Integrated Design and Analysis for Sustainable Energy Systems

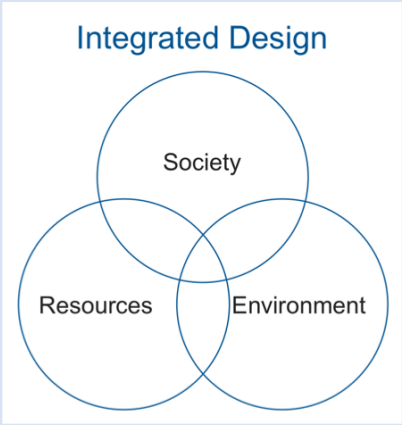
Low Carbon Asia Research Network, LoCARNet

6th Annual Meeting

Bangkok, Thailand

November 1-3, 2017

Toshihiko Nakata, Tohoku University



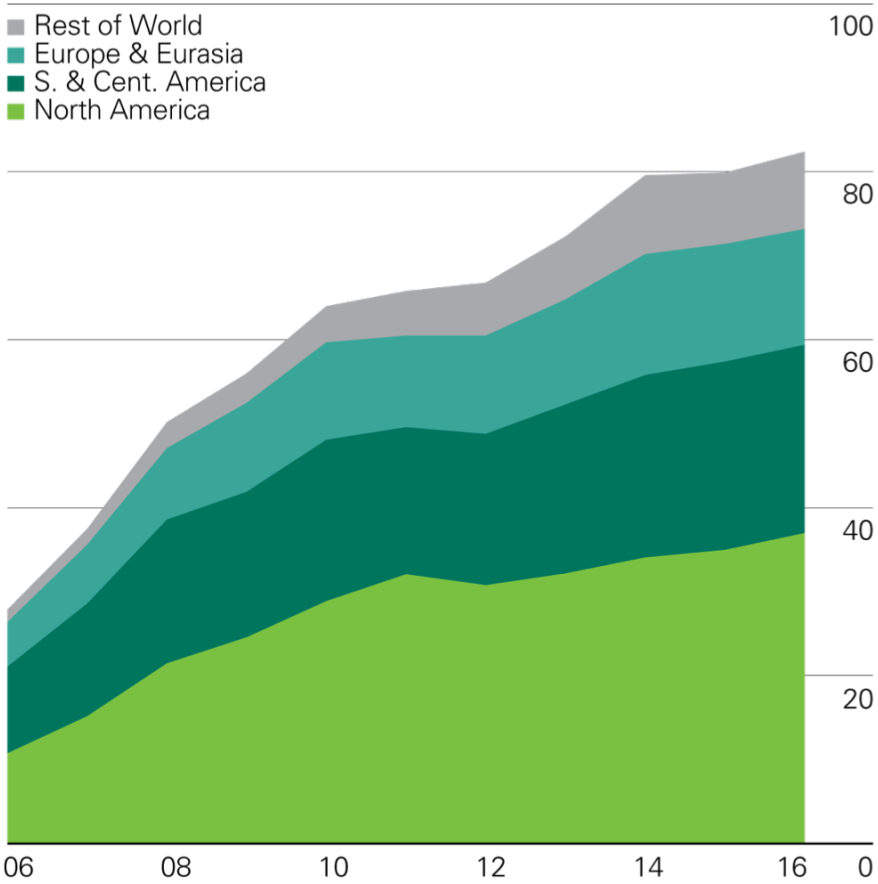
Weekly kerosene shoppers in Sendai on March 5, 2017

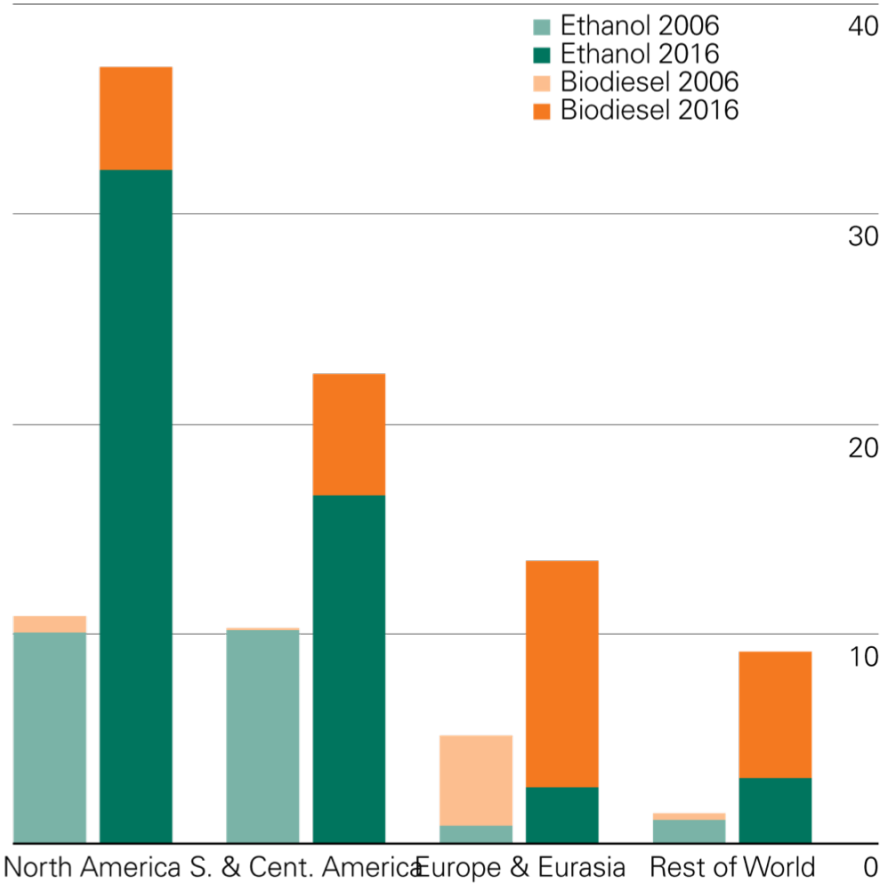
Biofuels production by region

Million tonnes oil equivalent

Japan as Zero biofuels

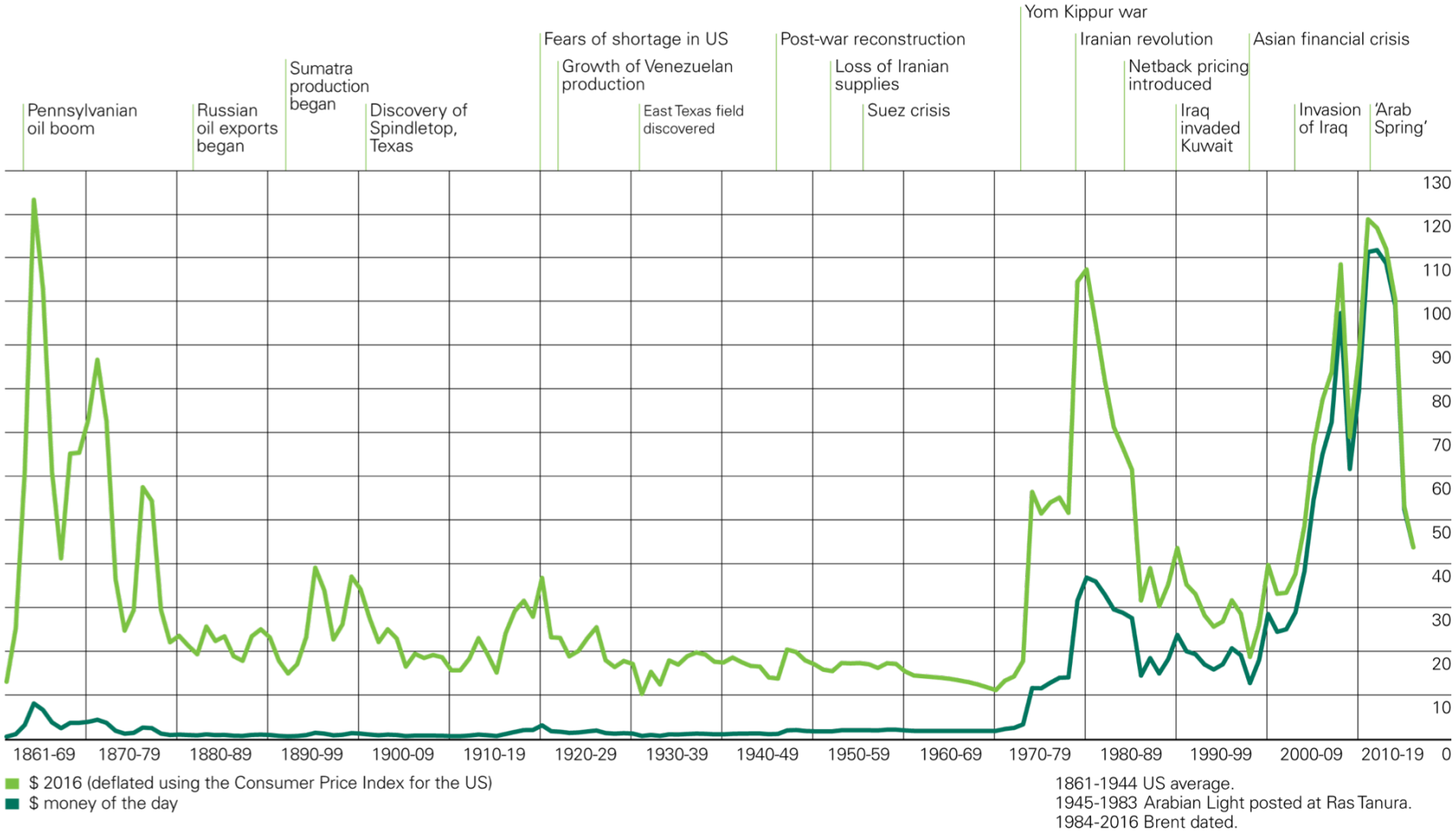
World biofuels production





Crude oil prices 1861-2016

US dollars per barrel, world events



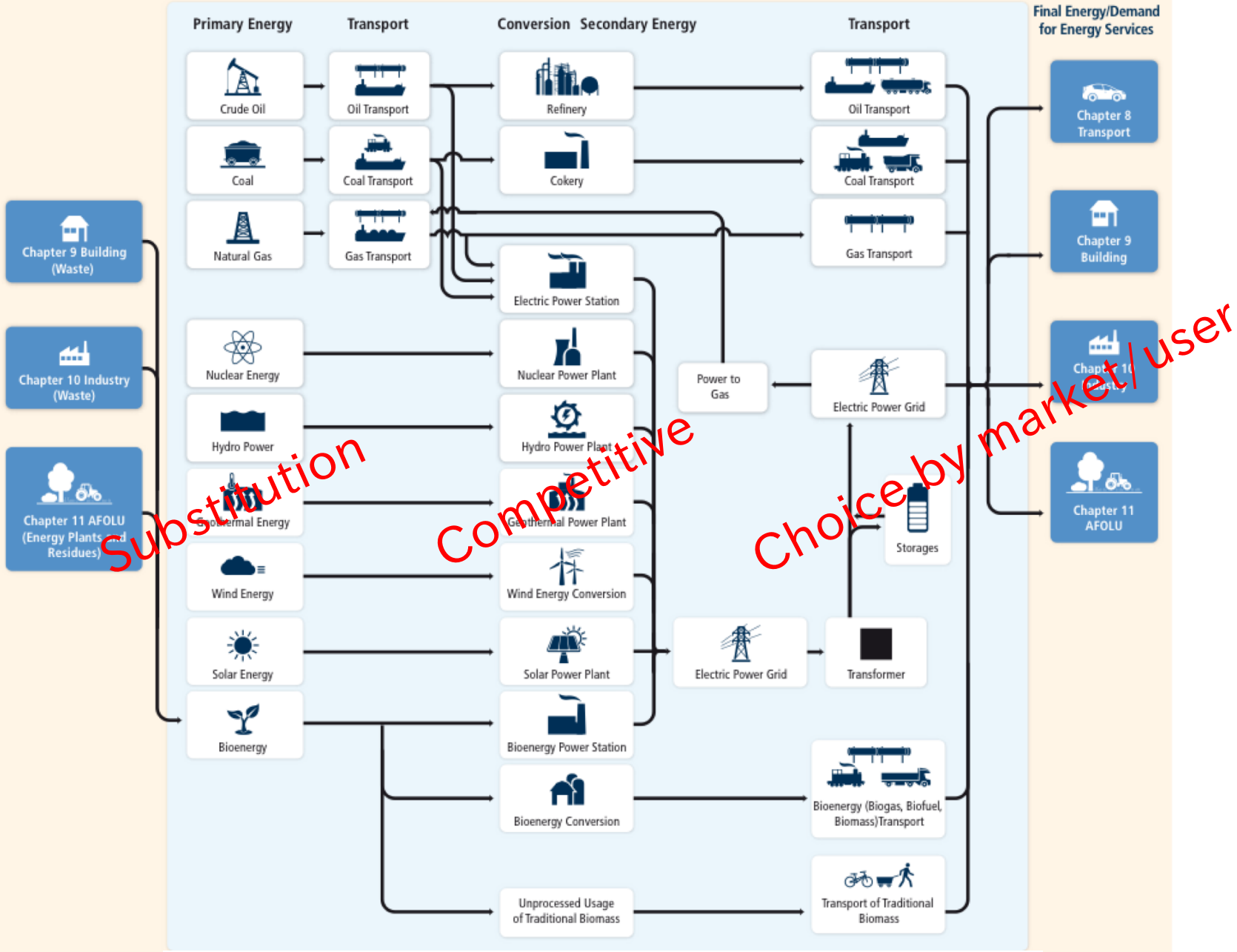
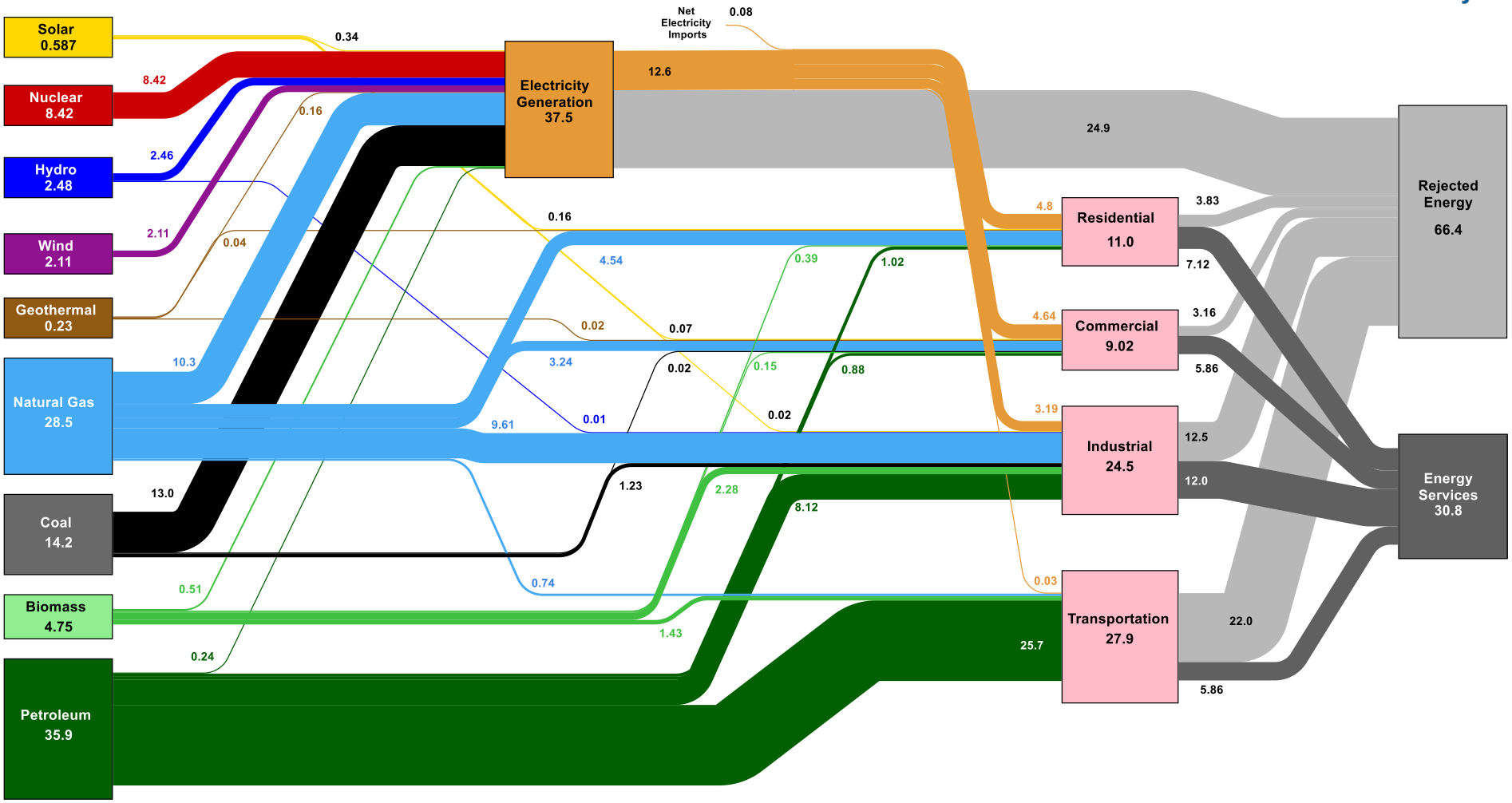


Figure 7.1 | Illustrative energy supply paths shown in order to illustrate the boundaries of the energy supply sector as defined in this report. The self-generation of heat and power in the end-use sectors (i.e., transport, buildings, industry, and Agriculture, Forestry, and Other Land Use (AFOLU)) is discussed in Chapters 8–11.

Energy flow in the US

Estimated U.S. Energy Consumption in 2016: 97.3 Quads

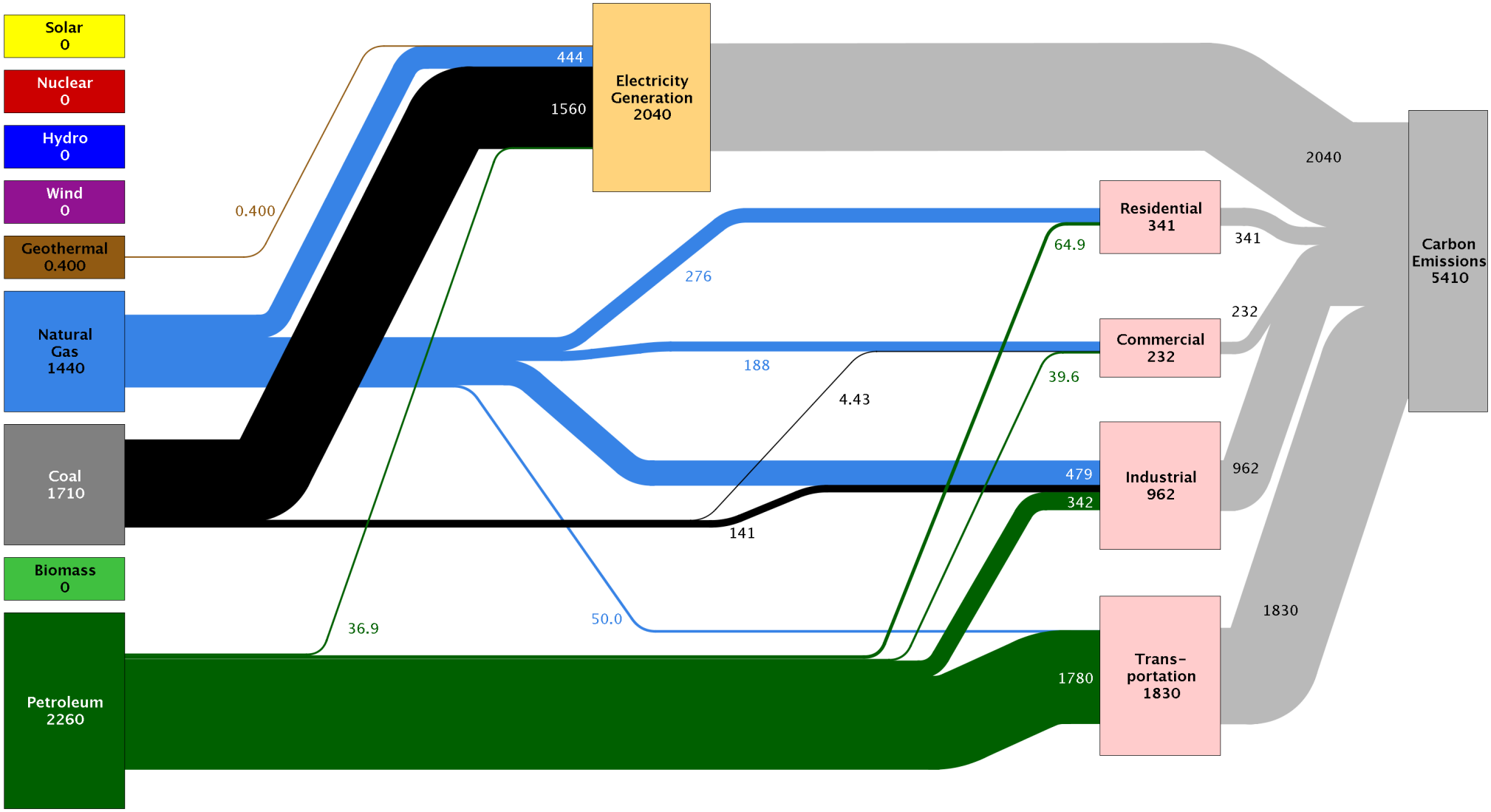


Source: LLNL March, 2017. Data is based on DOE/EIA MER (2016). If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. This chart was revised in 2017 to reflect changes made in mid-2016 to the Energy Information Administration's analysis methodology and reporting. The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 65% for the residential sector, 65% for the commercial sector, 21% for the transportation sector, and 49% for the industrial sector which was updated in 2017 to reflect DOE's analysis of manufacturing. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

Carbon flow in the US

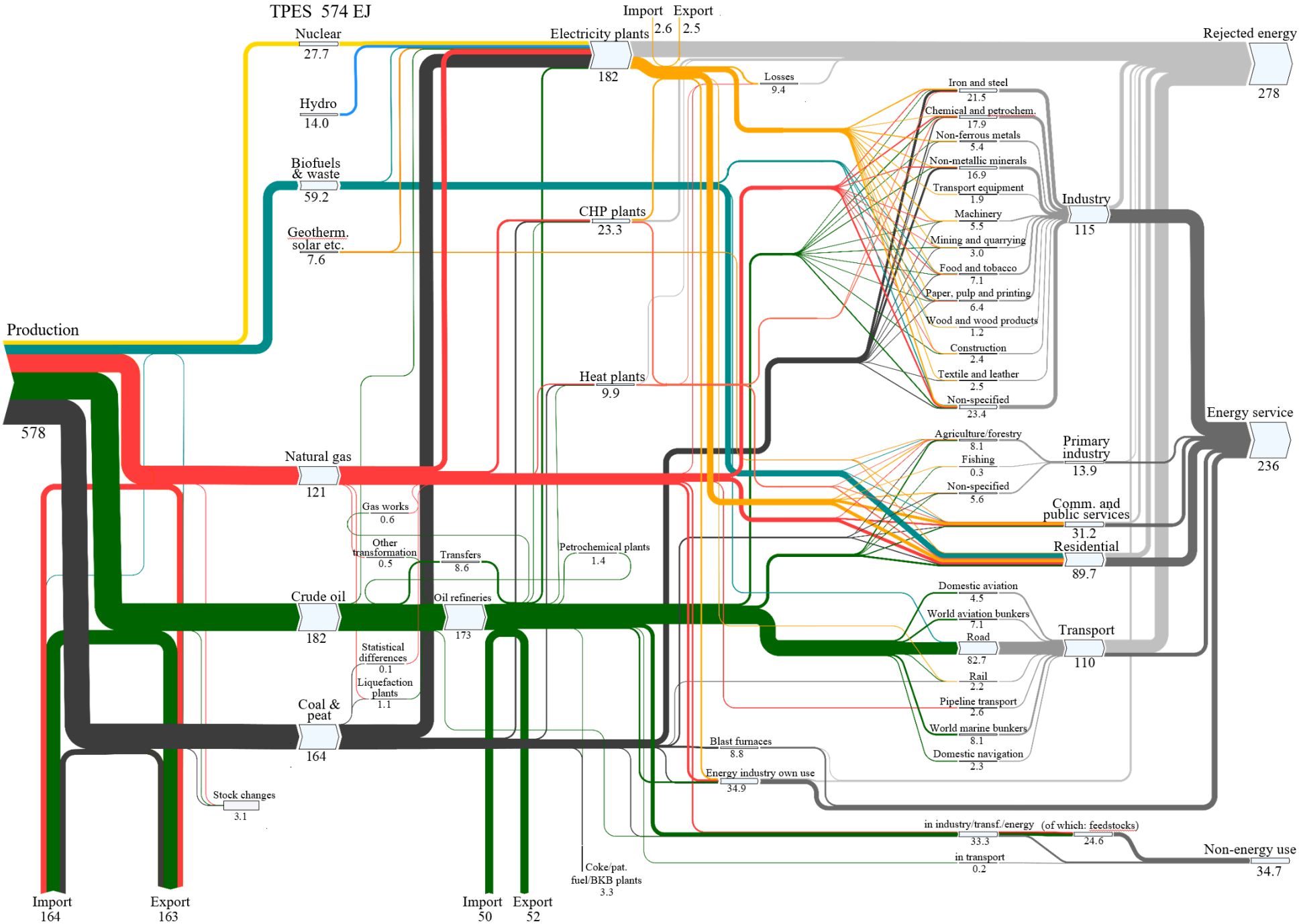
Estimated U.S. Carbon Emissions in 2014: ~5,410 Million Metric Tons

Lawrence Livermore National Laboratory



Source: LLNL 2015. Data is based on DOE/EIA-0035(2015-03), March, 2015. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Carbon emissions are attributed to their physical source, and are not allocated to end use for electricity consumption in the residential, commercial, industrial and transportation sectors. Petroleum consumption in the electric power sector includes the non-renewable portion of municipal solid waste. Combusition of biologically derived fuels is assumed to have zero net carbon emissions – the lifecycle emissions associated with producing biofuels are included in commercial and industrial emissions. Totals may not equal sum of components due to independent rounding errors. LLNL-MI-410527

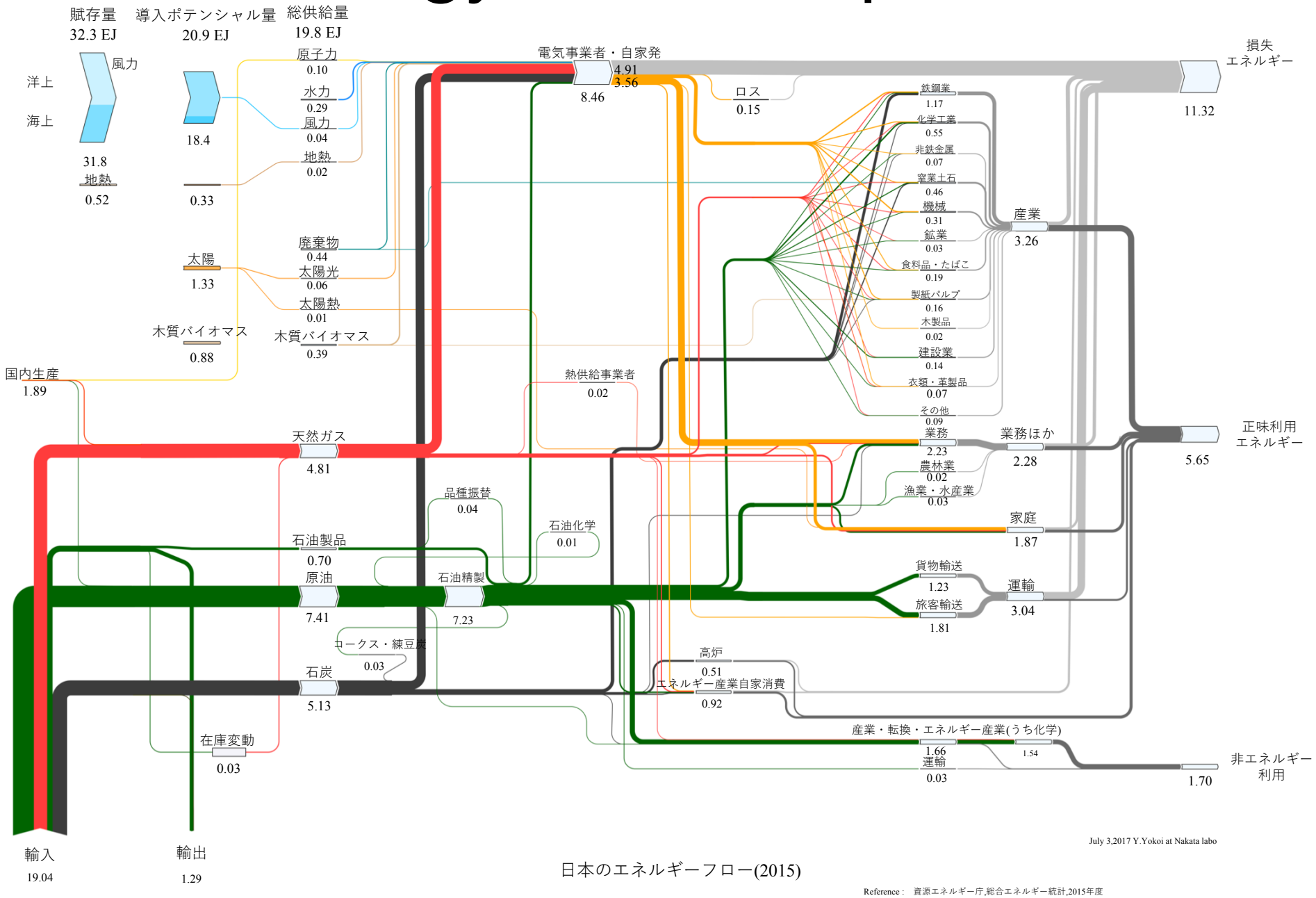
Energy flow in the world, 2014



Reference : IEA, World Energy Balances, 2016
LLNL, Energy Flow Charts, 2011 etc.

Sep. 24, 2017 S.Kawashima@Nakata lab.

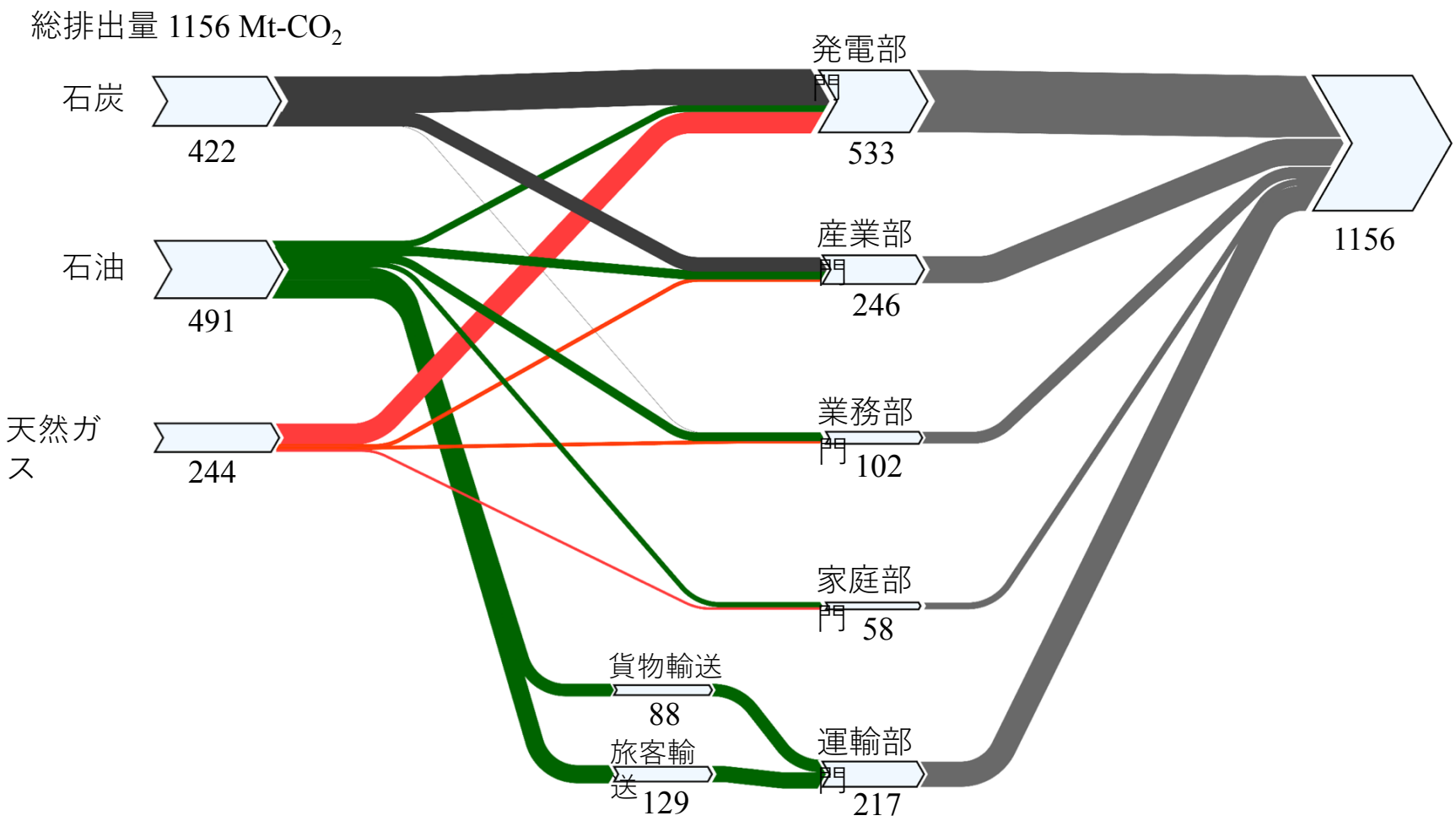
Energy flow in Japan



日本のエネルギーフロー(2015)

Reference : 資源エネルギー庁,総合エネルギー統計,2015年度
Kondo, Energy and energy utilization efficiencies in the Japanese residential/commercial sectors,2009 etc

Carbon flow in Japan



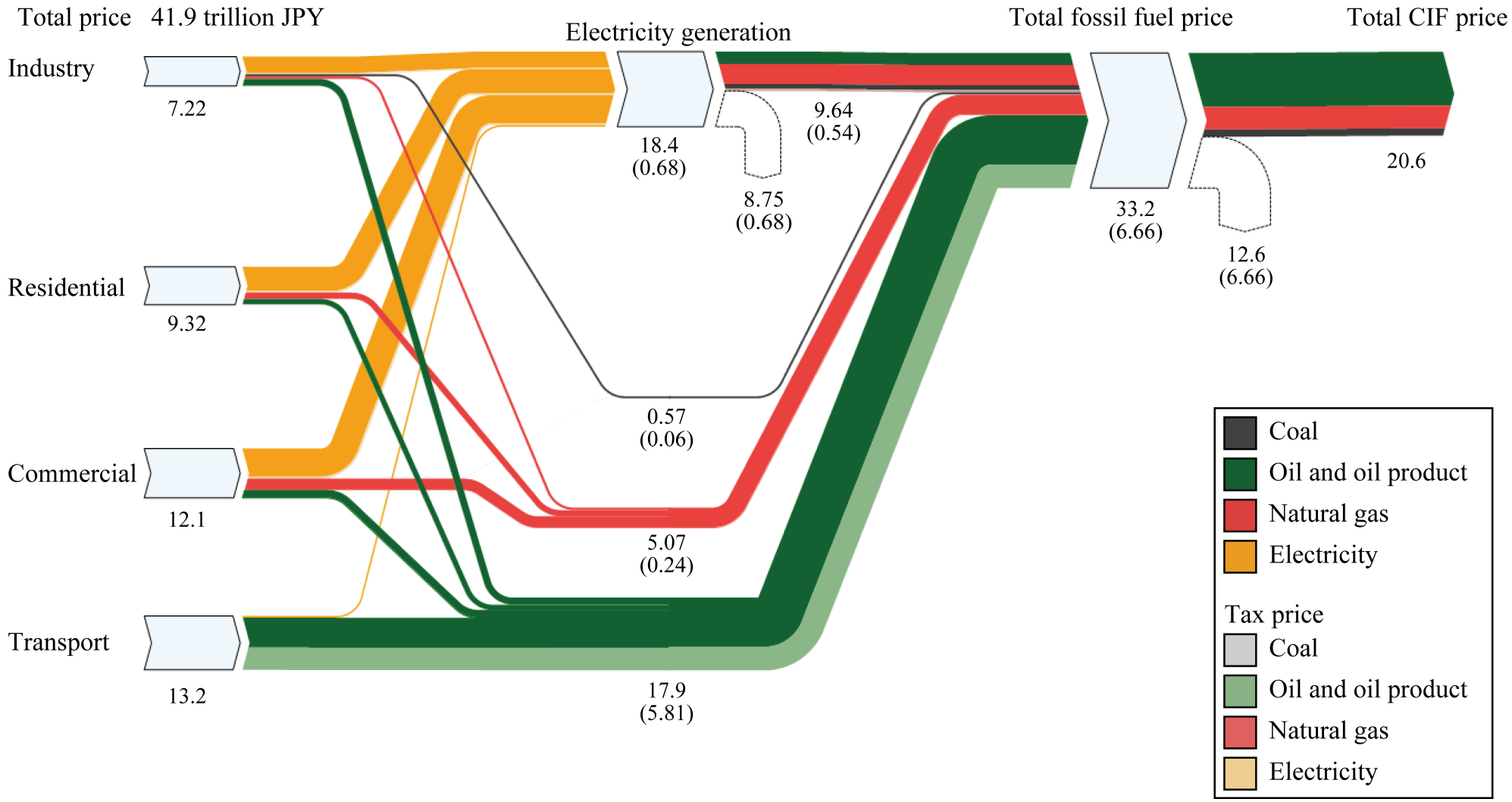
日本のカーボンフロー(2015)

Reference :

EDMC,部門別エネルギー起源CO_2排出量,2015.
資源エネルギー庁,総合エネルギー統計,2015年度
Kondo, Energy and energy utilization efficiencies in the Japanese residential/commercial sectors, 2009 etc

Energy cash in Japan

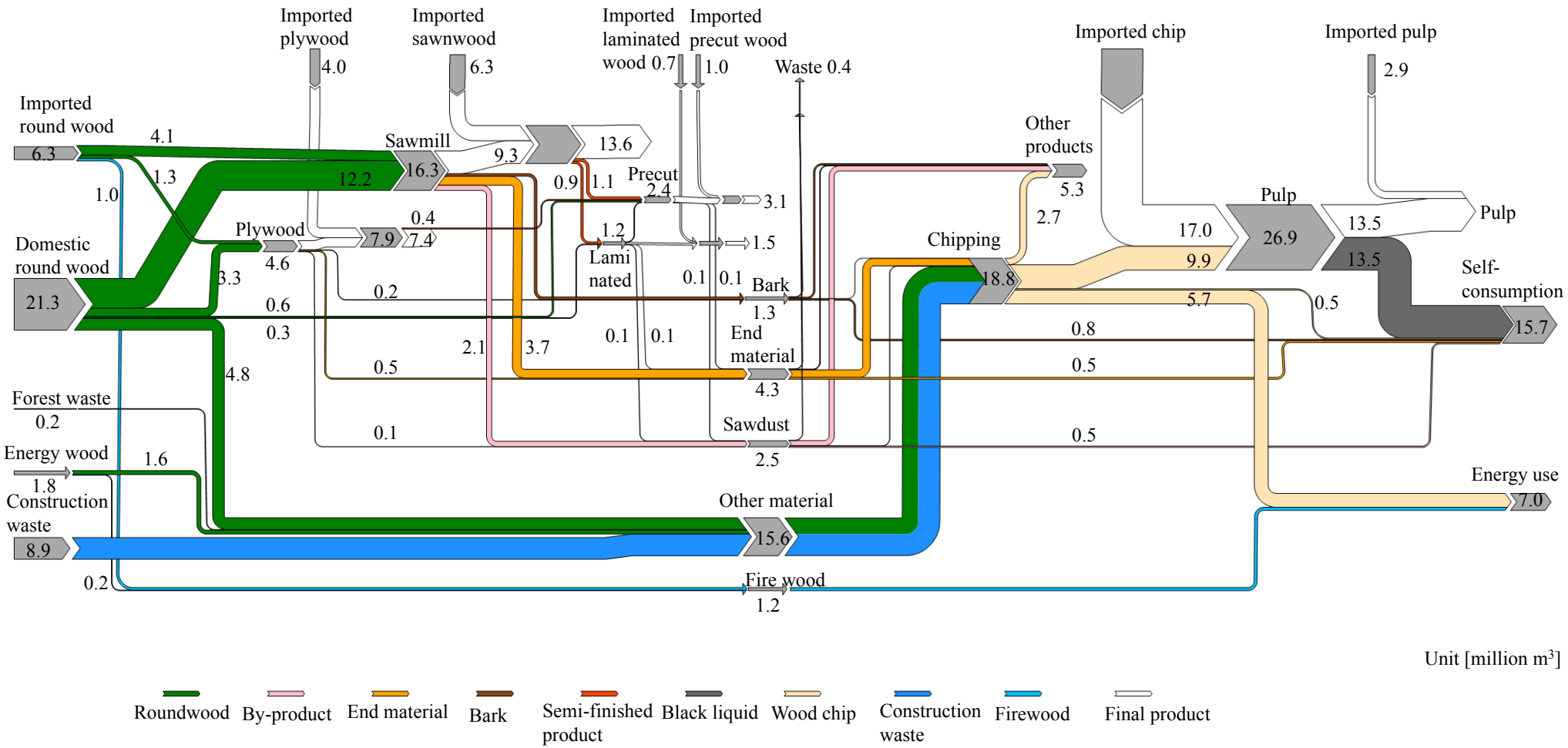
Japan fossil fuel cash flow (2012)



※(number) : tax

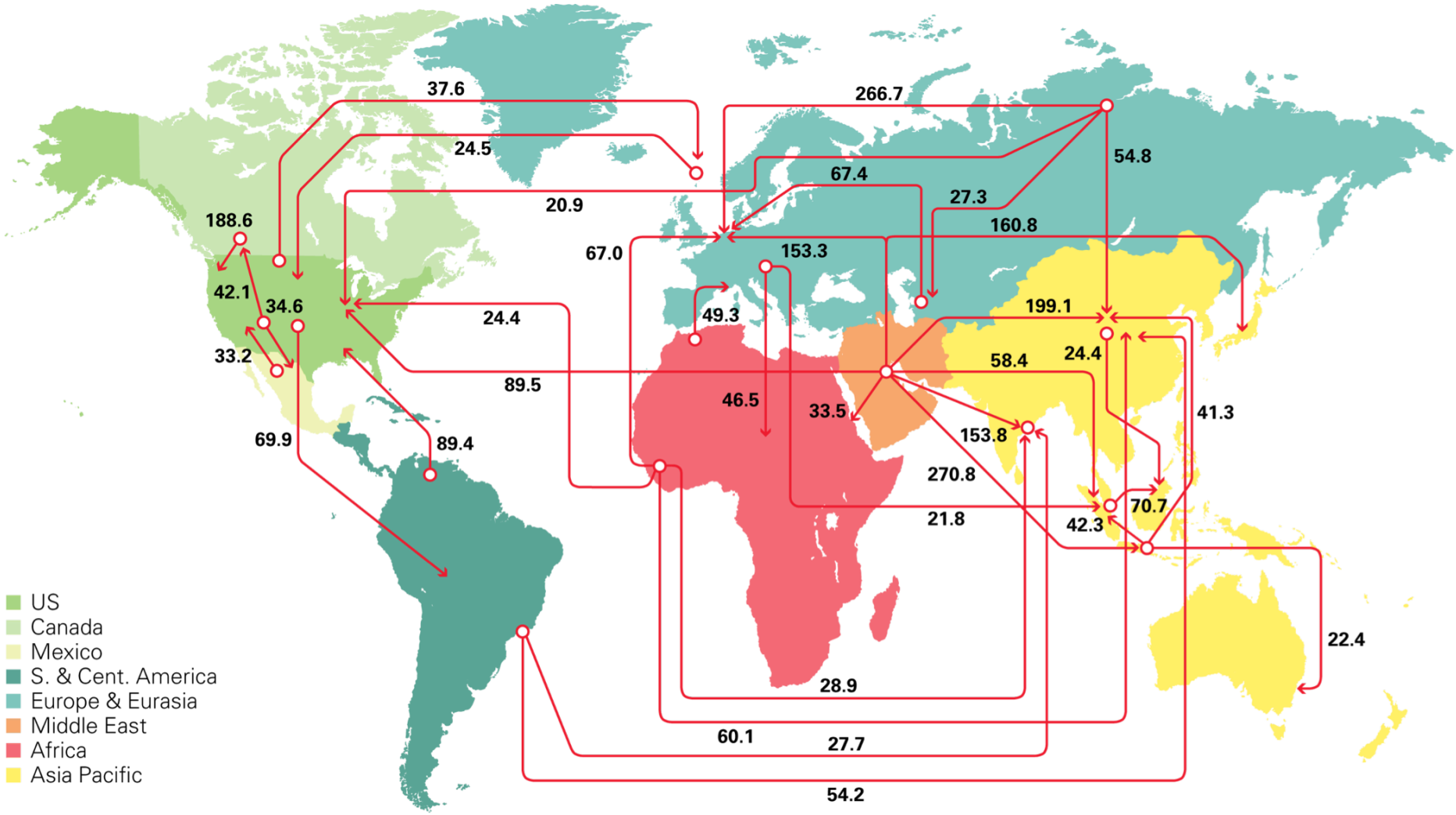
Reference: IEA, Energy Prices & Taxes 4th Quarter 2013.
IEA, Energy Balances of OECD Countries 2014. IEA, Renewable Informations 2014.
BP, BP Statistical Review of World Energy June 2014

Wood flow in Japan, 2014

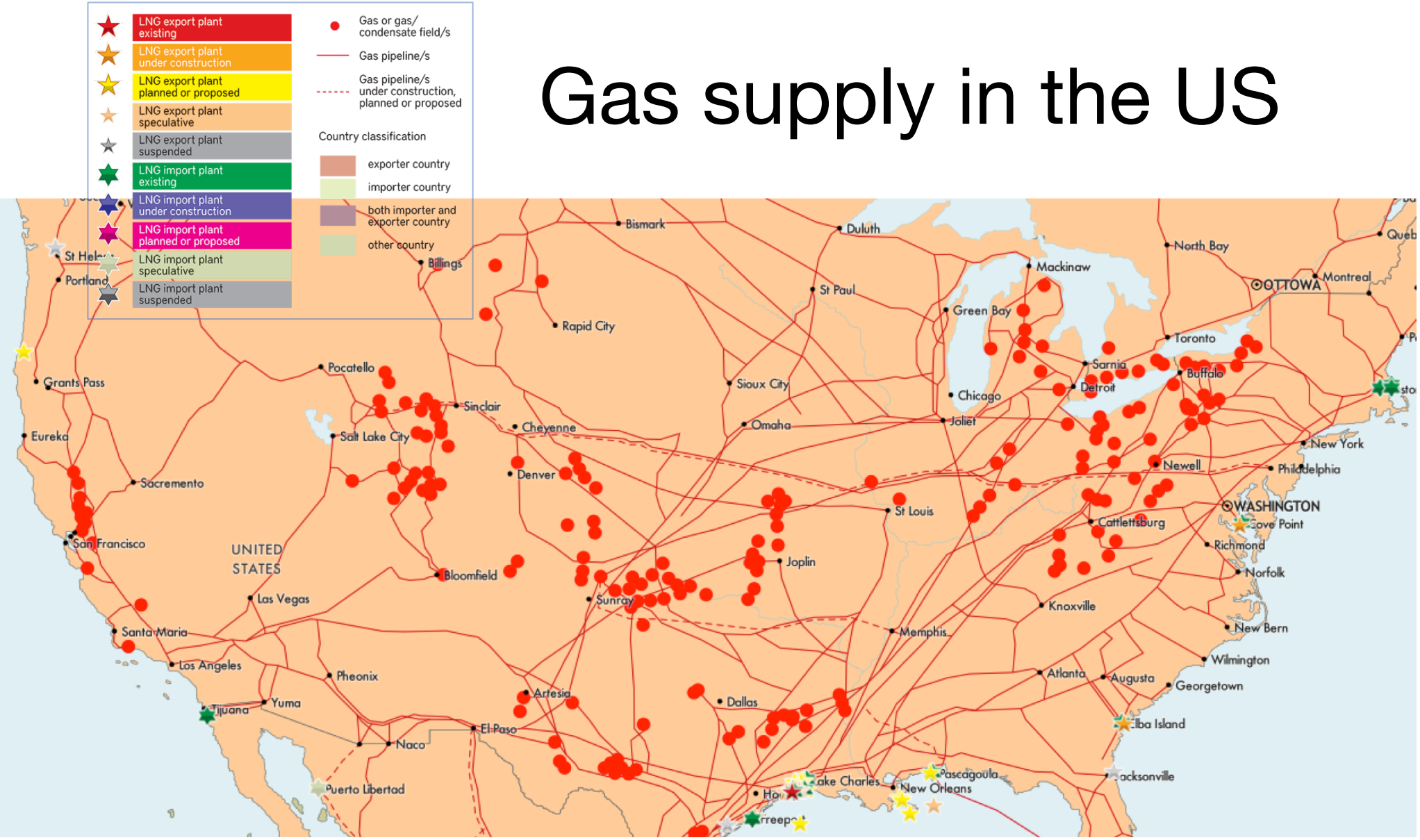


Major oil trade movements 2016

Trade flows worldwide (million tonnes)

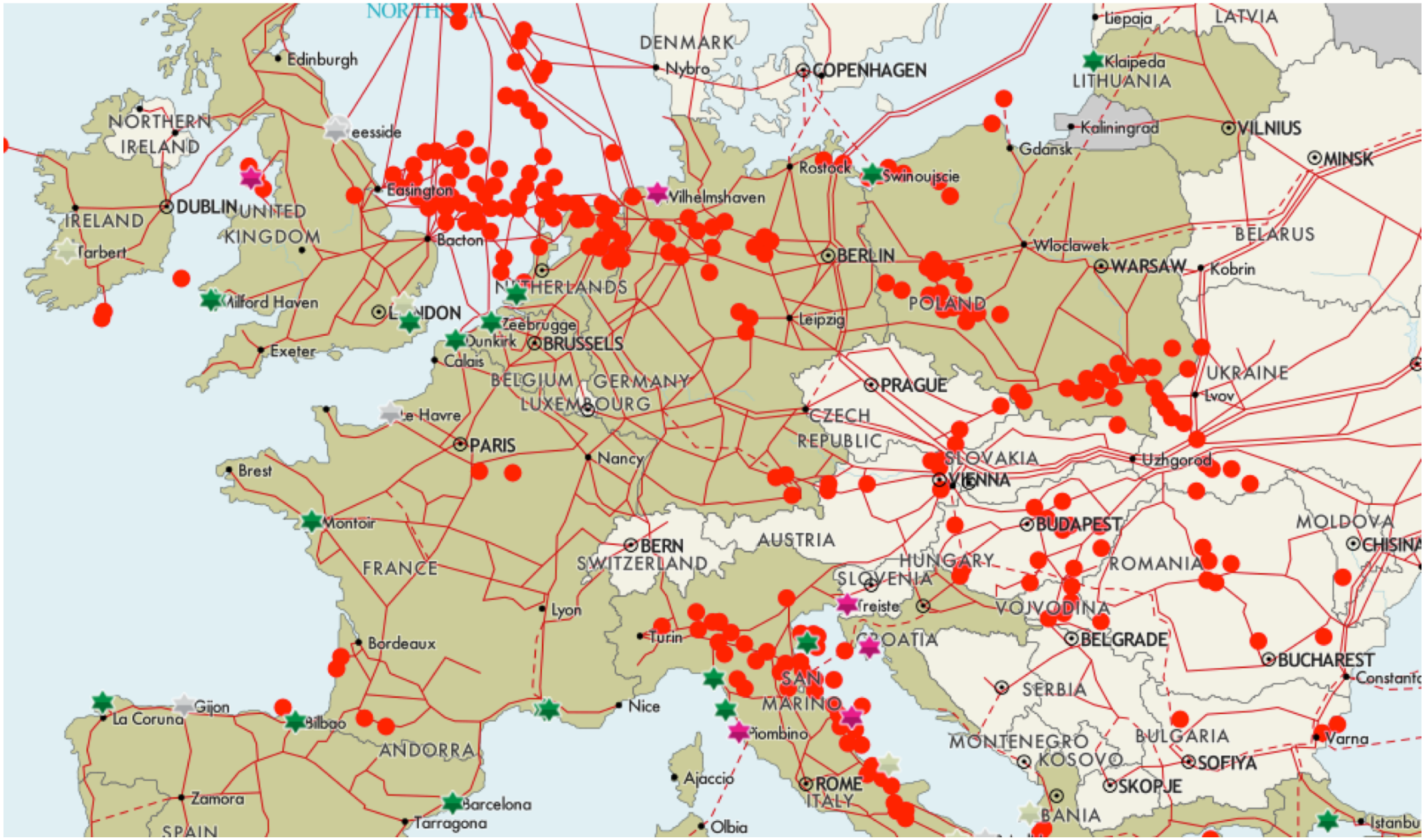


Gas supply in the US



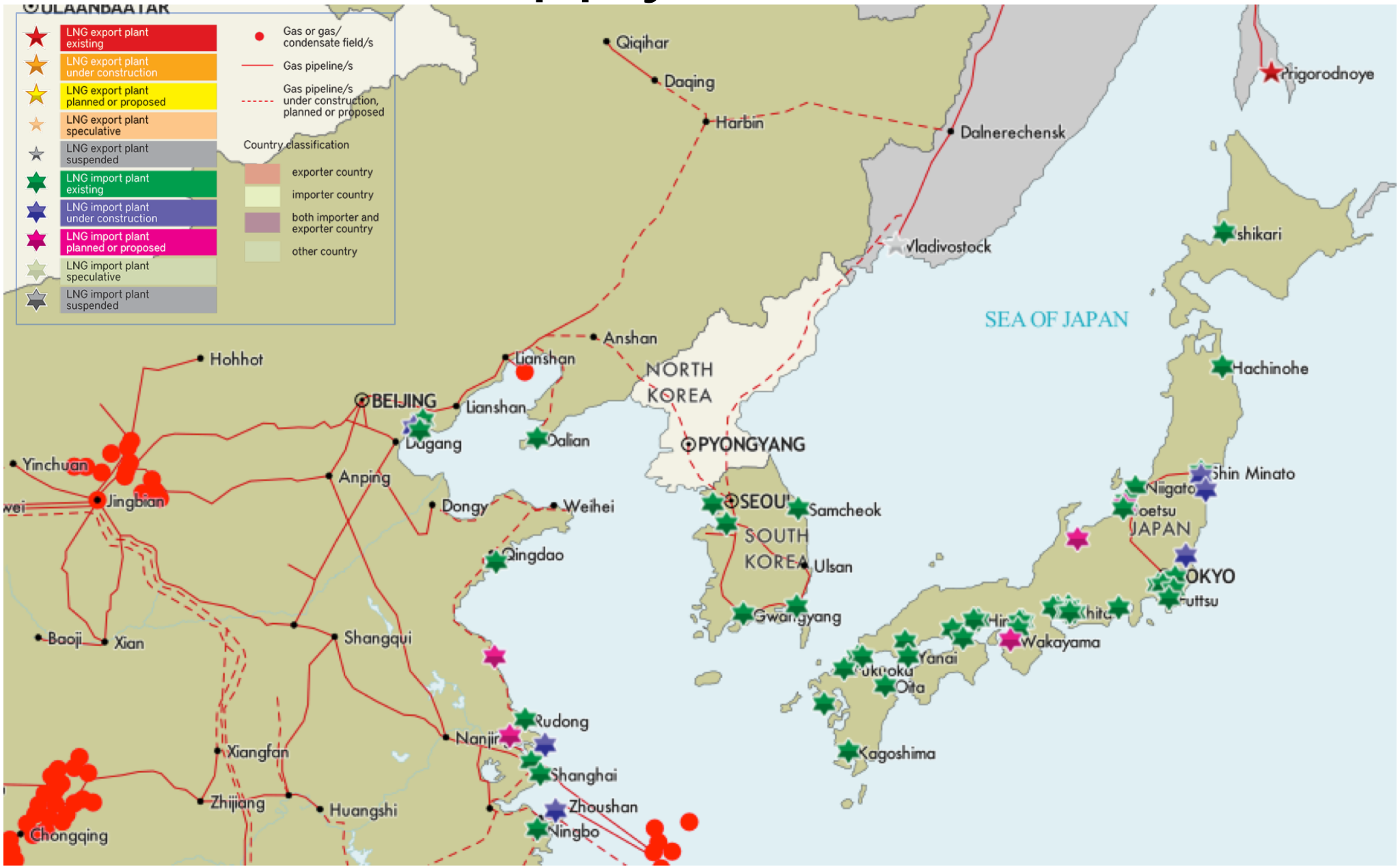
Interactive World LNG Map © 2017 Petroleum Economist

Gas supply in Europe



Interactive World LNG Map © 2017 Petroleum Economist

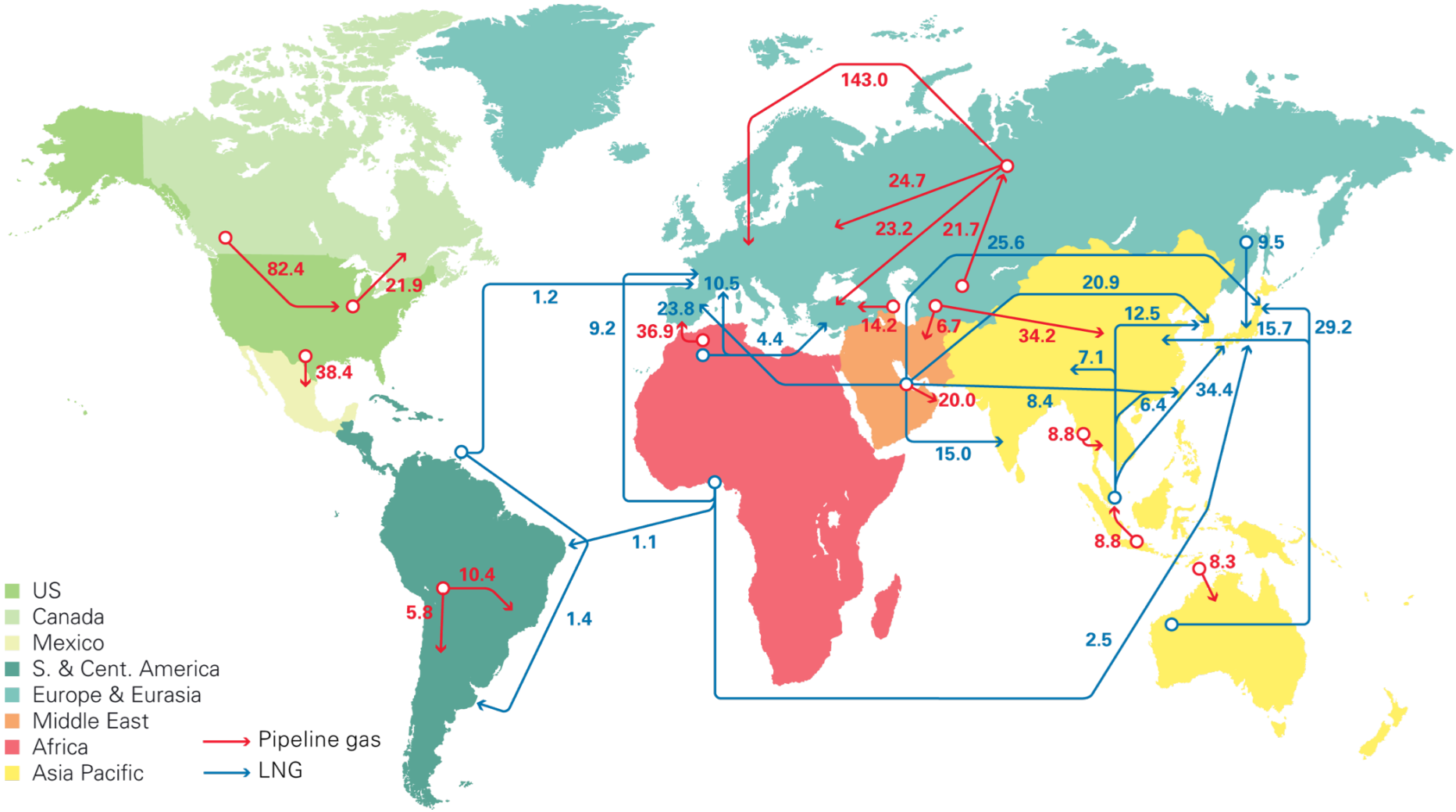
Gas supply in East Asia



Interactive World LNG Map © 2017 Petroleum Economist

Major gas trade movements 2016

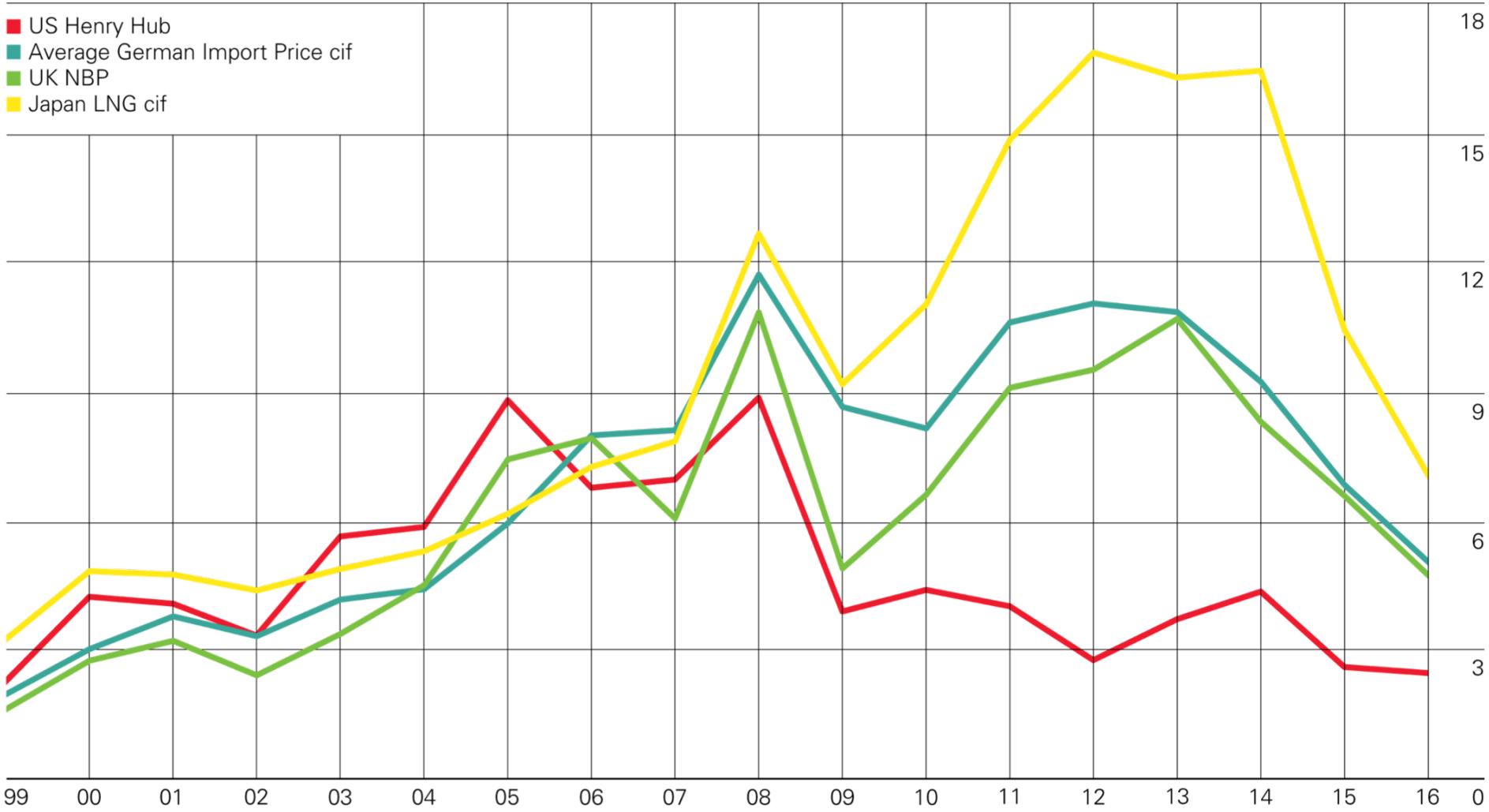
Trade flows worldwide (billion cubic metres)



Source: Includes data from FGE MENAgas service, GIIGNL, IHS Waterborne, PIRA Energy Group, Wood Mackenzie.

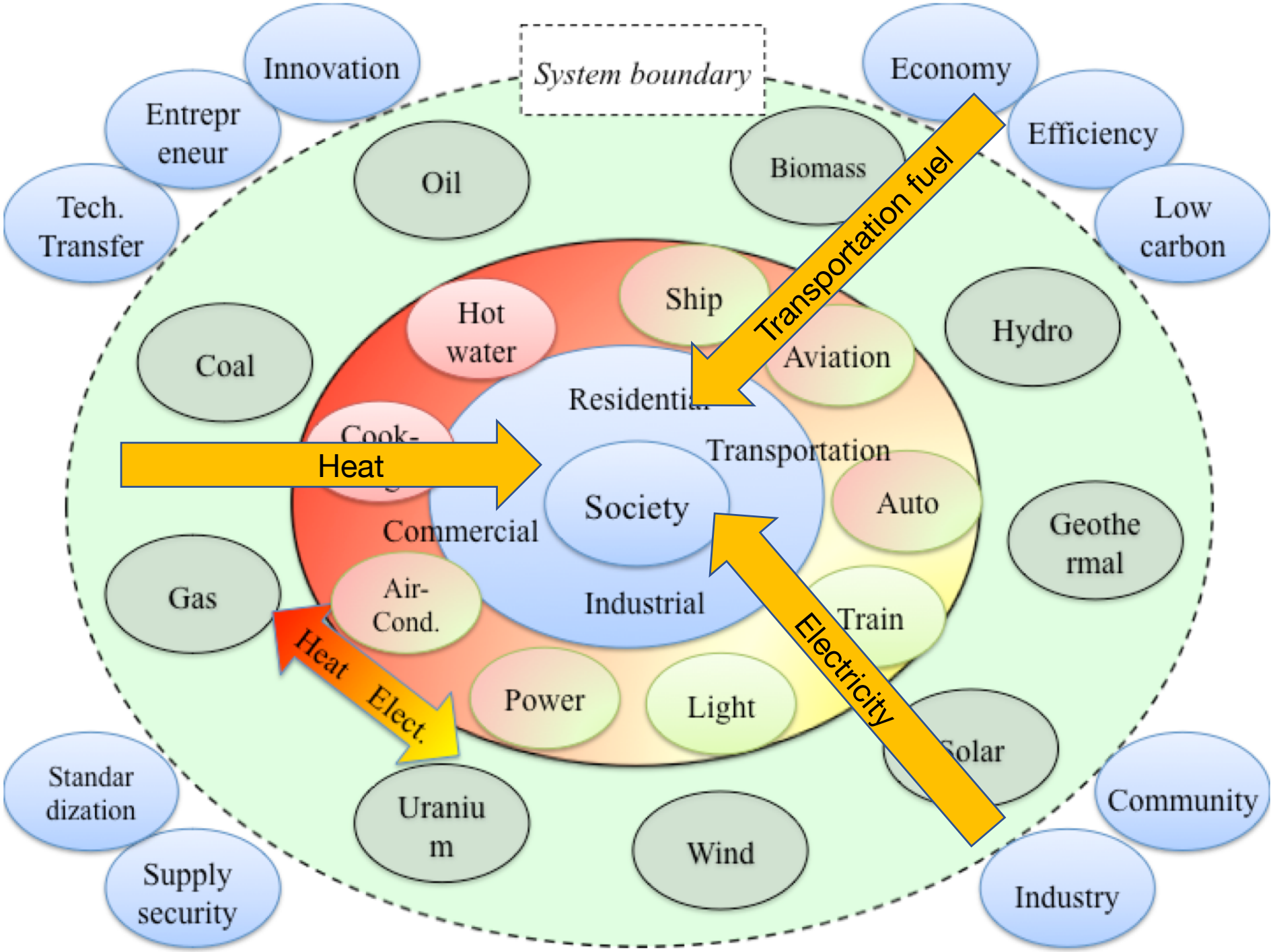
Gas prices

$/mmBtu

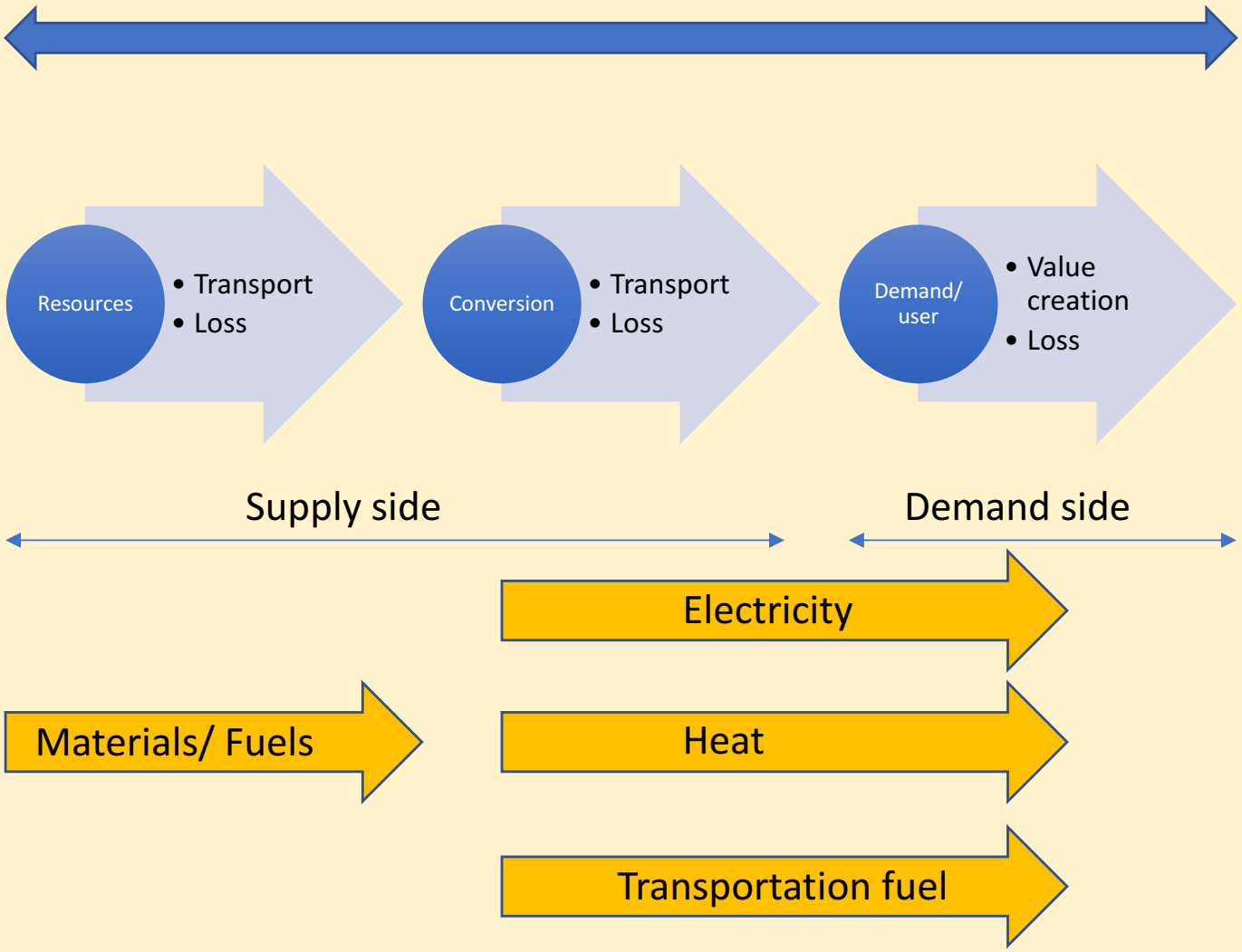


UN SDGs 2016-2030

Energy in life



Energy system integration



Dimensions for integration

A) Physical integration

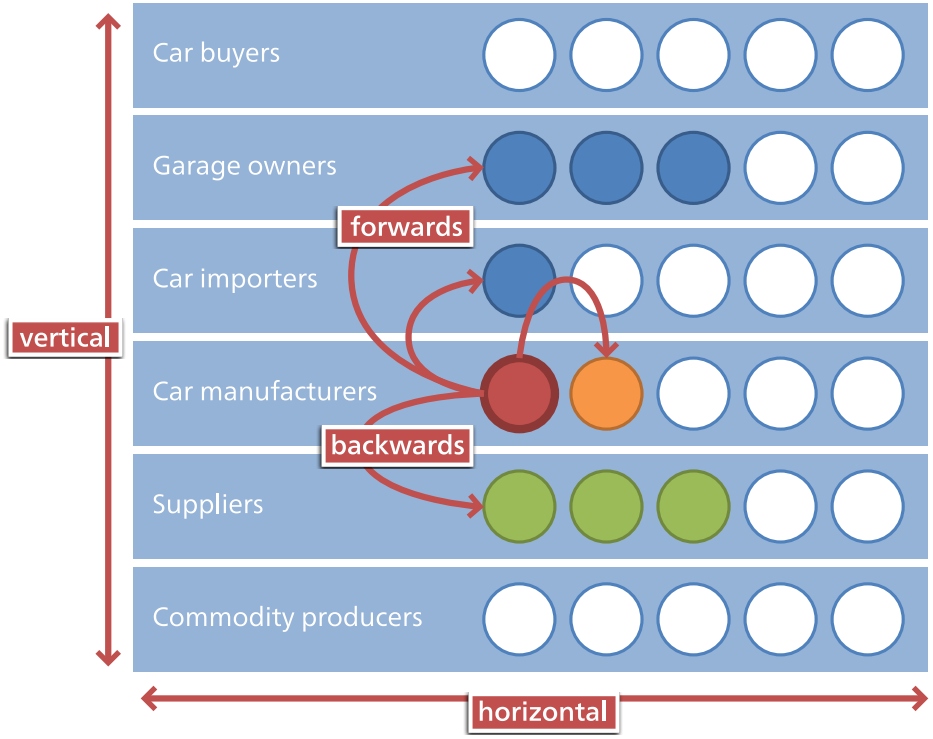
B) Spatial integration

C) Time transition

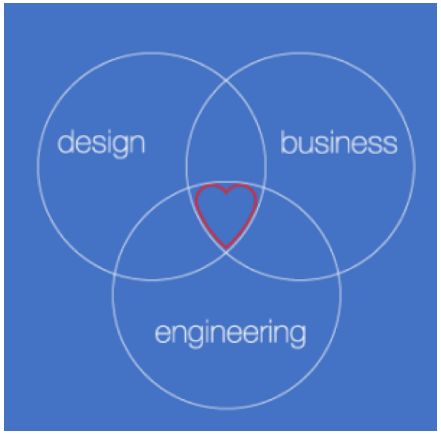
Integration

- The act of process of combining two or more things so that they work together.
- The action or process of integrating.

'economic and political integration' Oxford Dictionary

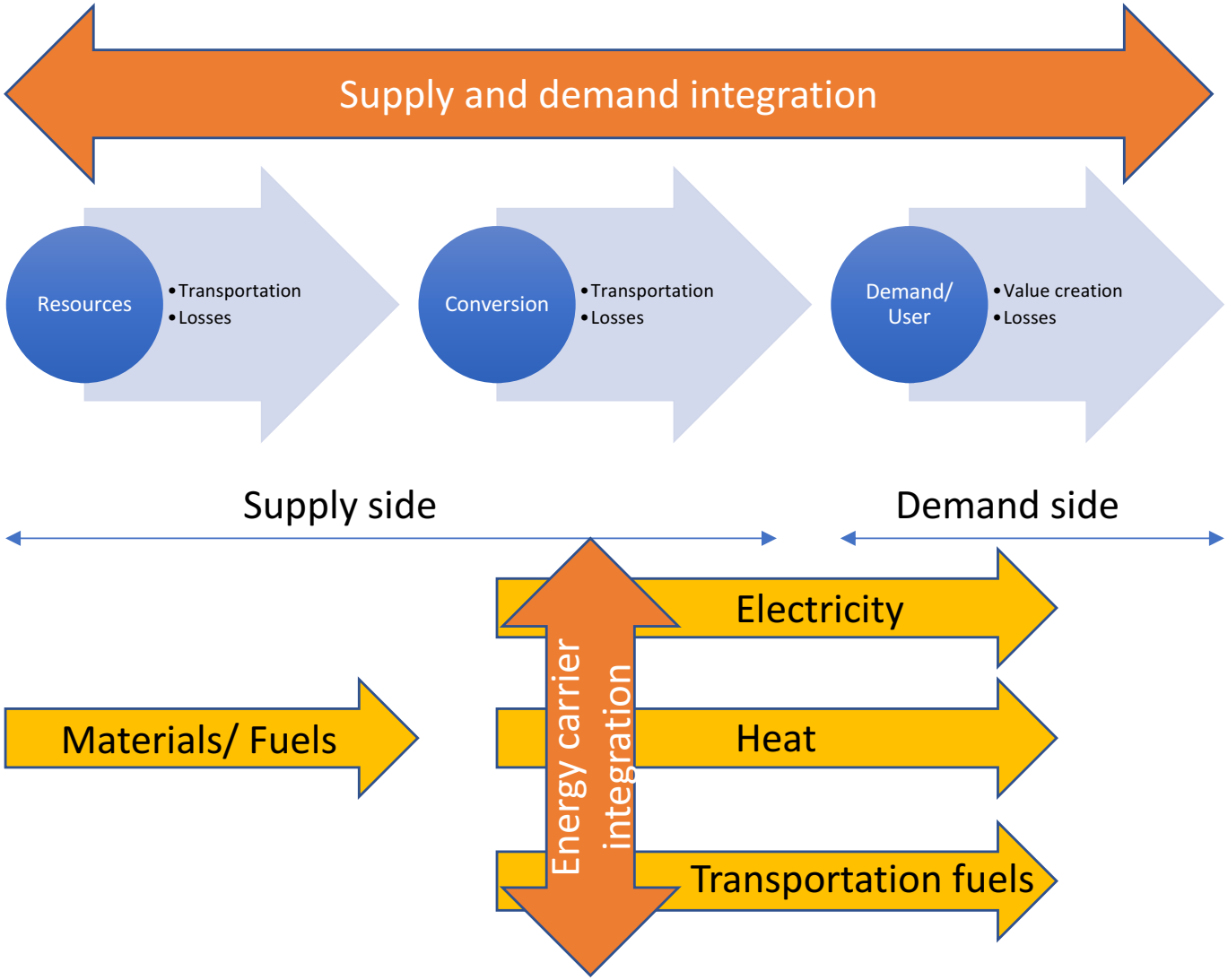


Martin Sauter (2010)

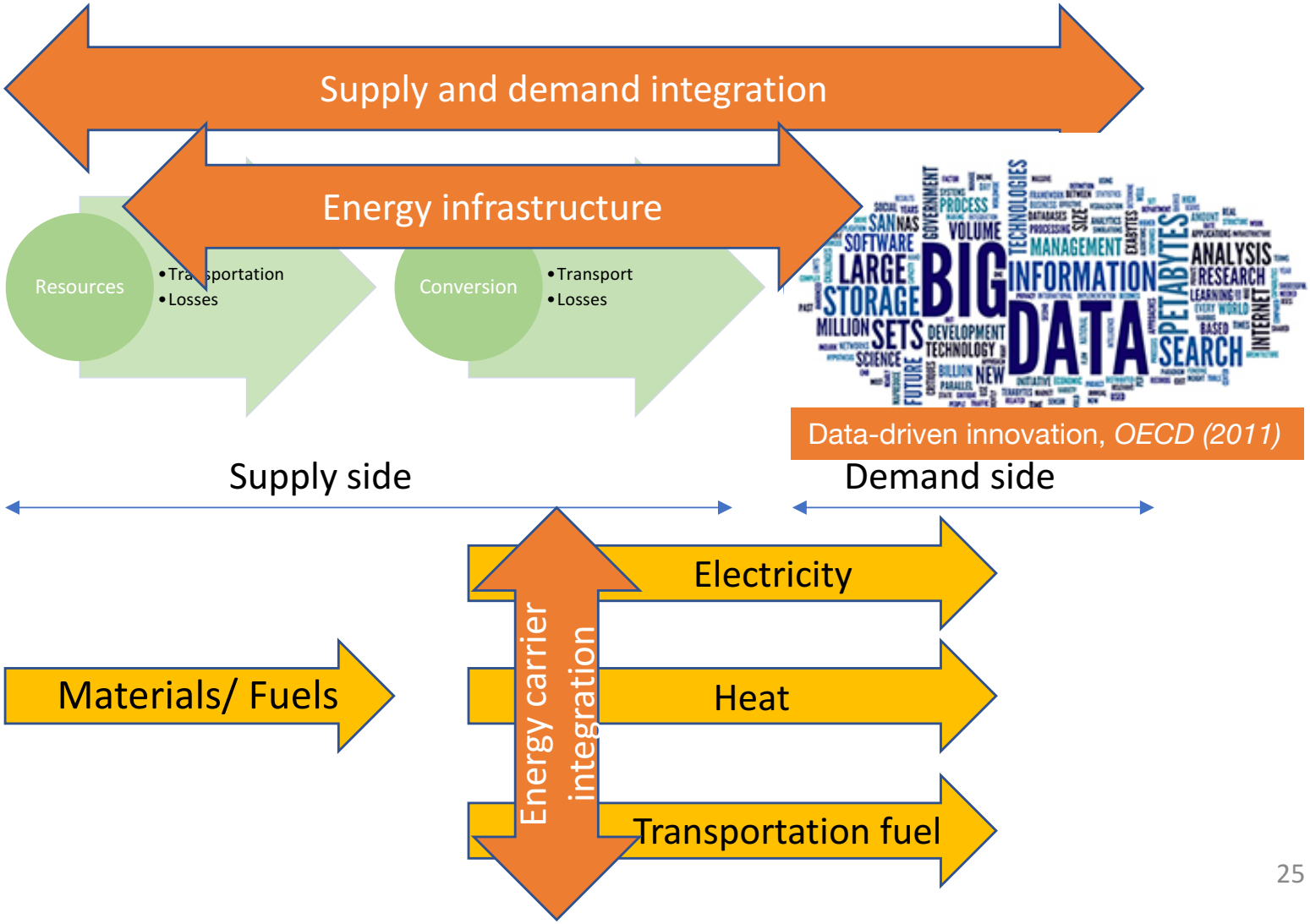


MIT idm (2017)

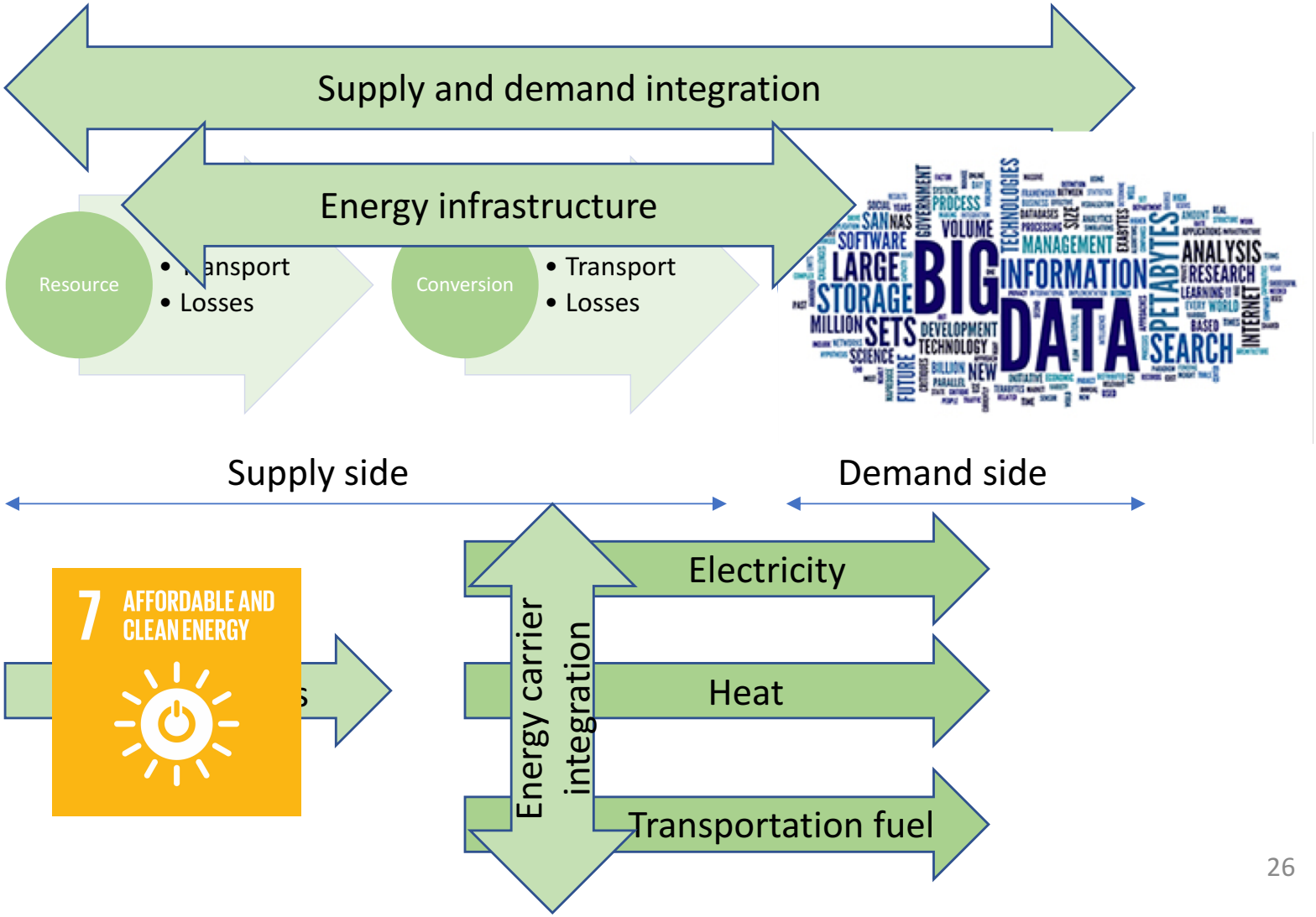
A) Physical integration



A) Physical integration



A) Physical integration



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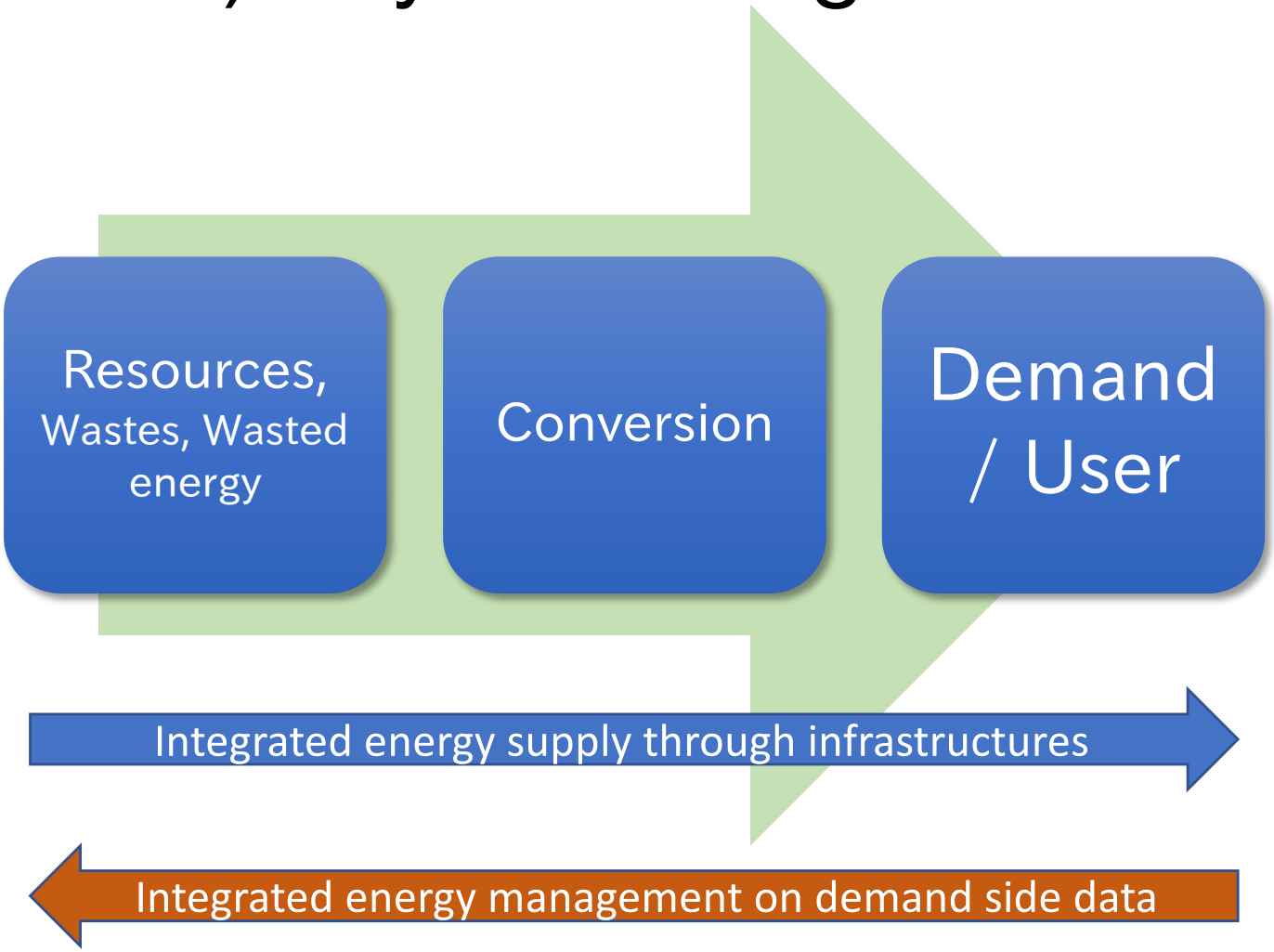
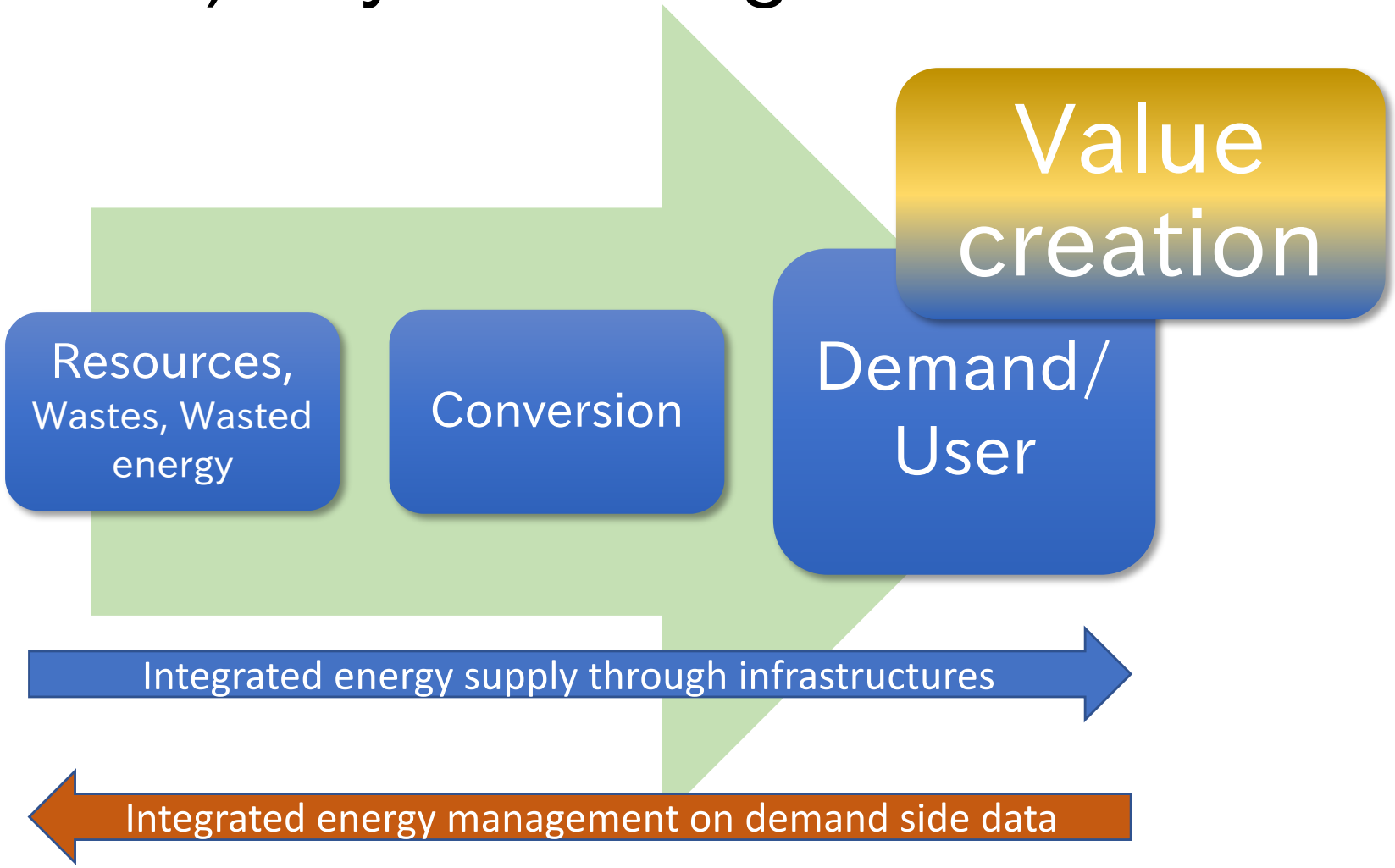


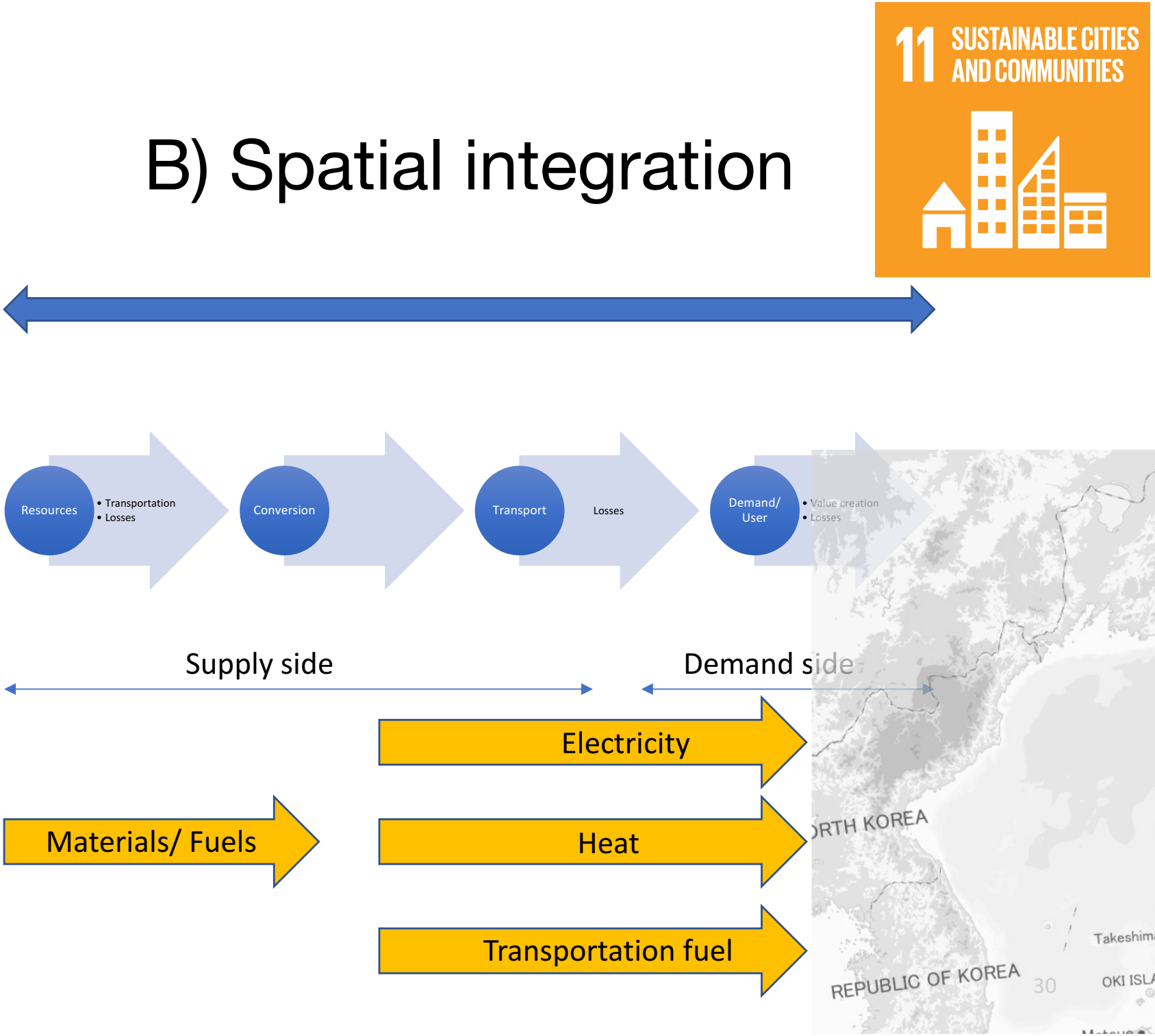
A) Physical integration



A) Physical integration

1. Supply-demand integration
   - ICT based management
   - Price & green sensitive emerging users
2. Energy carriers integration
   - ICVs→EVs, Global electrification
   - CHP, Waste to energy
3. Energy infrastructure investment
   - Oil/Gas pipeline→Heat pipelinet
   - Biomass resources logistics

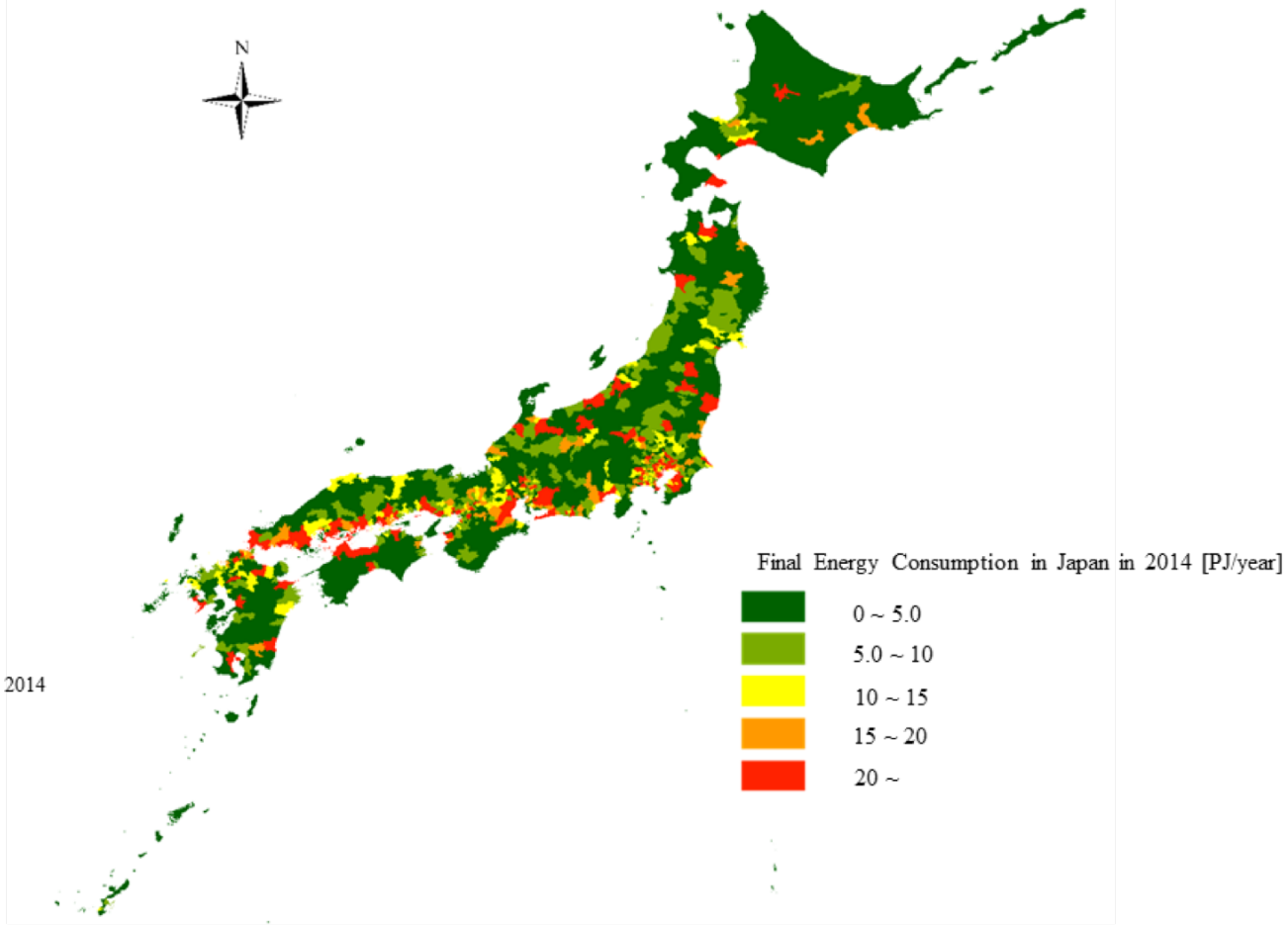
B) Spatial integration



Final energy consumption by cities

＜推計手法＞
産業部門
製造品は製造品出荷額により按分
非製造業は就業者数で按分
家庭部門
世帯数で按分
業務部門
就業者数で按分
運輸部門
自動車保有台数で按分

Reference :
・経済産業省資源エネルギー庁, 都道府県別エネルギー消費統計, 2014
・総務省統計局, 国勢調査, 平成22年
＞家庭世帯数
産業別就業者数
・経済産業省, 工業統計調査, 平成24年
＞産業別製造品出荷額及び付加価値額
・運輸局
＞自動車保有台数
など



日本の最終エネルギー消費量分布(2014)

Energy density by cities

＜推計手法＞
産業部門
製造品は製造品出荷額により按分
非製造業は就業者数で按分
家庭部門
世帯数で按分
業務部門
就業者数で按分
運輸部門
自動車保有台数で按分

Reference :
・経済産業省資源エネルギー庁, 都道府県別エネルギー消費統計, 2014
・総務省統計局, 国勢調査, 平成22年
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産業別就業者数
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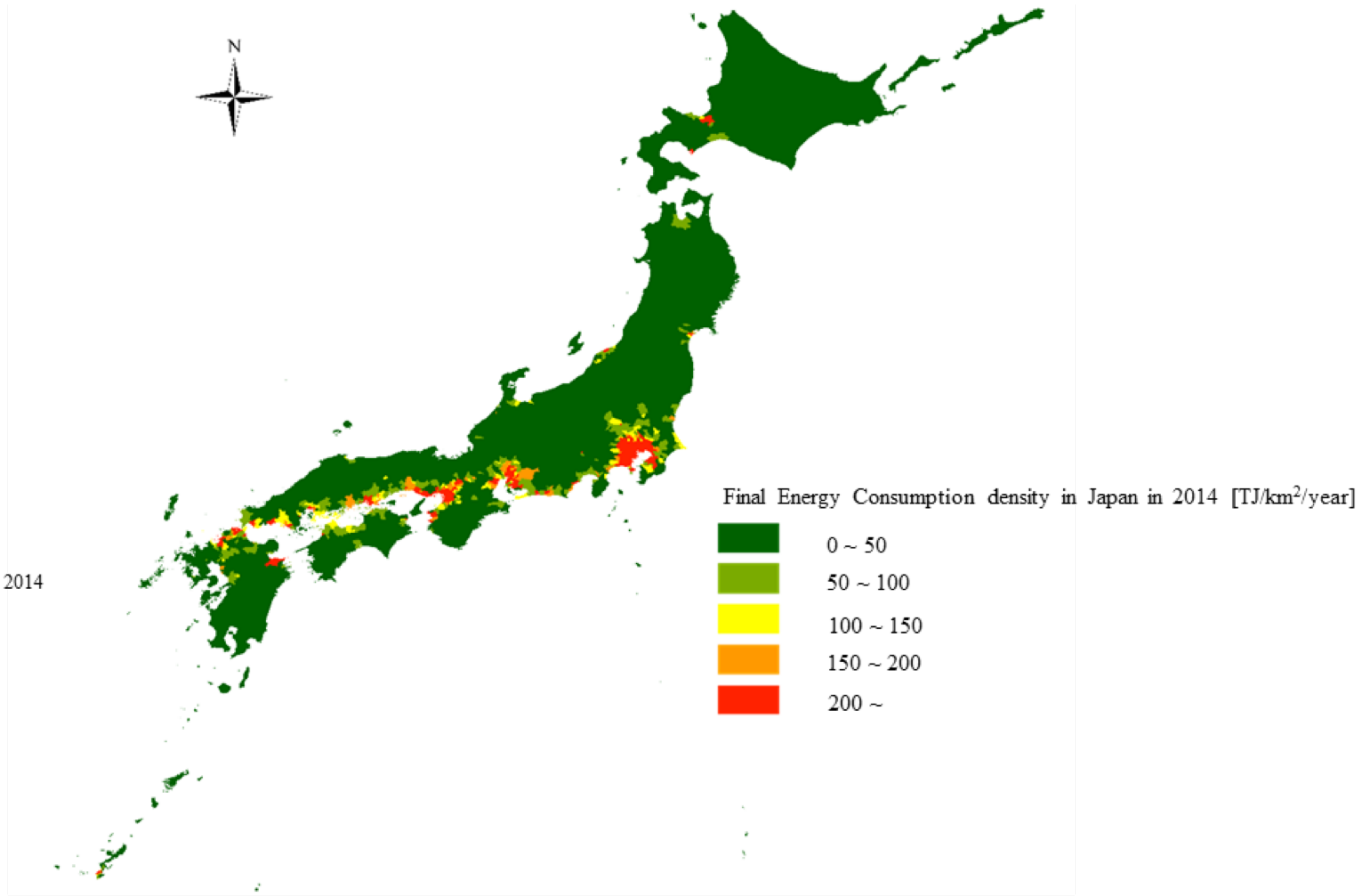
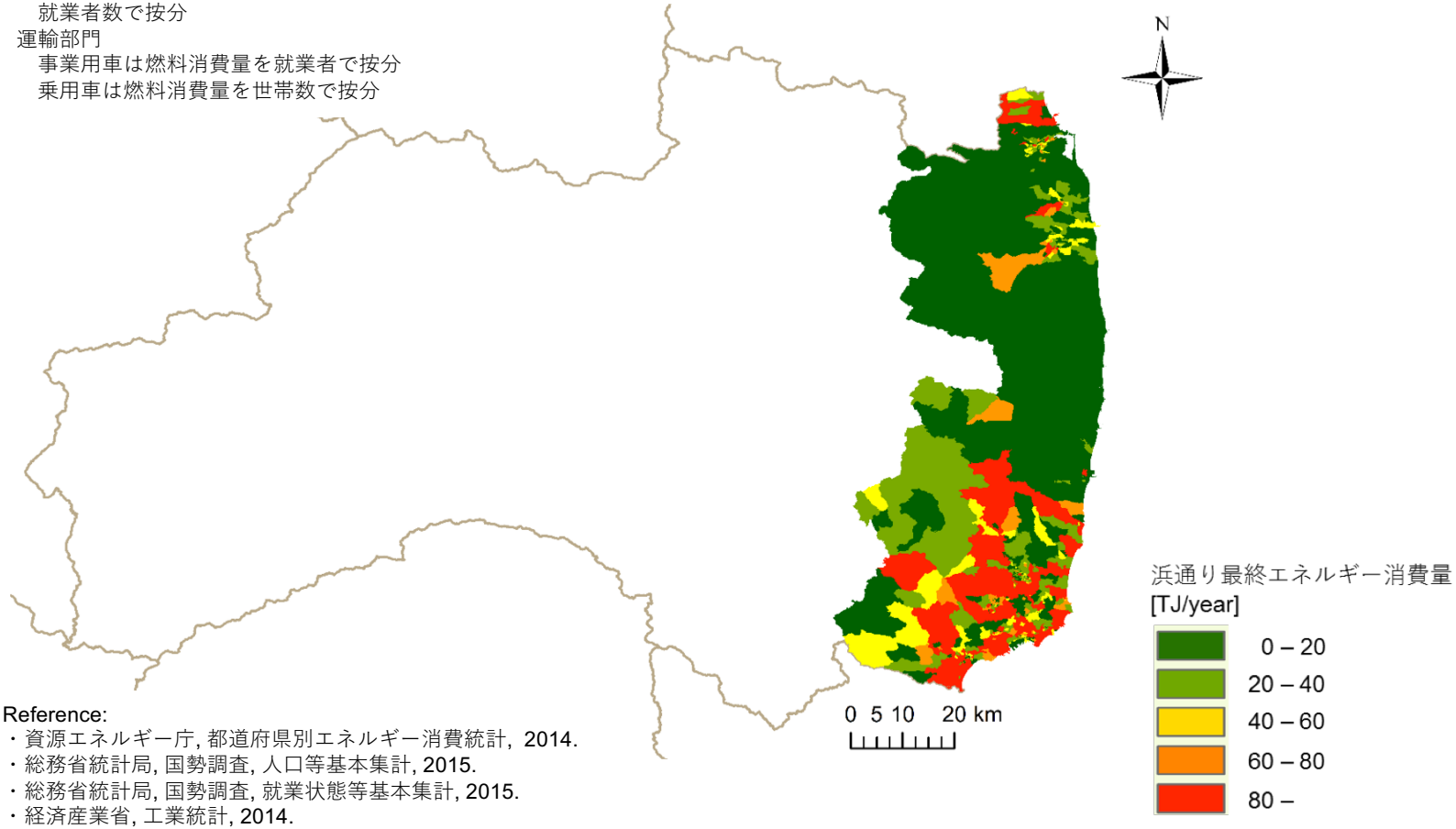
＞産業別製造品出荷額及び付加価値額
・運輸局
＞自動車保有台数
など



日本の最終エネルギー消費量密度分布(2014)

Final energy consumption by towns

製造業は市町村別製造品出荷額で按分
(小地域別出荷額は就業者で按分)
非製造業は就業者数で按分
家庭部門
世帯数で按分
業務部門
就業者数で按分
運輸部門
事業用車は燃料消費量を就業者で按分
乗用車は燃料消費量を世帯数で按分

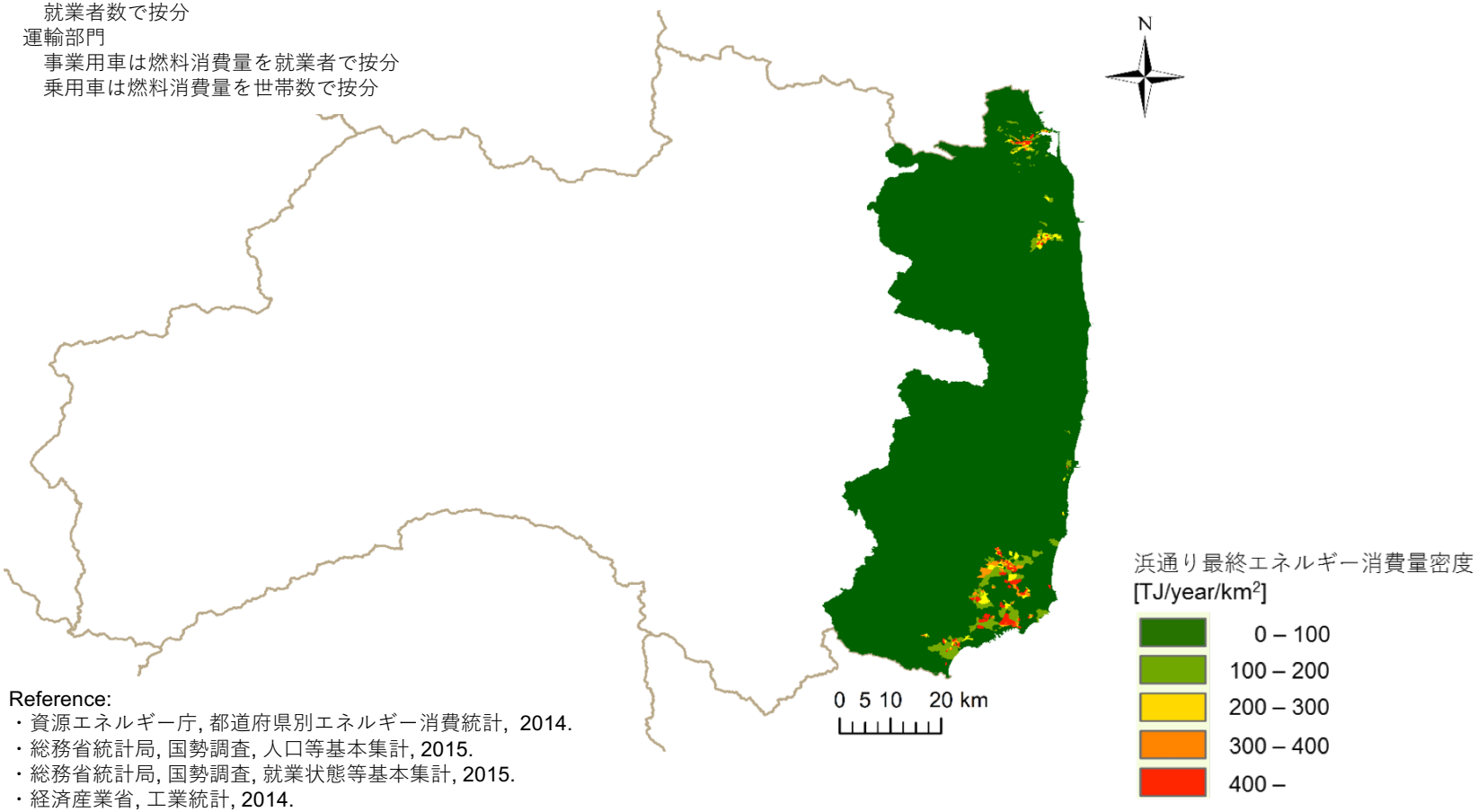


Reference:
・資源エネルギー庁, 都道府県別エネルギー消費統計, 2014.
・総務省統計局, 国勢調査, 人口等基本集計, 2015.
・総務省統計局, 国勢調査, 就業状態等基本集計, 2015.
・経済産業省, 工業統計, 2014.
・国土交通省, 自動車燃料消費統計年報, 2015.

浜通り最終エネルギー消費量 (2014)　[TJ/year]

Energy density by towns

(小地域別出荷額は就業者で按分)
非製造業は就業者数で按分
家庭部門
世帯数で按分
業務部門
就業者数で按分
運輸部門
事業用車は燃料消費量を就業者で按分
乗用車は燃料消費量を世帯数で按分



Reference:
・資源エネルギー庁, 都道府県別エネルギー消費統計, 2014.
・総務省統計局, 国勢調査, 人口等基本集計, 2015.
・総務省統計局, 国勢調査, 就業状態等基本集計, 2015.
・経済産業省, 工業統計, 2014.
・国土交通省, 自動車燃料消費統計年報, 2015.

浜通り最終エネルギー消費量密度 (2014)　[TJ/year/km^2]

B) Spatial integration

Regional condition A
- Life style
- Demand
- Density
- Biomass

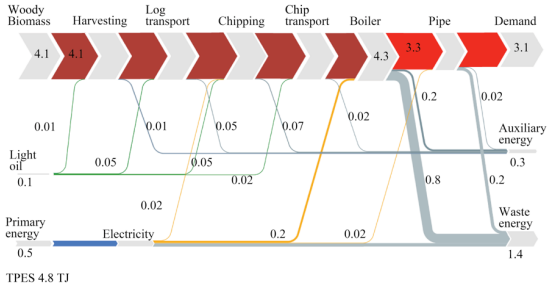
Regional condition B

Regional condition C

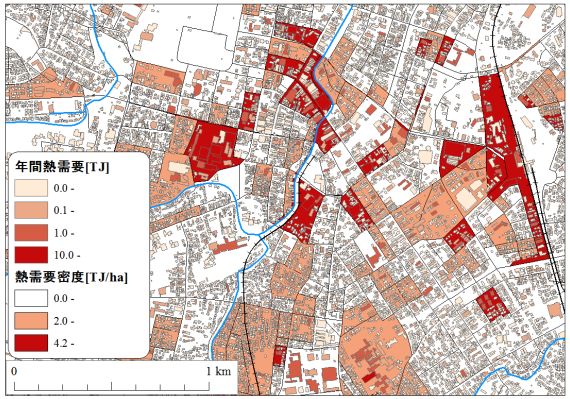
Common characteristics
- Conventional oil/gas/electricity infrastructure
- Changes in energy/utility business
- Carbon emission mitigation targets
- Imported fuel markets
- Stakeholders in energy planning

B) Spatial integration

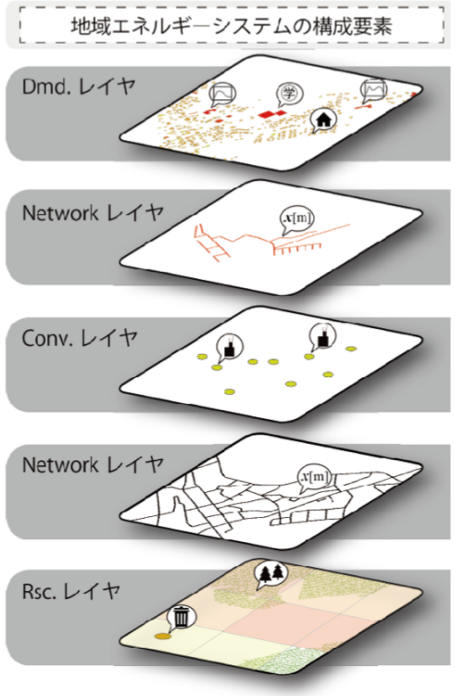
Demand/Supply matching



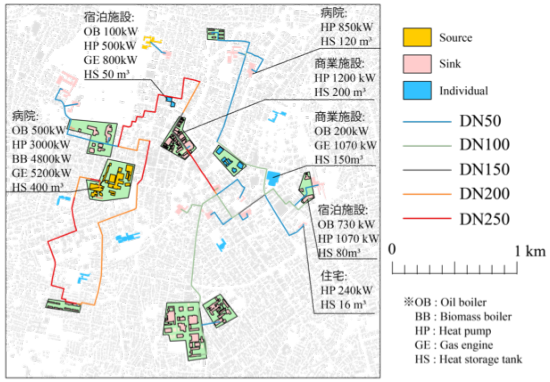
Input: Energy flow



Input: Energy map



Spatial optimization

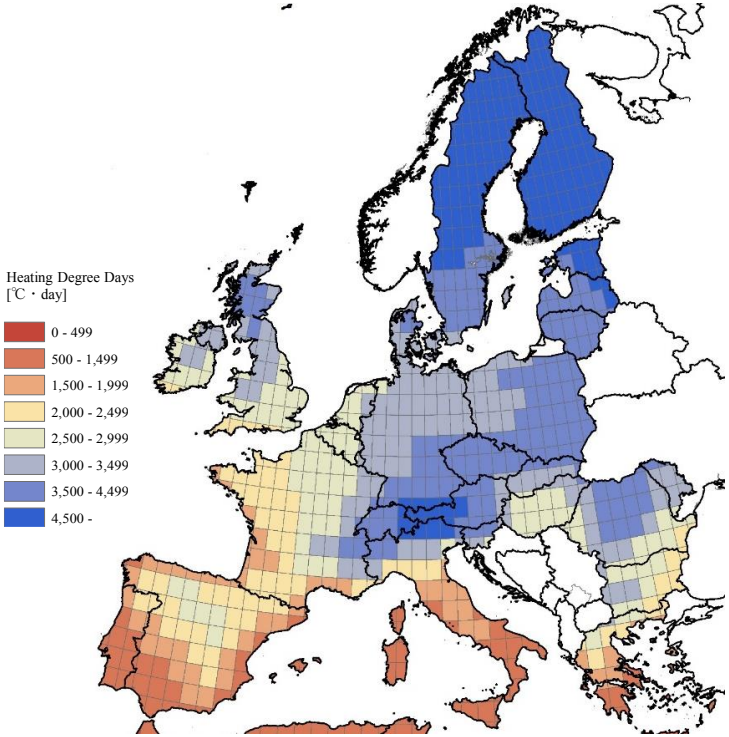


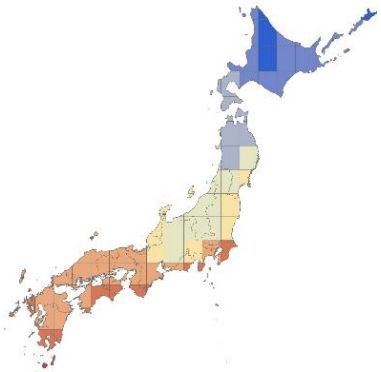
- CO_2 emissions
- Energy security
- Energy efficiency
- Sustainability
- Economic

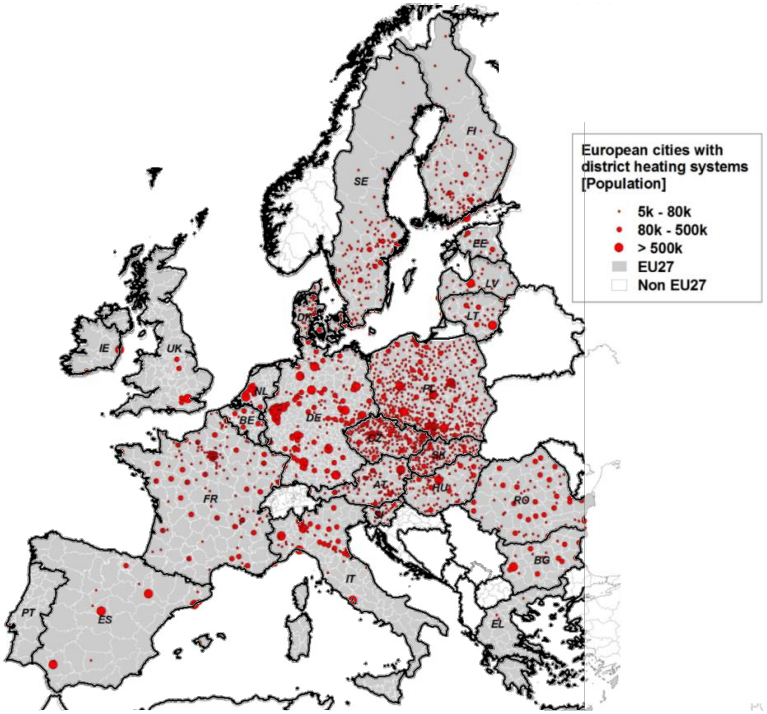
Output: Infrastructure

環境研究総合推進費(2017-) 地域拠点設計手法の開発と実証

Heating degree days and District Heating Systems in Europe

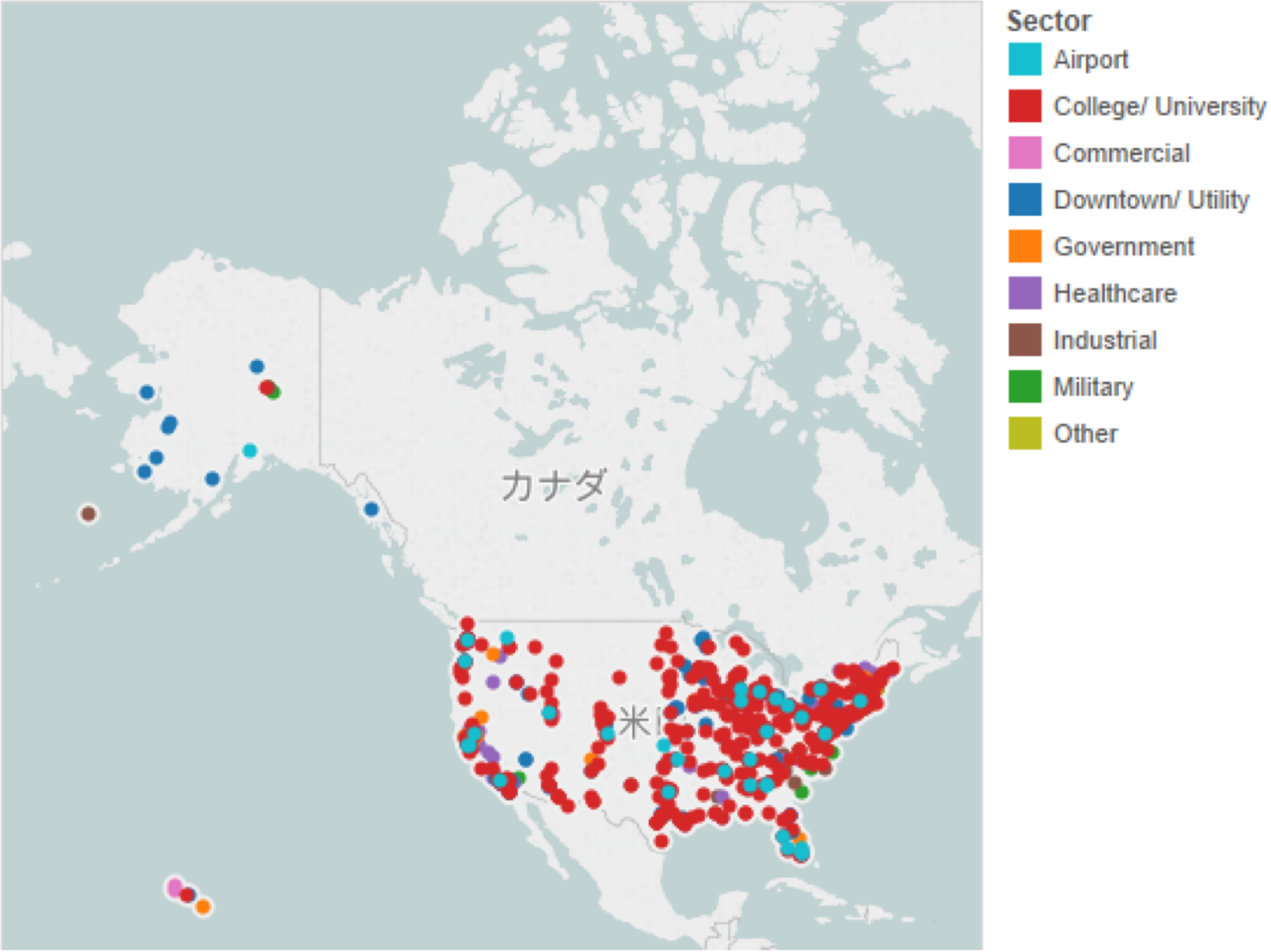






Ref. ：Climate: monthly and annual average heating degree days below 18℃ GIS data at one-degree resolution of the World from NASA/SSE, OpenIE
Heat Roadmap Europe 2 Maps, Halmstad & Aalborg Universities, 2013

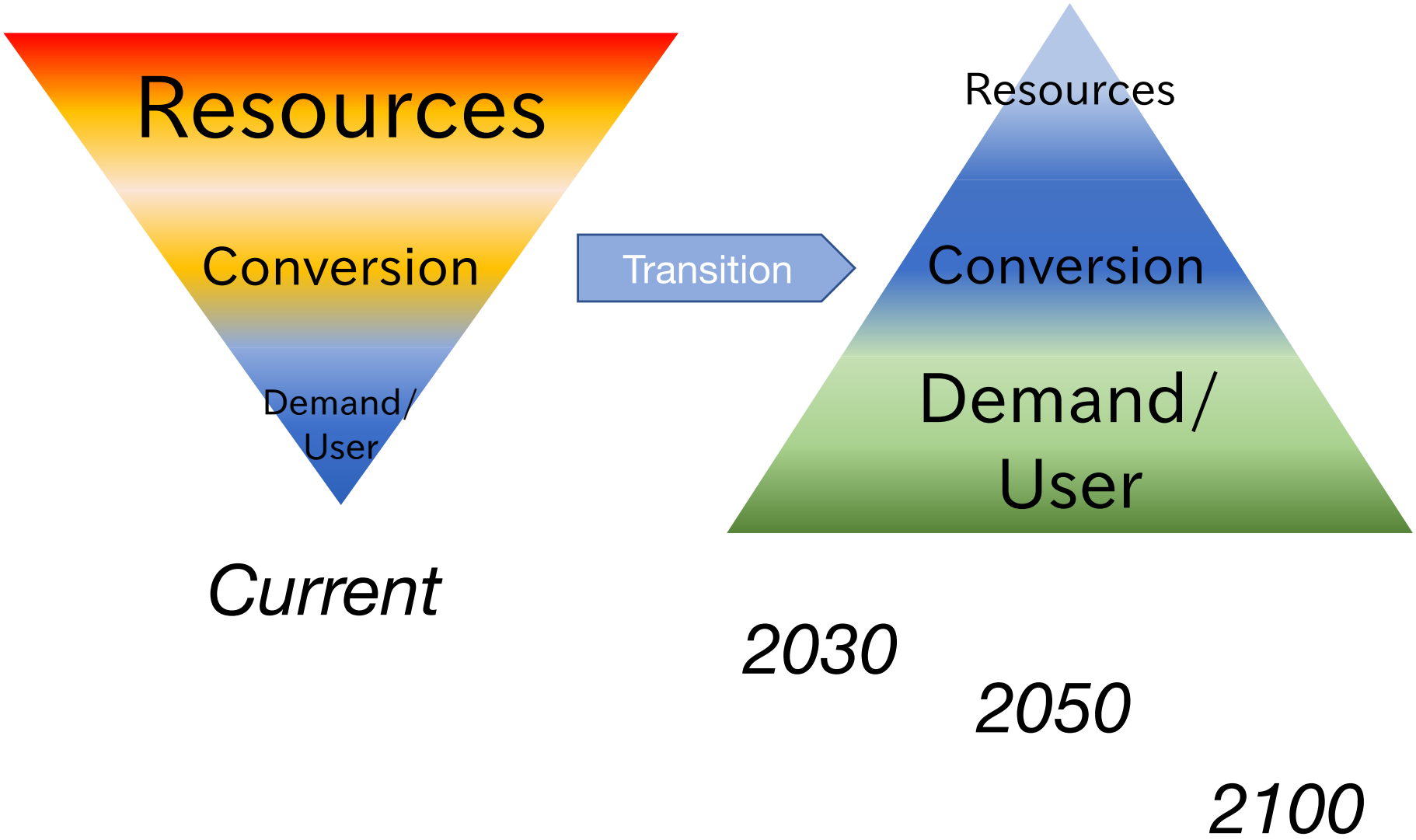
Heating degree days and District



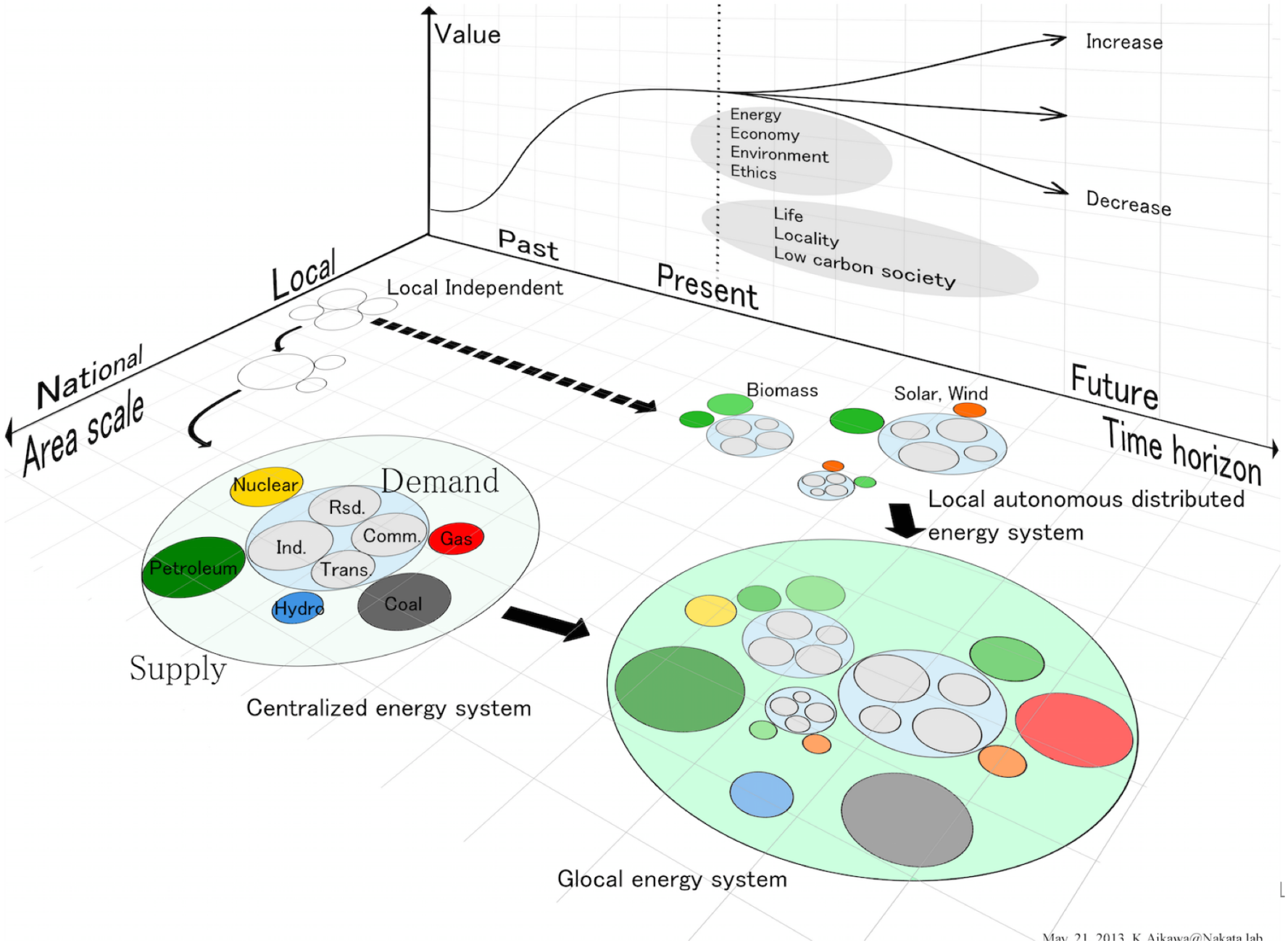
B) Spatial integration

1. Visualization of regional energy supply and demand
   - GIS based resource map
   - Energy density map
2. Regional energy planning
   - Area settings
   - District energy system
3. Valuing regional energy system
   - Direct/indirect economic ripple effect
   - Changes in the social value, quality of life

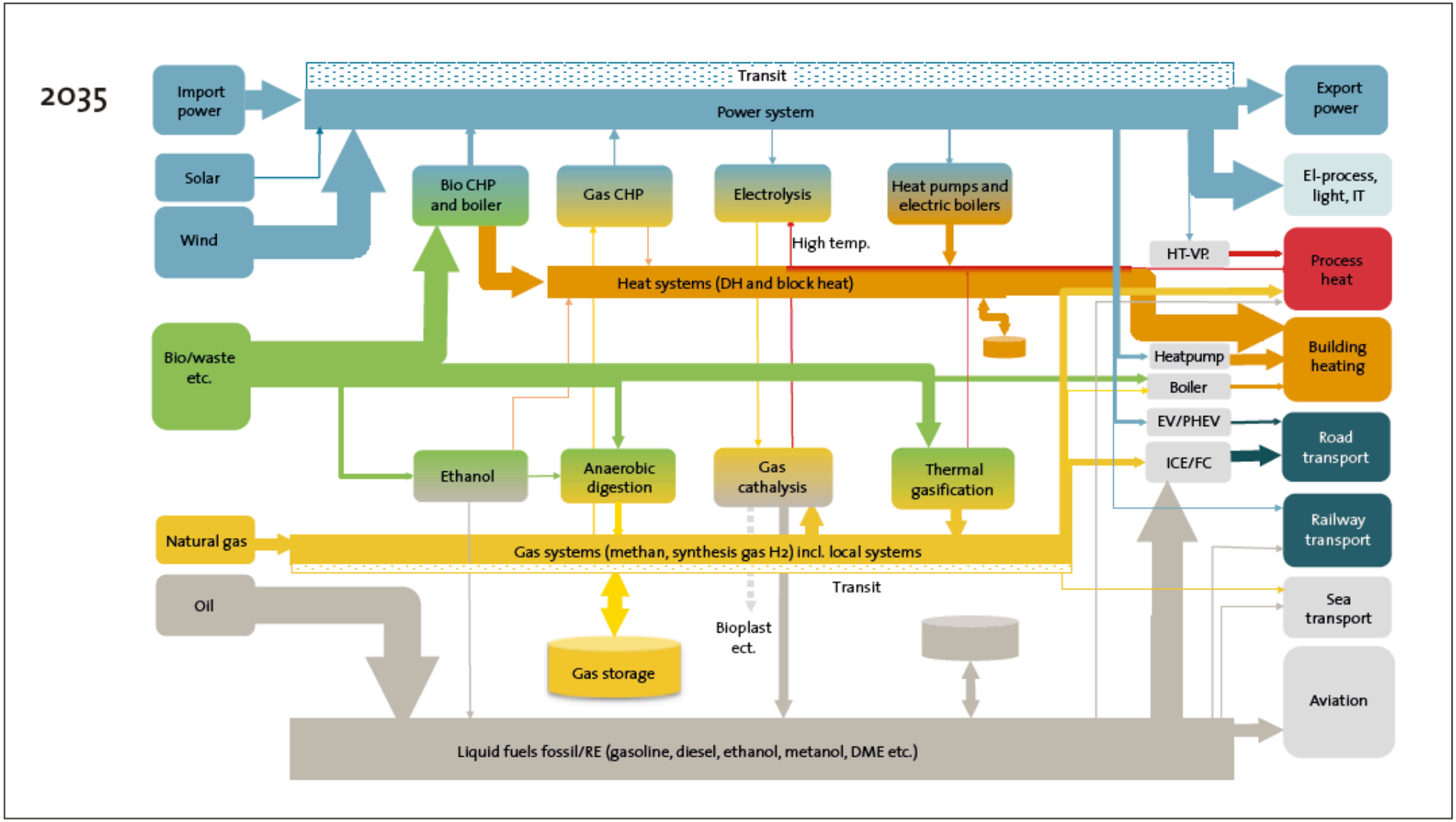
C) Time transition



C) Time transition



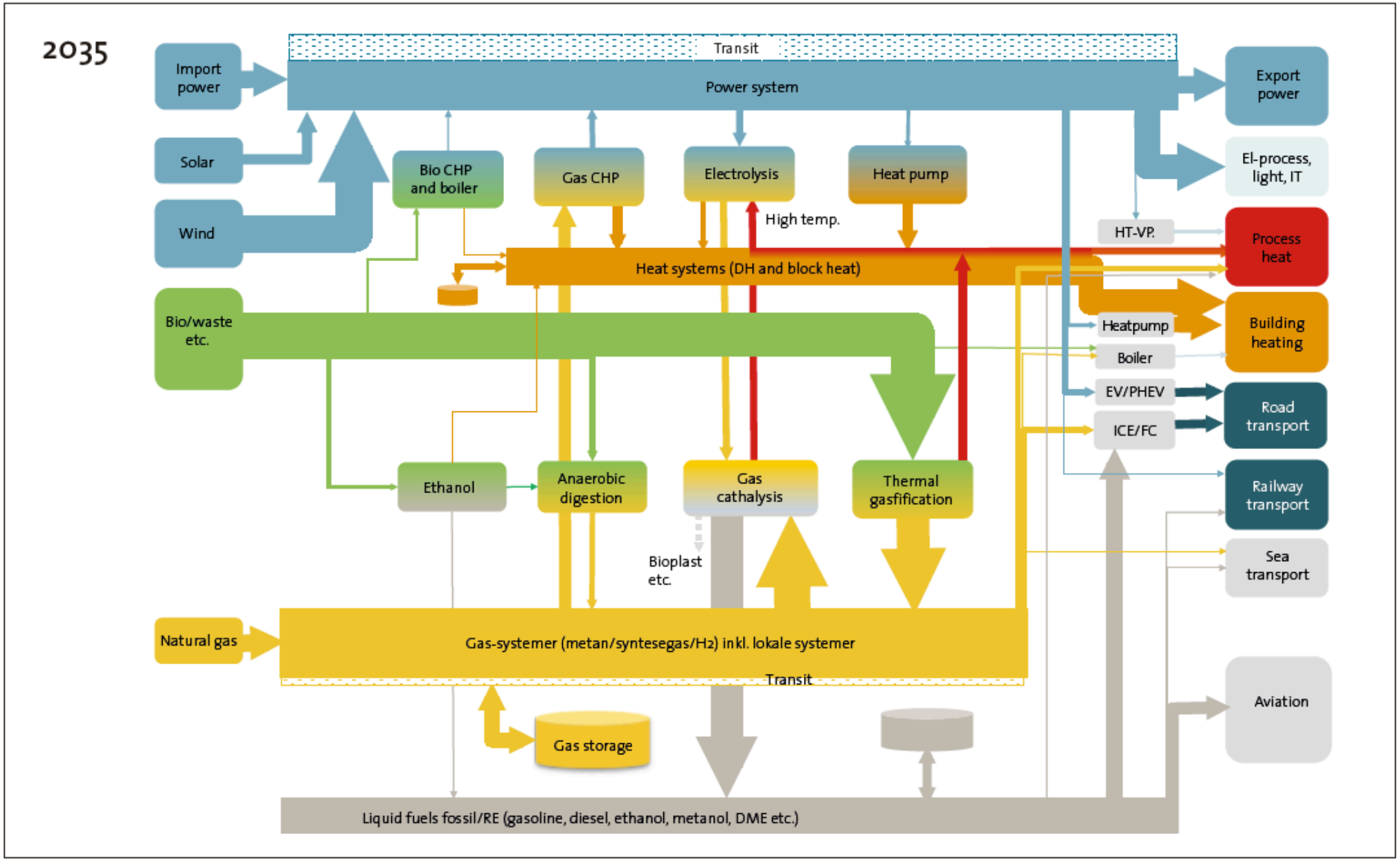
Denmark 2035 scenario No.1



Energy flows in the 2014, 2035 and 2050 scenarios. Arrows with energy flows are scaled indicatively. Reference is made to background data for a more accurate description of energy flows.

Energinet.dk

Denmark 2035 scenario No.2



2035 – Without fossil oil in the energy system

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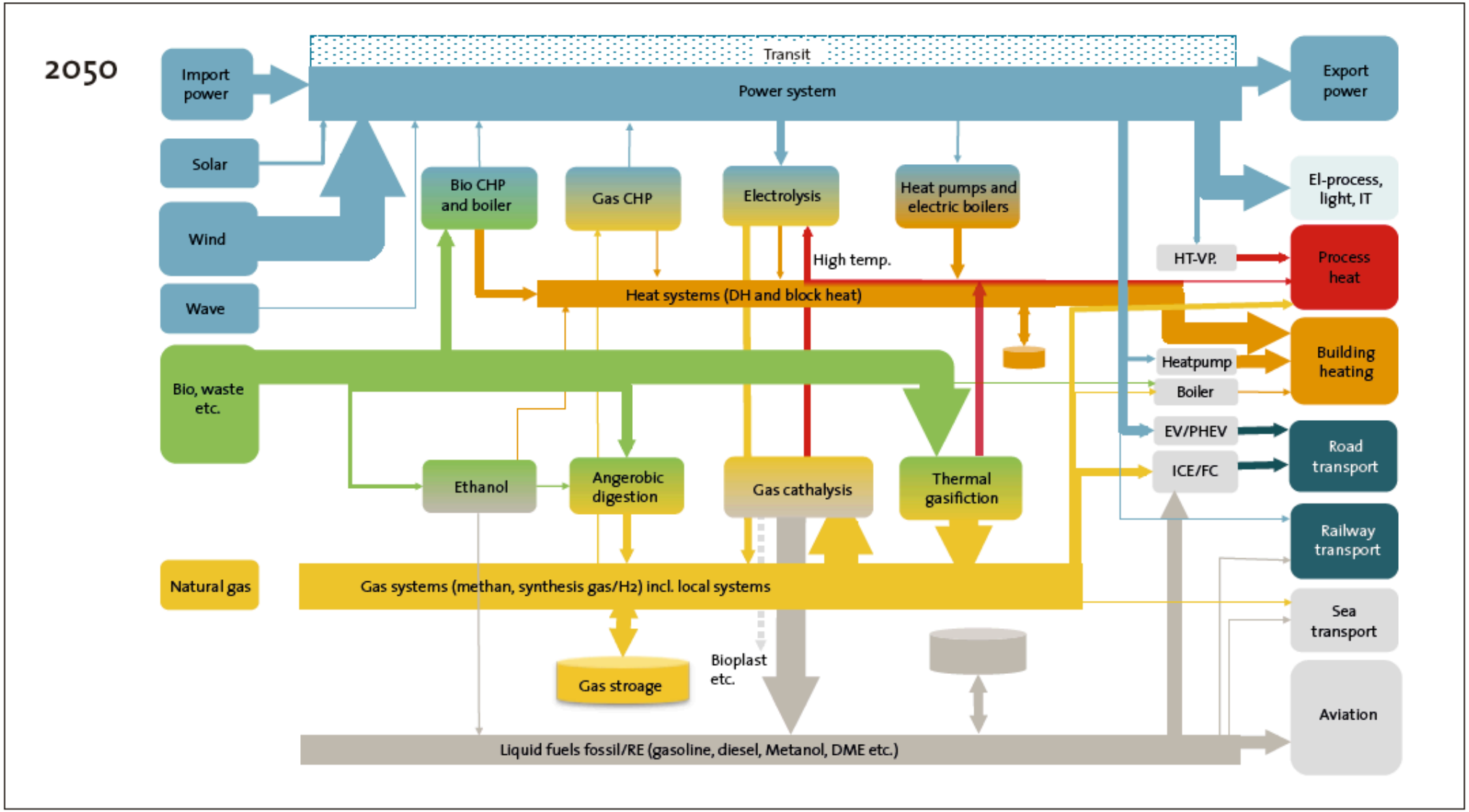
Denmark 2050 scenario



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C) Time transition

1. Goal setting
   - Low/Zero/Negative carbon society
   - Leading management with green sensitivity
2. Action plan
   - Transition in supply side
   - Transition in demand side
3. Exogenous impact assessment
   - Technological learnings
   - Lifestyle for sharing, connection, autonomous, etc.

Integrated design & analysis for energy systems

A) Physical integration

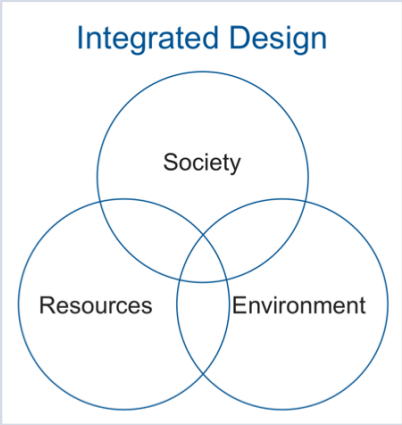
Energy flow, Energy efficiency, Environment

B) Spatial integration

Energy map, Logistics, Infrastructure

C) Time transition

Regional energy planning



Welcome to the Laboratory