

# Energy transitions in a comparative context: Germany, U.S. and others

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# Today's discussion

- *Stepping back to look at the full energy system in the context of climate change*
- *What is the German “Energiewende” and how does that compare to the U.S.?*
- *How do we think about how energy systems will evolve in the future*
  - *Electric power sector*
  - *End-use sectors, incl. transportation*
- *Where do other environmental issues fit in?*
  - *Public health and ecosystem impacts of air emissions*
  - *Water quality and stress*
  - *Adaptation and resilience*

*What do we mean by energy system?*

# *From extraction to use*

- **Primary energy resources**

- Fossil: coal, natural gas, petroleum
- Renewable: wind, solar, hydro, geothermal, biomass
- Other: uranium



- **Technologies to convert primary resources to useable energy like electricity, gasoline, ...**

- Refineries
- Electric Power Generation



- **End-use sectors that use electricity and fuels**

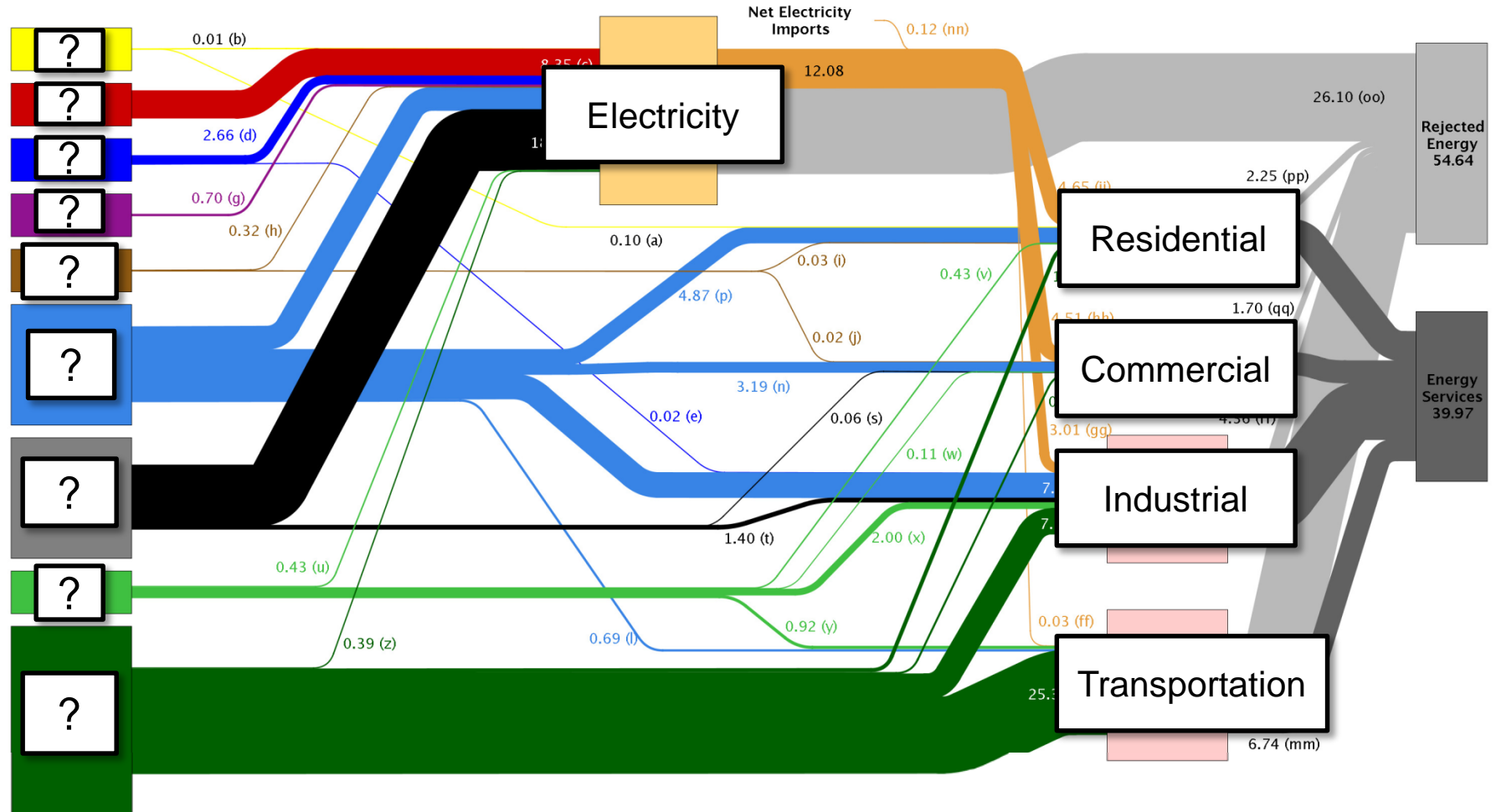
- Residential
- Commercial
- Industrial
- Transportation



- **Energy services**

- What people actually demand: vehicle miles traveled, lumens of lighting, finished products and services
- Important to remember that energy is a “derived demand”

Estimated U.S. Energy Use in 2009: ~94.6 Quads

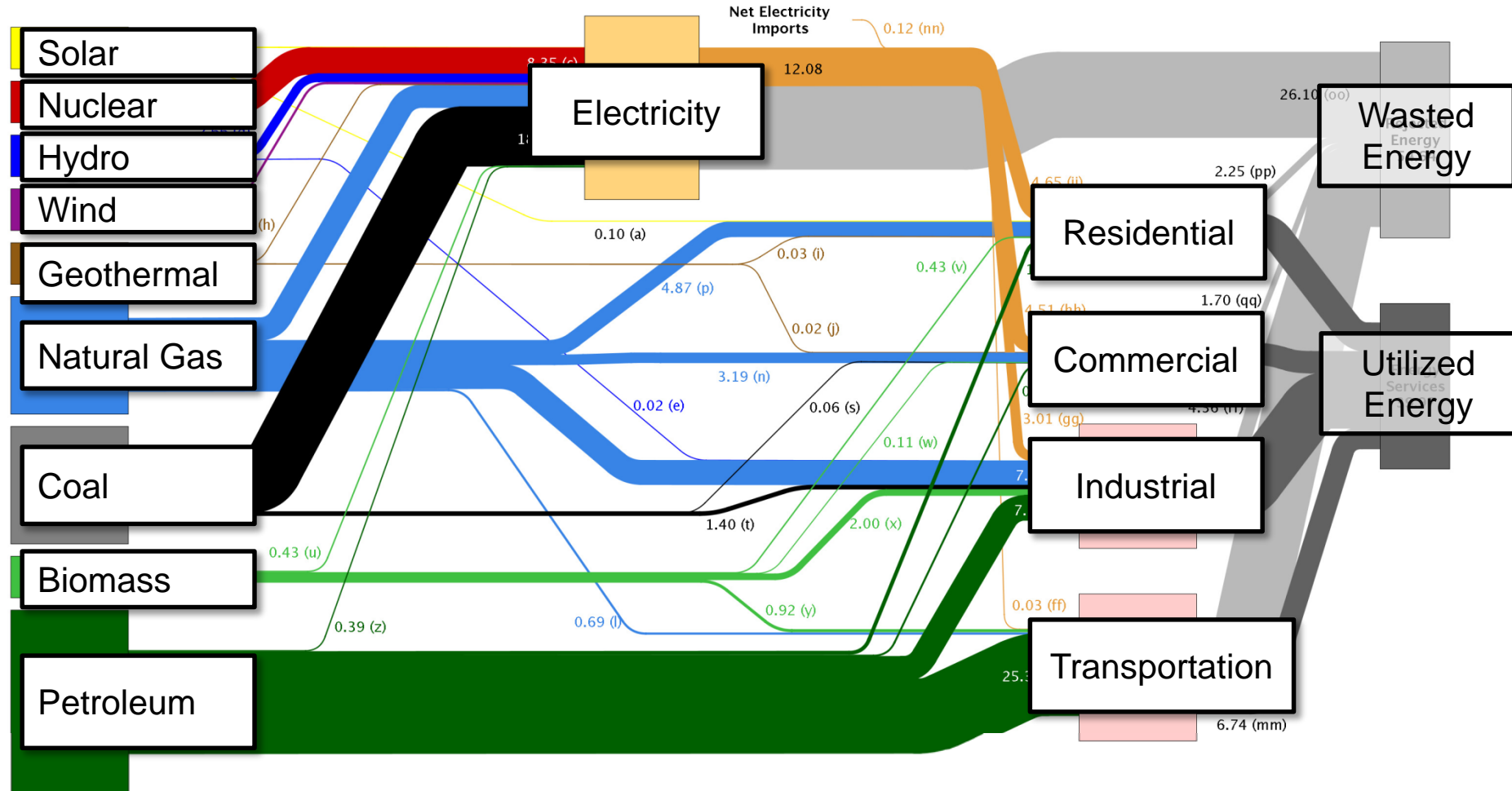


Coal  
Natural Gas  
Petroleum (Crude Oil)

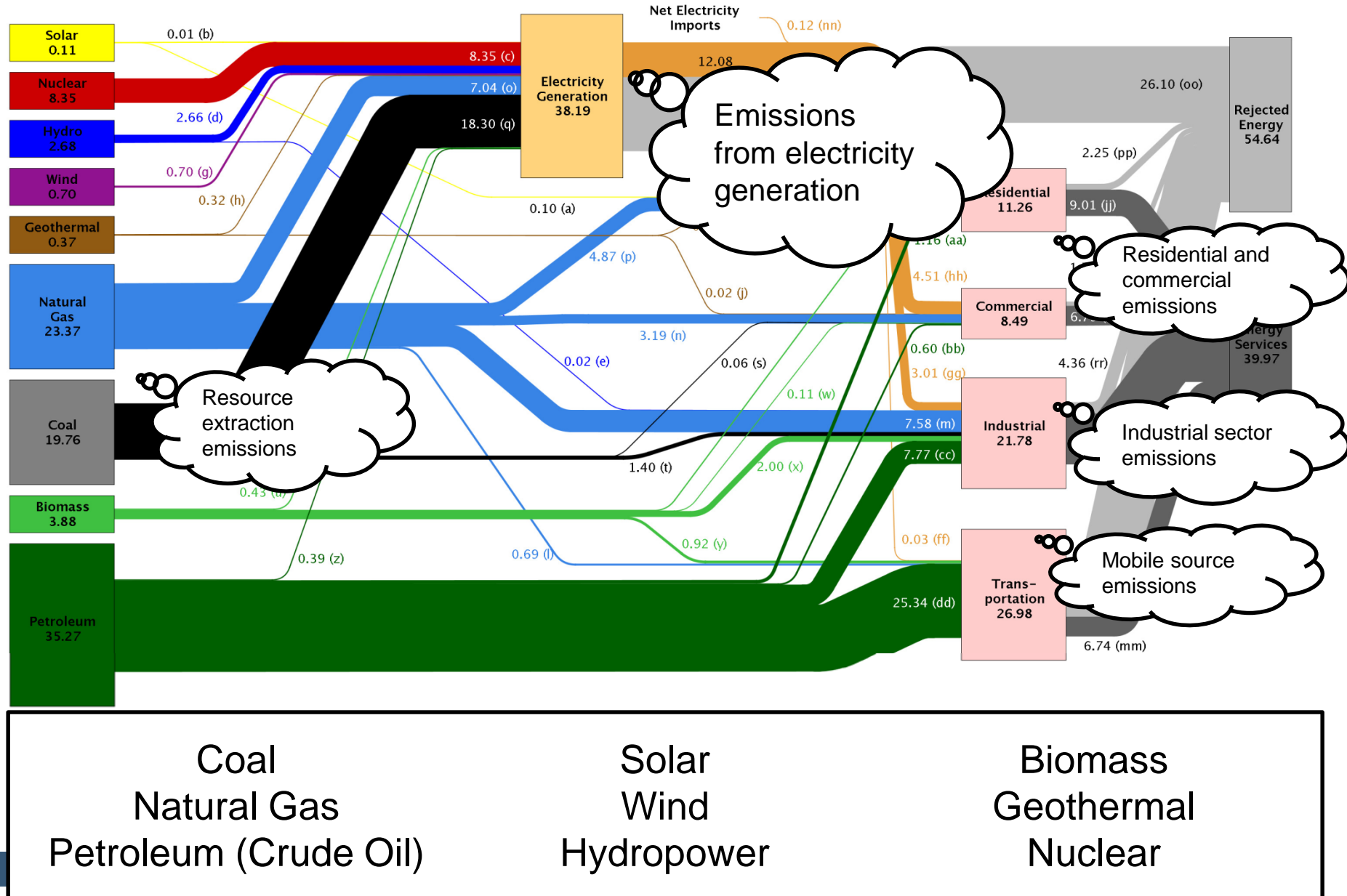
Solar  
Wind  
Hydropower

Biomass  
Geothermal  
Nuclear

Estimated U.S. Energy Use in 2009: ~94.6 Quads



# Estimated U.S. Energy Use in 2009: ~94.6 Quads

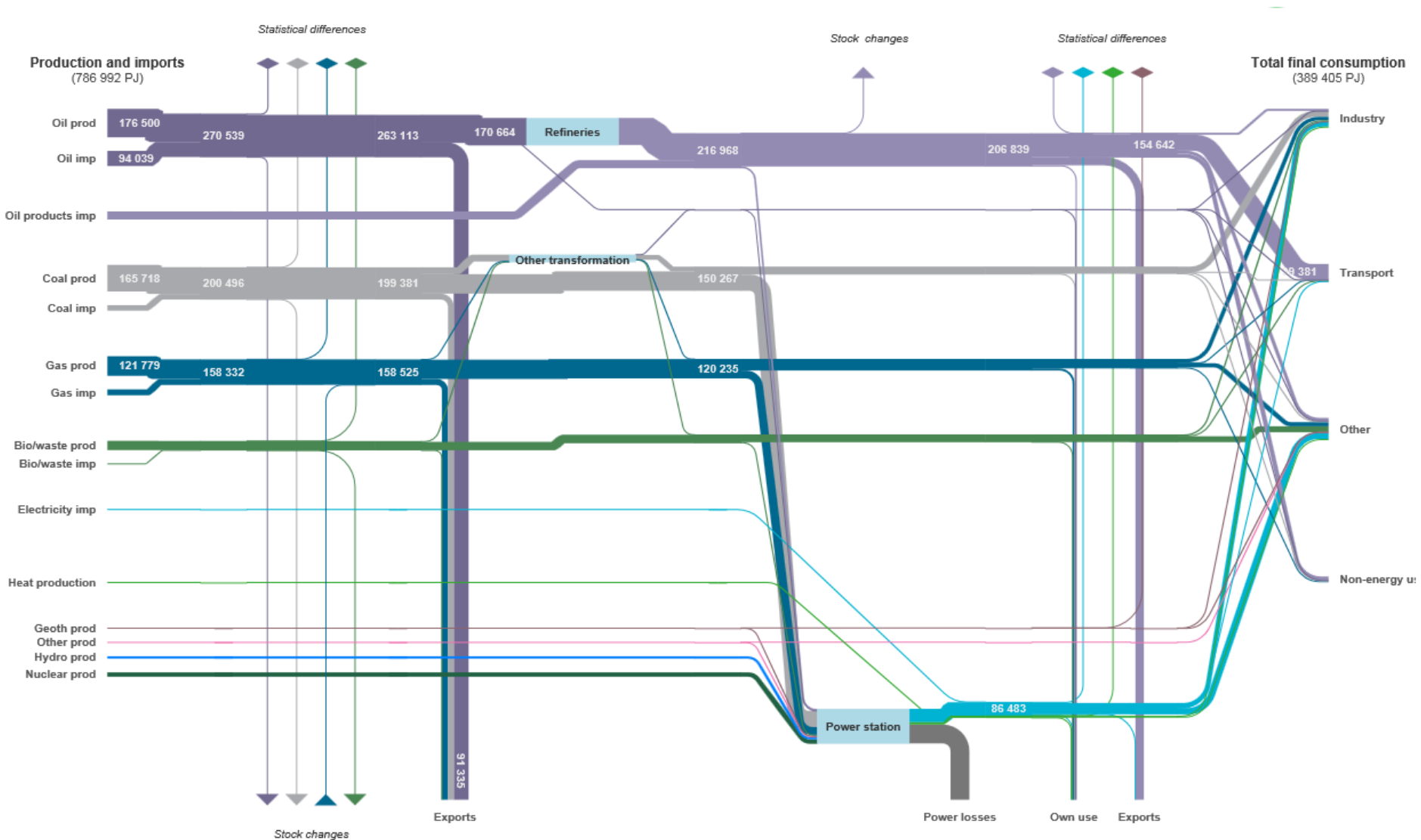


## *Energy in a comparative context*

- Energy systems can be vastly different from one country to another
- The differences emerge from a range of technological, economic, social and political factors
- Energy resource availability is an important driver, but not the only one
- Let's look through some examples

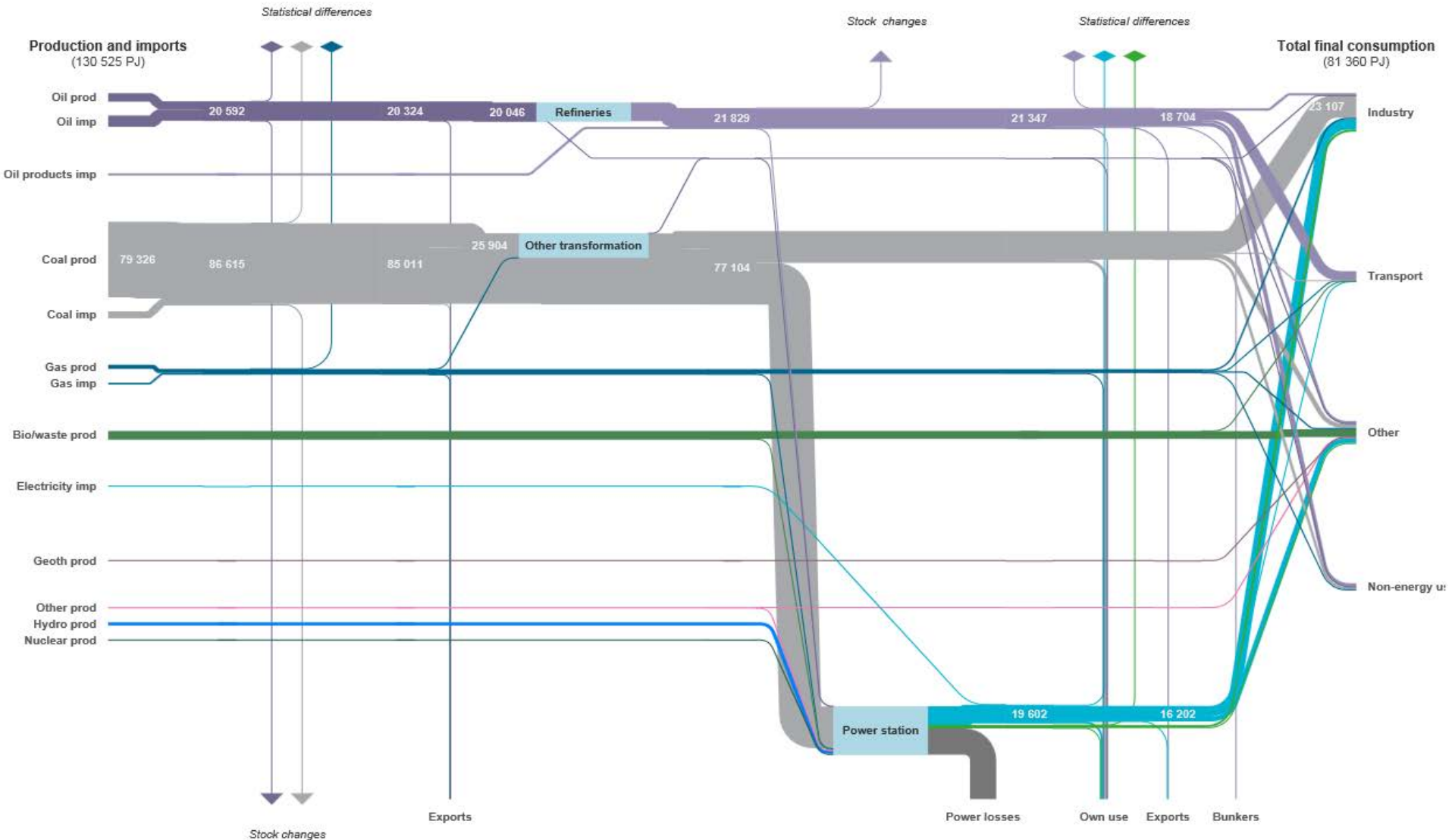


# Connecting the dots: The world's energy system (2013)



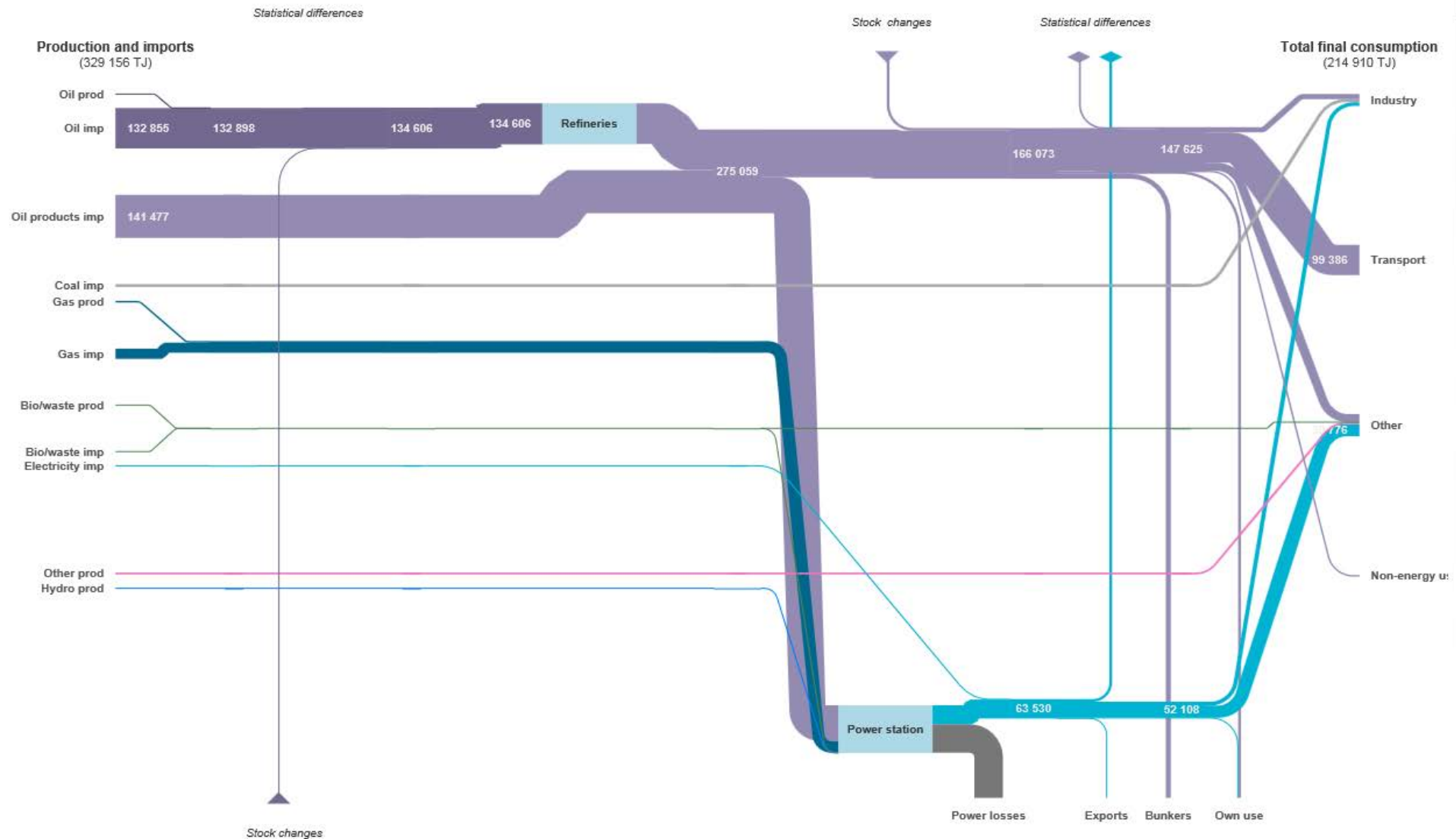
# Energy in a comparative context:

## People's Republic of China



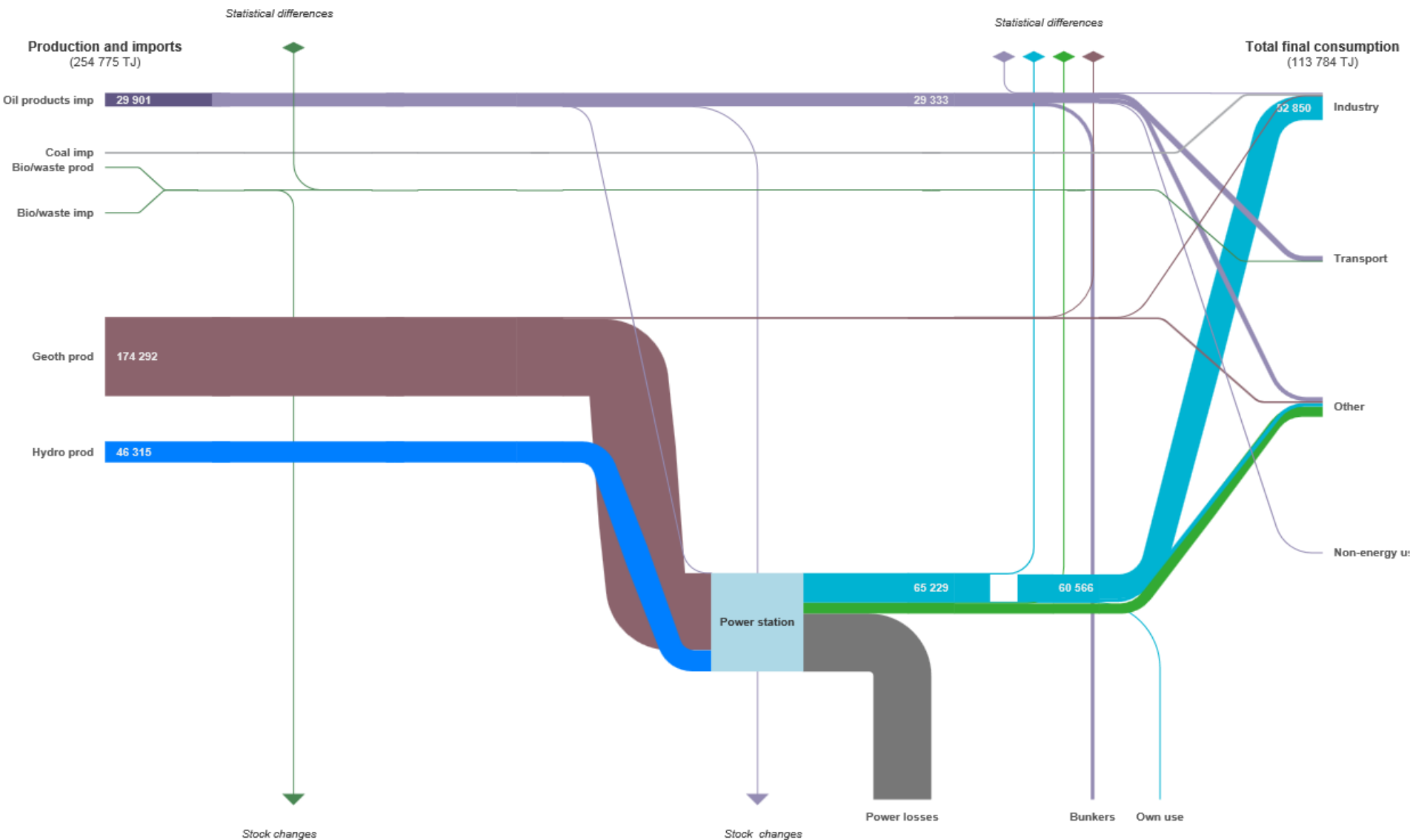
# Energy in a comparative context:

## Jordan



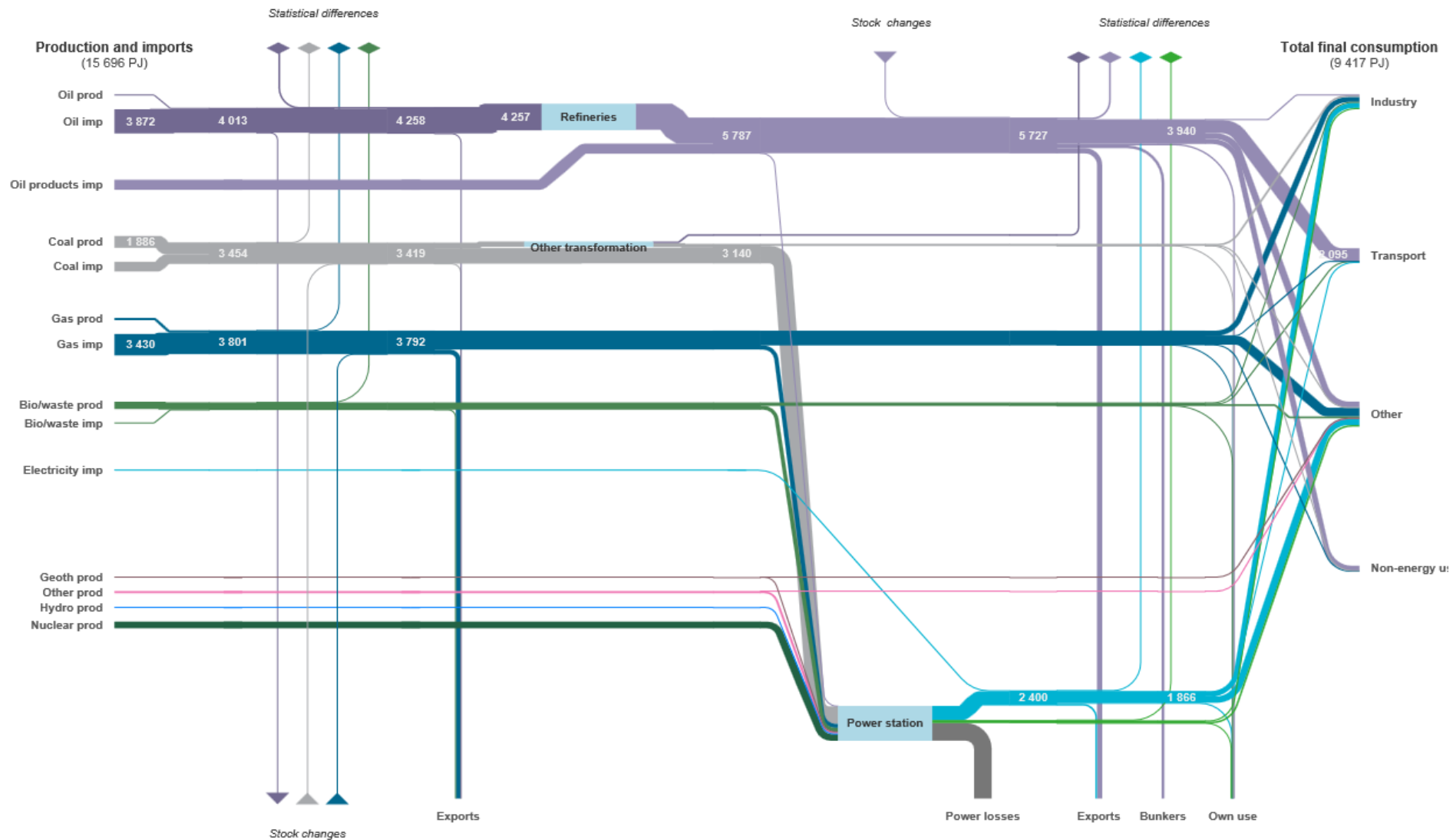
# Energy in a comparative context:

## Iceland



# Energy in a comparative context:

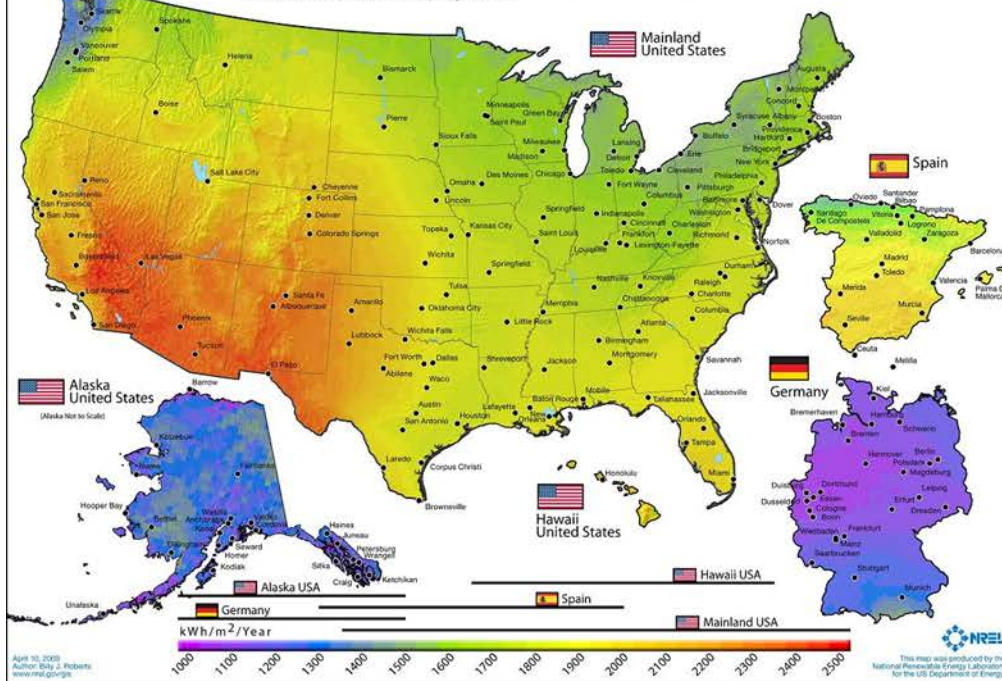
## Germany



# ***What is the German “Energiewende” and how does that compare to the U.S.***

### Photovoltaic Solar Resource: United States - Spain - Germany

Annual average solar resource data are for a solar collector oriented toward the south at a tilt = local latitude. The data for Hawaii and the 48 contiguous states are derived from a model developed at SUNY/Albany using geostationary weather satellite data for the period 1998-2005. The data for Alaska are derived from a 40-km satellite and surface cloud cover database for the period 1985-1991 (NREL, 2003). The data for Germany and Spain were acquired from the Joint Research Centre of the European Commission and is the yearly sum of global irradiation on an optimally-inclined surface for the period 1981-1990. States and countries are shown to scale, except for Alaska.



Source: Georg Maue, "Moving towards a sustainable, efficient and secure energy supply: The German Energy Transition State of Play" Presentation to the EPA/DOE Energy Horizons Seminar, Dec 1, 2015



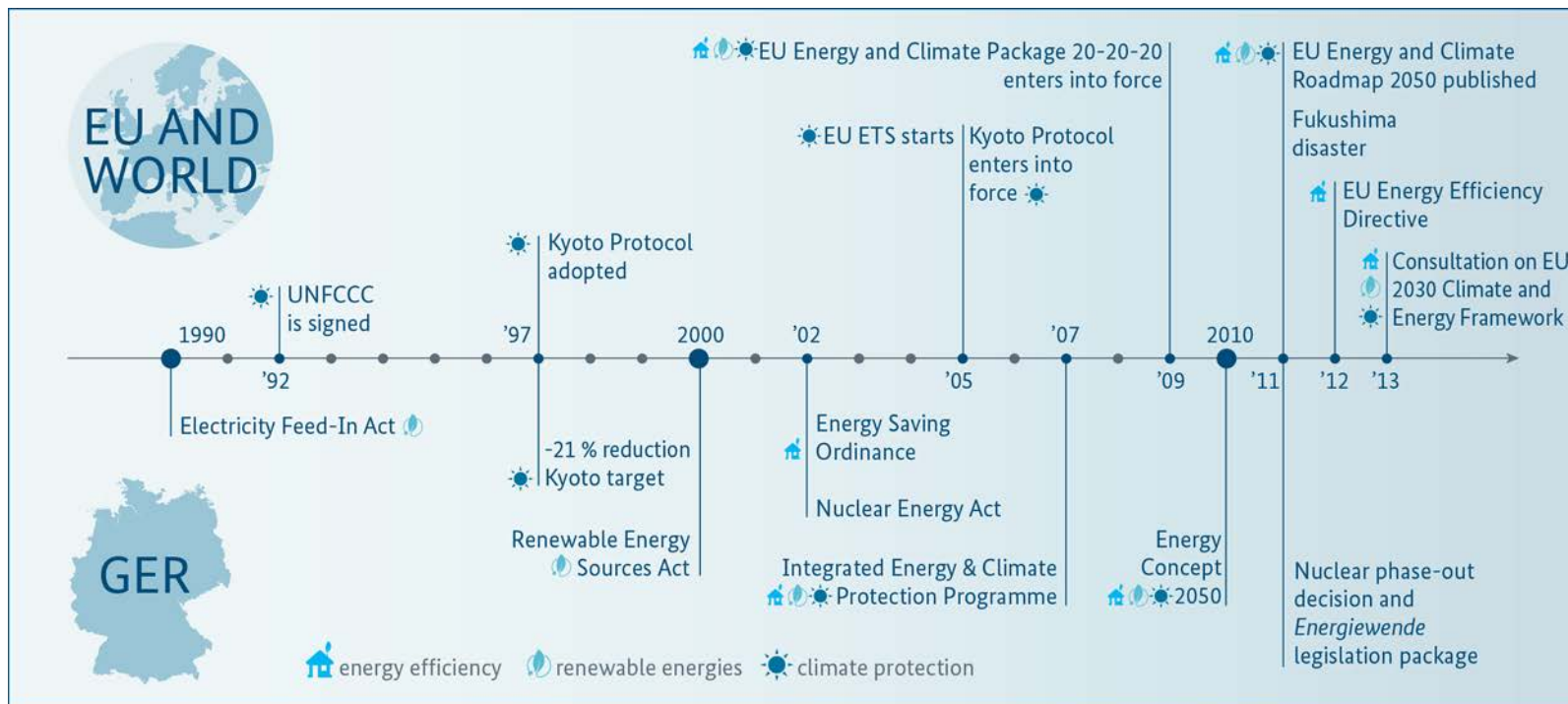
# Five reasons for the *Energiewende*

- Phase-out nuclear power generation
- Reduce dependency on energy imports
- Reduce carbon emissions and reach climate protection targets
- Development of new technologies as new sources of growth and employment
- Show that energy policy can be both sustainable and economically successful

Source: Georg Maue, “Moving towards a sustainable, efficient and secure energy supply: The German Energy Transition State of Play” Presentation to the EPA/DOE Energy Horizons Seminar, Dec 1, 2015



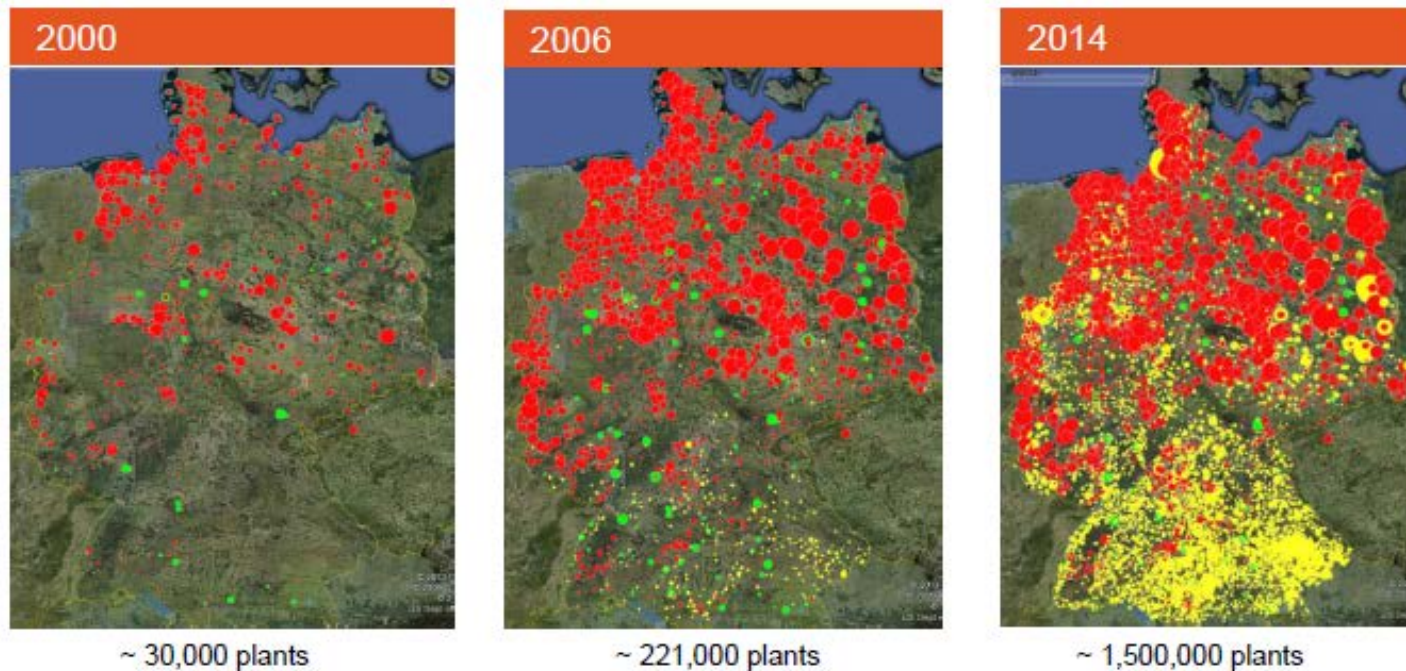
# Milestones of the *Energiewende*



*Germany is part of an integrated European energy and climate strategy.*

Source: Georg Maue, "Moving towards a sustainable, efficient and secure energy supply: The German Energy Transition State of Play" Presentation to the EPA/DOE Energy Horizons Seminar, Dec 1, 2015

## Expansion of renewable energy sources in Germany



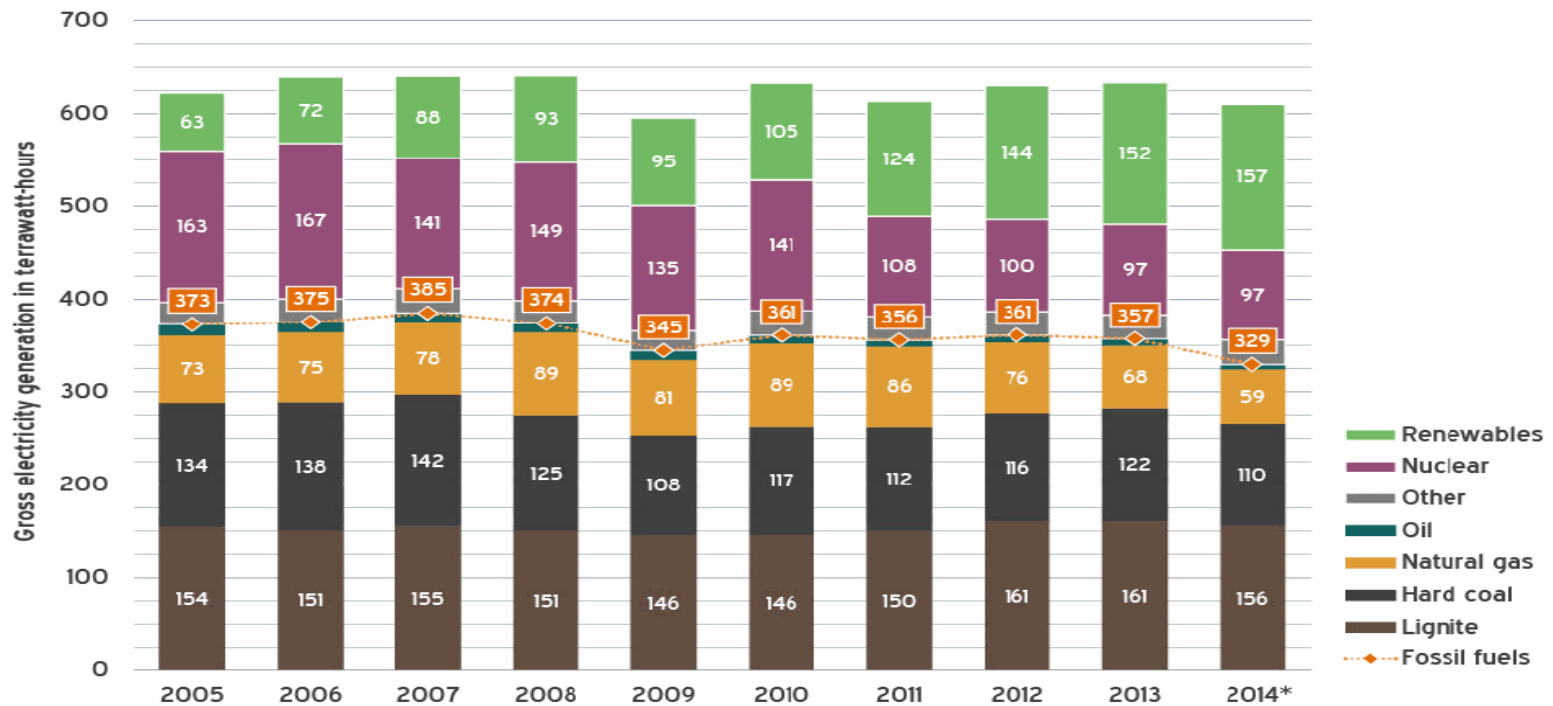
- The number of renewable power plants as grown exponentially over the past 14 years.

Source: Georg Maue, *"Moving towards a sustainable, efficient and secure energy supply: The German Energy Transition State of Play"* Presentation to the EPA/DOE Energy Horizons Seminar, Dec 1, 2015

## Power generation from fossil fuels in Germany at a historic low in 2014

Electricity generation by source, Germany 2005-2014

Source: AG Energiebilanzen



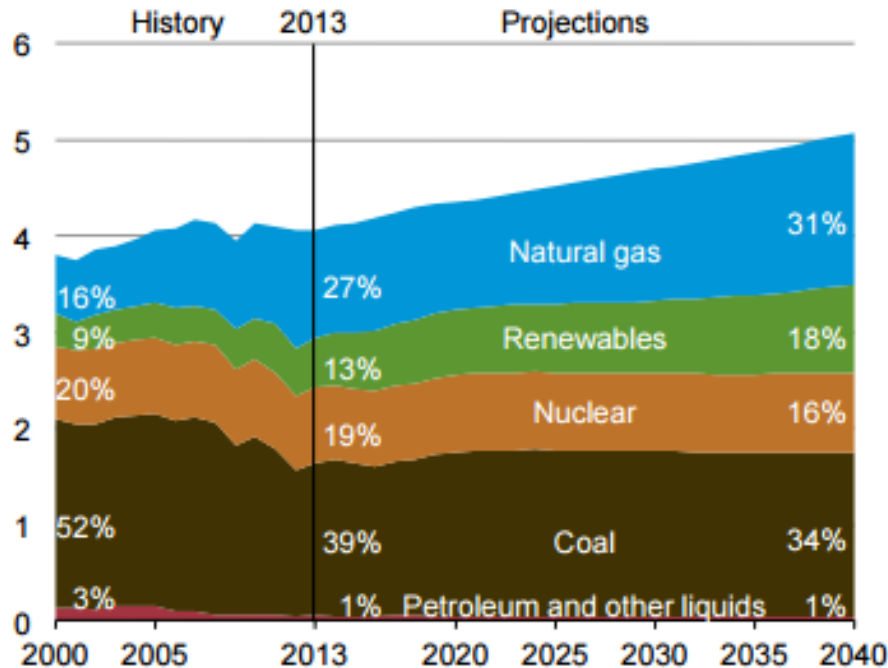
Source: AGEb 2014

- *Renewables have become the biggest source of power generation.*

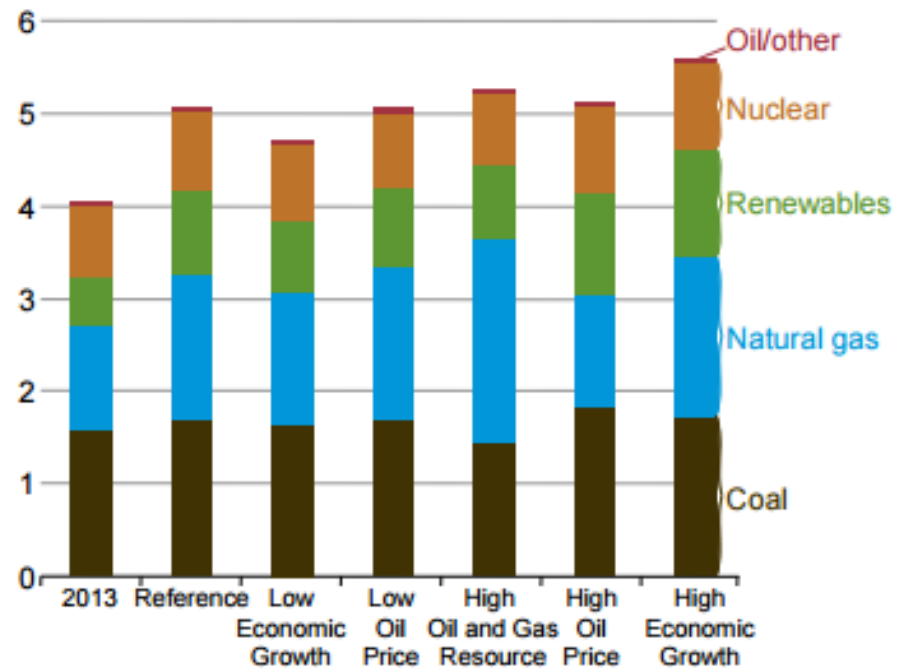
Source: Georg Maue, "Moving towards a sustainable, efficient and secure energy supply: The German Energy Transition State of Play" Presentation to the EPA/DOE Energy Horizons Seminar, Dec 1, 2015

# U.S. electricity generation mix

**Figure 31. Electricity generation by fuel in the Reference case, 2000-2040 (trillion kilowatthours)**

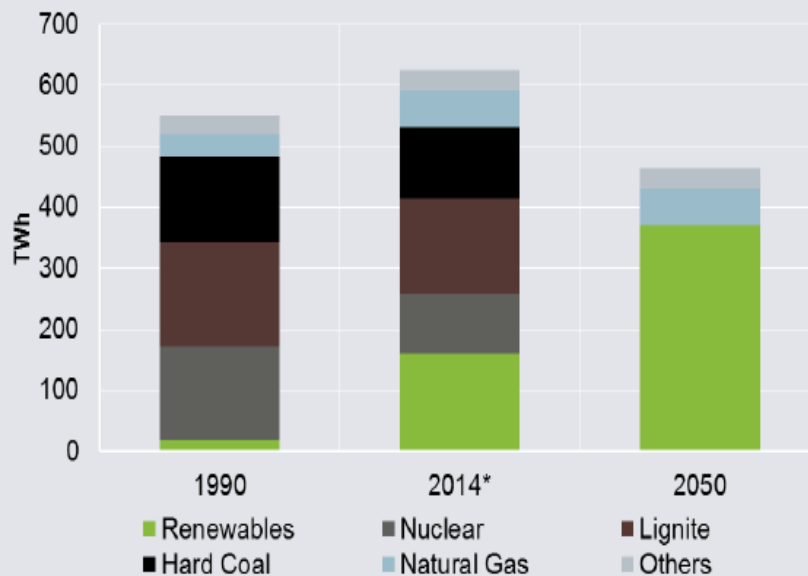


**Figure 32. Electricity generation by fuel in six cases, 2013 and 2040 (trillion kilowatthours)**



## The Energiewende means fundamentally changing the power system

Gross electricity generation 1990, 2014 and 2050



AGEB (2015a), BReg (2010), EEG (2014), own calculations \* preliminary

### Phase out of Nuclear Power

Gradual shut down of all nuclear power plants until 2022

### Reduction of Greenhouse Gas Emissions

Reduction targets below 1990 levels:

- 40% by 2020; - 55% by 2030; - 70% by 2040;
- 80% to - 95% by 2050

### Development of renewable energies

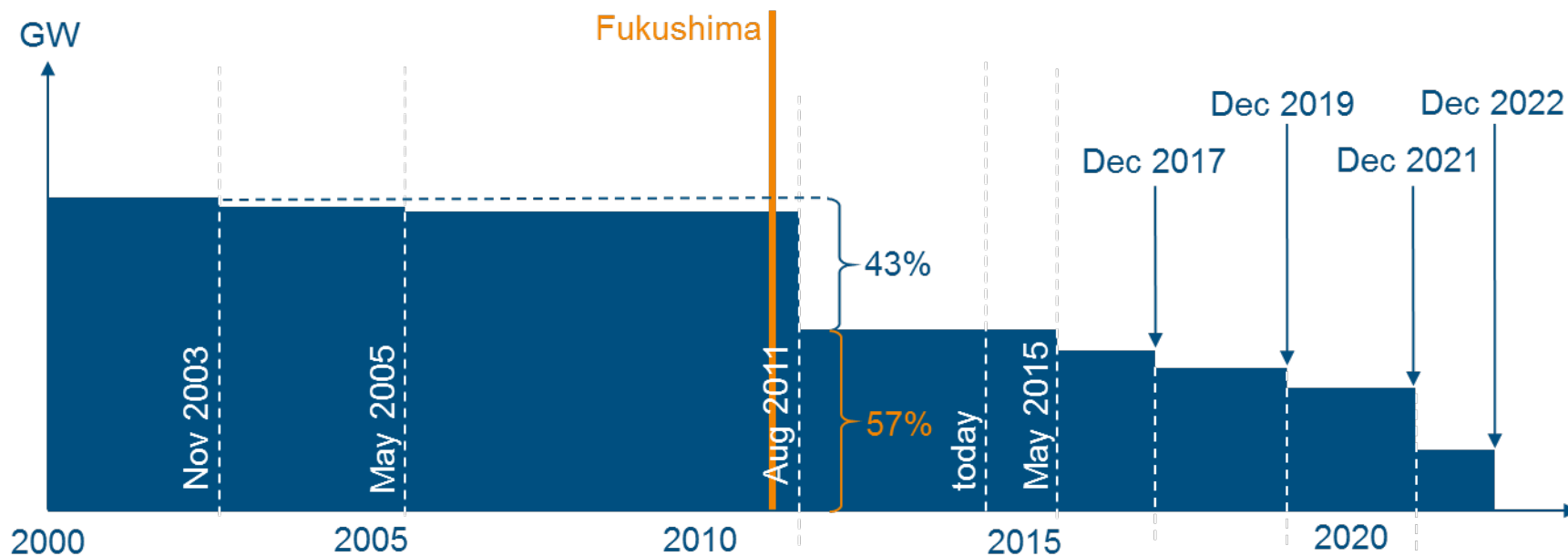
Share in power consumption to increase to:  
 40 - 45% in 2025; 55 - 60% in 2035; ≥ 80% in 2050

### Increase in efficiency

Reduction of power consumption compared to 2008 levels: - 10% in 2020; - 25% in 2050

Source: Georg Maue, "Moving towards a sustainable, efficient and secure energy supply: The German Energy Transition State of Play" Presentation to the EPA/DOE Energy Horizons Seminar, Dec 1, 2015

## German nuclear phase-out timeline



*Nuclear phase-out will reduce total power capacity. Remaining 10 nuclear power plants will be phased out by 2022.*

Source: Georg Maue, "Moving towards a sustainable, efficient and secure energy supply: The German Energy Transition State of Play" Presentation to the EPA/DOE Energy Horizons Seminar, Dec 1, 2015

# U.S. nuclear capacity



# *Where do other environmental issues fit in?*



# Where do other environmental issues fit in?

- Greenhouse Gas Emissions

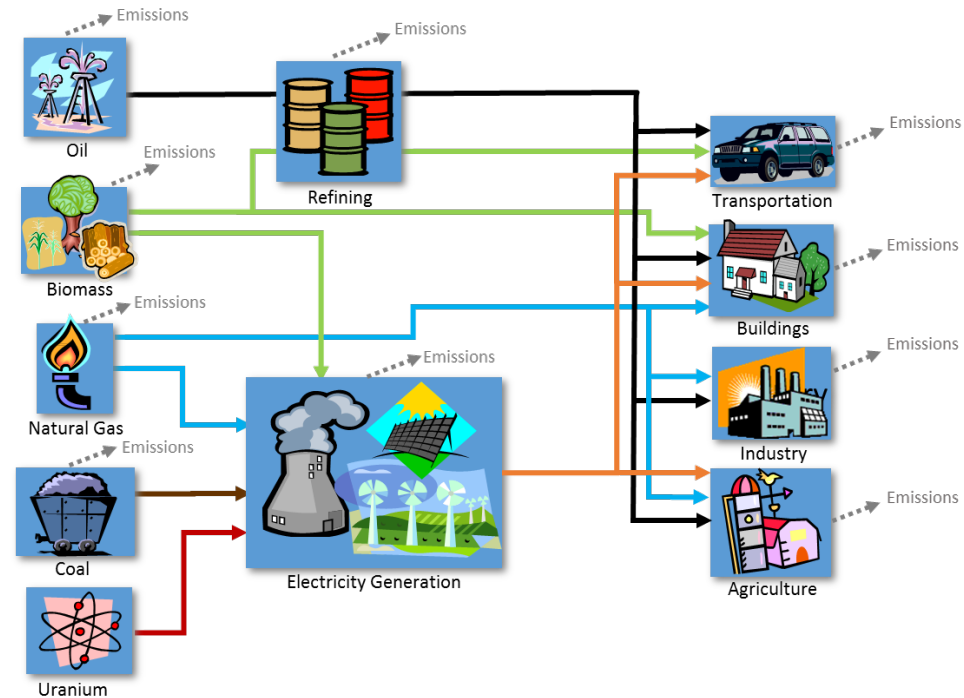
- *CO<sub>2</sub>, methane, nitrous oxide (N<sub>2</sub>O)*

- Air Pollutant Emissions

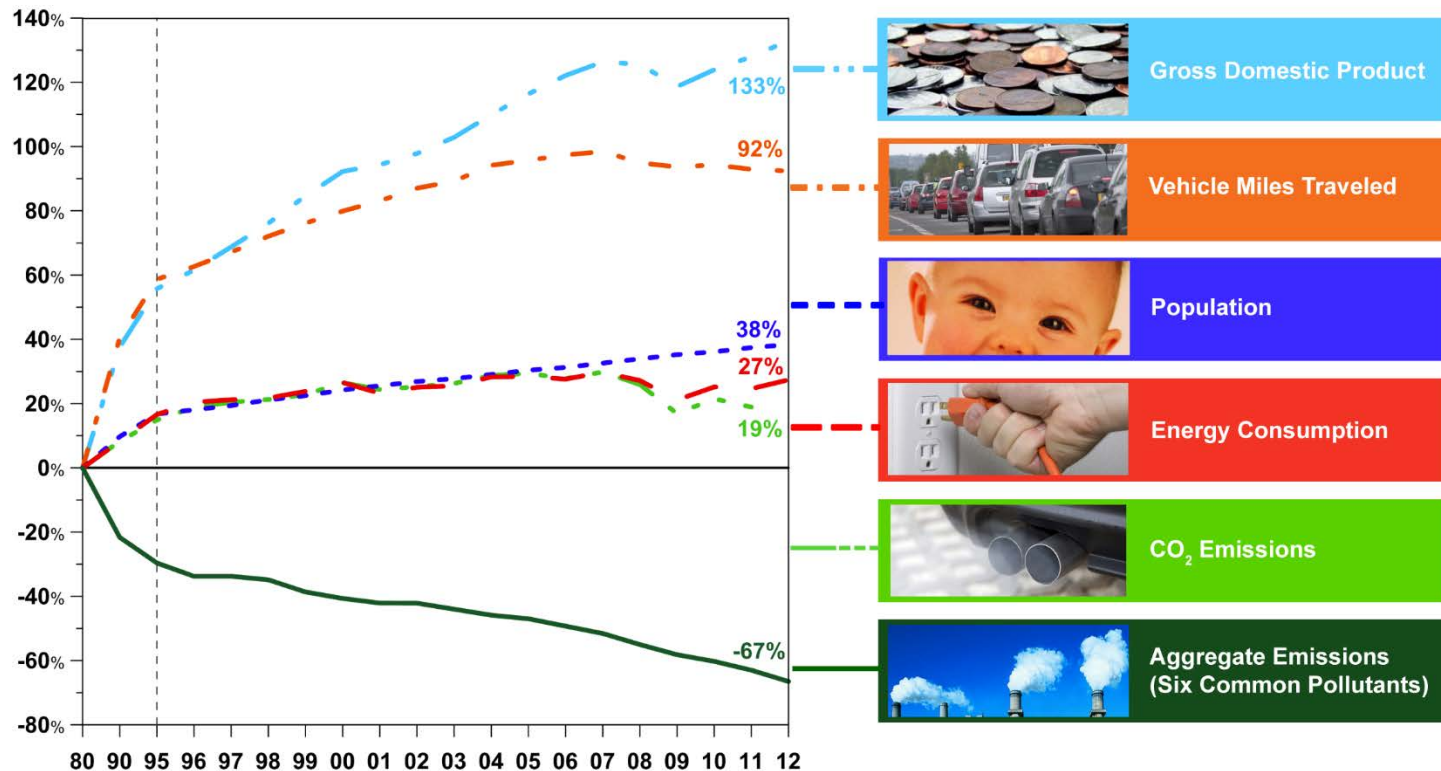
- *nitrogen oxides (NO<sub>x</sub>, ozone precursor), sulfur dioxide (SO<sub>2</sub>), (CO), air toxics, e.g., mercury*

- Water Supply, Use and Quality

- *51% of US fresh surface water withdrawals (more than irrigation or public supply)*
- *161,000 million gal per day is required*



# Growth measures and air emissions



<http://www.epa.gov/airtrends/aqtrends.html#comparison>

# *Different choices with very different impacts*

**How resilient is it to climate change?**

**What resources does it use?**

**How will it affect our climate?**

**How much does it cost?**



**What are the air emissions?**



**What are the other environmental impacts?**

**How much water does it require?**

# Additional slides