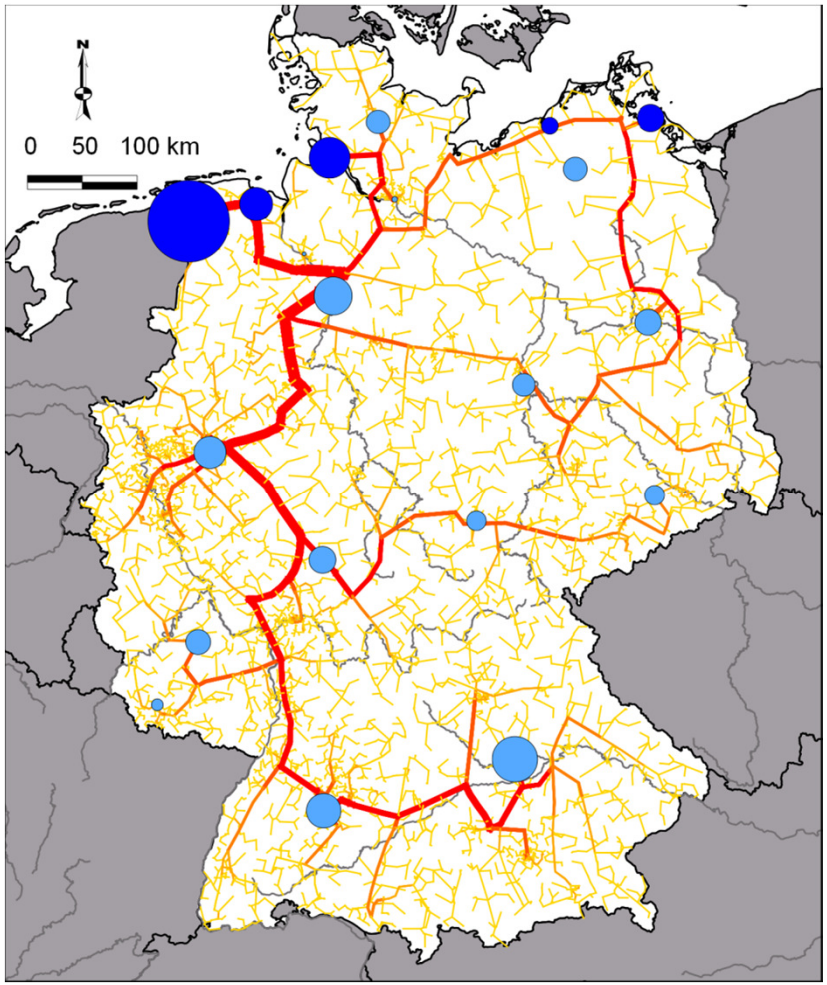
Summary of scenarios

		H_2 Production	
		Electrolysis with **offshore** wind generated electricity: **50%** Electrolysis with **onshore** wind generated electricity: **50%**	Electrolysis with **offshore** wind generated electricity: **50%** **Gasification of domestic lignite**: **50%**
H_2 Demand	**All districts**	A-100%	B-100%
	Districts with demand > 8000 t/year	A-8000	B-8000
		Scenario names	

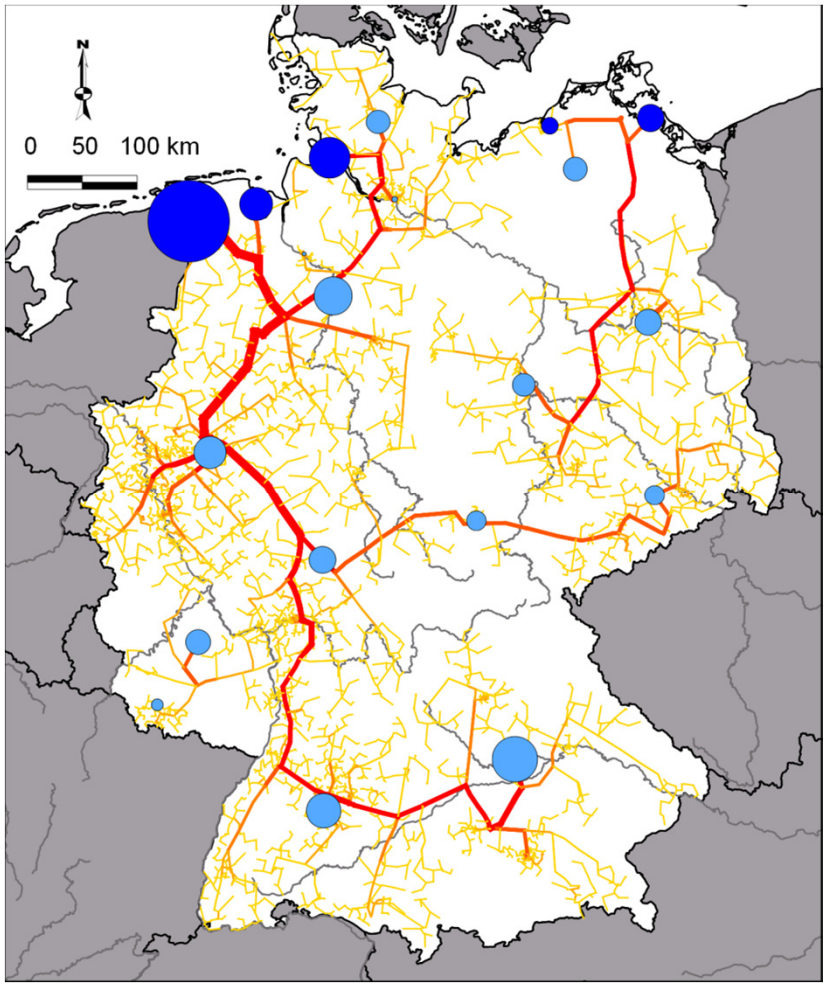
Scenario A-100% (413 districts – 7,826 stations)



H_2 transmission network		
Scenarios -	Exemplary cost [milliard €$_{2010}$]	Length [km]
A-100%	5.93	12,046

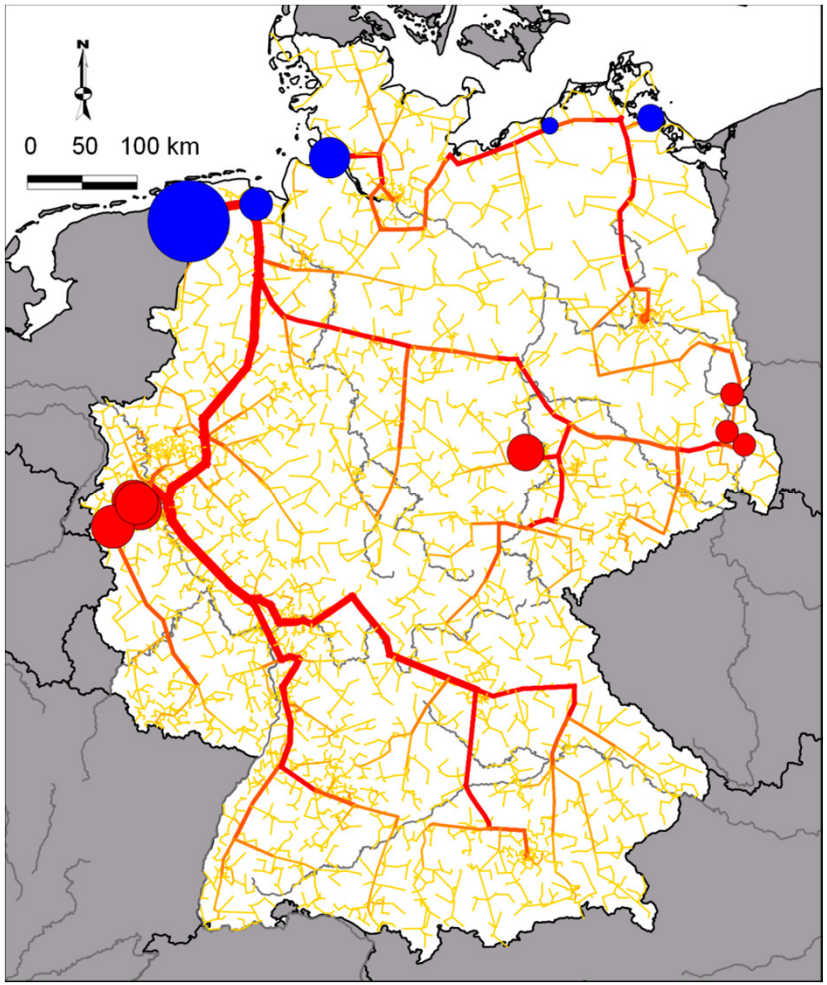
H_2 distribution network		
A-100%	10.72	26,388

Scenario A-8000 (242 districts – 6,227 stations)



H_2 transmission network		
Scenarios -	Exemplary cost [milliard €$_{2010}$]	Length [km]
A-100%	5.93	12,046
A-8000	4.40	9,246
H_2 distribution network		
A-100%	10.72	26,388
A-8000	8.12	19,653

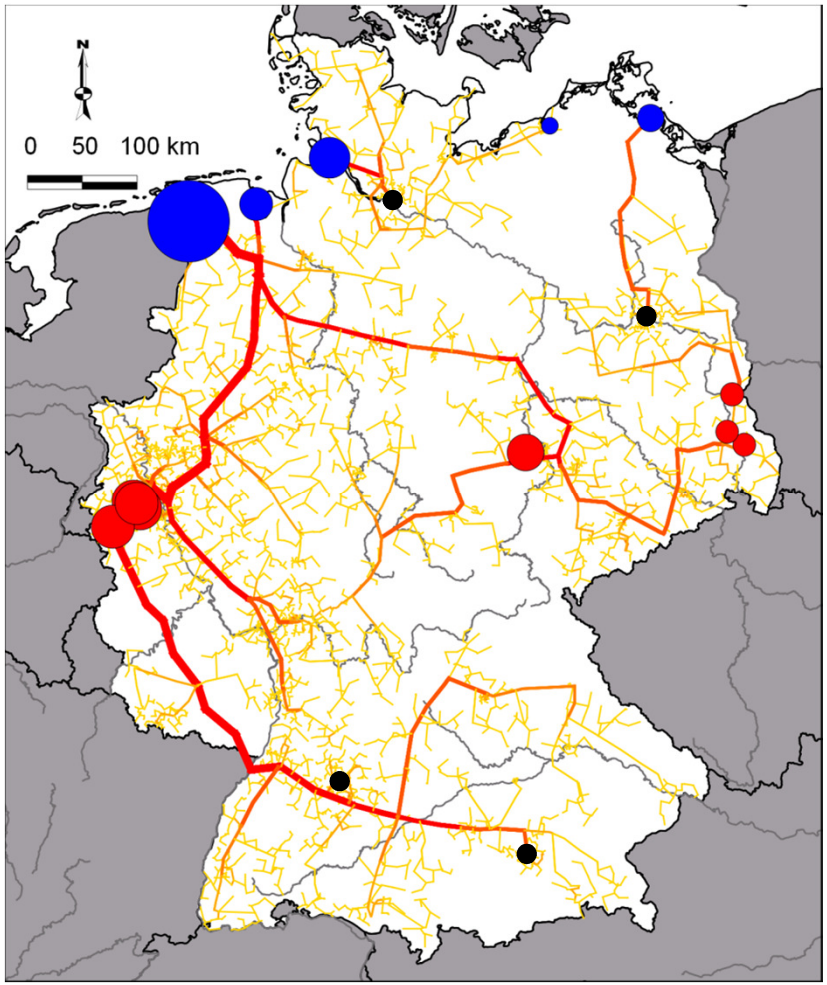
Scenario B-100% (413 districts – 7,826 stations)



H_2 transmission network		
Scenarios -	Exemplary cost [milliard €$_{2010}$]	Length [km]
B-100%	5.85	12,009

H_2 distribution network		
B-100%	10.72	26,388

Scenario B-8000 (242 districts – 6,227 stations)



H_2 transmission network		
Scenarios -	Exemplary cost [milliard €$_{2010}$]	Length [km]
B-100%	5.85	12,009
B-8000	4.51	9,273
H_2 distribution network		
B-100%	10.72	26,388
B-8000	8.12	19,653

Conclusions and discussion

- This tool generates a sensible pipeline network between several sources and sinks
- Localisation, capacities and needs of sources and sinks respectively can be defined on an individual basis
- Preferred routes can be defined for the construction of a new infrastructure (existing gas network here)
- Further works are planned to test additional scenarios and assumptions (market penetration of H_2-fuelled vehicles, capacities of refuelling stations, pipeline cost functions)

- Simulating the temporal network deployment is not implemented yet (simulations show the final the network)
- Time variability (production or demand) is not considered

Thank you for your attention

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In collaboration with:

Forschungszentrum Jülich GmbH – Institute of Energy and Climate Research – Fuel Cells

Ingmen GmbH

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[MWV, 2011] Mineralölwirtschaftsverband e.V. (MWV) - Entwicklung des Tankstellenbestandes

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[DEBRIV, 2011] Braunkohle in Deutschland 2011 - Profil eines Industriezweiges. Bundesverband Braunkohle (DEBRIV)

GIS-based analysis of hydrogen pipeline infrastructure for different supply and demand options

Back-up slides

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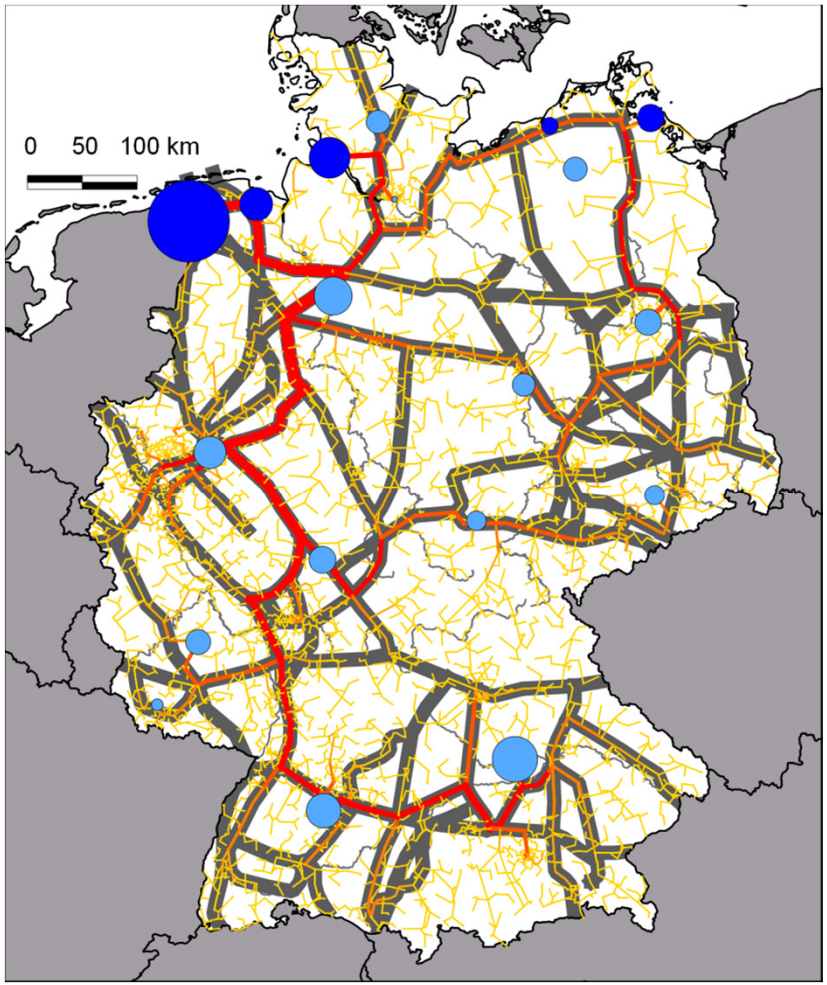
Scenario A-100% (413 districts – 7,826 stations)



H_2 transmission network		
Scenarios -	Exemplary cost [milliard €$_{2010}$]	Length [km]
A-100%	5.93	12,046
Preferred routes for transmission network (gas grid)		
H_2 distribution network		
A-100%	10.72	26,388

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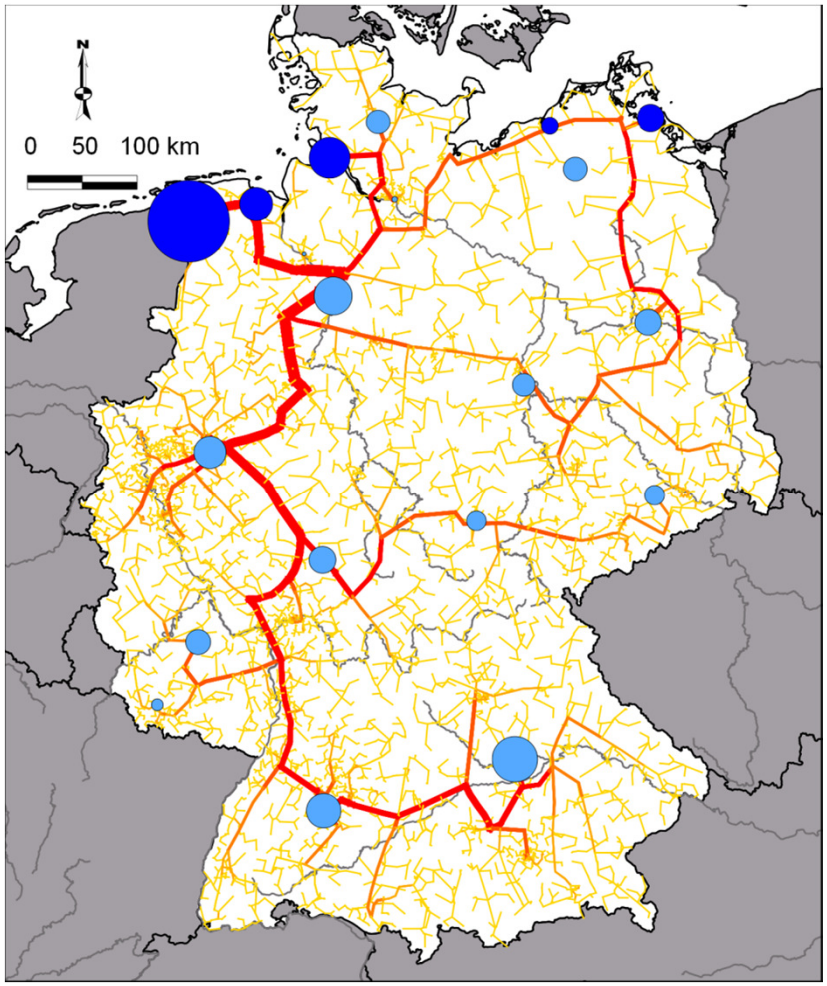
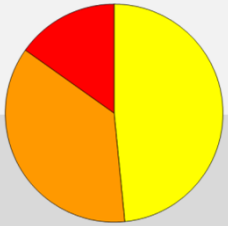
Scenario A-100% (413 districts – 7,826 stations)



H_2 transmission network		
Scenarios -	Diameter classes	Length [km]
A-100%		12,046
100 mm		101 – 300 mm > 301 mm

H_2 distribution network		
A-100%		26,388
100 mm		> 101 mm

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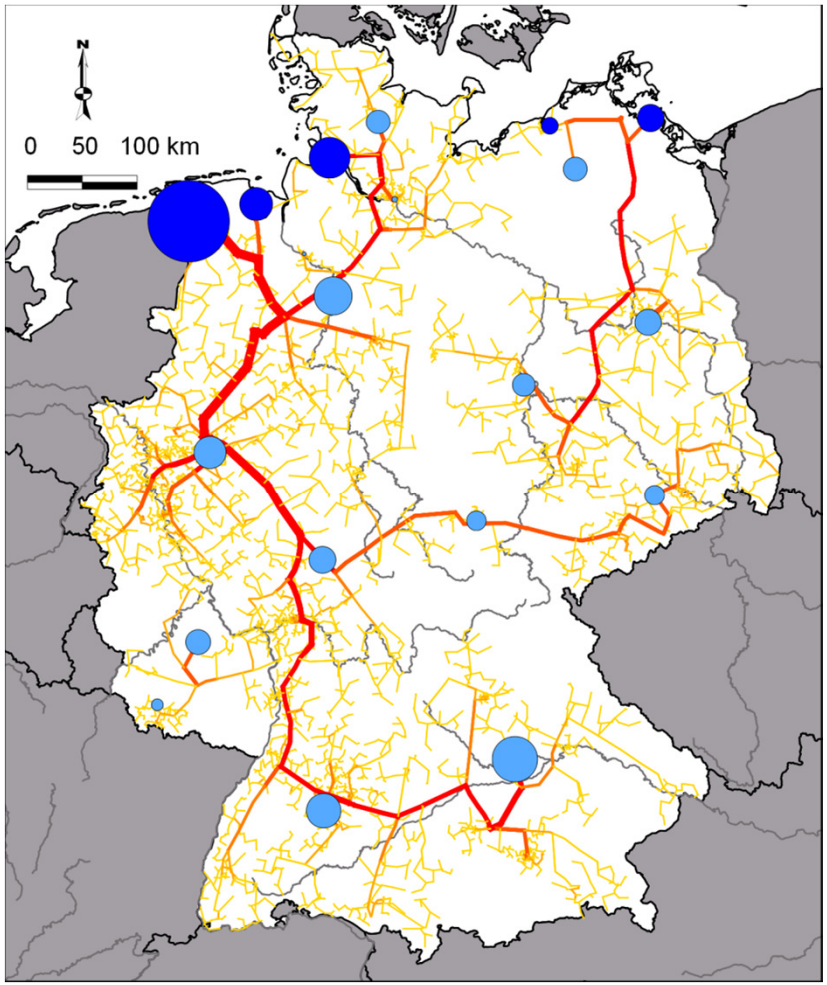
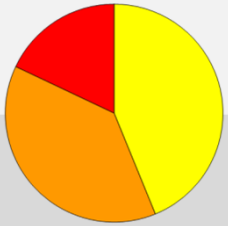
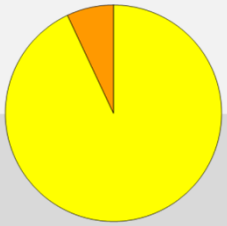
Scenario A-8000 (242 districts – 6,227 stations)



H_2 transmission network		
Scenarios -	Diameter classes	Length [km]
100 mm 101 – 300 mm > 301 mm		
A-8000		9,246

H_2 distribution network		
100 mm > 101 mm		
A-8000		19,653

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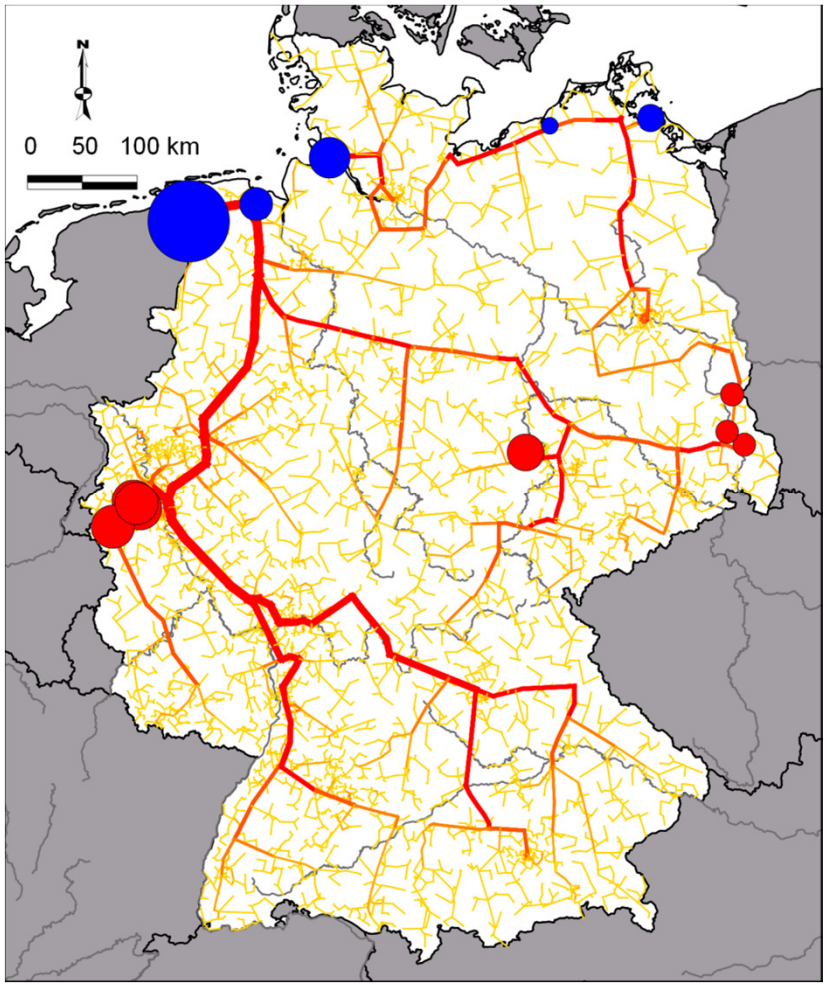
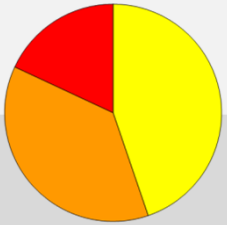
Scenario B-100% (413 districts – 7,826 stations)



H_2 transmission network		
Scenarios -	Diameter classes	Length [km]
B-100%		12,009
100 mm		101 – 300 mm > 301 mm

H_2 distribution network		
B-100%		26,388
100 mm		> 101 mm

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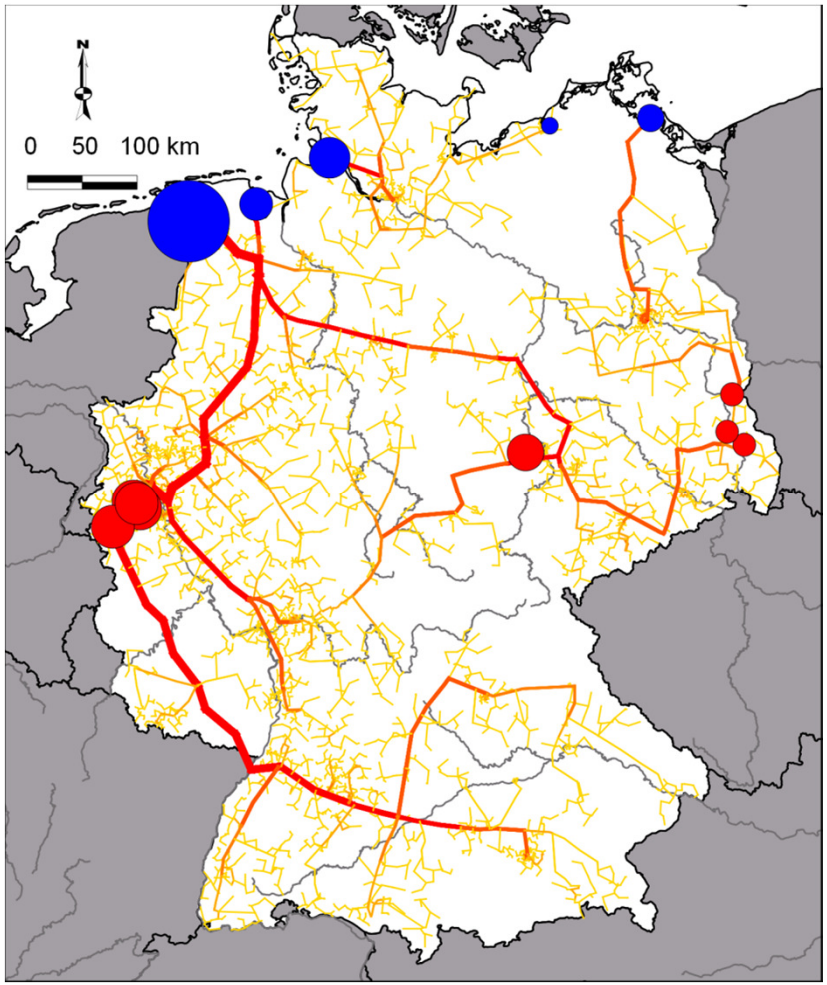
Scenario B-8000 (242 districts – 6,227 stations)



H_2 transmission network		
Scenarios -	Diameter classes	Length [km]
B-8000	100 mm 101 – 300 mm > 301 mm	9,273

H_2 distribution network		
B-8000	100 mm > 101 mm	19,653