THE EUCHEMS PERIODIC TABLE

Nicola Armaroli

CNR, The Italian National Research Council EuChemS Task Group on the Periodic Table

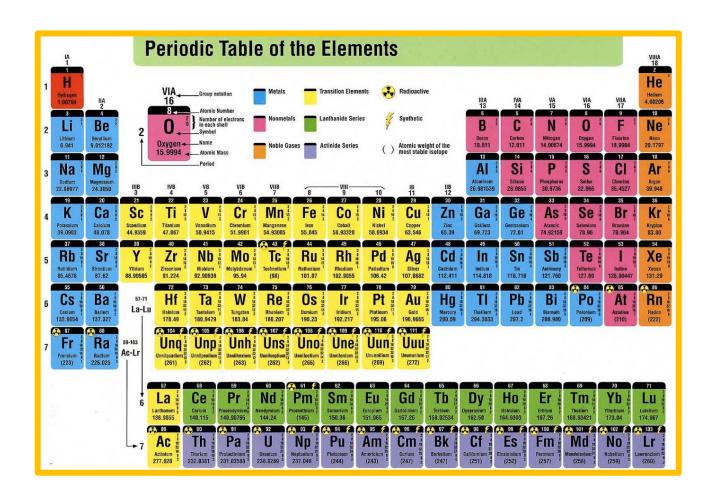
nicola.armaroli@cnr.it — www.isof.cnr.it/armaroli-nicola



The role of Chemicals in our daily life: The Phosphorus element – feeding the world and beyond

The European Parliament, Brussels, May 25th, 2023

THE PERIODIC TABLE OF THE ELEMENTS



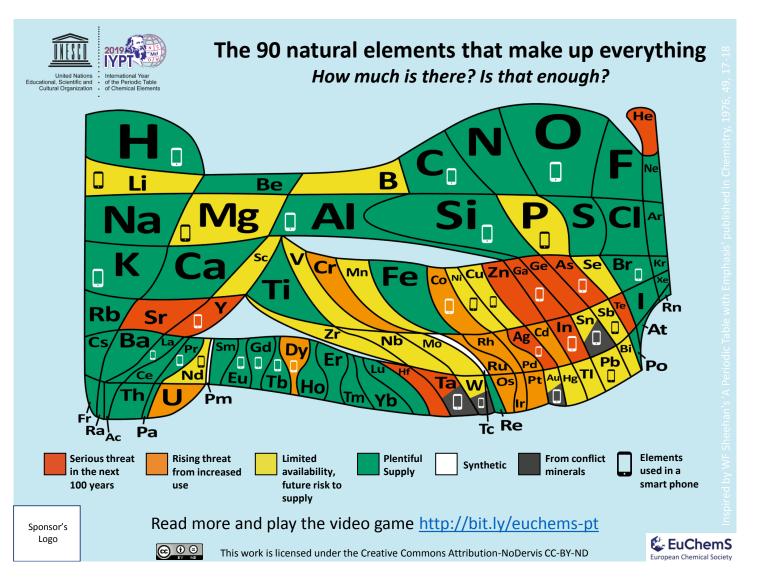
Why do we need a "new"periodic table? We already have one!

2019

International Year of the Periodic Table



THE EUCHEMS TABLE (2019 VERSION)



Each element characterized by

SIZE

The larger the more relatively abundant

COLOR(S)

They denote <u>current</u> human use

The Table is a **LIVING DOCUMENT**

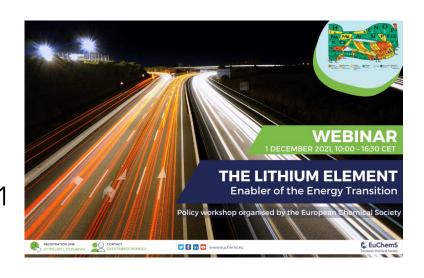


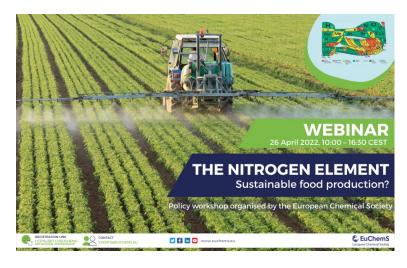
UPDATING THE TABLE VIA SCIENTIFIC DISCUSSION



April 22, 2021

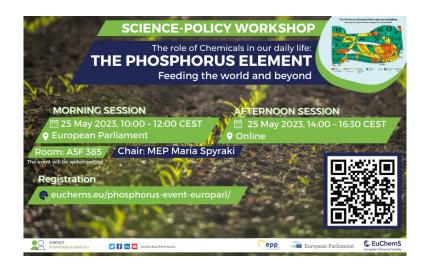
December 1, 2021



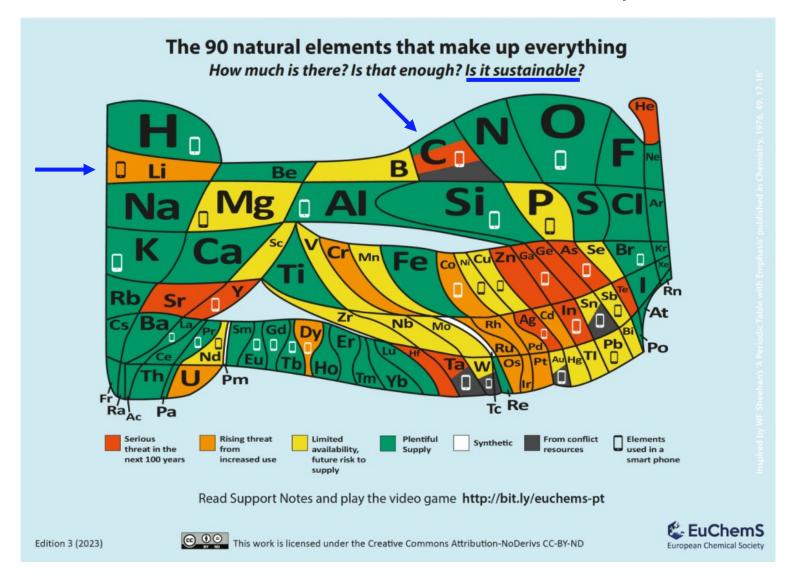


April 26, 2022

May 25, 2023



THE LATEST VERSION, 2022



THE THREE COLORS OF CARBON





Plentiful supply GREEN





Serious (double) threat in the next 100 years RED





From conflict resources **GREY**



LITHIUM: FROM YELLOW TO ORANGE

December 1, 2022

MORNING SESSION 10:00 to 12:00 CET

- Welcome

Floris Rutjes, EuChemS President

- MEP Speech

MEP Speaker

 Developments of the EuChemS periodic table

David Cole-Hamilton, University of St. Andrews

- Lithium: reserves, resources and geopolitical issues

Fernando Rocha, University of Aveiro

10 MIN BREAK

 Lithium-ion batteries in the automotive sector

Kristina Edstrom, University of Uppsala

Lithium batteries and the stationary applications

Luigi Lanuzza, Enel X

- Panel discussion

led by Katharine Sanderson, Science

Journalist and Editor

AFTERNOON SESSION 13:30 to 16:30 CET

- Alternatives to Lithium-ion batteries

Philipp Adelhelm, Humboldt-University of

Berlin

- Recycling Lithium-ion batteries

Paul Anderson, University of Manchester

- Lithium in ceramics

John C. Cochran, Corning Inc., Lexington, KY, USA

10 MIN BREAK

 The role of Europe in the expanding battery industry

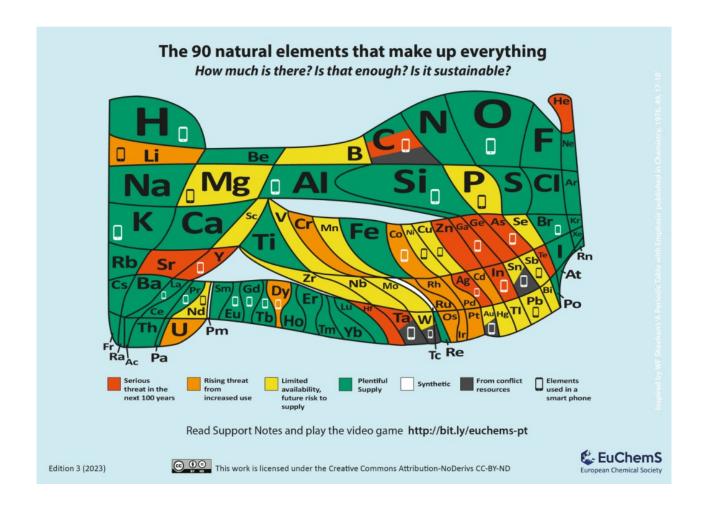
Speaker from EC

- Panel discussion

led by Nicola Armaroli, CNR/EuChemS

- Closing

Floris Rutjes, EuChemS President





THE RISING RELEVANCE OF LITHIUM

"For their contributions to the development of the lithium-ion battery (LIBs)"

The Nobel Prize in Chemistry 2019



III. Niklas Elmehed. © Nobel Media

John B. Goodenough
Prize share: 1/3



III. Niklas Elmehed. © Nobel Media.

M. Stanley Whittingham

Prize share: 1/3



III. Niklas Elmehed. © Nobel Media.

Akira Yoshino

Prize share: 1/3

Among the most disruptive enabling technologies ever



SMARTPHONES
ELECTRIC VEHICLES
PORTABLE DEVICES
HOME APPLIANCES

• •



LITHIUM AND DECARBONIZATION



Electric vehicles

VIRTUALLY NO ALTERNATIVES TO LIBs SO FAR



Storage of intermittent renewables

VIABLE ALTERNATIVES
CLOSE TO COMMERCIALIZATION
(sodium and flow batteries)



LITHIUM: RESOURCES AND RESERVES



From rocks (Australia)



From brines (South America)

Estimated RESOURCES 2013: 23 Mton

Estimated RESOURCES 2023: 98 Mton

Current RESERVES: 26 Mton



BEVs that can be made 3.2 billions (today 1.4)

DOABLE? HOW?

It depends from several factors...

Data from US Geological Survey

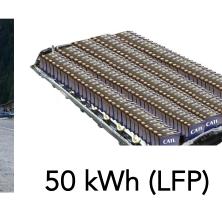


BATTERIES: THINGS EVOLVE





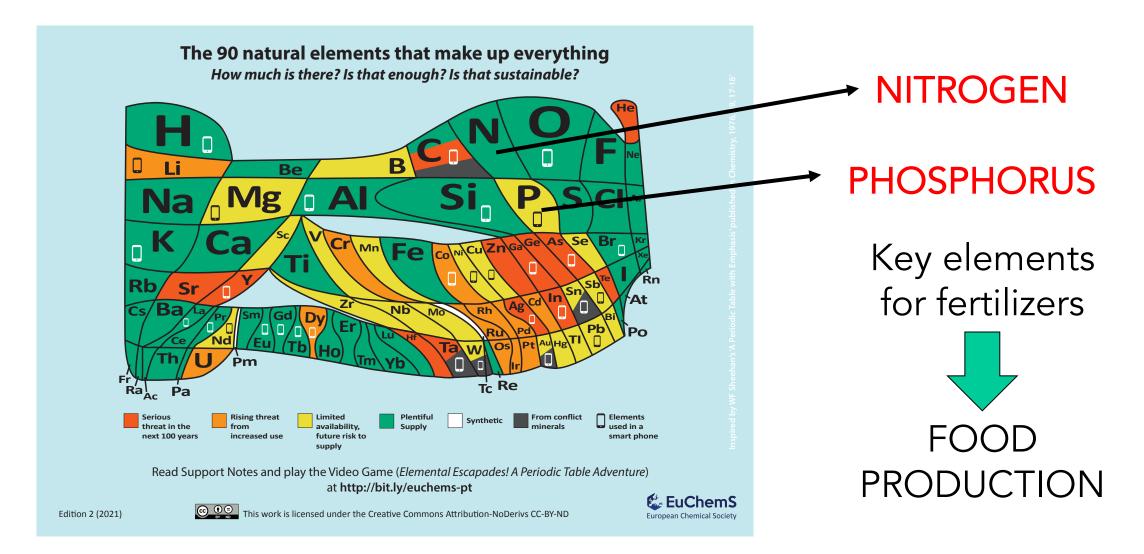
50 kWh (NMC 523)



	50 kWh Ni-Mn-Co 523	50 kWh Lithium Iron Phosphate
Lithium	5,5	4,9
Cobalt	9,5	/
Nickel	23,5	/
Graphite	44,0	59,4
Manganese	13,5	/
Copper	17,0	23,2
Aluminum	29,0	39,4
Iron	/	37,3
Phosphorus	/	20,7
TOTALE	142,0	208,1



THE ONGOING STEP: NITROGEN AND PHOSPHORUS



NITROGEN: PLENTIFUL AND ... IMPACTFUL

The Earth atmosphere contains about 4000 trillion tons of N. Virtually unlimited supply To do what?

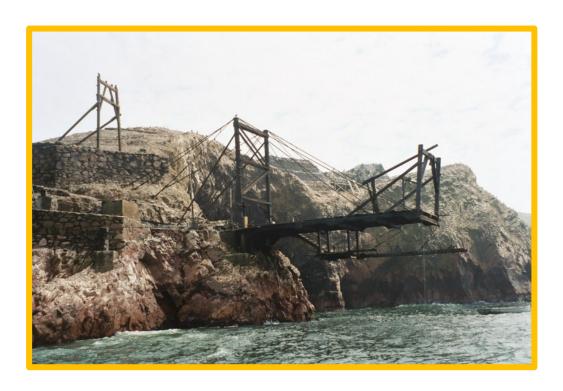


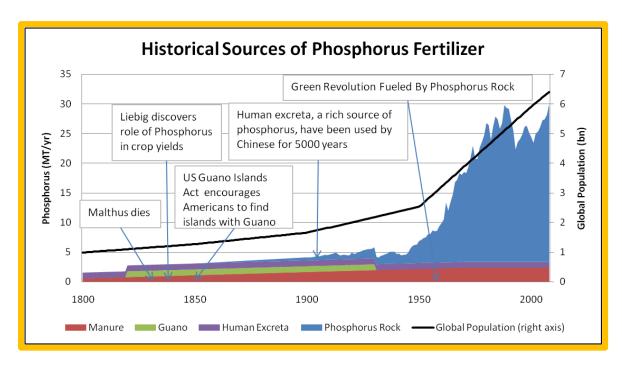


1.5 % of annual global greenhouse gas emission



PHOSPHORUS: AN INCREASINGLY EXPLOITED ELEMENT





Guano islands

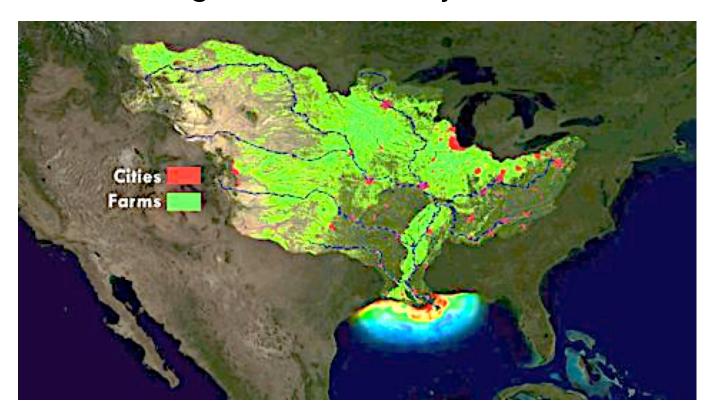
NOT ONLY FERTILIZERS

Steel, water treatments, batteries, food additives, pesticides, flame retardants, ...



N AND P: ENVIRONMENTAL IMPACT

N and P runoff in the Gulf of Mexico from agriculture, industry, urbanization



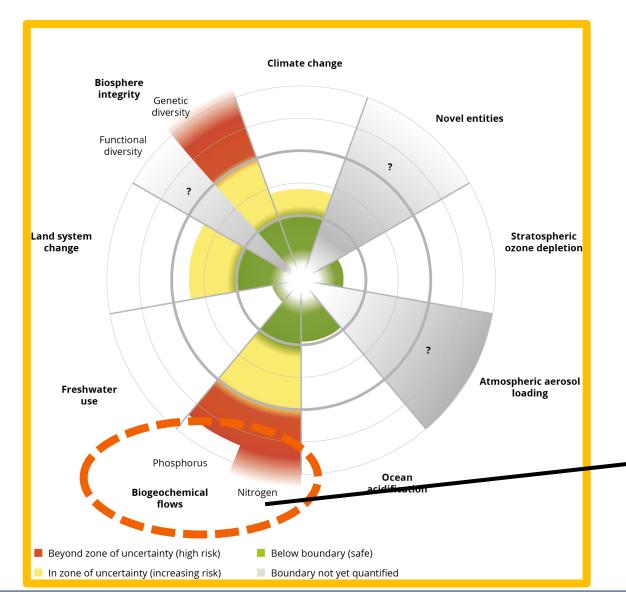




Dead Zones



N,P OVERUSE IS RELEVANT FOR THE BIOSPHERE



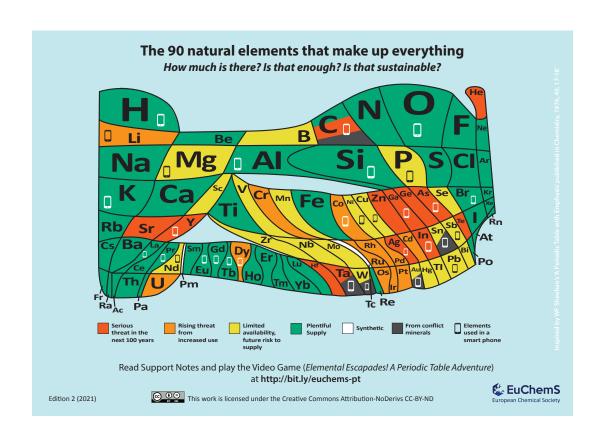
Status of the 9 planetary boundaries (European Environment Agency)

https://www.eea.europa.eu/soer/2020/soer-2020-visuals/status-of-the-nine-planetary-boundaries/view

LINEAR
APPROACH
TO RESOURCE USE



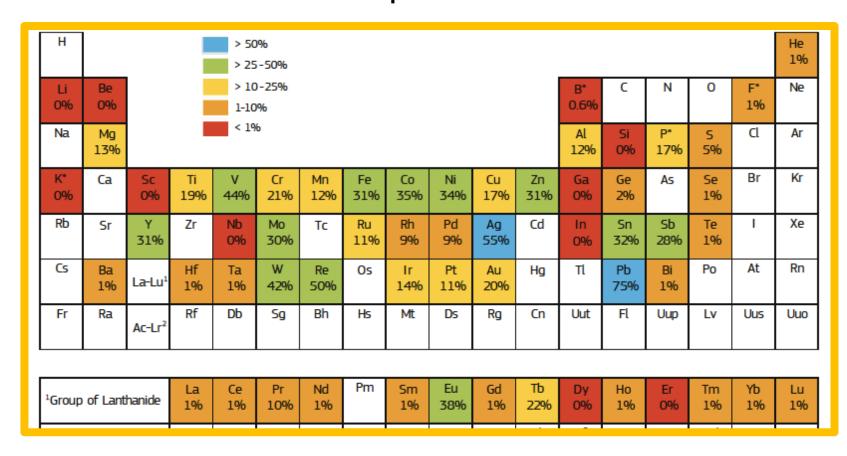
PROMOTING A CIRCULAR PERSPECTIVE





EU RECYCLING RATES (METALS)

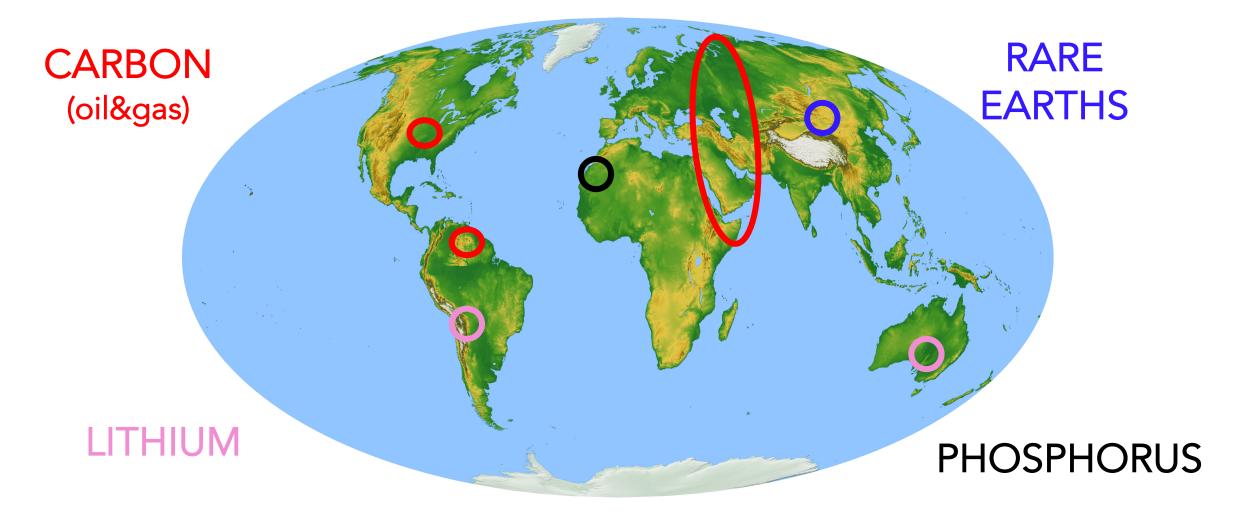
We need to perform better!



Raw Materials Scoreboard, The European Commission, **2018**



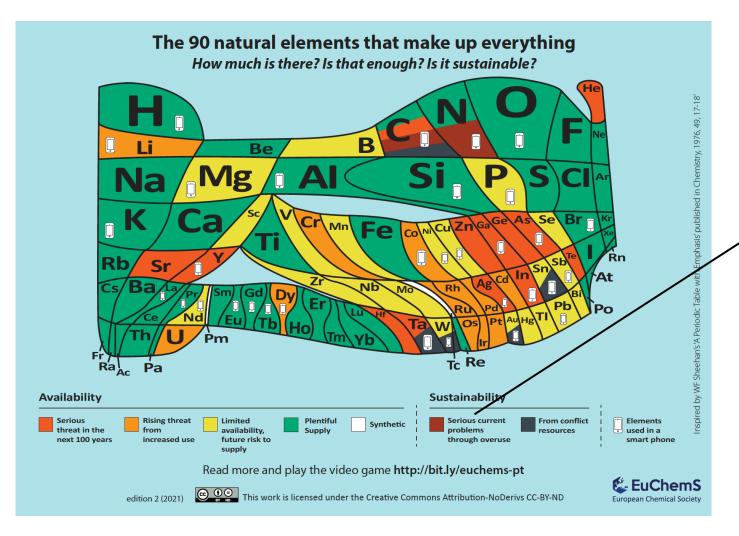
MINERAL RESOURCES ARE CONCENTRATED

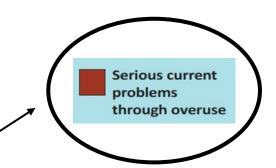


NO ALTERNATIVE TO INTERNATIONAL COOPERATION



DISCUSSION ONGOING IN EUCHEMS: SHOULD WE ADD A COLOR TO N (AND C AND P)?

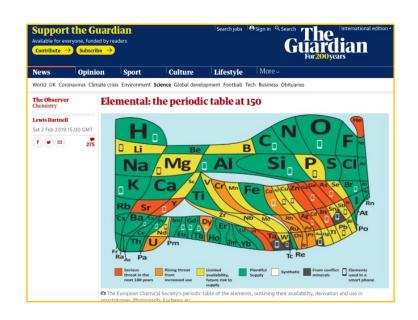




P is also a candidate
The today discussion
will be key to our
future decision

Paving the way for a circular economy: insights on status and potentials (50) 1977-8449 Figure 1994-2015 European Environment Agency

THE EUCHEMS PT HAS AN IMPACT



Newsday The 90 natural elements that make up everything How much is there? Is that enough? How much is there? Is that enough? How much is there? Is that enough? Newsday Newsday



The New York Times

Is It Time to Upend the Periodic Table?

The iconic chart of elements has served chemistry well for 150 years. But it's not the only option out there, and scientists are pushing its limits.





OUR SCIENTIFIC DISCUSSION WILL CONTINUE

Rare Earths

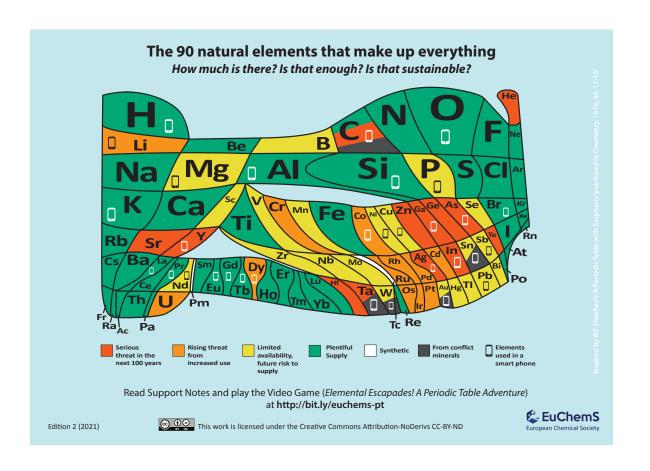
Hydrogen

Helium

Cobalt

Platinum Group Elements

Indium





THE EUCHEMS TASK GROUP ON THE PT



D. Cole-Hamilton, UK



C. Coperet, CH



M. Menche, DE



E. Hey-Hawkins, DE



R. Poli, FR



F. Rutjes, NL



N, Hrastelj (Sec. General)

Thank you!