Virtual Academy for Sustainability

WBGU
German Advisory Council on Global Change

Lecture 5: Technological and Economic Feasibility of the Transformation

Episode 2: Global Energy Transformation: Challenges and Possible Solutions

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Fraunhofer Institute for Wind Energy and Energy System Technology
Kassel (Germany)

World in Transition: A Social Contract for Sustainability supported by

DBU
Deutsche Bundesstiftung Umwelt

- Episode 1: Global Energy Transformation: Historical Dynamics, Possible Pathways and Investment Needs (Prof. Dr. Nebojsa Nakicenovic)
- **Episode 2: Global Energy Transformation: Challenges and Possible Solutions (Prof. Dr. Jürgen Schmid)**
- Episode 3: Interview

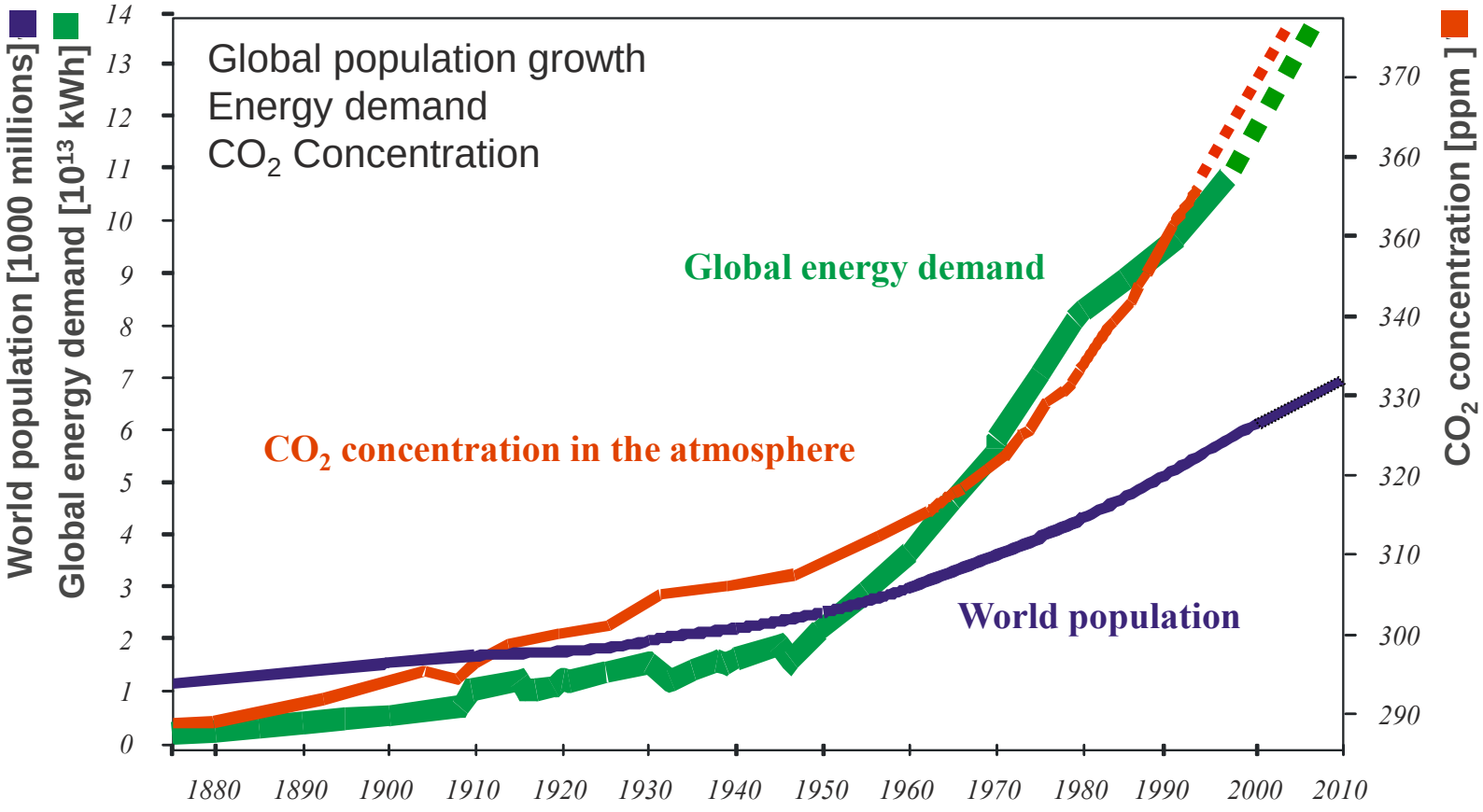
Learning Outcomes

1. You have an understanding of the sustainable potentials of renewable energies in relation to the future energy demand.
2. You understand the efficiency advantage of renewable energy use.
3. You are able to evaluate the challenges concerning the use of renewable energies and to classify the corresponding countermeasures.
4. You have an overview of a possible path for the transformation of the power supply sector.
5. You are able to assess the costs of renewable energy use in comparison to conventional energy supply systems.

Content

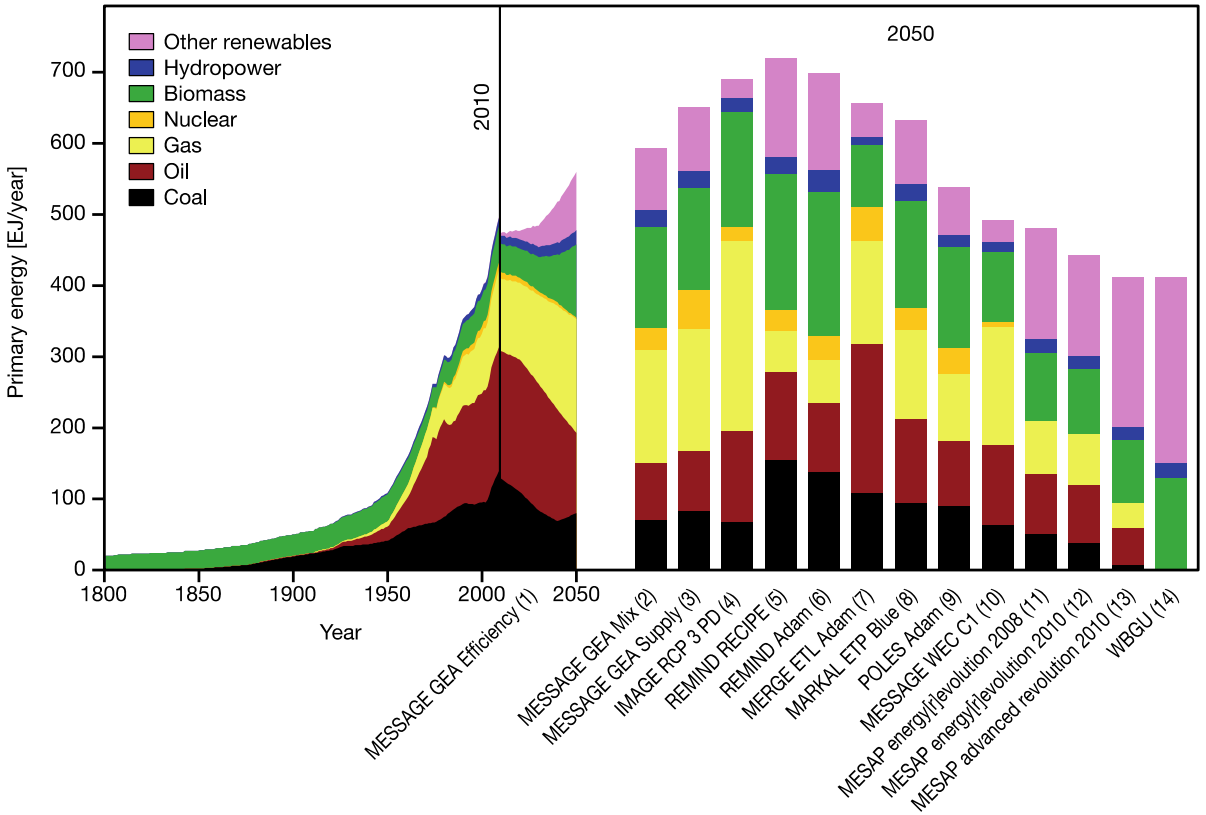
- **CO_2 Emissions, Energy Demand**
- Potential of Renewable Energy Production
- Efficiency of Renewable Energy Use
    - Power Supply
    - Heat Supply
    - Transport
- Balancing of Renewable Energy Feed-In
    - Power Network
    - Energy Management
    - Energy Storage
- Costs of Renewable Energy Use

Global Situation and Future Development



Source: Schmid, 2012 (unpublished)

Global Primary Energy Demand in Transformative Scenarios



Source: WBGU, based on data from Nakicenovic et al.,1998; EREC und Greenpeace, 2008, 2010; IEA, 2008b; Edenhofer et al., 2009a, 2010; IIASA, 2009; GEA, 2011

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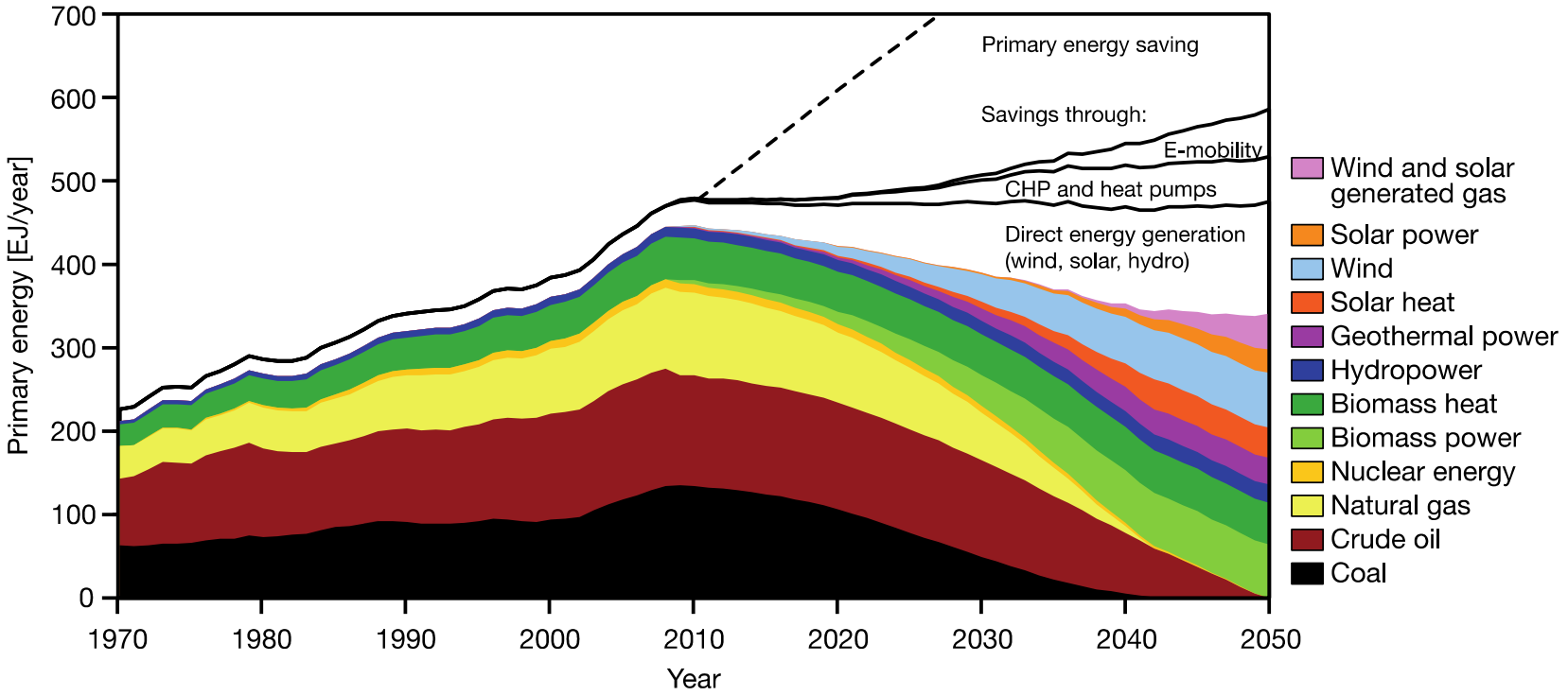
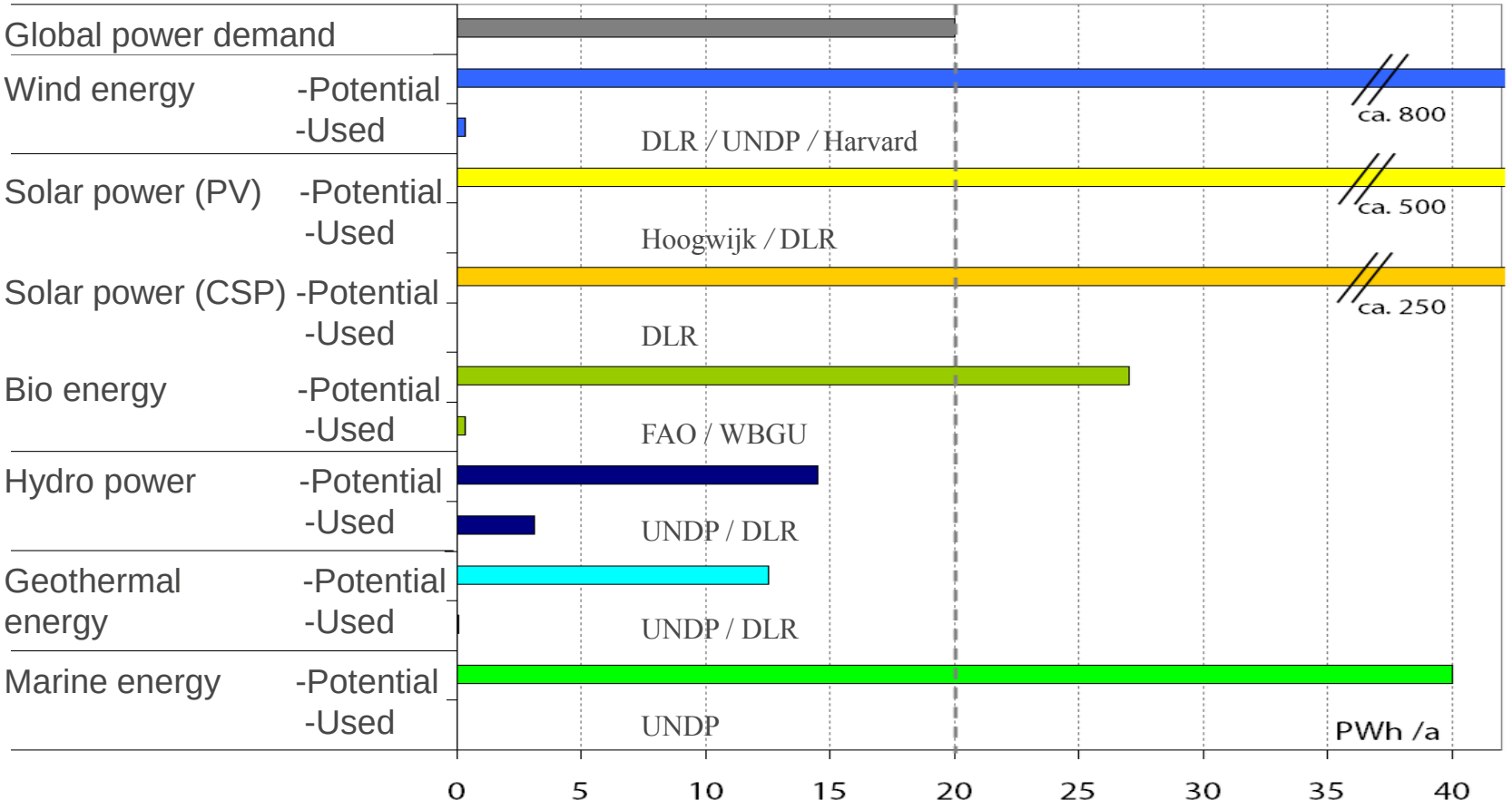
Vision: Global Renewable Energy Supply by 2050



The scenario is based on an extrapolation of current expansion rates for renewable energies. Renewables are accorded priority in the energy system, leading to the substitution of existing conventional energy carriers. The economy of existing infrastructures and the availability of key materials have not been taken into account. The dotted line shows the development of global primary energy demand without transformation, based on the GEA baseline scenario.

Source: WBGU, 2011

Technical Potential of Renewable Energies Worldwide



Source: refer to figure

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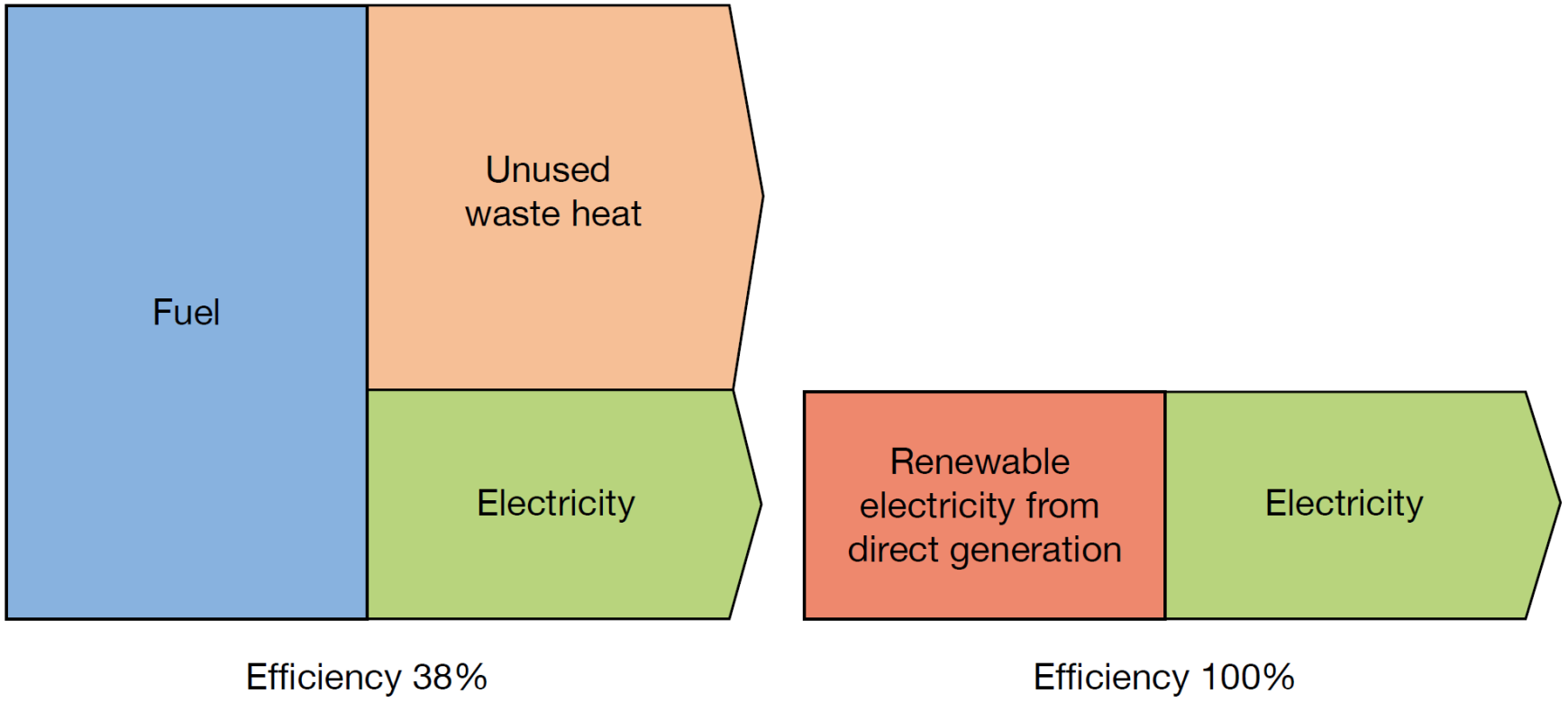
Efficiency leap:

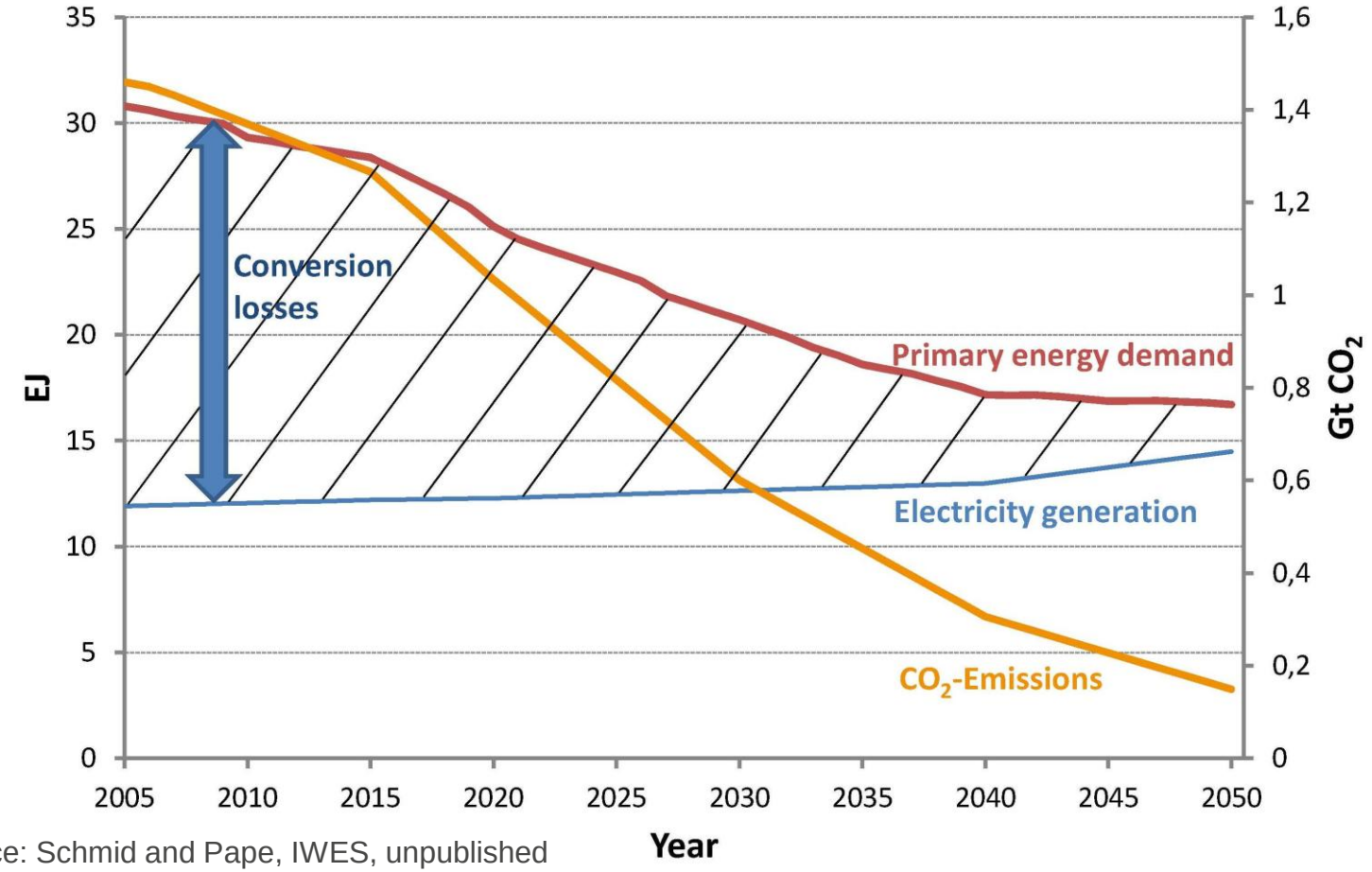
Conventional power plants and direct power from renewable energies



Source: Sterner et al., 2008; WBGU, 2008

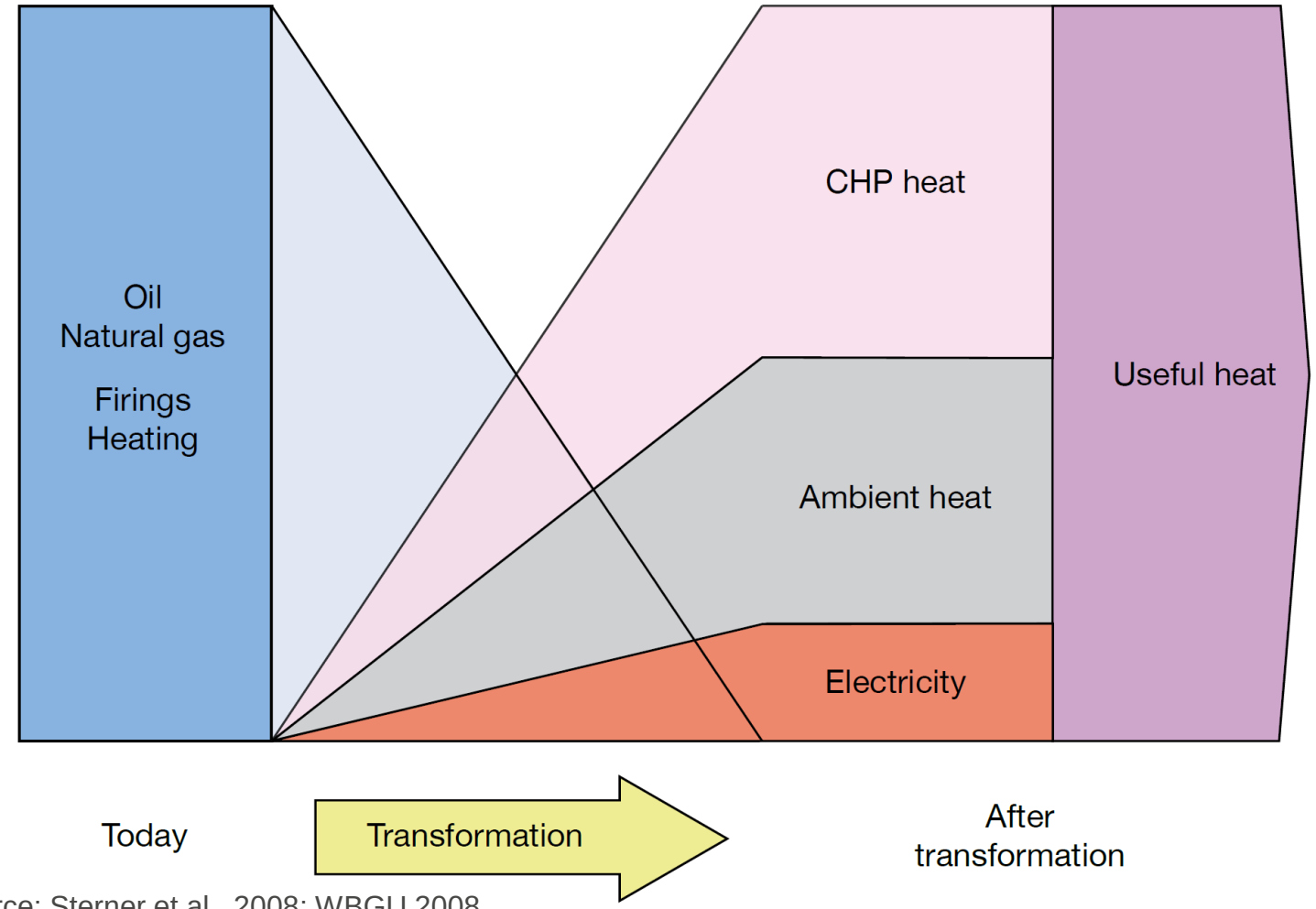
Power supply:

Renewable energies reduce the demand for primary energies and CO_2-emissions



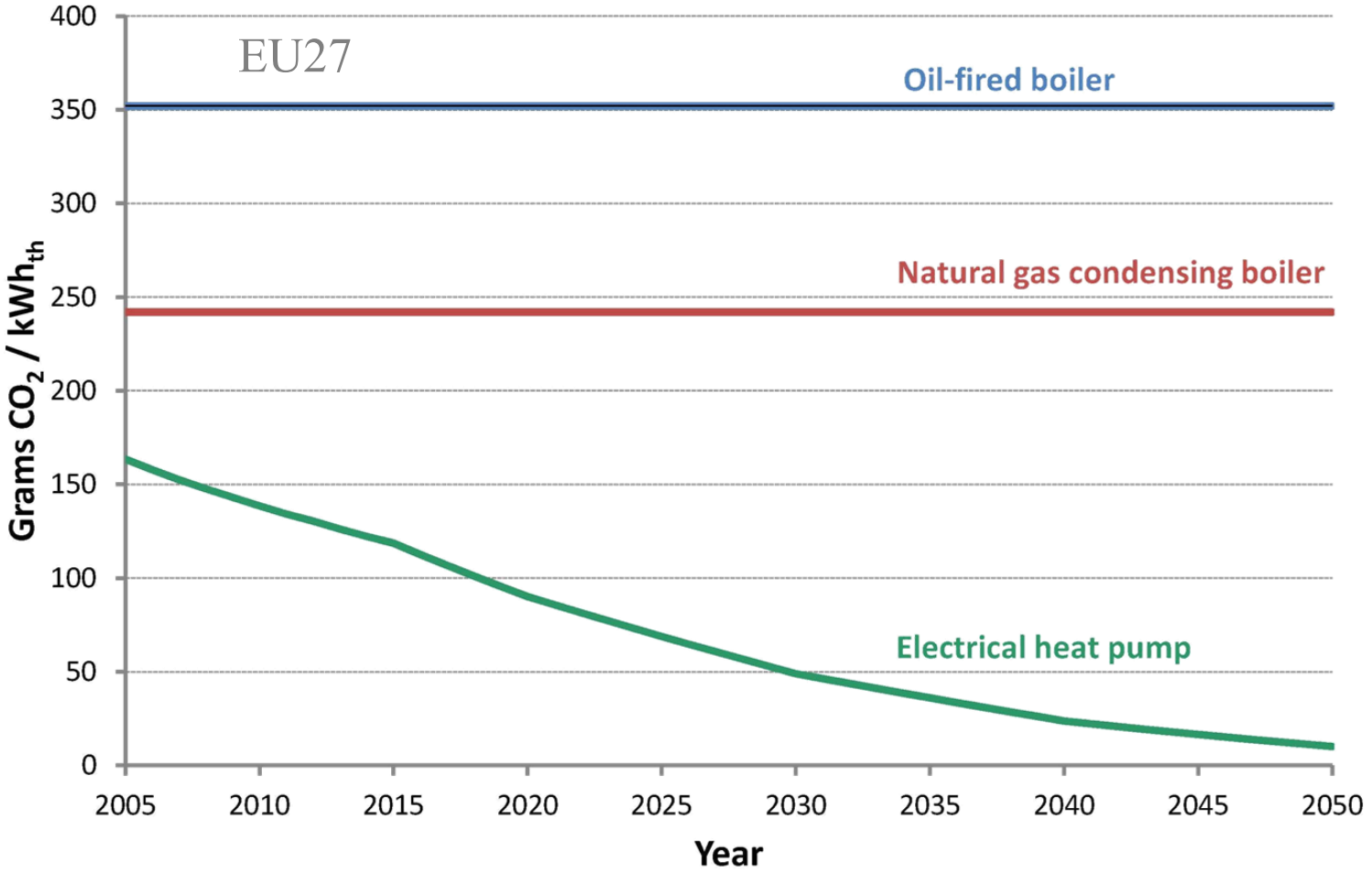
Source: Schmid and Pape, IWES, unpublished

Transformation of Heat Supply



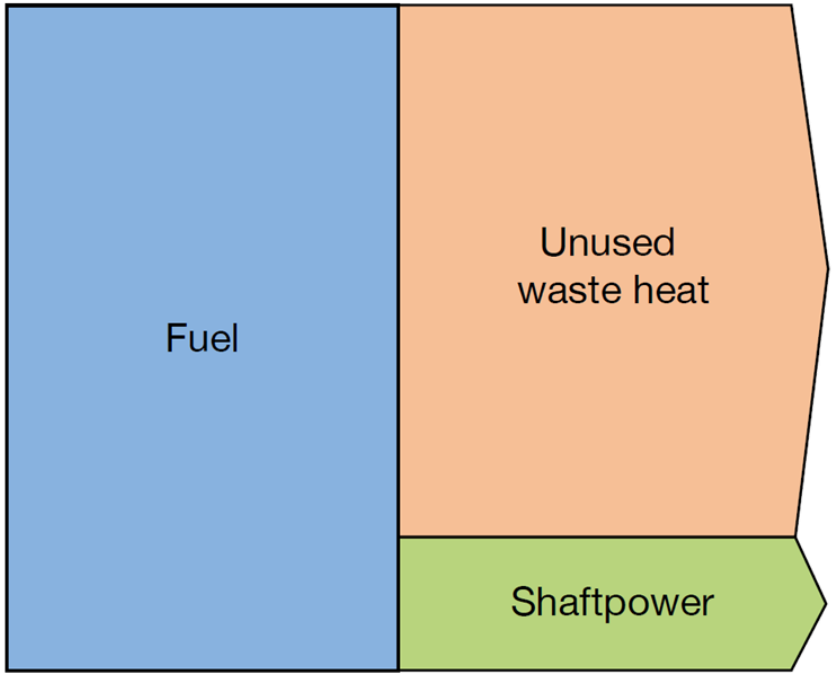
Source: Sterner et al., 2008; WBGU 2008

Heat Supply: Renewable Energies reduce CO_2-emissions



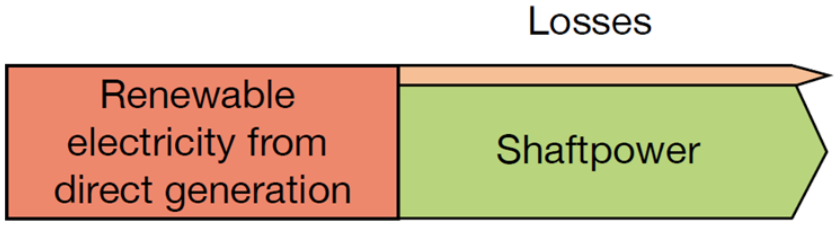
Source: Schmid, Pape, IWES

Transformation of Transport Sector



Combustion engine
Efficiency 20%

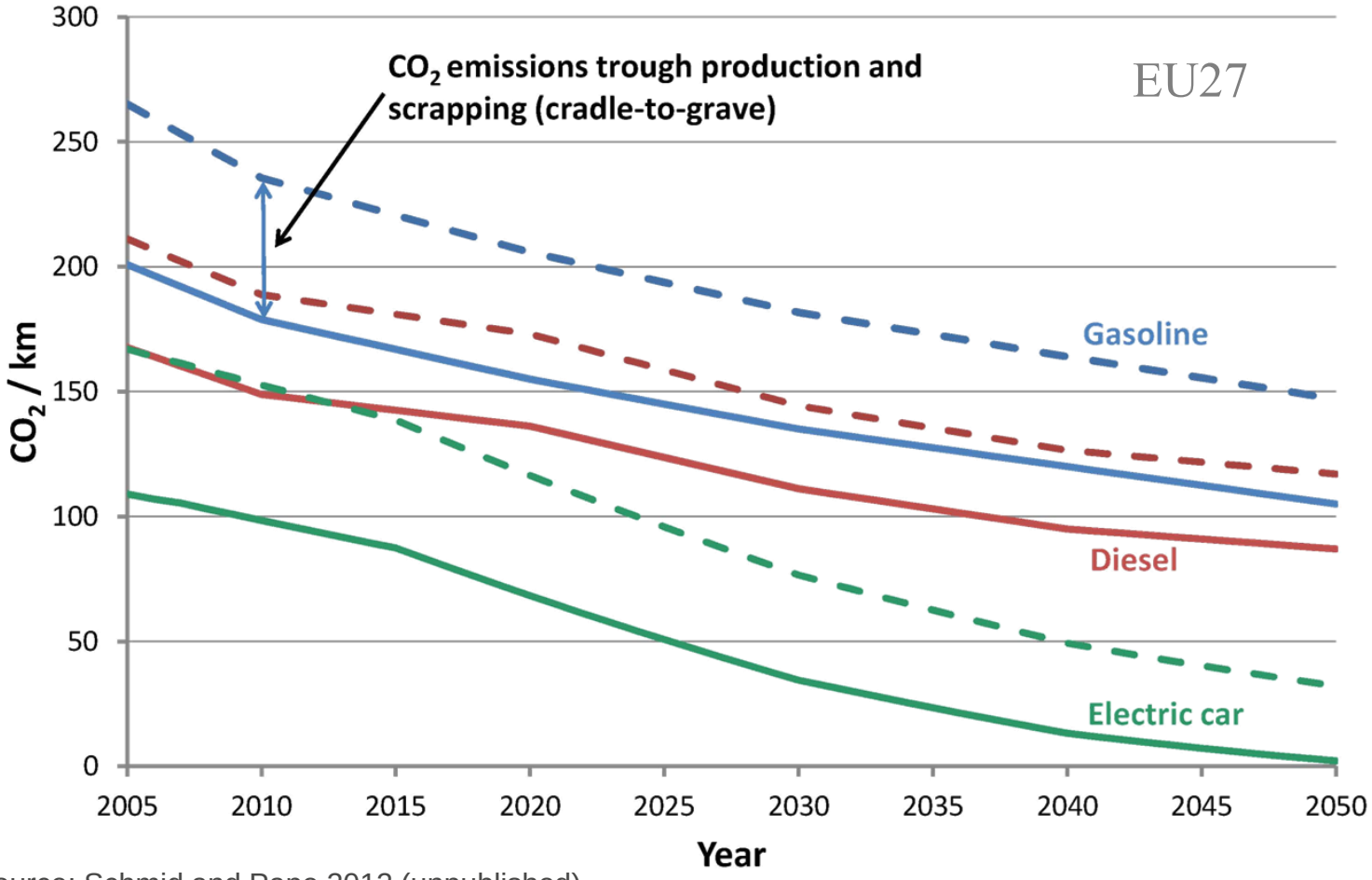
- Advantages of electric mobility:
- Use of waste heat possible
- CO_2-sequestration possible
- No fine dust in the cities
- Less noise
- Storage system



Electric drive
Efficiency 80%

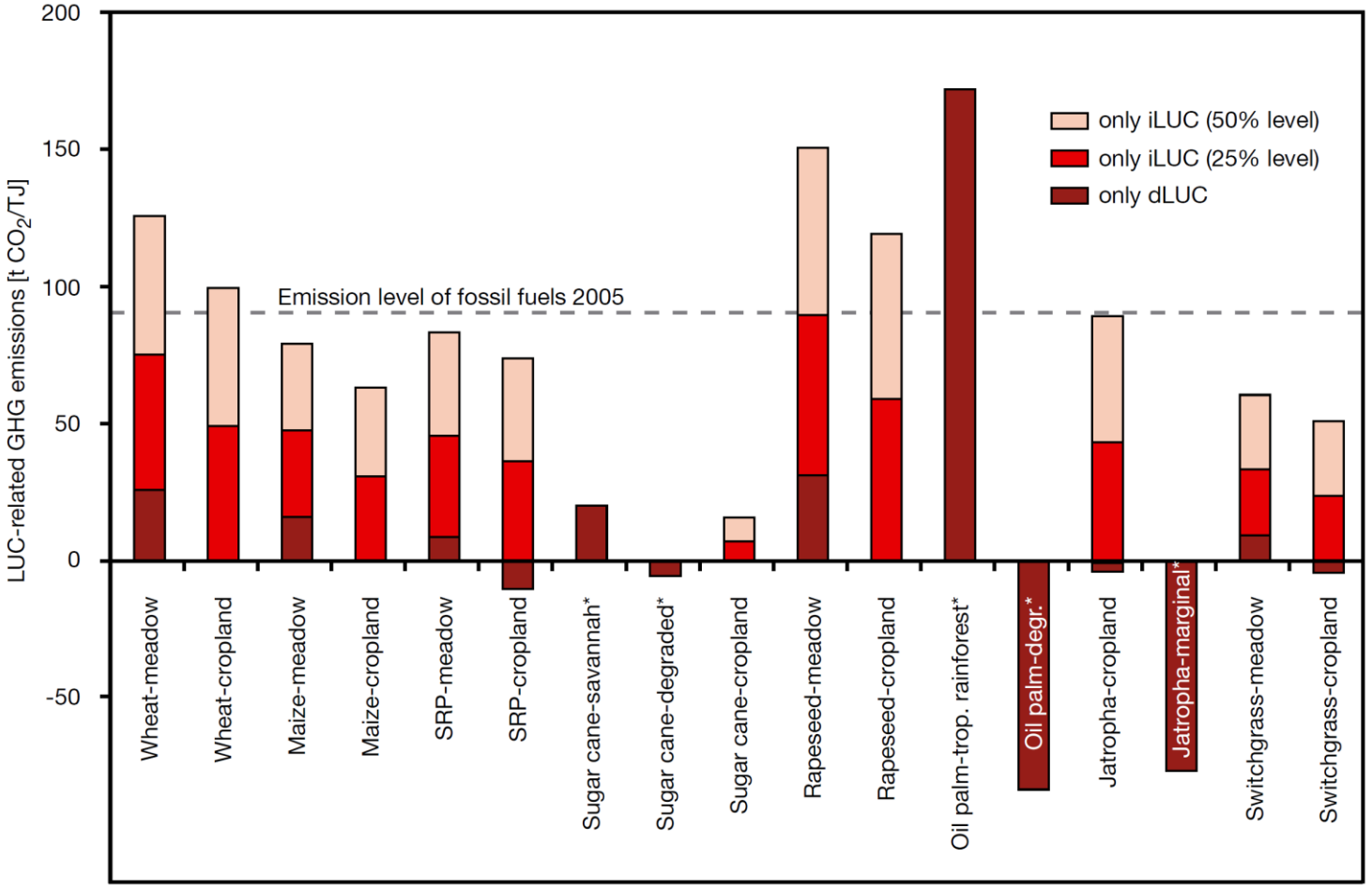
Source: Sterner et al., 2008; WBGU 2008

Efficiency Development in the Transport Sector



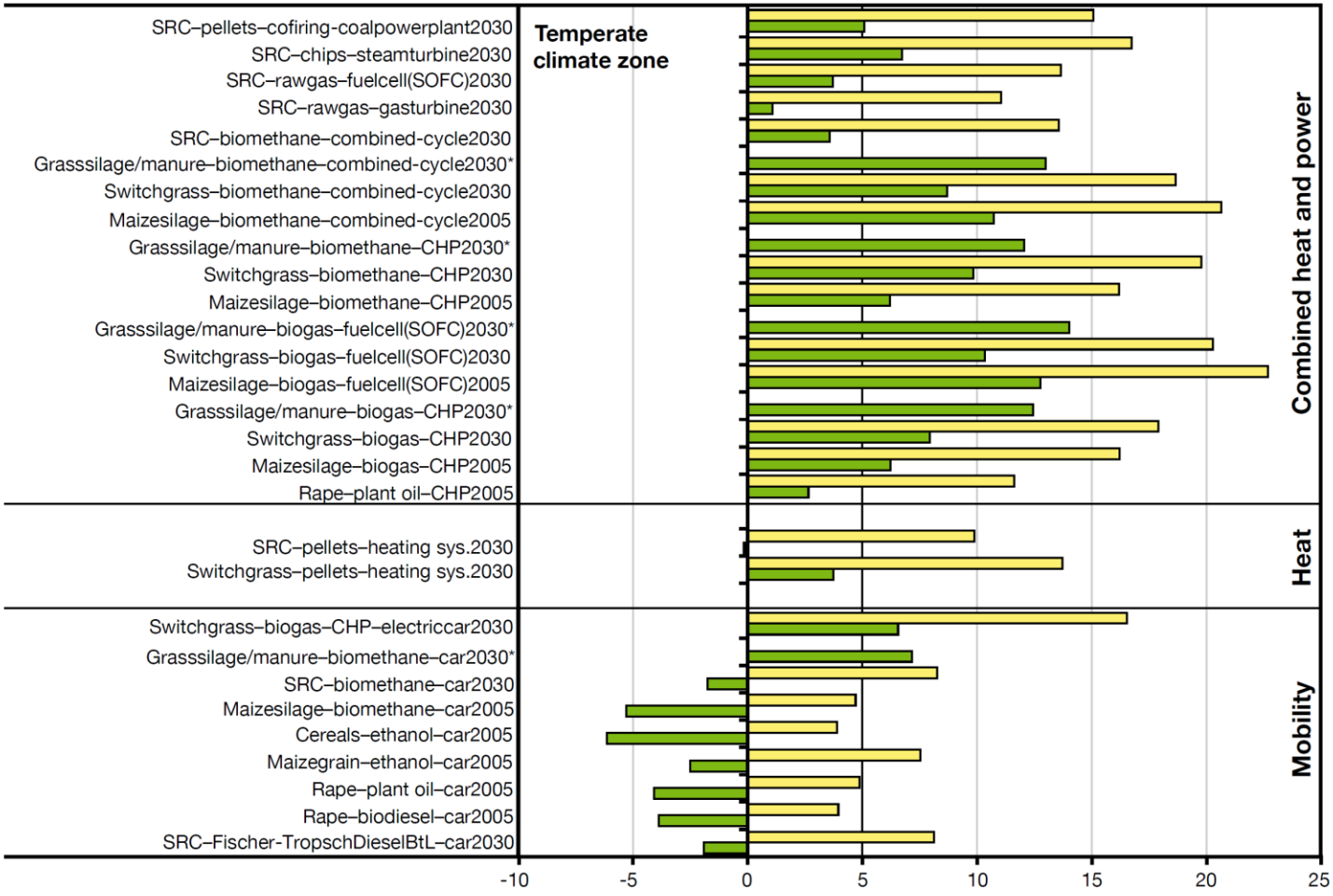
Source: Schmid and Pape 2012 (unpublished)

GHG Emissions from Direct and Indirect Land Use Change



Source: WBGU, 2008

GHG Reduction in Relation to Allocated Cropland



Source: WBGU, 2008

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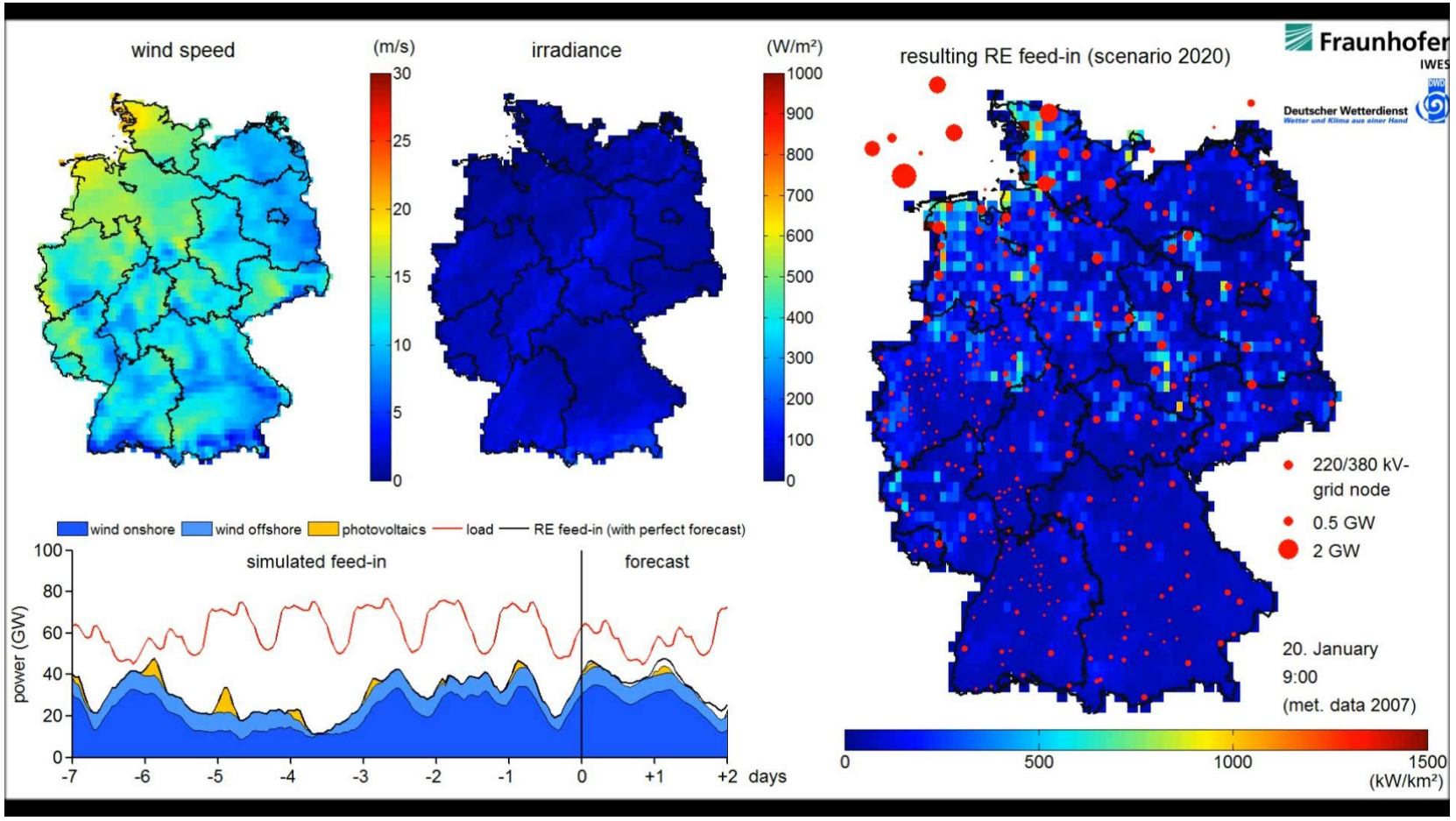
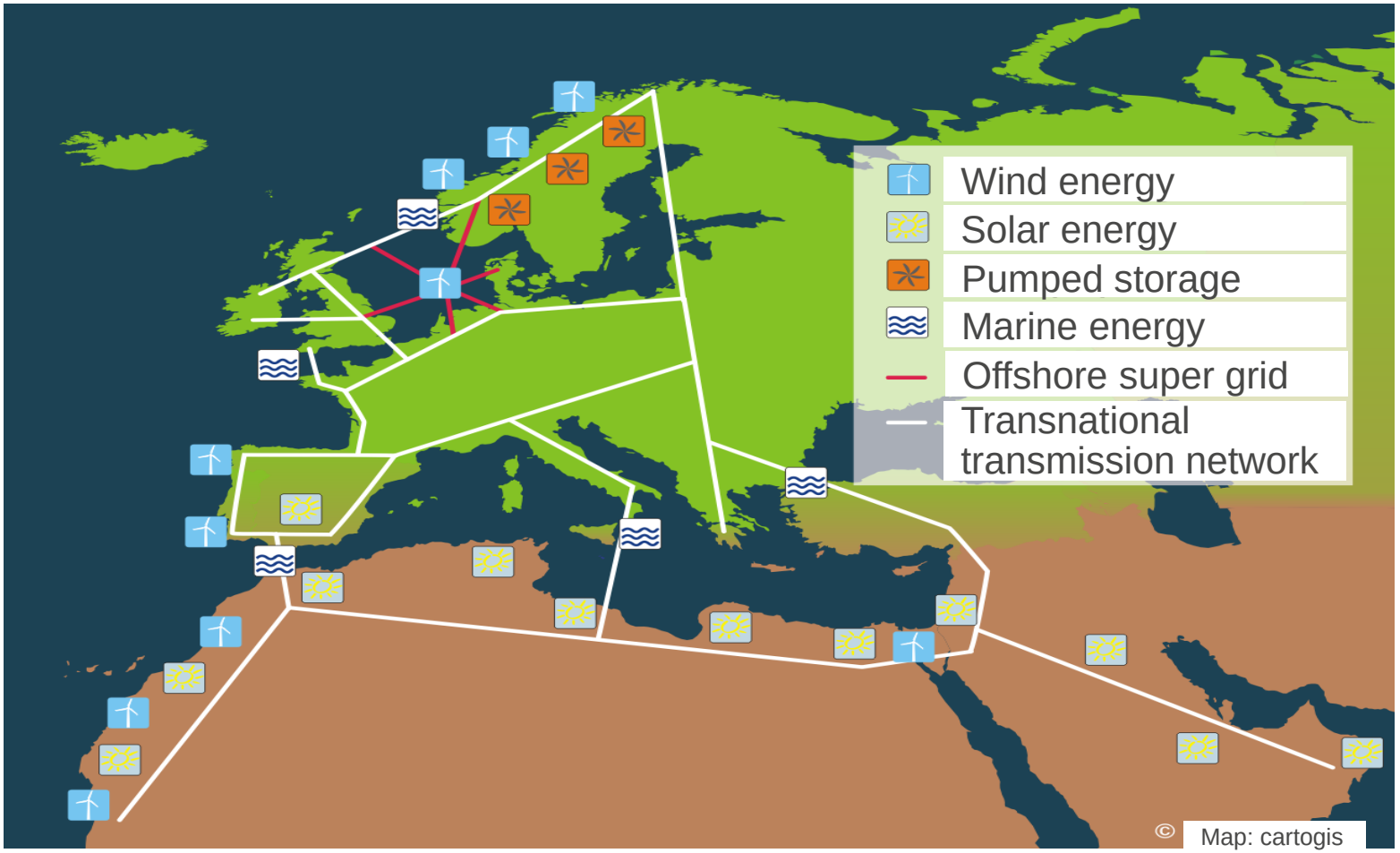
Characteristics of Renewable Energy Feed-In



Source: IWES, based on simulations for the German Lead Study 2011

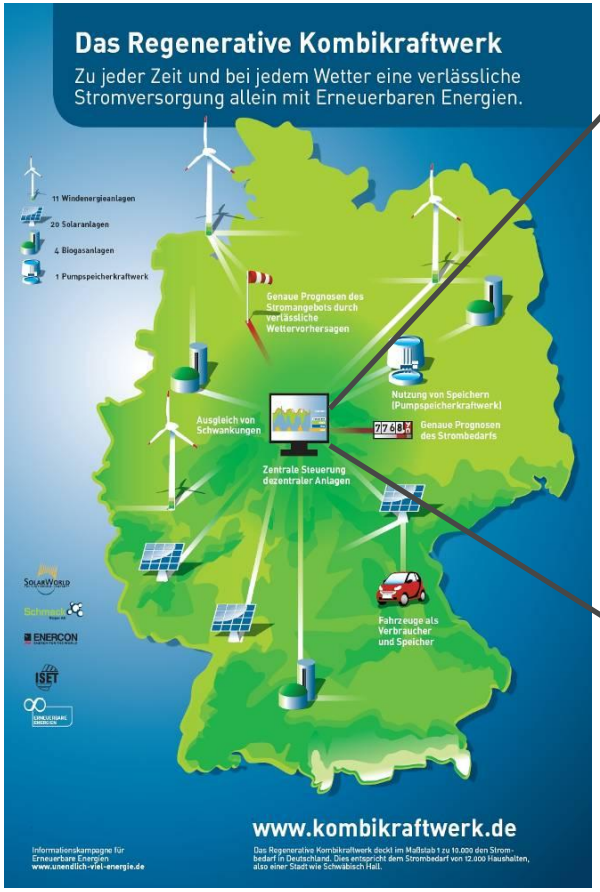
Grid Expansion

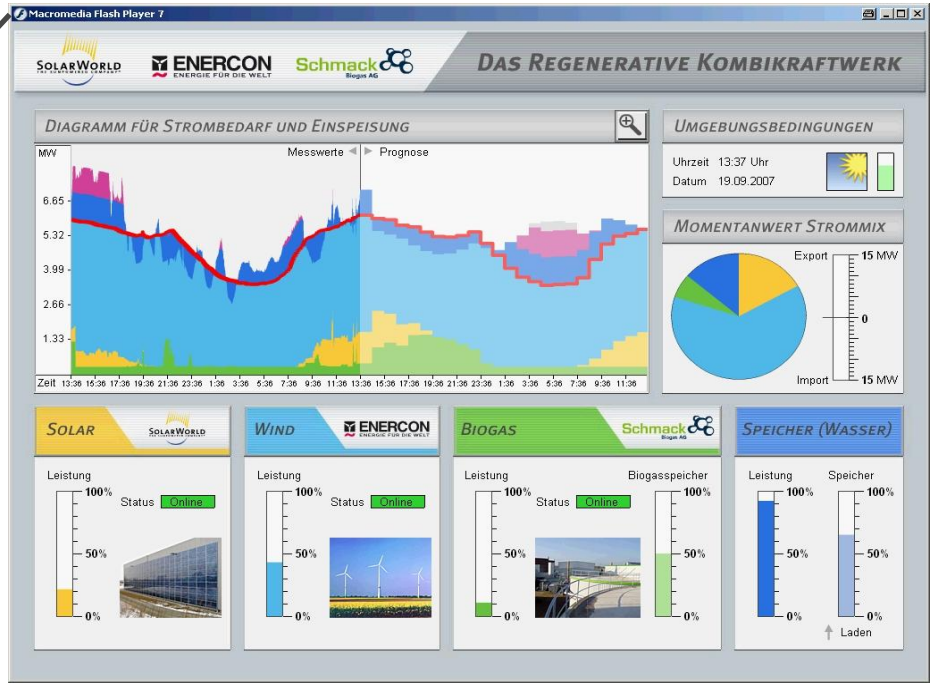


Source: IWES 2012 (unpublished)

The Renewable Combined Power Plant

Coverage of 1/10.000 of the German load curve at all times – Controlling real plants



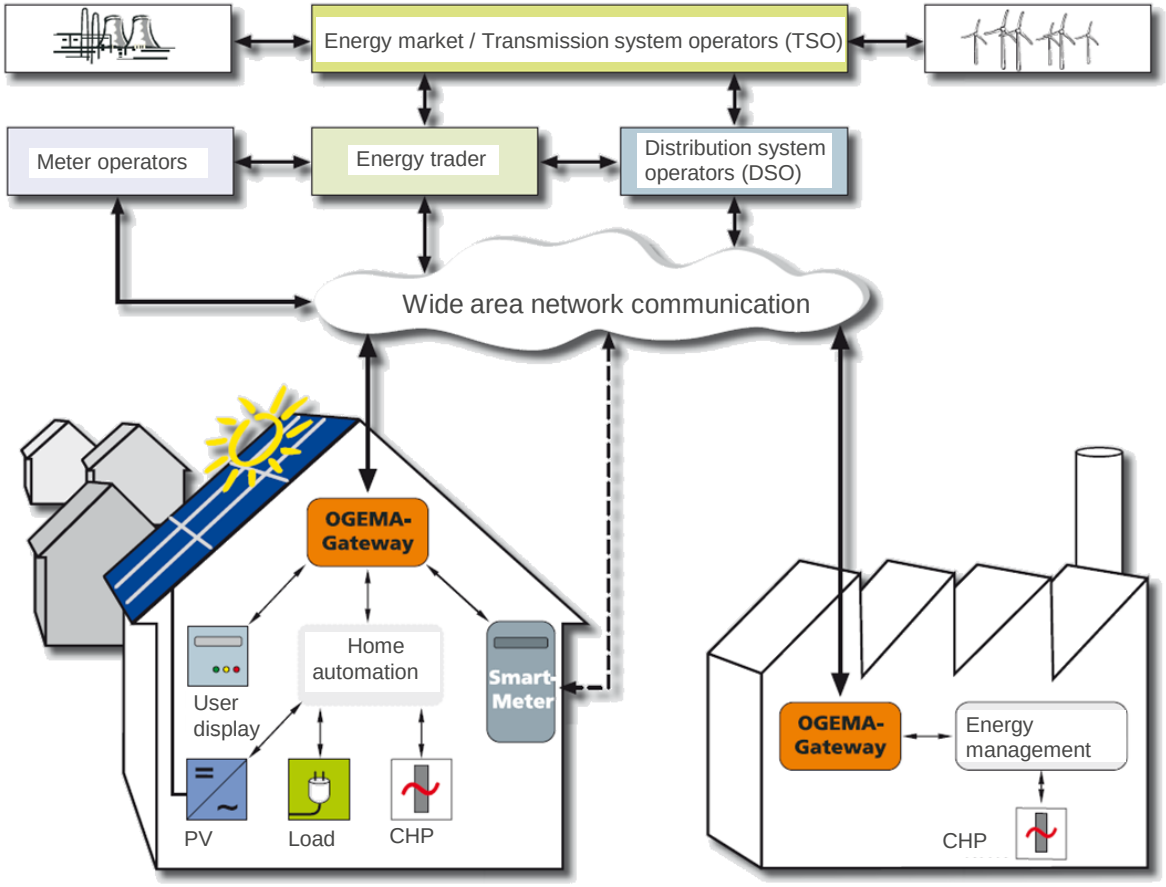


Wind	Solar	Biogas	Hydro	Import/ Export
12,6 MW	**5,5 MW**	**4,0 MW**	**1,0 MW**	**1,0 MW**

Source: ISET / IWES 2012

Load Management – Intelligent Distribution Networks

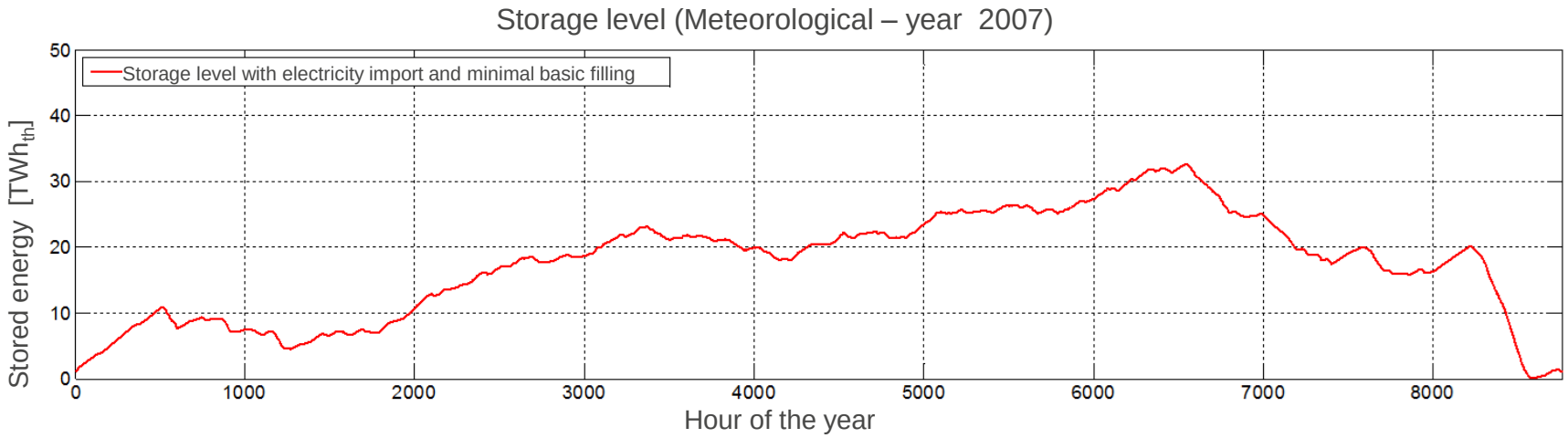
Bidirectional energy management interface

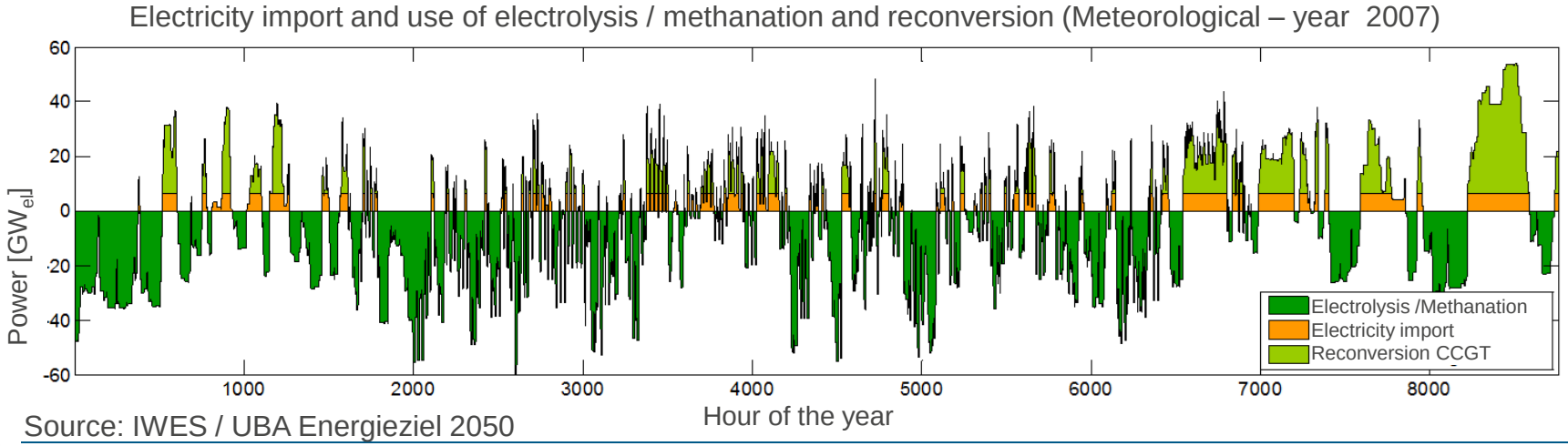


Source: Nestle et al., 2010

Example: Use of Gas Storage Facilities in Germany

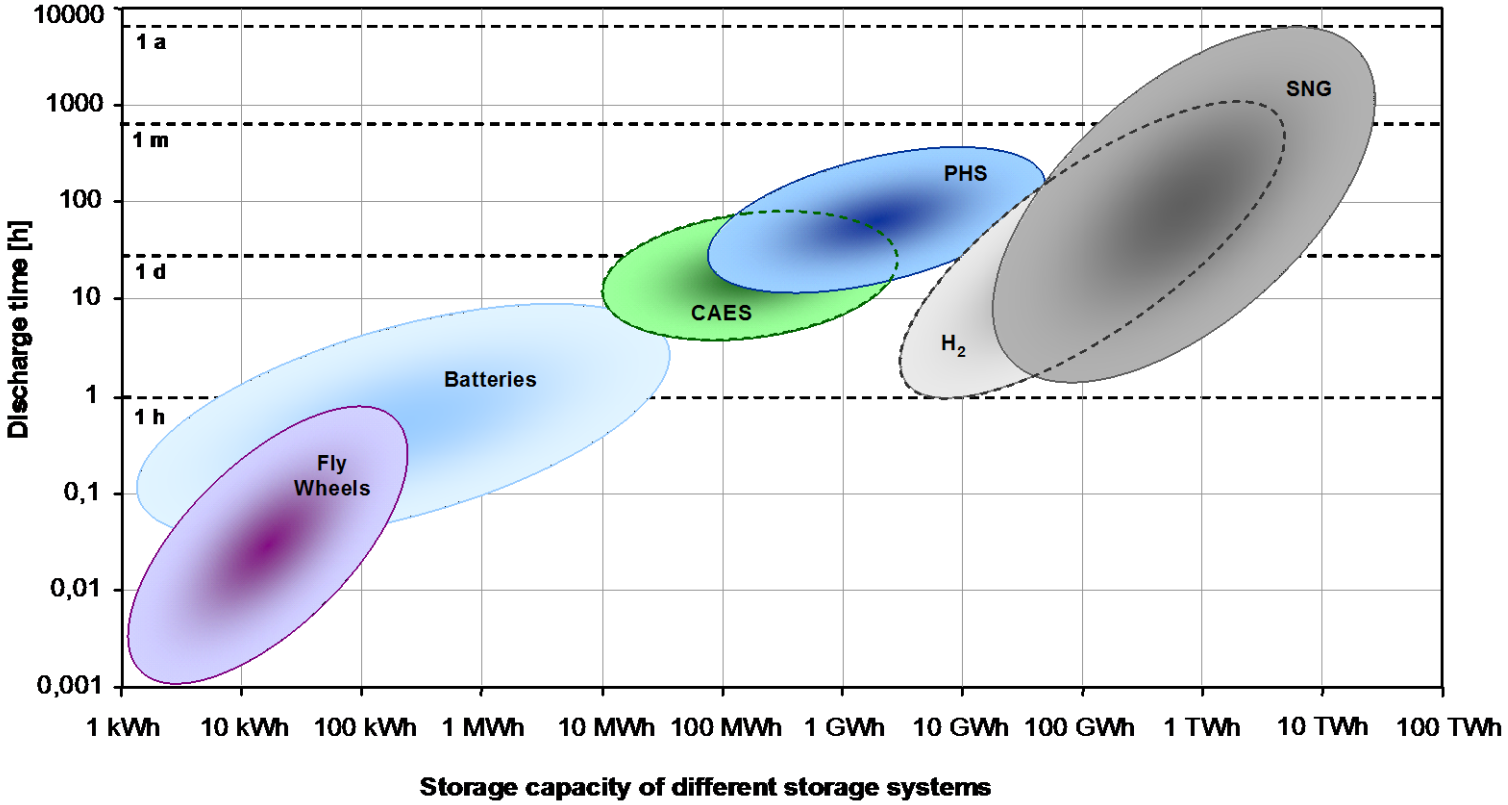
as simulated in a 100% renewable energy scenario





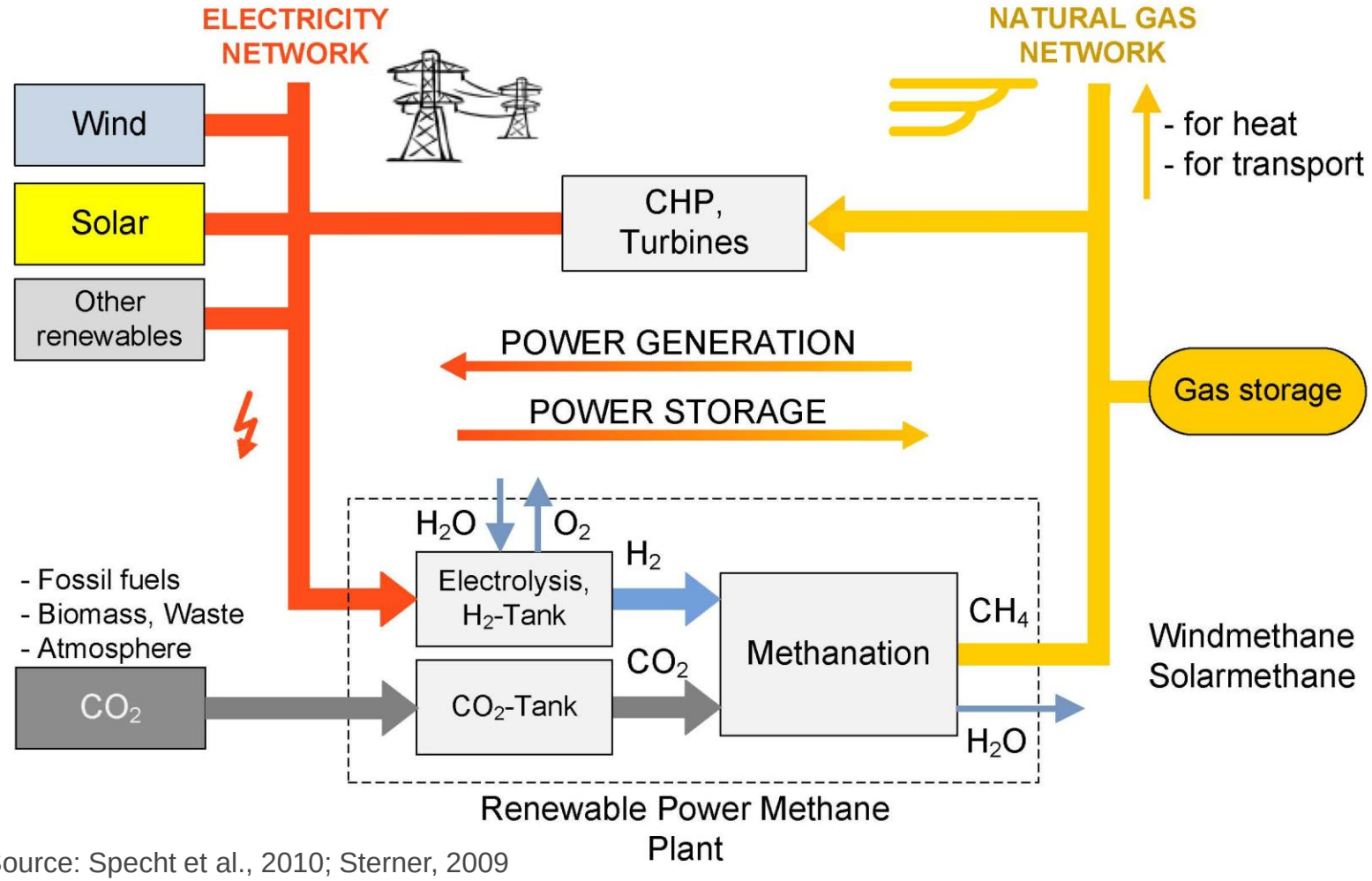
Source: IWES / UBA Energieziel 2050

Storage Capacity and Discharge Time of Different Storage Systems



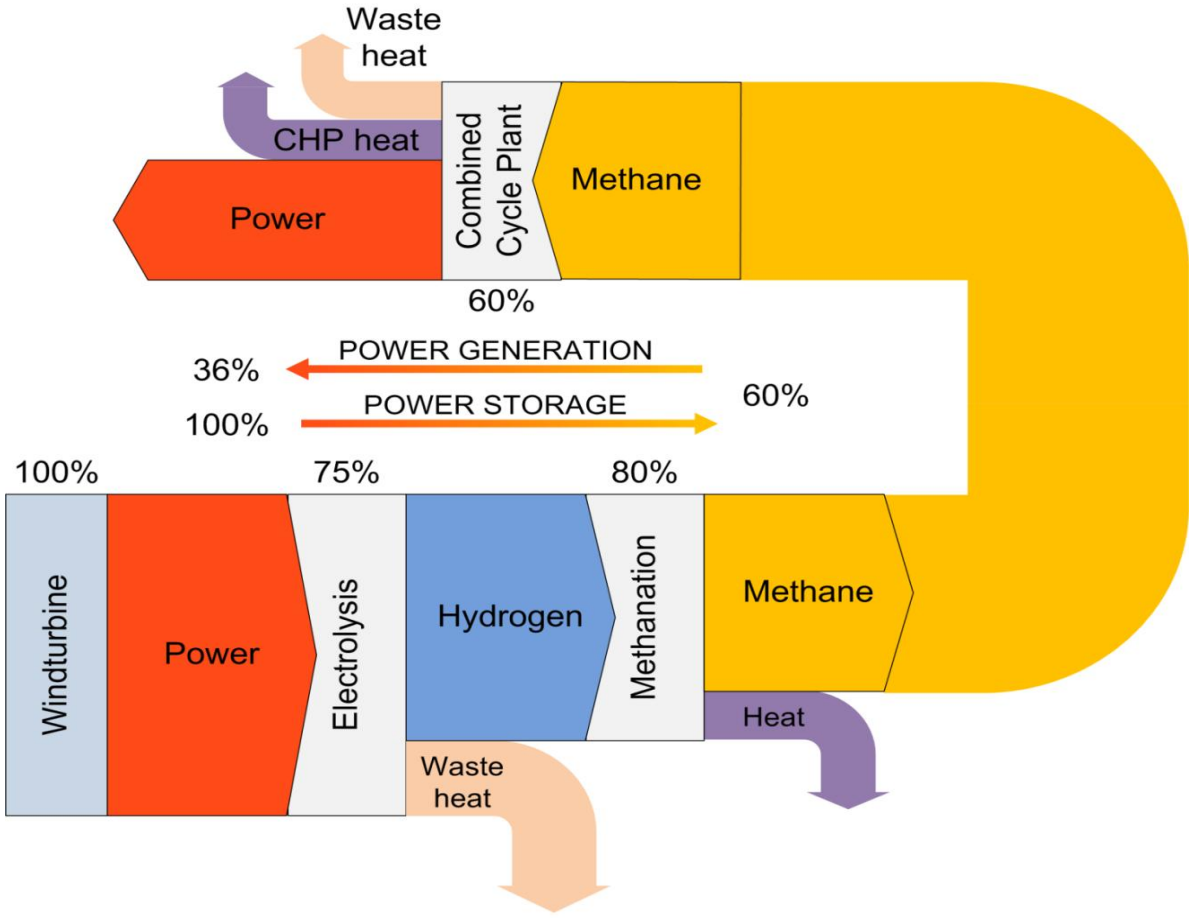
Source: Specht et al., 2010

Coupling of electricity and gas grids as storage system



Source: Specht et al., 2010; Sterner, 2009

Renewable power (to) methane | efficiency



60-65% Methane

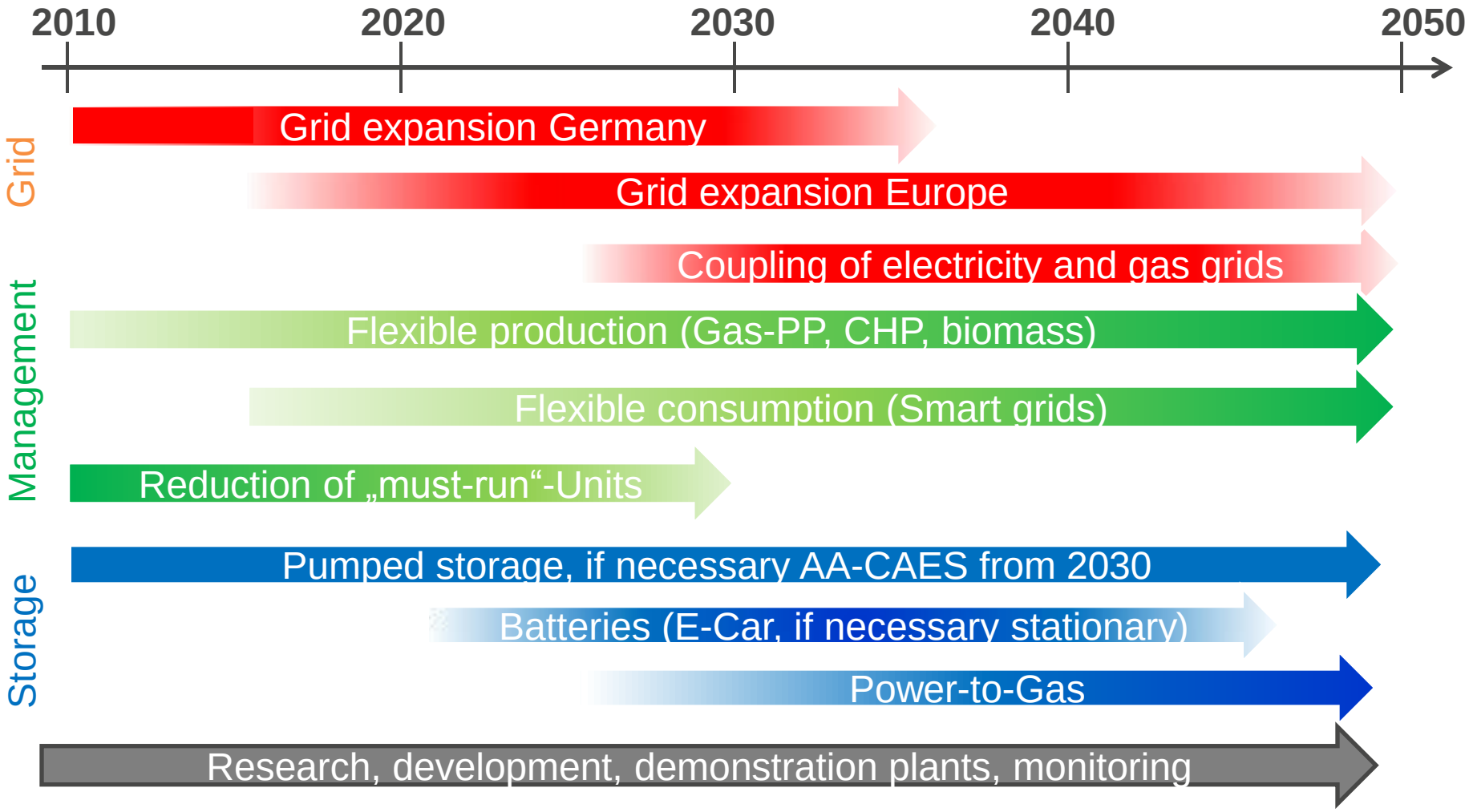
35-40% Power

50-60% CHP

Vs. 0% Curtailment of electricity

Source: Specht et al., 2009; Sterner, 2009

Roadmap Transformation Power Supply System - Germany



Source: IWES, 2011

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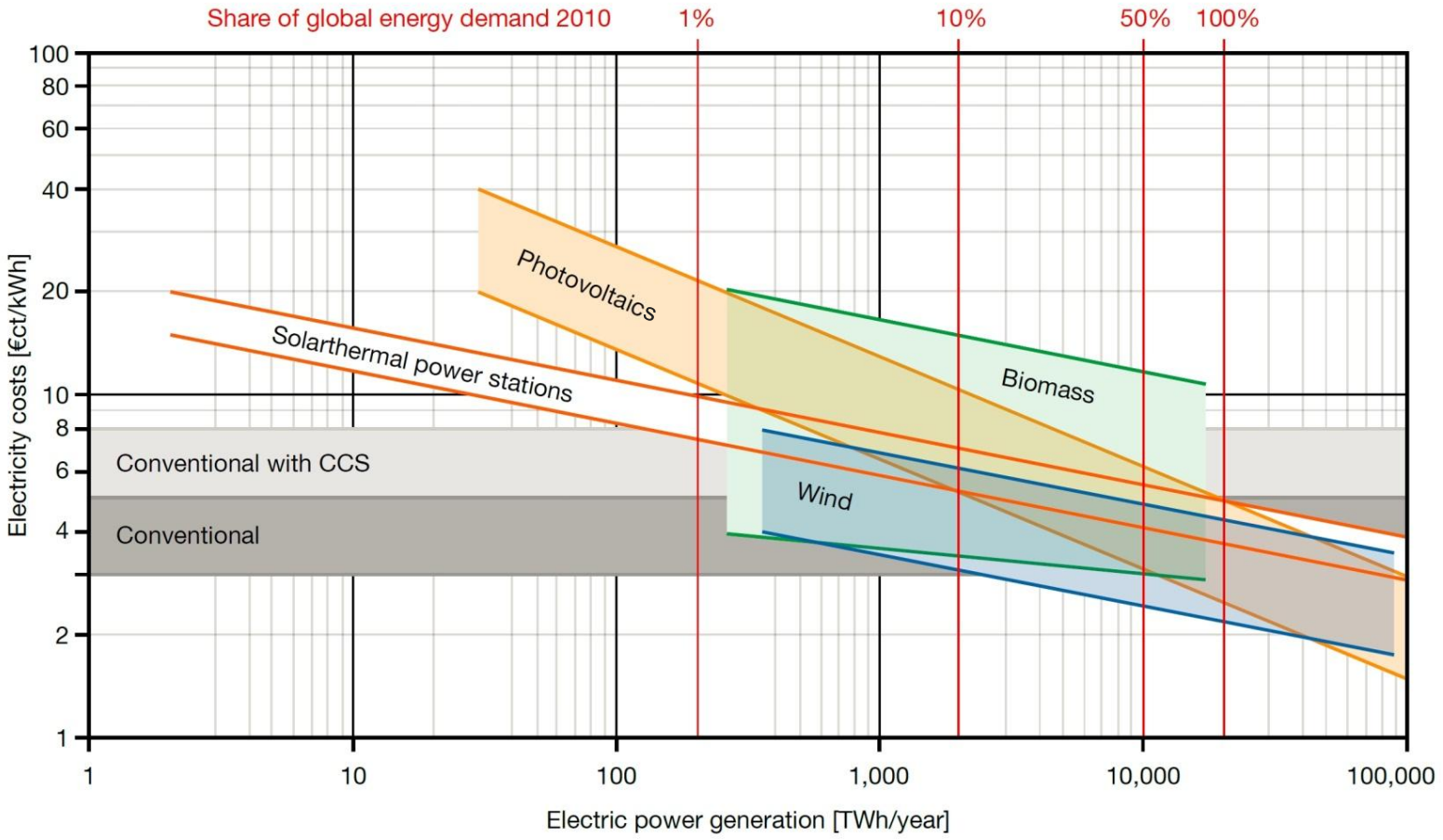
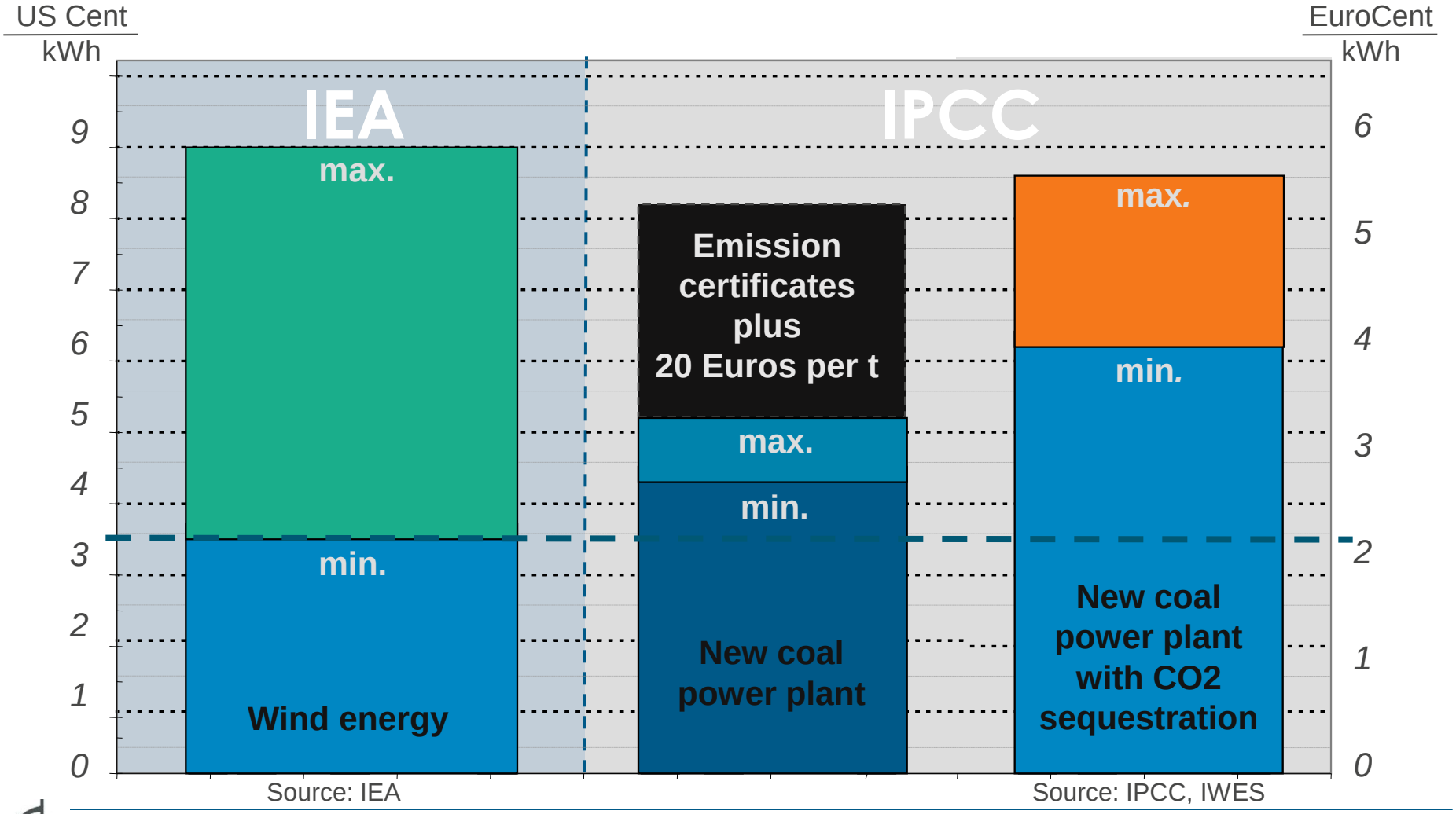
- **Costs of Renewable Energy Use**

Global Development Potential of Costs for Electricity from Renewable Energies

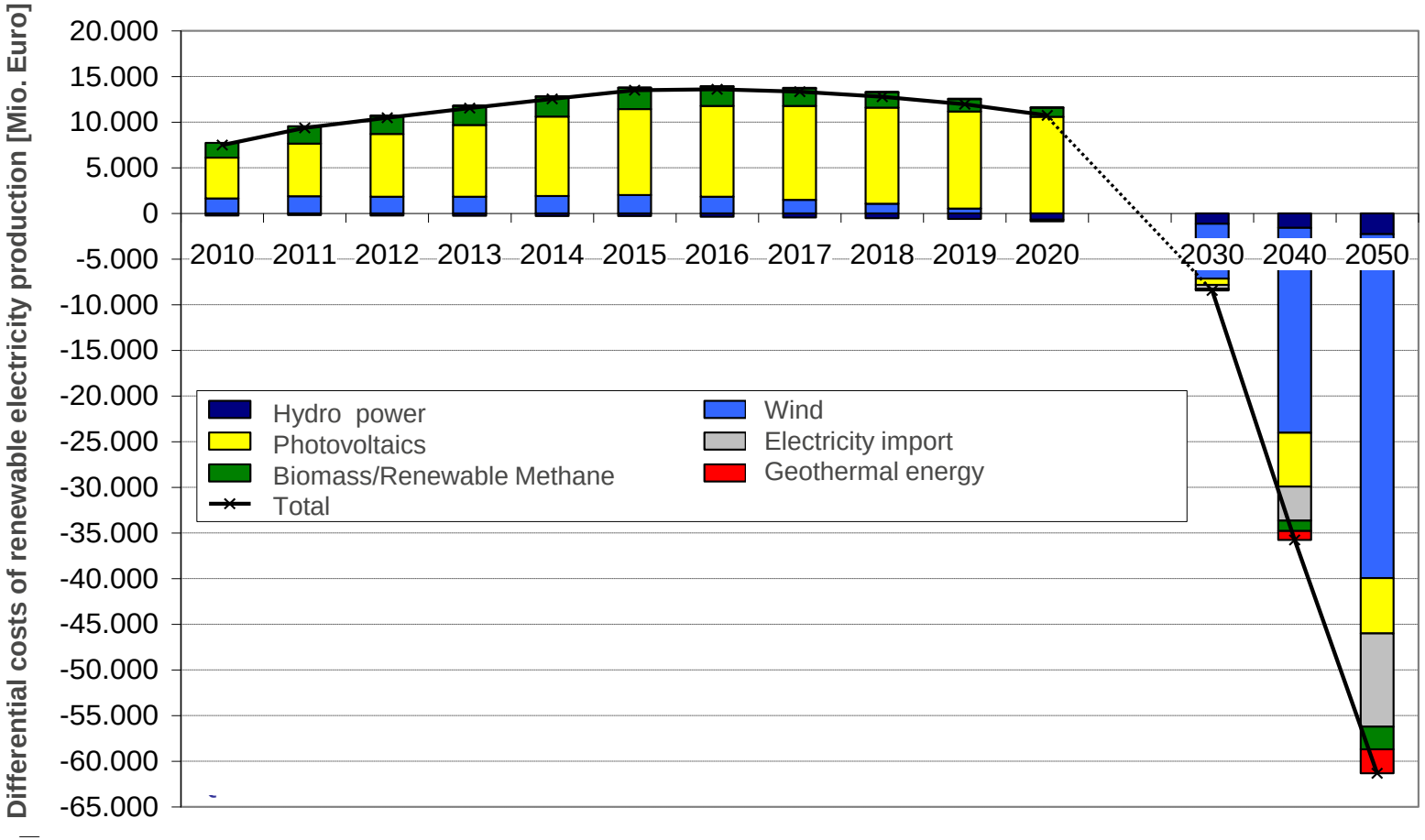


Source: WBGU, 2011

Comparison of Prime Costs



Development of Differential Costs of Renewable Electricity Production in Germany



Source: FVEE und ZSW, 2010

Conclusions

- The transformation of the energy system is based on energy efficiency and the use of renewable energies.
- Switching to renewable energies reduces the primary energy demand.
- Network expansion, energy management and storage systems are essential to integrate high shares of renewable energies.
- The renewable path is the less costly option in the long term.

Exercises for Self-Study

1. Could a 100% renewable power system exclusively based on PV be realised (e.g. for Europe)? Discuss the characteristics of the required storage (power vs. capacity).

2. Compare the pros and cons of renewable energy use. Which actions have to be taken to compensate the negative aspects? Gather information and investigate the current development status of different balancing options.

3. Compare the different options for CO_2 -neutral mobility.

References

Basic reading

- WBGU (2011): World in Transition: A Social Contract for Sustainability. Chapter 4. Berlin: WBGU:

Further reading

- BMU (2012): German Lead Study 2011 (Leitstudie 2011: Langfristszenarien und Strategien für den Ausbau der erneuerbaren Energien in Deutschland bei Berücksichtigung der Entwicklung in Europa und global). Berlin: BMU.
- Edenhofer, O., Carraro, C., Hourcade, J.-C., Neuhoff, K., Luderer, G., Flachsland, C., Jakob, M., Popp, A., Steckel, J., Strohschein, J., Bauer, N., Brunner, S., Leimbach, M., Lotze-Campen, H., Bosetti, V., de Cian, E., Tavoni, M., Sassi, O., Waisman, H., Crassous-Doerfler, R., Monjon, S., Dröge, S., van Essen, H., del Río, P. und Türk, A. (2009a): The Economics of Decarbonisation. Report of the RECIPE Project. Potsdam: Potsdam-Institut für Klimafolgenforschung (PIK).
- Edenhofer, O., Knopf, B., Barker, T., Baumstark, L., Bellevrat, E., Chateau, B., Criqui, P., Isaac, M., Kitous, A., Kypreos, S., Leimbach, M., Lessmann, K., Magné, B., Scrieciu, S., Turton, H. und van Vuuren, D. P. (2010): The economics of low stabilization: model comparison of mitigation strategies and costs. The Energy Journal 31 (Special Issue 1), 11–48.
- EREC – European Renewable Energy Council und Greenpeace (2008): Energy [r]evolution. A Sustainable Global Energy Outlook 2008. Brüssel, Amsterdam: EREC, Greenpeace International.
- EREC – European Renewable Energy Council und Greenpeace (2010): Energy [r]evolution. A Sustainable Global Energy Outlook. Advanced Scenario. Third Edition 2010. Brüssel, Amsterdam: Greenpeace International, EREC.
- GEA – Global Energy Assessment (2011): Global Energy Assessment. Laxenburg: IIASA.
- FVEE – ForschungsVerbund Erneuerbare Energien (2010): Energiekonzept 2050 – Eine Vision für ein nachhaltiges Energiekonzept auf Basis von Energieeffizienz und 100% erneuerbaren Energien. Internet: http://www.fvee.de/publikationen/publikation/download/energiekonzept. Berlin: FVEE.
- IEA – International Energy Agency (2008b): Energy Technology Perspectives 2008. Paris: IEA.
- IIASA – International Institute for Applied Systems Analysis (2009): Representative Concentration Pathway Database. Internet: Laxenburg: IIASA.

References

- Nakicenovic, N., Grübler, A. und McDonald, A. (Hrsg.) (1998): Global Energy Perspectives. Cambridge, New York: Cambridge University Press.

- SRU (2011): Pathways Towards a 100 % Renewable Electricity System. Special Report. Internet: http://www.umweltrat.de/SharedDocs/Downloads/EN/02_Special_Reports 2011_10_Special_Report Pathways_renewables.html. Berlin: SRU.

- Specht, M., Baumgart, F., Feigl, B., Frick, V., Stürmer, B., Zuberbühler, U., Sterner, M. und Waldstein, G. (2010): Speicherung von Bioenergie und erneuerbarem Strom im Erdgasnetz. Berlin: Forschungsverbund Erneuerbare Energien (FVEE).

- Sterner, M. (2009): Bioenergy and renewable power methane in integrated 100% renewable energy systems. Limiting global warming by transforming energy systems. Kassel University, Dissertation. http://www.upress.uni-kassel.de/publi/abstract.php?978-3-89958-798-2

- UBA (2010): Energy Target 2050: 100% Renewable Electricity Supply. English-Language Summary. Internet: http://www.uba.de/uba-info-medien/3997.html. Dessau-Roßlau: UBA.

- WBGU (2008): Future Bioenergy and Sustainable Land Use. Berlin. www.wbgu.de

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