



NORWEGIAN PETROLEUM  
DIRECTORATE  
50 years

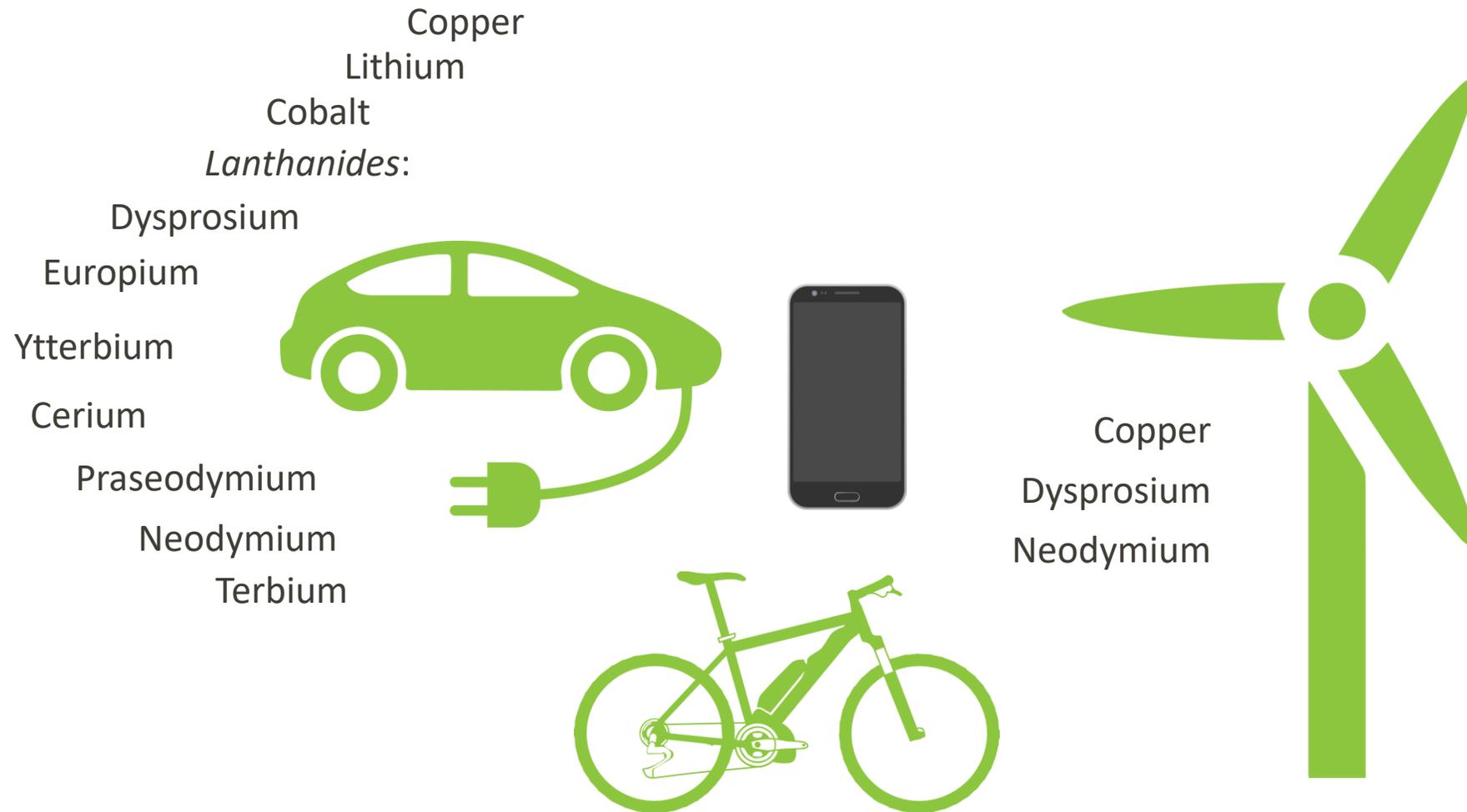
# Seabed Minerals

Harald Brekke



# Electricity Demands Metals

# Examples of necessary elements in a modern world



# Some Critical Metals - IEA



## Critical mineral needs for clean energy technologies

	Copper	Cobalt	Nickel	Lithium	REEs	Chromium	Zinc	PGMs	Aluminium
Solar PV	●	●	●	●	●	●	●	●	●
Wind	●	●	●	●	●	●	●	●	●
Hydro	●	●	●	●	●	●	●	●	●
CSP	●	●	●	●	●	●	●	●	●
Bioenergy	●	●	●	●	●	●	●	●	●
Geothermal	●	●	●	●	●	●	●	●	●
Nuclear	●	●	●	●	●	●	●	●	●
Electricity networks	●	●	●	●	●	●	●	●	●
EVs and battery storage	●	●	●	●	●	●	●	●	●
Hydrogen	●	●	●	●	●	●	●	●	●

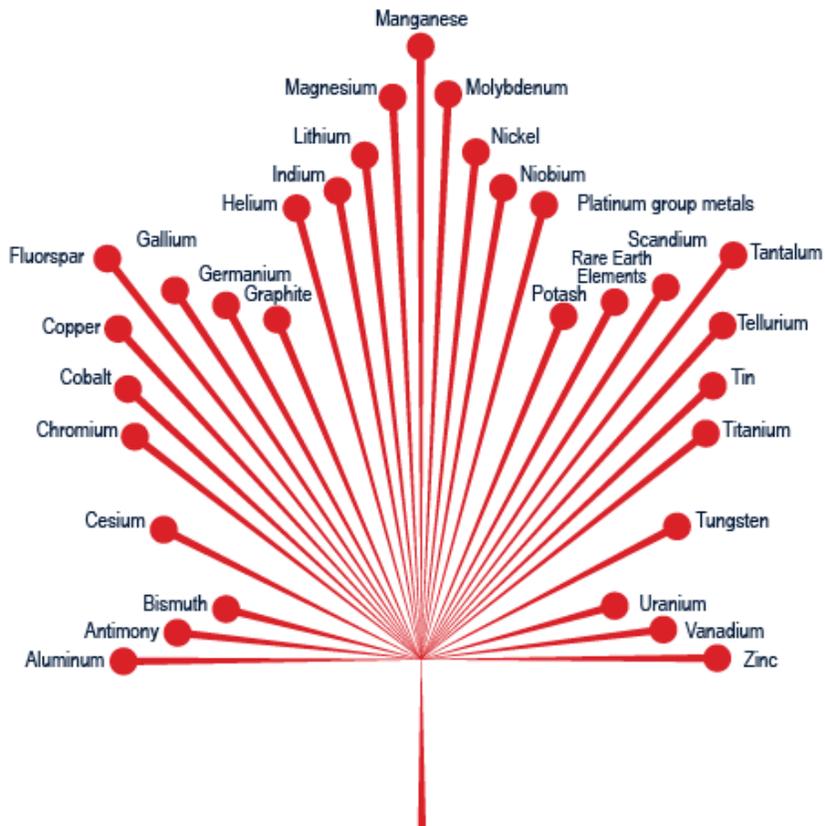
Relative importance of minerals for a particular clean energy technology:

High: ● Moderate: ● Low: ●

Shading indicates the relative importance of minerals for a particular clean energy technology, which are discussed in their respective sections in this chapter. CSP = concentrating solar power; REEs = rare earth elements; PGM = platinum group metals. \* In this report, aluminium demand is assessed for electricity networks only and is not included in the aggregate demand projections.

IEA [The Role of Critical Minerals in Clean Energy Transitions \(windows.net\)](https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions)

# Critical Metals - Canada



## CANADA'S CRITICAL MINERALS LIST 2021

ESSENTIAL TO CANADA'S ECONOMIC SECURITY

REQUIRED FOR CANADA'S TRANSITION TO A LOW-CARBON ECONOMY

A SUSTAINABLE SOURCE OF CRITICAL MINERALS FOR OUR PARTNERS

### PERIODIC TABLE OF THE ELEMENTS

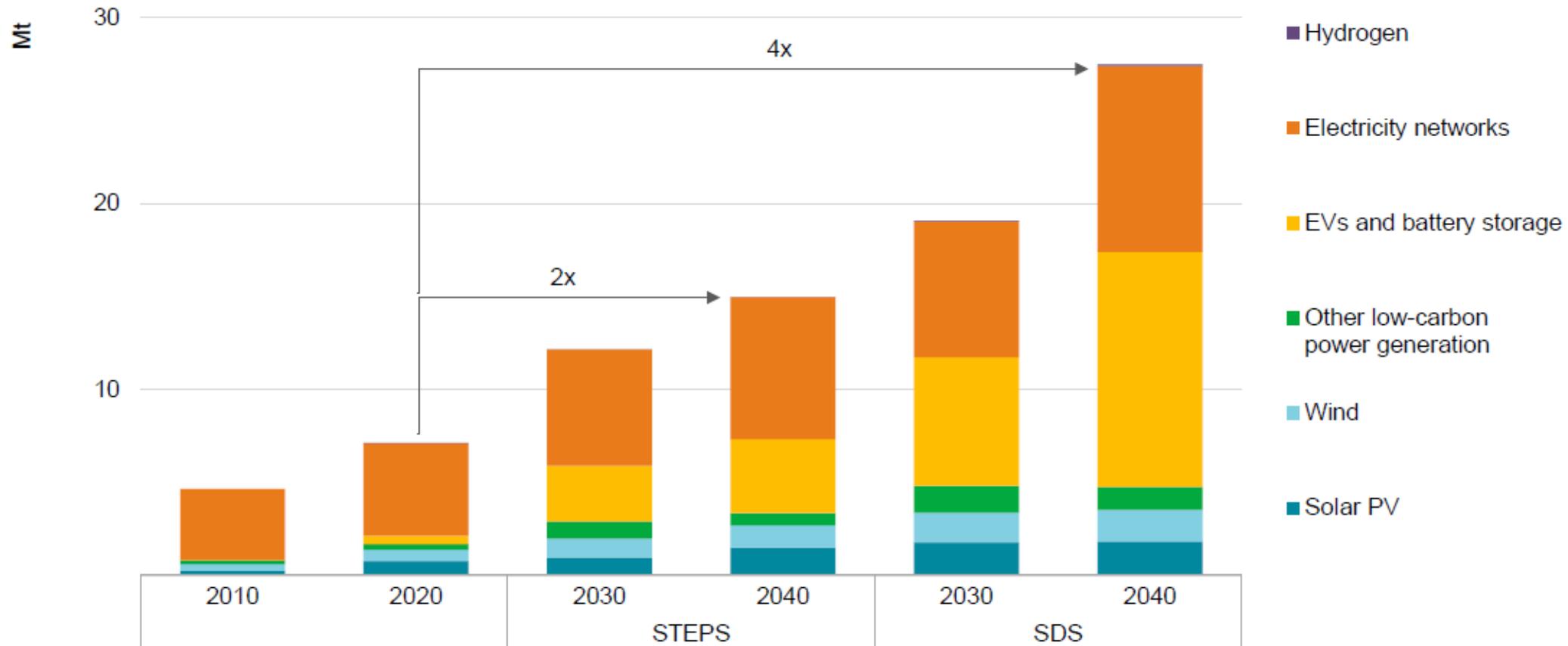
1 H Hydrogen 1.008																	2 He Helium 4.003																														
3 Li Lithium 6.941	4 Be Beryllium 9.012											5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.180																														
11 Na Sodium 22.990	12 Mg Magnesium 24.305											13 Al Aluminum 26.982	14 Si Silicon 28.086	15 P Phosphorus 30.974	16 S Sulfur 32.065	17 Cl Chlorine 35.453	18 Ar Argon 39.948																														
19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956	22 Ti Titanium 47.867	23 V Vanadium 50.942	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.845	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.390	31 Ga Gallium 69.723	32 Ge Germanium 72.640	33 As Arsenic 74.922	34 Se Selenium 78.960	35 Br Bromine 79.904	36 Kr Krypton 83.800																														
37 Rb Rubidium 85.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.939	43 Tc Technetium 98.000	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.905	46 Pd Palladium 106.42	47 Ag Silver 107.868	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.710	51 Sb Antimony 121.760	52 Te Tellurium 127.60	53 I Iodine 126.905	54 Xe Xenon 131.29																														
55 Cs Cesium 132.905	56 Ba Barium 137.327	57-71 Lanthanides	72 Hf Hafnium 178.49	73 Ta Tantalum 180.948	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.222	78 Pt Platinum 195.078	79 Au Gold 196.967	80 Hg Mercury 200.59	81 Tl Thallium 204.383	82 Pb Lead 207.2	83 Bi Bismuth 208.980	84 Po Polonium 209	85 At Astatine 210	86 Rn Radon 222																														
87 Fr Francium 223	88 Ra Radium 226	89-103 Actinides	104 Rf Rutherfordium 261	105 Db Dubnium 262	106 Sg Seaborgium 266	107 Bh Bohrium 264	108 Hs Hassium 277	109 Mt Meitnerium 276	110 Ds Darmstadtium 285	111 Rg Roentgenium 282	112 Cn Copernicium 285	113 Nh Nihonium 284	114 Fl Flerovium 289	115 Mc Moscovium 288	116 Lv Livermorium 293	117 Ts Tennessine 294	118 Og Oganesson 294																														
<table border="1"> <tr> <td>57 La Lanthanum 138.905</td> <td>58 Ce Cerium 140.116</td> <td>59 Pr Praseodymium 140.908</td> <td>60 Nd Neodymium 144.24</td> <td>61 Pm Promethium 145.000</td> <td>62 Sm Samarium 150.36</td> <td>63 Eu Europium 151.964</td> <td>64 Gd Gadolinium 157.25</td> <td>65 Tb Terbium 158.925</td> <td>66 Dy Dysprosium 162.50</td> <td>67 Ho Holmium 164.930</td> <td>68 Er Erbium 167.257</td> <td>69 Tm Thulium 168.934</td> <td>70 Yb Ytterbium 173.046</td> <td>71 Lu Lutetium 174.967</td> </tr> <tr> <td>89 Ac Actinium 227</td> <td>90 Th Thorium 232.038</td> <td>91 Pa Protactinium 231.036</td> <td>92 U Uranium 238.029</td> <td>93 Np Neptunium 237</td> <td>94 Pu Plutonium 244</td> <td>95 Am Americium 243</td> <td>96 Cm Curium 247</td> <td>97 Bk Berkelium 247</td> <td>98 Cf Californium 251</td> <td>99 Es Einsteinium 252</td> <td>100 Fm Fermium 257</td> <td>101 Md Mendelevium 258</td> <td>102 No Nobelium 259</td> <td>103 Lr Lawrencium 262</td> </tr> </table>																		57 La Lanthanum 138.905	58 Ce Cerium 140.116	59 Pr Praseodymium 140.908	60 Nd Neodymium 144.24	61 Pm Promethium 145.000	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.925	66 Dy Dysprosium 162.50	67 Ho Holmium 164.930	68 Er Erbium 167.257	69 Tm Thulium 168.934	70 Yb Ytterbium 173.046	71 Lu Lutetium 174.967	89 Ac Actinium 227	90 Th Thorium 232.038	91 Pa Protactinium 231.036	92 U Uranium 238.029	93 Np Neptunium 237	94 Pu Plutonium 244	95 Am Americium 243	96 Cm Curium 247	97 Bk Berkelium 247	98 Cf Californium 251	99 Es Einsteinium 252	100 Fm Fermium 257	101 Md Mendelevium 258	102 No Nobelium 259	103 Lr Lawrencium 262
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www.periodictable.co.za | Designed by Mia Viljoen

# Total mineral demand from clean energy technologies is set to double in the STEPS and quadruple in the SDS by 2040



Total mineral demand for clean energy technologies by scenario



STEPS = Stated Policies Scenario, SDS = Sustainable Development Scenario

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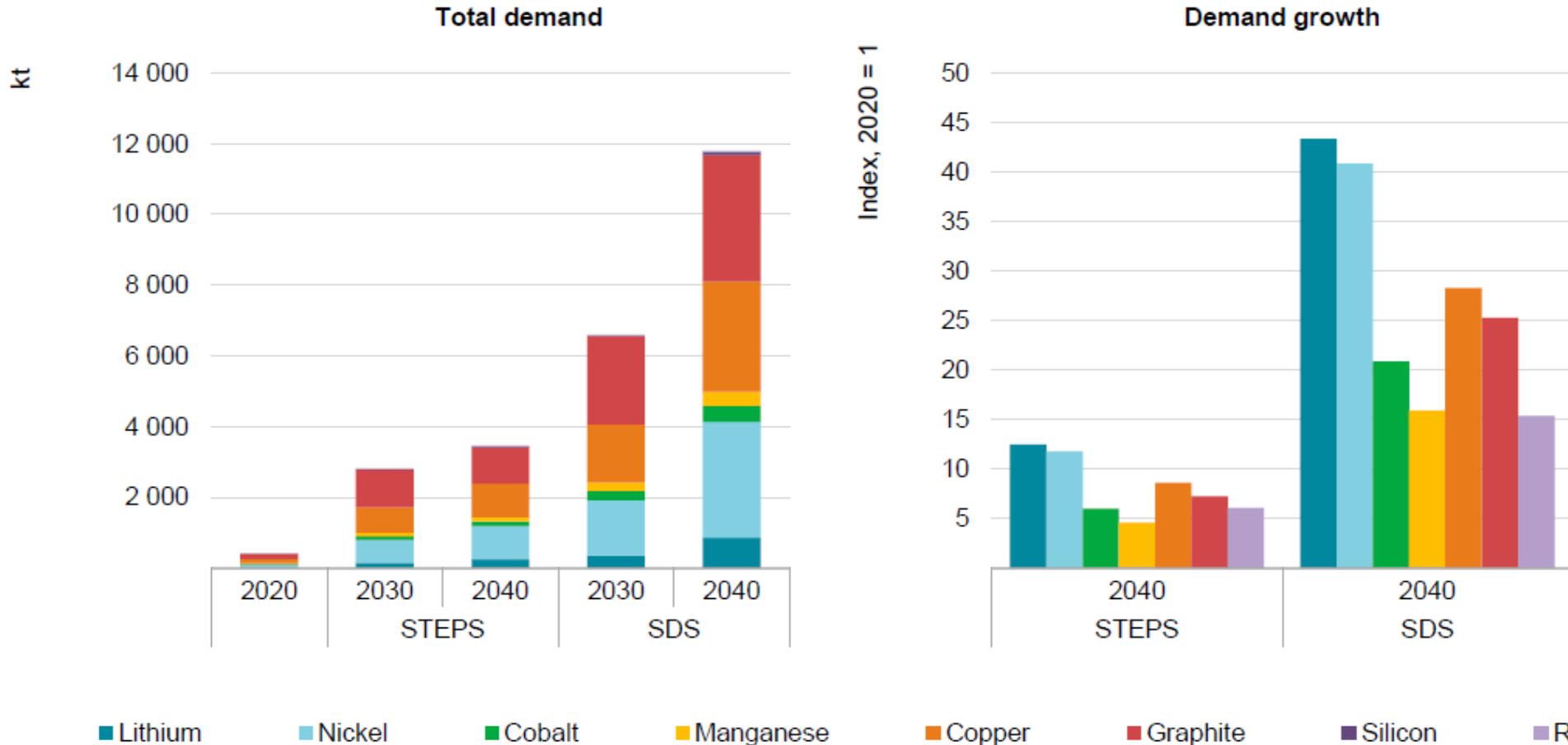
Notes: Includes all minerals in the scope of this report, including chromium, copper, major battery metals (lithium, nickel, cobalt, manganese and graphite), molybdenum, platinum group metals, zinc, REEs and others, but does not include steel and aluminium (see Annex for a full list of minerals). Mt = million tonnes.

[The Role of Critical Minerals in Clean Energy Transitions \(windows.net\)](https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions)

# Mineral demand for EVs in the SDS grows by nearly 30 times between 2020 and 2040, with demand for lithium and nickel growing by around 40 times



Mineral demand from new EV sales



STEPS = Stated Policies Scenario, SDS = Sustainable Development Scenario

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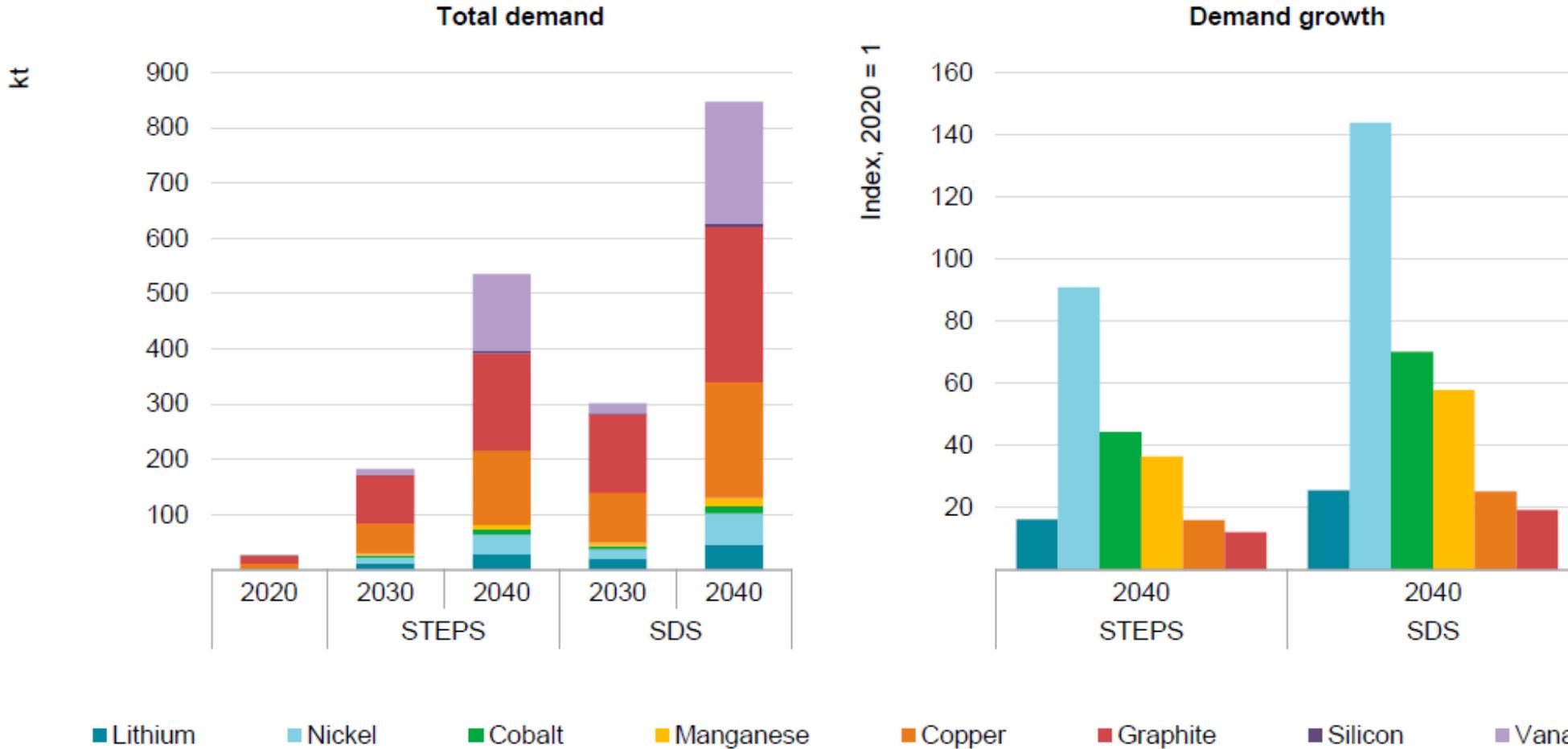
Note: Silicon is excluded from the demand growth graph due to its very high growth (over 500-fold increase), starting from a low base.

[The Role of Critical Minerals in Clean Energy Transitions \(windows.net\)](https://www.iea.org/publications-and-resources/publications/critical-minerals)

# Mineral demand for storage in the SDS grows by over 30 times between 2020 and 2040, with demand for nickel and cobalt growing by 140 times and 70 times respectively



Mineral demand from battery storage additions in the SDS



STEPS = Stated Policies Scenario, SDS = Sustainable Development Scenario

Note: Silicon and vanadium are excluded from the demand growth graph.

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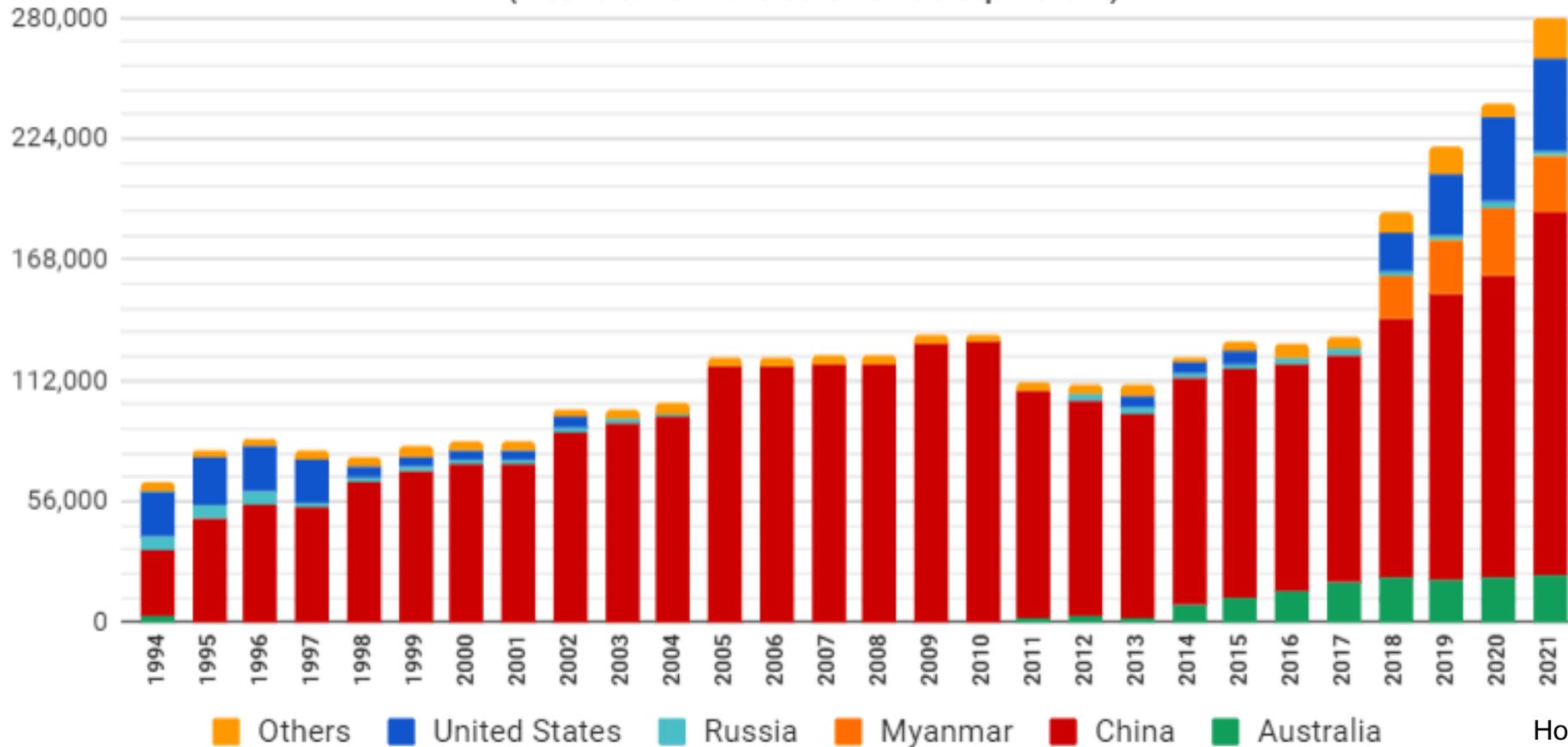
[The Role of Critical Minerals in Clean Energy Transitions \(windows.net\)](https://www.iea.org/publications-and-resources/publications/the-role-of-critical-minerals-in-clean-energy-transitions)

# REE Production



## Rare Earth Element Production

(Metric tons - rare earth oxide equivalent)



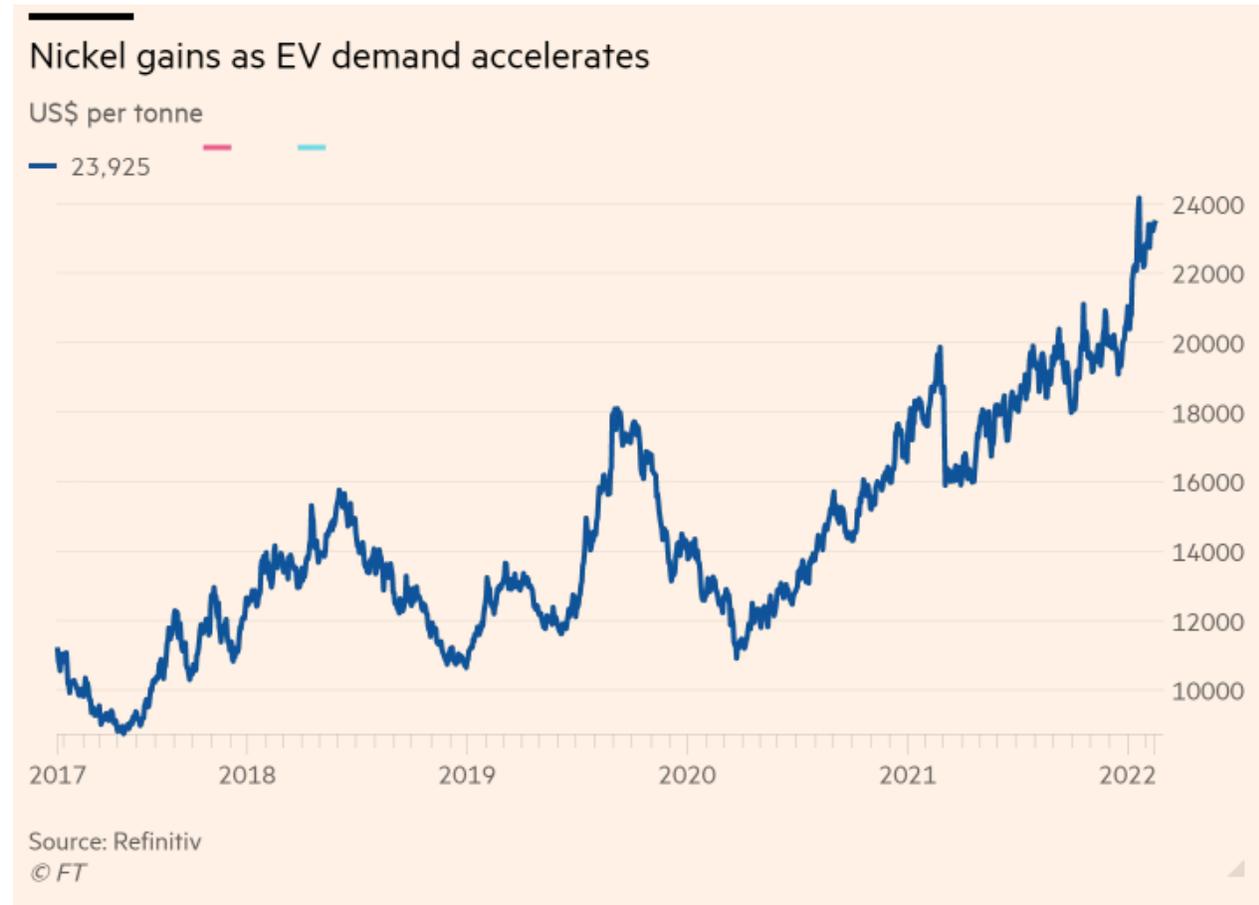
Hobart M. King, Geology.com

# Copper Prices



[Is there a new supercycle in metals and minerals? | Financial Times \(ft.com\)](#)

# Nickel Prices



[Is there a new supercycle in metals and minerals? | Financial Times \(ft.com\)](#)

# Nickel and Cobalt Prices



## Nickel and cobalt prices surge amid fear for Russian supply disruptions

Prices in USD/T over the last ten years



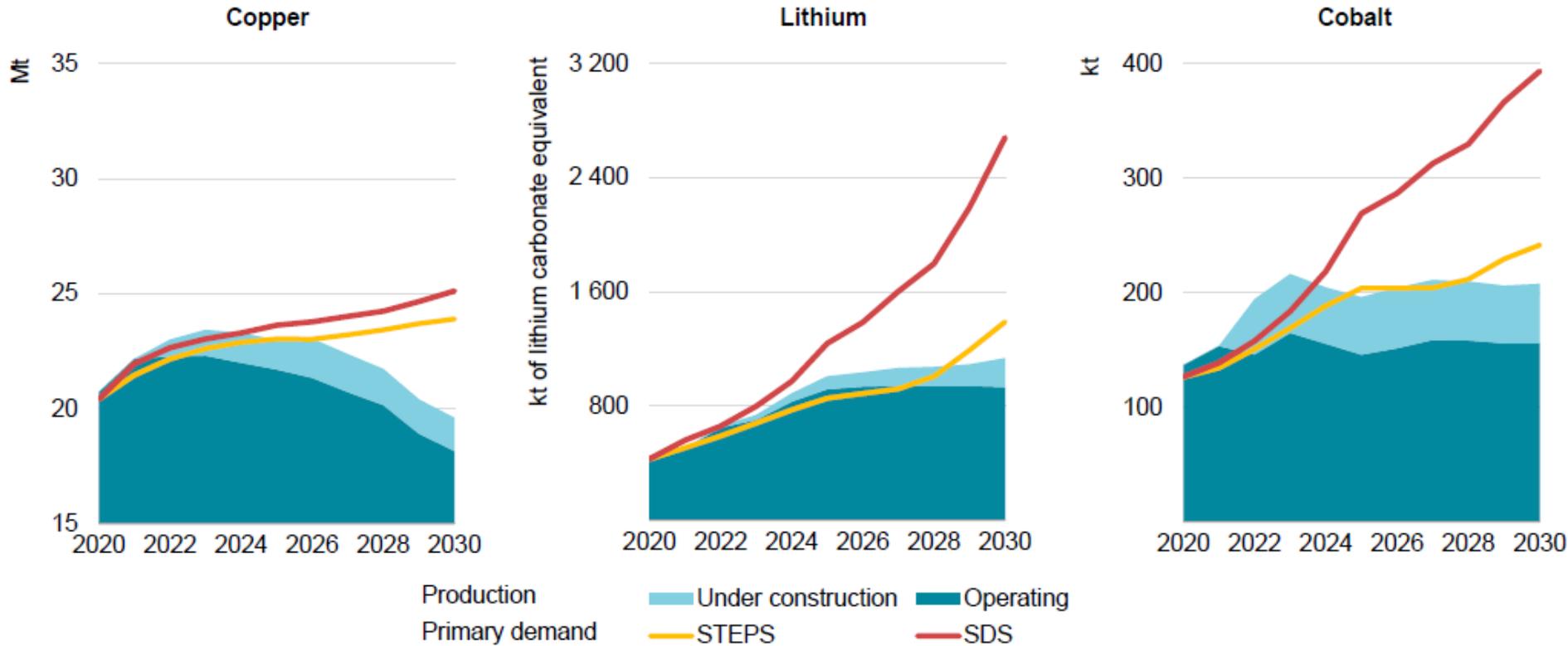
Source: Trading Economics

Mining Technology

# Meeting primary demand in the SDS requires strong growth in investment to bring forward new supply sources over the next decade



Committed mine production and primary demand for selected minerals



STEPS = Stated Policies Scenario, SDS = Sustainable Development Scenario

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Notes: Primary demand is total demand net of recycled volume (also called primary supply requirements). Projected production profiles are sourced from the S&P Global Market Intelligence database with adjustments to unspecified volumes. Operating projects include the expansion of existing mines. Under-construction projects include those for which the development stage is indicated as commissioning, construction planned, construction started or preproduction. Mt = million tonnes.

Source: IEA analysis based on S&P Global (2021).

[The Role of Critical Minerals in Clean Energy Transitions \(windows.net\)](https://www.iea.org/en/topics/energy/energy-transitions/clean-energy-transitions)

# Seabed minerals

# Seabed Minerals – Types and Metal Content

1. Polymetallic Nodules – Ni, Cu, Mn, Co (Mo, REE, Li, Ti)
2. Polymetallic Crusts – Co, Ni, Mn, Cu (Ti, REE, Pt, Mo, Bi, V)
3. Polymetallic Sulphides – Cu, Zn, Au, Ag (Co, Pb, Ga, Ge, In, Sb)

# Some Critical Metals



## Critical mineral needs for clean energy technologies

	Copper	Cobalt	Nickel	Lithium	REEs	Chromium	Zinc	PGMs	Aluminium
Solar PV	●	●	●	●	●	●	●	●	●
Wind	●	●	●	●	●	●	●	●	●
Hydro	●	●	●	●	●	●	●	●	●
CSP	●	●	●	●	●	●	●	●	●
Bioenergy	●	●	●	●	●	●	●	●	●
Geothermal	●	●	●	●	●	●	●	●	●
Nuclear	●	●	●	●	●	●	●	●	●
Electricity networks	●	●	●	●	●	●	●	●	●
EVs and battery storage	●	●	●	●	●	●	●	●	●
Hydrogen	●	●	●	●	●	●	●	●	●

Relative importance of minerals for a particular clean energy technology:

High: ● Moderate: ● Low: ●

Shading indicates the relative importance of minerals for a particular clean energy technology, which are discussed in their respective sections in this chapter. CSP = concentrating solar power; REEs = rare earth elements; PGM = platinum group metals. \* In this report, aluminium demand is assessed for electricity networks only and is not included in the aggregate demand projections.

# Some Critical Metals in Seabed Minerals

## Critical mineral needs for clean energy technologies

	Copper	Cobalt	Nickel	Lithium	REEs	Chromium	Zinc	PGMs	Aluminium
Solar PV	●	●	●	●	●	●	●	●	●
Wind	●	●	●	●	●	●	●	●	●
Hydro	●	●	●	●	●	●	●	●	●
CSP	●	●	●	●	●	●	●	●	●
Bioenergy	●	●	●	●	●	●	●	●	●
Geothermal	●	●	●	●	●	●	●	●	●
Nuclear	●	●	●	●	●	●	●	●	●
Electricity networks	●	●	●	●	●	●	●	●	●
EVs and battery storage	●	●	●	●	●	●	●	●	●
Hydrogen	●	●	●	●	●	●	●	●	●

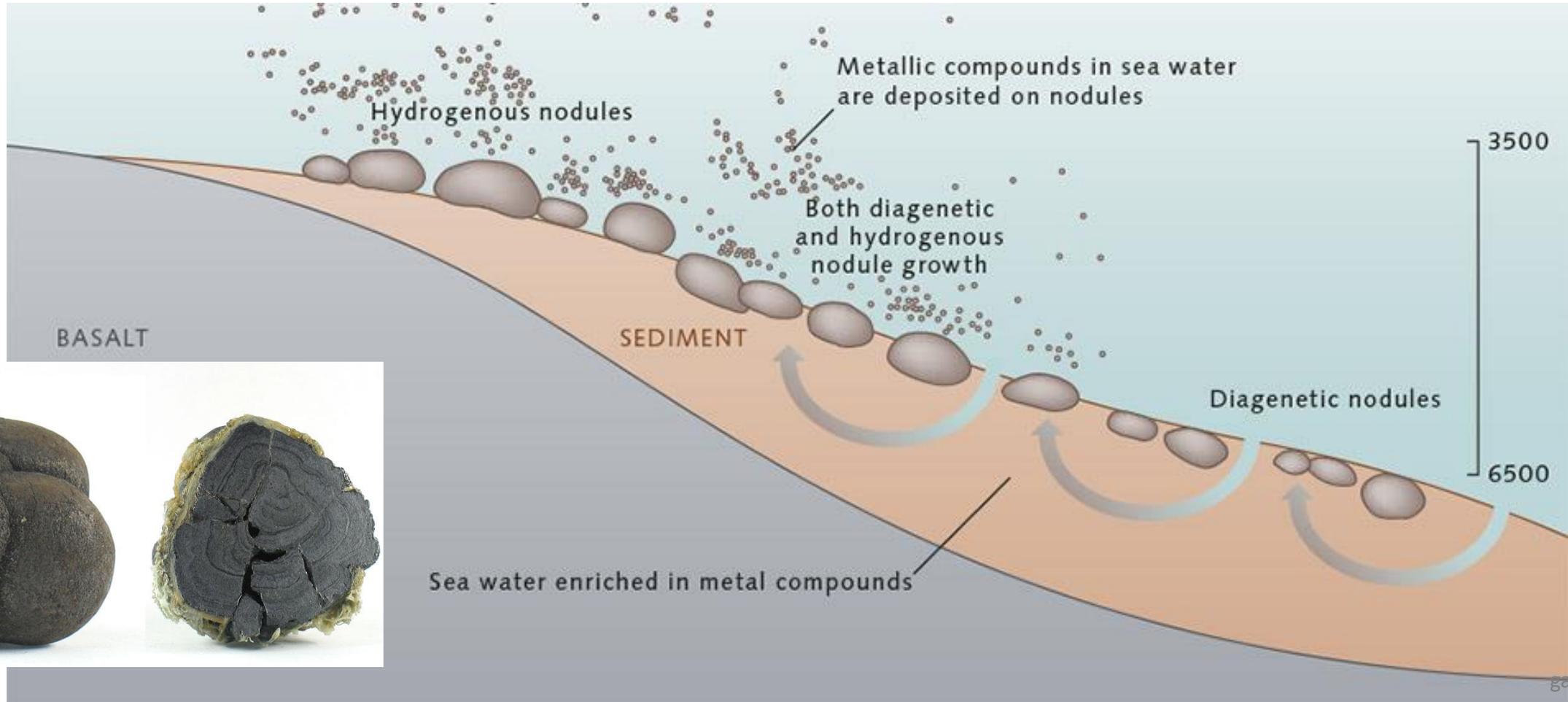
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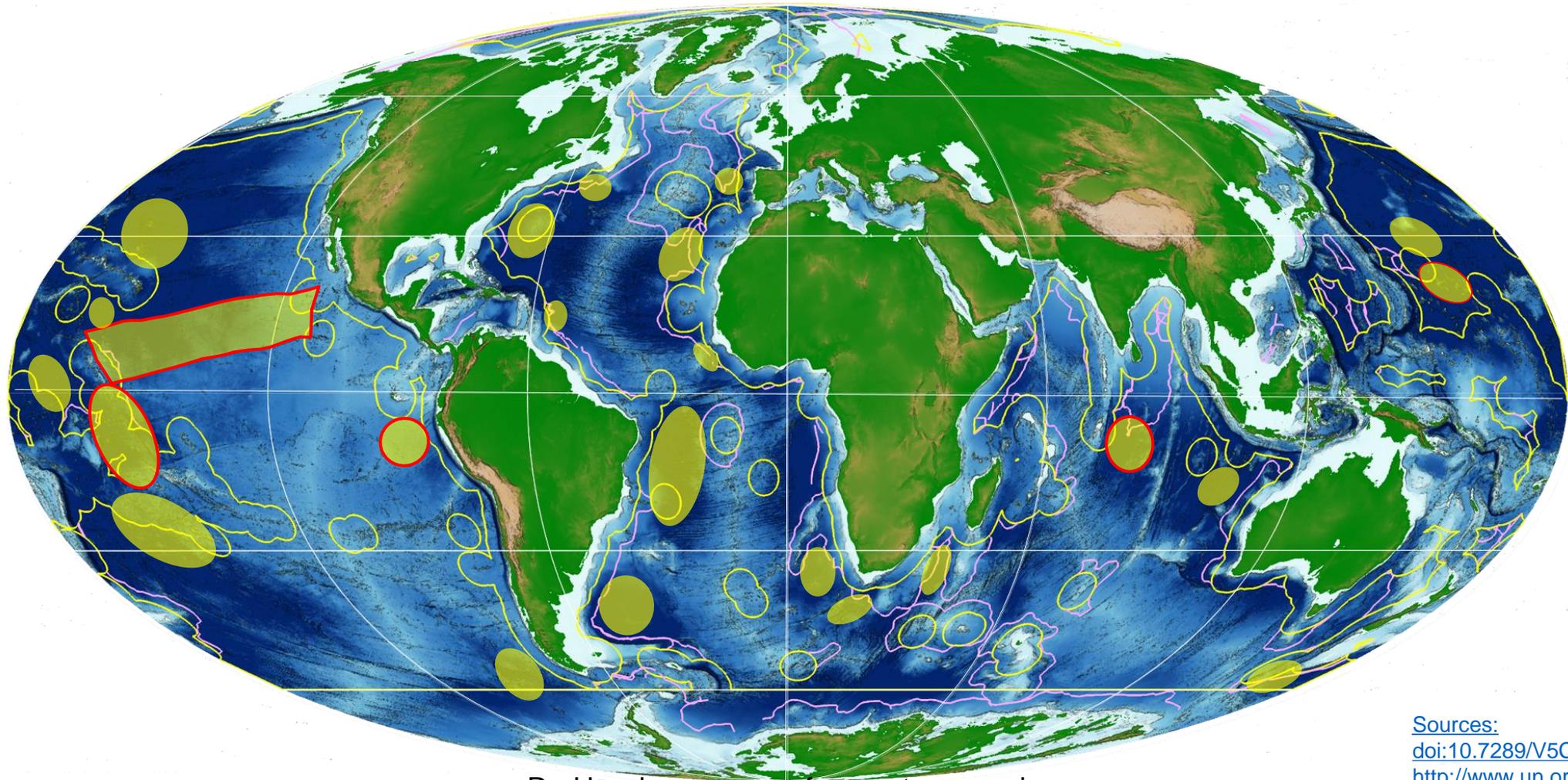
# Polymetallic Nodules

[Mn, Ni, Co, Cu (Li, Ti)]



World Ocean Review,  
<http://worldoceanreview.com/en/>

# Favourable areas for PM nodules



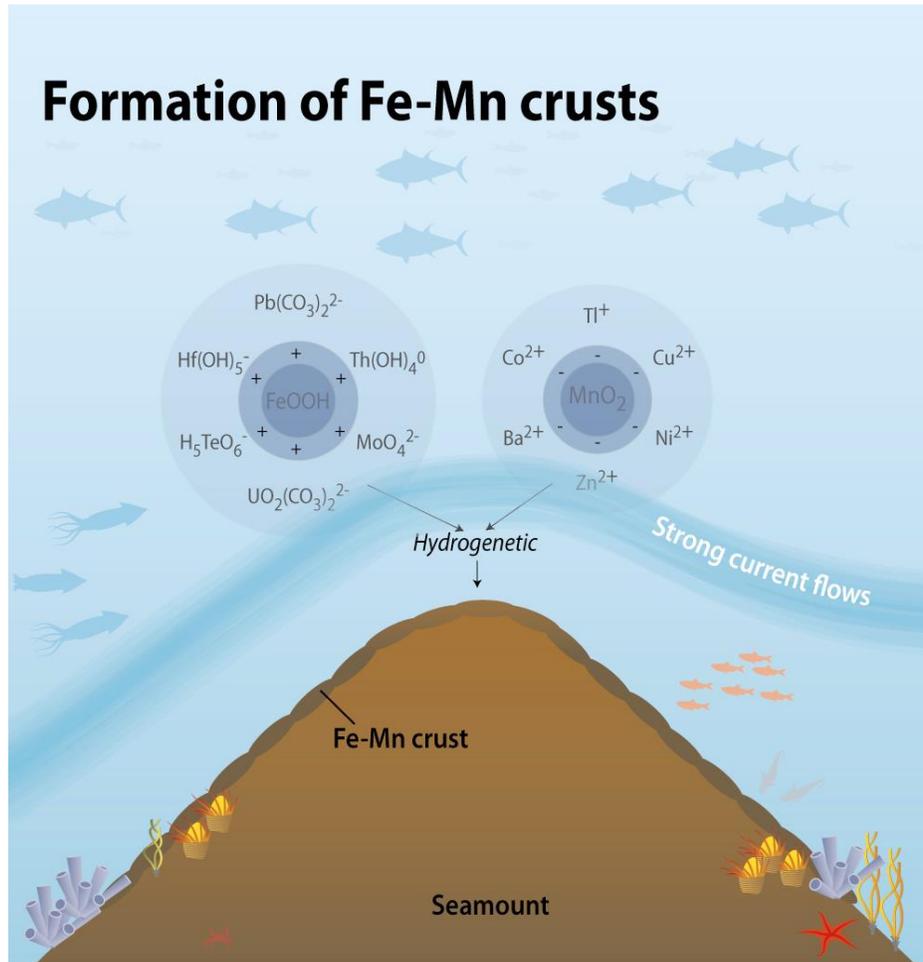
Red borders - areas of current economic interest

Oil and gas as part of the solution for energy transition and security

Sources:  
[doi:10.7289/V5C8276M](https://doi.org/10.7289/V5C8276M), ETOPO1  
<http://www.un.org/depts/los/index.htm>  
Global Maritime Boundaries Database  
T. Khun et al., 2017

# Polymetallic Crusts

[Mn, Co, Cu, REE (Ti, Pt, V)]



J.R. Hein 2004

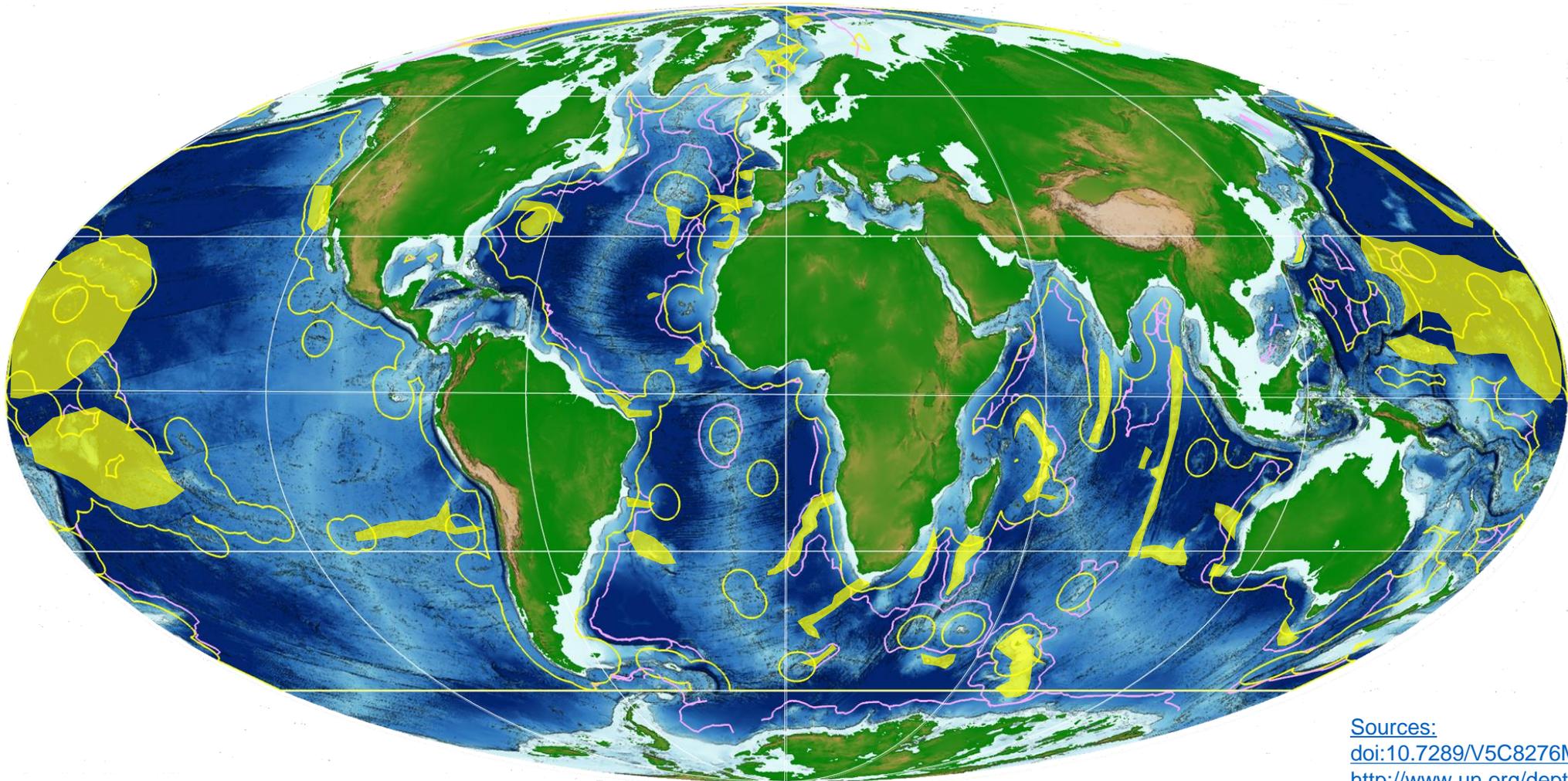
Norwegian Petroleum Directorate

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# Favourable areas for PM crusts



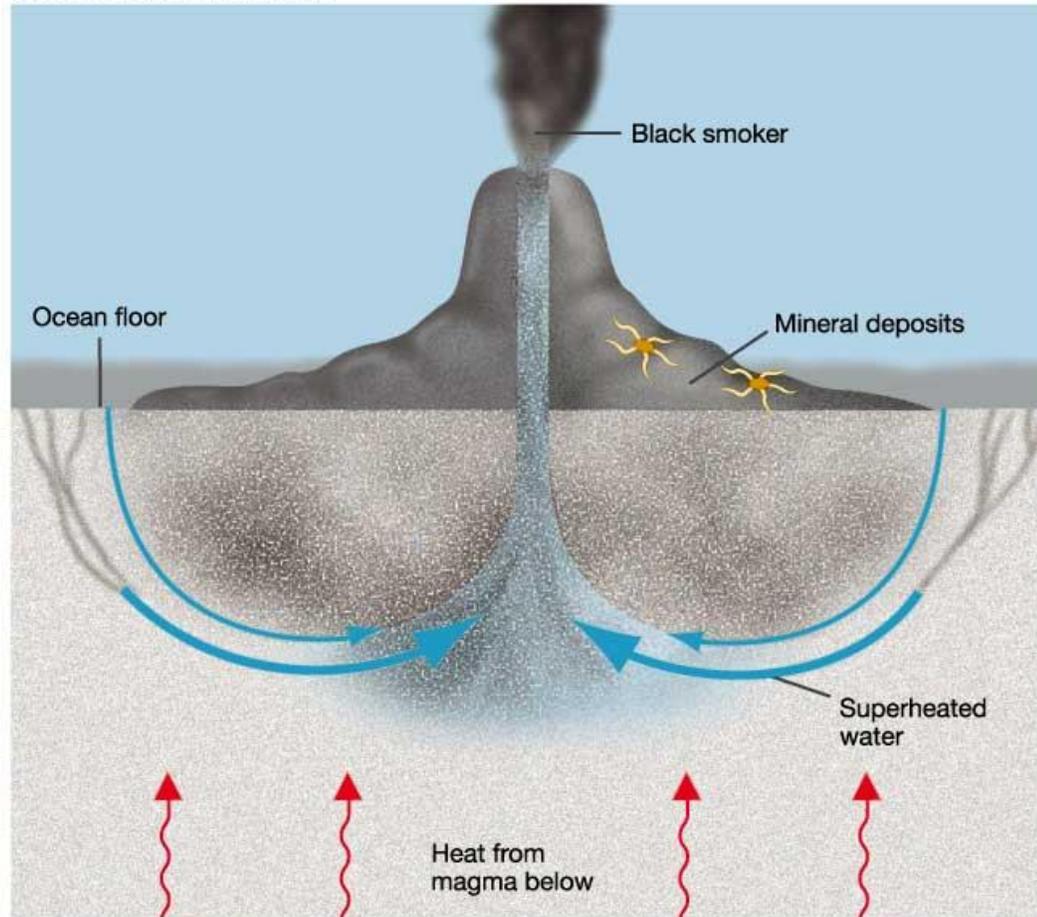
Sources:  
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<http://www.un.org/depts/los/index.htm>  
Global Maritime Boundaries Database  
P.E. Halbach et al., 2017

# Polymetallic Sulphides

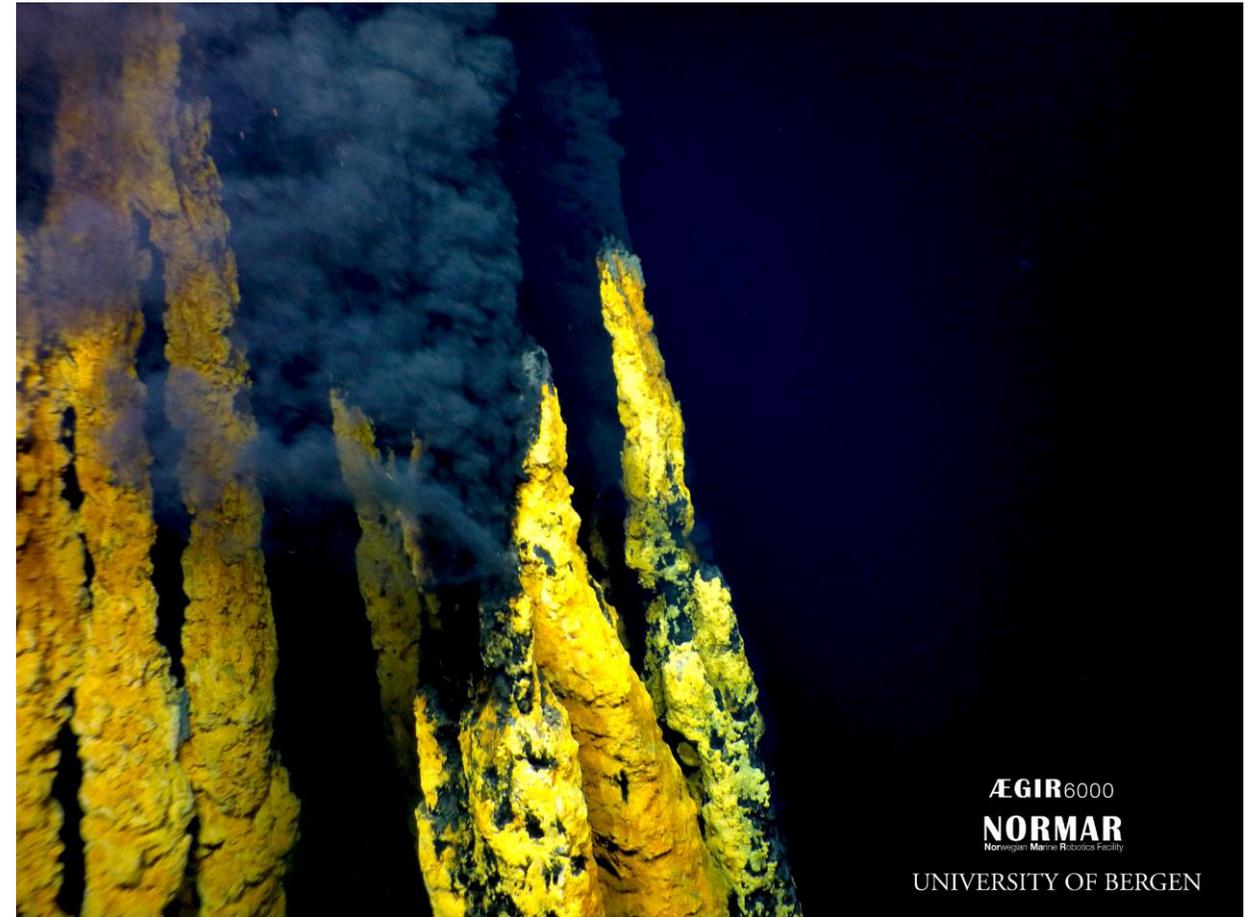
[Cu, Zn, Au, Ag (Pb, Co)]



Formation of black smokers

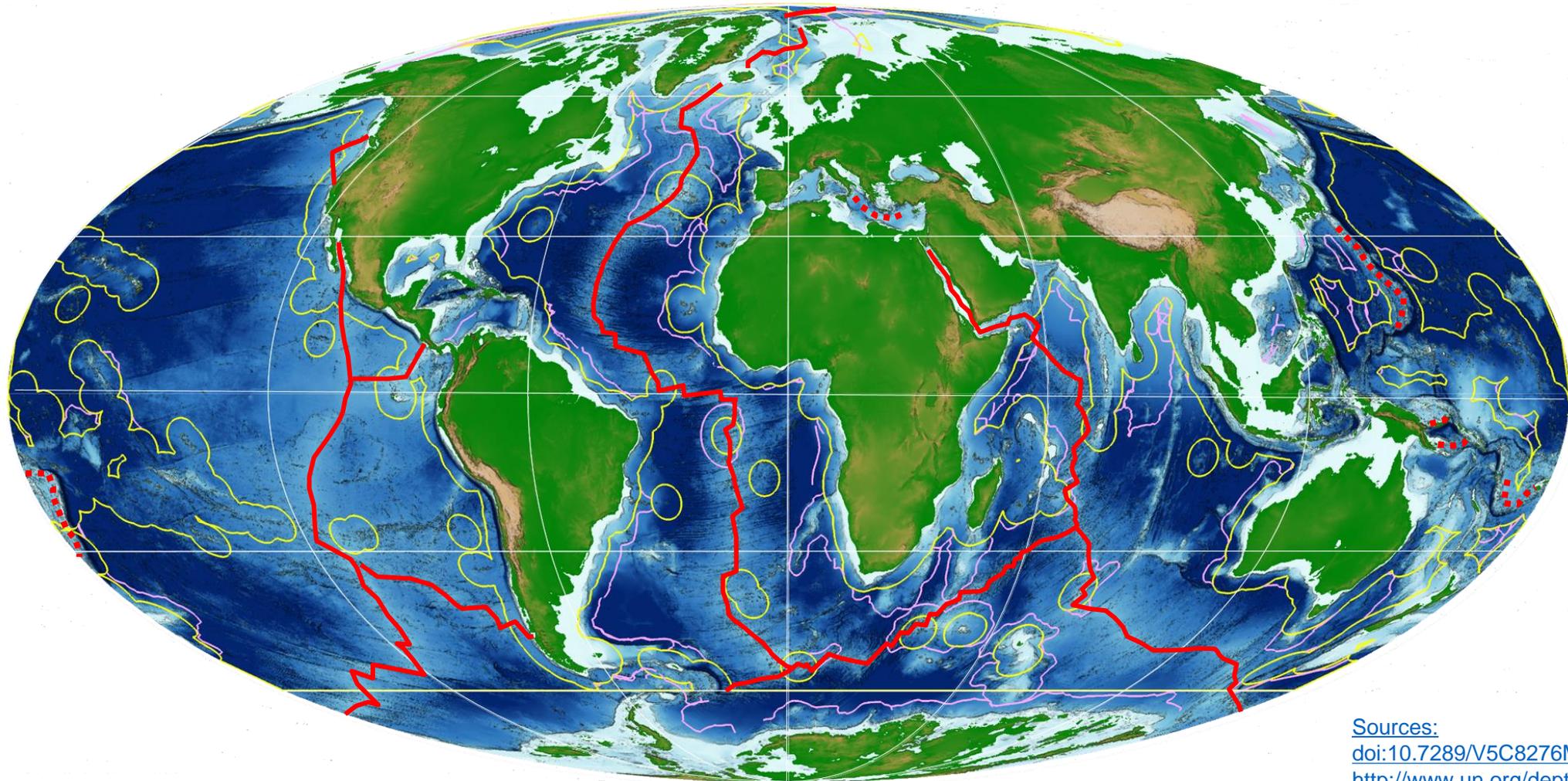


[Black smokers or hydrothermal vent, Formation of black smokers \(karadimov.info\)](http://karadimov.info)



ÆGIR6000  
NORMAR  
Norwegian Marine Robotics Facility  
UNIVERSITY OF BERGEN

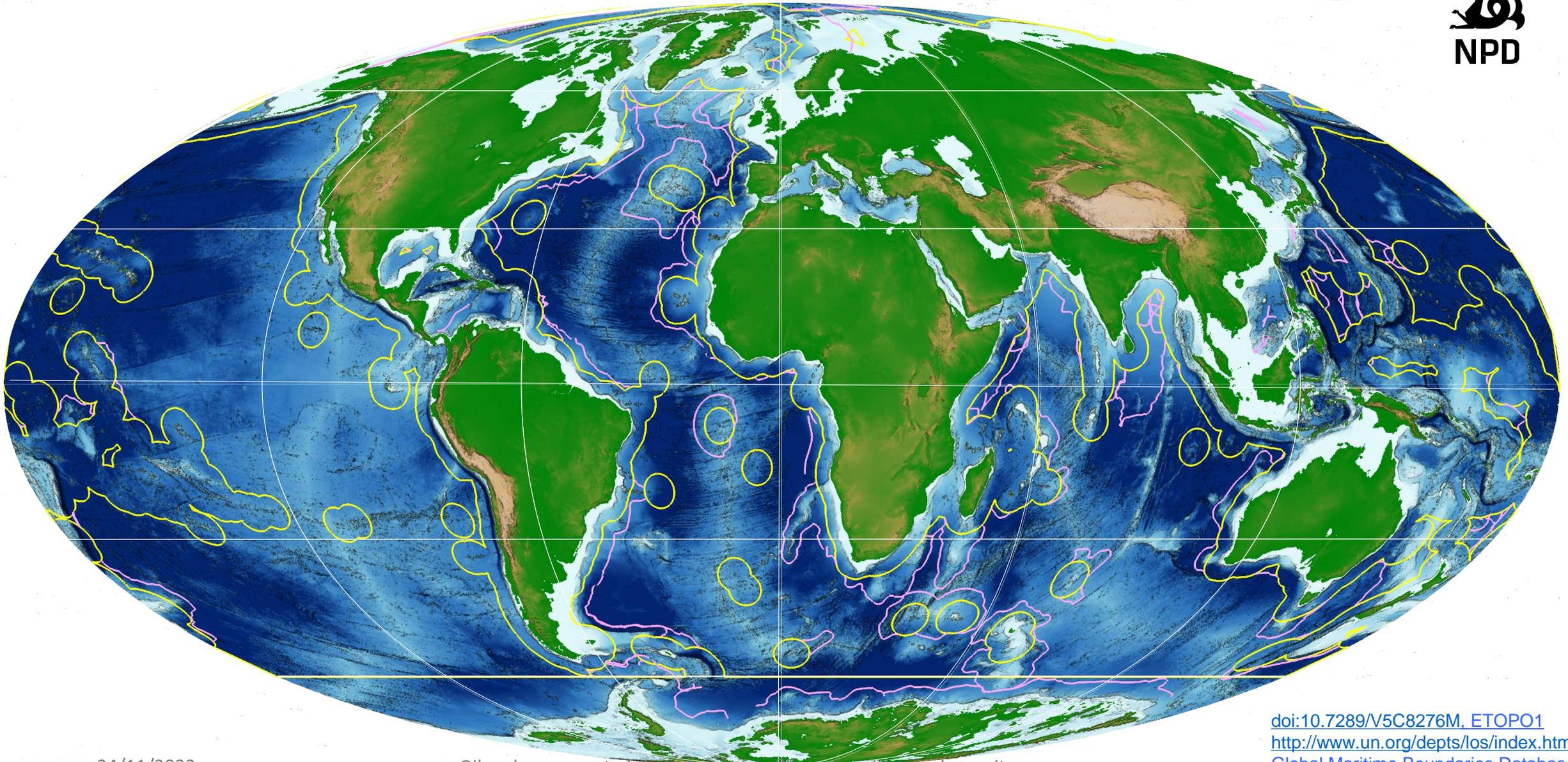
# Favourable areas for hydrothermal sulphide deposits



Sources:  
[doi:10.7289/V5C8276M](https://doi.org/10.7289/V5C8276M), ETOPO1  
<http://www.un.org/depts/los/index.htm>  
Global Maritime Boundaries Database

# Seabed Jurisdiction and Resource Management

# EEZ and Continental Shelf limits



24/11/2022

Oil and gas as part of the solution for energy transition and security

doi:10.7289/V5C8276M, ETOPO1  
<http://www.un.org/depts/los/index.htm>  
Global Maritime Boundaries Database

# Seabed Jurisdiction areas

- Percentage of total world ocean seabed:

The International Seabed (The Area) 53 %

The Continental Shelf 46 %

(the EEZ 39 %)

Source - <http://www.grida.no/publications/shelf-last-zone/>

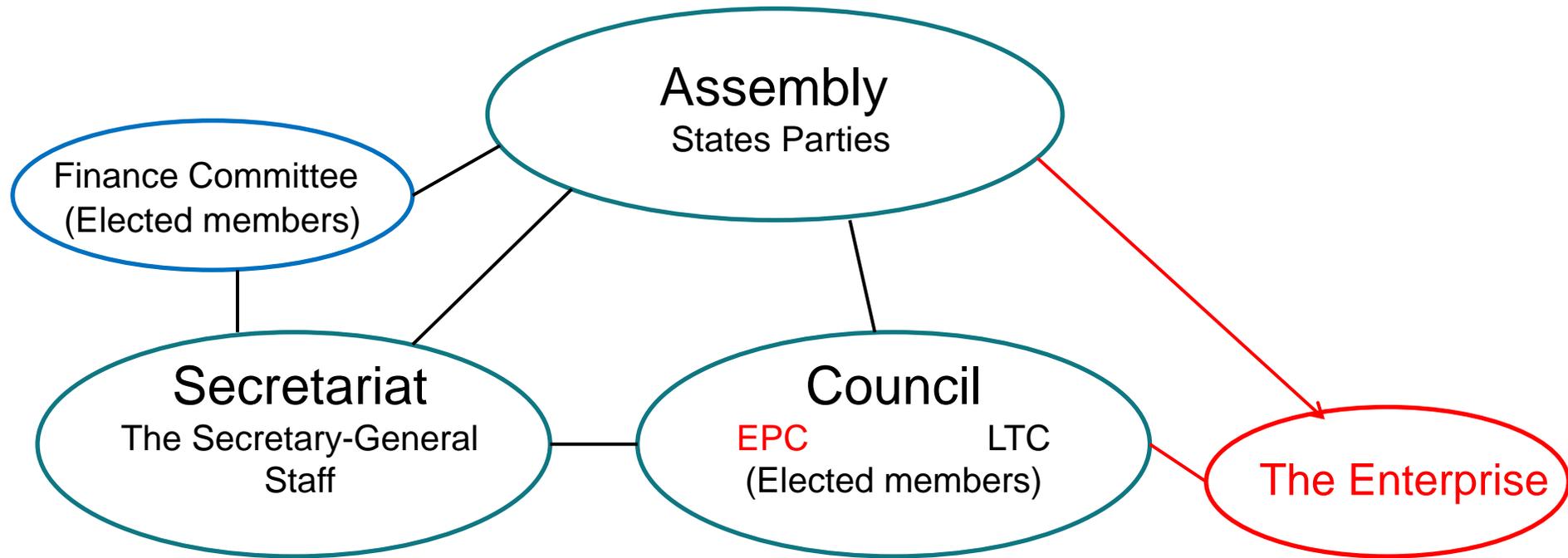
# The Area

The International Seabed

# The International Seabed Authority (ISA)

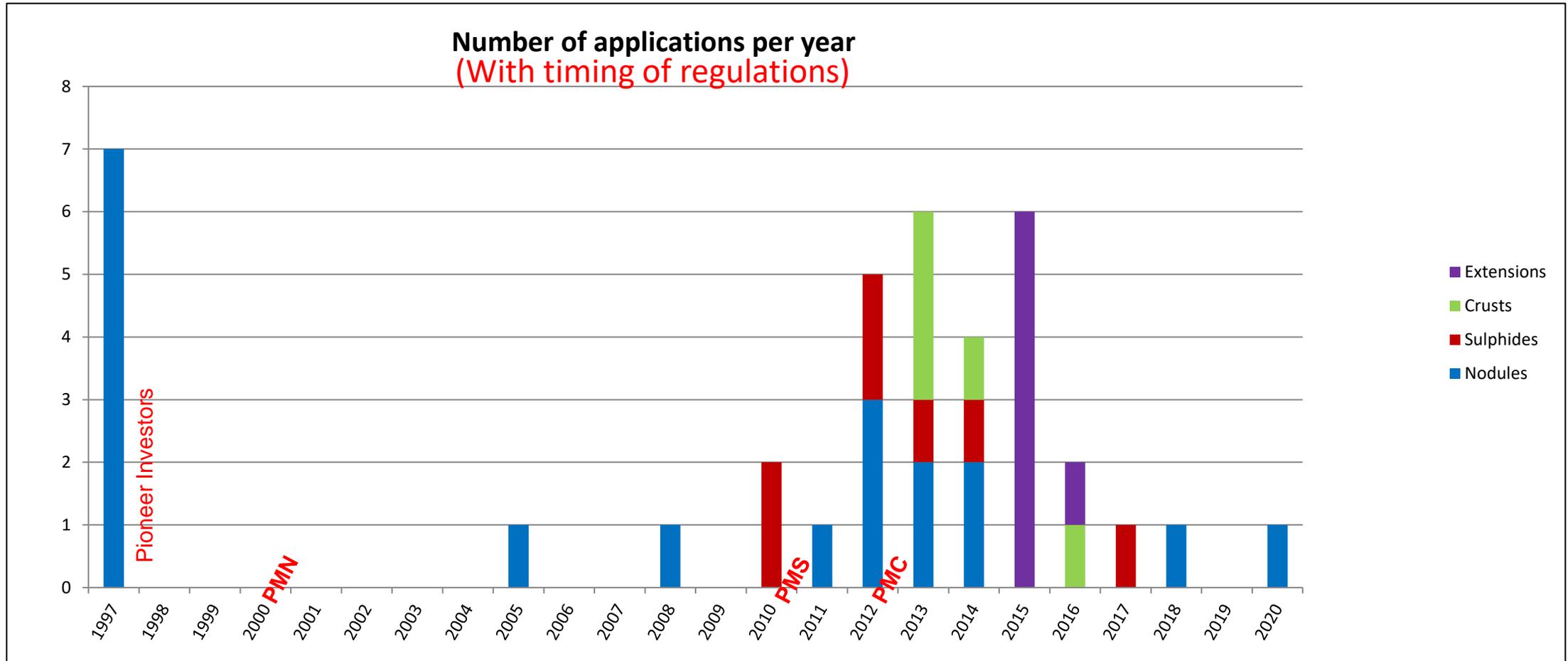


# The International Seabed Authority



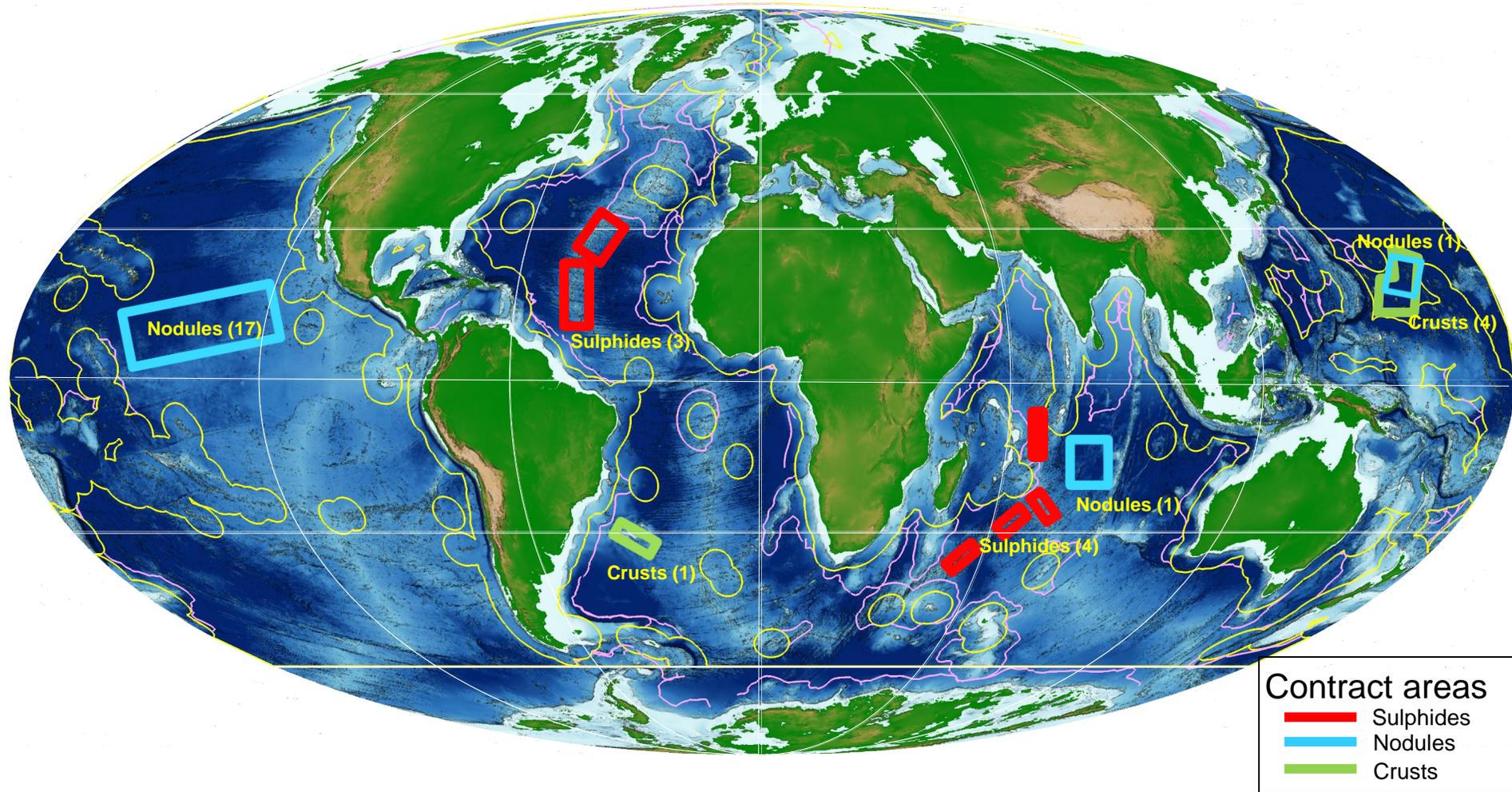
**EPC - The Economic Planning Commission**  
**LTC - The Legal and Technical Commission**

# Applications for international exploration contracts



- |                          |    |
|--------------------------|----|
| • Polymetallic nodules   | 19 |
| • Polymetallic sulphides | 7  |
| • Polymetallic crusts    | 5  |
| • Contracts total        | 31 |
- ISA is currently preparing regulations for development and production

# Areas of exploration contracts under ISA



# States sponsoring exploration

- Cook Isls
- Jamaica
- Kiribati
- Nauru
- Singapore
- Tonga
- Brazil
- China
- India
- Japan
- South-Korea
- Belgium
- France
- Germany
- Poland
- Russia
- UK

# The Continental Shelf

The Seabed of Coastal States

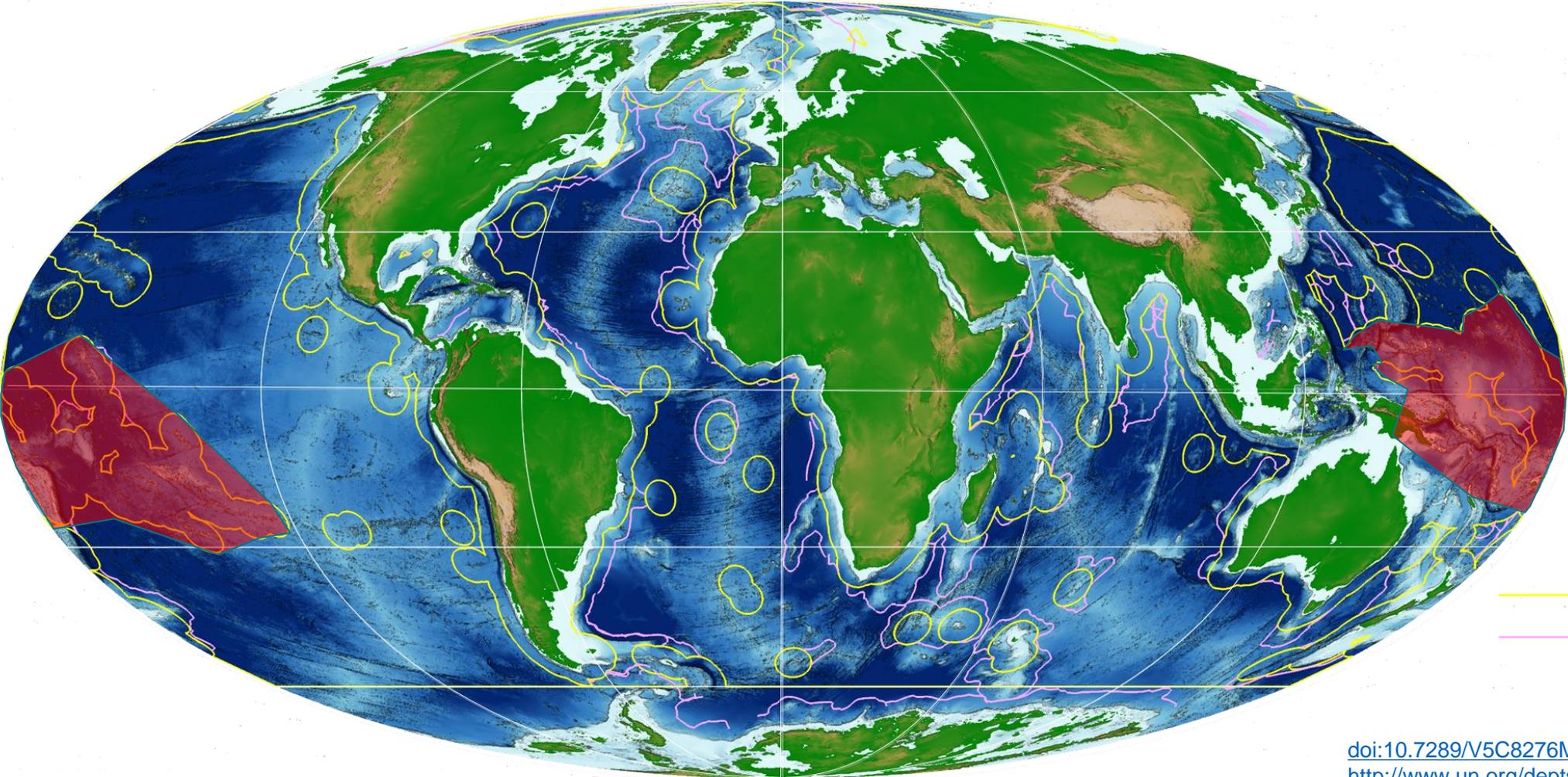
# Percentage of favourable mineral areas and total ocean area



	Nodule areas	Crust areas	Sulphide areas	World Ocean seabed area
The Area	81	46	58	53
The CS	19	54	42	47
(The EEZ)	(14)	(44)	(36)	(39)

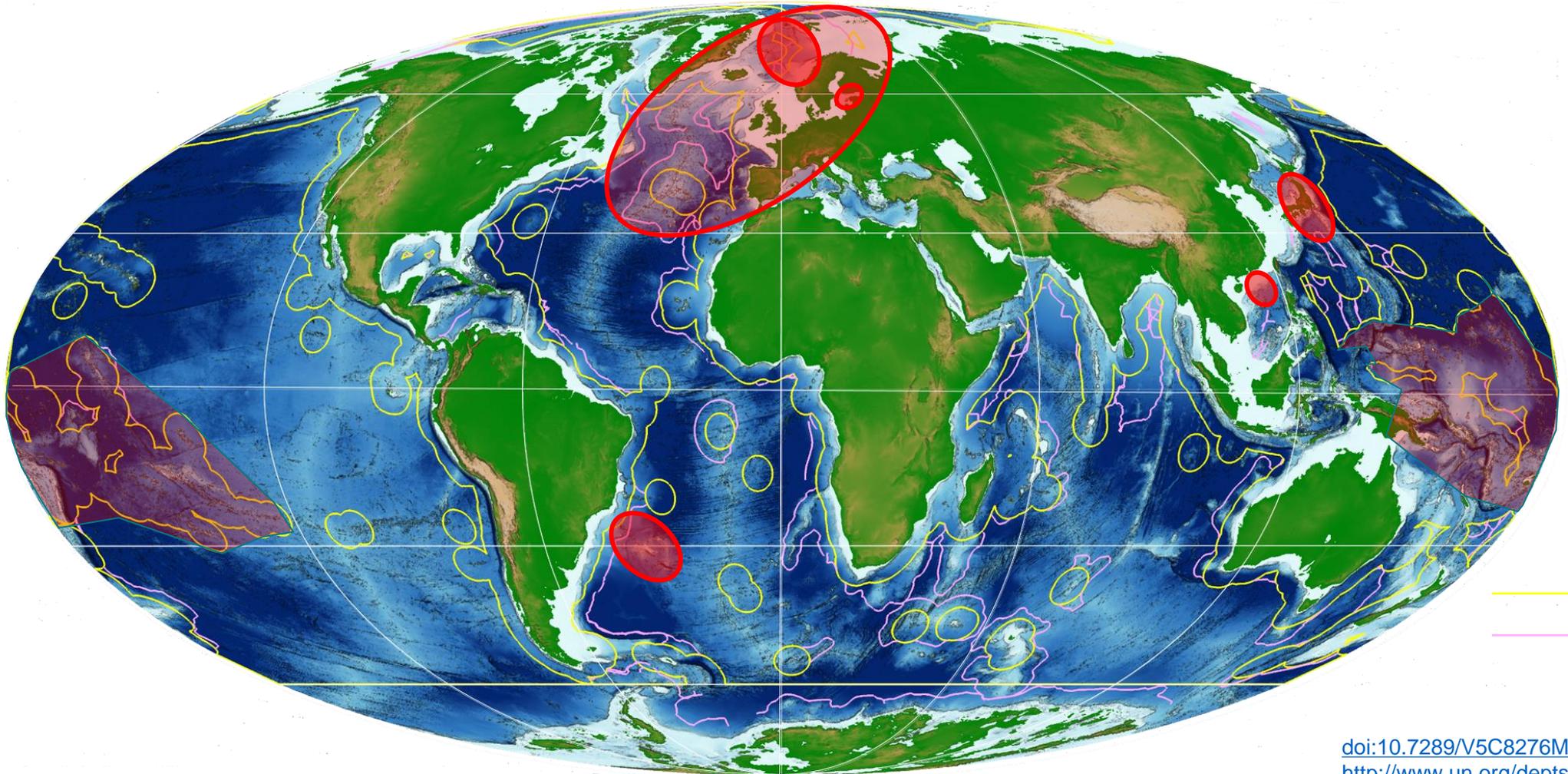
Petersen et al., 2016, Marine Policy

# Small Island Pacific States – the Continental Shelf



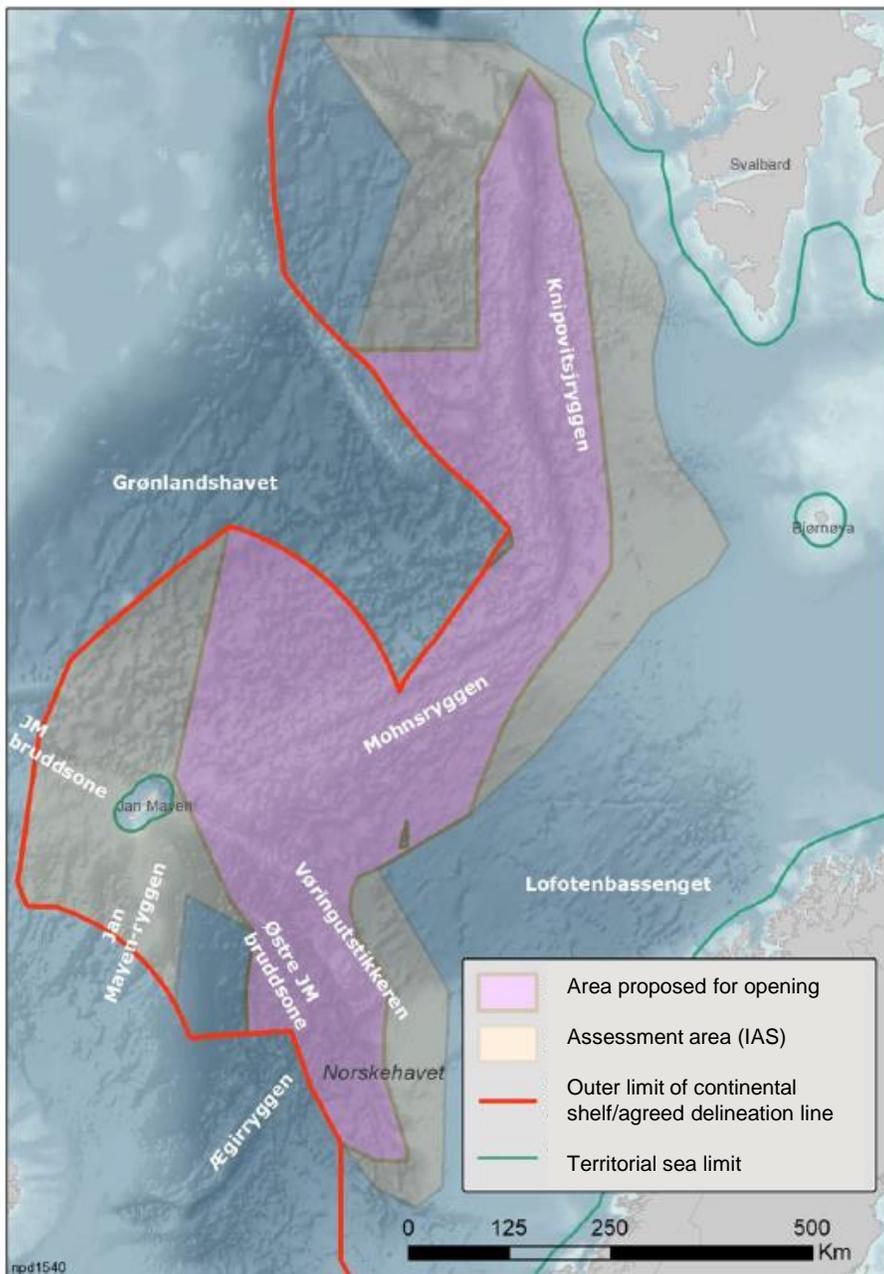
doi:10.7289/V5C8276M. ETOPO1  
<http://www.un.org/depts/los/index.htm>  
Global Maritime Boundaries Database

# Areas of activity – the Continental Shelf



[doi:10.7289/V5C8276M](https://doi.org/10.7289/V5C8276M), [ETOP01](http://www.un.org/depts/los/index.htm)  
<http://www.un.org/depts/los/index.htm>  
Global Maritime Boundaries Database

# Norway – Continental Shelf



- Marine scientific research from 1999
- Government data acquisition cruises from 2018
- Subsea Minerals Act 2019
- Initiated opening process in 2020
- Impact assessment study (IAS) 2021-2022
- IAS on public consultation 27.10.2022 – 27.01.2023

# Thank you for your attention!

[npd.no](http://npd.no)  
[factpages.npd.no/no](http://factpages.npd.no/no)  
[norskpetroleum.no](http://norskpetroleum.no)

