Doutoramento em Alterações Climáticas e Políticas de Desenvolvimento Sustentável

Class 6 | 8th April 2022 | Global energy and climate

Sofia G. Simoes

SEMINAR ENERGY & CLIMATE CHANGE

Climate Change and Sustainable Development Policies

LNEG

NOVA SCHOOL OF SCIENCE & TECHNOLOGY

CENSE center for environmental and sustainability research

1	04/03 6ª Feira	16h-18h	Session reserved for students meeting with the Scientific Committee on practical aspects of the PhD Program, and choice of tutors.	Comissão Científica
2	11/03 6ª Feira	16h-18h	ENERGY & CLIMATE CHANGE: A COMPLEX RELATION, PERENE AND INTERDISCIPLINARY. Framework and purpose of the course in the PDACPDS. Practicalities and seminar program. Basic concepts of the energy systems.	J. Seixas, FCT NOVA
3	18/03 6ª Feira	16h-18h	**Current state of the global energy system :** main energy carriers, energy production and consumption regions; energy access; concepts of energy and carbon intensity.	S. Simões
4	25/03 6ª Feira	14h-16h	**Global balance of CO_2 emissions** associated with energy and industrial processes. Estimates of the Global Carbon Budget (http://www.globalcarbonproject.org/) and its relationship to the global energy system and changes in land use. Future scenarios for greenhouse gas emissions: RCPs (Representative Concentration Pathways). Global emissions based on consumption vs. production.	S. Simões
5	02/04 Sábado	09h-11h	**Renewables:** Economic, environmental and energy security of endogenous vs. imported resources. Renewable technologies. Sustainability issues related with renewables. Land & water use, critical raw materials. Discussion: Where to place 7GW of solar PV in Portugal till 2030?	S. Simões
6	08/04 6ª Feira	16h-18h	**Energy concepts:** Primary/final energy; Sankey diagrams; energy efficiency; Energy services; Energy carriers; Final energy supply cost curves; learning curves of energy technologies. Definition and usefulness of LCOE. System value of Renewables. Global renewables' market.	S. Simões
7	22/04 6ª Feira	16h-18h	**Drawdown** - Climate Solutions for a New Decade	João P. Gouveia, FCT NOVA
8	30/04 Sábado	09h-11h	**Green hydrogen:** technological options, costs and the role for a carbon neutral energy system	P. Fortes, FCT NOVA
9	06/05 6ª Feira	18h-20h	**CARBON PRICING.** Regulatory framework in the European Union: 2020 - 2030 targets. Fit for 55. European low-carbon Roadmap 2050. Paris Agreement, and its implications.	S. Simões
10	13/05 6ª Feira	16h-18h	**Debate Como perspetivar o futuro da energia e alterações climáticas?** Baseado no artigo *An energy vision: the transformation towards sustainability — interconnected challenges and solution s*	students/S. Simões
11	21/05 Sábado	11h-13h	**Hands-on energy data**: access to energy databases, Portuguese and European (PORDATA, DGEG, EUROSTAT). i) How to find and explore energy statistics and emissions of greenhouse gas (GHG) emissions for Europe and Portugal; ii) How to make energy conversions; iii) How to build indicators and charts with added value; iii) How to analyze economic sectors, and interpret their performance in terms of energy consumption and greenhouse gas emissions.	S. Simões
12	27/05 6ª Feira	16h-18h	**Integrated assessment of energy systems:** The energy system addressed by the systems analysis approach. How to envisage the future energy system? Implications for the decision making in the medium and long term. Concept and formulation of cost-effectiveness within the integrated energy systems. Hands on Climate Mitigation Simulation	S. Simões
13	03/06 6ª Feira	16h-18h	Mentoring with each students' group : discussion on the approach and methods adopted by the students, expected results to be obtained with the final work; assessing preliminary results, if any.	S. Simões
14	17/06 6ª feira	18h-20h	**Smart and Sustainable cities:** concept, components and implications for the energy systems. The concept of Positive Energy Districts, and implications for future planning at the city level.	João P. Gouveia, FCT NOVA
	2 julho, 14h	14h-16h	Avaliações: apresentação dos trabalhos pelos alunos.	S. Simões/J. Seixas


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If you need to discuss topics related to the course, including the assignment, I am available on Fridays 10h-11h – send me an e-mail to book this slot at least 4 days before

Para discussão de assuntos relacionados com o seminário, incluindo o trabalho final, estou disponível às sextas 10h-11h – têm que enviar-me e-mail previamente (pelo menos 4 dias antes)

Às 5as feiras 12h-13h é dada aula complementar em Português (zoom) para quem tem mais dificuldades com o inglês

Sofia G. Simões
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PROGRAM & RESOURCES @
https://moodle.fct.unl.pt/course/view.php?id=7450

Climate Change and Sustainable Development Policies

Assignment

Challenge: Within the scope of your personal interests, select an economic activity:
Fashion I Communication I Food and BeverageI Industry I Health services I Mobility I Other

Assuming your country will be in the midst of a pathway to achieve a carbon neutral economy by 2050 (as stated in the Paris Agreement) or earlier, how do you envisage the selected activity will picture by 2030?

Team work I Think out of the box I Innovate

What is the challenge for the activity? Who are the challenge owners?
What do you envisage the activity must/should deliver in the future?

Assignment | Suggestion of script for development:

- firstly, **formulate (and detail) the problem** as far as you are able;
- characterize the **activity at present** [for example, production / import technologies| type of markets and consumers | competition from other markets? | energy consumption profile | indicators of carbon intensity]
- **envisage the activity up to 2030** [technological options | product change - green| change of consumers | energy consumption profile | indicators of carbon intensity]
- systematize **opportunities for the mitigation** of the selected activities (identify needs of R & D, act on consumption preferences, the product value chain, among others)
- identify and anticipate **constraints and barriers to the desired mitigation**, and explain how to overcome them.

Tips: Start now; try to be objective and quantify what is possible; do not try to be exhaustive (you can not do it within just one course); explore examples that already exist in other countries; be creative.

Assignment | GROUPS?

- Locate yourself in a specific country
- Put yourself in the “shoes” of a **company or public organization (or a group/ association)** – do not leave the topic too wide
- **Groups**: 6 or 7 so far
- **Topics…**
  - Fashion
  - Decentralization of energy/prosumer markets
  - MSW management Portugal
  - MSW management in Brazil
  - Agriculture’s carbon neutrality in Portugal
  - Energy supply in megacities (you need to either choose to be an energy company or a municipality)
  - Banking?
  - Water management?

Bonus (?) what is going on with Hydrogen in Portugal

2019 | **2020** | **2021** | **2022**

RNC2050
Carbon Neutrality Roadmap

Alternative pathways for all sectors of economy that allow the achievement of net carbon emissions by 2050

PNEC 2030
PLANO NACIONAL ENERGIA E CLIMA

National Energy and Climate Plan (NECP)
[Energy and GHG emission targets for 2030/2040]

74 EoI for **IPCEI call** on Green H_2 → 37projects to 2nd phase

HIDROGÉNIO

National Strategy for H_2
(August 2020)

PRR
Plano de Recuperação e Resiliência

Recovery and Resilience Plan (RRP or PRR)
1st call for projects **on renewable H_2 & other renewable gases 62M€** (30 Set 2021) - total **185M€** for renewable gases in PRR

41 proposals ~380M€
(19th Feb 2022)

PRR Mobilizing and Green Agendas for Business Innovation: H_2 & Lithium pannel with >6 green H_2 proposals
2nd stage proposals to be submitted till 31st March 2022

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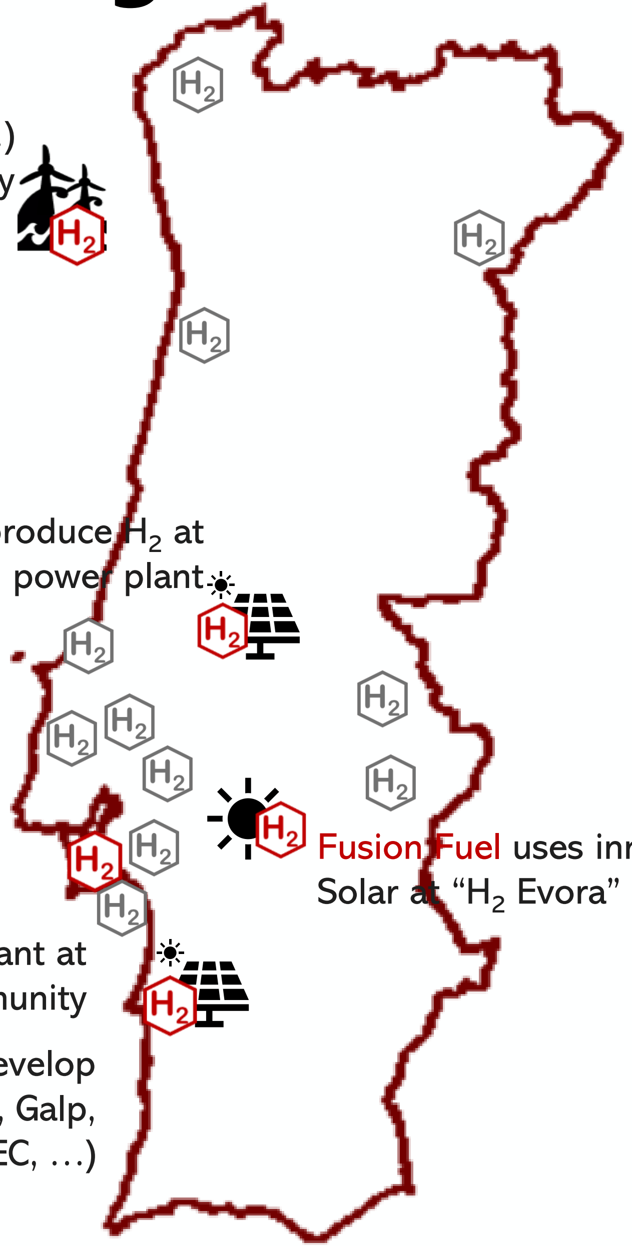
H_2 production investment in Portugal (non-exhaustive)

A multitude of different projects with different business models and offtakers is appearing in Portugal

29 H_2 production projects in Portugal registered with European Clean Hydrogen Alliance Project pipeline (Nov 2021) **2981 MW (1500 MW in Sines)**

https://ec.europa.eu/growth/industry/strategy/industrial-alliances/european-clean-hydrogen-alliance/project-pipeline_en



BEHYOND project (EDP, TechnipFMC, CEiiA, …) assessing green H_2 production using offshore energy

GreenVolt aims to produce H_2 at decomissioned Pego coal power plant

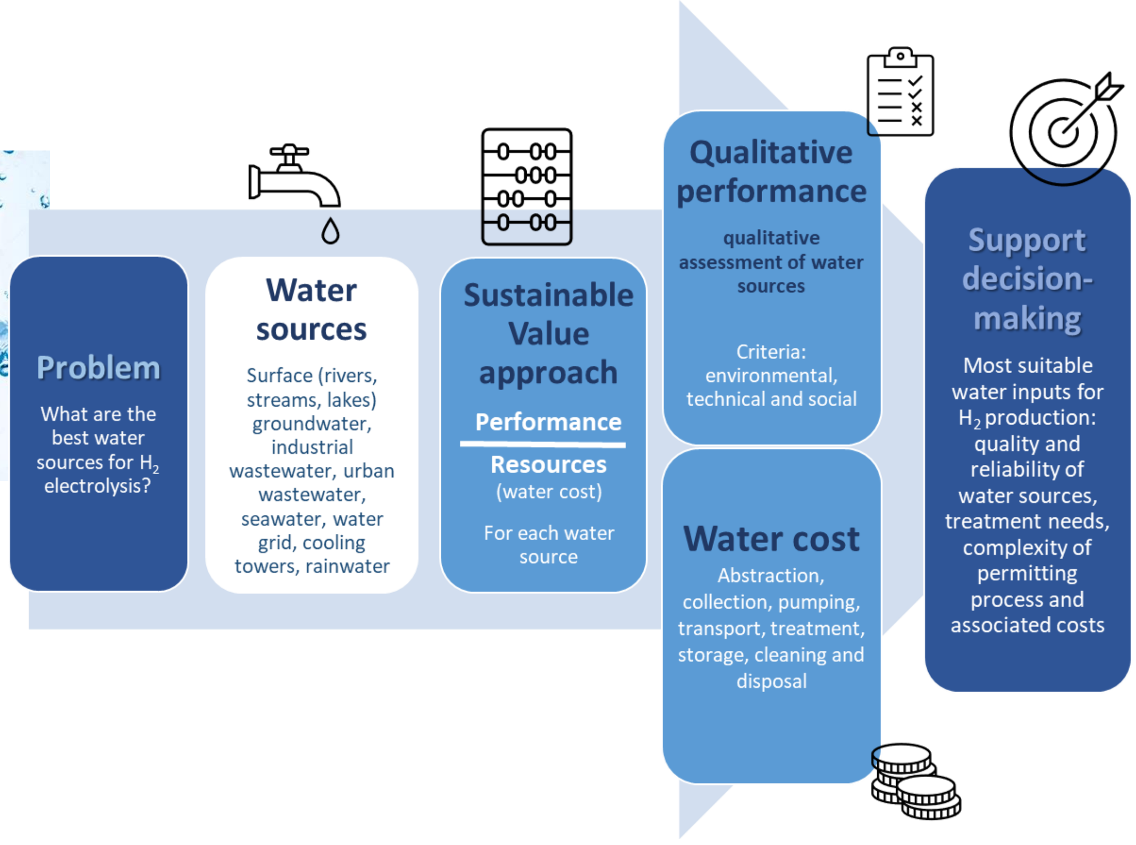
Green Pipeline project injecting H_2 into natural gas grid at Seixal

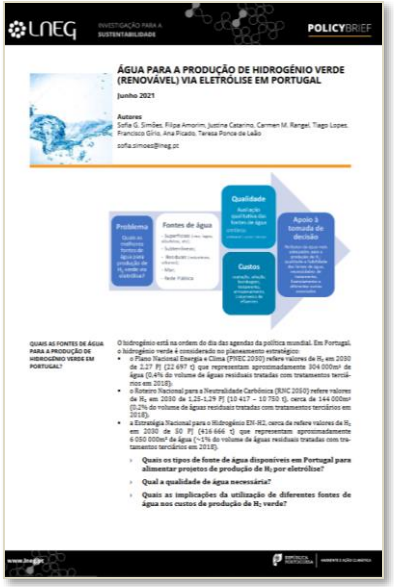
Fusion Fuel uses innovative Hevo-Solar at "H_2 Evora" site near Évora

Keme Energy 1.26 MW green H_2 plant at Sines for an energy community

GreenH2Atlantic funded by H2020 will develop 100 MW electrolyser in Sines (EDP, Galp, Martifer, Efacec, Bondalti, INESC-TEC, …)

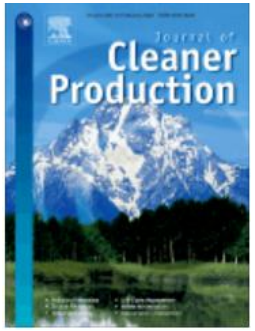
What about water?





Policy brief | H_2O for H_2 (in PT)

https://www.lneg.pt/wp-content/uploads/2021/10/PB_UER_Fontes_de_Agua_para_H2_2021_PT_v7.pdf



Water availability and water usage solutions for electrolysis in hydrogen production
https://doi.org/10.1016/j.jclepro.2021.128124
S.G. Simoes, J. Catarino, A. Picado, T.F. Lopes, S. di Berardino, F. Amorim, F. Gírio, C.M. Rangel, T. Ponce de Leão

- Highly relevant for countries with water scarcity
- Increasing concern due to climate change
- Wastewater use can be a sustainable “circular” solution – additional treatment costs
- Meeting Portugal EN-H2 2030’s H_2 goals require ~1% of current wastewater volumes

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Outline

- (Recap) some basic energy concepts

  Primary/final energy; energy efficiency; Energy services; Energy carriers; Final energy supply cost curves; learning curves of energy technologies; Energy security & endogenous vs. imported resources; Sankey diagrams

- Sustainability issues related with renewables - Land & water use, materials use
- GHG mitigation
- Discussion: Where to place 7GW of solar PV in Portugal till 2030?.

Outline

- (Recap) some basic energy concepts

  Primary/final energy; energy efficiency; Energy services; Energy carriers; Final energy supply cost curves; learning curves of energy technologies; Energy security & endogenous vs. imported resources; Sankey diagrams;

- Sustainability issues related with energy (& renewables): land and & water use, materials use
- GHG emission mitigation
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(Recap) some basic energy concepts

Primary/final energy

Primary energy consumption refers to energy the is converted into **final energy** (e.g. coal, crude oil, natural gas, wind resources, solar power, biomass), which in turns refers to what end users actually consume (e.g. electricity, heat, gasoline, and here it can also be natural gas if used directly in a boiler and not for electricity generation). The difference between the two relates mainly to what the energy sector needs itself and to transformation and distribution losses.

Energy efficiency

In general terms, **energy efficiency** refers to the amount of output that can be produced with a given input of energy. It is frequently measured as the amount of energy output for a given energy input (e.g. the amount of mechanical energy that an electric motor produces for a given input of electrical energy). More info here

Energy services

Energy services are the tasks performed using energy, such as: space heating and cooling, domestic water heating, machine drive, process heat for industry, mobility of passengers and goods, lighting, entertainment, cooking, clothes washing & drying, refrigeration, etc. More info here.

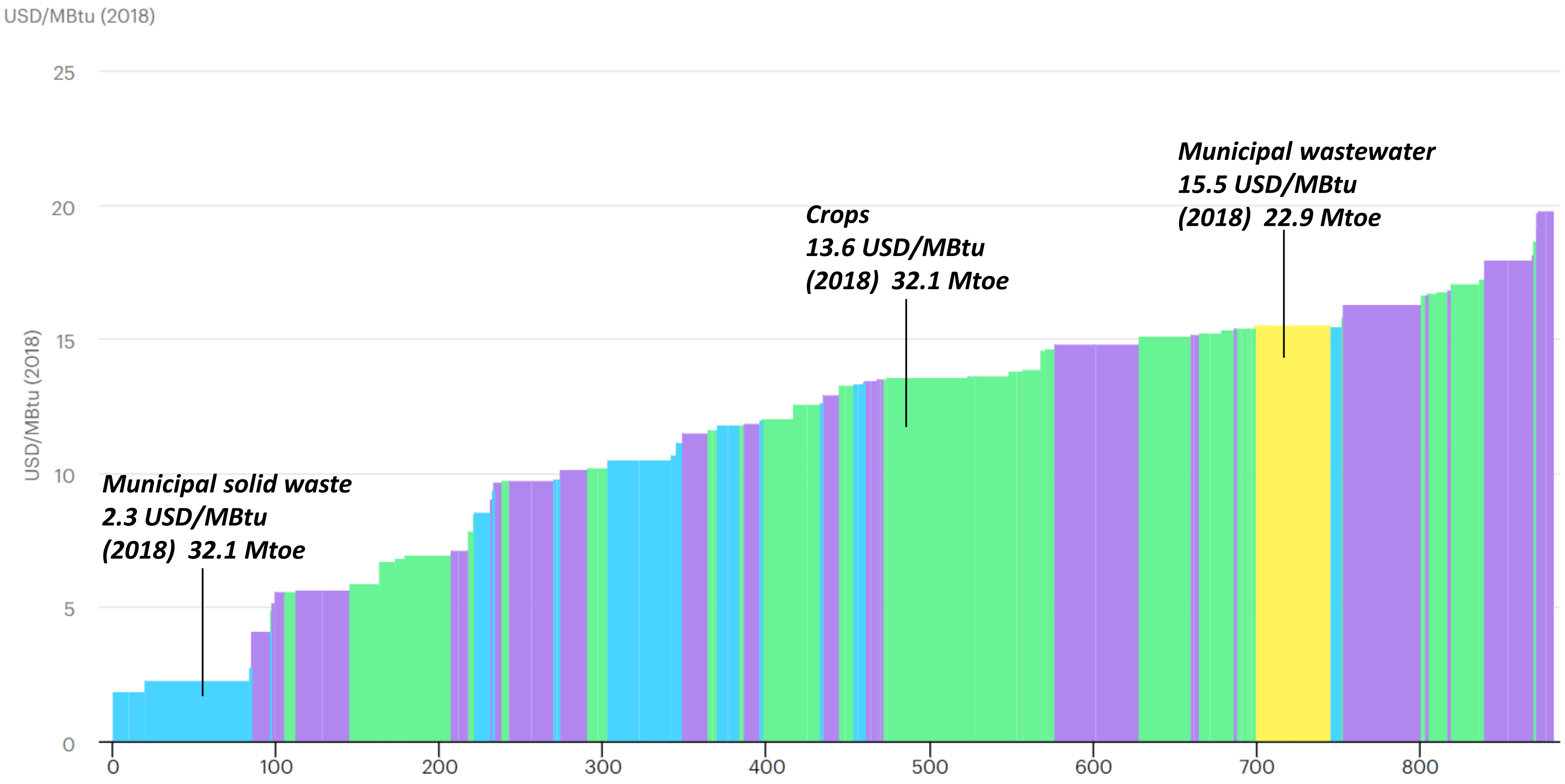
Energy carriers

An **energy carrier** is a substance or a phenomenon that can be used to produce mechanical work or heat or to operate chemical or physical processes. **Energy carriers** occupy intermediate steps in the energy-supply chain between primary sources and end-use applications. "An energy carrier is thus a transmitter of energy, or, in other words, any system or substance that contains energy for conversion as usable energy later or somewhere else". Examples of energy carriers are: electricity, heat and solid (coal, wood), liquid(petroleum, ethanol, gasoline) or gaseous(hydrogen, natural gas) fuels, but the concept can also be applied to springs, electrical batteries, capacitors, pressurized air or dammed water. More info here

(Recap) some basic energy concepts – part II

Final energy supply cost curves

Cost curve of potential global biogas supply by feedstock, 2040

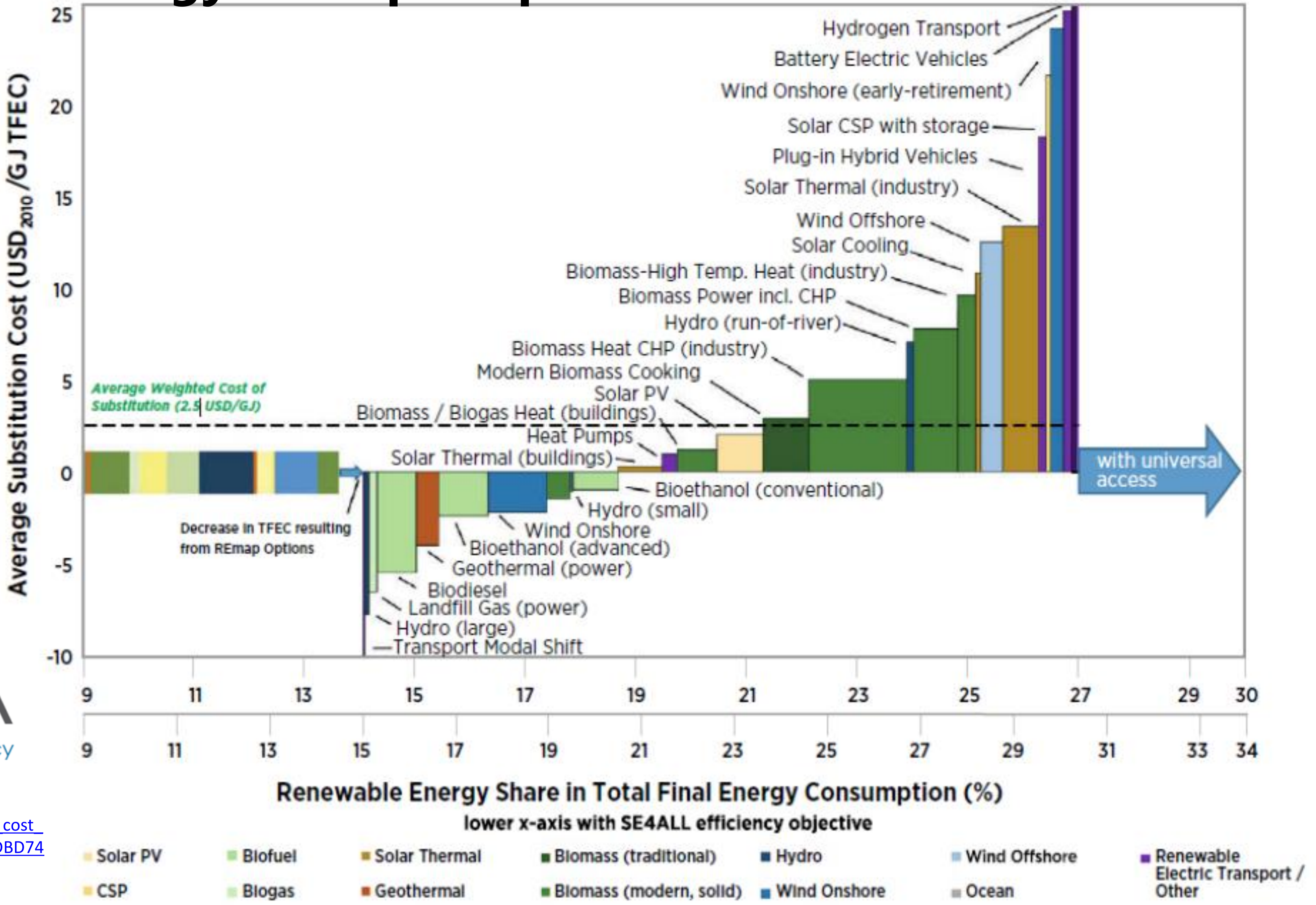


https://www.iea.org/data-and-statistics/charts/cost-curve-of-potential-global-biogas-supply-by-feedstock-2040

(Recap) some basic energy concepts – part III

Final energy supply cost curves for 26 REmap countries

TFEC = total final energy consumption



![IRENA International Renewable Energy Agency]

https://www.irena.org/-/media/Files/IRENA/REmap/Methodology/IRENA_REmap_cost_methodology_2014.pdf?la=en&hash=A60771A19A50742DBD747B69B775BAC8849A4539

(Recap) some basic energy concepts – part IV

Learning curves of energy technologies

A learning curve describes technological progress (measured generally in terms of decreasing costs for a specific technology) as a function of accumulating experience with that technology (see here). This is highly relevant for energy technologies in the context of energy system transition as we anticipate that technology learning for less mature technologies will lead to substantially lower investment and O&M costs. Solar PV has had a very high learning and most probably the same will occur for offshore power and hydrogen in the coming years.

Energy security & endogenous vs. imported resources

“The IEA defines energy security as the uninterrupted availability of energy sources at an affordable price. Energy security has many aspects: long-term energy security mainly deals with timely investments to supply energy in line with economic developments and environmental needs. On the other hand, short-term energy security focuses on the ability of the energy system to react promptly to sudden changes in the supply-demand balance.” More here.

Energy dependency (rate)

“shows the proportion of energy that an economy must import. It is defined as net energy imports divided by gross inland energy consumption plus fuel supplied to international maritime bunkers, expressed as a percentage. A negative dependency rate indicates a net exporter of energy, while a dependency rate in excess of 100 % indicates that energy products have been stocked.” See more here

Endogenous energy resources are the ones that can be sourced within the borders of a certain region, whereas exogenous resources are consumed in the region but where extracted/produced outside its borders.

Outline

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Materials use per low carbon technologies

Ocean	Fe, Cu, Al, Cr, Ni, Mo, Ti **[#7]**
Carbon Capture	Mn, Pr, Cr, Nb, Va, Mo, Co **[#7]**
Batteries	Bauxite, Co, Fe, Li, Mn, Ni, Graphite, Cu **[#8]**
Geothermal	Fe, Ni, Cr, Al, Mo, Mn, Cu, Ti, Nb, Ta **[#10]**
Hydropower	Fe, Cu, Ni, Cr, Zn, Pb, Mo, Mn, Magnesite, Sn **[#10]**
Solar PV	Al, Cu, Sn, Pb, Magnesite, Zn, Ag, Cd, Te, Se, In, Ga **[#12]**
Concentrated Solar	Fe, Al, Mn, Cr, Cu, Ni, Zn, Mo, Nb, Ag, Ti, Va **[#12]**
Onshore Wind	Fe , Zn, Cr, Cu, Al, Mn, Ni, Mo, Nd, Pr, Dy, Tb, Pb **[#13]**
Offshore Wind	Fe, Cu, Zn, Pb, Mn, Al, Cr, Ni, Nd, Mo, Pr, Dy, Tb **[#13]**
Nuclear	Cr, Ni, Mo, Cu, Zr, Ag, W, Pb, Ti, Nb, In, Va, Cd, Yt **[#14]**
Electric vehicles	Al, B, Ce, Co, Cu, Dy, Ga, Ge, Au, Graphite, In, Fe, La, Pb, Li, Mn, Nd, Ni, Pd, Pr, Sm, Ag, Tb, Ti **[#24]**

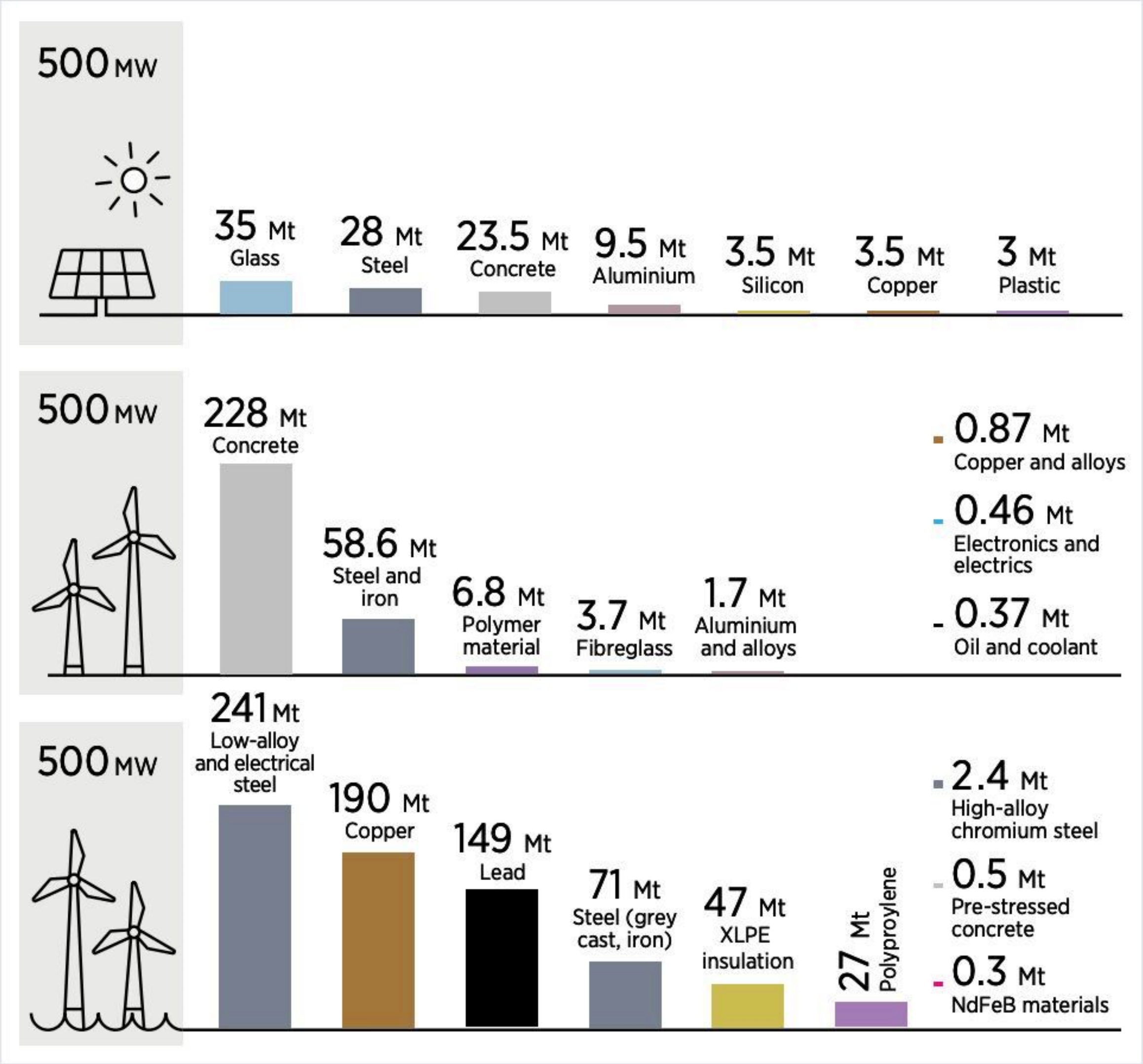
Literature review

JRC (2011, 2013, 2016)
Garcia - Olivares et al. (2012)
Ashby, Attwood and Lord, (2012)
B.Guezuraga (2012)
Corona et al. (2017)
Elshkaki & Graedel (2013)
Gamesa, (2014)
Kavlak (2015)
Kleijn and Voet (2010)
Kleijn et al, (2018)
Ohrlund (2012)
Pihl,_et al (2012)
Primard, Pierre (2015)
Till Zimmermann (2013)
USGS (2011)
Vestas, (2012)
World Bank (2017)
Zimmermann (2013

Em Português
Ag (prata), Al (alumínio), B (boro), Cd (cádmio), Ce (cério), Co (cobalto), Cr (crómio), Cu (cobre), Dy (disprósio), Fe (ferro), Ga (gálio), Ge (germânio), In (índio), La (lantânio), Mg (magnésio), Mn (manganês), Mo (molibdénio), Nb (nióbio), Nd (neodímio), Ni (níquel), Pb (chumbo), Pd (paládio), Pr (praseodímio), Se (selénio), Sm (samário), Sn (estanho), Ta (tântalo), Tb (térbio), Te (telúrio), Ti (titânio), Va (vanádio), Yt (ítrio), W (tungsténio), Zn (zinco), Zr (zircónio).

Stilwell. T., Simoes. S.G. (n.d.) Mapping necessary resources for the transition to a low carbon energy system. *(in preparation)*

Non-critical materials needs for RES technologies



Note: values are intended for 500 solar PV systems of 1 MW size, ten onshore wind farms of 50 MW and an offshore wind farm of 500 MW

Note: XLPE = cross-linked polyethylene.

Sources: IRENA (2017a, 2017b, 2018, 2019, 2021b).

https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2022/Mar/IRENA_Green_Hydrogen_Industry_2022.pdf

Climate Change and Sustainable Development Policies

More on materials for energy…

Payne Institute - Colorado School of Mines

https://econbus.mines.edu/

Climate-Smart Mining: Minerals for Climate Action

https://www.worldbank.org/en/topic/extractiveindustries/brief/climate-smart-mining-minerals-for-climate-action

USA Energy Resource Governance Initiative

https://www.state.gov/energy-resource-governance-initiative/

Intergovernmental Forum on Mining. Minerals. Metals and Sustainable Development (IGF)

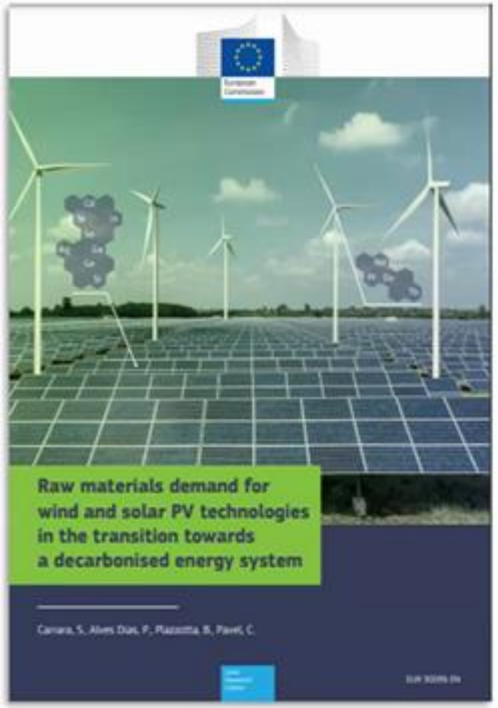
https://www.igfmining.org/

CMI – US Critical Material Institute

https://www.ameslab.gov/cmi

2016

https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/substitution-critical-raw-materials-low-carbon-technologies-lighting-wind-turbines-and



2020

https://ec.europa.eu/jrc/en/publication/raw-materials-demand-wind-and-solar-pv-technologies-transition-towards-decarbonised-energy-system

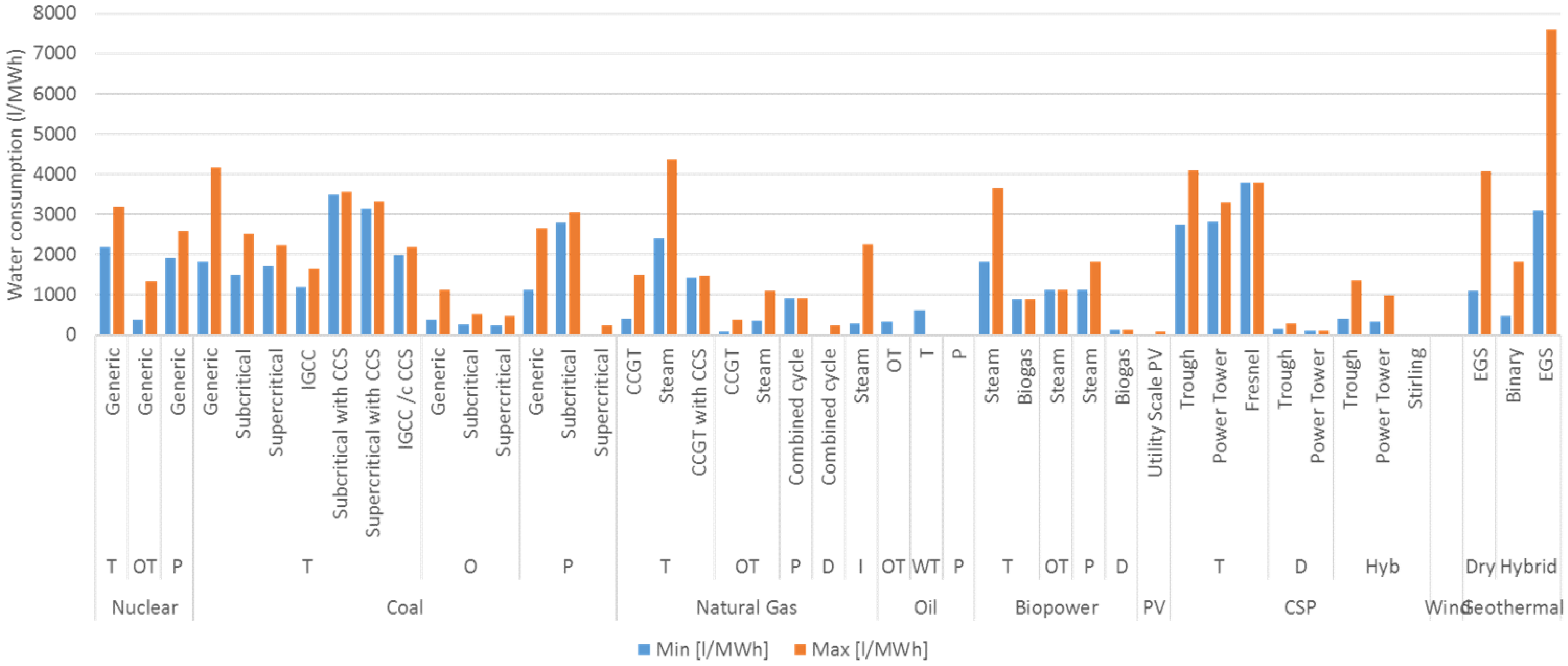
Water consumption & withdrawal for energy

Table 4 – Water consumption and withdrawal factors for coal-fired power plants (Sources: Meldrum et al., 2012; Macknick et al., 2011; Zhai et al., 2011; NETL, 2009; Tzimas, 2011; EPRI, 2011)			
Plant type	Cooling system	Water consumption (gallons/MWh)	Water Withdrawal (gallons/MWh)
Supercritical (incl. SCPC)	Tower	458 – 594	582 – 669
	Once-through	64 – 124	22,551 – 22,611
	Pond	4 – 64	14,996 – 15,057
Subcritical	Tower	394 – 664	463 – 678
	Once-through	71 – 138	27,046 – 27,113
	Pond	737 - 804	17,859 – 17,927
IGCC	Tower	318 - 439	358 - 605

Table 4–Water consumption and withdrawalfactors for CSP plants (Sources: Meldrum et al., 2012; Macknick et al., 2011; Zhai et al., 2011; NETL, 2009; Tzimas, 2011; EPRI, 2011)			
Plant type	Cooling system	Water consumption (gallons/MWh)	Water Withdrawal (gallons/MWh)
CSP	Tower	725-1,057	725-1,057
	Dry	26-79	26-79
	None	4-6	4-6

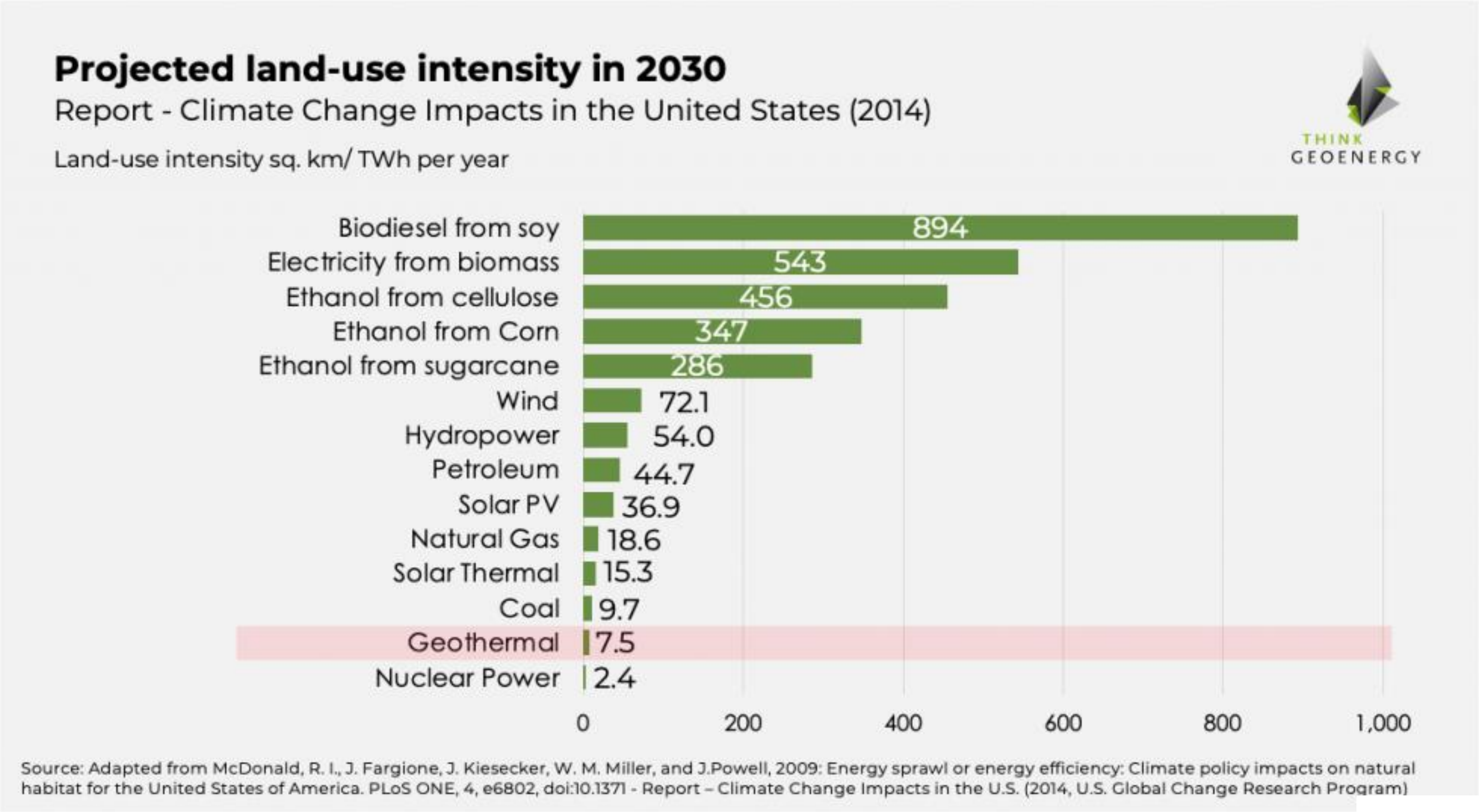
Table 1 – Water consumption and withdrawal factors for nuclear power plants (Sources: Meldrum et al., 2012; Macknick et al., 2011; Zhai et al., 2011; NETL, 2009; Tzimas, 2011; EPRI, 2011)			
Plant type	Cooling system	Water consumption (gallons/MWh)	Water Withdrawal (gallons/MWh)
Nuclear	Tower	581-845	800-2,600
	Pond	560-720	500-13,000
	Once-through	100-400	25,000-60,000

Water consumption & withdrawal for energy



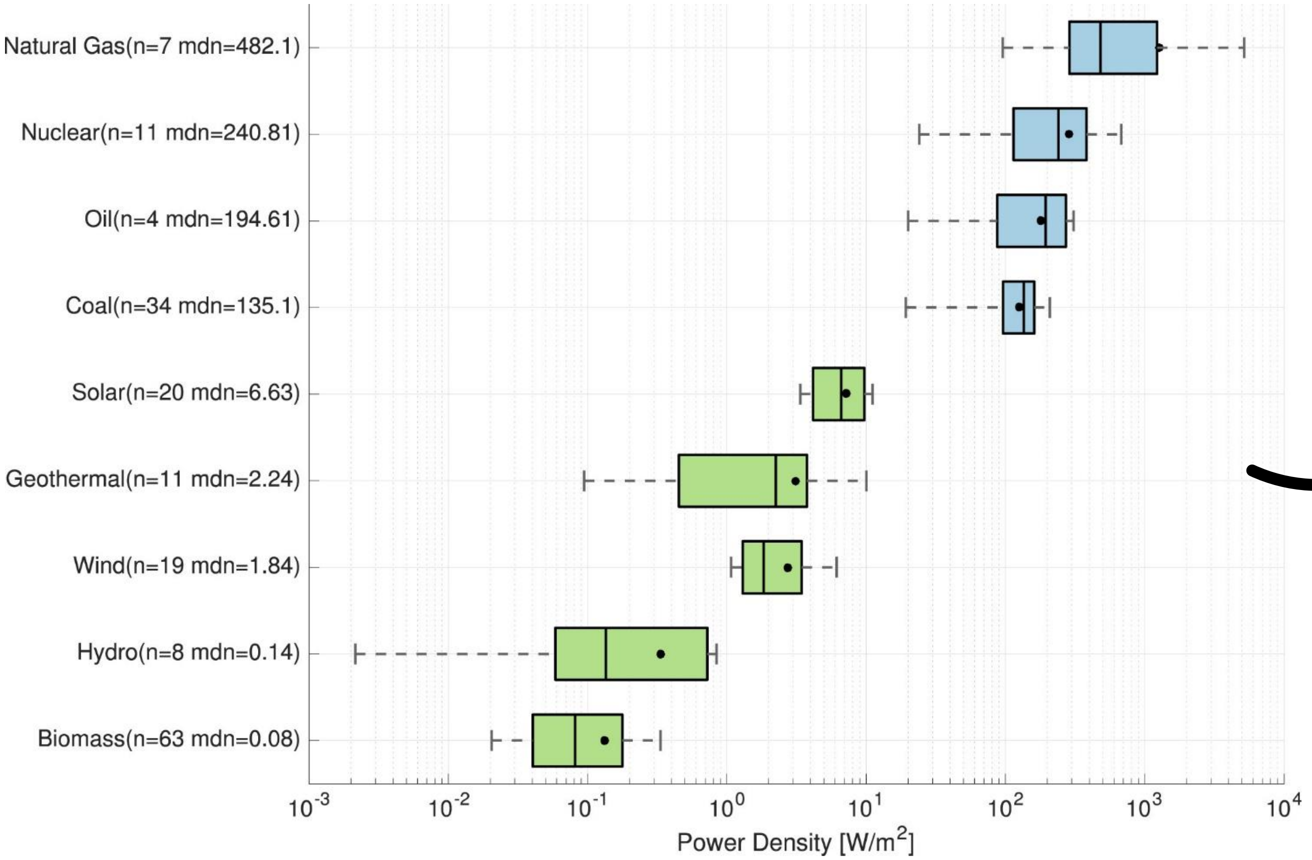
Climate Change and Sustainable Development Policies

Land use intensity for energy

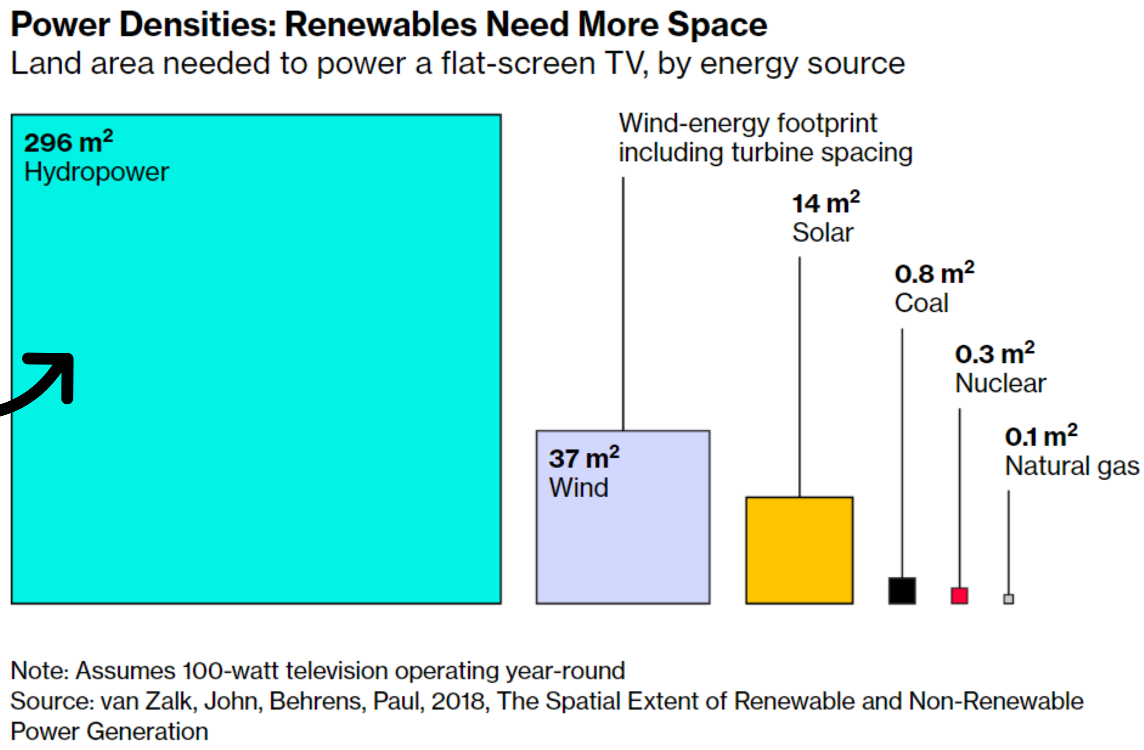


https://www.thinkgeoenergy.com/geothermal-energy-is-least-land-use-intense-source-of-the-renewable-energy-technologies/

Land use intensity for energy (III)



van Zalk, J., Behrens, P. (2018) The spatial extent of renewable and non-renewable power generation: A review and meta-analysis of power densities and their application in the U.S. Energy Policy Journal (123). https://doi.org/10.1016/j.enpol.2018.08.023

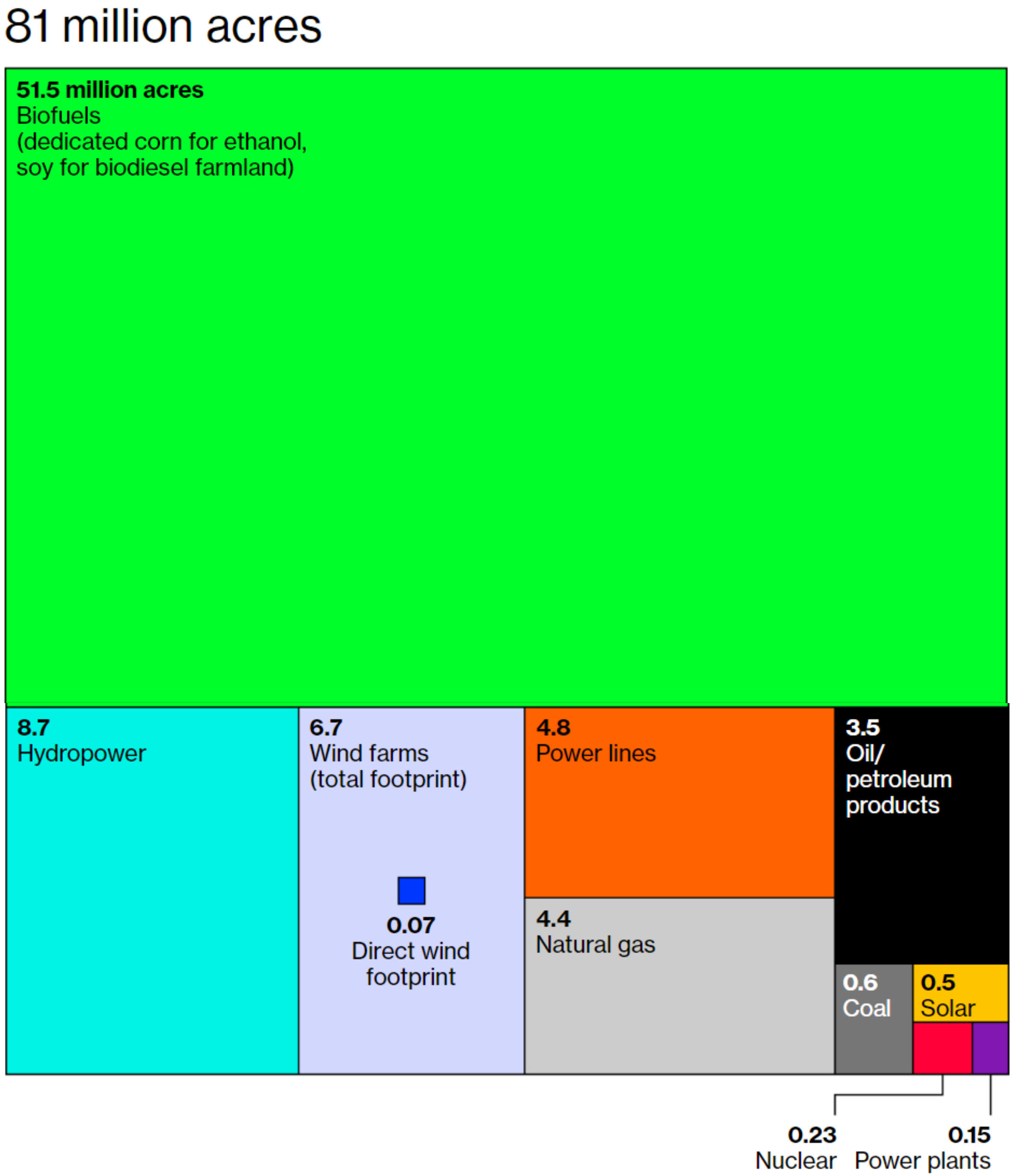


Published: April 29, 2021 | Updated: June 3, 2021

https://www.bloomberg.com/graphics/2021-energy-land-use-economy/

Land use intensity for energy in the USA

*“Right now, the current U.S. energy sector requires about **81 million acres (33 million hectares) of land**, according to the Bloomberg News analysis. That estimate includes not only energy sources fueling the electric grid, but also transportation, home-heating and manufacturing.”*



Note: Wind’s direct footprint includes only turbine bases and access roads.

https://www.bloomberg.com/graphics/2021-energy-land-use-economy/

Minimize impact of RES power plants on land use

1. Minimising **total land-use requirements** for renewable energy by promoting offshore wind, rooftop solar and solar on water bodies

2. **Identification and assessment of land for renewable generation** by limiting undue regional concentration and developing environmental and social standards for rating potential sites.

3. Attention on **agrivoltaics sector** — securing benefits to farmers and incentivizing agrivoltaics uptake where crops, soils and conditions are suitable, and yields can be maintained or improved

van de Ven, DJ., Capellan-Peréz, I., Arto, I. *et al.* **The potential land requirements and related land use change emissions of solar energy**. *Sci Rep* **11,** 2907 (2021). https://doi.org/10.1038/s41598-021-82042-5

Outline

- (Recap) some basic energy concepts

  Primary/final energy; energy efficiency; Energy services; Energy carriers; Final energy supply cost curves; learning curves of energy technologies; Energy security & endogenous vs. imported resources; Sankey diagrams;
- Sustainability issues related with renewables - Land & water use, materials use
- **GHG mitigation**
- Discussion: Where to place 7GW of solar PV in Portugal till 2030?.

STEPPING UP EUROPE'S 2030 CLIMATE AMBITION - INVESTING **IN A CLIMATE-NEUTRAL FUTURE FOR THE BENEFIT OF OUR PEOPLE**

Brussels, 17.9.2020

COM(2020) 562 final

Communication from the Commission to the European Parliament, the Council, The European Economic and Social Committee and the Committee of the Regions

EUROPEAN COMMISSION

Climate Change and Sustainable Development Policies

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1990-2019

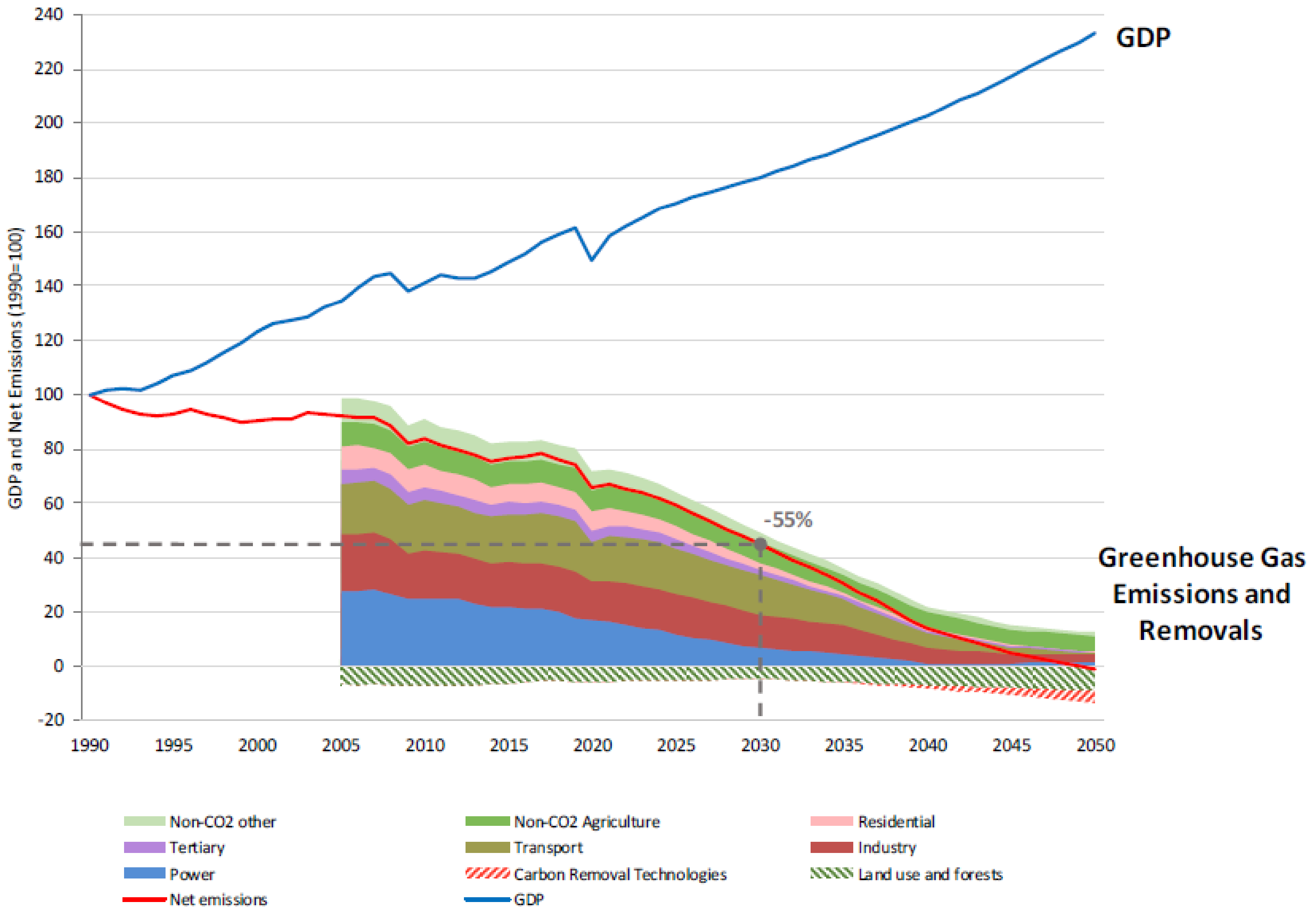
EU GHG (with removals) -25%

EU economy +62%

Current EU GHG emission pathway leads -60% GHG_{1990} by 2050

2030

-55% GHG_{1990}



Climate Change and Sustainable Development Policies

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	today	2030
% RES electricity	32%	≥65%
% RES in heating & cooling	...%	40%
% RES in transport	6%	24%
% RES	..%	38.5%

regulate at least intra-EU aviation emissions in the EU ETS and include at least intra-EU maritime transport in the EU ETS

Fossil fuels consumption

coal -70% $_{2015}$

oil -30% $_{2015}$

gas -25% $_{2015}$

savings of 36-37% for final energy consumption and 39-41% for primary energy

2030 GHG emissions reduction

-20% $_{2015}$

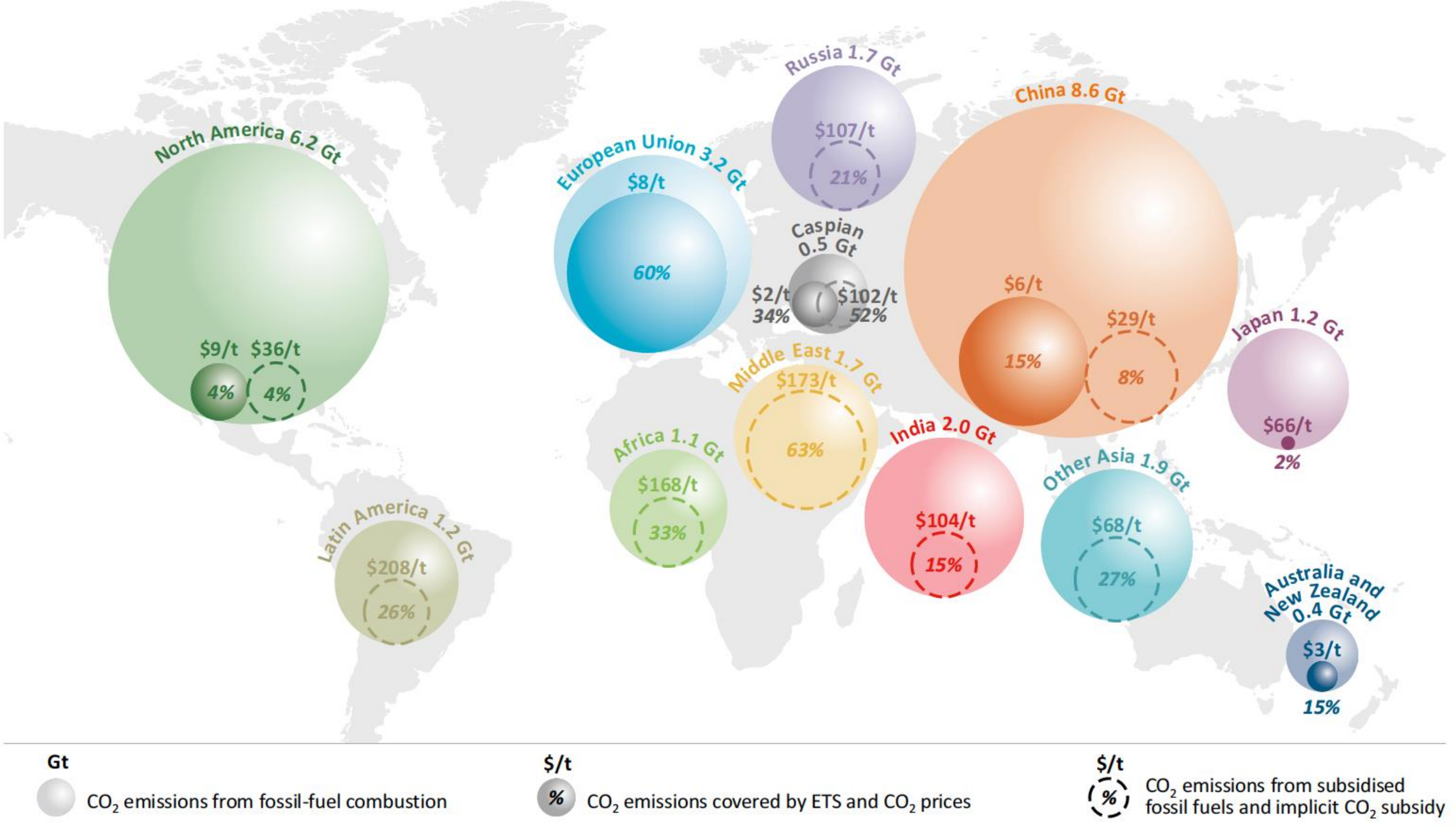
-25% $_{2015}$

CH_4, N_2O, F-gases -35% $_{2015}$

Climate Change and Sustainable Development Policies

Energy, CO_2 & some policies for mitigation

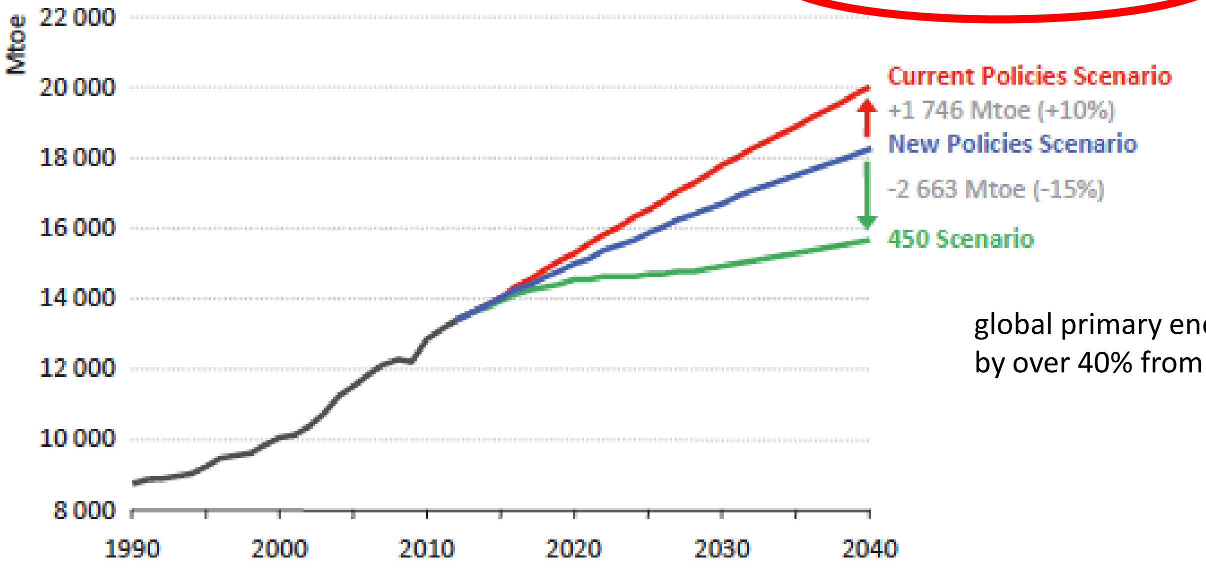
In some regions in 2014 (65% global emissions)



Notes: The implicit CO_2 subsidy is calculated as the ratio of the economic value of those subsidies to the CO_2 emissions released from subsidised energy consumption. ETS = emissions trading scheme.

GHG mitigation needs to address energy demand trends

Figure 2.1 ▷ World total primary energy demand by scenario

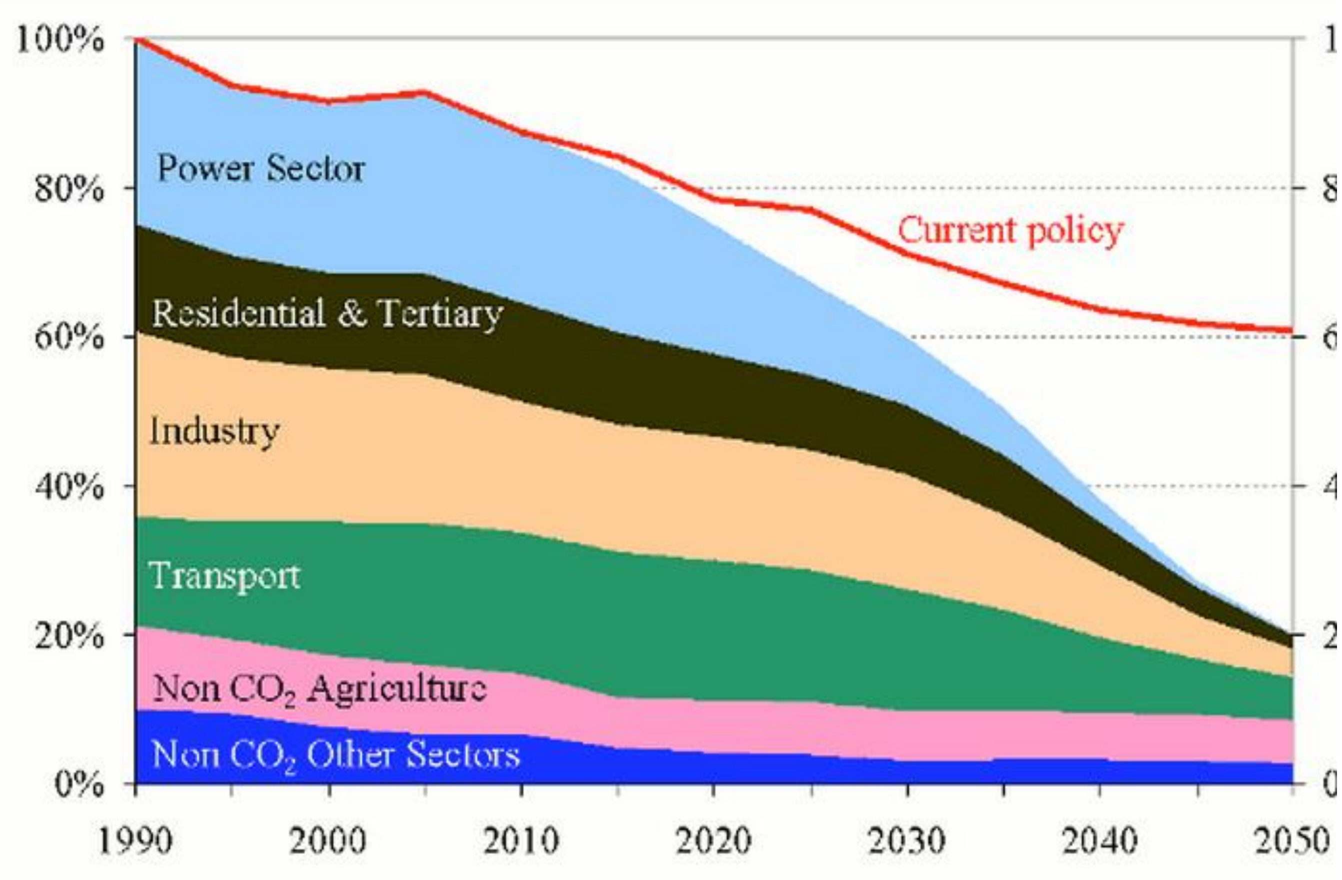


global primary energy demand rises by over 40% from now to 2040

	Current Policies Scenario	New Policies Scenario	450 Scenario	Efficient World Scenario
Definitions	Government policies that had been enacted or adopted by mid-2012 continue unchanged.	Existing policies are maintained and recently announced commitments and plans, including those yet to be formally adopted, are implemented in a cautious manner.	Policies are adopted that put the world on a pathway that is consistent with having around a 50% chance of limiting the global increase in average temperature to 2 °C in the long term, compared with pre-industrial levels.	All energy efficiency investments that are economically viable are made and all necessary policies to eliminate market barriers to energy efficiency are adopted.

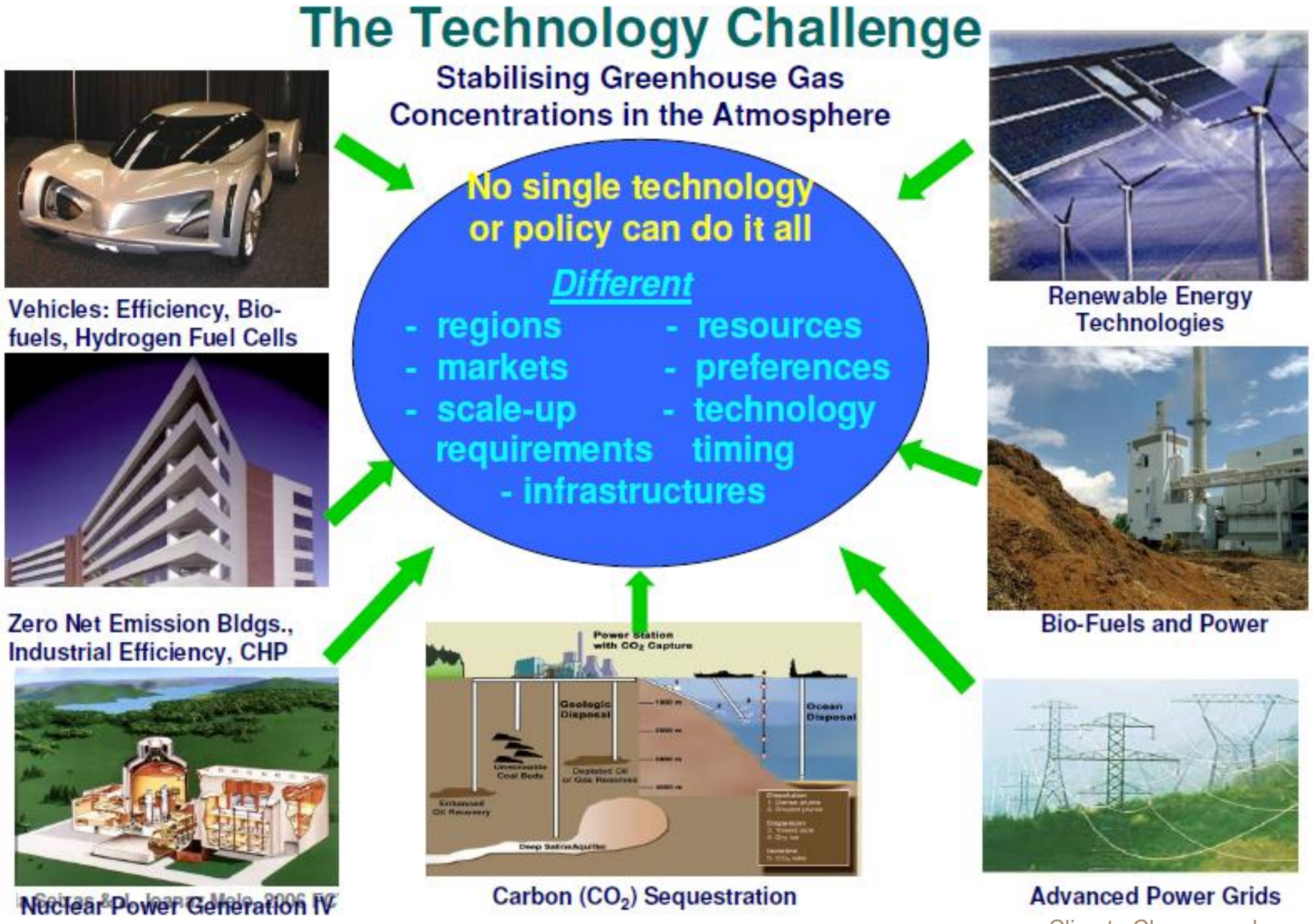
The magnitude of the mitigation effort is huge

EU's Energy roadmap for moving to a low Carbon economy



http://ec.europa.eu/clima/policies/roadmap/index_en.htm

GHG emission mitigation should consider the whole technological possibilities



Low carbon technologies – no quick shift?

Also need to address demand-side

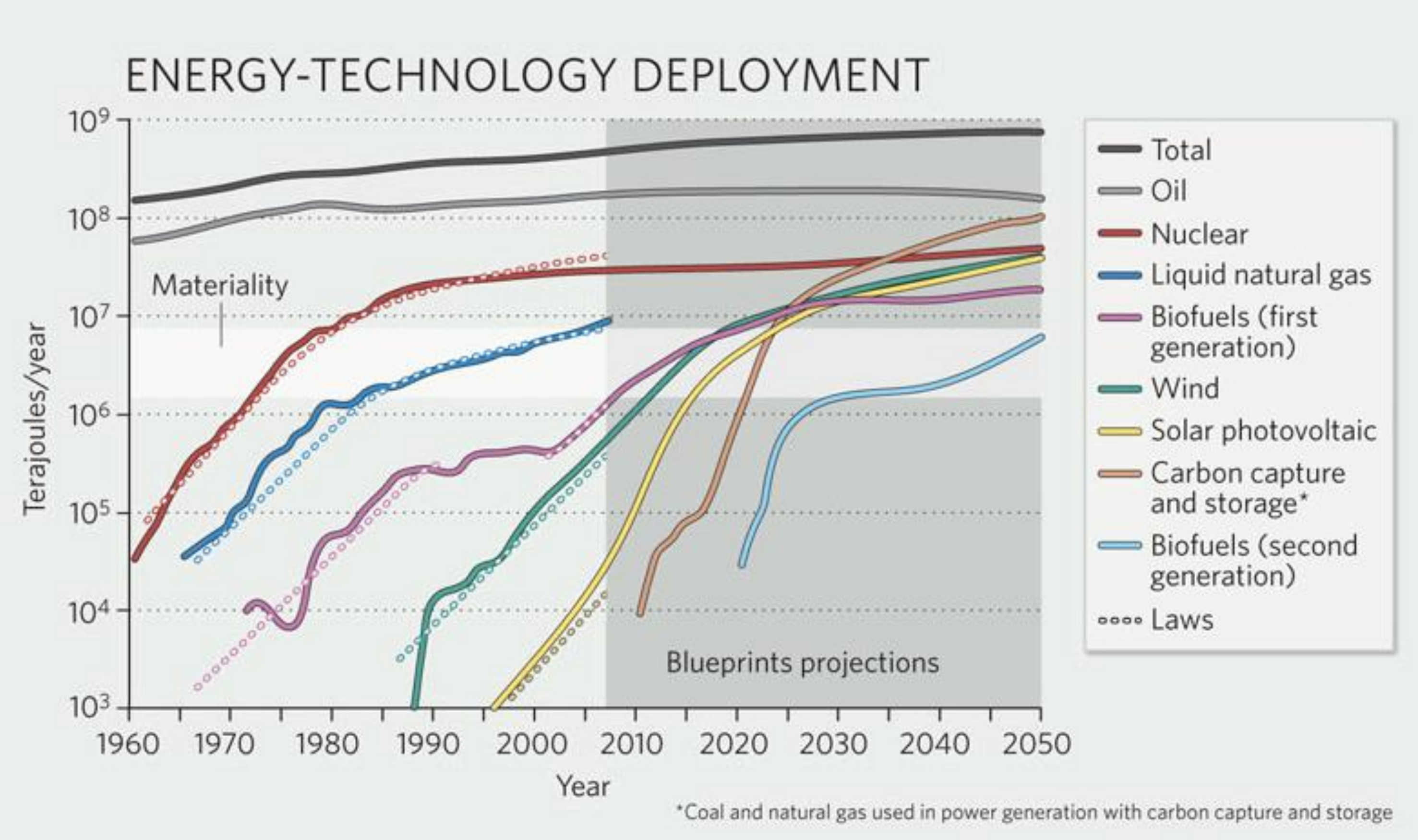
Box 1: The laws of energy-technology deployment *(it is not like mobile phones!!!)*

Law 1

When technologies **are new,** they go through a **few decades of exponential growth**, which in the twentieth century was characterized by scale-up at a rate of one order of magnitude a decade (corresponding to 26% annual growth). **Exponential growth proceeds until the energy source becomes 'material'** — typically around 1% of world energy.

Law 2

After **'materiality', growth changes to linear** as the technology settles at a market share. These deployment curves are remarkably similar across different technologies



Kramer, G., Haigh, M. No quick switch to low-carbon energy. Nature 462, 568–569 (2009). https://doi.org/10.1038/462568a

“more action is required on the **demand side to increase efficiency and curtail consumption**. The good news is that demand-side solutions are subject to different laws. In principle, everyone in the developed world could use less energy tomorrow. The bad news is that it has proven exceedingly difficult to restrain our appetite for more energy. ”

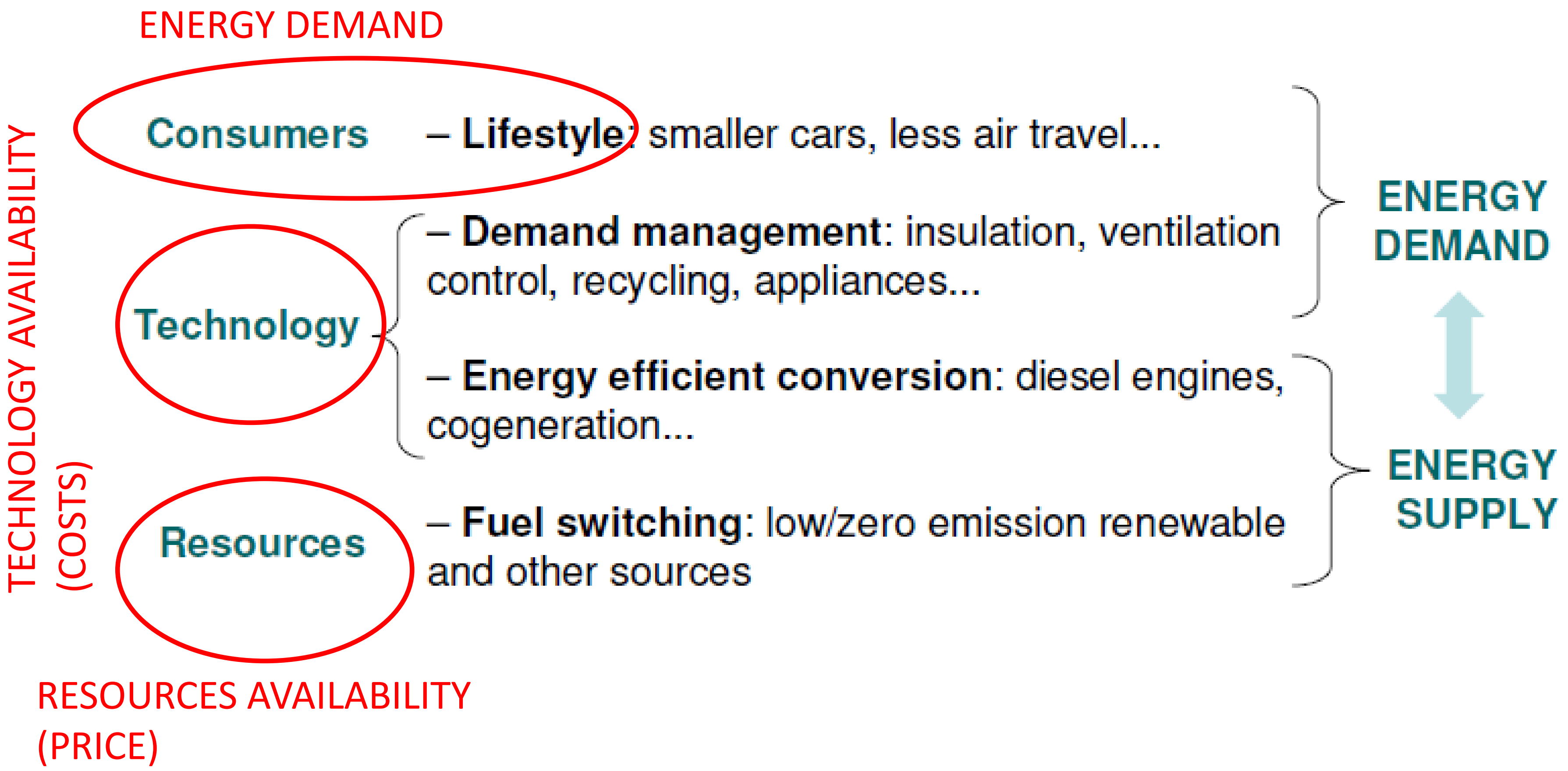
Never forget the varied energy demand drivers

- Level of economic activity
- Demographic trends
- Energy price
- Efficiency of current energy technologies improvement and new technologies

Energy demand = Population * GDP/Capita * Energy/GDP

GDP/Capita – Development Index
Energy/GDP – Energy Intensity

Where can we act for GHG emission mitigation?



GHG emission mitigation has to deal with energy system complexity

HOW TO DEAL WITH THE COMPLEXITY OF ENERGY SYSTEM?

 # GREENHOUSE GAS EMISSIONS AND CLIMATE CHANGE
 # ENERGY SECURITY AND ENERGY ACCESS
 # INCREASING ENERGY CONSUMPTION TRENDS
 # ENERGY RESOURCES DEPLETION

The tools

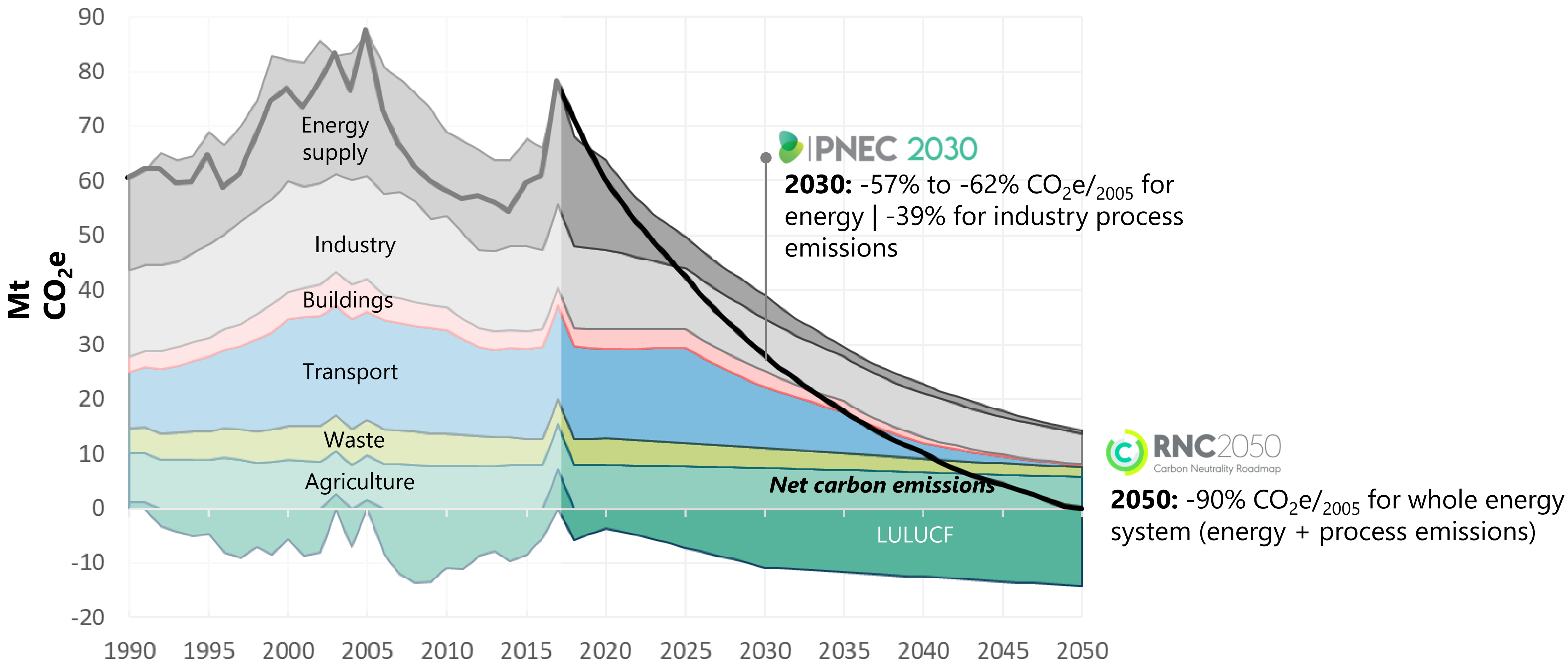
 # How to reason on such complexity?
 # What methods to assess and project energy systems into the future?
 # What type of solutions to achieve sustainable energy systems?

Outline

- (Recap) some basic energy concepts

  Primary/final energy; energy efficiency; Energy services; Energy carriers; Final energy supply cost curves; learning curves of energy technologies; Energy security & endogenous vs. imported resources; Sankey diagrams;
- Sustainability issues related with energy (& renewables): land and & water use, materials use
- GHG emission mitigation
- **Discussion: Where to place 7GW of solar PV in Portugal till 2030?**

On the way to carbon neutrality



Fonte: **P. Fortes (NOVA-FCT)** em Simões, S., Fortes, P., Amorim, F. (2021) USO DE MATERIAIS PARA A DESCARBONIZAÇÃO DO SISTEMA ENERGÉTICO PORTUGUÊS. Webinar / Palestra LNEG ONLINE. 11 maio 2021

Climate Change and Sustainable Development Policies

Evolution in installed capacity for Portugal

	2019	2030	2050
Solar	0.8 GW	+8GW	+21GW / +45 GW
Wind	5.44 GW	+3.5 GW	+11GW/ +15 GW

PNEC 2030 PLANO NACIONAL ENERGIA E CLIMA

RNC2050 Carbon Neutrality Roadmap

Energy Scenarios in support of the EN H2 National Strategy for Hydrogen. Supporting scenarios - should not be considered as targets or goals!!!

Climate Change and Sustainable Development Policies

LNEG

NOVA SCHOOL OF SCIENCE & TECHNOLOGY

CENSE center for environmental and sustainability research

On the way to carbon neutrality…

- Land use
- Water needs
- Minerals and other materials
- Endogenous Energy resources

Which determinants affect (environmental) permitting process?

- Industrial hazards
- Water sources for electrolysis
- Industry emissions
- (...)

Which criteria determine potential location exclusion from land management point of view?

- Nature protected areas
- Urban areas
- Agriculture areas
- (...)

Which possibilities regarding available infrastructure for storing, transporting and distribution of H_2?

- Distance to consumers
- Gas grid injection points
- Other transport possibilities
- Storage in salt caverns

Which options to input electrolysis with renewable electricity?

- Solar power
- Wind power
- Hydropower
- Bioenergy power
- Distance to power grid

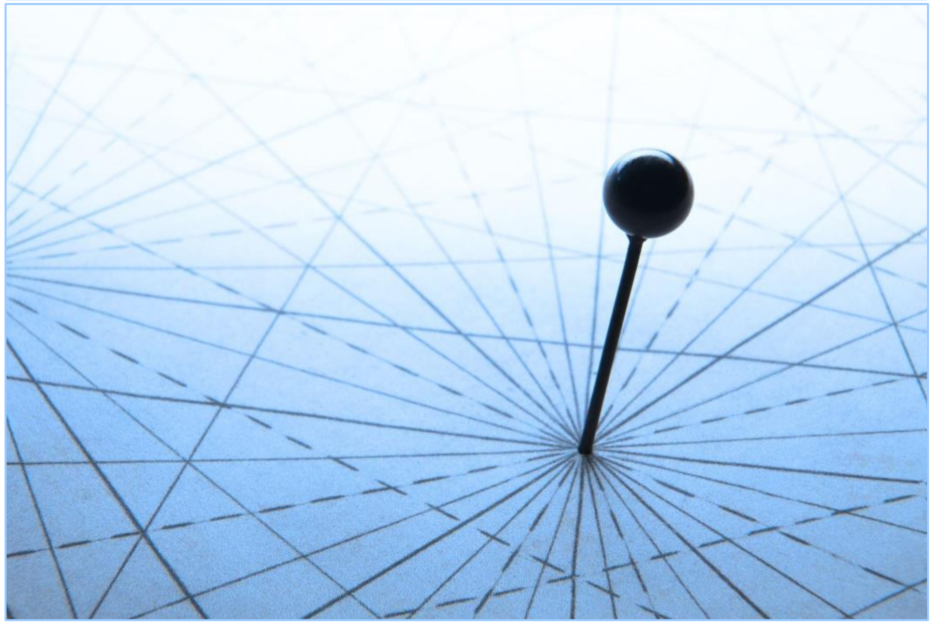
Define criteria for assessing adequacy of green H_2 production plant's location

Mapping and assessing land use restrictions

Alternative scenarios for assessing location suitability

Portuguese Atlas for Sustainable Green H_2

LNEG

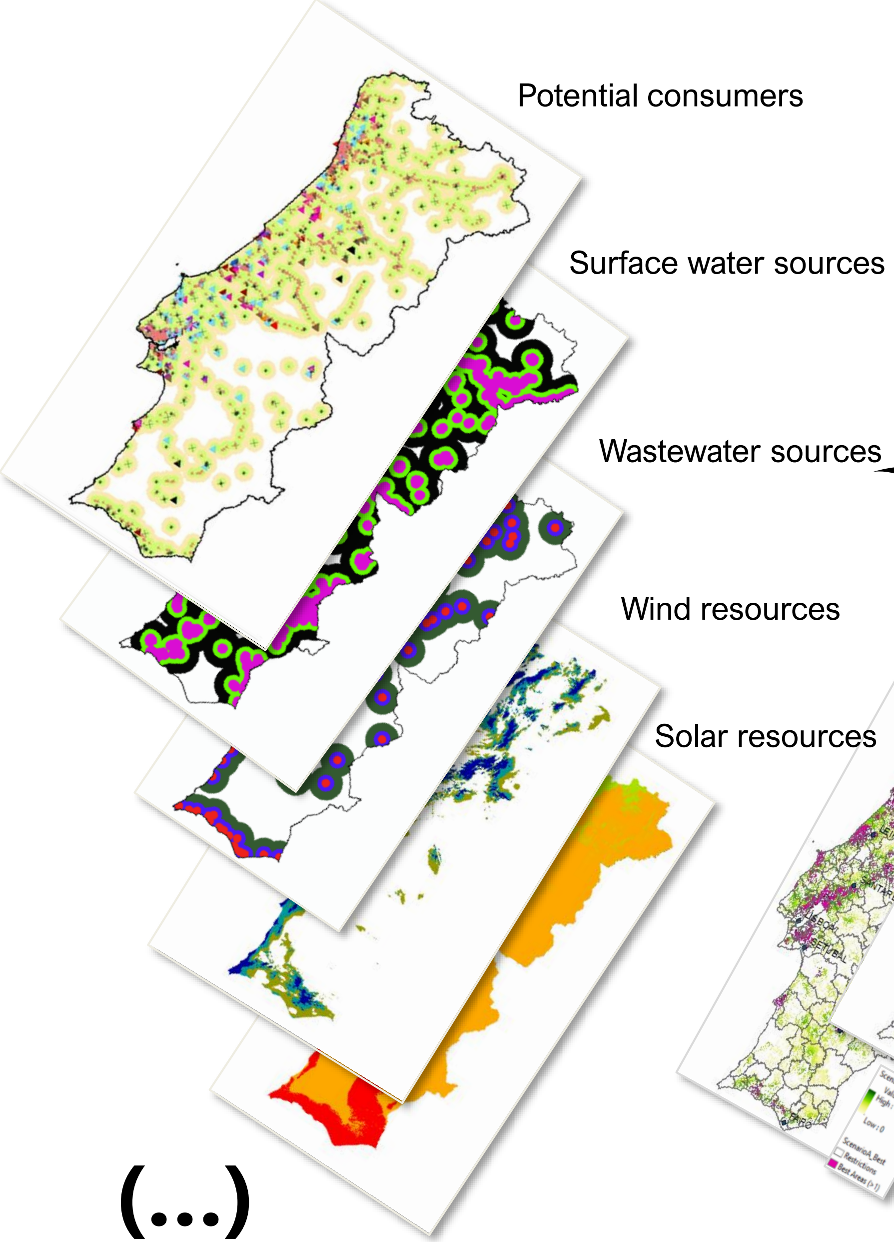


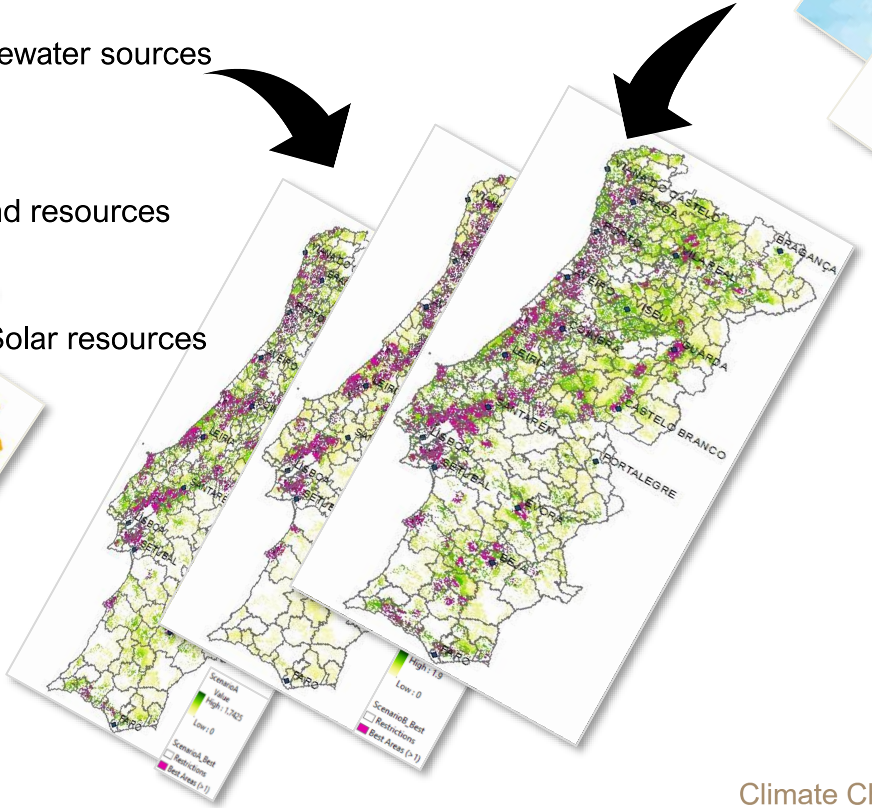
Climate Change and Sustainable Development Policies

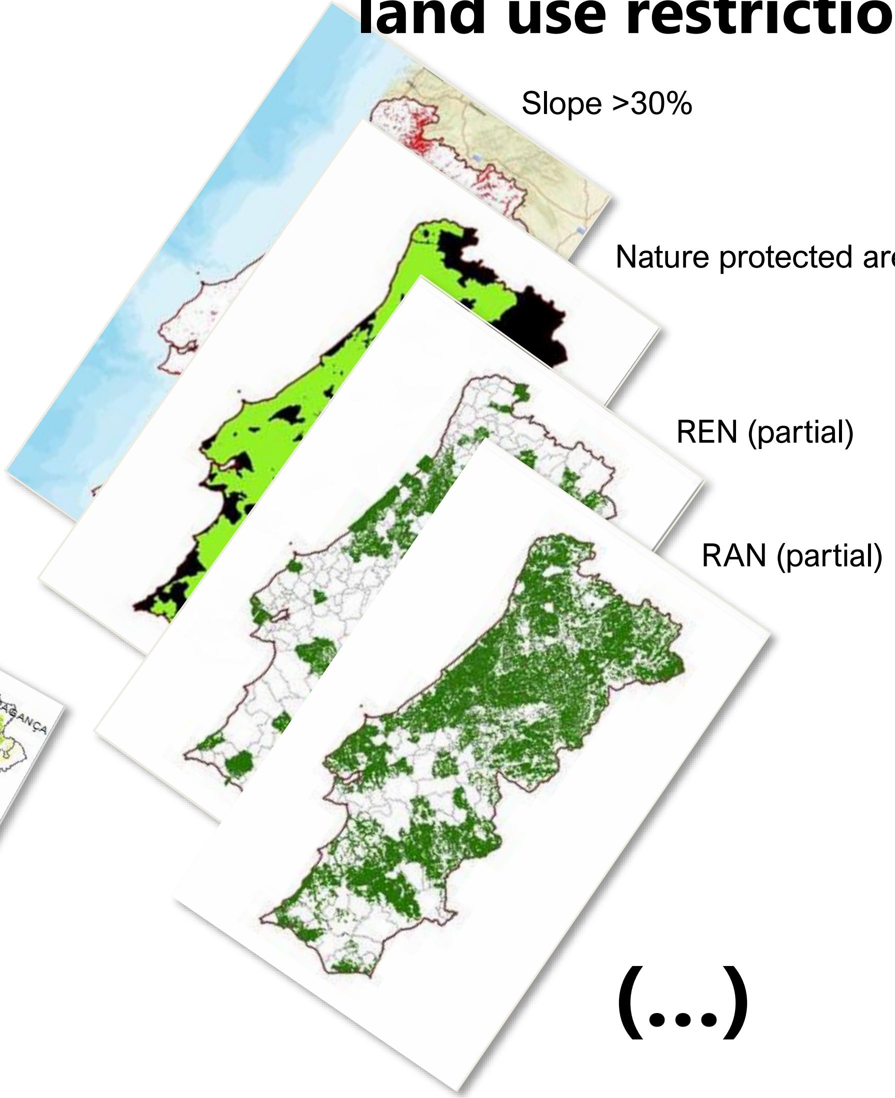
LNEG | NOVA SCHOOL OF SCIENCE & TECHNOLOGY | CENSE center for environmental and sustainability research

water, energy, market

land use restrictions





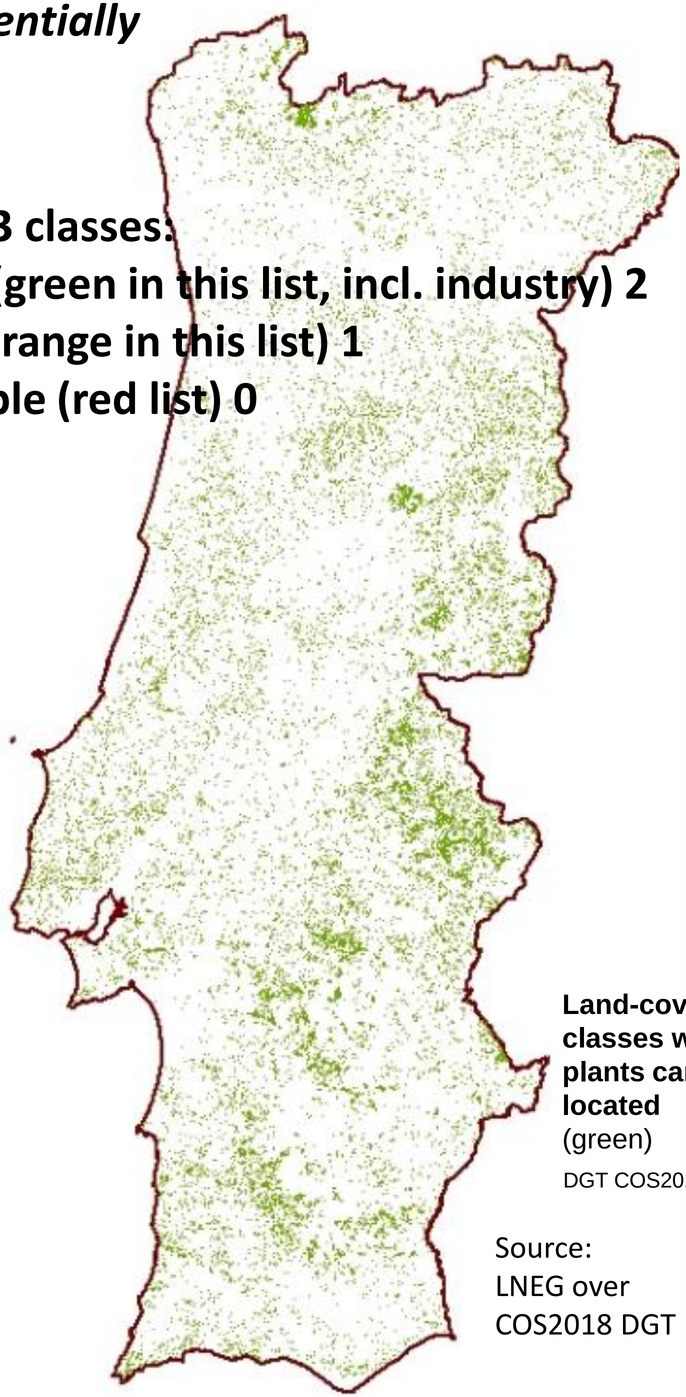


Climate Change and Sustainable Development Policies

Land-cover/use classes where plants can potentially be located (green and orange below)

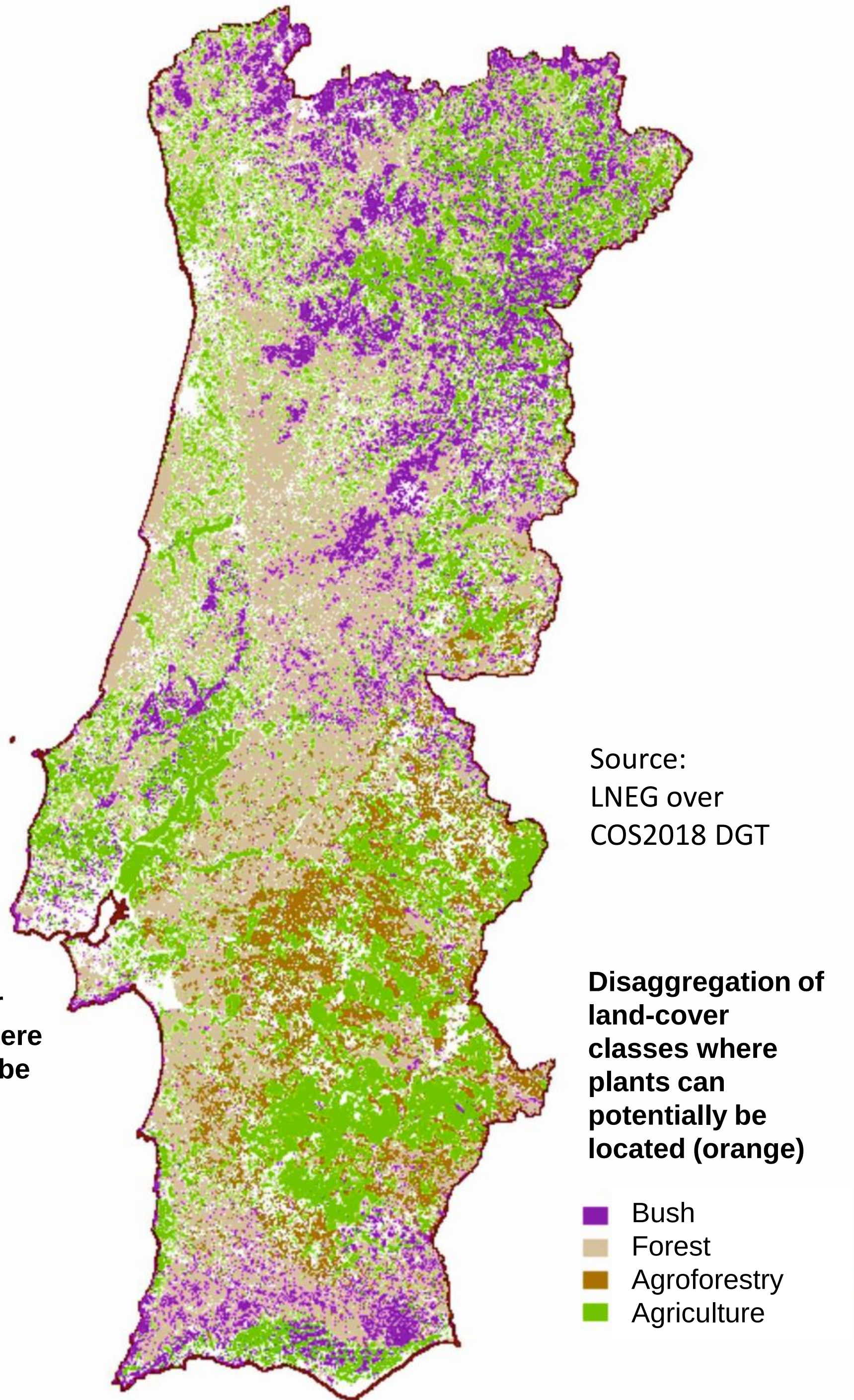
1. Industry
2. Polygons with culturally complex plots
3. Agriculture with natural and semi-natural areas
4. Improved pastures
5. Spontaneous pastures
6. Sparse vegetation
7. Temporary rainfed and irrigated crops
8. Protected agriculture and nurseries
9. Rice fields
10. Vineyards
11. Orchards
12. Olive groves
13. Temporary cultures and /or improved pasture lands associated to vineyards
14. Temporary cultures and /or improved pasture lands associated to orchards
15. Temporary cultures and /or improved pasture lands associated to olive groves
16. Cork trees agroforestry zones (SAF)
17. Holm oak (azinheira) trees agroforestry zones (SAF)
18. Other oak trees agroforestry zones (SAF)
19. Stone pine (pinheiro manso) trees agroforestry zones (SAF)
20. Other species agroforestry zones (SAF)
21. Stone pine and holm oak trees agroforestry zones (SAF)
22. Other mixed agroforestry zones (SAF)
23. Cork trees forest
24. Holm oak forests
25. Other oaks forests
26. Chestnut forests
27. Eucalyptus forests
28. Exotic species forests
29. Other hardwood forests
30. Pine forests
31. Stone pine forests
32. Other resinous forests
33. Bushes

MAP WITH 3 classes:
Class Good (green in this list, incl. industry) 2
Class Fair (Orange in this list) 1
Class Unviable (red list) 0



Land-cover classes where plants can be located (green)
DGT COS2018

Source:
LNEG over
COS2018 DGT

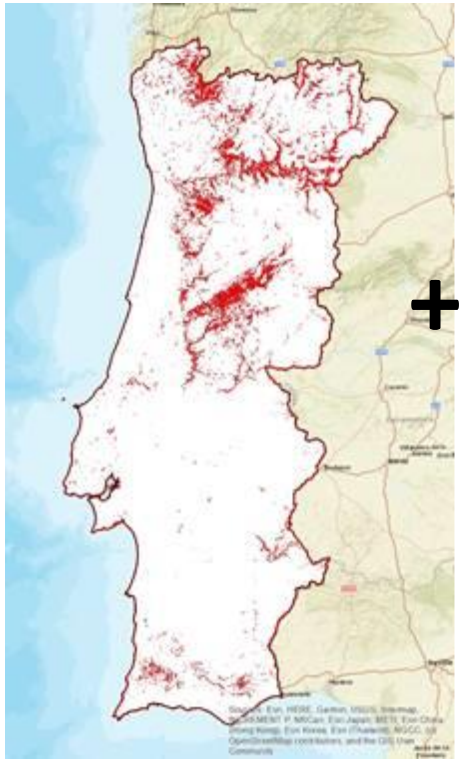


Source:
LNEG over
COS2018 DGT

Disaggregation of land-cover classes where plants can potentially be located (orange)

Find best locations considering:

- **land cover & use restrictions**



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Slope >30%

Nature protected areas Network & Natura 2000

LNEG over ICNF

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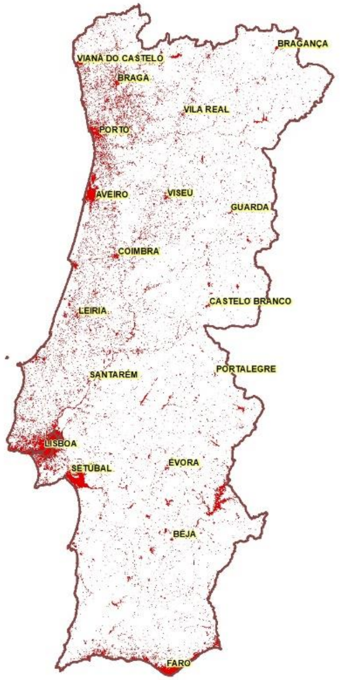


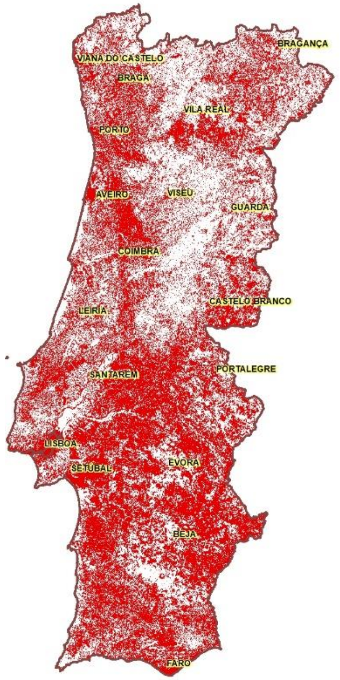
Land-cover classes where plants cannot be located

(red)

LNEG over DGT COS2018

Excludes inadequate terrain

or



Land-cover classes where plants cannot located

(red)

LNEG over DGT COS2018

Excludes traditional forests

REPowerEU: Joint European Action for more affordable, secure and sustainable energy

8 março 2022

EUROPEAN COMMISSION

Strasbourg, 8.3.2022
COM(2022) 108 final

COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE EUROPEAN COUNCIL, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS

REPowerEU: Joint European Action for more affordable, secure and sustainable energy

*“**Member States should swiftly map, assess and ensure suitable land and sea areas that are available for renewable energy projects**, commensurate with their national energy and climate plans, the contributions towards the revised 2030 renewable energy target and other factors such as the availability of resources, grid infrastructure and the targets of the EU Biodiversity Strategy. The Commission will propose in the upcoming nature restoration law proposal that Member States should, when preparing their national plans to meet restoration targets, take into account limited and clearly defined areas as particularly suitable (‘go-to’ areas), while avoiding as much as possible environmentally valuable areas. Member States can use the review of their plans under the Maritime Spatial Planning Directive to further the deployment of renewable energy projects.”*

https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2022%3A108%3AFIN

http://transrisk-project.eu/sites/default/files/Documents/4.4.6_Land-use%20impacts%20from%20renewable%20energy%20policies.pdf

Key information you should have apprehended after the class

- Primary/final energy
- Energy efficiency
- Energy services & Energy carriers
- Final energy supply cost curves; learning curves of energy technologies
- Energy security & endogenous vs. imported resources
- Land and & water needs for low carbon power
- Portfolio of options for GHG emission mitigation (technology on supply and demand-side)