News Views on De-carbonisation: Good and Bad Carbon

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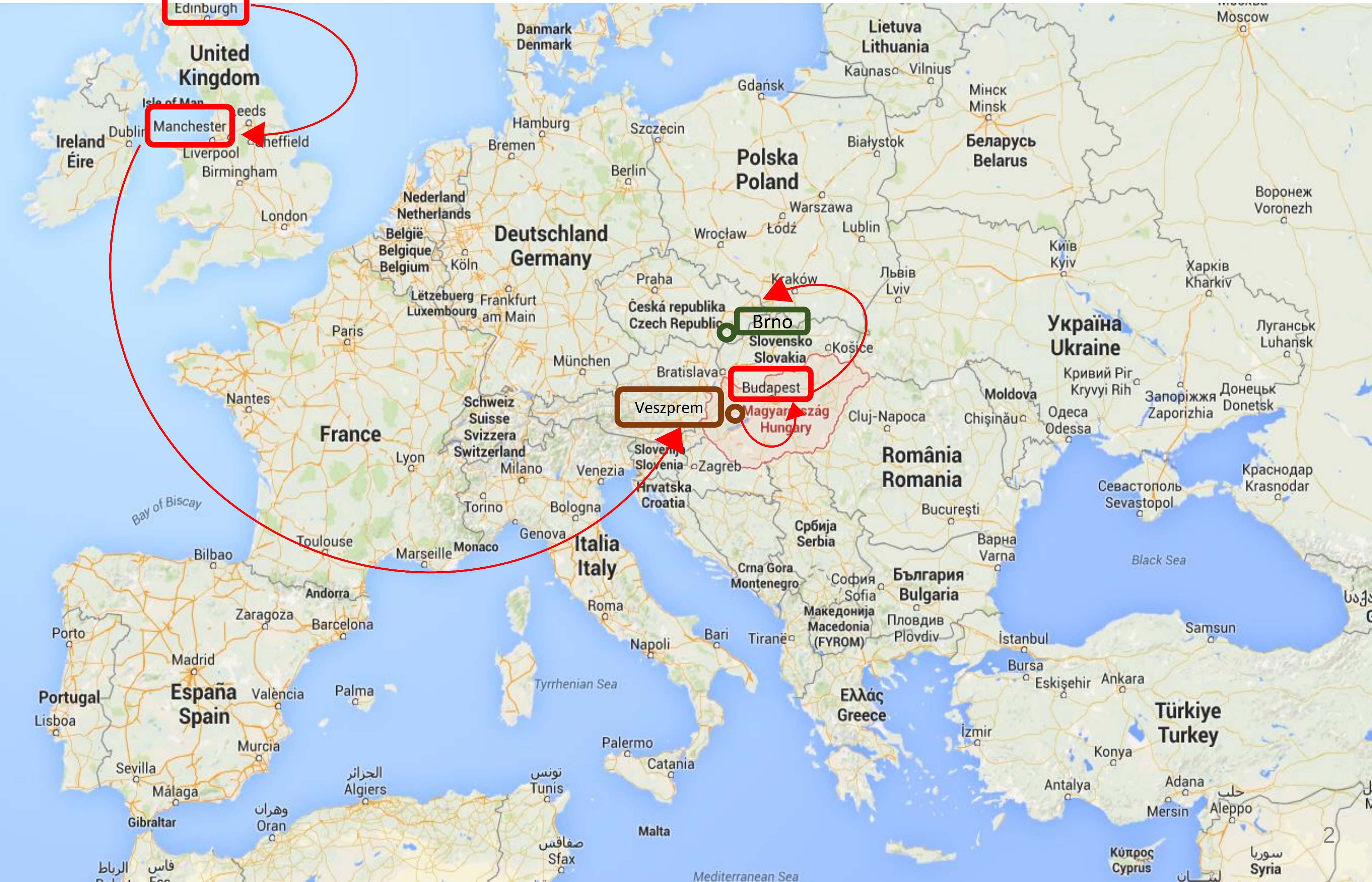
EUROPEAN UNION
European Structural and Investment Funds
Operational Programme Research, Development and Education

MINISTRY OF EDUCATION, YOUTH AND SPORTS

The 3rd International Conference of Low Carbon Asia and Beyond (ICLCA 2017), 1-3 November 2017, Bangkok, Thailand.

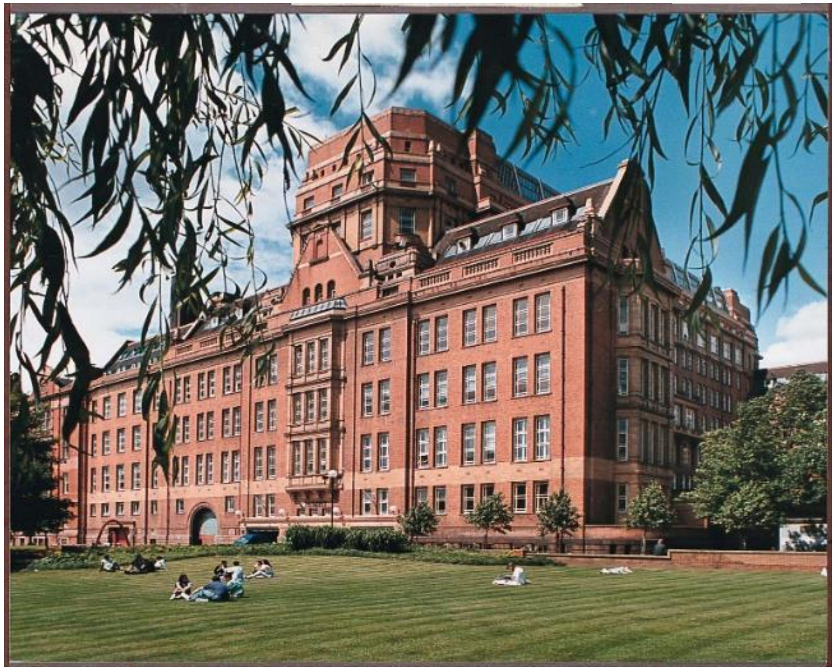
The route

United Kingdom→ Hungary → Czech Republic



UMIST – Pioneering Pinch Analysis

Department of Process Integration at UMIST 1990 – 2004



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NETME Centre

SPIL

SUSTAINABLE PROCESS INTEGRATION LABORATORY

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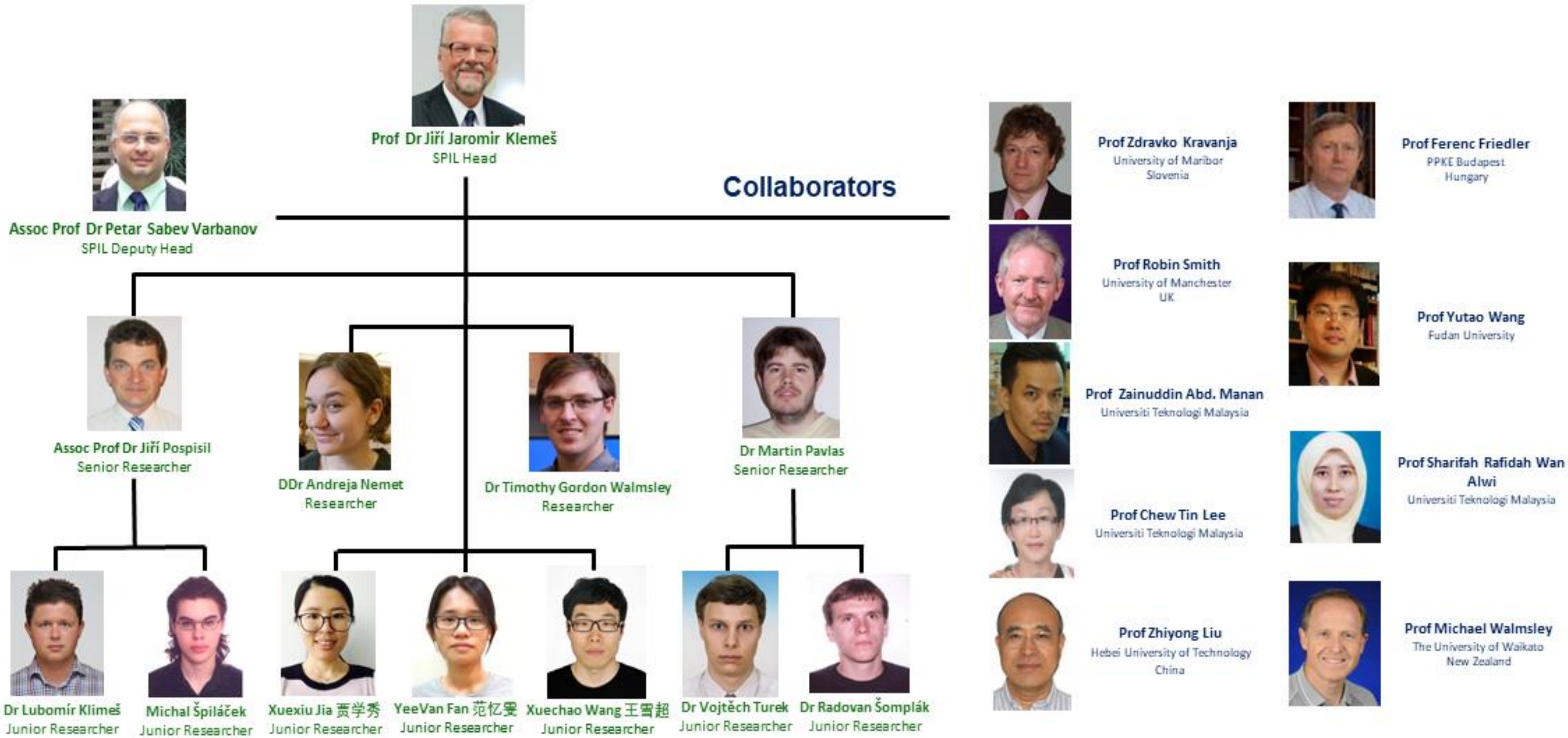

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5-Year Impact Factor: 6.207

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SCImago Journal Rank (SJR): 1.615

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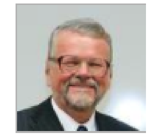

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• Cleaner Production and Technical Processes• Green/sustainable engineering• Green/sustainable supply chains• Biomass• Energy use and consumption• Waste minimisation• Pollution reduction• Renewable energy• Environmental assessment• Emergy/exergy analyses• LCA of product and process - Footprints and other assessment types• Supply chains (modelling, mathematical, and engineering)• Eco-industrial parks• Energy-water nexus

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*Cecilia is the first contact point for Review articles*Sustainability indicators, Cleaner production practices (industrial, agricultural and supply chains), Emergy and exergy analysis (resource and energy use), Regional sustainability, Education for sustainability, Environmental and sustainability assessment, Sustainable products and services, Corporate sustainability, Corporate social responsibility, Sustainable consumption

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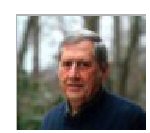
Founder and Editor-in-Chief Emeritus



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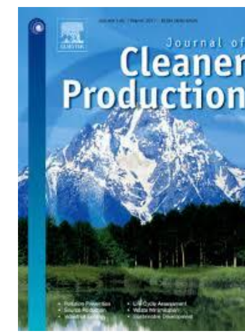
University of Tennessee, Knoxville, Tennessee, USA



Motto

- The increase in the world population that has occurred has placed increasing pressure on the demands of world society, and especially that of industrial and agricultural production.
- The accelerating development of countries with large populations has resulted in increased demands on agricultural production and processing, which resulted in further increases in energy and water demands.
- The supplies sharply increase in cost and many cases of shortages of all forms of energy and water are witnessed

Outline

1. Good and Bad Carbon introduction + Statistics

2. Example of solutions/ strategies for GHGs (Bad Carbon) reduction
   - Sequestration
   - Electricity & heat
   - Transportation
   - Waste treatment

3. Relationship with the non-main global warming contributors (the air pollutants). Limitation of current assessments
   - Biomass Energy
   - Sea Transportation

4. Environmental footprints

5. Concluding Remarks

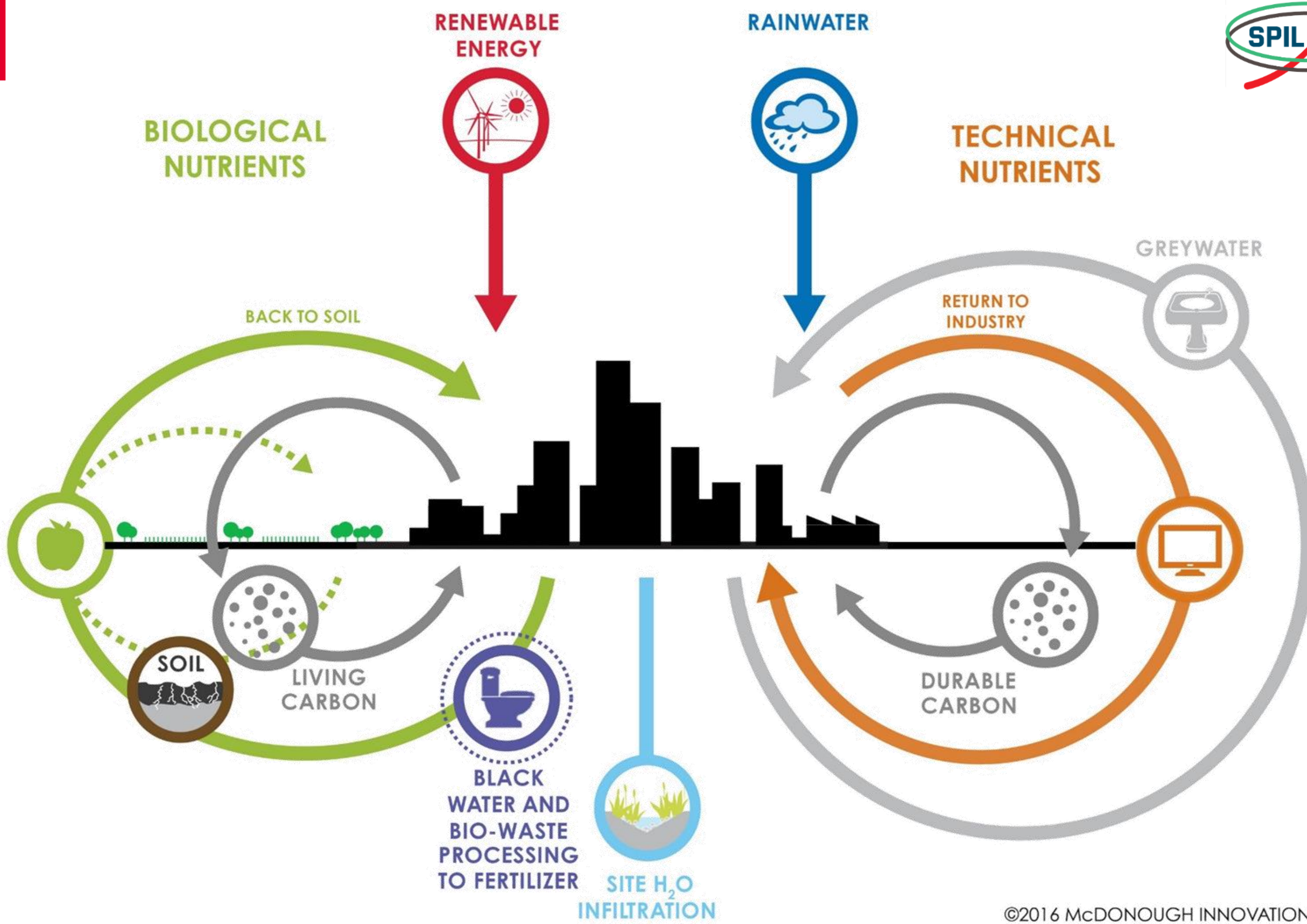
Low Carbon?! Zero Carbon?! Carbon-free?!

Carbon is an ASSET

Design with the natural cycle in mind to ensure the carbon end ups in the right place, right dose &right duration

"It is we who made carbon toxic"

McDonough W., 2016, Carbon is not the enemy. Nature, 539(7629):349-351. DOI: 10.1038/539349a.



- Climate change is a design failure
- CO_2 in the atmosphere is a liability but in the soil it is an asset

<blogs.scientificamerican.com/observations/new-view-carbon-is-not-the-enemy/>

The New Language

- **Fugitive Carbon** - ended up somewhere **unwanted** and can be **toxic as emissions**(e.g. atmosphere)

- **Durable Carbon - Locked** in stable solids that are **used and reused** (e.g. soil)

- **Living Carbon** - **Organic**, **flowing** in biological cycles, providing fresh food, healthy forests and fertile soil

<www.nature.com/news/carbon-is-not-the-enemy-1.20976>

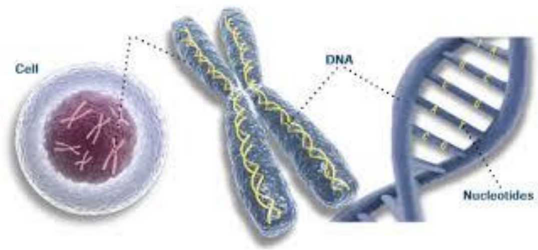
Management Strategies

- **Carbon Negative** - actions pollute the land, water and atmosphere with various forms of carbon
- **Carbon Neutral -** actions transform or maintain carbon in durable earthbound forms and cycles for use across generations; or renewable energy such as solar, wind and hydropower that do not release carbon emissions.
- **Carbon Positive** - actions convert atmospheric carbon/carbon from organic materials to forms that enhance soil nutrition, green plants grow or to durable forms.

<www.nature.com/news/carbon-is-not-the-enemy-1.20976>

Carbon World: The Good

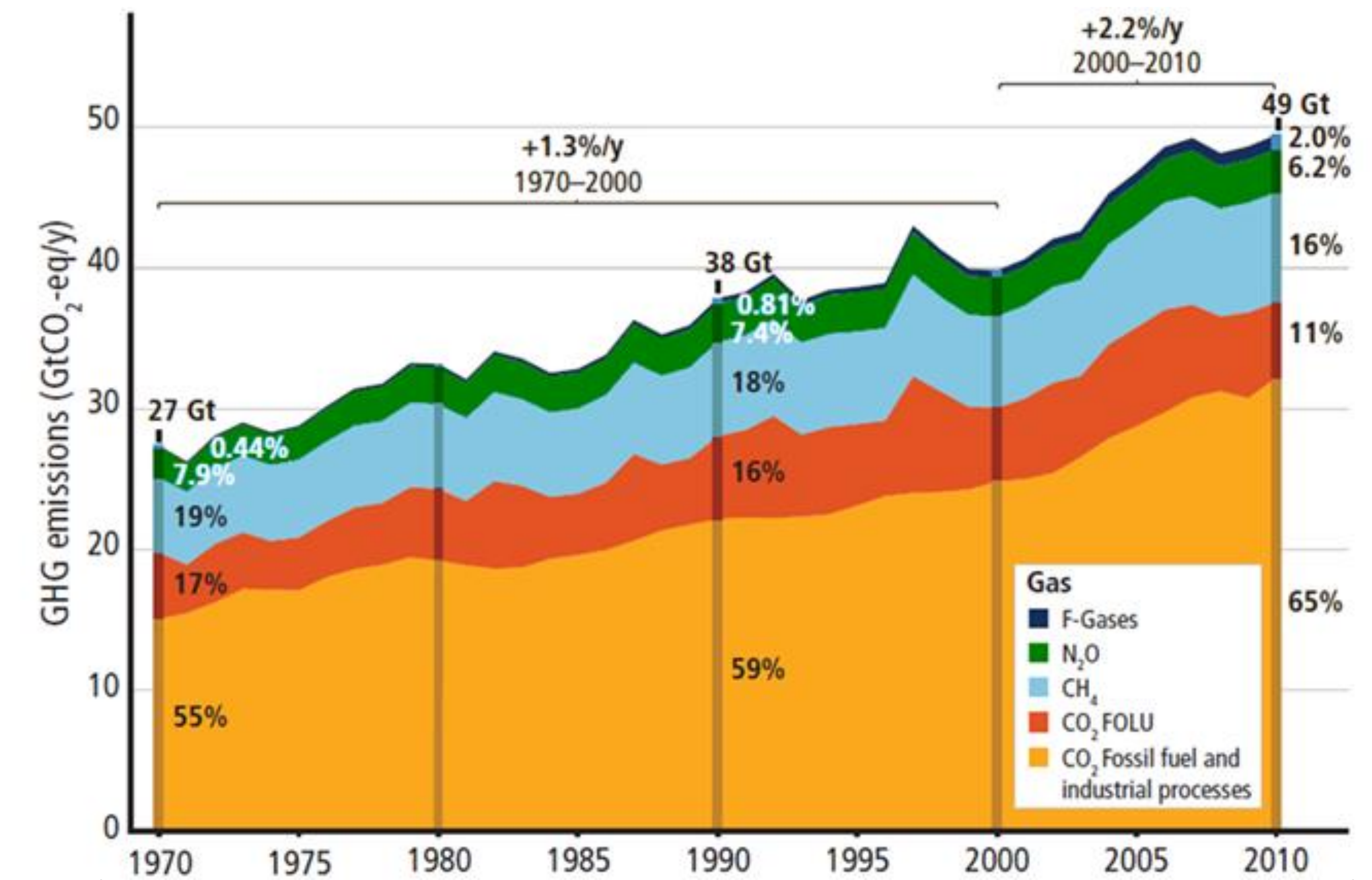
- Every living organism on the planet is a carbon based life form



18 % carbon

Energy

Total Annual Anthropogenic GHG Emissions

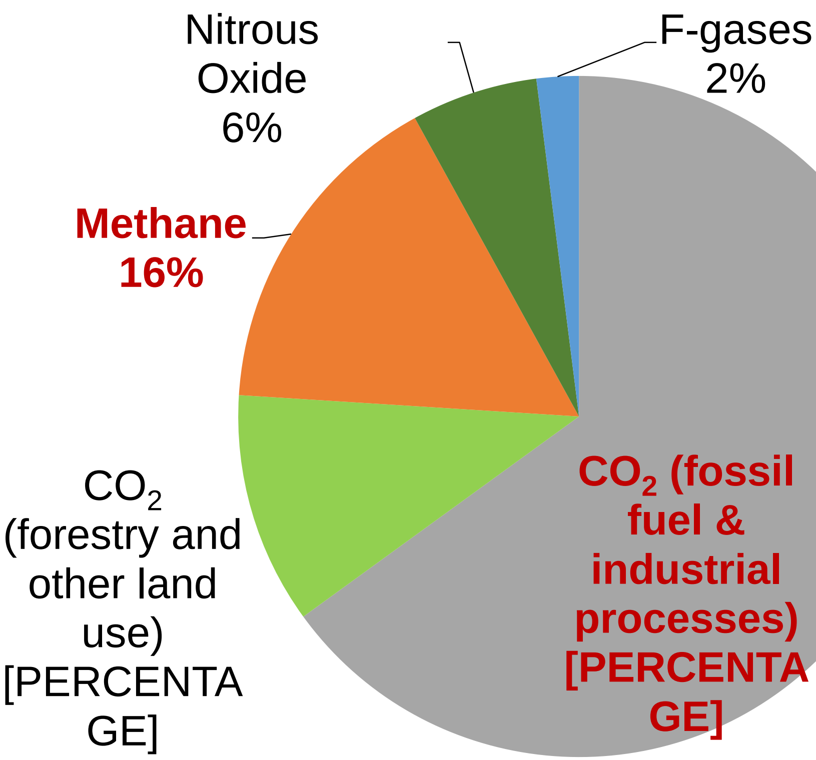


(FOLU - Forestry and Other Land Use, F-Gases = Fluorinated Gases)

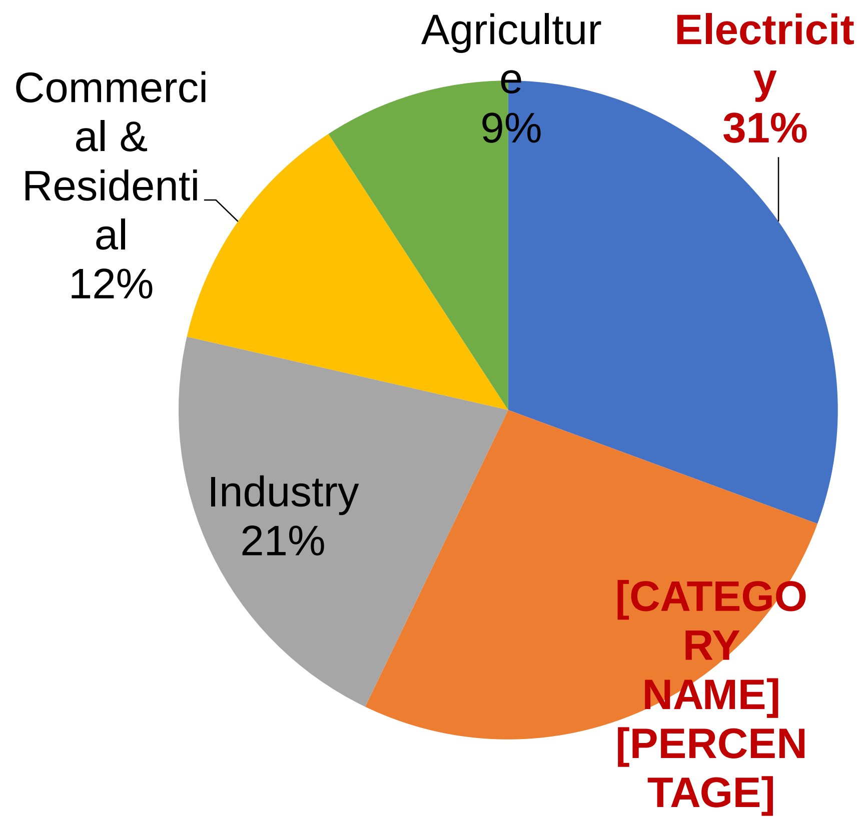
IPCC (Intergovernmental Panel on Climate Change), Developed from Climate Change 2014: Synthesis Report, Report Graphic, IPCC Secretariat, World Meteorological Organization, Geneva, Switzerland <www.ipcc.ch/report/graphics/index.php?t=Assessment%20Reports&r=AR5%20-%20Synthesis%20Report&f= Topic% 203>

The Bad Carbon

The Global Emission GHG: Types and by Sectors

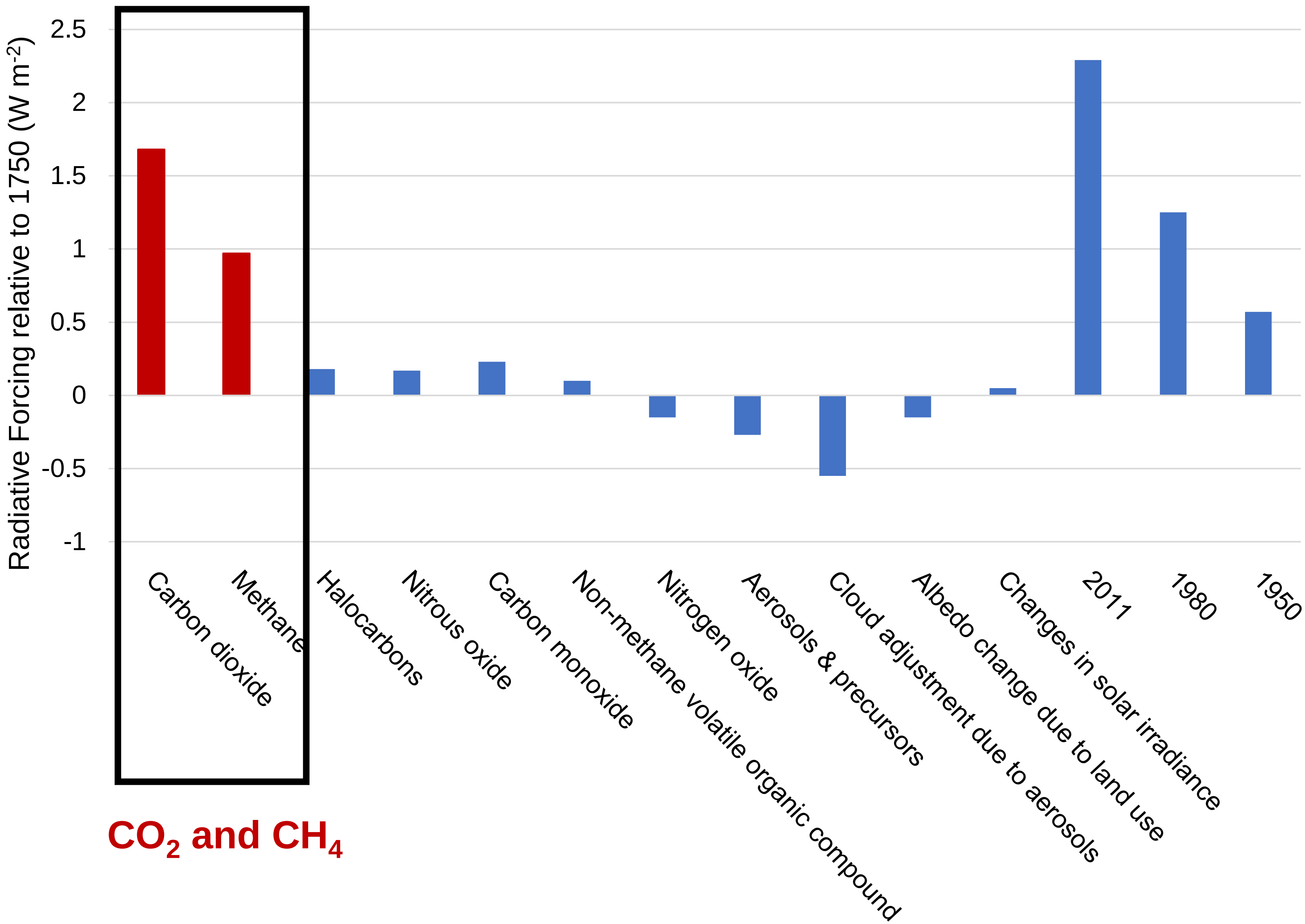


Data for Year 2010



<www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data>

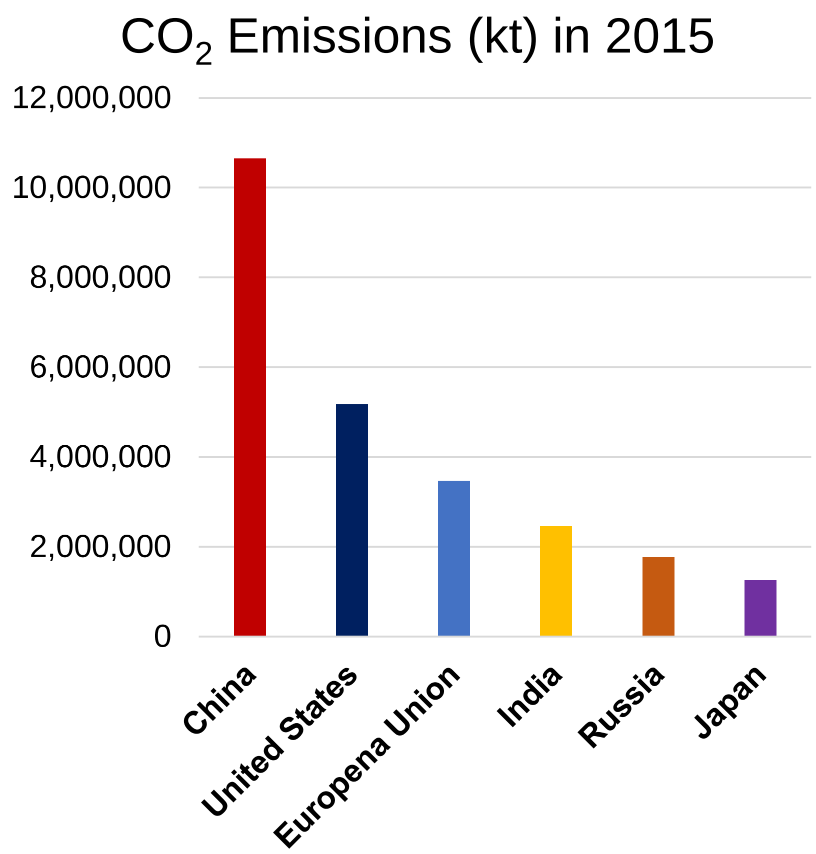
C emissions Climate Influence

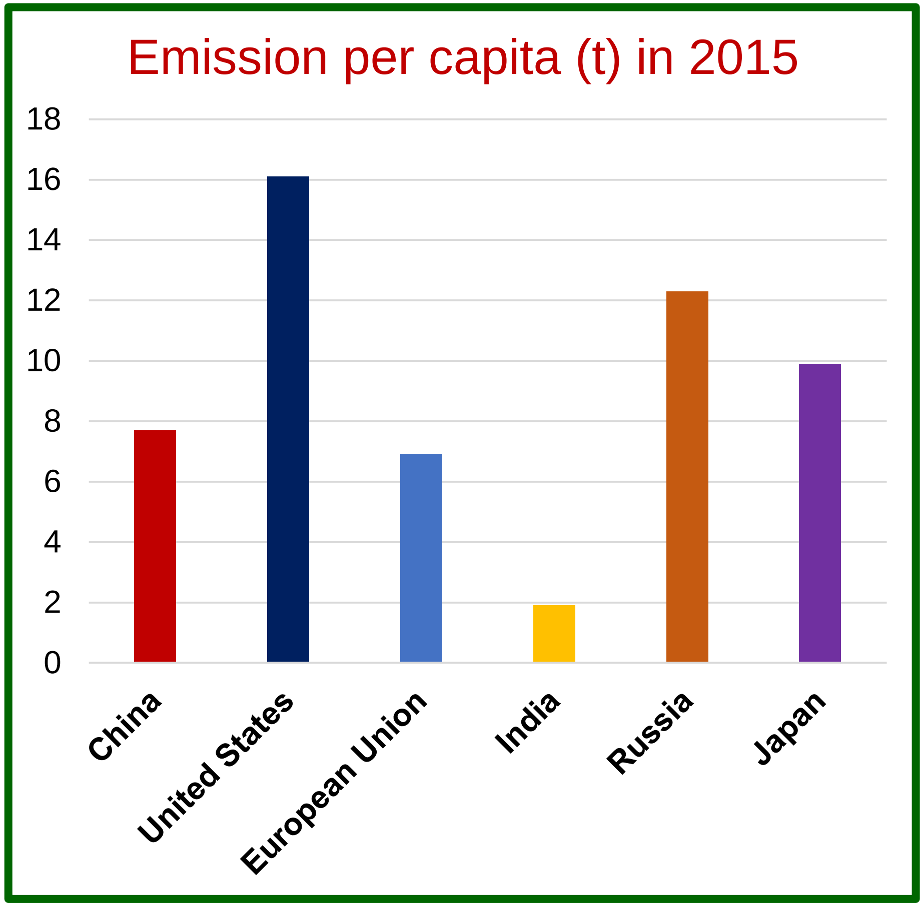


*Between Year 1750-2011, refer the reference for SD value

<www.ucsusa.org/global_warming/science_and_impacts/science/CO2-and-global-warming-faq.html#.WeirrWiCyUI>, data from IPCC

CO_2 Contributors



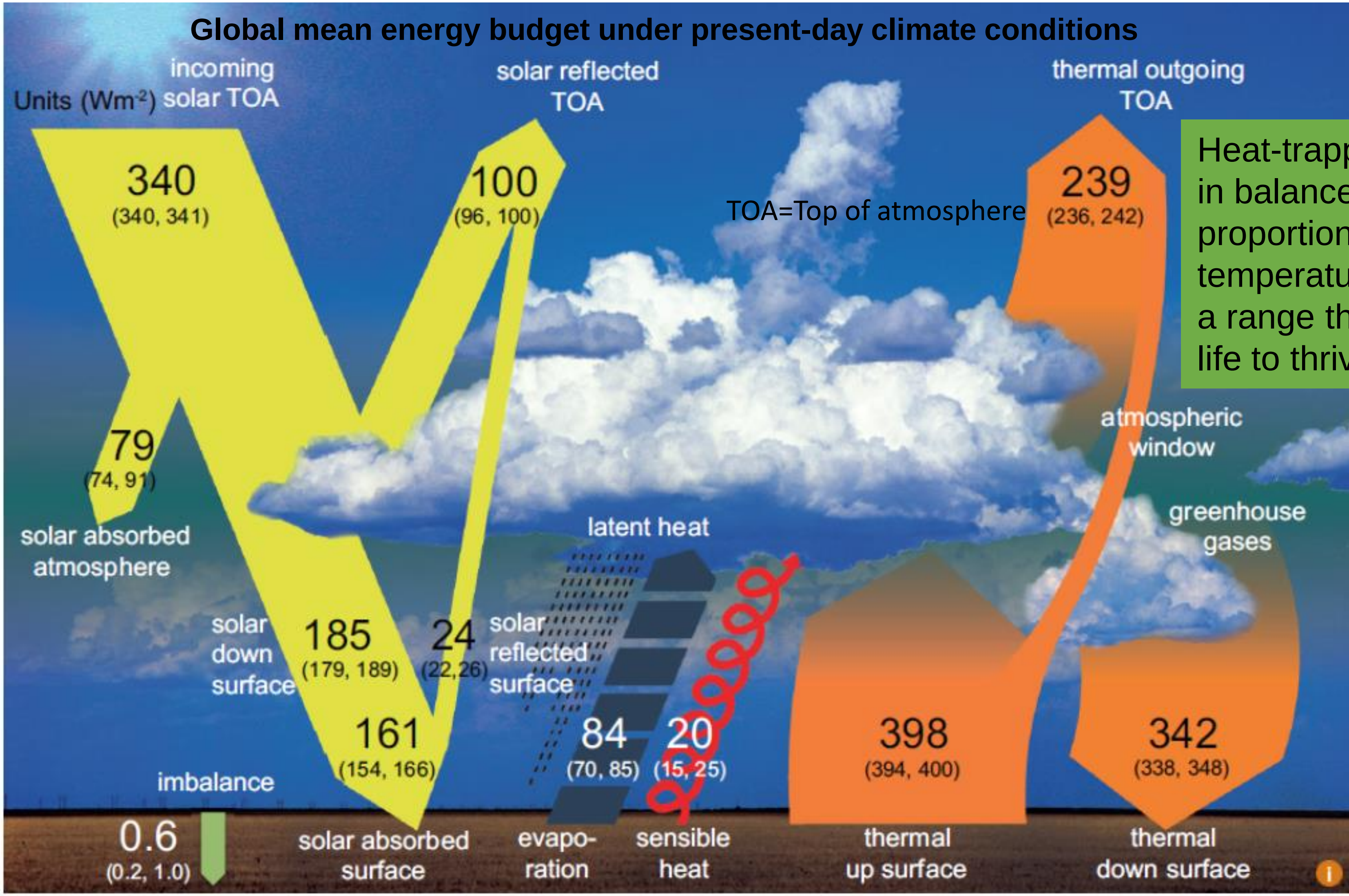


The data only considers carbon dioxide emissions from the burning of fossil fuels and cement manufacture, but not emissions from land use, land-use change and forestry. Emissions from international shipping or bunker fuels are also not included in national figures

CO_2 emissions by country 29.5% 14.34% 9.62% 6.81% 4.88% 3.47%

<www.pbl.nl/en/>

Imbalanced

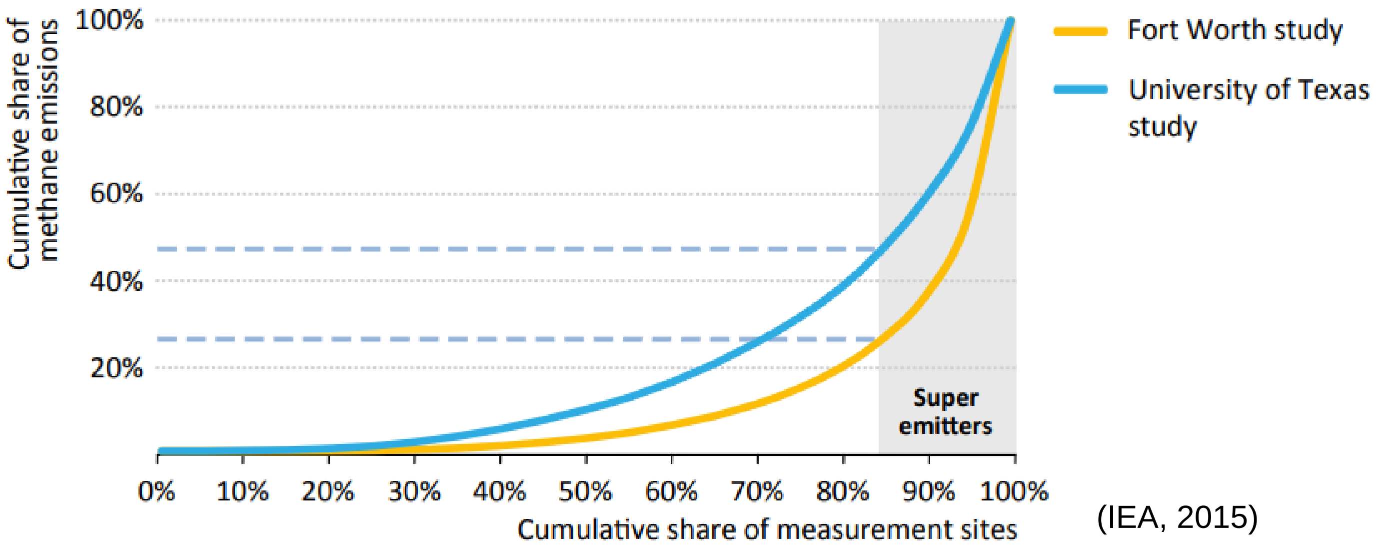


Heat-trapping gases, in balanced proportions, keeping temperatures within a range that enables life to thrive

Wild M., Folini D., Schär C., Loeb N., Dutton E. G., König-Langlo G. (2013). The global energy balance from a surface perspective. Climate dynamics, 40(11-12), 3107-3134.
<www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_Chapter02_FINAL.pdf>

Methane CH_4

- Flaring of Methane by petroleum industry is much more regulated
- Main problem - The natural gas. Shale gas development, venting of unburned CH_4 from oil field facilities and equipment (fugitive emissions or leaks),



(IEA, 2015)

Canadian Chemical News, 2017, Methane mitigation. Chemical Institute of Canada, 1-30. <www.cheminst.ca>
Howarth R. W., 2015, Methane emissions and climatic warming risk from hydraulic fracturing and shale gas development: implications for policy. Energy and Emission Control Technologies, 3, 45-54.
International Energy Agency

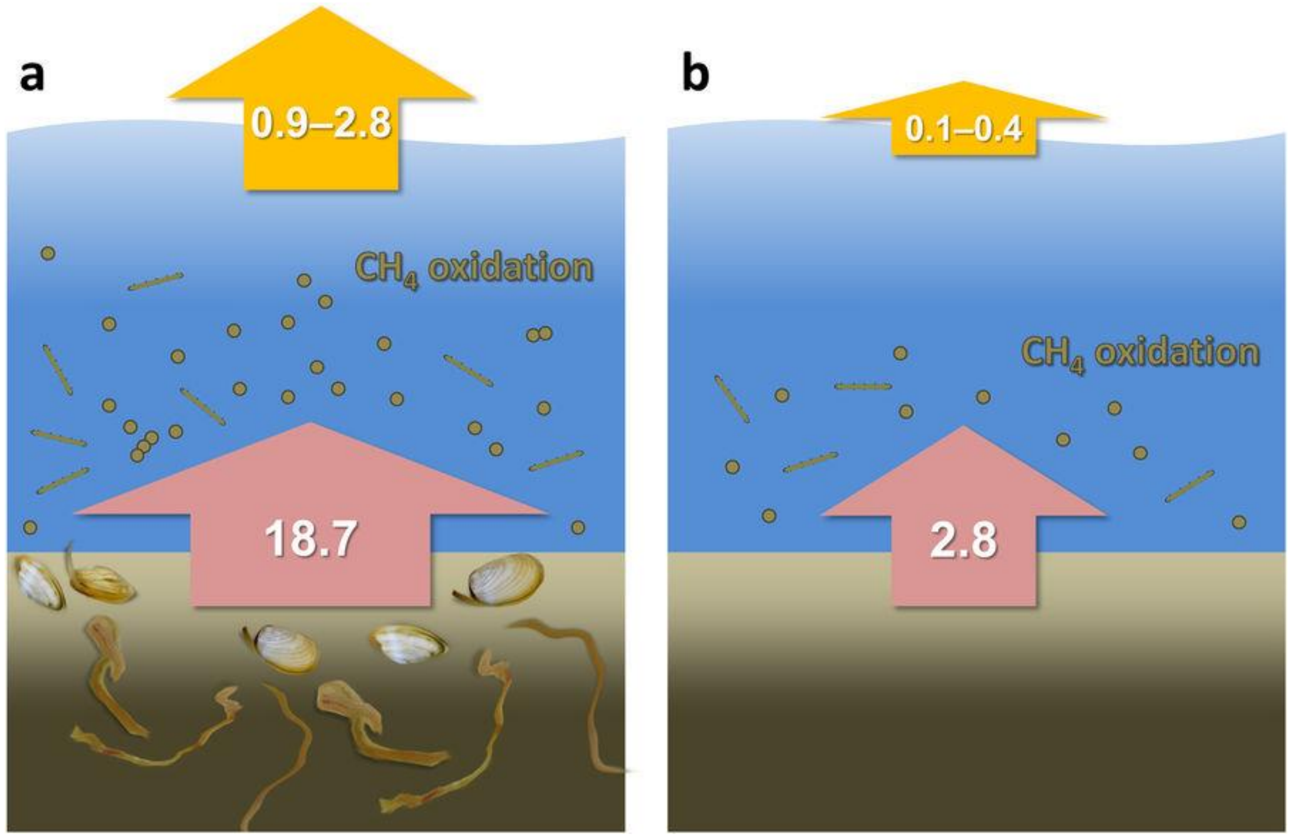
Methane fluxes from coastal sediments

- Eutrophication, has been recognized to be the principal driver for the enhanced GHG flux from aquatic environments.
- According to recent budgets, shallow aquatic systems may contribute ~10% of global N_2O emissions.
- No clear consensus on the contribution of these environments to the global CH_4 emission because source magnitude and variability remain highly uncertain.
- However, up to 30–40% of the methane emissions may be due to methane produced in sediments of aquatic ecosystems.
- The role of coastal benthic macrofauna in mediating gas release is still amply debated since the mechanisms regulating production and transport of gases by invertebrates are largely unknown.
- Bivalves isolated from coastal sediments were shown to be strong emitters of N_2O. However, it is not clear from these studies whether the N_2O produced by bivalves reaches the water column or is reduced to dinitrogen by denitrifying bacteria living in the sediment.

Bonaglia S., Brüchert V., Callac N., Vicenzi A., Fru E. C., Nascimento F. J., 2017, Methane fluxes from coastal sediments are enhanced by macrofauna. *Scientific Reports*, *7*(1), 13145.

Methane fluxes from coastal sediments

THE ROLES OR MACROFAUNA



- Macrofauna contributes to GHG production and that the extent is dependent on lineage.
- It may play an important but overlooked role in regulating GHG production and exchange in coastal sediment ecosystems

Bonaglia S., Brüchert V., Callac N., Vicenzi A., Fru E. C., Nascimento F. J., 2017, Methane fluxes from coastal sediments are enhanced by macrofauna. *Scientific Reports*, *7*(1), 13145.

Solutions/ Strategies for Bad Carbon (emissions)

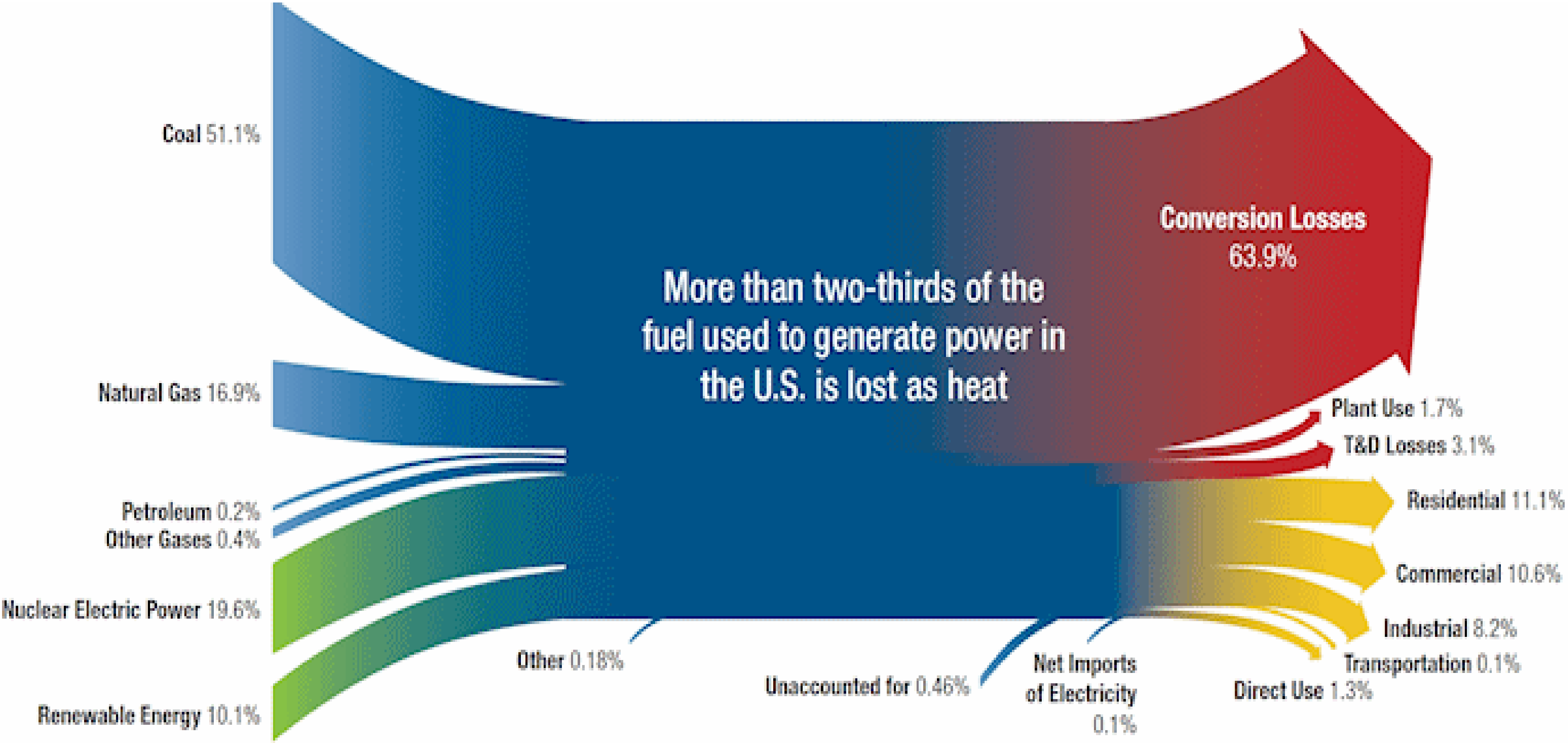
- **SAVING** and **EFFICIENCY**
- Through Electricity and Heat Sector (Renewable energy, Process Integration)
- Through Transportation Sector (Electrical transport, brake system etc)
- Waste Management (Waste to energy etc)
- Sequestration

Energy

The most environmentally friendly is energy not used / saved

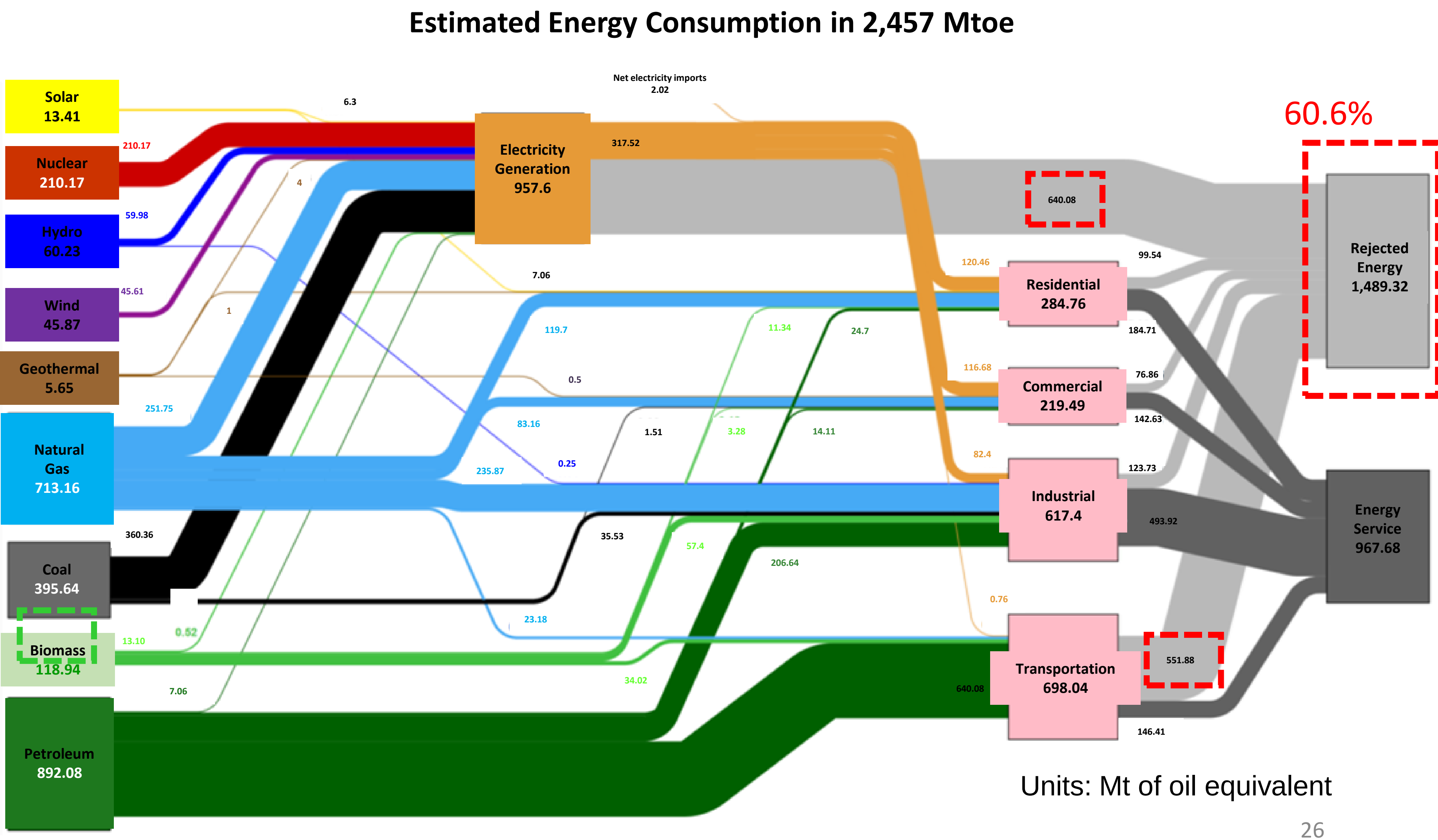
How to achieve better energy efficiency and conservation?

US Balance: Economy Wide Losses



<www.gulfcoastcleanenergy.org/CLEANENERGY/CombinedHeatandPower/tabid/1698/Default.aspx>

The US Energy



Units: Mt of oil equivalent

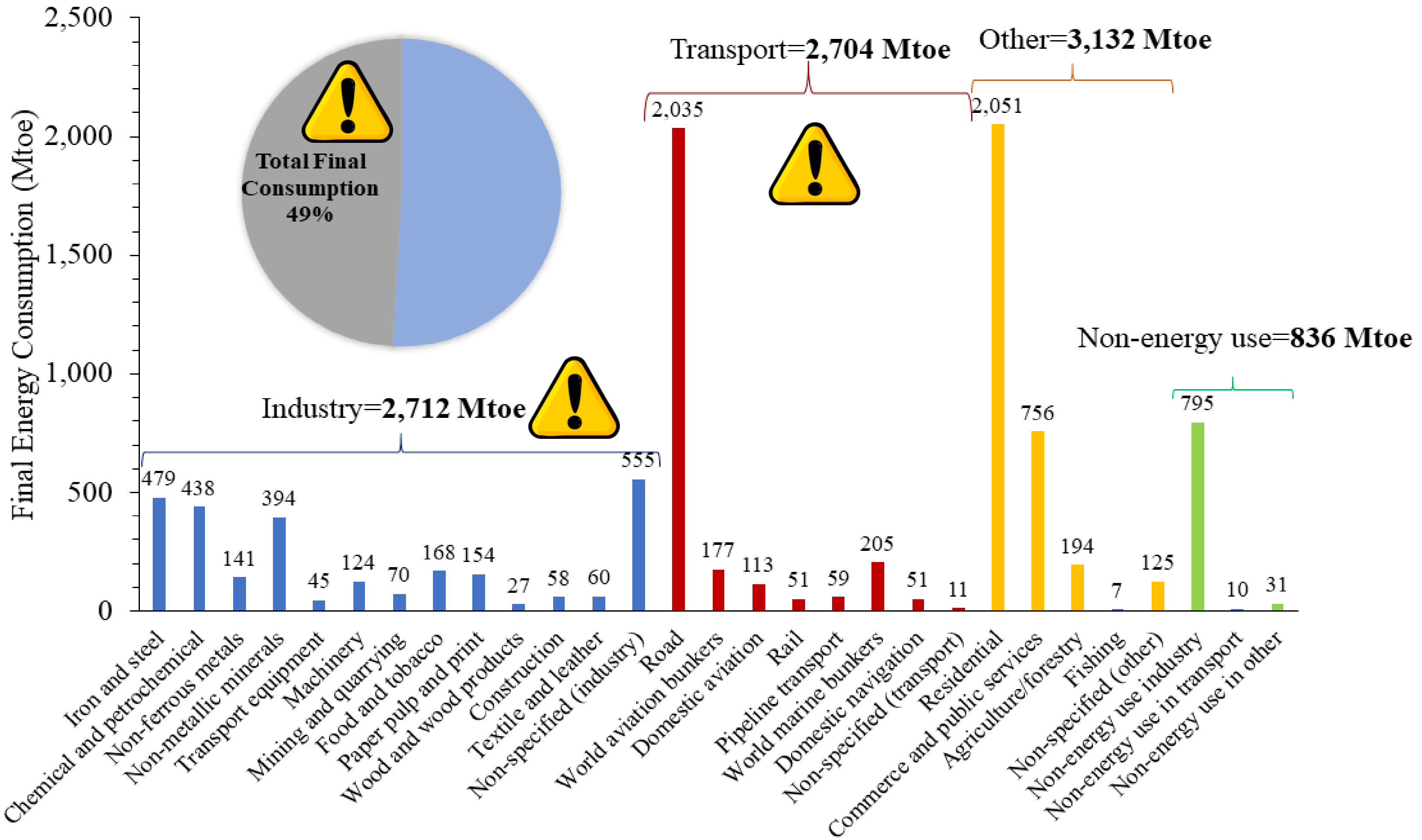
Lawrence Livermore National Laboratory and the Department of Energy (US)

<www.visualcapitalist.com/u-s-energy-consumption-one-giant-diagram/>accessed 16 May 2017

Electricity and Heat

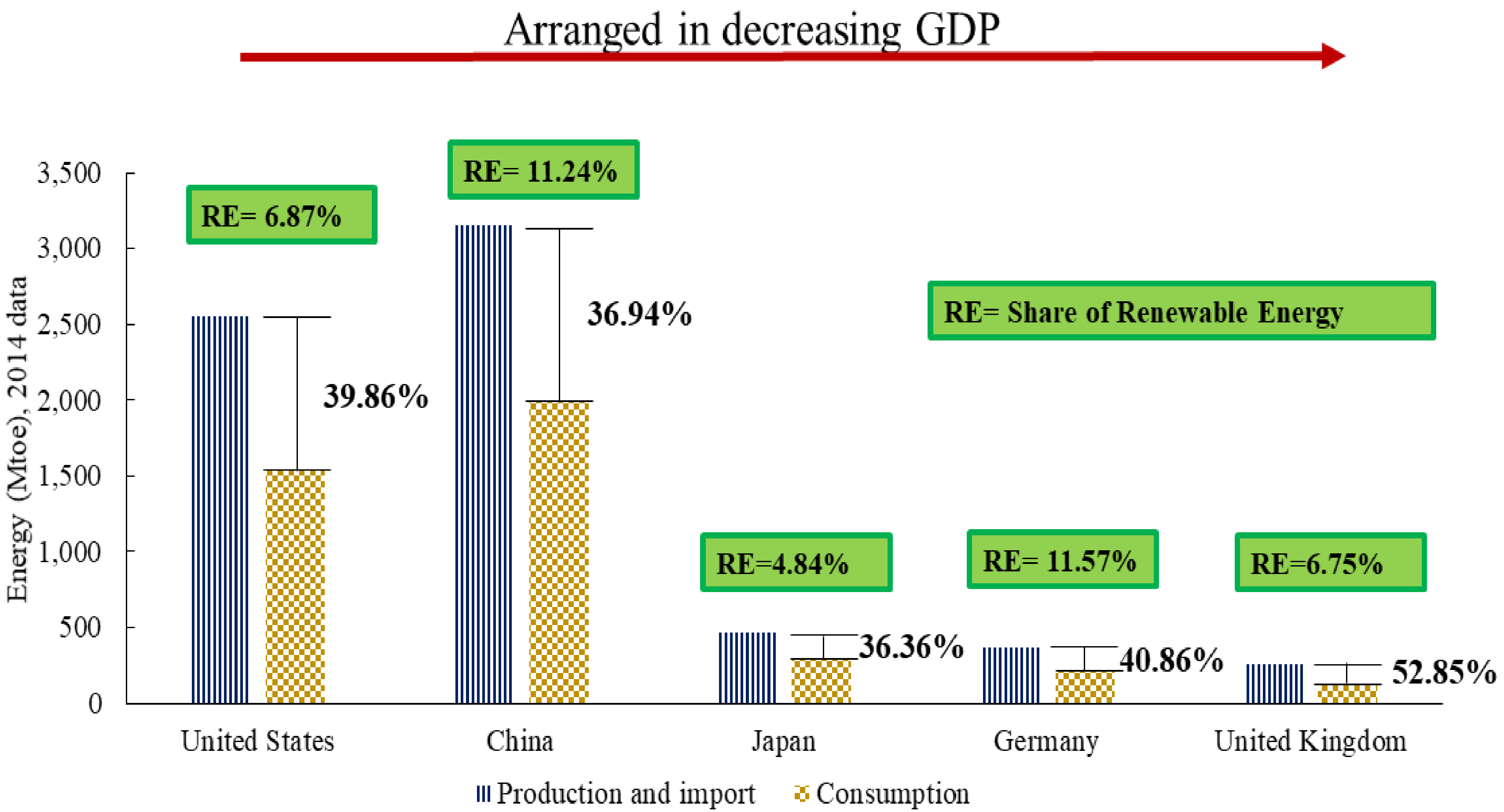
- Statistics (Renewables energy)
- Examples/ issues (RE & PI)

Global energy consumption, (2015)



Fan Y.V., Varbanov P.S., Nemet A., Klemeš J.J., 2017, Process Efficiency Optimisation and Integration for Cleaner Production. Journal of Cleaner Production. Submitted Manuscript. Special Issues PRES 16

Energy production & consumption



Fan Y.V., Varbanov P.S., Nemet A., Klemeš J.J., 2017, Process Efficiency Optimisation and Integration for Cleaner Production. Journal of Cleaner Production. Submitted Manuscript. Special Issues PRES 2016

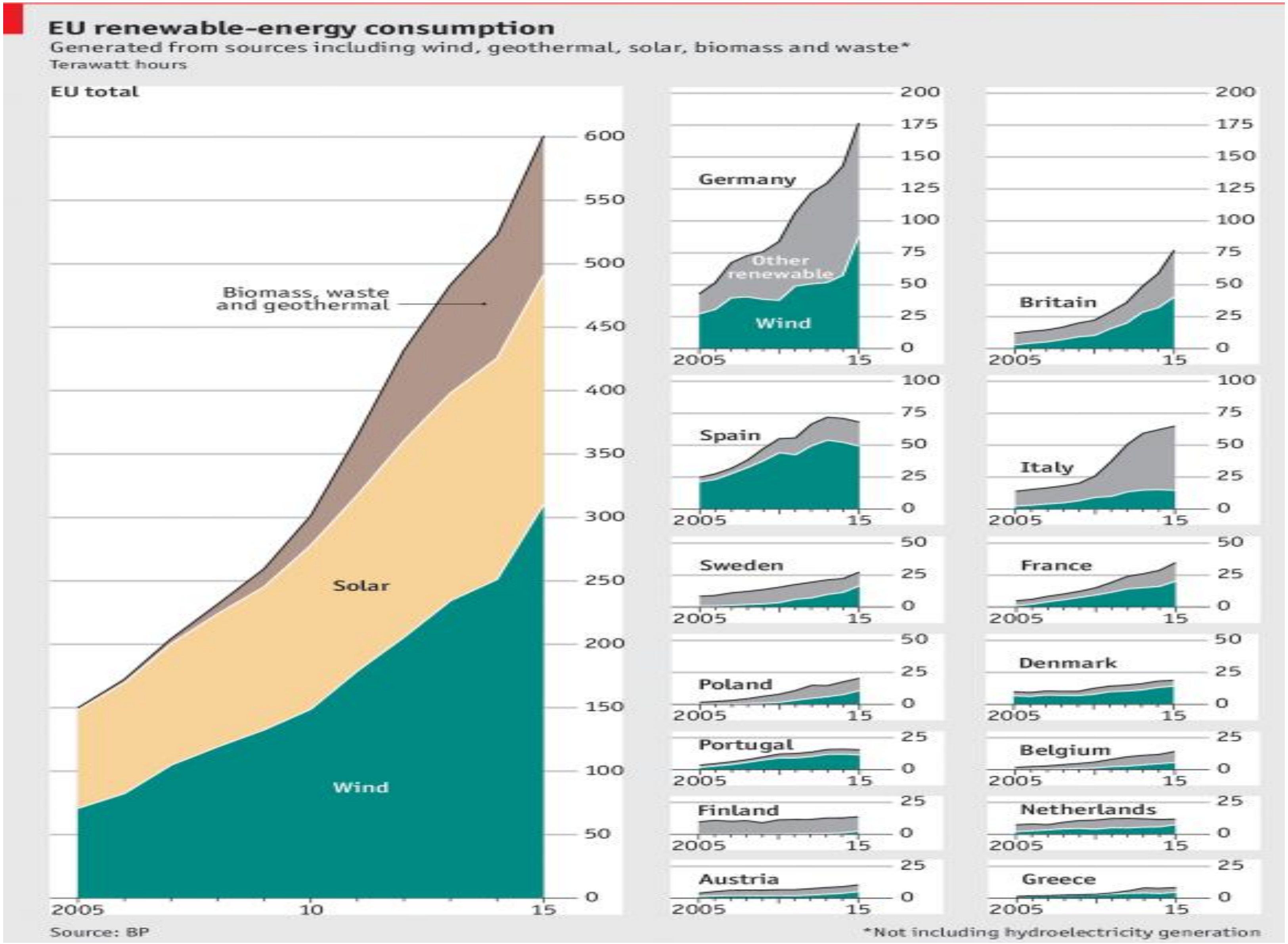
Renewable Energy

- RE is one of the contributors to high energy loss and low energy efficiency. (Desjardins, 2016)
- More research attention is needed to further promote the development of **better dispatch ability** and **efficiency**, as well as to lower the cost of renewable energy technologies
- The sources of RE can be classified into natural resources (such as sun, water, wind, waves, geothermal and biomass) and waste (such as agricultural, plastic, industrial and municipal solid waste).
- Hybrid solar PV and wind energy systems are among the most common combinations because of the natural synergies of sun and wind (co-located) (FS-UNEP, 2017).

Desjardins J., 2016. <www.visualcapitalist.com/u-s-energy-consumption-one-giant-diagram/>

FS-UNEP (Frankfurt School-United Nations Environmental Programme), 2017. Global trends in renewable energy investment 2017. <fs-unep-centre.org/sites/default/files/publications/globaltrendsinrenewableenergyinvestment2017.pdf>.

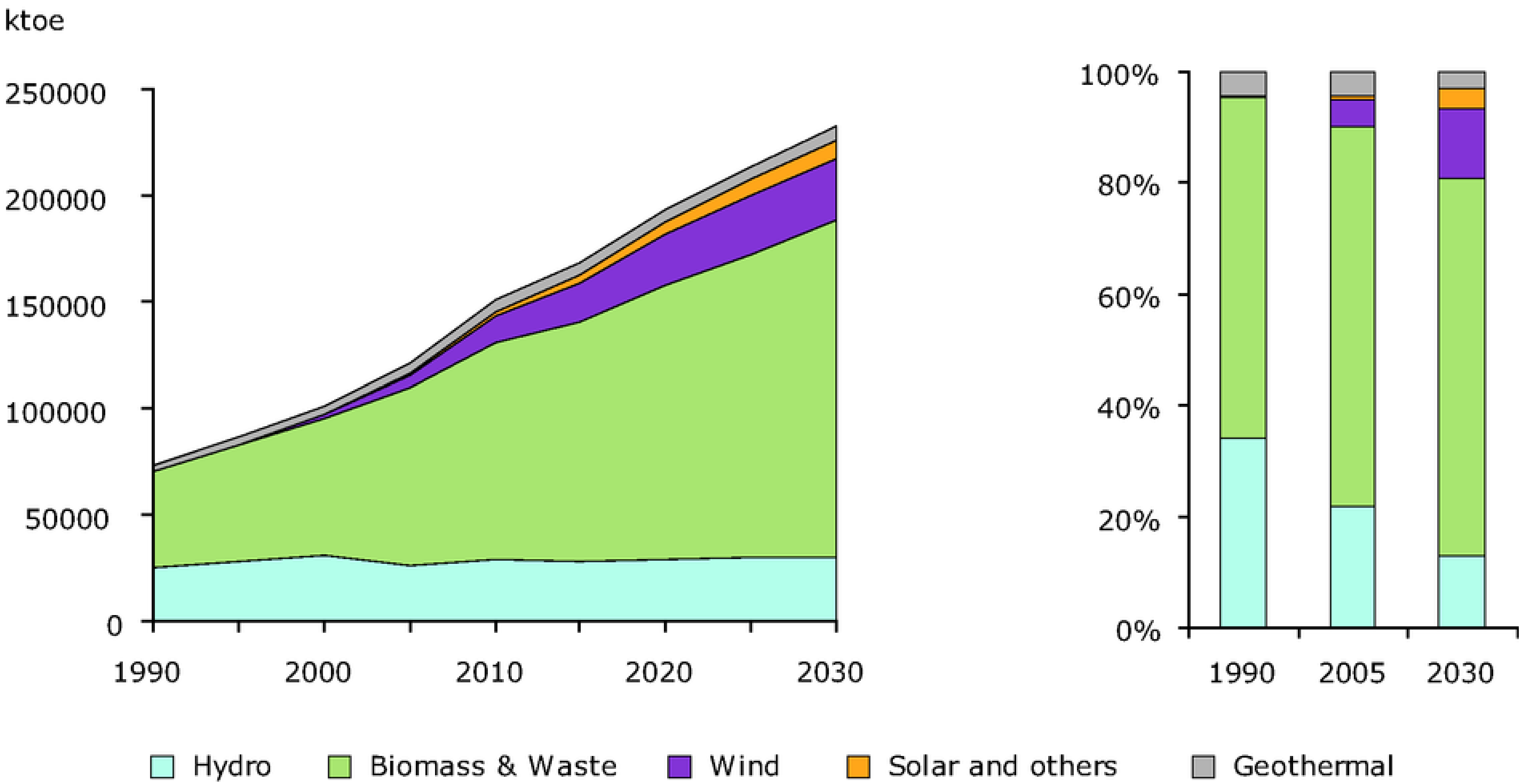
Renewable energy



<www.economist.com/blogs/graphicdetail/2017/03/daily-chart-2>

RE deployment 2020, 2030

EU



<www.eea.europa.eu/data-and-maps/indicators/renewable-energy-consumption-outlook-from-eea/renewable-energy-consumption-outlook-from-1>

Unscheduled power flows

- Peaks in wind electricity supplies, have caused serious and costly problems in Central Europe, for example between the Czech Republic and Germany. (Korab and Owczarek, 2016)


<www.ceps.cz/ENG/Media/Tiskove-zpravy/Pages/Regula%C4%8Dn%C3%AD-transform%C3%A1tory-dorazily-na-sv%C3%A9-m%C3%ADsto.aspx>

Korab R., Owczarek R., 2016. Impact of phase shifting transformers on cross-border power flows in the Central and Eastern Europe region. Bulletin of the Polish Academy of Sciences Technical Sciences, 64(1), 127-133.

Transportation

- Statistics
- Examples and issues

Transportation Sector

- Utilisation of biofuels and the development of electric cars.
- Recently, countries such as the UK, France, Netherland and China have **considered banning the production of petrol and diesel cars.**
- A range of battery issues needs to be solved for meeting the targets.
- Would the electric car will completely displace the roles of petrol and diesel?
- eCars energy recuperation

<www.sciencealert.com/the-netherlands-is-planning-to-end-all-its-coal-power-by-2030>

FT (Financial Times), 2017. China eyes eventual ban of petrol and diesel cars. <www.ft.com/content/d3bcc6f2-95f0-11e7-a652-cde3f882dd7b.

Vehicle technologies

Vehicle	Initial cost (kUSD)	Power plant to wheel efficiency	Commercial availability	Main challenges
Electric	21.3	High (>50%)	Now	Chemical sustainability, battery costs
Hybrid electric	24.2	Moderate (≤50%)	Now	Chemical sustainability, battery costs
Hydrogen internal combustion engine	18	Low (<25%)	In 2–3 y	Lack of infrastructure
Fuel-Cell	40	Low (<25%)	In 2–3 y	Lack of infras. high costs
Biofuels	17.1	Low (<25%)	Now	CO_2 fixation, responsible farming

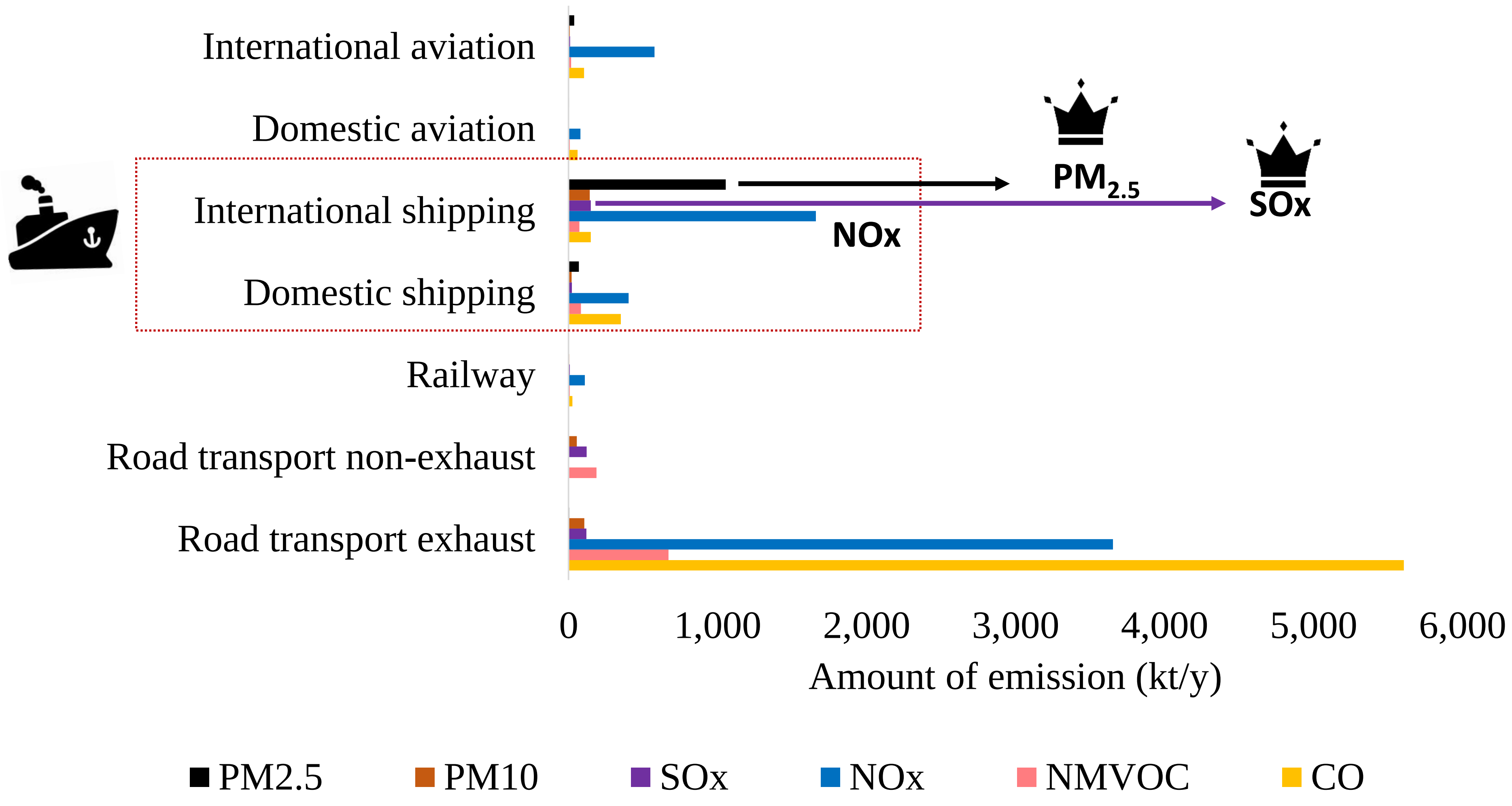
Toyota- Hydrogen-Fuel Trucks. The only emission is water vapour
<www.sciencealert.com/toyota-s-trucks-that-only-emit-water-vapour-are-moving-goods-in-la>

Calvillo C. F., Sánchez-Miralles A., Villar, J., 2016, Energy management and planning in smart cities. Renewable and Sustainable Energy Reviews, 55, 273-287.

Sea Transportation

Lower CO_2 emission?
Greener freight transportation mode?

Transportation: Ship



Dataset from EEA (European Environment Agency), 2016. Emissions of air pollutants from transport. <www.eea.europa.eu/data-and-maps/indicators/transport-emissions-of-air-pollutants-8/transport-emissions-of-air-pollutants-4 >

Emission Factor-Example*

- **CO_2/t-km:** Truck= **348** g/tkm Ship= **4**g/tkm

	Emission factor (g/ tkm)	
Pollutants	Road Transport (Truck)	Sea Transport (Ship)
SO_x	**0.00175**	**0.091**
NO_x,	0.127	0.033
$PM_{2.5}$	**0.00136**	**0.00187**
CO	0.272	0.0402

- VOCs, lead, PM_{10}, PM>10 etc

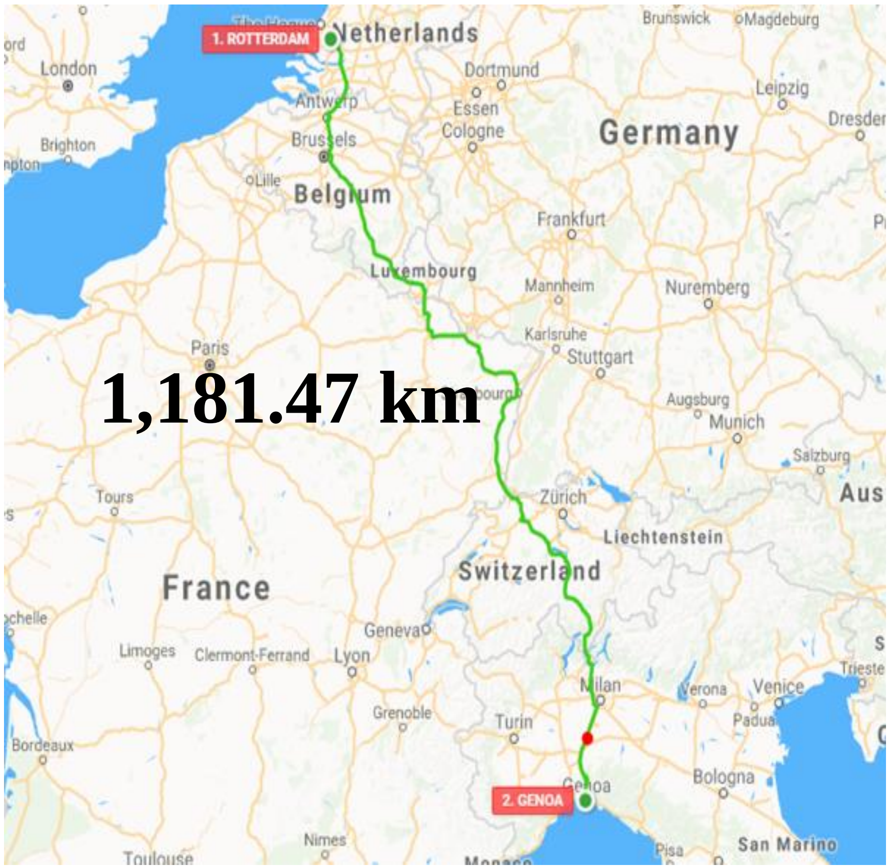
Ecoinvent Database

<www.nature.com/>

</twitter.com/KNectMaritime>

Distance

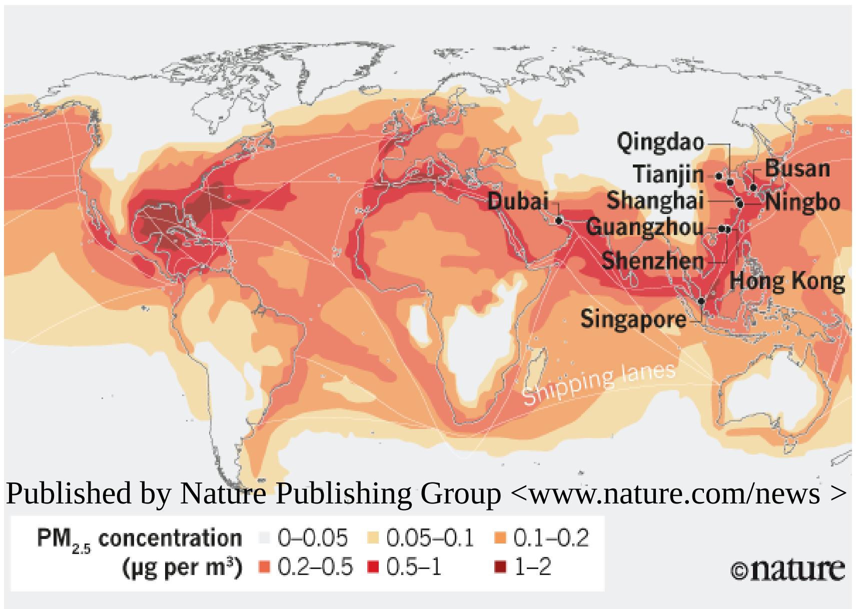
Example: Rotterdam to Genoa

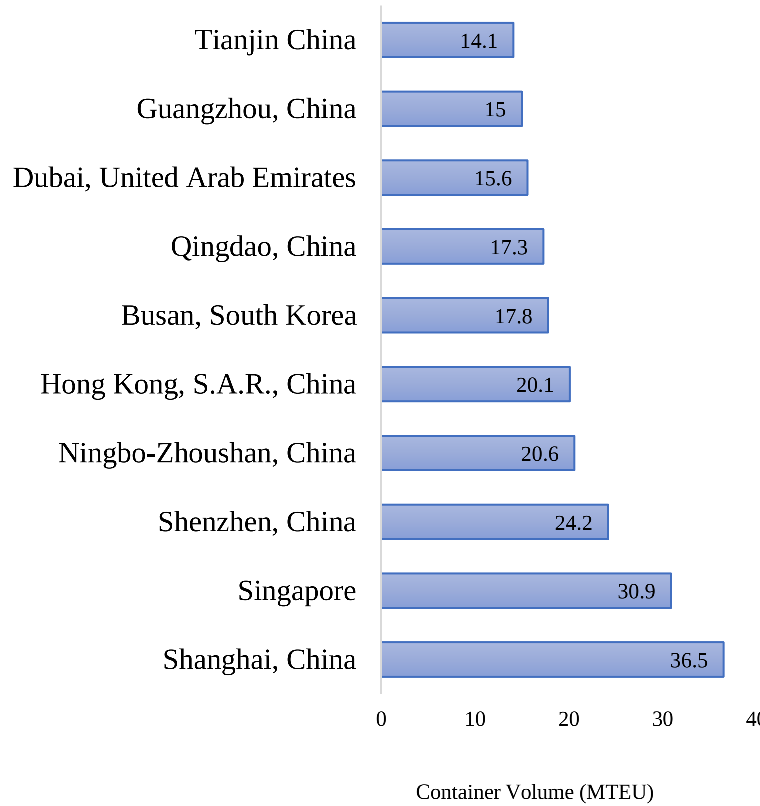


Presented by <www.searates.com/reference/portdistance/>, Google maps

Concentration at Place

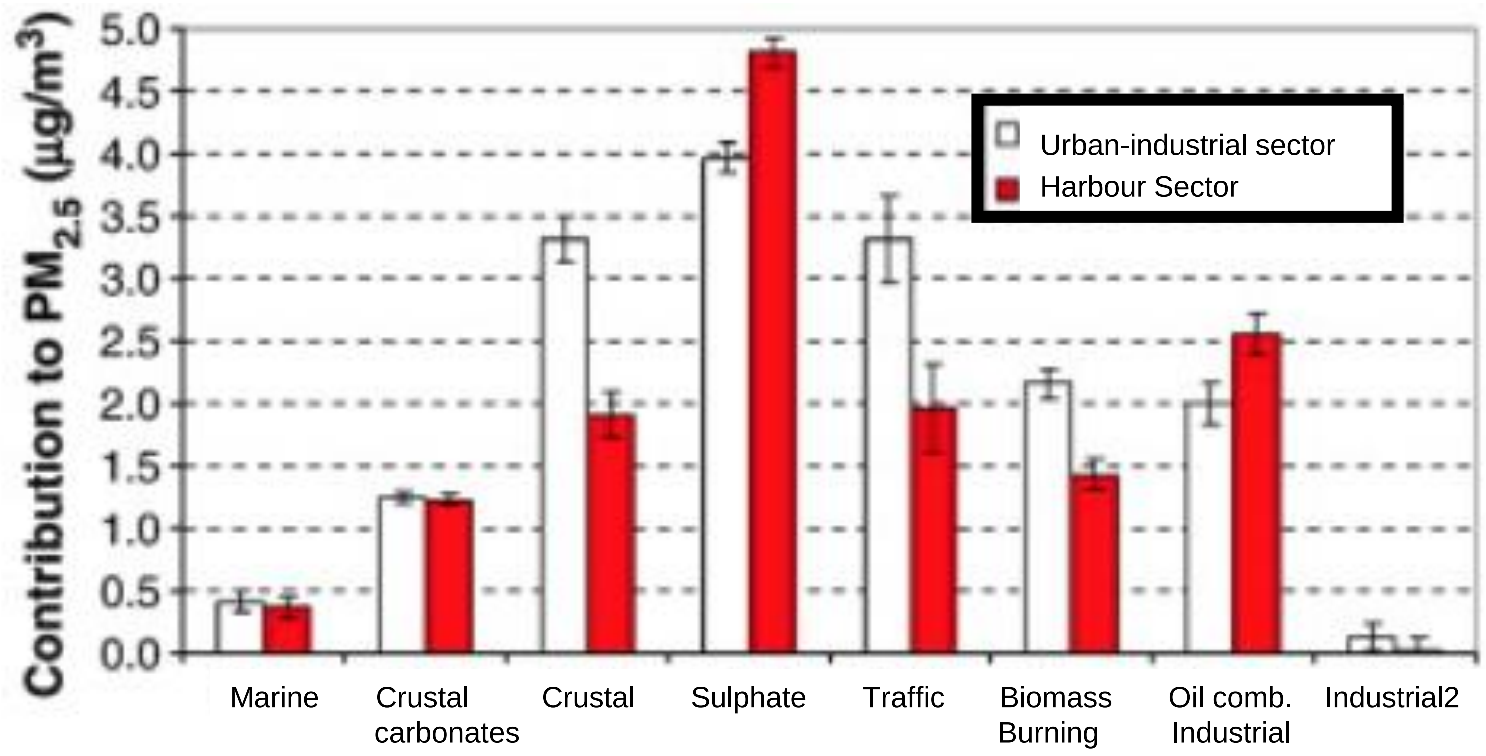
Dirty Ten





Asia Weekly, 2016. Shipping's dirty secrets by Marc Lajole. <www.projects. asiaweekly.com/shippings-dirty-secrets/> Wan, Z., Zhu, M., Chen, S., Sperling, D., 2016. Pollution: three steps to a green shipping industry, Nature. <www.nature.com/news/pollution-three-steps-to-a-green-shipping-industry-1.19369>

PM emission- Example



Brindisi (**Italy**)- **Port city** of the Adriatic sea

Cesari D., Genga A., Ielpo P., Siciliano M., Mascolo G., Grasso F. M., Contini D., 2014, Source apportionment of PM 2.5 in the harbour–industrial area of Brindisi (Italy): Identification and estimation of the contribution of in-port ship emissions. *Science of the Total Environment*, *497*, 392-400.

Remarks

3. The emissions factors of CO_2 is much lower, but it might not for the other harmful pollutants (e.g. SO_x). A longer distance may be needed by ship but it has a larger capacity

4. The high concentration at one place (big port cities) could significantly affect the local air quality and human health.

5. The impact of other activities such as ship scrapping, container loading, unloading, distribution also contribute to the pollution. The ship engines are not always turn off at the berth.

Freight

- Method and measurement of emission ✓
- Assessment **approach/ framework/ methodology** for decision making needs more development. (Environmental issues vs time vs cost vs flexibility/frequency vs reliability/safety)

Waste Management

- Waste to Energy
- Issues

WtE technologies

WtE technologies	Form of energy produced
Thermochemical	
1. Incineration (Mass burn >1,000^{o}C, Co-combustion with coal, biomass, Refuse-derived fuel)	Heat, power, Combined heat and power (CHP)
1. Thermal gasification (Conventional 750^{o}C, Plasma arc 4,000-7,000 ^{o}C)	Hydrogen, methane, syngas
1. Pyrolysis (300-800^{o}C, absence of O_2)	Char, gases, aerosols, syngas
Biochemical	
1. Fermentation	Ethanol, hydrogen, biodiesel
1. Anaerobic digestion	Methane
1. Sanitary landfill	Methane
1. Microbial Fuel cell	Power
Chemical	
1. Esterification	Ethanol, biodiesel

Fan Y.V., Varbanov P.S., Nemet A., Klemeš J.J., 2017, Process Efficiency Optimisation and Integration for Cleaner Production. Journal of Cleaner Production. Submitted Manuscript. Special Issues PRES 16

WtE technologies

- The global WtE market was valued at USD 25.32 x 10^9 in 2013, a growth of 5.5% over the previous year. WtE plant can save 100-350 kg CO_2eq/t of waste processed
- Thermal energy conversion leads the WtE market, 88.2% of total market revenue in 2013
- The EU is the largest market (47.6%), fastest market growth is in China. Important discovery and leap forward for a sustainable future.
- Inconsistent supply, burdening effect of waste collection and pre-treatment for different waste characteristics are the key barriers to the current implementation.

WEC (World Energy Council), 2016. World energy resources: waste to energy. <www.worldenergy.org/wp-content/uploads/2017/03/WEResources_Waste_to_Energy_ 2016 .pdf>.

Current Waste Treatment Practice is Sustainable?!

Good business (source=waste), but in ENVIRONMENT PERSPECTIVE?

- **Incineration:** Emission worries**,** Importing garbage/ waste from the other city/country (E.g. Sweden)
- **MBT plant:** Discourage waste separation at source, centralised (transport issues)
- **AD plant:** Planting of energy crop
- **Composting:** Open process (emission, leachate) without energy recover, heavy metal issues, compost application

Propose of New Footprint

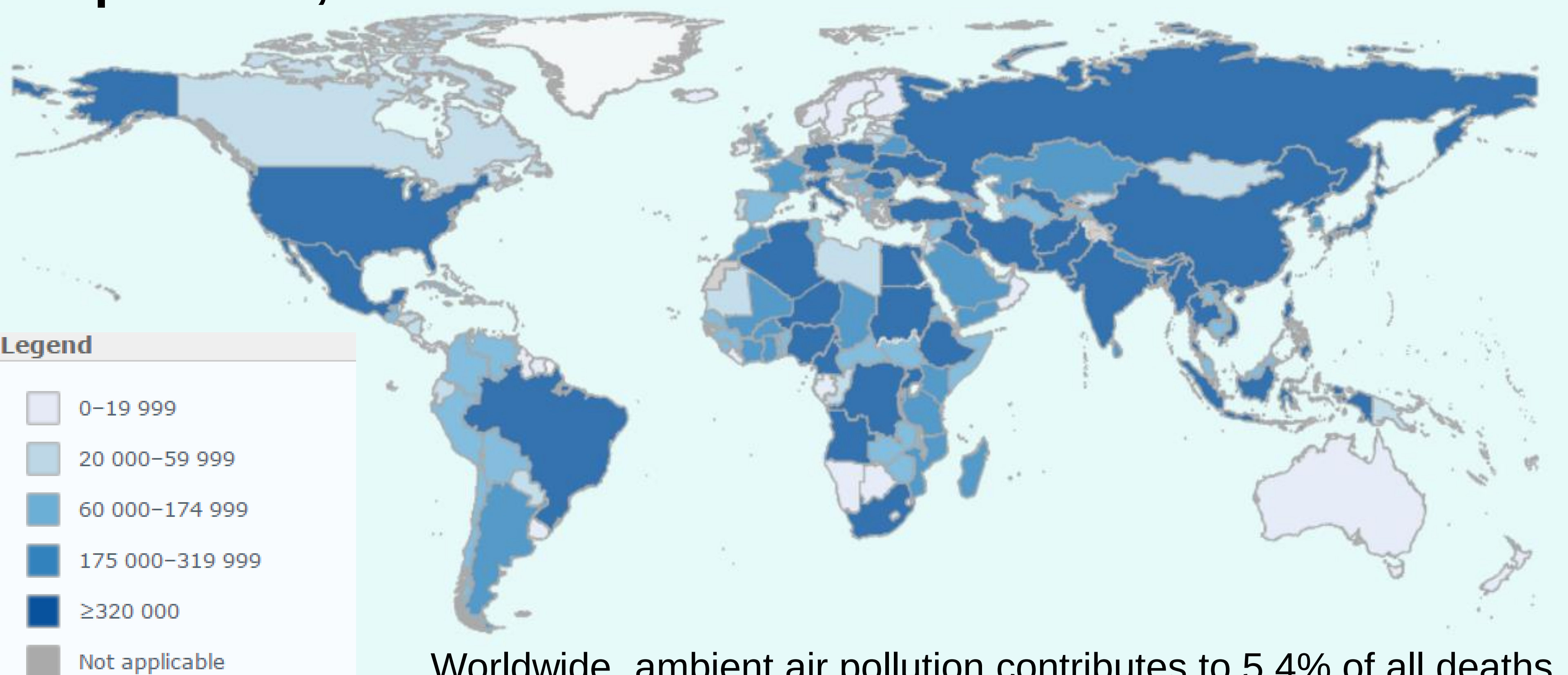
SMOG/HAZE FOOTPRINT

WHY?

- Over the past few years, the concern of anthropogenic emission has been focused on the **greenhouse gases** than the air pollutants **SO_x, NO_x, VOC, Particulate Matter (PM)** that causing air pollution and poses an **instantaneous impact to human health**.
- GHG and the air pollutants share some of the components, but the evaluation perspective is different.
- Major source: Transportation, burning etc.

Mortality and burden of disease from ambient air pollution

Ambient air pollution DALYS attributable to air pollution, 2012



Worldwide, ambient air pollution contributes to 5.4% of all deaths

Adopted from <www.who.int/gho/phe/outdoor_air_pollution/burden/en/>Date of publication 2016.

Environmental Sustainability far wider than carbon emissions and climate change. A multi-dimensional approach is needed in optimisation study and planning

Image by <www.perceiveproject.eu/2017/08/29/european-cities-are-smart/>

Concluding Remarks

- Let's recognise carbon as an resources and the life-giving carbon cycle as a model for human designs.

- The management for an environmentally sustainable system is not all about minimisation. Prevention (e.g. waste)

- Environmental sustainability solution is not just about CO_2/GHG reduction.

- Change is the only permanent, toward the efficient resources allocation or utilisation to adapt the activities changes of population and economic development is important for a sustainable future.

Overall Remarks

Air emission impact in optimisation study- consider both GHG and the air pollutants in an overall system

- Especially: Transportation mode, Biomass energy etc.
- Methodology with defined criteria, boundary, interaction/ relationship between GHG and air pollutant is needed
- To minimise the potential of footprint shifting and support more appropriate decision-making.

PRES2018

20th Conference on Process Integration, Modelling and Optimisation for Energy Saving and Pollution Reduction

In conjunction with

CHISA 2018- 23rd International Congress of Chemical and Process Engineering

25 – 29 August 2018 @Prague, Czech Republic

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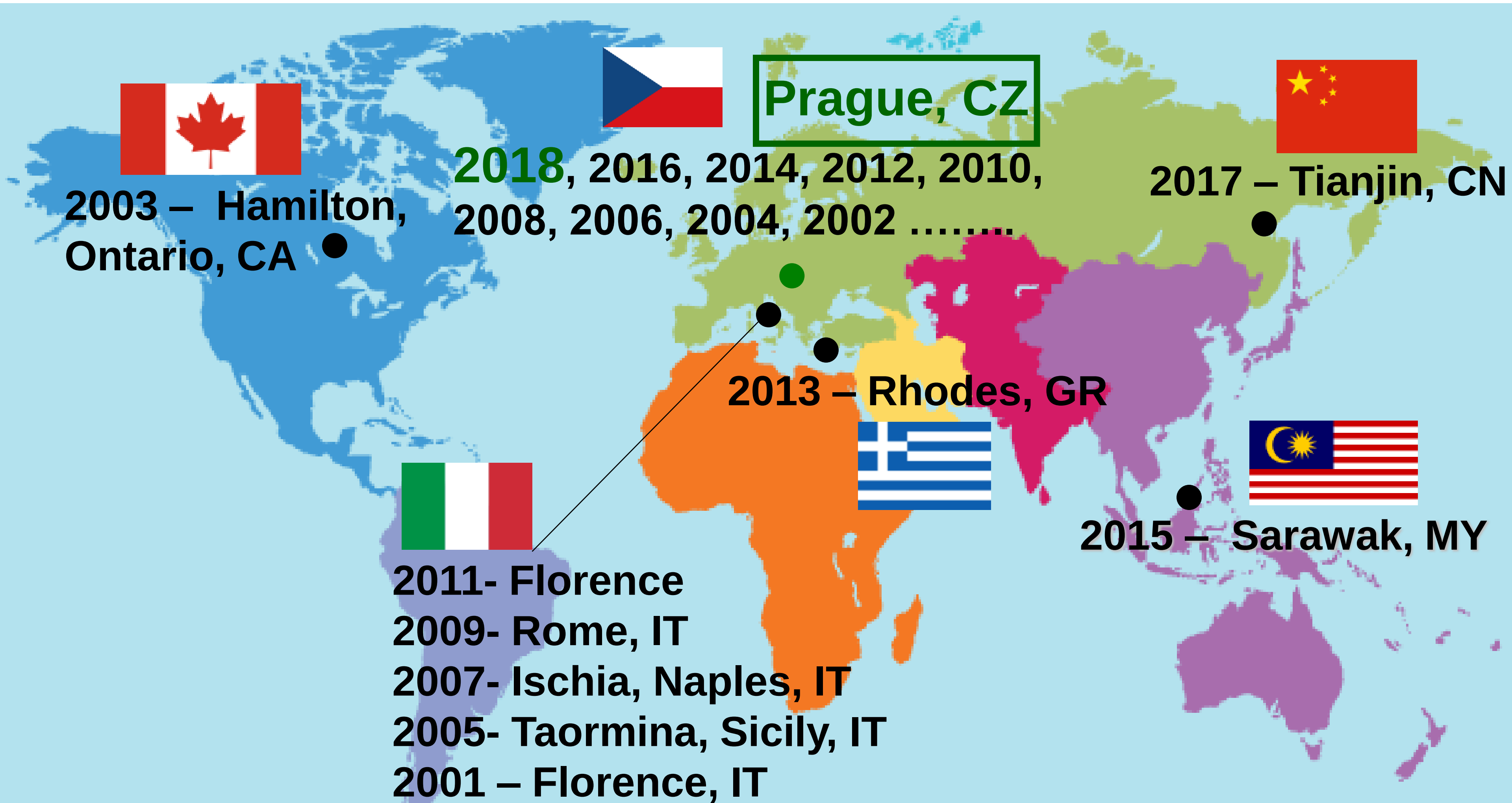
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Ontario, CA
2017 – Tianjin, CN
2013 – Rhodes, GR
2015 – Sarawak, MY
2011- Florence
2009- Rome, IT
2007- Ischia, Naples, IT
2005- Taormina, Sicily, IT
2001 – Florence, IT

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Scenery

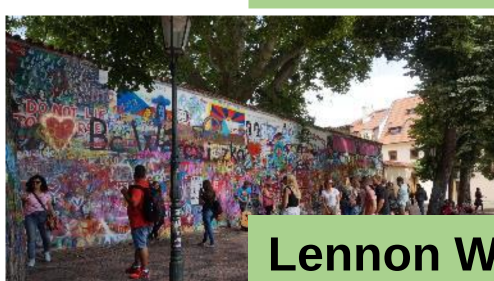
Charles Bridge

Red roofs of Prague

Astronomical clock

Historical Buildings

Old town square



Lennon Wall

Prague Castle

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Footprints

- ❑ Footprint is a quantitative measure showing the appropriation of natural resources by human beings (Hoekstra, 2008).

Footprints:

- Carbon footprint (CFP)
- Energy footprint (EFP)
- Water footprint (WFP)
- Ecological footprint (ECOFP)
- Nitrogen footprint (NFP)
- Land footprint (LFP)
- Social footprint (SFP) etc.

Hoekstra A. Y., 2008, Water neutral: Reducing and offsetting the impacts of water footprints, Value of Water Research Report Series No. 28, UNESCO-IHE, Delft, the Netherlands

Carbon footprint - definitions

- CFP usually stands for **the amount of CO_2 and other greenhouse gases, emitted over the full life cycle of a process or product**

- The CFP is quantified using indicators as the Global Warming Potential, which stands for **the quantities of greenhouse gases** that contribute to global warming and climate change, by considering a specific time horizon, usually 100 y.

- **The land-based definition of CFP** stands for the land area required for the sequestration of atmospheric fossils' CO_2 emissions through aforestation (De Benedetto and Klemeš, 2009).

De Benedetto L., Klemeš J., 2009, The environmental performance strategy map: an integrated LCA approach to support the decision making process, Journal of Cleaner Production, 17, 900-906

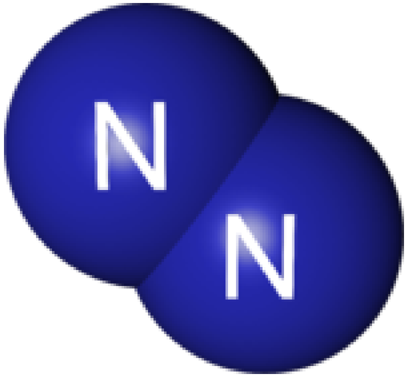
- Wiedmann and Minx (2008) proposed that CFP is a measure of **exclusive direct and indirect CO_2 emissions over a life cycle.**

Wiedmann T., Minx J., 2008, A definition of 'carbon footprint'. In: C. C. Pertsova, Ecological Economics Research Trends: Ch 1, 1-11, Nova Science Publisher, Hauppauge, NY, USA

Most recognised concept

Nitrogen footprint

- Increases as a result of artificial nitrogen fertilization, manure run-off, burning of biomass and fuels, and planting of legumes
- Nitrogen fertilization leads to the contamination of drinking water, algal blooms, eutrophication, etc.
- NO_x emissions can lead to smog, acid-rain, haze and climate change.
- The deposition of N, P and other contaminants is expected to have an impact on the biodiversity.
- N pollution damages ecosystems and affects human health, including respiratory diseases and the risk of birth defects (N-Print).



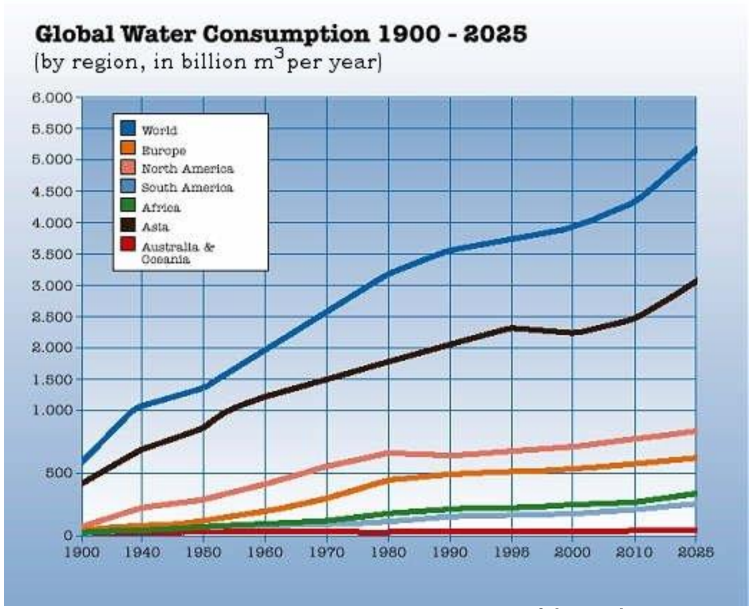
Water Footprint - Definition

WFP stands for the total volume of direct and indirect freshwater used, consumed and/or polluted.

WFP consists of:

- Blue (consumption of surface and groundwater),
- Green (consumption of rainwater)
- **Grey water footprint** - polluted water sometimes expressed as the volume of water required to dilute pollutants to water quality standards.

Mekonnen M. M., Hoekstra A. Y., 2010, The green, blue and grey water footprint of farm animals and animal products, Value of Water Research Report Series No. 48, UNESCO-IHE, Delft, the Netherlands



Source: Umweltbundesamt

WF of primary energy carriers

Primary energy carriers	Global average WF (m^3/GJ)
Natural gas	0.11
Coal	0.16
Crude oil	1.06
Uranium	0.09
Wind energy	Negligible
Solar thermal energy	0.30
Hydropower	22.30
Biomass energy	70 (range: 10-250)

(Gerbens-Leenes et al., 2008; <www.waterfootprint.org>)