LCA OF ELECTRICITY GENERATION TECHNOLOGIES

UNECE modelling activities – Carbon neutrality project

01.07.2021

UNECE

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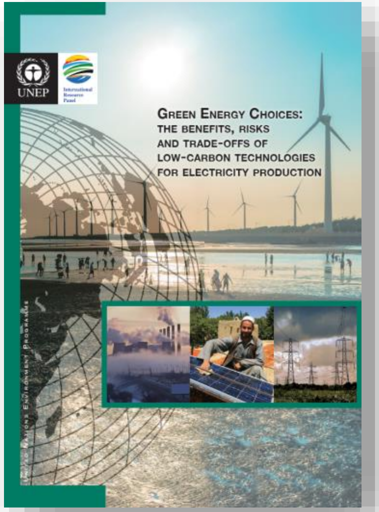
CONTEXT OF LIFE CYCLE ASSESSMENT TASK



Starting point: UNEP IRP report “Green Energy Choices”

Life cycle assessment (LCA) of electricity production technologies

Coal, natural gas, with and without CCS
Hydropower
Wind power
Concentrating solar power
Photovoltaic power
Geothermal power

Impact assessment over 2010-2050 period

Two IEA scenarios (Baseline, Blue Map) and 9 world regions

UN environment programme

International Resource Panel

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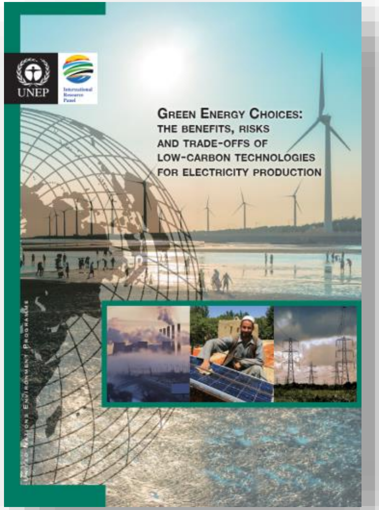
https://www.resourcepanel.org/reports/green-energy-choices-benefits-risks-and-trade-offs-low-carbon-technologies-electricity

CONTEXT OF LCA TASK

Starting point: UNEP IRP report “Green Energy Choices”



https://www.resourcepanel.org/reports/green-energy-choices-benefits-risks-and-trade-offs-low-carbon-technologies-electricity

Limitations

Absence of state-of-the-art nuclear power and biomass

==> need for expertise on these technologies

Optimistic efficiencies?

Limited consideration of methane leakage in fossil fuel extraction

No direct emissions in hydropower

No consistent end-of-life treatment consideration across technologies

Energy scenarios outdated: use REMIND? MESSAGE? …?

Update welcome!

Most data is 10 years

Add newer technologies (namely small modular reactors)

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TECHNOLOGIES

Full list

Photovoltaics

Polycrystalline silicon, ground-/roof-mounted
CIGS, ground-/roof-mounted
CdTe, ground-/roof-mounted

CSP

Trough
Tower

Coal

Existing PC, with and without CCS
Integrated gasification CC, with and without CCS
Coal SCPC, with and without CCS

Gas

NGCC, with and without CCS

Hydropower

660 and 360 MW designs

Wind

Onshore
Offshore, concrete and steel foundation

Nuclear power

Boiling water reactor
Pressure water reactor (average global reactor)

REGIONS

Why regionalizing?

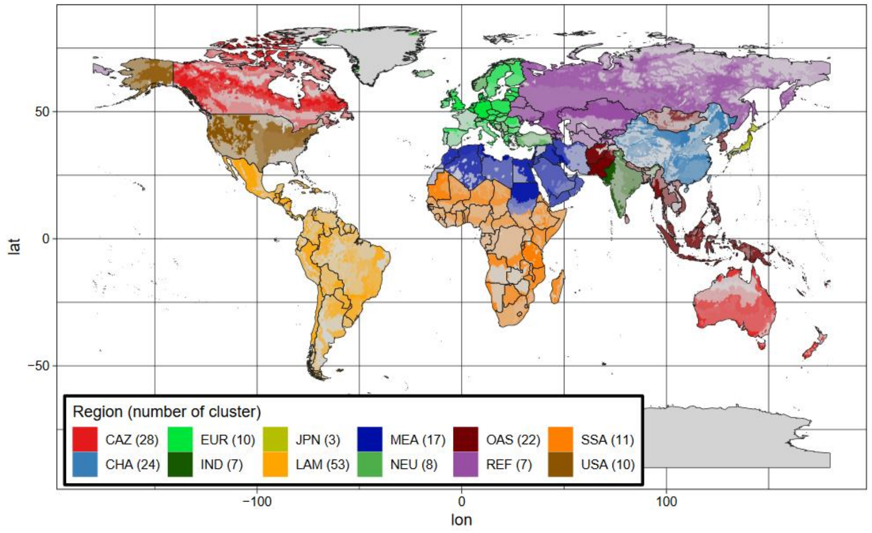
Data representativeness

Electricity mixes can be systematically adapted to region, year, and a given scenario (with REMIND “Base SSP2” as baseline), as well as a few other processes (cement…)

Adapting load factors to regional climate conditions

Solar irradiation

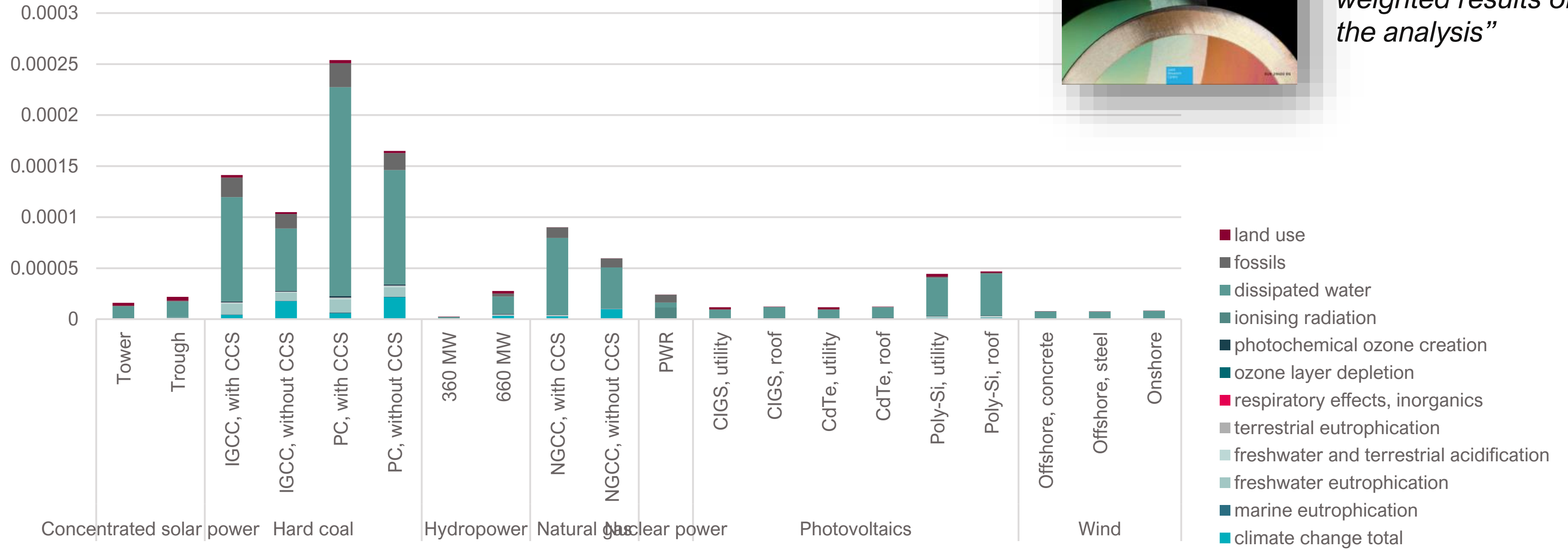
Wind regimes

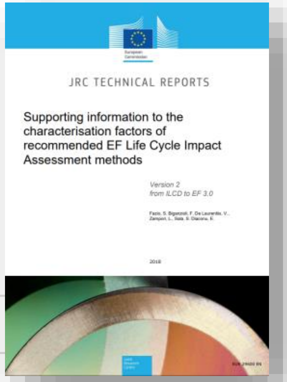


REMIND regions	Code
Canada, Australia & New Zealand	CAZ
China	CHA
European Union	EUR
India	IND
Japan	JPN
Latin America	LAM
Middle East and NorthAfrica	MEA
Non-EU member states	NEU
Other Asia	OAS
Reforming countries	REF
Sub Saharan Africa	SSA
United States	USA

CHOOSING INDICATORS

Results normalized & weighted, Europe EU region





"impact assessment categories should be selected depending on their contribution to the normalised and weighted results of the analysis"

CHOOSING INDICATORS

List of retained indicators, following EC recommendations

Category	Unit	Reference	Description
Climate change	kg CO_2 eq.	IPCC (2013)	Radiative forcing as Global Warming Potential (GWP100).
Freshwater eutrophication	kg P eq.	Struijs et al. (2009)	Expression of the degree to which the emitted nutrients reach the freshwater end compartment.
Ionising radiation (HH)	kBq ^{235}U eq	Frischknecht et al (2000)	Human exposure efficiency relative to U235.
Land use	points	LANCA model (Bos et al. 2016)	The LANCA model provides five indicators for assessing the impacts due to the use of soil: 1. erosion resistance, 2. mechanical filtration, 3. physicochemical filtration, 4. groundwater regeneration and 5. biotic production
Water resource depletion	m^3	Model for water consumption as in Swiss Ecoscarcity (Frischknecht et al, 2008)	Water use related to local scarcity of water
Mineral, fossil and renewable resource depletion	kg Sb eq.	Van Oers et al. (2002)	Scarcity of resource in relation to that of antimony. Scarcity is calculated as « reserve base ».

+ cumulative energy demand
+ endpoint score
as information

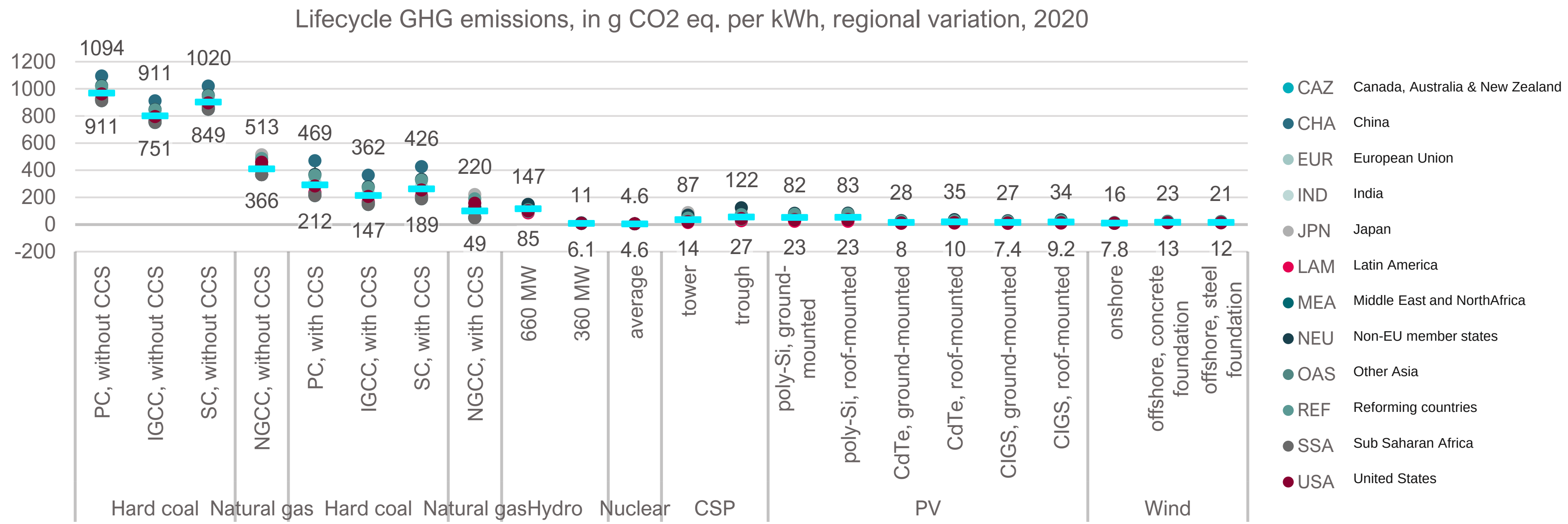
TECHNOLOGY PARAMETERS

Results

CLIMATE CHANGE

Variations are due to region-specific electricity mixes, fossil fuel chain, and climate conditions

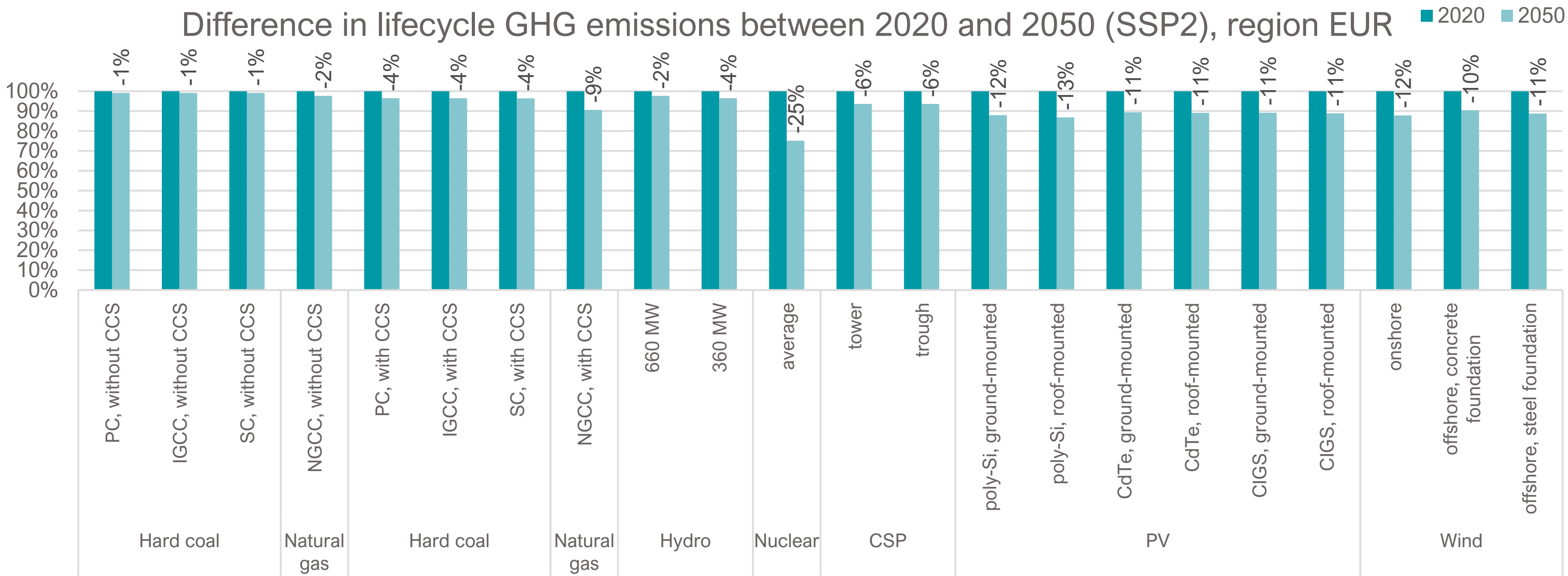
Life cycle emissions for each region, g CO_2 eq./kWh



Variations are due to the decarbonisation of the electricity background.
In Europe

CLIMATE CHANGE

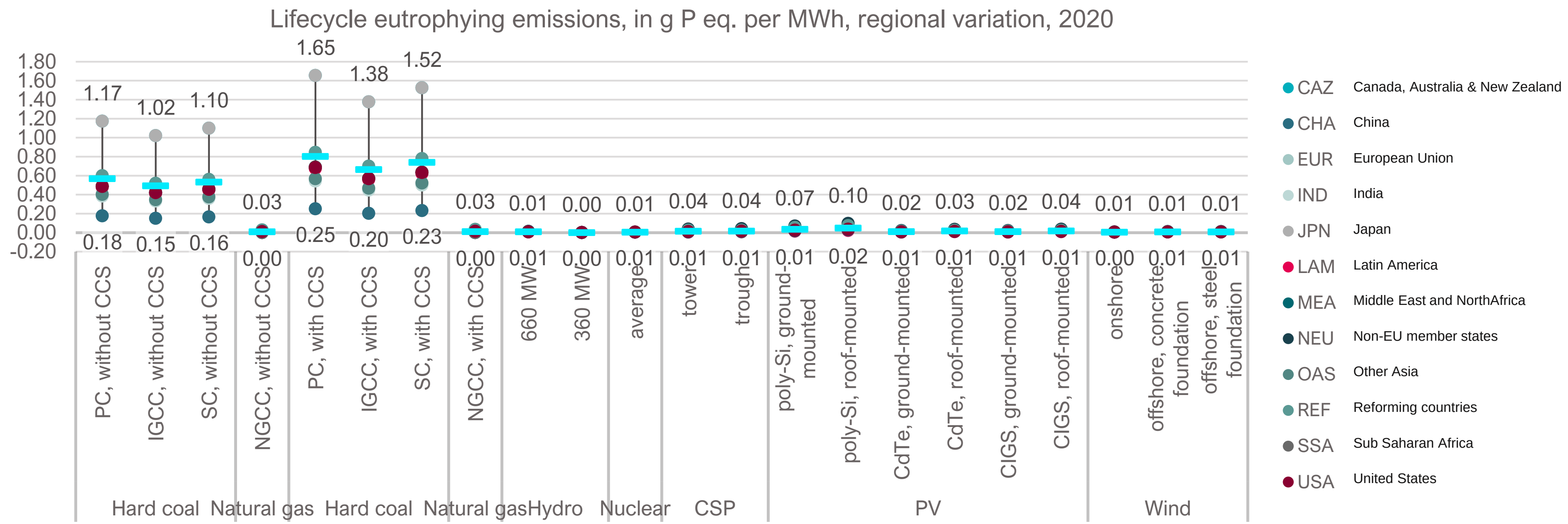
And in 2050?



FRESHWATER EUTROPHICATION

Variations are due to region-specific electricity mixes, fossil fuel chain, and climate conditions

Life cycle emissions for each region, g phosphorus/MWh

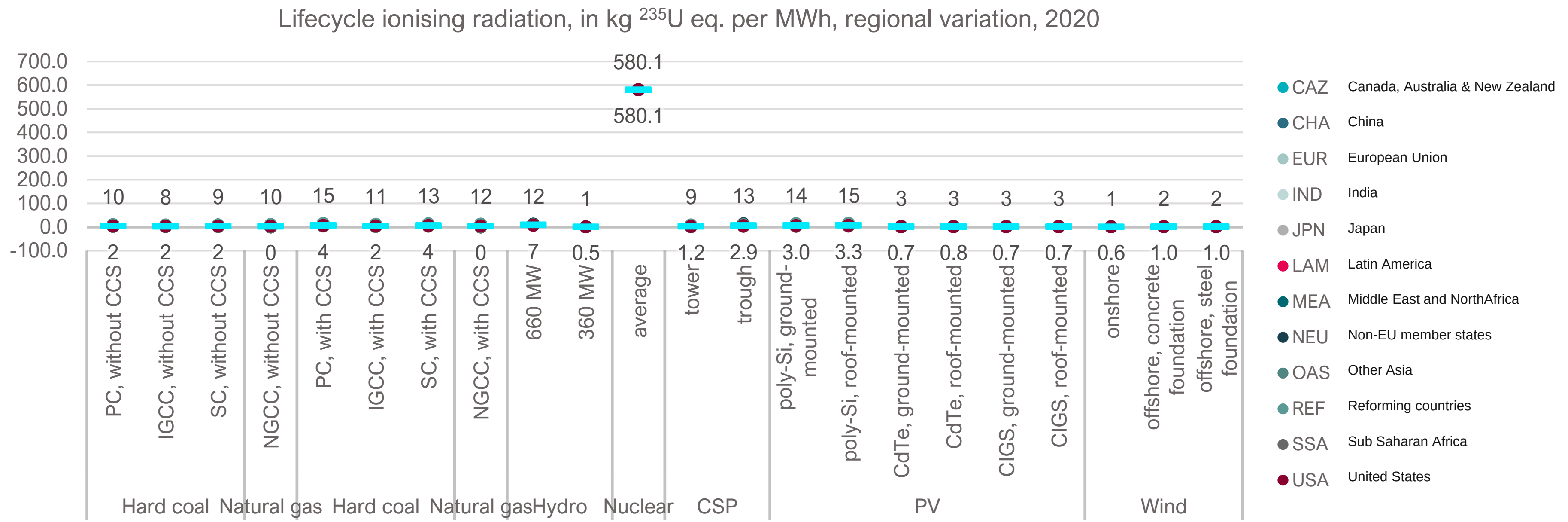


Mostly phosphate emissions from mining

Variations are due to region-specific electricity mixes, fossil fuel chain, and climate conditions

IONISING RADIATION

Life cycle emissions for each region, kg ^{235}U eq./MWh



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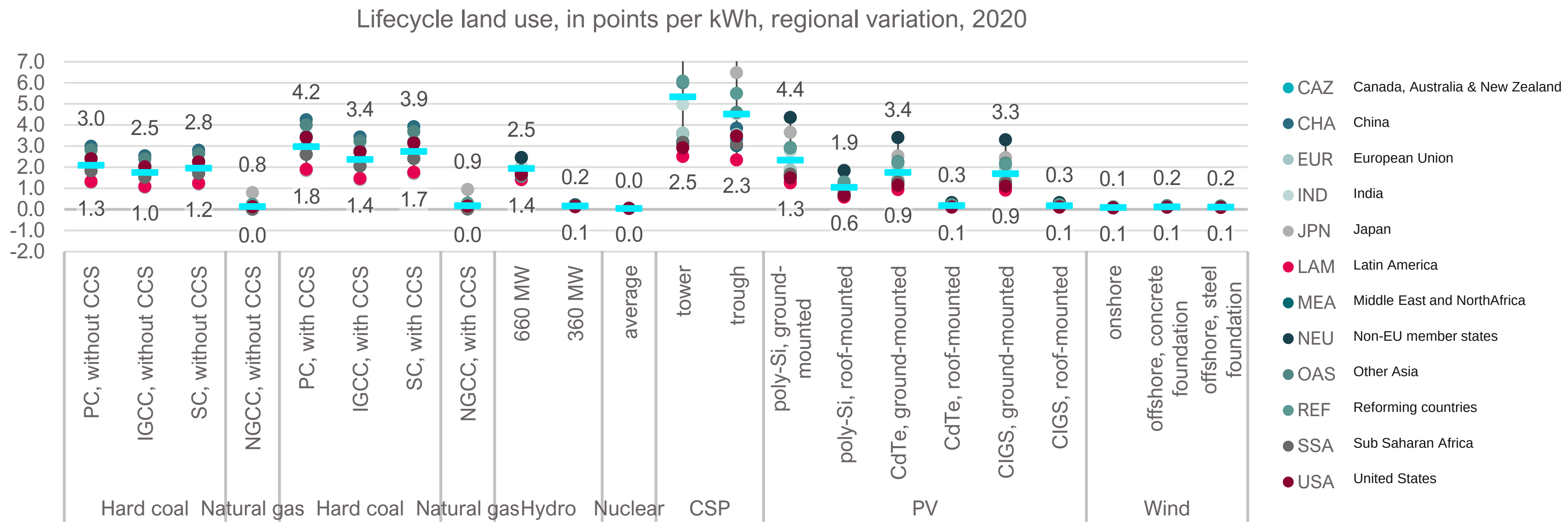
LAND USE

Lifecycle land occupation, in points*

*The LANCA model provides five indicators for assessing the impacts due to the use of soil:
1. **erosion resistance**,
2. **mechanical filtration**,
3. **physicochemical filtration**,
4. **groundwater regeneration** and
5. **biotic production**

– all aggregated as points.



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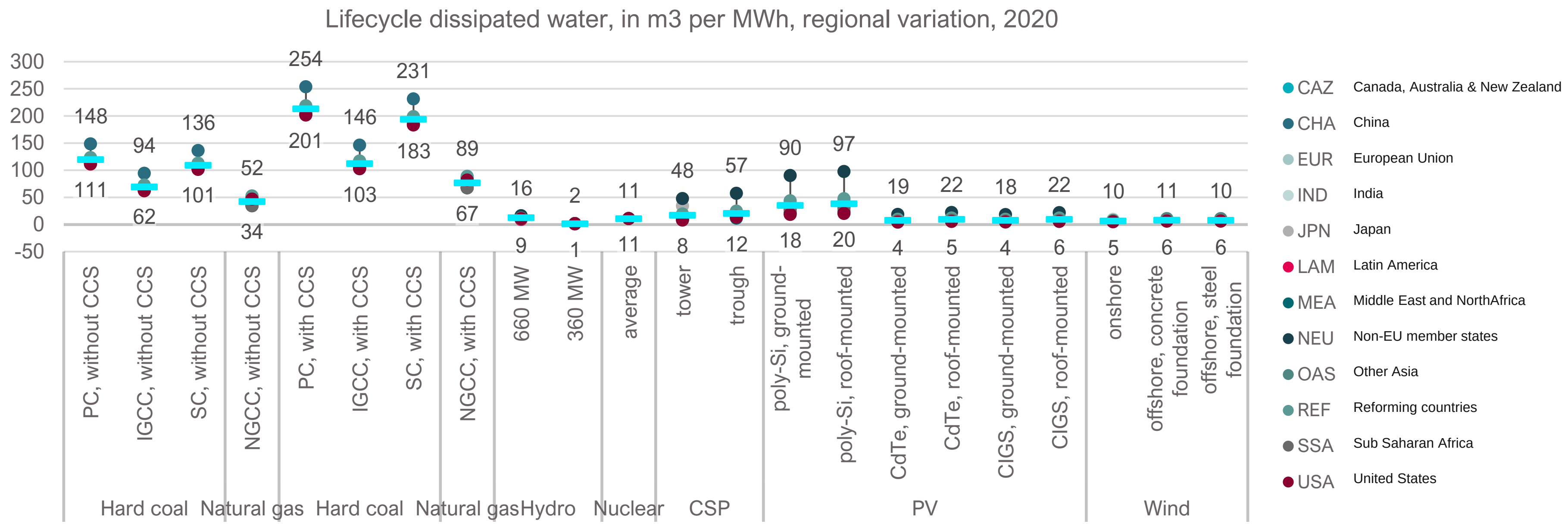
Variations are due to region-specific electricity mixes, fossil fuel chain, and climate conditions

DISSIPATED WATER

Lifecycle water requirements, in m³/MWh (l/kWh)



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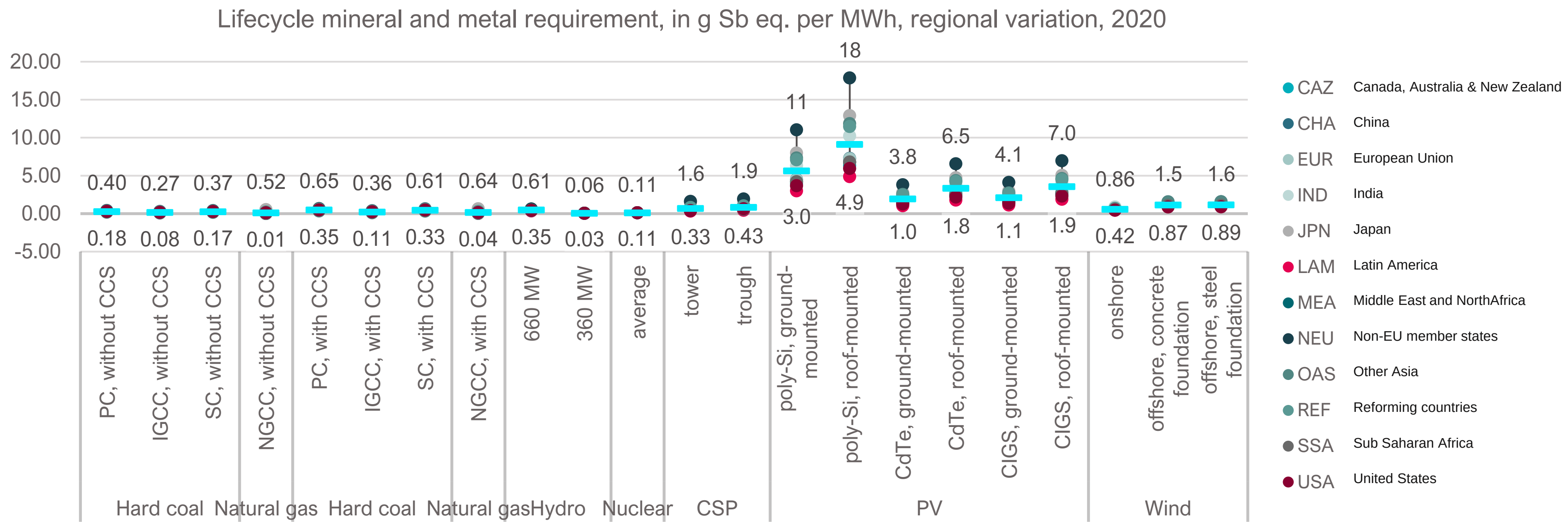
RESOURCES, MATERIAL

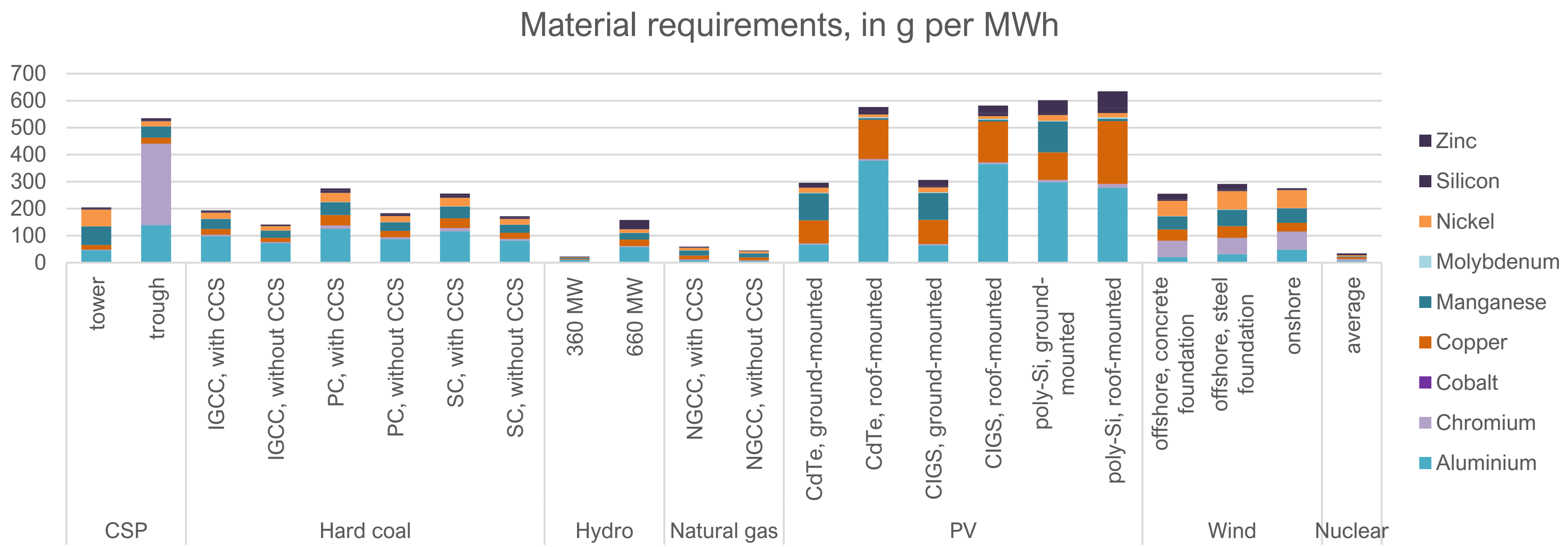
Variations are due to region-specific electricity mixes, fossil fuel chain, and climate conditions

Lifecycle resource requirements, scarcity-weighted, in g Sb eq./kWh



RESOURCES, MATERIAL

Lifecycle material requirements, extracted from ground, in g/MWh



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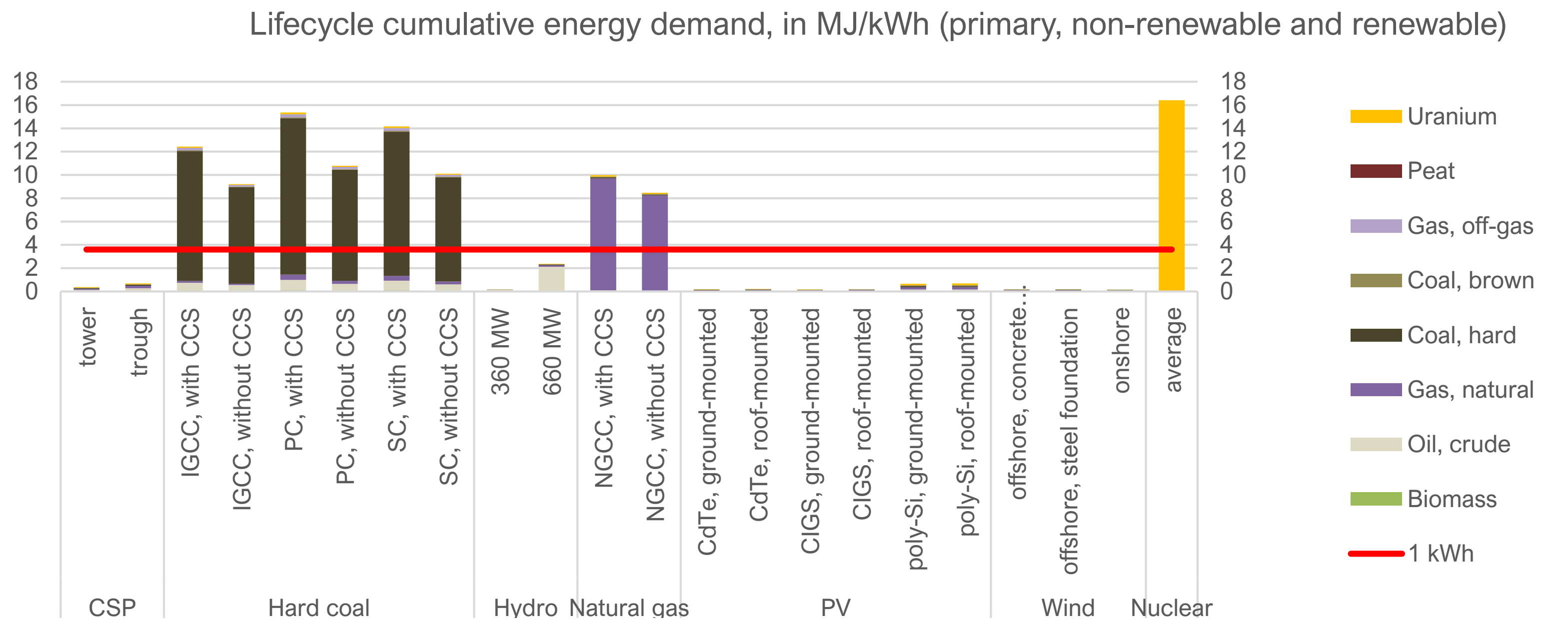
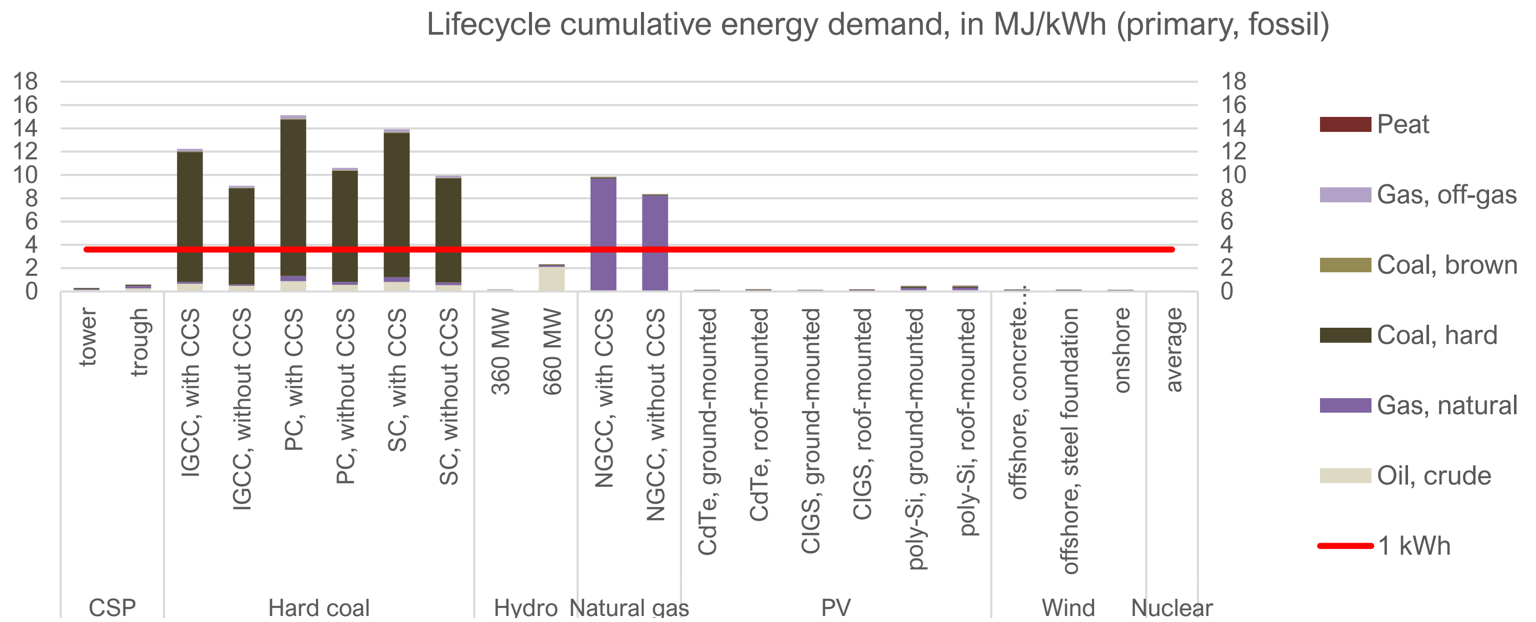
RESOURCES, PRIMARY ENERGY

Primary energy demand over lifecycle, in MJ of energy carrier from ground



RESOURCES, PRIMARY ENERGY

Primary energy demand over lifecycle, in MJ of fossil energy from ground



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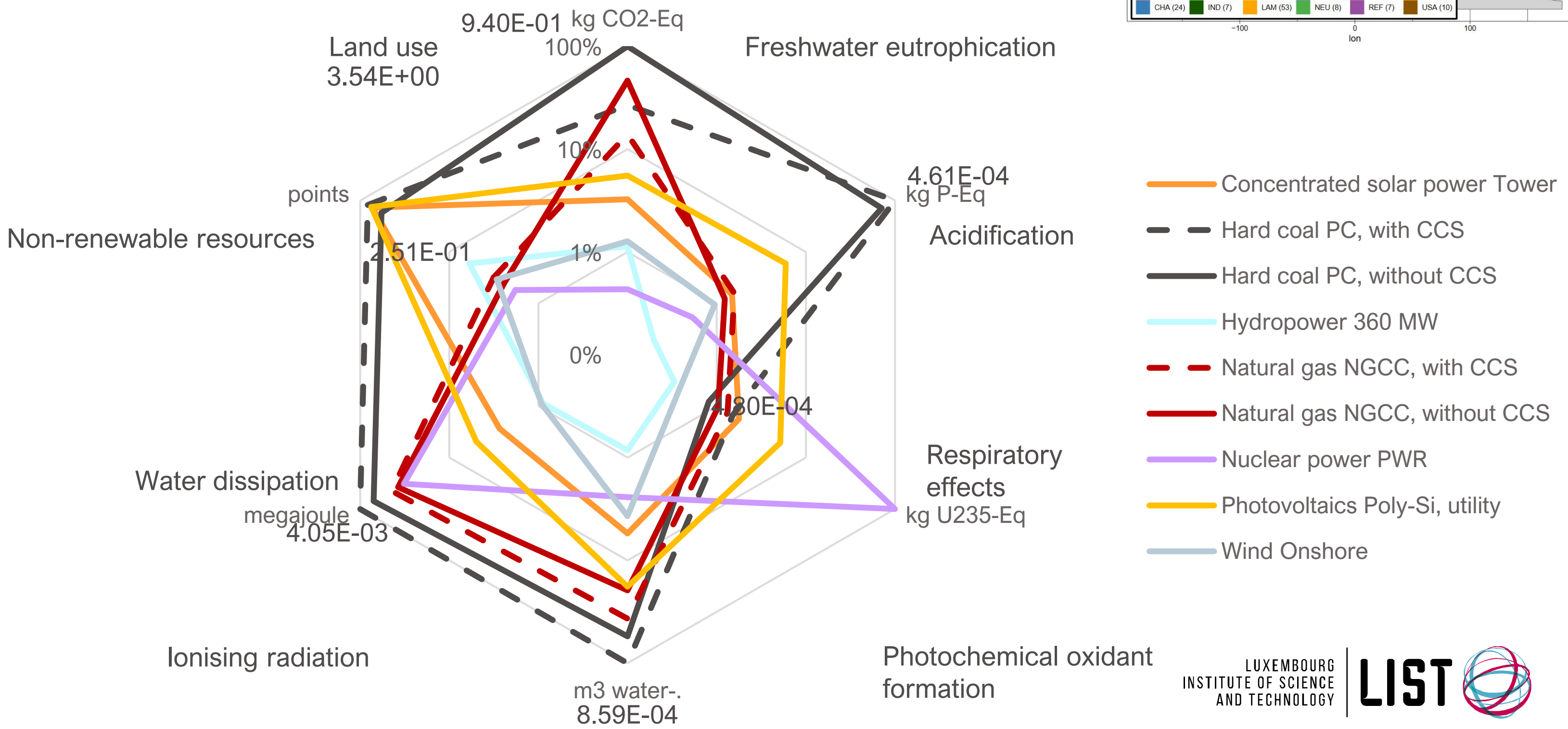
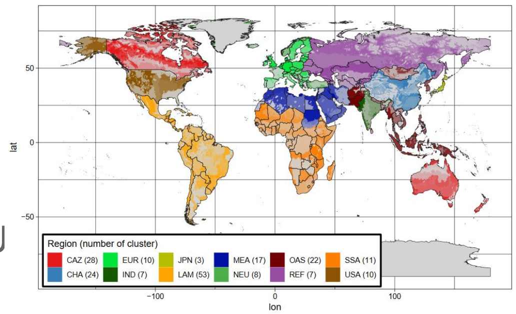
RESULTS UNECE REGIONS – EUR

Different visualisation

Environmental impacts from electricity production, Europe EU





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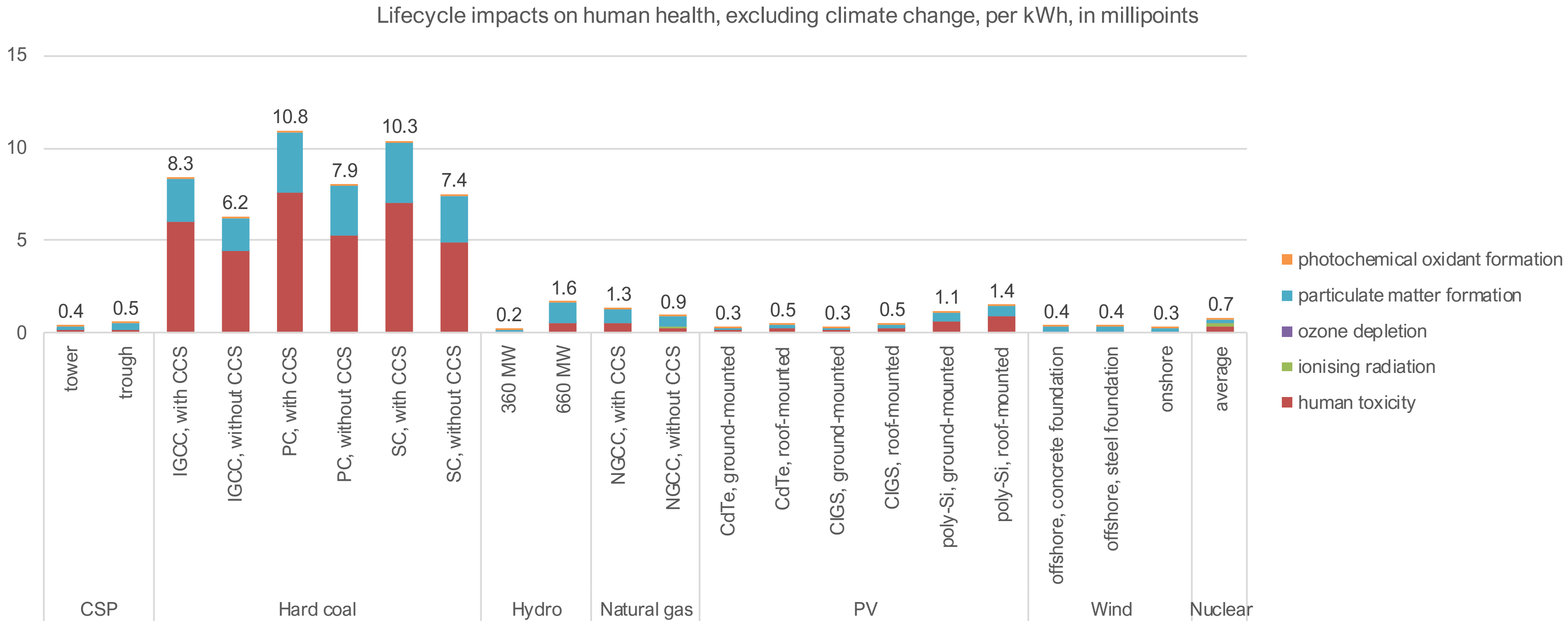
AGGREGATED SCORES

Endpoint indicators: human health



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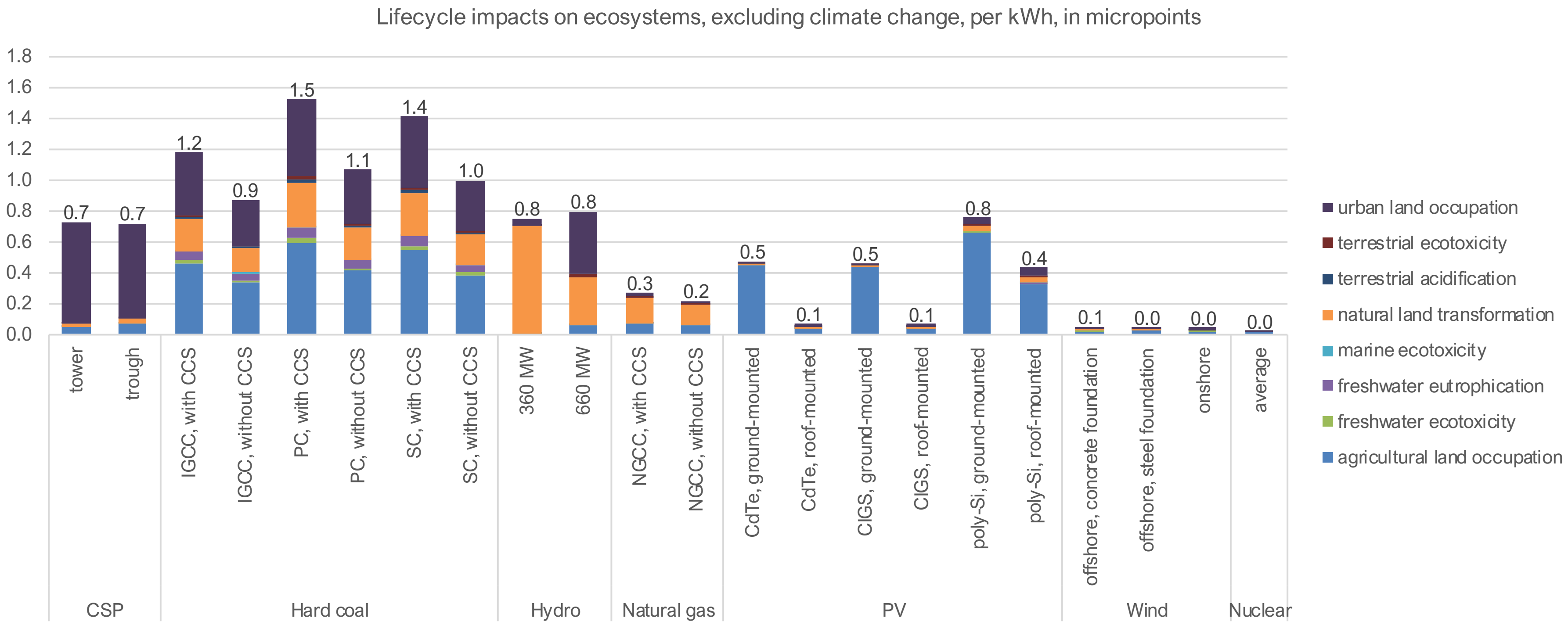
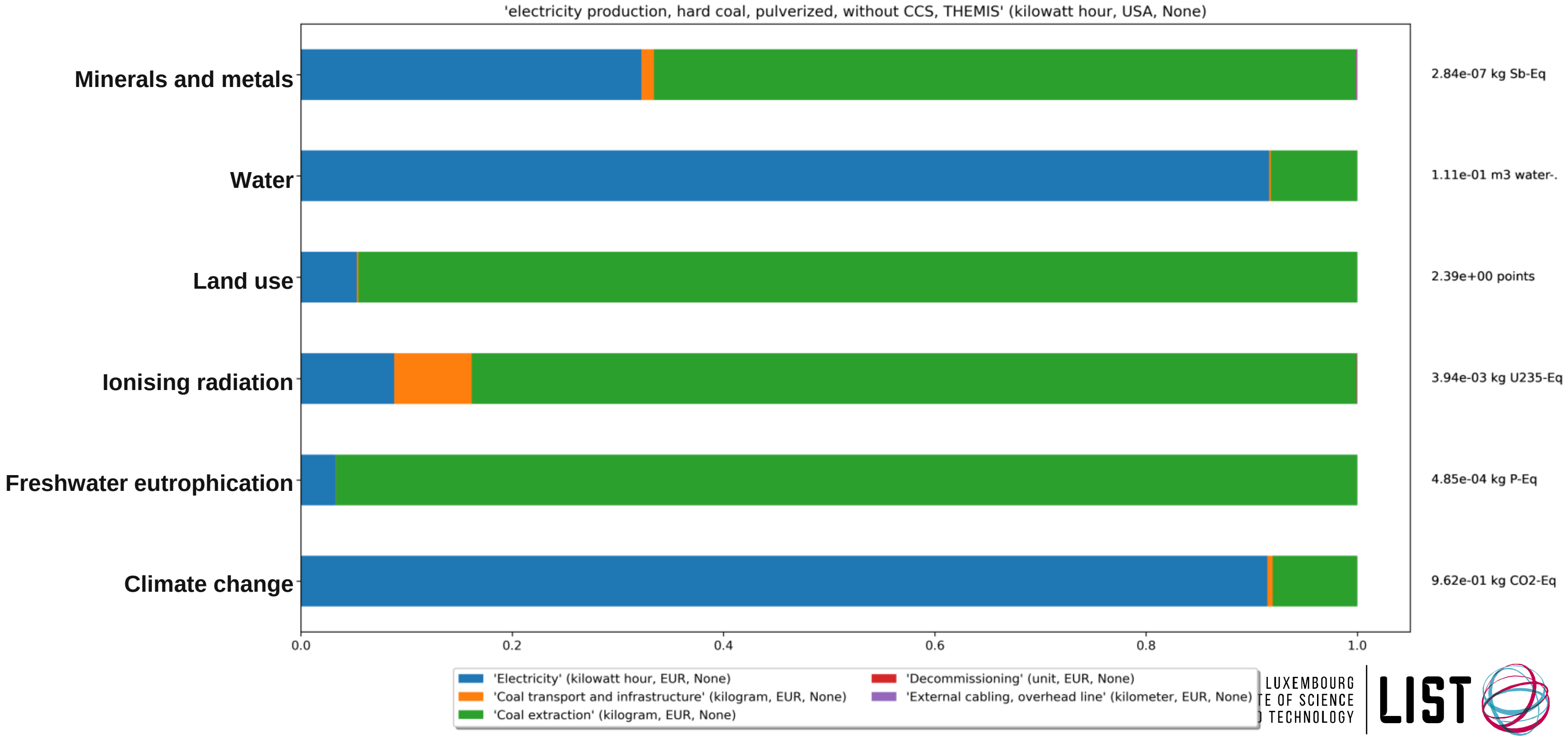


Results per technology

COAL POWER

Lifecycle impacts per kWh (PC 550 MW, 30-year lifetime)



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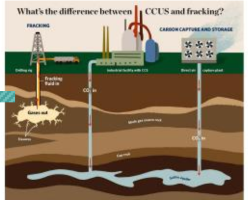
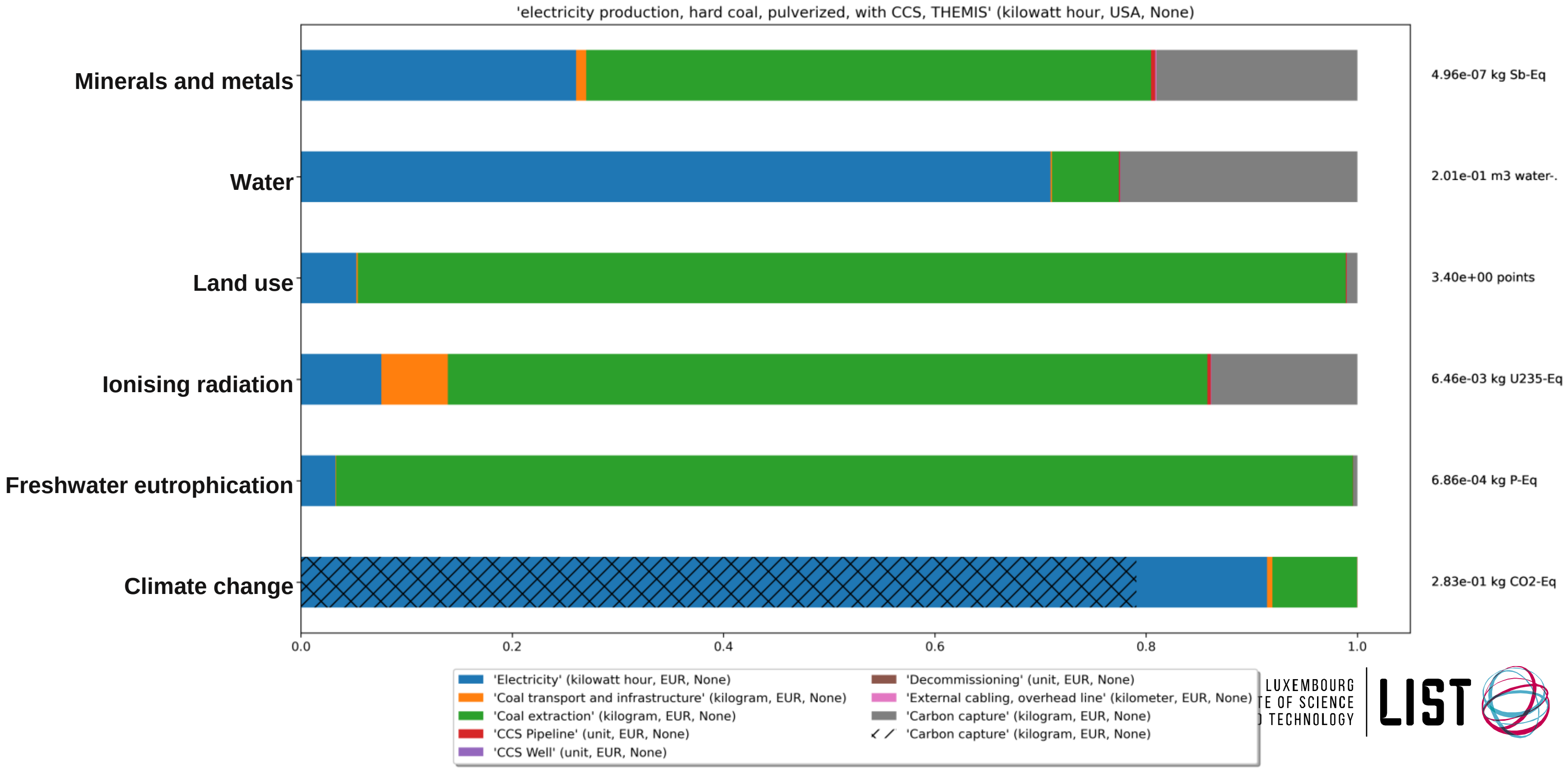
COAL POWER WITH CCS



Lifecycle impacts per kWh (PC 550 MW, 30-year lifetime)



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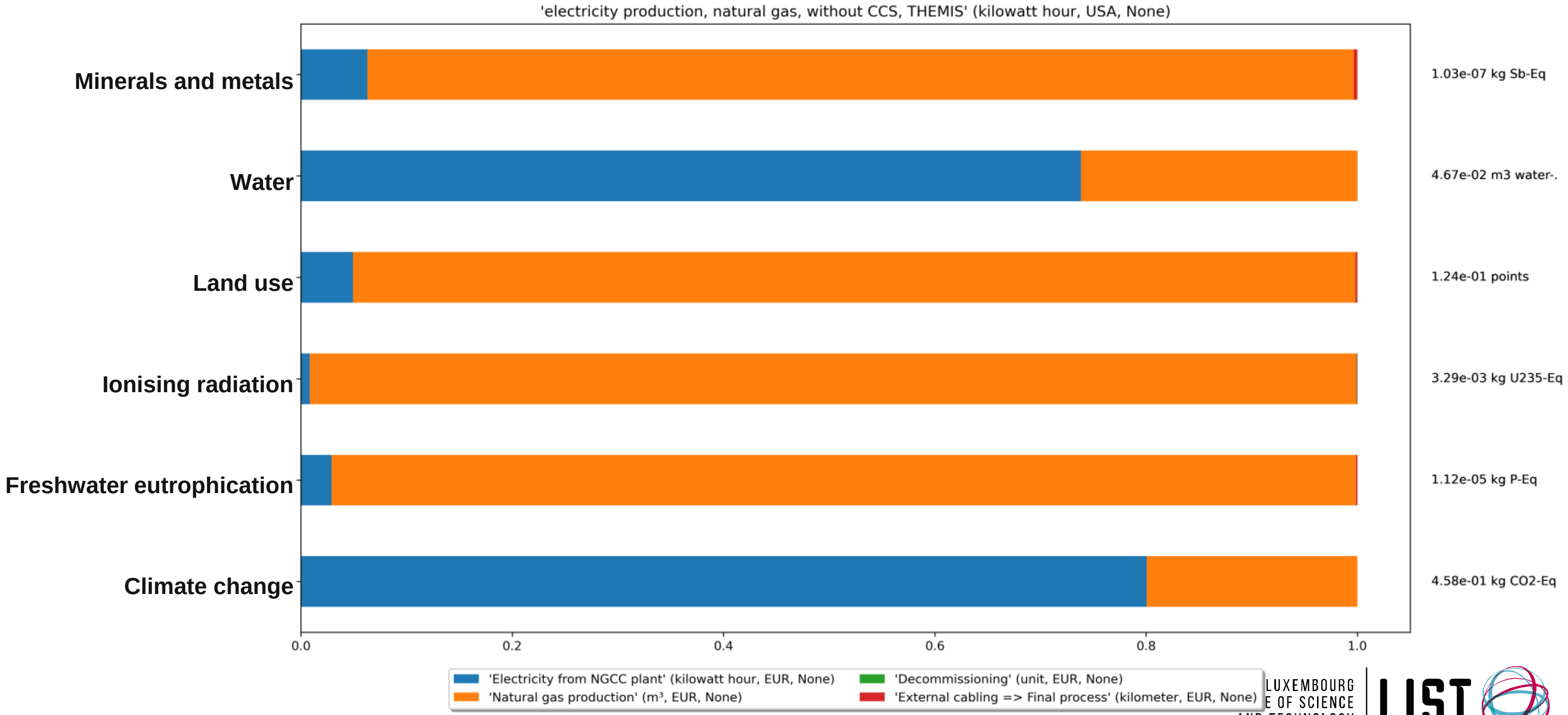
NATURAL GAS

Lifecycle impacts per kWh (NGCC 555 MW, 30-year lifetime)



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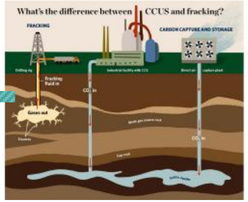
NATURAL GAS WITH CCS



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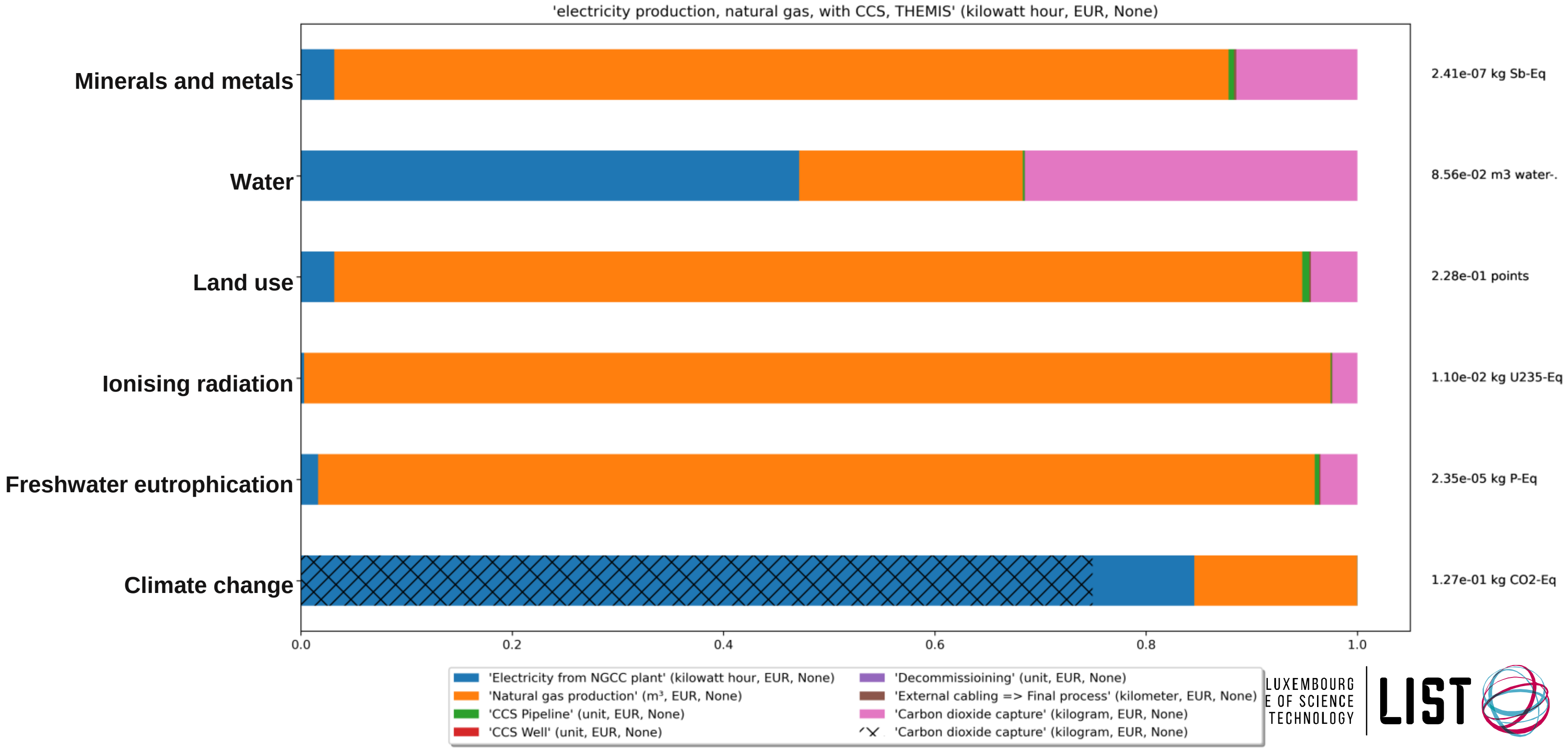

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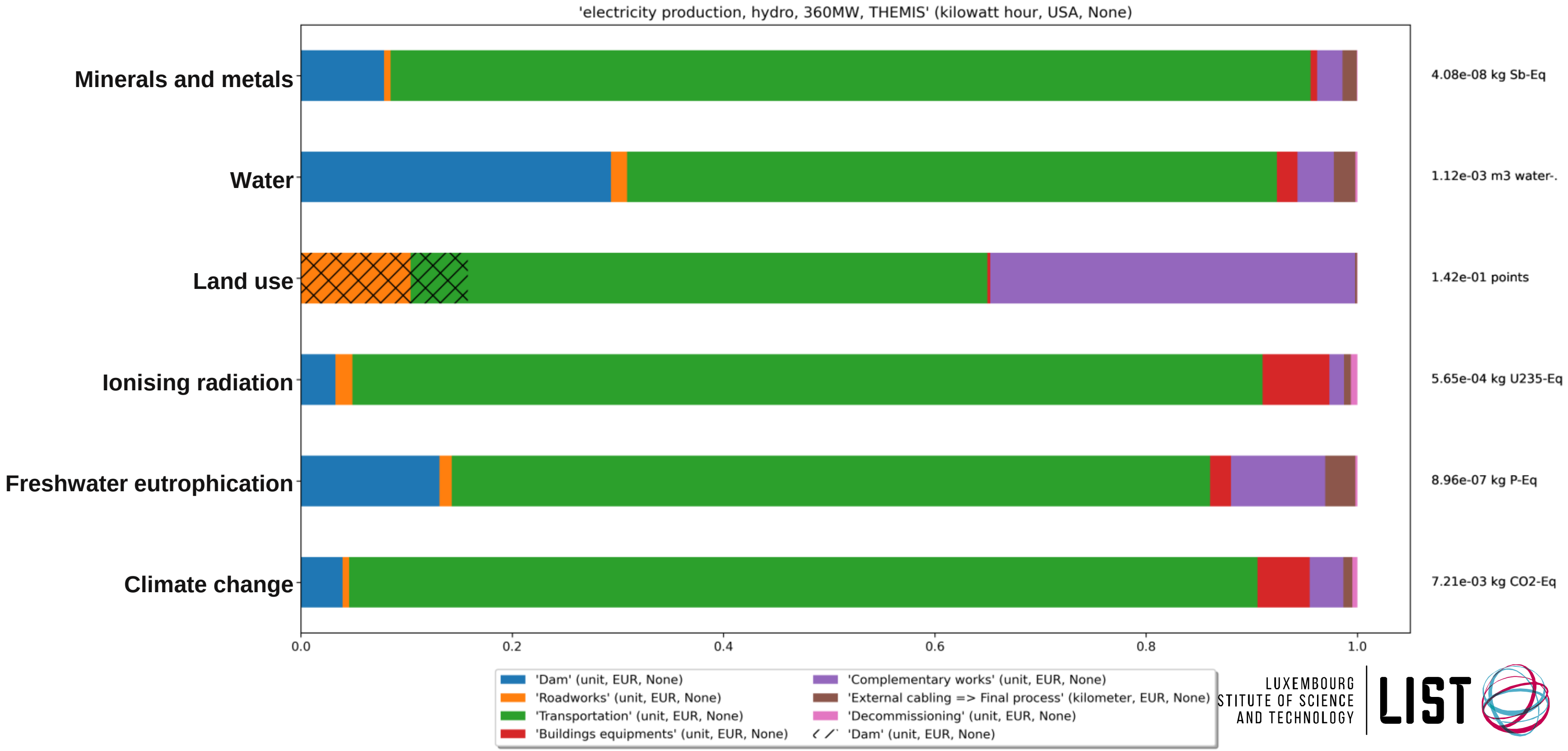
HYDROPOWER

Lifecycle impacts per kWh (360 MW, 80-year lifetime)



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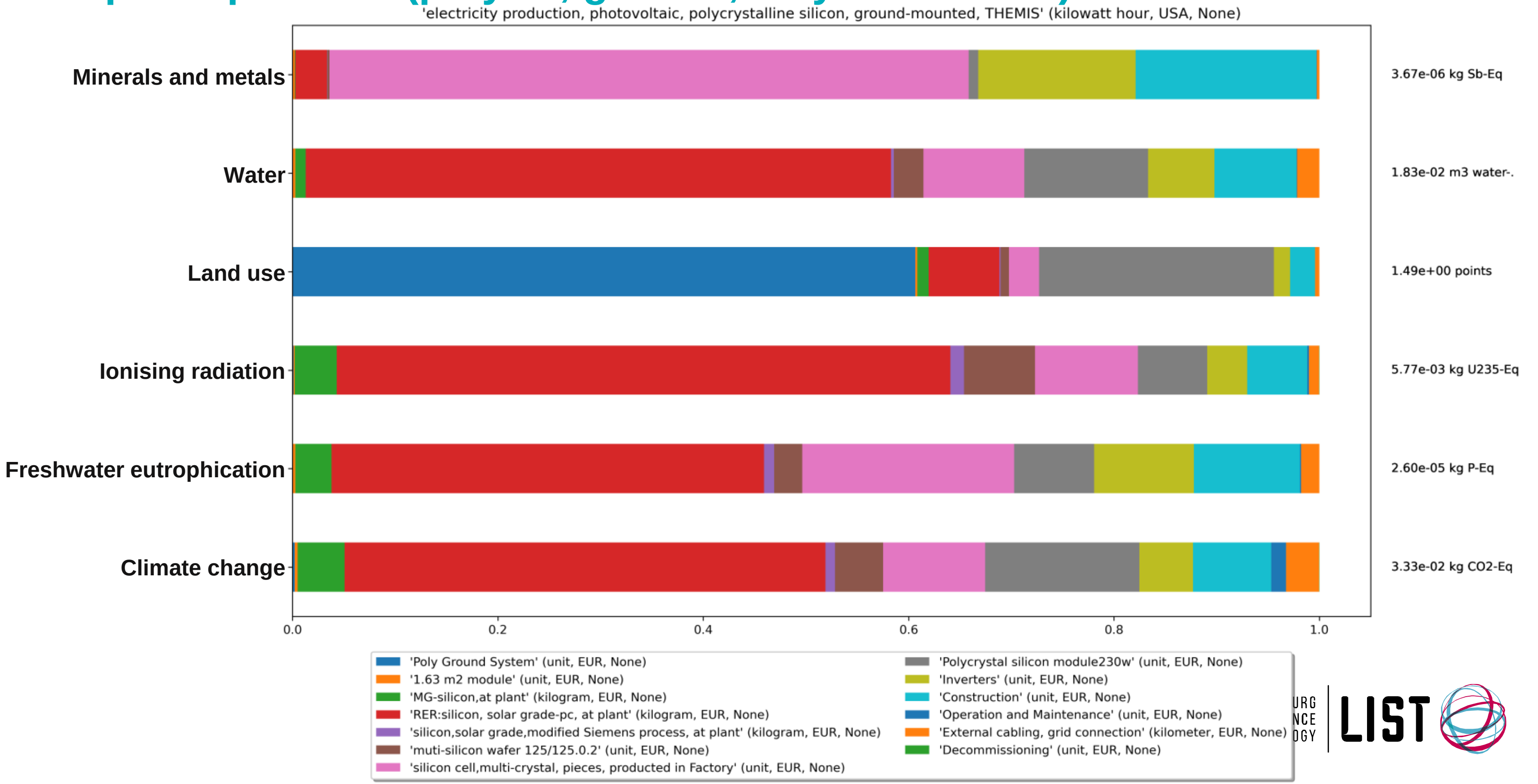
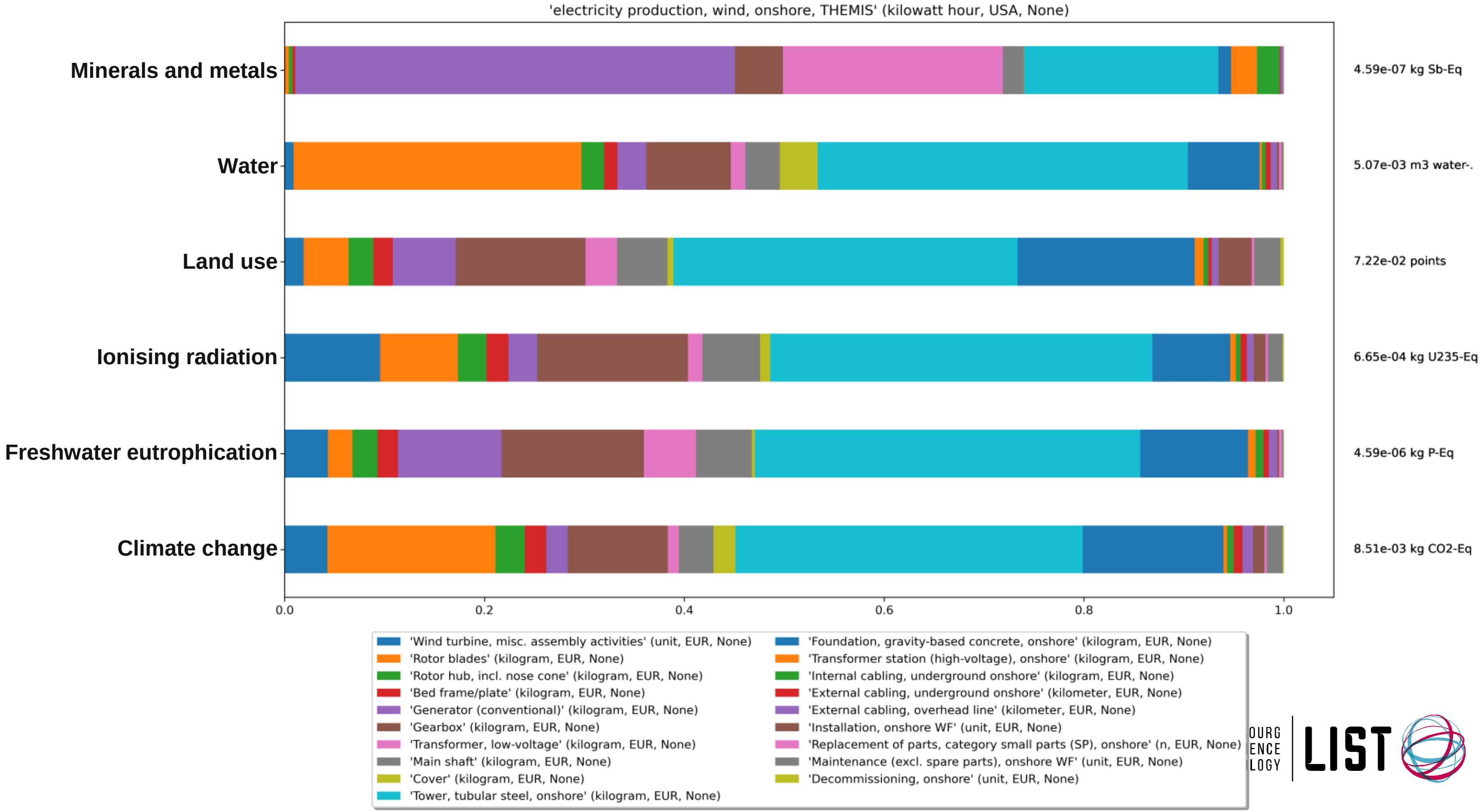
PHOTOVOLTAICS

Lifecycle impacts per kWh (poly-Si, ground, 25-year lifetime)



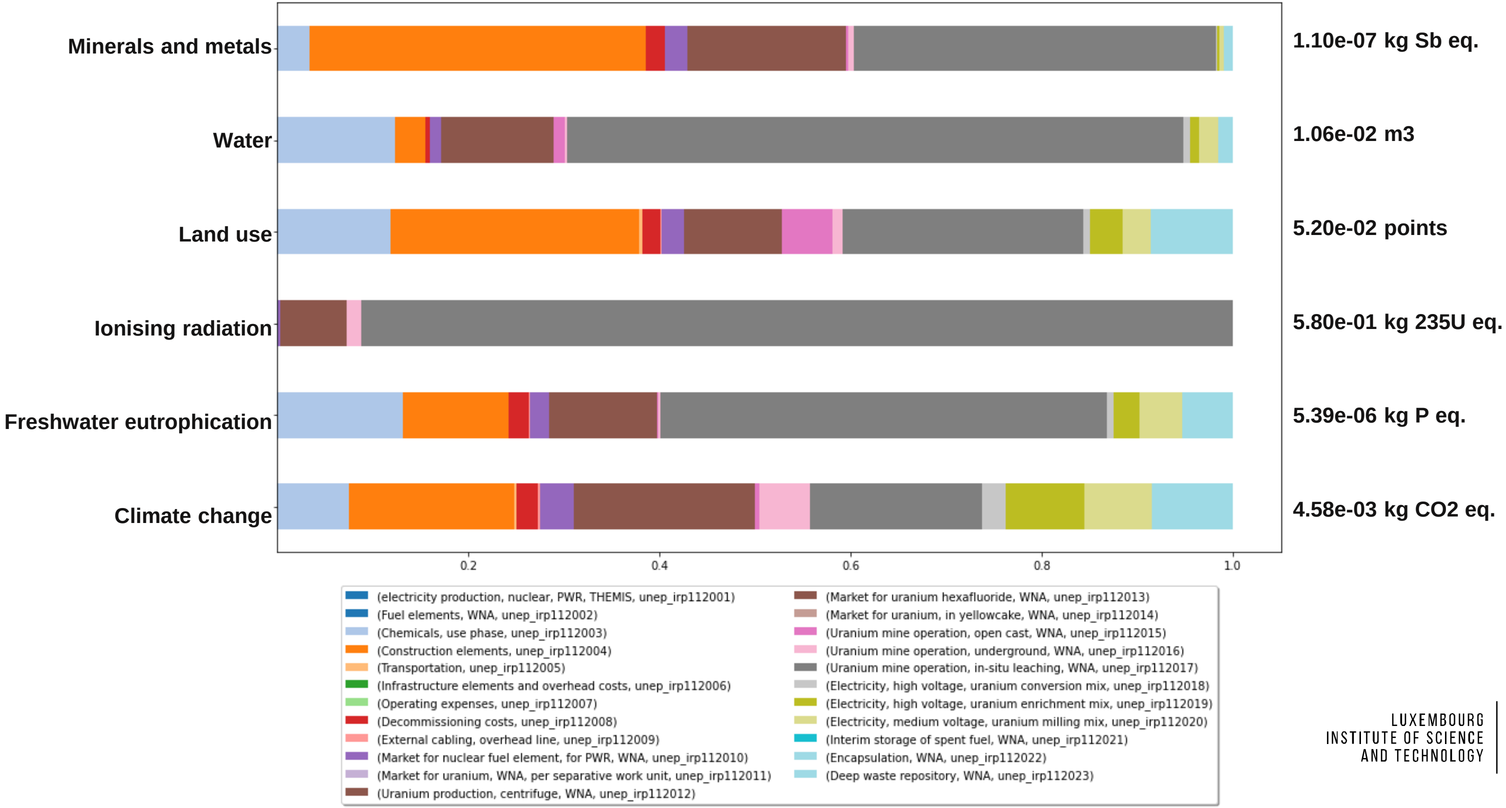
WIND POWER

Lifecycle impacts per kWh (onshore, 2.5 MW, 20-year)



NUCLEAR POWER

Lifecycle impacts per kWh (1000 MW PWR, 60 year lifetime)



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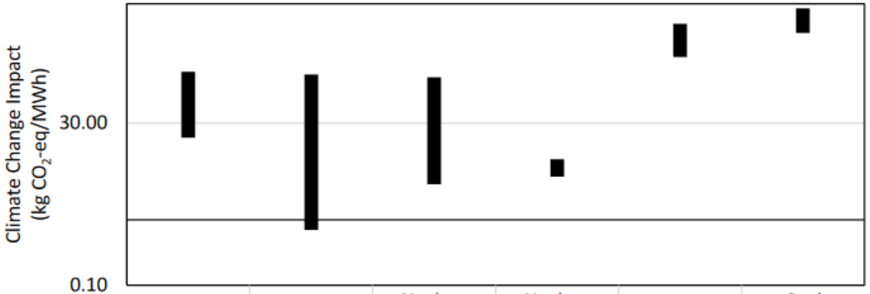
NUCLEAR POWER, SMR?

Lifecycle impacts per kWh



	PV	Hydropower	Nuclear (LWR)	Nuclear (SMR)	Natural Gas	Coal (Pulverized)
MIN	18.00	0.70	3.50	4.55	306.79	714.00
MAX	182.63	165.10	150.00	8.40	987.50	1689.00

Figure 4.4. Bar graph marking the maximum and minimum LCA climate change impacts of various electricity generators (kg CO_2-eq/MWh). The nuclear SMR minimum is from this study and the maximum is from Carless et al.[2] All other maximum and minimum values are from OpenEI.[82]

Analysis has not been done but data is available for modular versions of light-water reactors

Existing studies indicate similar ranges for LWR SMRs

Godsey, K. (2019). *Life Cycle Assessment of Small Modular Reactors Using US Nuclear Fuel Cycle* (Doctoral dissertation, Clemson University).

PROGRESS MEETING JULY 1ST, 2021

Results presentation – discussion

NEXT STEPS

Simplify contribution graphs

Use percentages
Reduce the amount of text to the necessary
Group categories together?
Adapt units ("3.6e-07 kg P" = ".36 mg P")
-> only show UNECE regions?

Finalize report

Commenting results
Discussion on hotspots/blindspots from LCA
Outlook and opportunities for further work