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Evaluations of consumption-based CO_2 emissions in Europe

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Background and purpose of this study

Background

- Until now, there has been a strong positive correlation between GDP growth and CO2 emissions increase. However, in recent years, the correlation may not always be clearly seen, and it is pointed out that “decoupling” between GDP growth and increased CO2 emissions has occurred.
- On the other hand, it has been pointed out that most of developed countries kept constantly higher CO2 emissions embodied in goods imports through international trade in the global economy, instead of increasing emissions through production in their own countries. (OECD (2015 and 2019)).
- It is important to present various data related to “decoupling” of GDP and CO2 emissions, as well as to better understand the factors, and to guide the future outlook of emissions and suggestions for global warming countermeasures.

Purpose

- To estimate and analyze the consumption-based emissions of major countries for 2000-2014, based on the latest statistical data, including a part of the period when the increase in global CO2 emissions slowed down
  - In order to evaluate the contribution to global decoupling, it is important to consider the international division of trade, and consumption structure by region. Evaluation of consumption-based CO2 emissions includes these aspects.

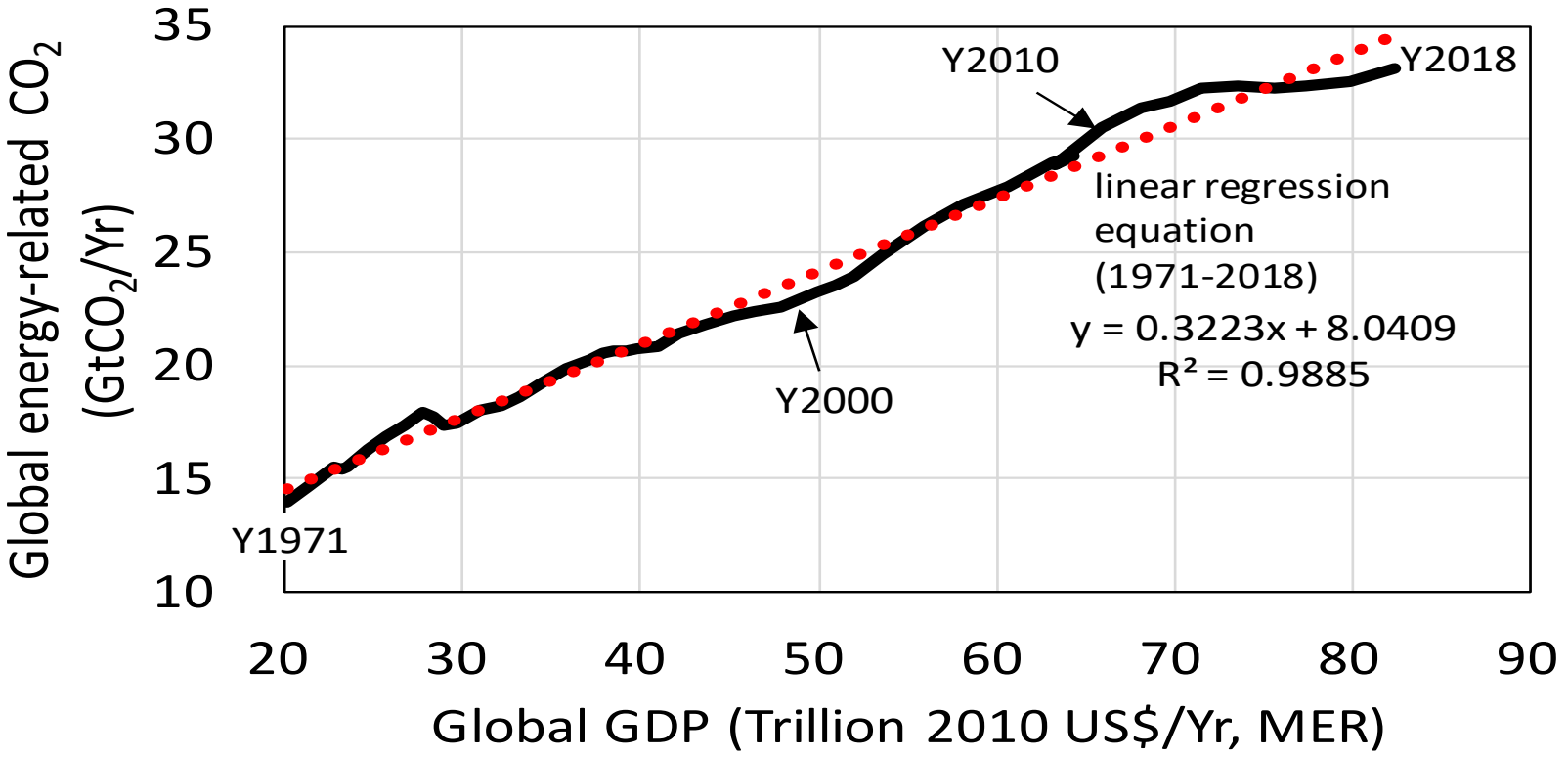
Definition: Producion-based and Consumption-based emissions

- In this study, we use the term “consumption-based emission” based on IPCC(2014) and OECD(2015), IMF(2018). Exactly, it represents “CO_2 Emissions Embodied in Final Demand and Net Imports.”

- Production-based emission : Production-based CO2 emissions are emissions from combustions of fossil fuels generated inside the territory of the country. These are equivalent to common CO2 emissions statistics.

- Consumption-based emission : Consumption(demand)-based emissions are direct and indirect emissions generated to meet the domestic demand of the country, regardless of production sites. National consumption-based emissions include emissions embodied in imports and exclude emissions embodied in exports.

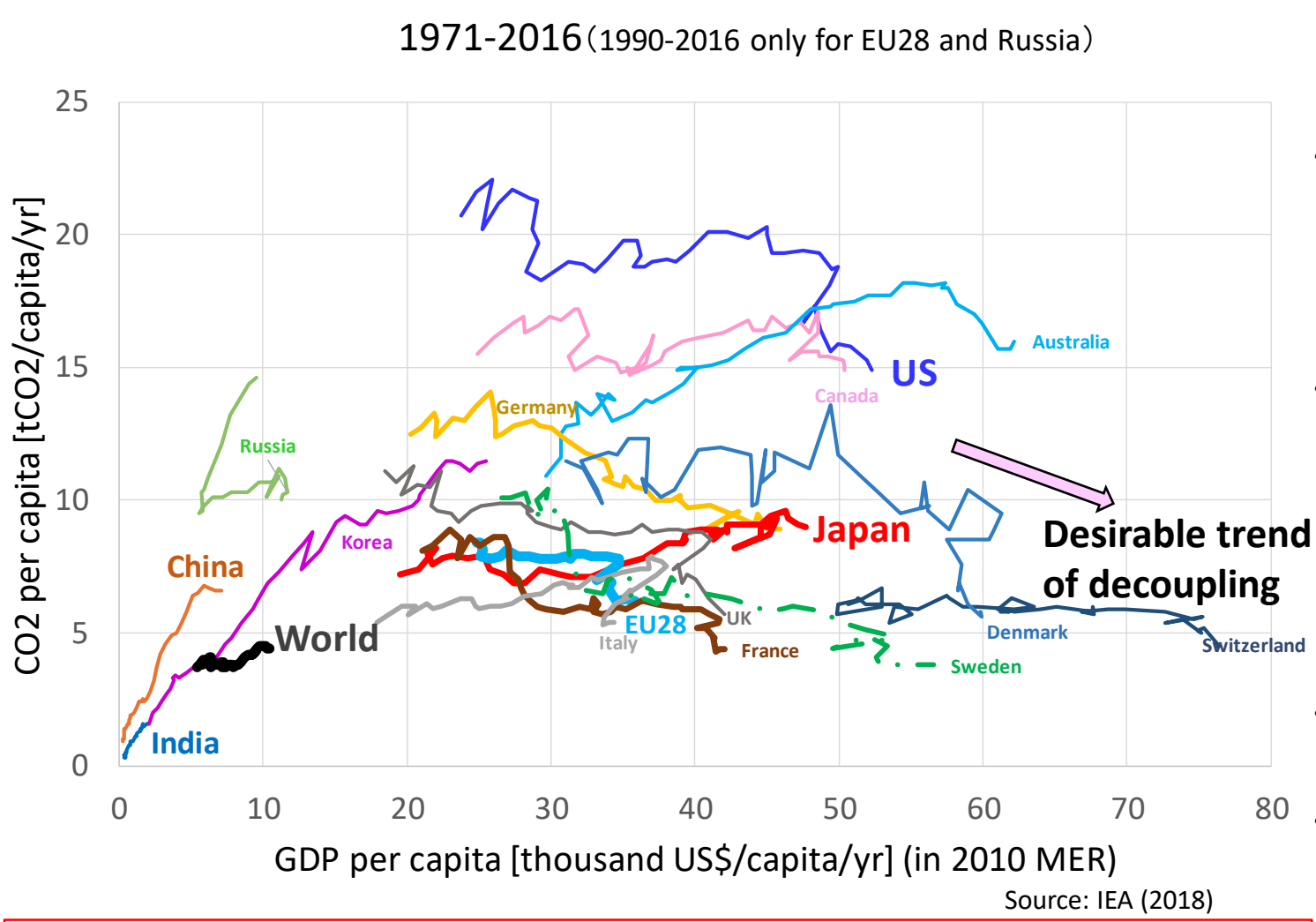
Global GDP and energy-related CO2 emissions for 1971-2018



Source: IEA (2018,2019)

- A strong positive correlation between global GDP and CO2 emissions is observed.
- Although global emissions were almost flat between 2013 and 2016, the emission is in an upward trend again in 2017 and 2018.
- The trend for 2013-2016 can be regarded as adjustments of larger emissions growth in 2009-2013 to the long term trend. Major contributions of this leveling were production adjustment of steel or cement sectors mainly in China, and a shift to shale gas in U.S. Impact of increase in renewable energy diffusion seemingly is relatively small.
- According to the long-term trend, the prospect for decreasing global CO2 emission is not so optimistic.

GDP vs CO_2 emissions in major countries: overview



Source: IEA (2018)

Although several developed countries appear to be following decoupling trend as a whole, it is hard to reach a clear conclusion as various and complicated factors are entangled.

- Several developed countries seem to follow decoupling trend, i.e. GDP increases while CO_2 emission decreases.
- On the other hand, CO_2 emissions per capita vary widely among countries with similar GDP per capita, due to heterogeneity in their land area and industrial structure.
- Switzerland, Sweden and France are thought to be on the leading edge of decoupling trend because of their small CO_2 emissions despite their relatively high GDP. But their emission levels have conventionally been low due to high ratios of hydro and nuclear.
- Increase of historical CO_2 emissions by China is much steeper than forerunners.
- Detailed investigation is required to conclude whether these trends are truly contributing to global decoupling, considering international sharing of industry and domestic industrial structure.

Definition : “decoupling” between economy and CO2 emission (or energy consumption)

	GDP increases, but CO2 emissions intensity (divided by GDP) decreases （0<GDP elasticity< 1.0）	GDP increases, but CO2 emissions decreases （GDP elasticity<=0）
By Handrich et al. (2015)	weak decoupling	strong decoupling
By PwC (2013)	relative decoupling	absolute decoupling

This paper uses this definition as “decoupling.”

1) Handrich et al.(2015) Turning point: Decoupling Greenhouse Gas Emissions from Economic Growth
2) PwC(2013) Decarbonisation and the Economy

Methodology for estimating consumption-based CO2 emissions

・Production-based CO2 emissions (by sector) were estimated using IEA-CO2 statistics (2017, energy-related CO2), and consumption-based CO2 was estimated using the input-output table in the following manner.

Estimation of Consumption-based CO2 emissions（Cons CO2）based on Peters et al.(2008)：

$$ConsCO2(r) = EF(r)\cdot(I-(I-M(r))A(r))^{-1}\cdot(1-M(r))(C(r)+I(r)) + ImCO2(r) + RCO2(r) \quad (1)$$

CO2 emissions for domestic demand of domestic goods

CO2 emissions embodied in imports

Direct emissions for residential

$$L(r)=EF(r)\cdot(I-(I-M(r))A(r))^{-1},$$

$$ImCO2(r)=\Sigma_{(s)}\{L(s)\cdot Ex(s,r)\}\ (=\Sigma_{(s)}\{L(s)\cdot Im(r,s)\}) \quad (2)$$

←Emissions embodied in exports from region S to region R (imports in region R)

The following equation represents relationships between consumption- and production-based emissions. :

$$ConsCO2(r) = ProdCO2(r) + ImCO2(r) - ExCO2(r)$$

Note: $ExCO2(r)=\Sigma_{(r)}\{L(r)\cdot Ex(r,s)\}$ (3)

$$ConsCO2(r) - ProdCO2(r) = ImCO2(r) - ExCO2(r) \quad (4)$$

r、s: region(country)
I: unit matrix
A: input-output coefficient matrix,
M: import rate matrix
EF: sectoral CO2 factor (CO2/output for sector i),
C:final consumption（household＋government）, I:investment,
ImCO2：CO2 emissions embodied in imports,
RCO2: Direct CO2 emissions for residential sector,
Ex：export, Im：import

Assumptions for estimates on consumption-based emissions

- (production-based) CO2 emissions based on IEA-CO2 statistics (2017): by country and by sector
  - ✓When CO2 emissions by sector were zero in the statistical data, we assumed alternatives using emissions in the proxy areas.
  - ✓ For the steel sector emissions in this analysis, CO2 emissions from coke ovens and blast furnaces are also included (however, CO2 emissions from by-product gas power generation are accounted for by the electricity sector). IEA statistics are counted in the energy conversion sector.
  - ✓This analysis excludes emissions for international bunker based on Davis&Caldeira(2010).

- Input-output tables and trade matrix tables based on WIOD2016 (World Input-Output Database）

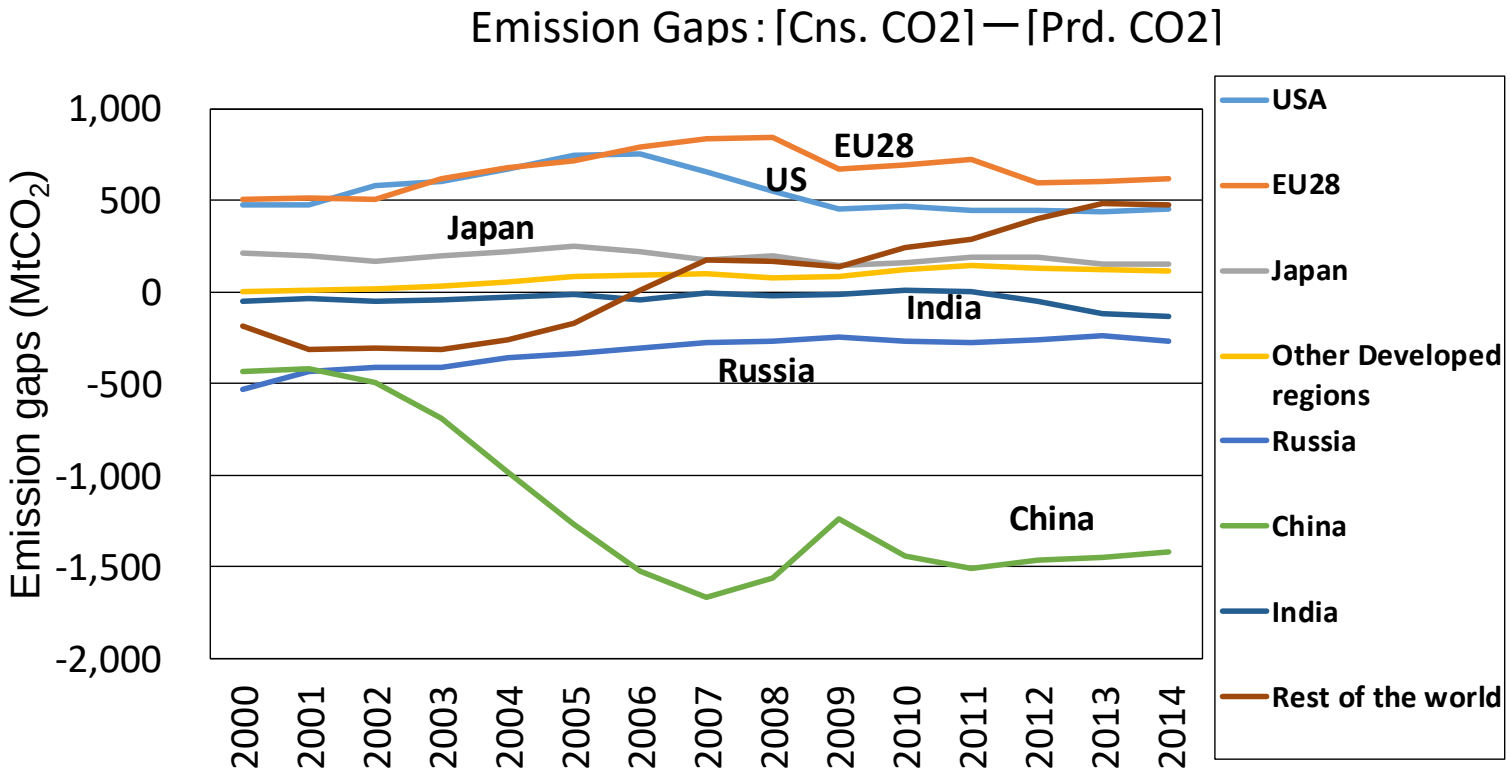
- As for the industrial classification, 16 industrial classifications (+ households) were assumed to match the industrial classification of IEA-CO2 statistics, and both data were aggregated and used.

* http://www.wiod.org/database/wiots16

Regional comparisons: Emission Gaps between consumption- and production-based CO2 emissions

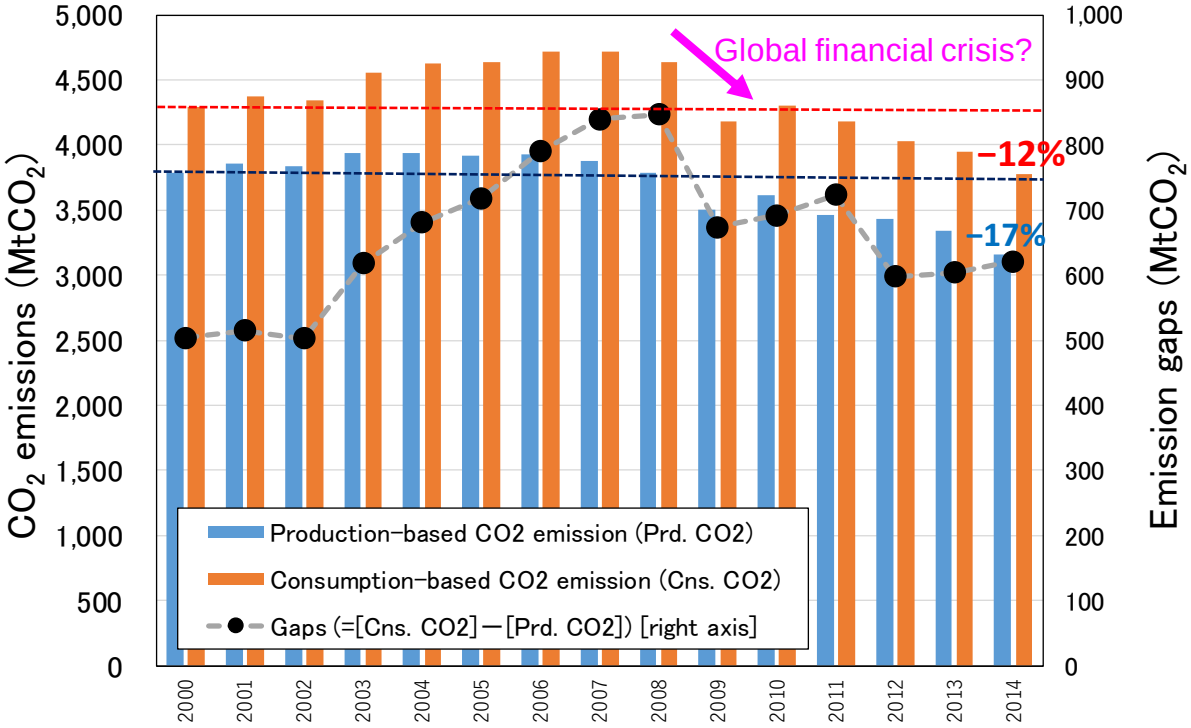
Net CO2 emissions imports: Consumption-based emissions higher than production-based emissions

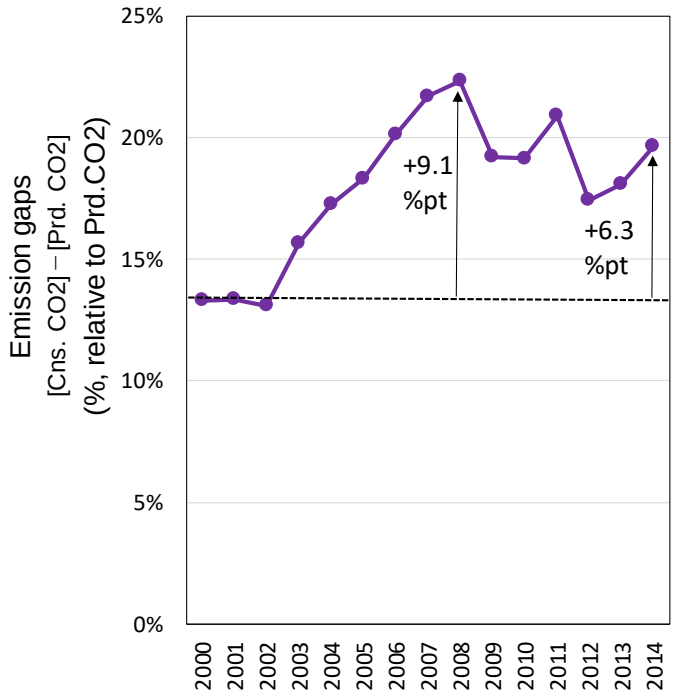
Net CO2 emissions exports: Consumption-based emissions lower than production-based emissions



- In major developed countries (US and EU28, Japan), it has been estimated that since 2000, consumption-based CO2 emissions have been continuously higher than production-based emissions. Much of the imported CO2 comes from China.
- Even in developed countries, the trend of differences in emissions varies by region.

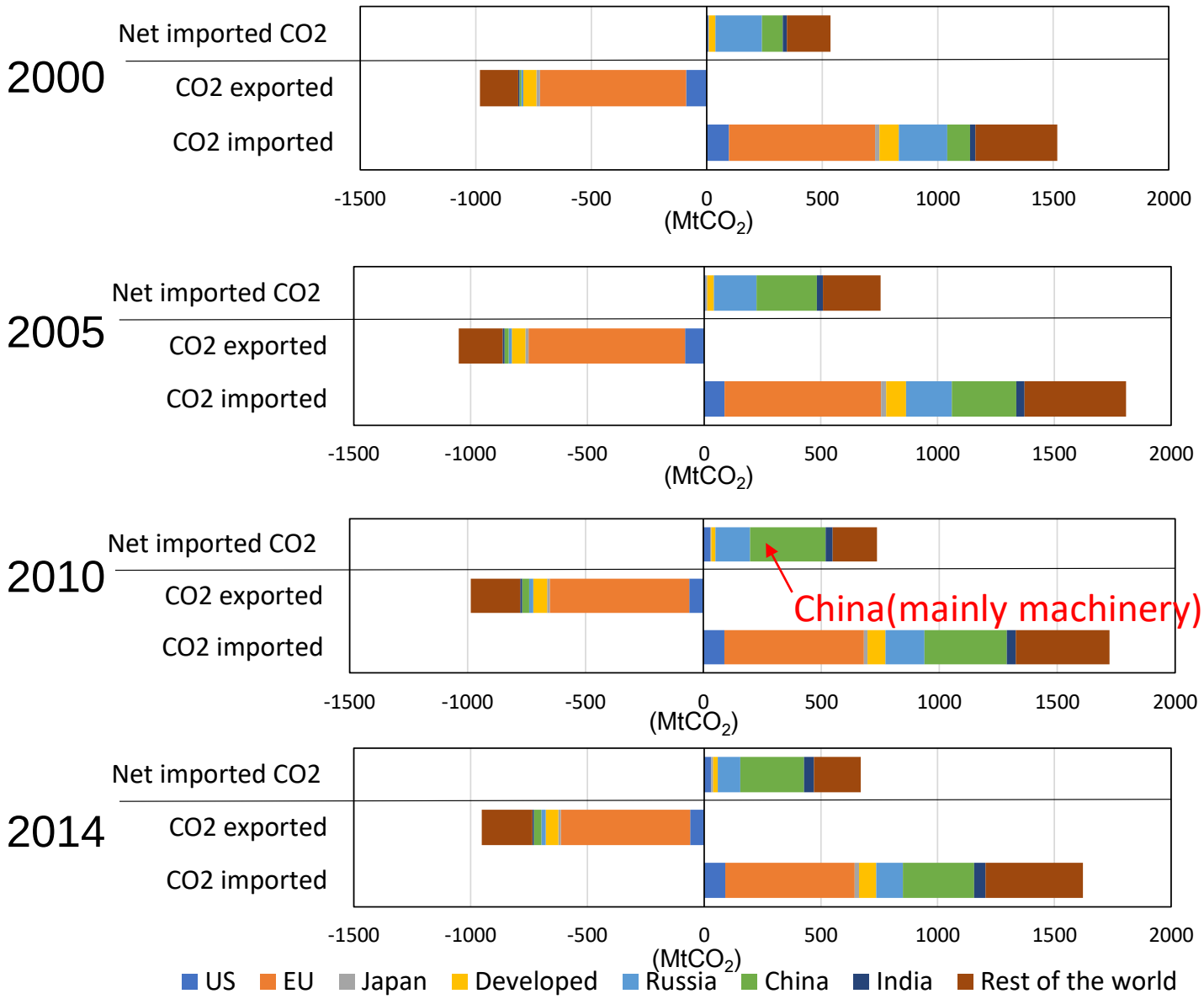
EU28：Production-based and consumption-based CO2 emissions（2000-2014）





- Growth of consumption-based CO2 was larger until 2008 than that of production-based, expanding emission gaps between consumption- and production-based CO2.
- Those are because of increases in emissions embodied in imports (mainly of machinery from China). While production-based emissions for EU decreased, imports increased and then the embodied emissions in imports increased. As a result, the EU contributions to global emissions reduction were not so large.
- But, after the global financial crisis, the gaps were shrinking. Although amounts of imports increased continuously, sectoral CO2 intensities of imports in the production sites (mainly China) decreased considerably after late 2000s.

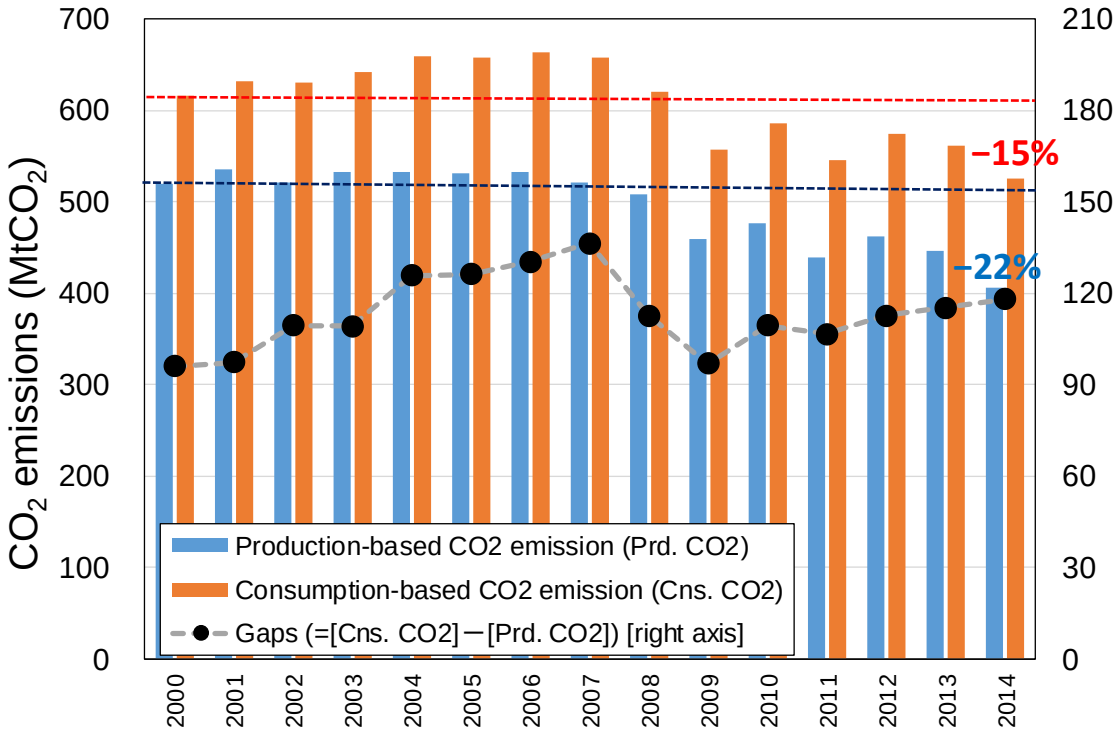
EU：CO2 emissions embodied In Imports

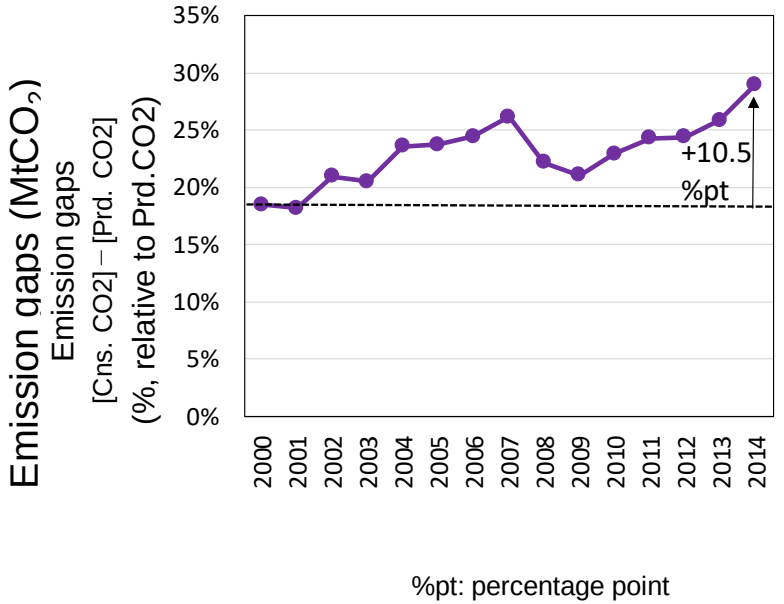


- Since 2005, embodied CO2 from China (mainly mechanical products) and other regions (mining) has increased.
- Although the amount of imports continued to increase after 2005, the change in the CO2 intensity of importers is much more improved. Therefore the amount of CO2 embodied in imports has decreased slightly after 2005.

Note：Imports are represented as positive values and exports as negative values.

UK：Production-based and consumption-based CO2 emissions（2000-2014）



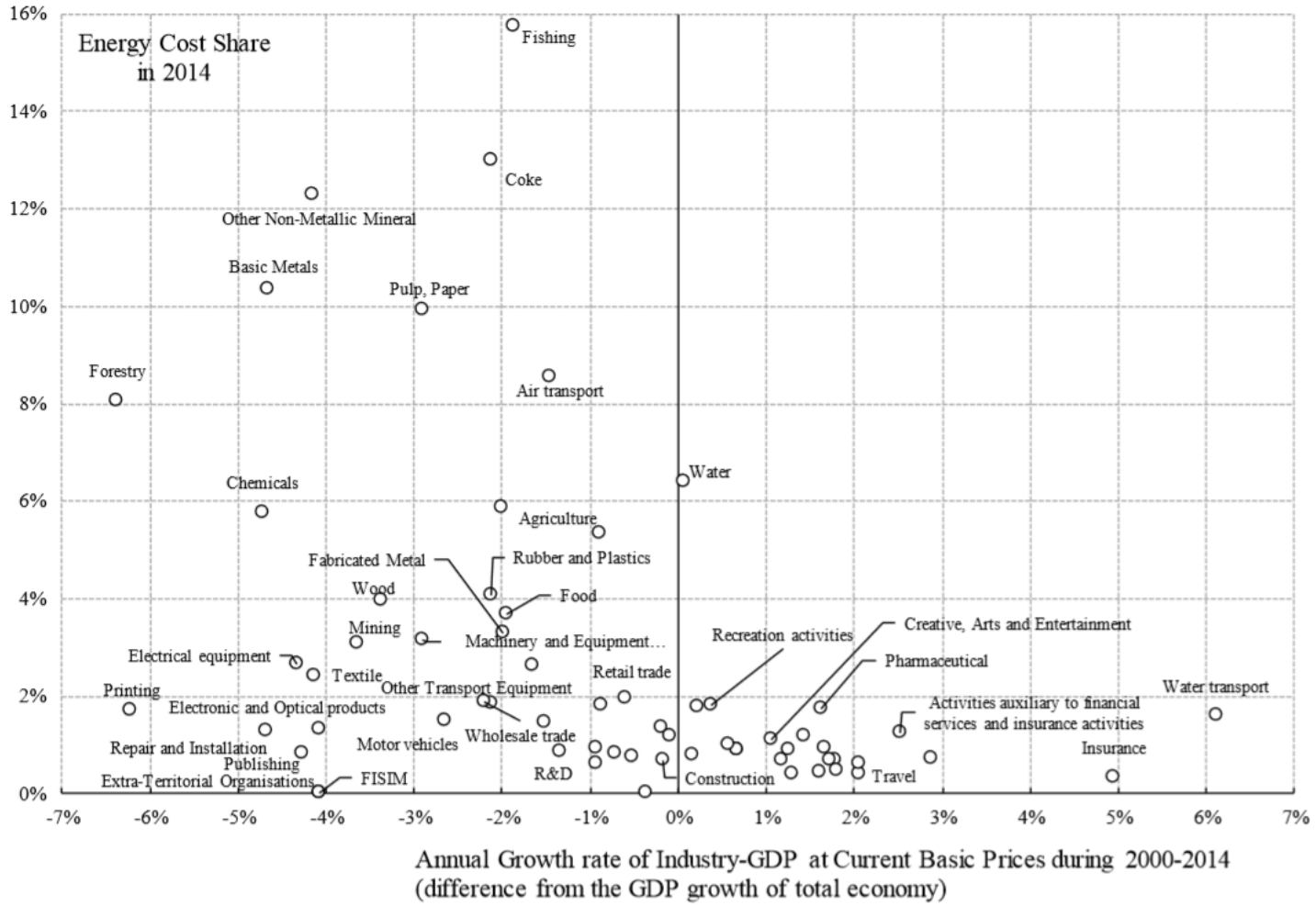


%pt: percentage point

- Previous studies reported that the U.K. is a country that has made significant progress in improving efficiency (according to production-based emissions). However, considering consumption basis, the proportion of consumption-based CO2 is continually greater than production-based CO2.
- The emission gaps (Cons.-Prod.) increased through 2007. Although the gaps decreased around the financial crisis, it has slightly increased again since 2010 .
- For 2000-2014, the decrease rate in consumption-based emissions since 2000 (-15%) is lower than that of production-based emissions (-22%).

Energy cost share (2014) vs Economic growth (2000-14) of industrial sectors in UK

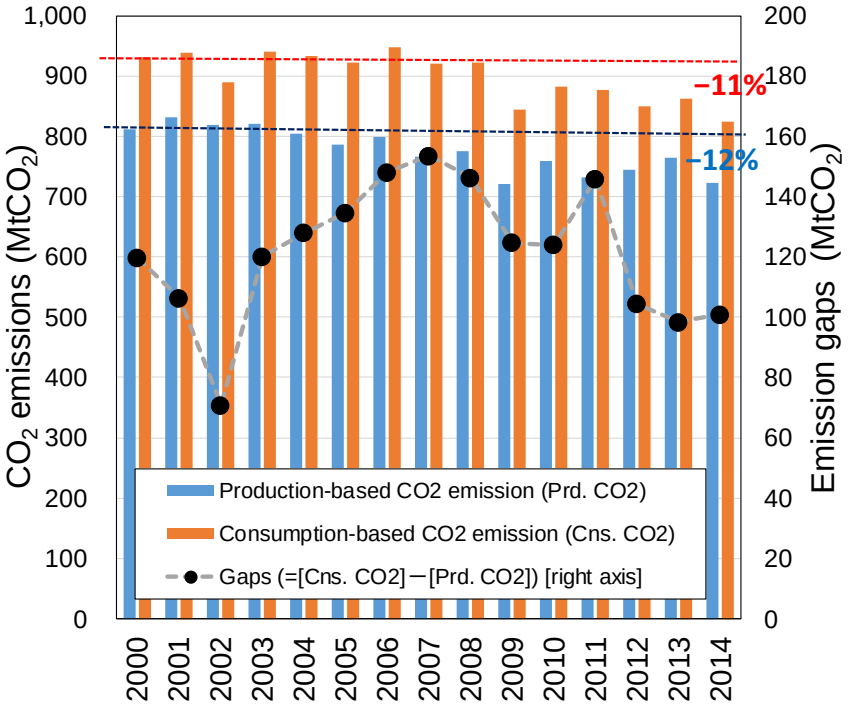
Source: K. Nomura, https://www.dbj.jp/ricf/pdf/research/DBJ_RCGW_DP60.pdf (in Japanese)



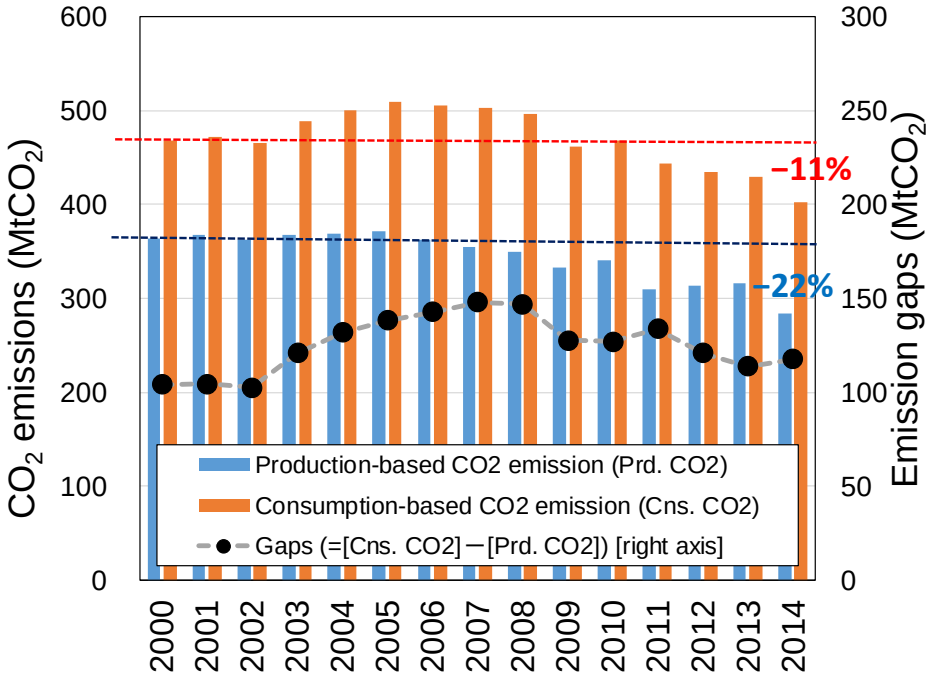
The industrial sectors having high shares of energy costs in the total costs showed relatively small growth rate between 2000 and 2014. These sectors shifted to outside the UK according to the analyses of consumption-based CO_2 emissions.

Germany and France:
Production-based and consumption-based CO2 emissions（2000-2014）

Germany



France

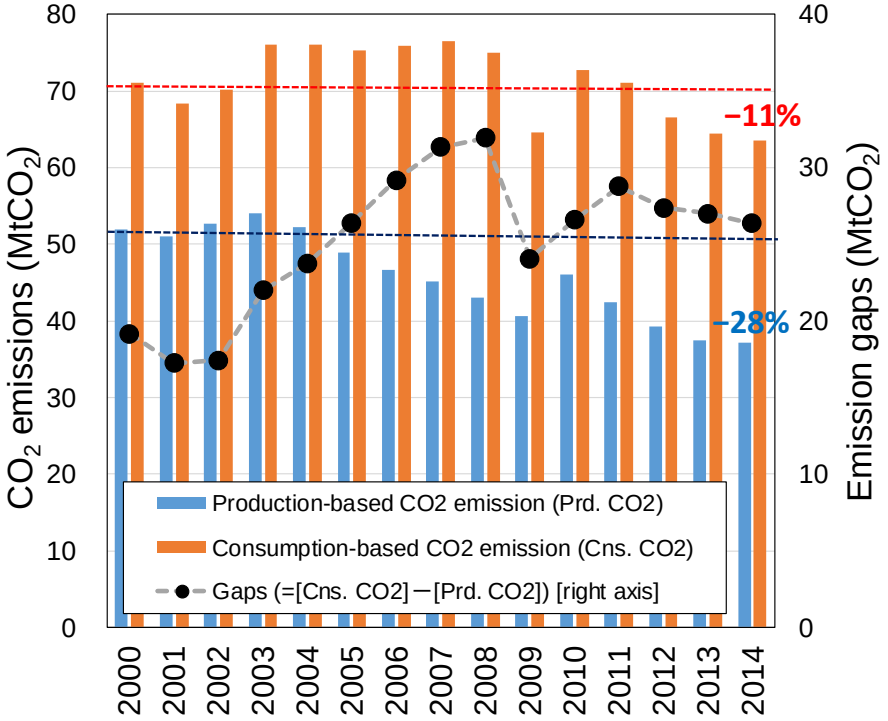


- Exceptionally among the EU countries, Germany has made gradual reductions on both production- (Prd.CO2) and consumption-based (Cns.CO2) emissions during the periods.
- The change rates of Prd.CO2 and Cns.CO2 in 2014 were -12% and -11% compared to 2000, respectively, which shows similar decrease rates.

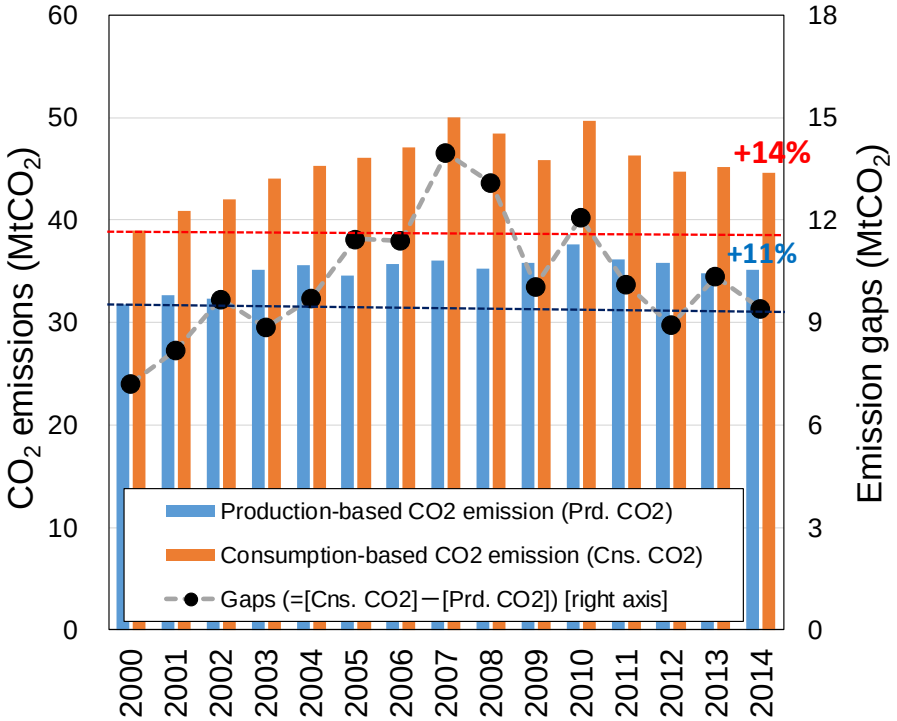
- Change rates of Prd.CO2 and Cns.CO2 in 2014 were -22% and -11% compared to 2000, respectively. Decreases in Cns.CO2 were smaller than those in Prd.CO2 . The gaps in decrease rates are relatively large in Europe.
- Similar to EU countries, until 2009 of the global financial crisis, the emission gaps expanded.

Sweden and Norway:
Production-based and consumption-based CO2 emissions（2000-2014）

Sweden



Norway

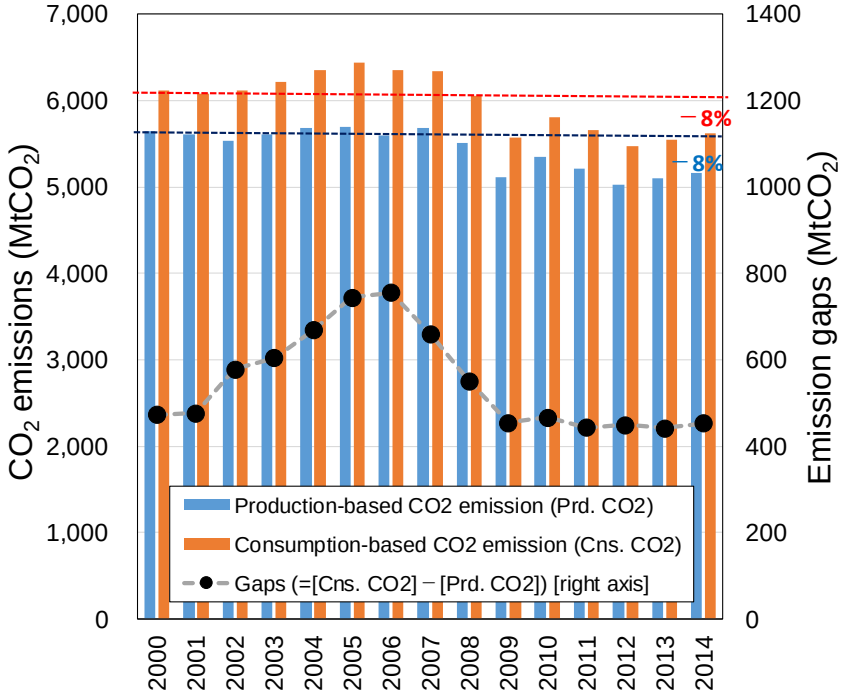


- Change rates of (Prd.CO2) and consumption-based (Cns.CO2) in 2014 were -28% and -11% compared to 2000, respectively. Decreases in Cns.CO2 were much smaller than those in Prd.CO2. The differences in decrease rates are relatively large in Europe.
- Similar to EU countries, until 2009 of the global financial crisis, the emission gaps substantially expanded where the growth of Cns.CO2 became larger in EU countries.

- Norway (Non-EU) increased both emissions for the period except in the developed regions, and change rates of Prd.CO2 and Cns.CO2 in 2014 were +11% and +17% compared to 2000, respectively.
- In terms of Cns.CO2, the domestic demands on manufacturing industry are highly dependent on imports and the relevant emissions embodied in imports through international trade.

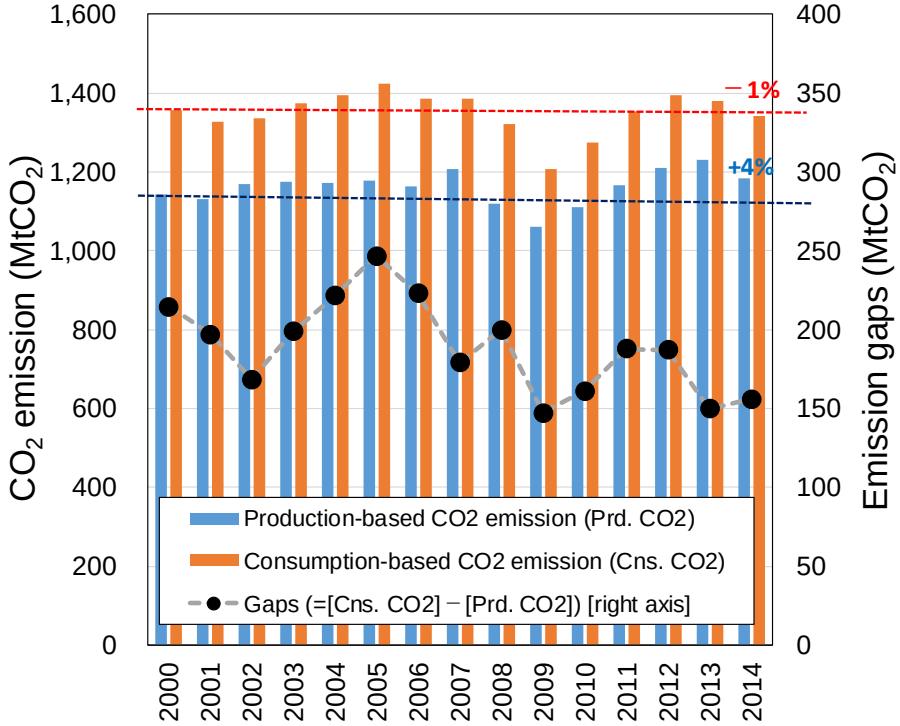
USA and Japan:
Production-based and consumption-based CO2 emissions (2000-2014)

USA



- Gaps between consumption- (Cns.CO2) and production-based (Prd.CO2) emissions increased substantially towards 2006, which were similar to most of the EU countries.
- However, the emission gaps turned to decrease due to the expansion of domestic production of shale gas launched around 2006, where manufacturing reshoring was possibly caused by the availability of cheaper energy. The gaps became almost flat after 2009.

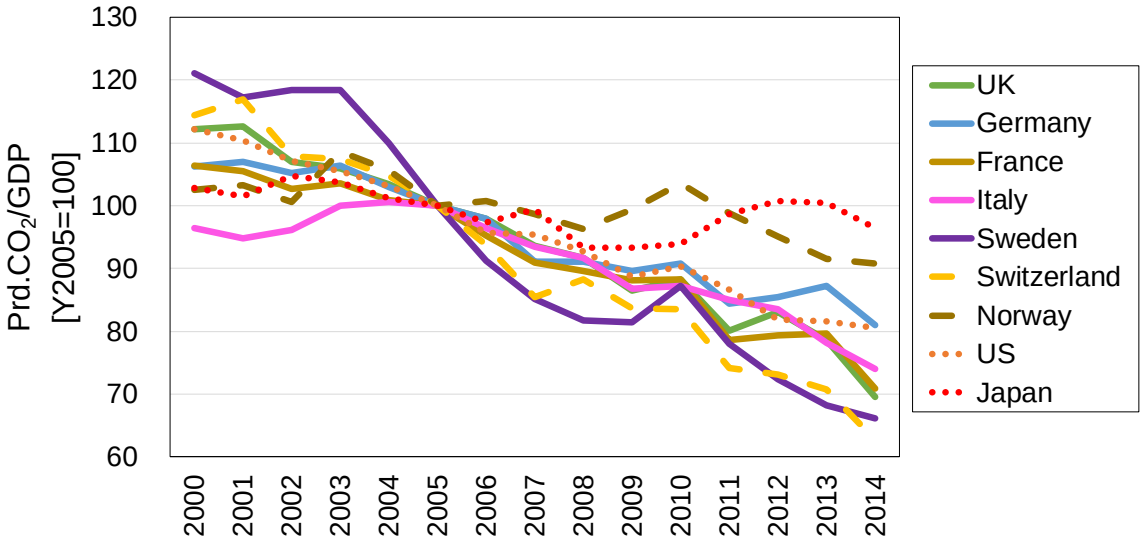
Japan



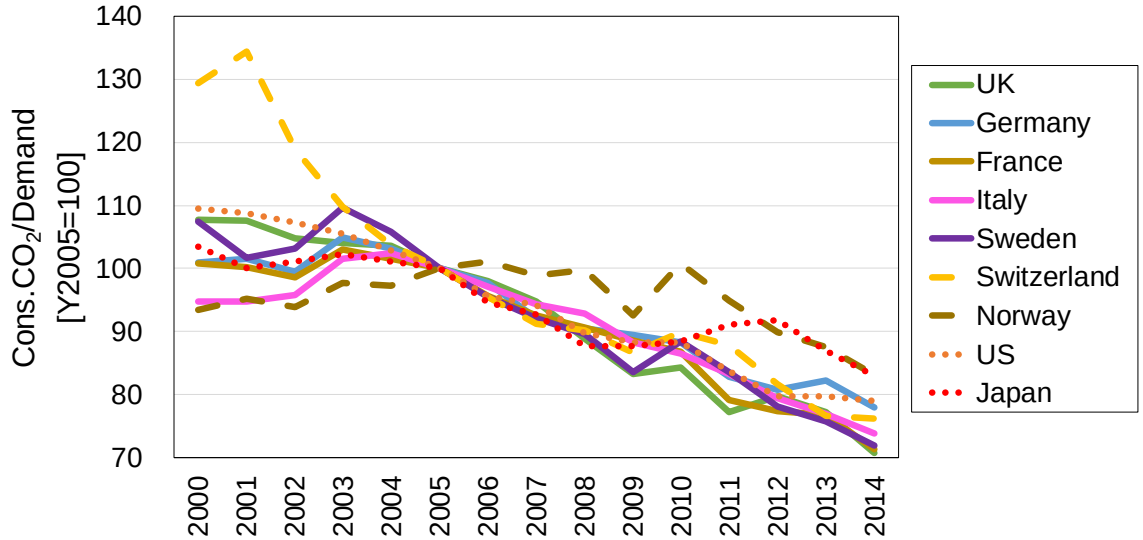
- Changes in Cns.CO2 were similar to those in Prd.CO2, and the gaps were gradually shrinking.
- Those results indicate that manufacturing industries having relatively higher emission intensities maintained at relatively high levels in Japan economic structure. And then carbon leakage due to increases in import dependencies did not largely expand during the years.

CO2 Emission Intensities in European countries and US, Japan: Production-base v.s. Consumption-base

Production-based CO_2 per Production (GDP)



Consumption-based CO_2 per Demand*



- In terms of the production-based CO_2 emissions per GDP, the degrees of improvement differs greatly.
- However, concerning the consumption-based emissions intensities, the improvement rate of the EU countries and U.S., Japan* (-2011) does not differ much.
- ** Exceptionally, Japan's emission intensities increased after 2011 because of the shutdown of nuclear power generation after the Fukushima Daiichi nuclear power accident caused by the Great East Japan Earthquake.*

Note: GDP and Demand are based on real local currency unit.

**Demand represents domestic demands for domestic and imported goods, which corresponds to final demand plus Imports.*

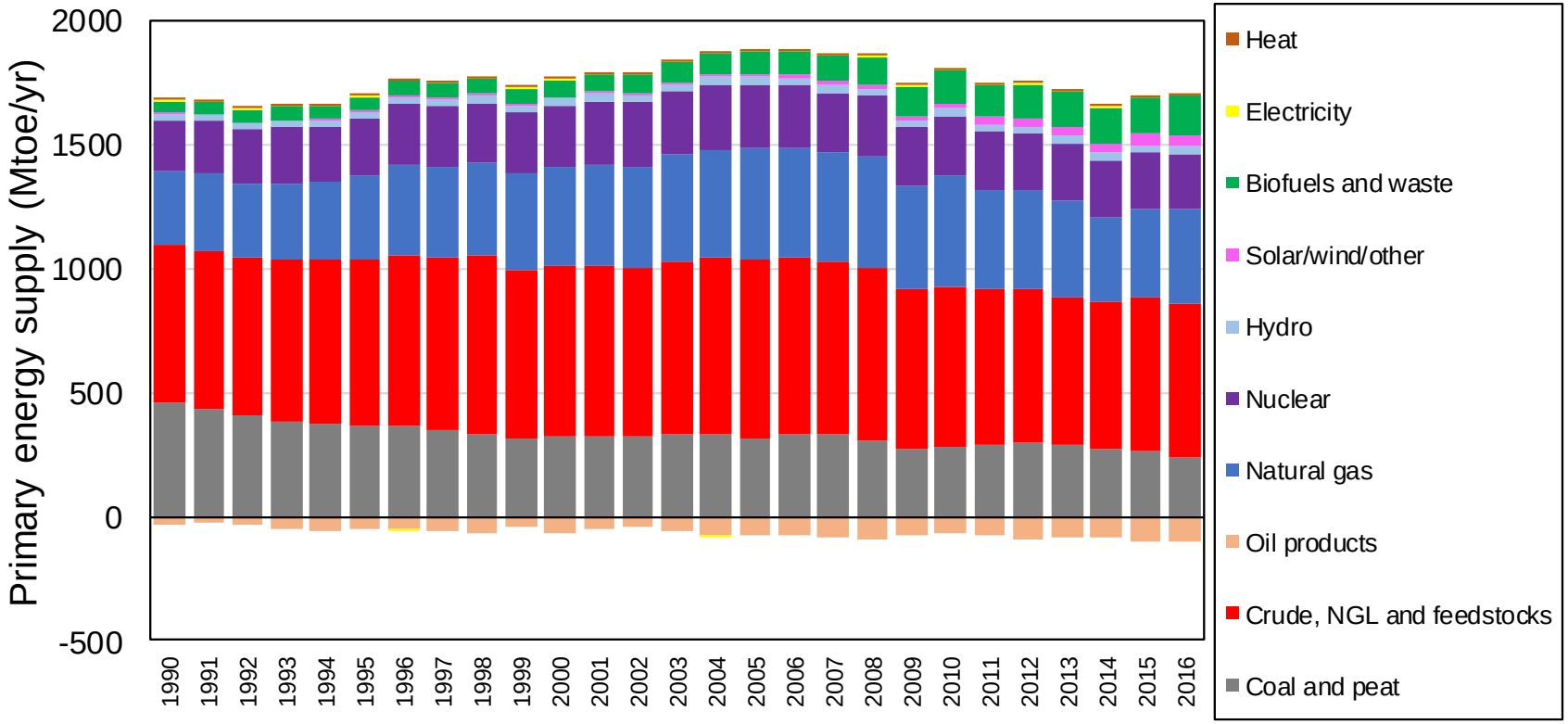
Conclusion

- According to production basis, some European countries and EU as a whole seem to be successful in decoupling between GDPs and CO2 emission increases.
- However, considering consumption basis like LCA, the estimates on consumption-based emissions revealed the impact of significant dependence on imports. Imported CO2 emissions are large, and it has been evaluated that CO2 emissions have been transferred to other parts (mainly China) of the world. The European contribution to global reduction is not so large as generally believed.

- True decoupling between GDP and CO2 emissions increases is important for sustainable climate change mitigation. Structural changes in consumption with low carbon intensities and innovations in products and services for lowering consumption-based CO2 (carbon footprint) bring global decoupling. (e.g. MaaS(inc. Car-sharing/Ride-sharing) and LED, Shale gas)

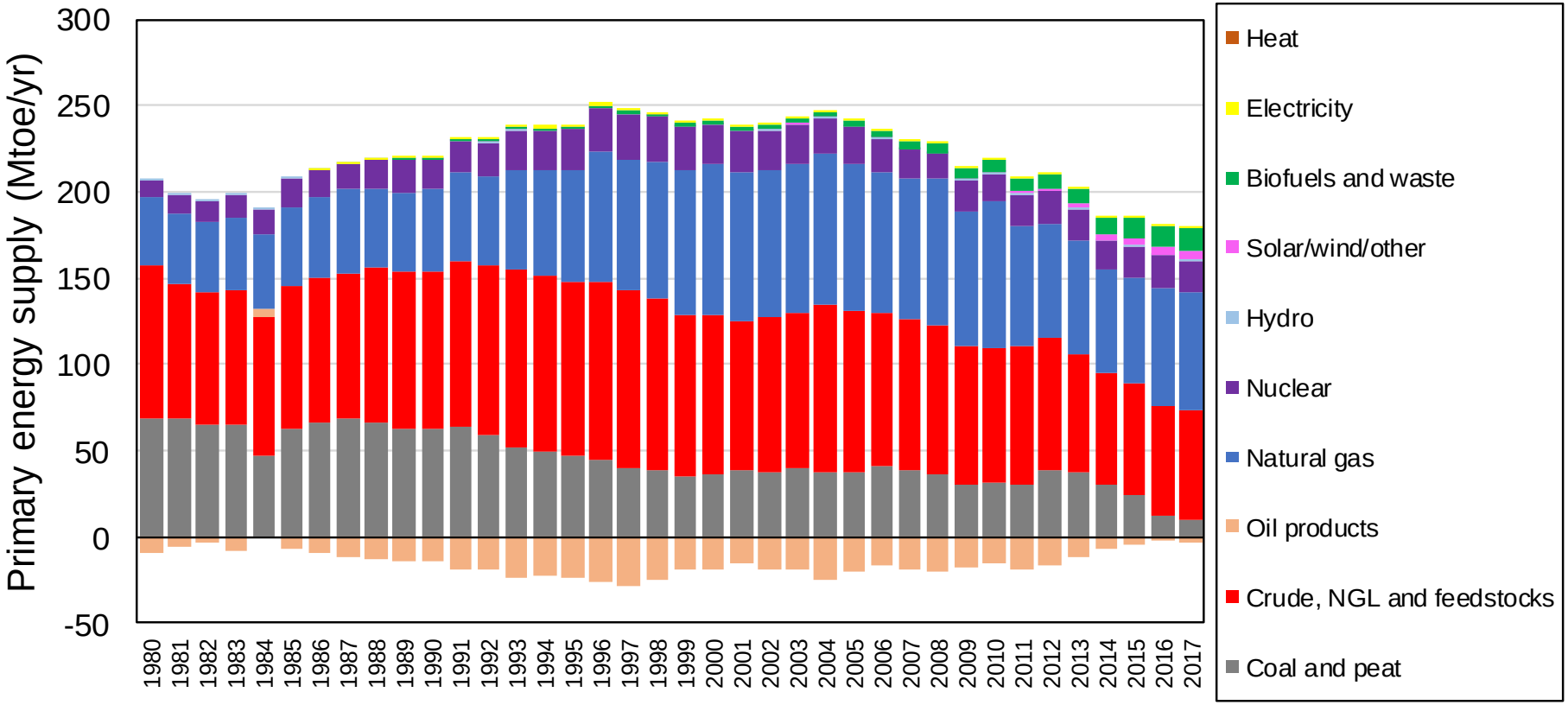
Appendix

EU28：Primary energy supply



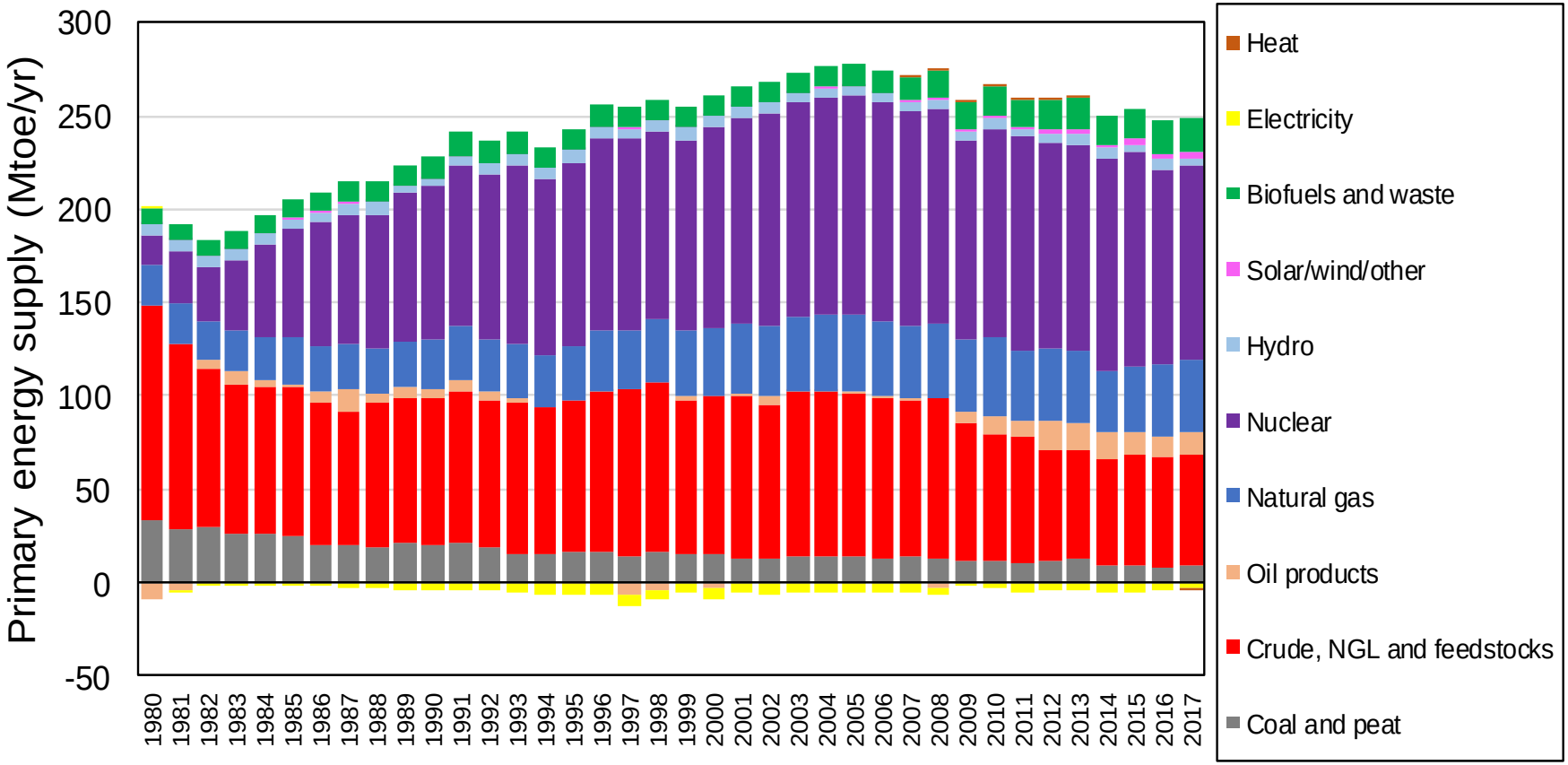
- EU region remained relatively high shares of fossil fuel.
- Total fossil fuel supply decreased after 2006.
- Wind and PV in total primary energy supply remained low level whereas wind and PV increased.
- Rather, biomass shares are higher than wind and PV.

UK：Primary energy supply



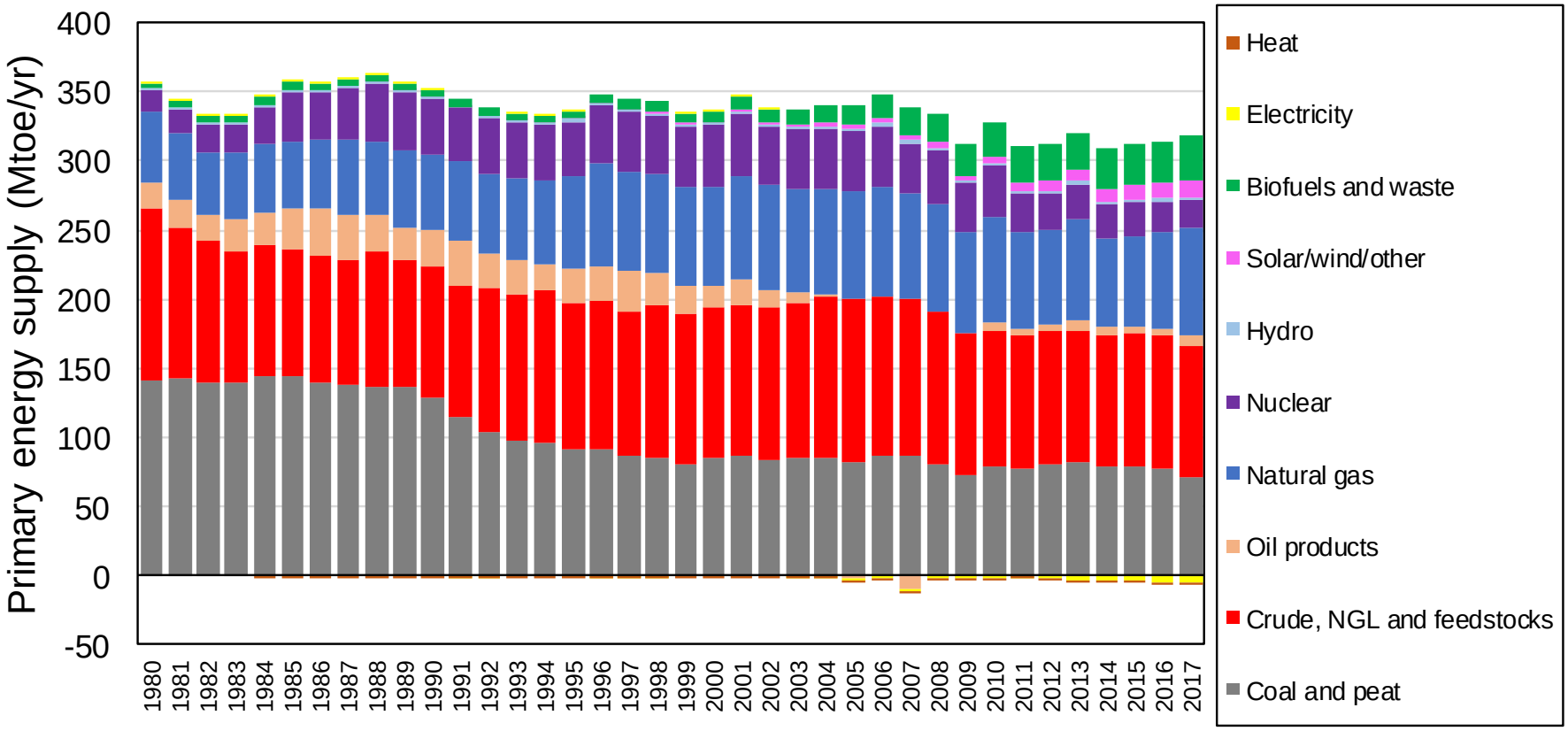
- There was recently significant change in total primary energy supply.
- Coal decreased largely whereas biomass slightly increased.
- Energy-saving also improved.

France：Primary energy supply



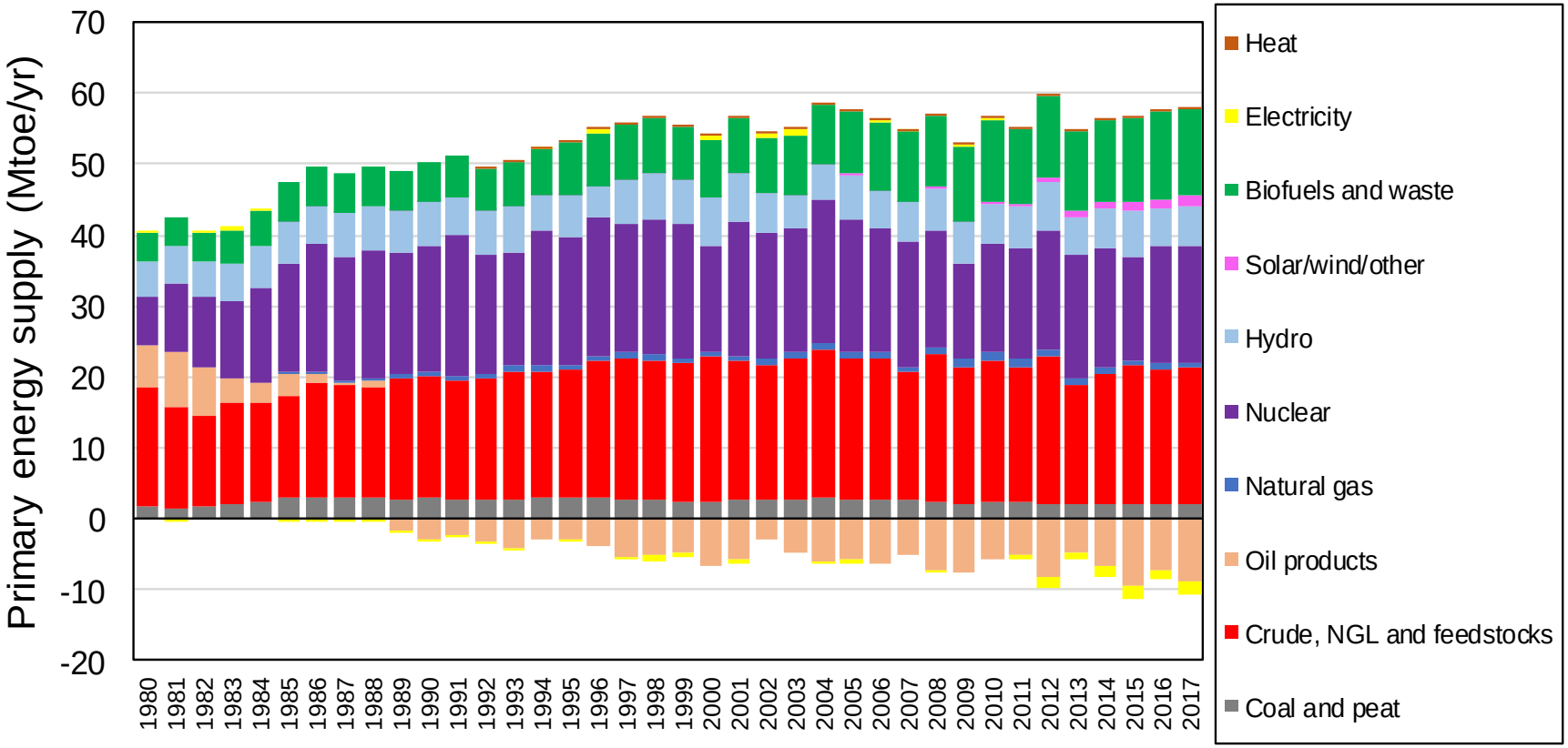
- Relatively high shares of nuclear power and low shares of coal in energy mix were kept.
- Large structure changes in primary energy supply were not observed although oil supply decreased slightly.

Germany：Primary energy supply



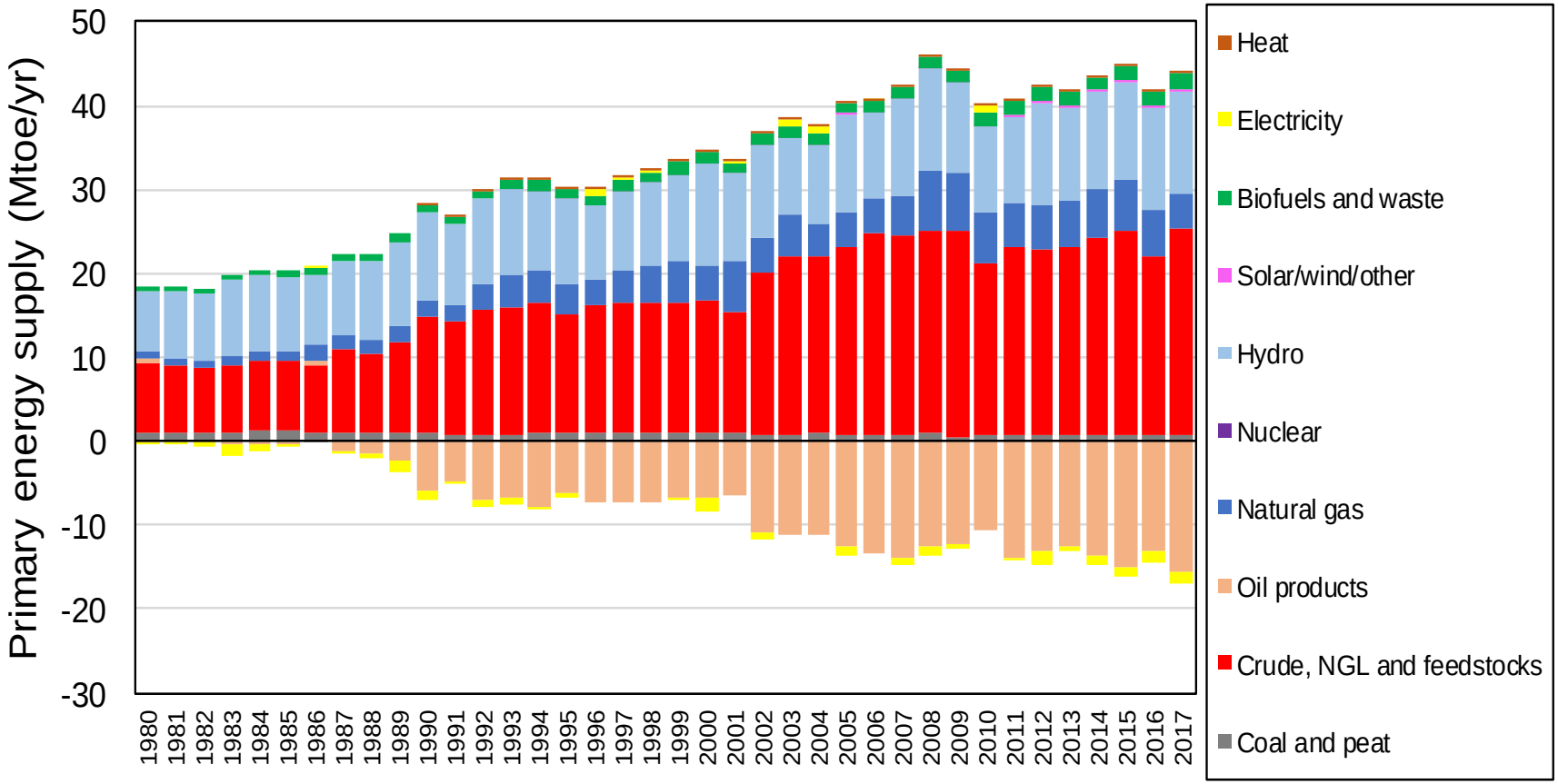
- Germany remained relatively high shares of coal.
- Total fossil fuel supply decreased slightly.
- Wind and PV in total primary energy supply remained low level whereas wind and PV increased.
- Rather, biomass shares are higher than wind and PV.

Sweden：Primary energy supply



- There was recently little change in total primary energy supply, although biomass slightly increased.
- On the whole, trends of relatively high shares of nuclear power were kept in energy mix whereas the recent shares decreased slightly.

Norway：Primary energy supply



- Gross primary energy supply for Norway increased.
- Norway remained the largest gas producers in Europe, and substantial exports of gas and oil greatly contributed to steady economic growths. In particular, Norwegian gas exports, mainly to other countries in Europe, were record-high for three years in 2017.
- Net primary energy supply recently remained unchanged, although small increases in hydro and biomass energy were observed.