Mapping the Energy Flow from Supply to End Use in three Geographic Regions of China

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MAPPING THE ENERGY FLOW FROM SUPPLY TO END USE IN THREE GEOGRAPHIC REGIONS OF CHINA

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Overview

China's past economic development policies resulted in different energy infrastructure patterns across China. There is a long tradition in analysing and discussing regional disparities of China's economy. For more than 20 years, regional differences in GDP, industrial outputs, household income and consumption were analysed across China's provincial units. Regional disparities in China's current energy flow are rarely visualised and quantified from a comprehensive, system-wide perspective that is tracing all major fuels and energy carriers in supply, transformation and final end-use in different sectors. A few national and provincial energy flow diagrams of China were developed since 2000, althoug with limited detail on major regional disparities and inter-regional fuel flows. No regional energy flow charts are yet available for East-, Central- and West-China.

This study maps and quantifies energy supply, transformation and end-use for East-, Central- and West-China in 2010 using Sankey diagrams. The regional energy flow diagrams introduced in this study will help to make regional characteristics in China's energy system easier to understand and to analyse for a broad audience, including economists, engineers, infrastructure planners, policy makers, and other non-technical experts. The future development of China's energy infrastructure, interlinked with regional economic development planning, needs to account for various regional differences: (i) in the locations of traditional and renewable energy resources, (ii) in the coverage of existing energy transmission networks and pipelines, (iii) in the location of major load centers, and (vi) in energy trade links with neighboring countries.

Methods

This analysis is based on China's national and provincial energy balance data from 2010 and the current regional division of China in East-, Central- and West-China from the National Bureau of Statistics. Accordingly East-China consists of Liaoning, Beijing, Tianjin, Hebei, Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong, and Hainan. Central-China consists of Heilongjiang, Jilin, Shanxi, Henan, Anhui, Hubei, Hunan and Jiangxi. West-China consists Inner Mongolia, Shaanxi, Gansu, Ningxia, Xinjiang, Qinghai, Sichuan, Guizhou and Yunnan.

The use of energy flow charts and Sankey diagrams in China is relatively new, however it increased since 2005. Most of the energy flow charts for China are mapping the national energy system since 2005 and these flow diagrams are usually based on the national energy balance data from official statistics. A few examples of provincial energy flow charts for two of China's eastern, coastal provinces exist currently, namely for Jiangsu Province in 2008 and Shandong Province in 2009. One fuel specific energy flow diagram is also available for China, this is tracing the national use of crude oil and petroleum products in 2009.

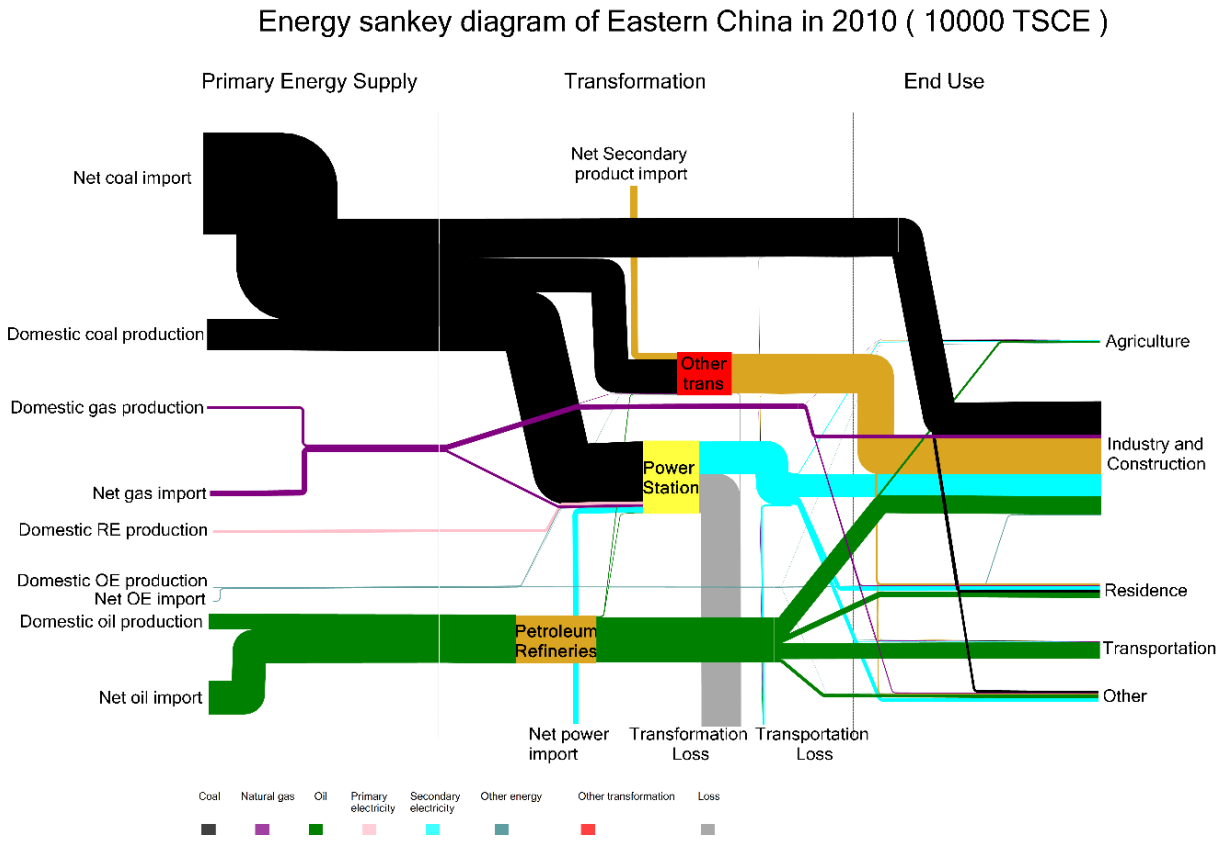
For the case of China, energy flow charts proved in particular useful to identify, classify and sort comparable energy statistical data in order to provide a full picture of China's energy system. A few Chinese researchers started to adjust the official national energy statistics with additional data sources and methodologies to allow for a more detailed mapping of China's national energy flow and associated energy demand drivers as well as to make China's national energy data better comparable to other countries. Apart from China's official statistics, an internationally comparable energy flow chart for China in SI units is annually published by the International Energy Agency, the most recent one is available for 2011.

Sankey diagrams for East-, Central- and West-China are developed in this paper to analyse and map regional characteristics and inter-regional flows of China's energy system. These three regional energy flow charts are benchmarked to the corresponding national Sankey Diagram of China's energy flow in 2010.The following fuels are traced: primary coal products, secondary coal products and heat, oil and petroleum products, natural gas and LNG, primary and secondary electricity and other energy (mainly combustible biomass and waste). In this paper, we

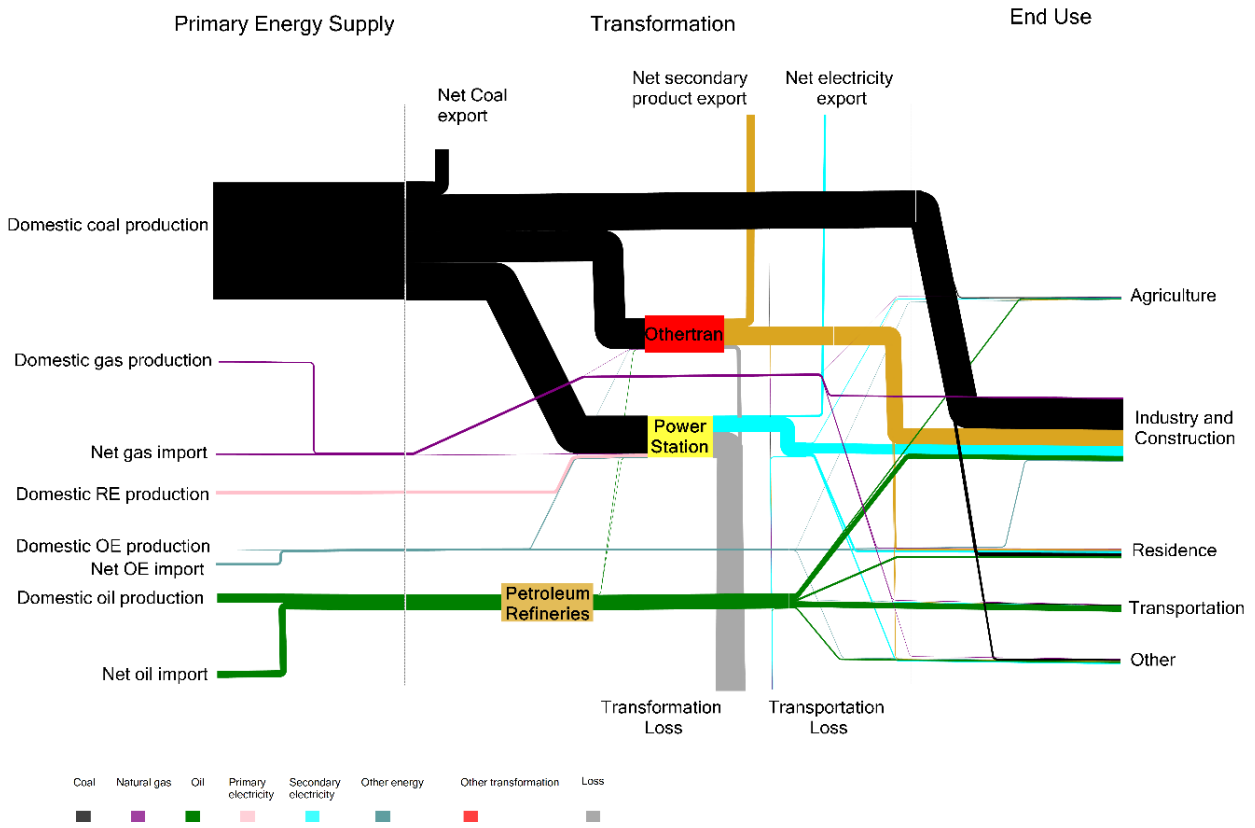
calculate and estimate the regional energy flows for East-, Central- and West-China in 2010, as follows: We collect all provincial energy balance sheets, disaggregated in the format of 30 specific fuels and energy products. We aggregate the provinces into three regions, with 30 disaggregated fuels and energy products. We calculate national conversion factors fuel by fuel from the national disaggregated NBS energy balance in both physical units and in energy units (in total 30 conversion factors). Without having official provincial conversion factors from physical unit to energy unit available for China, we assumed that the national conversion factors could be applied in three regions. The sums of physical data in three aggregated regions of China are then transferred from physical quantity units to energy units by applying the different conversion factors. The regional energy balances in energy units are then aggregated form 30 disaggregated fuels and energy products to six major groups, as per NBS definition (see table below). On this basis Sankey Diagrams are constructed, that follow the requirement of maintaining a regional energy balance in the unit of tons of standard coal equivalent.

Results

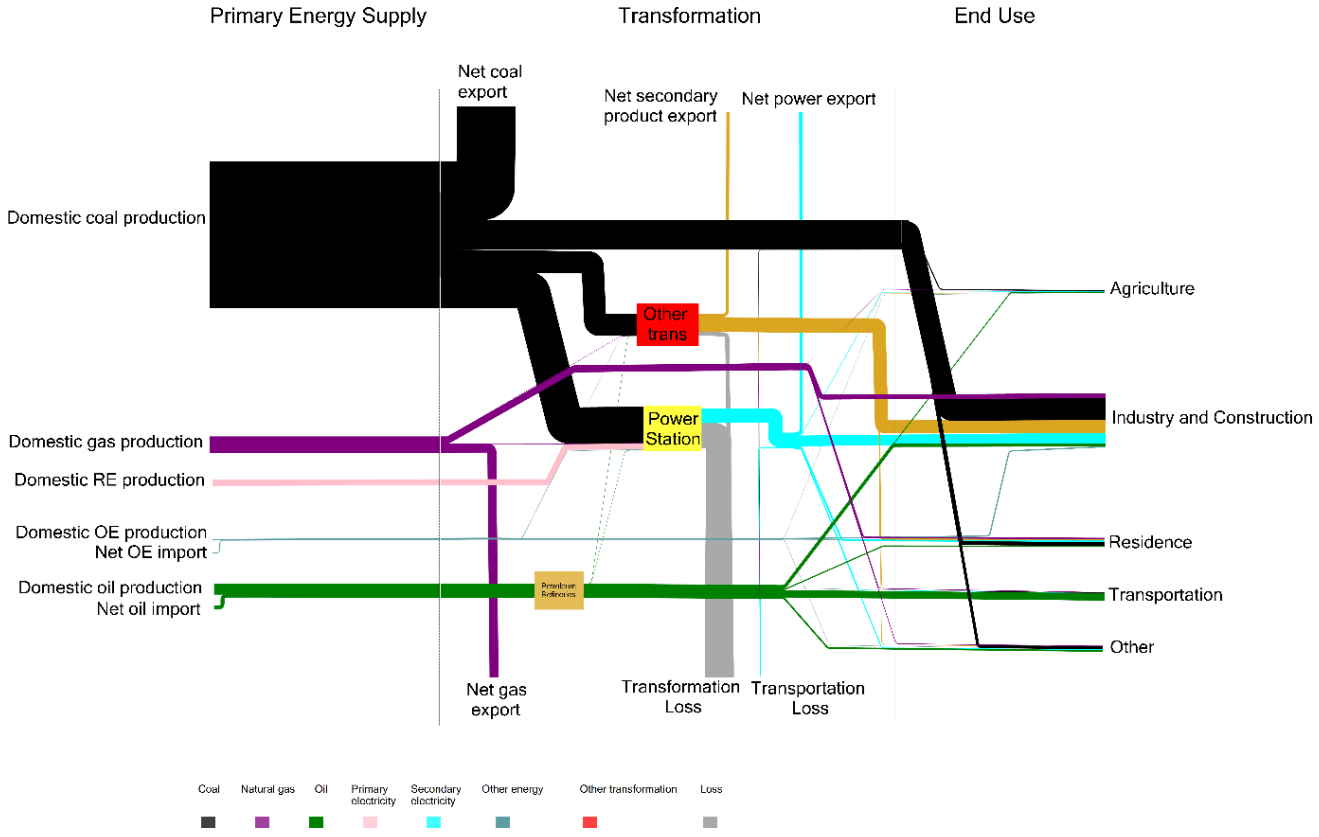
The first energy flow charts (Sankey Diagrams) for East-, Central- and West-China are developped. These include inter-regional fuel flows for coal products, oil and petroleum products, gas, electricity and other energy, which are not quantifiable and comparable in national energy flow charts for China.



Energy sankey diagram of Central China in 2010 (10000 TSCE)



Energy sankey diagram of Western China in 2010 (10000 TSCE)



2. Main regional characteristics of China's current energy supply are quantified and visualised. Coal is the major fuel in China's energy supply, with domestic coal production taking mainly place in Central- (about 50% of national coal production) and West-China (about 39% of national coal production). Domestic oil production of the three regions of China combined amounts to about 299 million tsce in 2010, this is relatively evenly distributed across the different regions of China. Most of the domestic crude production is mapped to East-China, equivalent to about46%. International net-imports of oil and petroleum products are about as large as the domestic crude oil production in 2010. Natural gas production is mostly located in West-China (about 83% of national gas production) . Primary electricity production (excluding secondary electricity from thermal power plants) is mainly mapped to West-China (about 49% of domestic renewable and nuclear power production).

3. Main regional characteristics of China's current energy power production, coal transformation and refining are quantified and visualised. Thermal power production is mainly located in East-China. About 50% of thermal power plants are mapped to East-China, accordingly most of the coal used in power plants is also mapped to East-China in 2010. About 90% of crude oil inputs for refining are mapped to East-China. With regards to coking, the main coal transformation process, Central-China (about 40%) and in East-China (about 35%) are the regions with most of the national coke output in 2010.

4. Main regional characteristics of China's current final energy use in different sectors are quantified and visualised. Industry and construction account for the largest energy consumption in all energy end use sectors, both at a national and a regional level. Within industry and construction, direct raw coal use and secondary coal products use are much higher than electricity, petroleum productan and gas use, both at a national level and at a regional level. Electricity use and petroleum product use in industry and construction are highest in East-China, accounting for about 53% of national electricity use and about 70% of national petroleum product use. The use of petroleum products in the residential sector and in the transport sector shows the largest regional disparities with about 55%-65% located in East-China.

5. Domestic net-energy flows between the three regions of China are larger than international net-energy trade. East-China relies heavily on domestic net-coal-imports from Central- and West-China, while on the other hand East-China is a major domestic net-exporter of oil and petroleum products.

6. Statistical differences persists when working with different official energy data sources in China. When benchmarking key regional energy supply, transformation, and final energy use data with the corresponding national data, this study finds various un-accounted statistical differences, in particular for coal data.

Conclusions

The regional energy flow diagrams introduced in this study will help to make regional patterns in China's energy flow easier to understand and to analyse for a broad audience, including economists, engineers, infrastructure planners, policy makers, and other non-technical experts.

As the regional characteristics of energy supply, transformation, end use vary to a large extend in China today, this study suggest to apply regional energy sytem analysis when introducing major economic and energy policies in China at a national, regional or provincial level. Potential application areas are the design of regional strategies to combat persisting air pollution during the winter heating season in East-China and a cost-benefit analysis of inter-regional coal product supply via road and rail networks, inter-regional electricity trade via grid expansion and international energy trade.

Benchmarking of regional energy flows with national energy flows is important to identify main uncertainties in regional energy flow data, in particular for regional coal data. Further research is needed to understand the underlying causes of these data uncertainties. Comparing the regional and national coal production data, the study suggests that bottom-up reported provincial coal production figures in 2010, the final year of the 11th Five-Year-Plan, might be too high.

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