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THE INDUSTRIAL TRANSFORMATION

NAVIGATING THE BERMUDA TRIANGLE

ACHEMA 2022

REINIER GRIMBERGEN

PRINCIPAL CONSULTANT, TNO

INDUSTRIAL TRANSFORMATION

MAIN DRIVERS AND CHALLENGES

DRIVER: EU GREEN DEAL

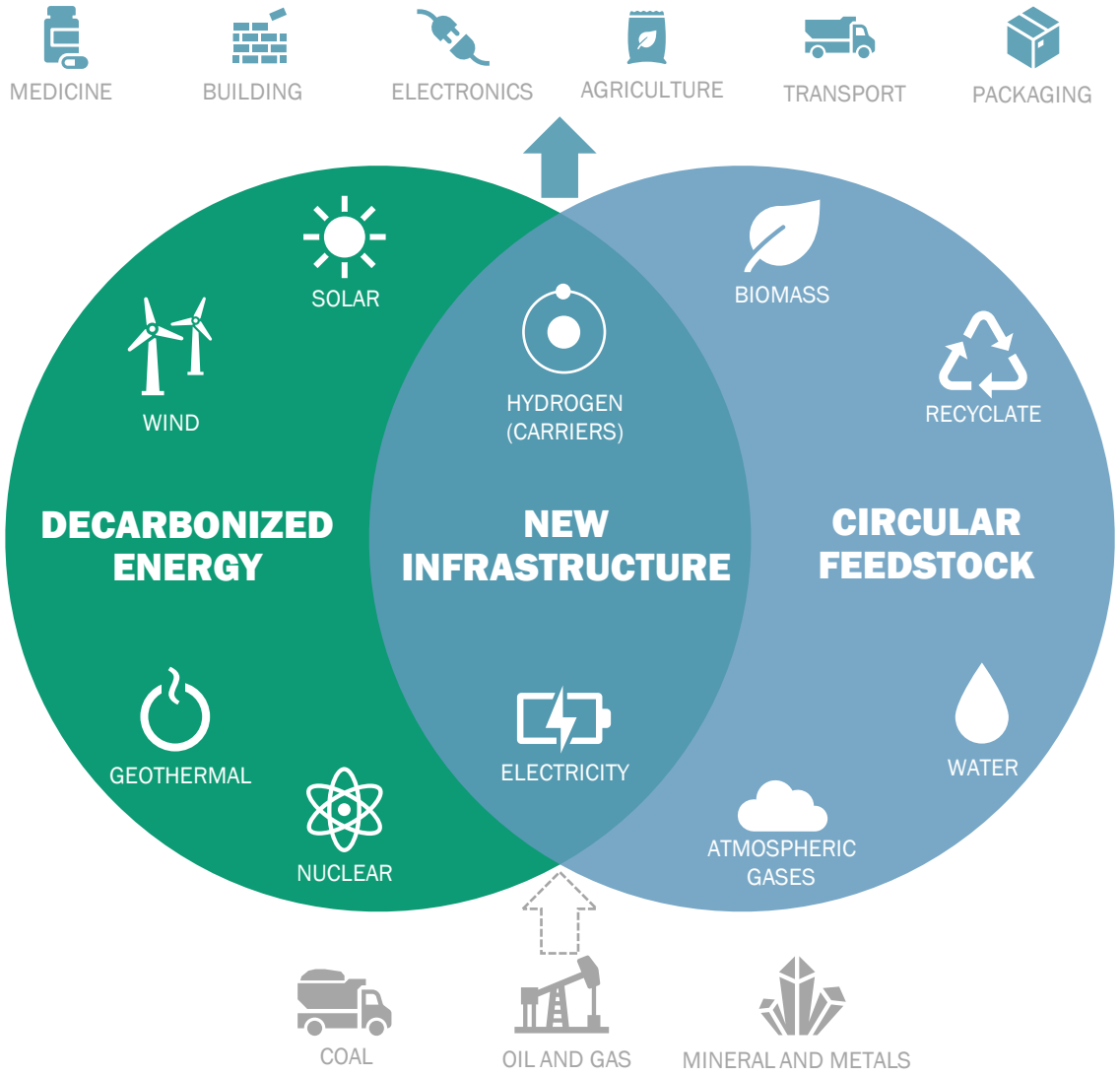
- Fit for 55 Package
- Chemicals Strategy for Sustainability (CSS)
- Circular economy

MAIN TECHNICAL CHALLENGES

- **Energy transition:** access to low-emission electricity and direct electrification
- **Feedstock transition:** access to circular carbon and minerals/metals
- **New feedstock induced products:** Oxygenated products from CO2 and biomass
- **Infrastructure for transport & storage:** energy, hydrogen, biomass, waste and CO2

OTHER CHALLENGES

- **Communication and Societal acceptance:** regain trust
- **Human capital:** education and training
- **Financing:** funding the transformation
- **Digitization and AI:** facilitate and accelerate the transformation



NAVIGATING THE BERMUDA TRIANGLE

NAVIGATE WELL OR GO TO THE BOTTOM...

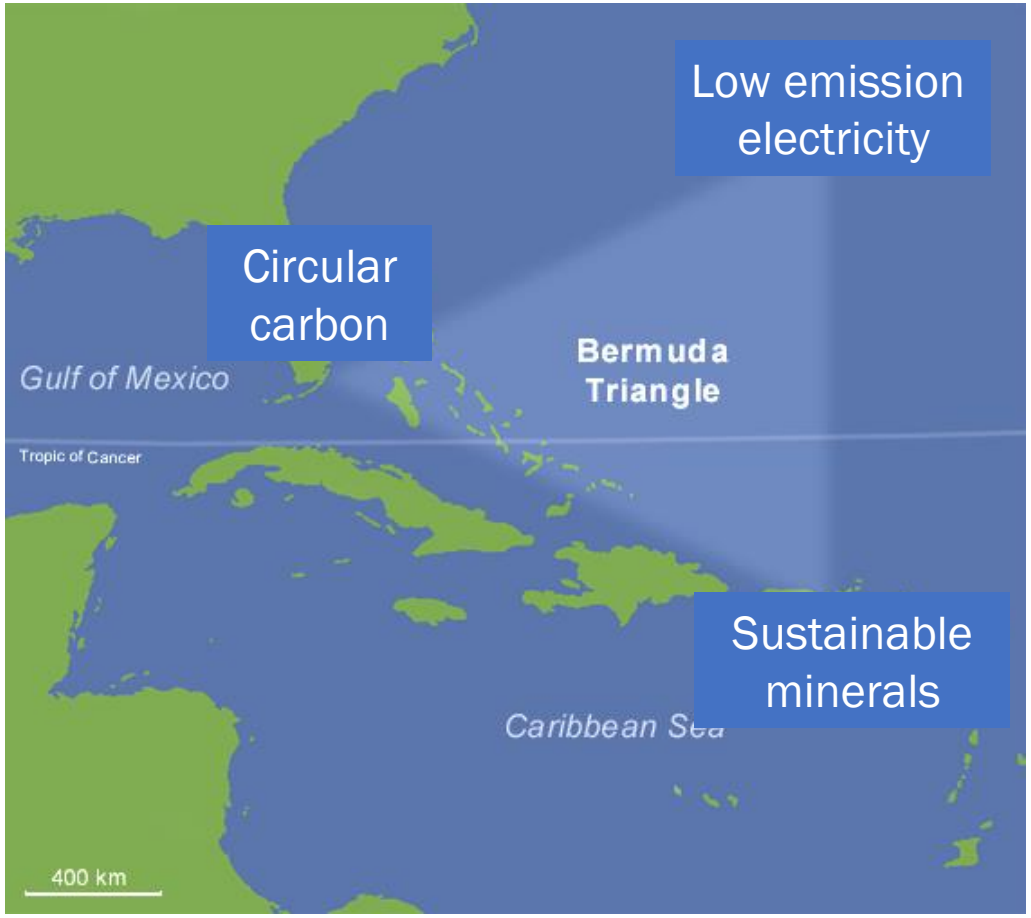
THE BERMUDA TRIANGLE OF THE INDUSTRIAL TRANSFORMATION

SUPPLY AND DEMAND STRESS

LOW EMISSION ELECTRICITY

CIRCULAR CARBON

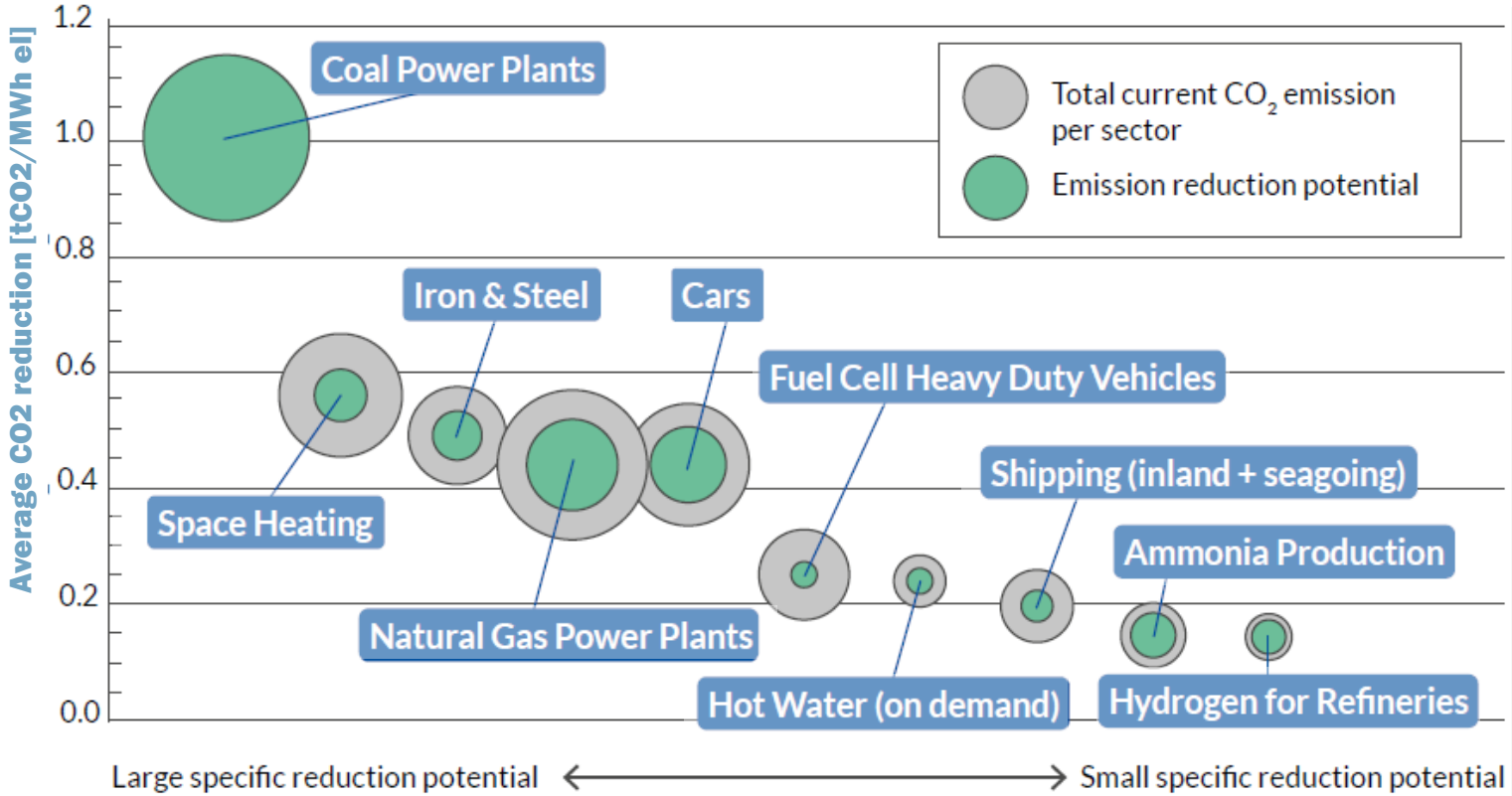
SUSTAINABLE MINERALS/METALS



LOW EMISSION ELECTRICITY AND DECARBONIZATION

ELECTRIFICATION MERIT ORDER FOR THE NETHERLANDS

2030 CO_2 reduction potential of the different options for the Netherlands (bubble sizes are correlated with the Mton/CO_2/year values)



		Coal PPs	Space heating	Iron & Steel	NG PPs	Cars	HDVs	Hot water	Shipping	Ammonia	Refinery Hydrogen	Total
2018 CO_2 emissions	[Mton CO_2/y]	35.0	18.9	12.5	28.4	18.6	10.2	3.5	7.0	5.4	2.9	142.4
2030 percentage	[% 'green']	100.0	20.0	25.0	40.0	40.0	10.0	33.0	20.0	50.0	50.0	48.0
2030 reduction potential	[Mton CO_2/y]	35.0	3.8	3.1	11.4	7.4	1.0	1.2	1.4	2.7	1.4	68.4
Power demand in 2030	[TWh/y]	35.0	6.7	6.4	25.8	16.9	4.1	4.9	7.1	18.2	10.0	135.2

MERIT ORDER OF ELECTRIFICATION

1. **FOSSIL POWER GENERATION**
2. **SPACE HEATING (HEAT PUMPS)**
3. **IRON & STEEL (H-DRI)**
4. **PASSENGER VEHICLES (BEV)**

48% reduction emission in 2030 requires **135 TWh/yr (15.5 GW)** green electricity.

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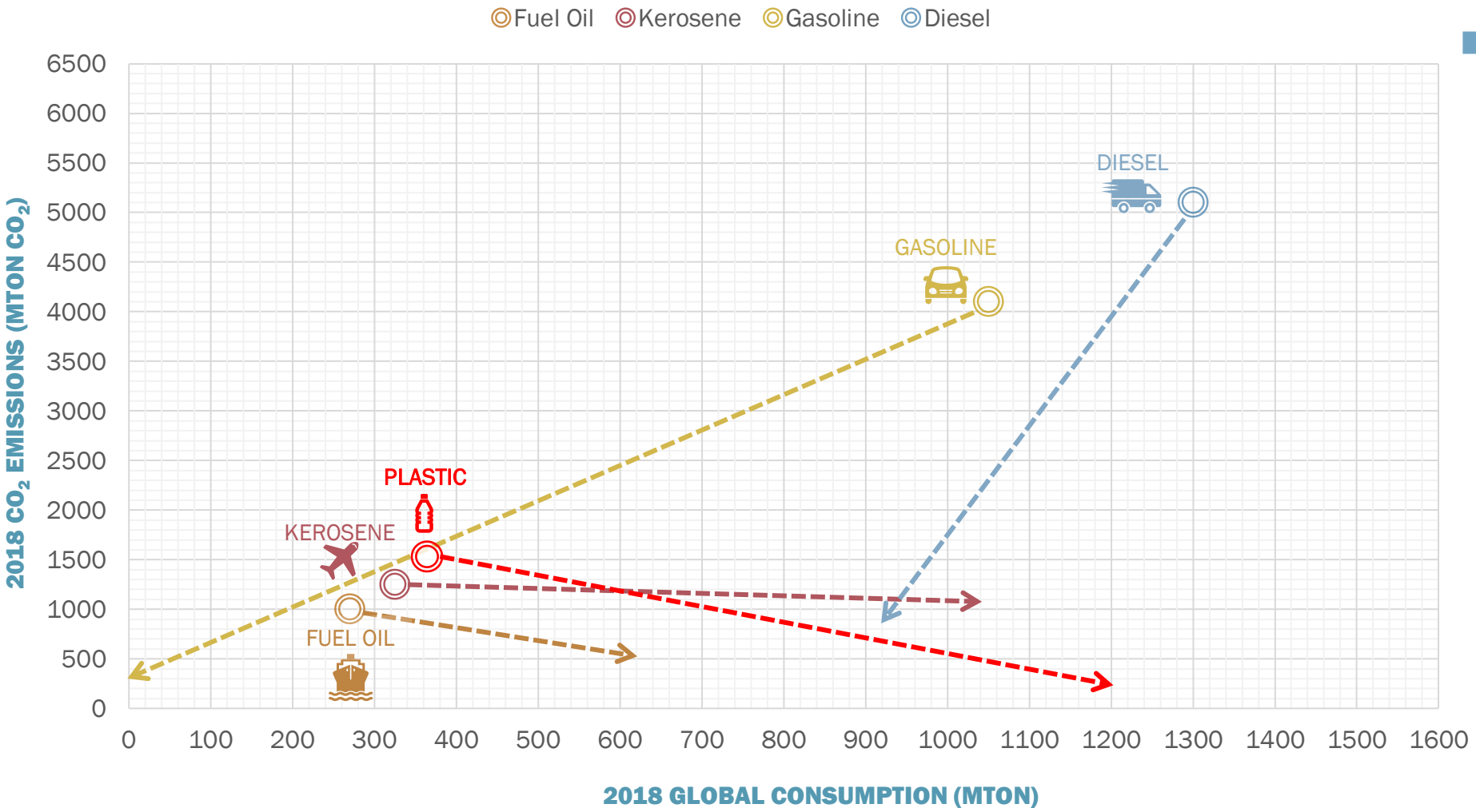
CIRCULAR CARBON AND SCOPE 3 EMISSIONS

GLOBAL GHG EMISSION DEVELOPMENT FOR FUELS AND PLASTICS[1]



Refineries will shift their output from **80/20** in 2018 to **20/80** by 2050 (Fuel/Feedstock ratio)

CARS: 2018→2050
100% electric

AVIATION: 2018→2050
25% bio-fuel, 75% e-fuel

TRUCKS: 2018→2050
70% electric, 20% bio-fuel, 10% e-fuel

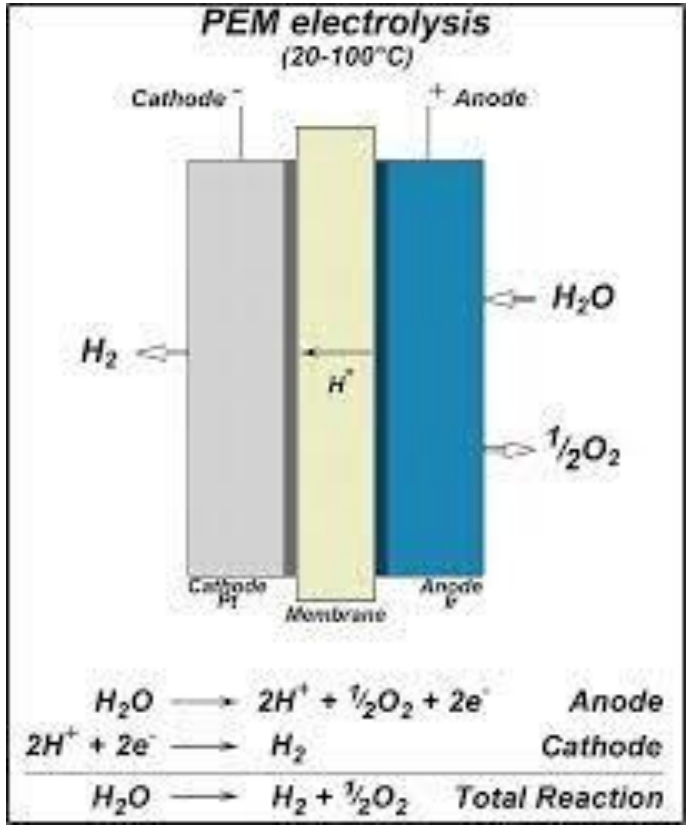
SHIPPING: 2018→2050
50% bio-fuel + 50% e-fuel

PLASTICS: 2018→2050[2]
Recycling (63%) + CCU (26%) + bio-feedstock (11%)

[1] Personal analysis based on public data and 2050 fuels data derived from Irena Global Energy Transformation Report 2018
[2] Plastics 2050 volumes and scenarios taken from Nova Paper #12, Nova Institut.

SUSTAINABLE METALS FOR ELECTRIFICATION

EXAMPLE OF IRIDIUM FOR PEM ELECTROLYZERS*



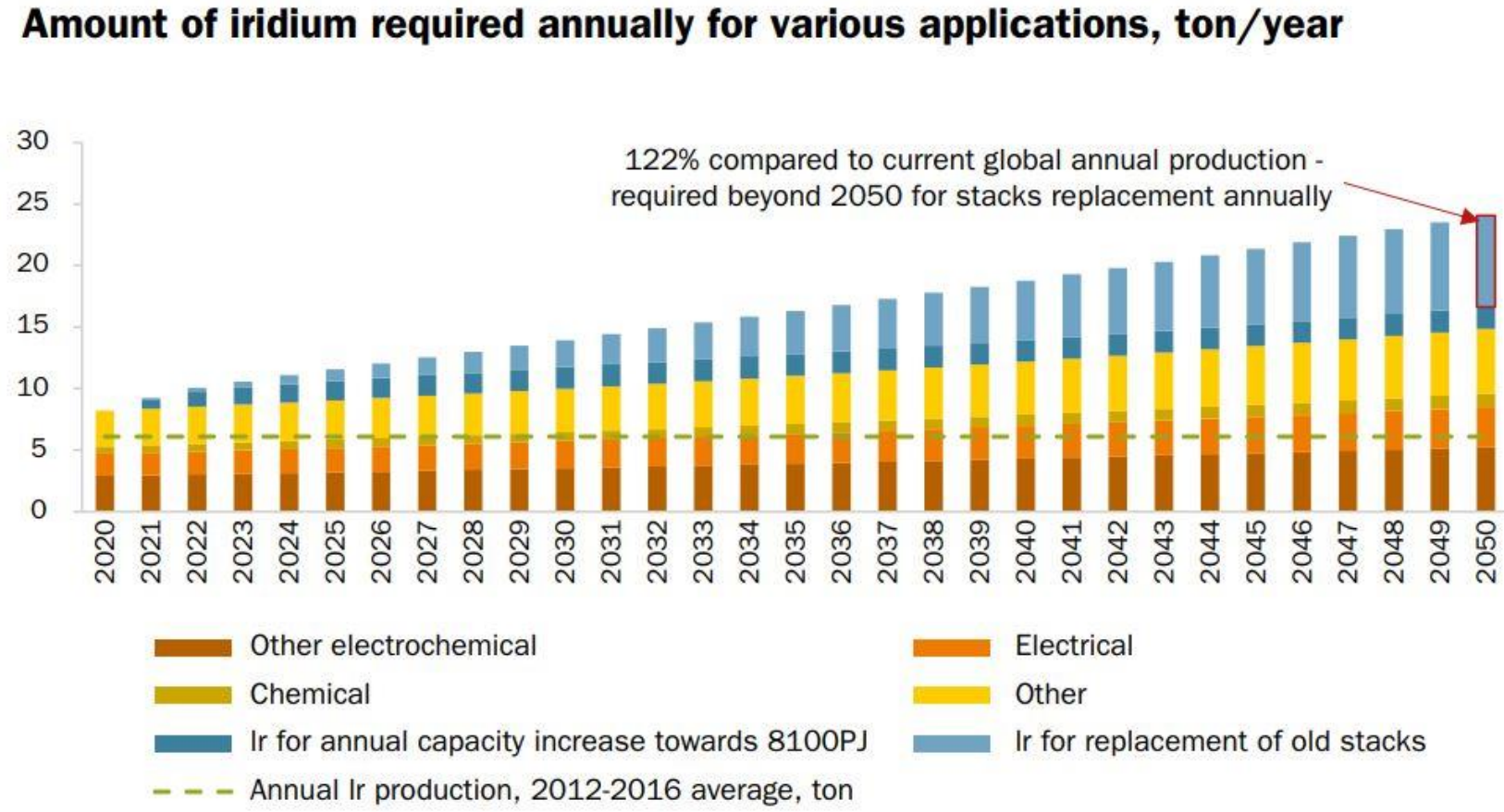


Figure 2 *Amount of iridium required annually to upscale green hydrogen production and for other uses*[25]

*Figure 2 taken from TNO report: https://publications.tno.nl/publication/34638000/RwfRMH/wieclawska-2021-towards.pdf

KEY TAKE-AWAYS

FOR NAVIGATING THE BERMUDA TRIANGLE SUCCESSFULLY

The Transformation of the Chemical industry will play a crucial role in realizing the ambitions of the EU Green Deal.

Bermuda triangle related risks and opportunities for the Chemical Industry:

Low emission electricity:

- Electrify processes and secure access to low emission electricity
- Secure import of green hydrogen/ammonia as additional low emission energy carriers
- Innovative solutions to improve renewable energy generation and storage

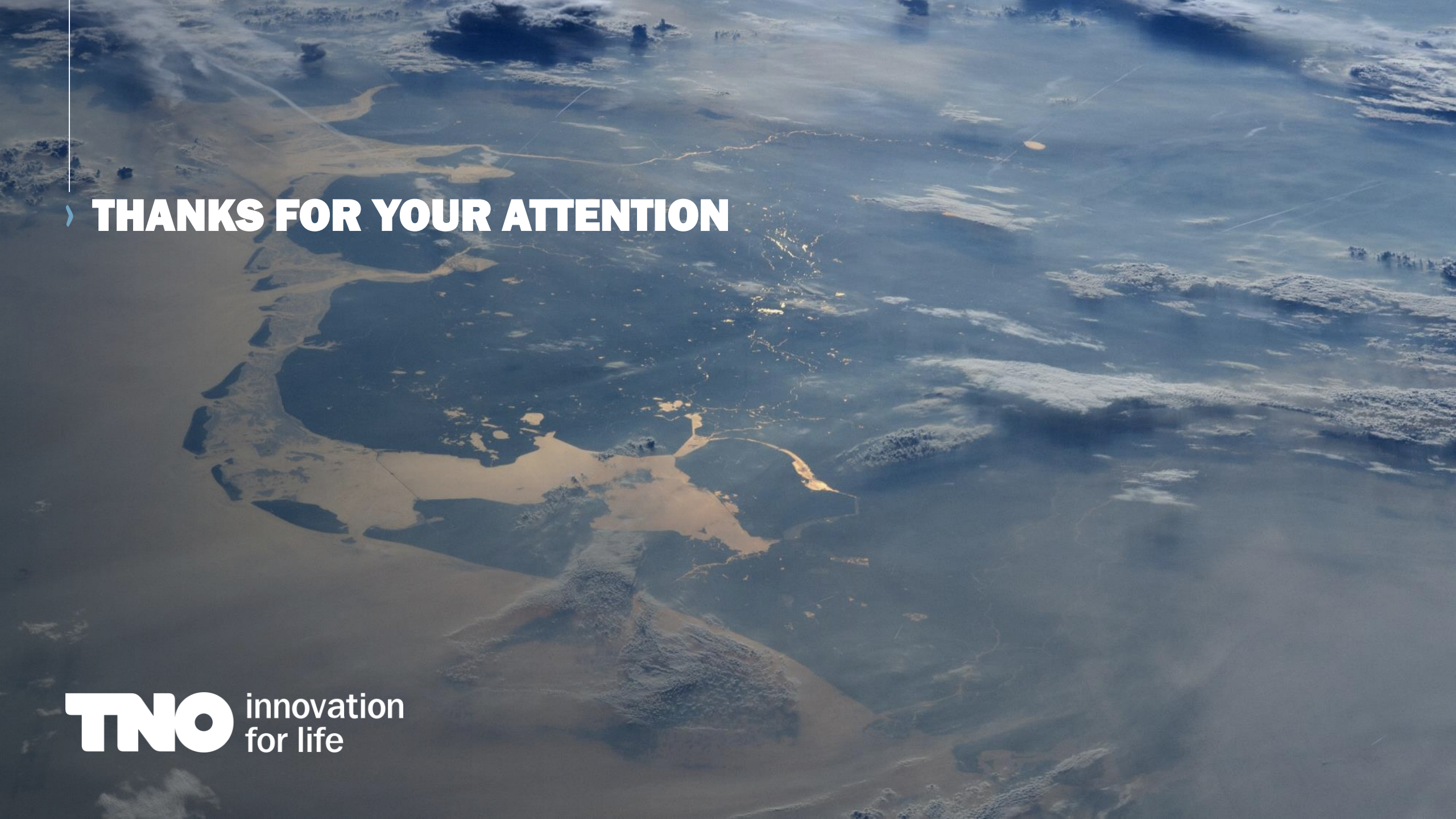
Circular carbon:

- Transition from a fossil to circular carbon feedstocks such as plastic recyclate, biomass or CO_2
- Secure local supply and import of plastic waste, pyrolysis oil, biomass, bio-/e-methanol, bio-ethanol…
- Innovative solutions for a circular carbon economy

Sustainable minerals/metals:

- Massive electrification will invoke a steep demand increase for (critical) minerals/metals
- Innovative solutions for sustainable mining and recycling

The Chemical Industry will deliver key solutions required for a sustainable future!



THANKS FOR YOUR ATTENTION

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