IRENA
International Renewable Energy Agency

Reaching zero with renewables: outlook and challenges for renewable energy generation

Dolf Gielen
Director Innovation and Technology

Worldsteel Open Forum, Brussels, 4-5 October 2022

Who is IRENA

IRENA
International Renewable Energy Agency

Analysis

Convening & Networking

- **Global near-universal membership:** 167 member countries, 17 countries in accession
- **Offices in:** Abu Dhabi, Bonn & New York
- **Annual Ministerial level Energy Transition Forum**
- **Public-Private Collaborative Frameworks**
  - Geopolitics
  - **Green Hydrogen**
  - Hydropower
  - High Shares of Renewables
  - Critical Materials for the Energy Transition
  - Just and Inclusive Energy Transition
  - Offshore Renewables
- **Coalition for Action** (2014) brings together over **130 leading renewable energy players** incl. companies, industry associations, civil society, research institutes and IGO
- **Events:** multiple events every month, large & small

IRENA VIRTUAL EDITION INNOVATION WEEK

IRENA INNOVATION DAY

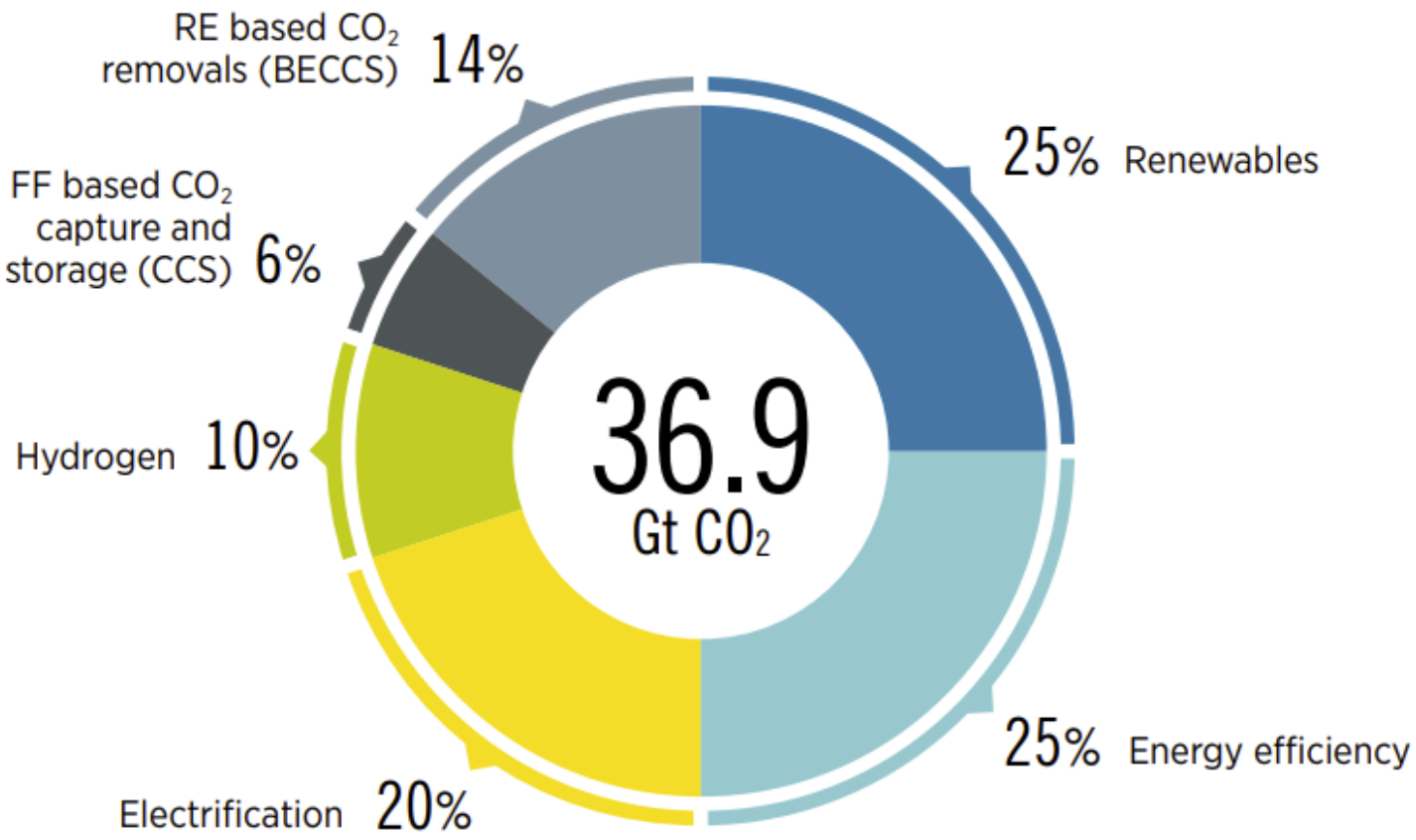
Energy intensive industry a major source of global CO_2 emissions

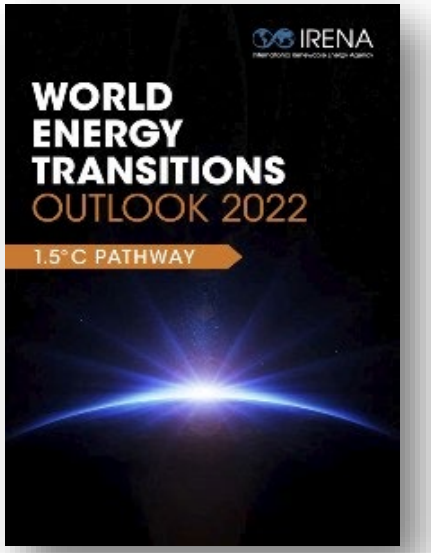
Sector	2017 Final energy use	2017 CO_2 emissions (Direct and indirect energy & process)
	[EJ/yr]	[Gt/yr]
Iron and steel	34	3.63
Aluminum	6.0	0.85
Chemical and petrochemical	46.8	2.72
Cement	10.7	2.48

IRENA calculations

Renewables, efficiency and electrification dominate energy transition

Reducing emissions by 2050 through six technological avenues





90% of all decarbonisation in 2050 will involve renewable energy through direct supply of low-cost power, efficiency, electrification, bioenergy with CCS and green hydrogen.

Industry CO_2 mitigation and the link with renewables

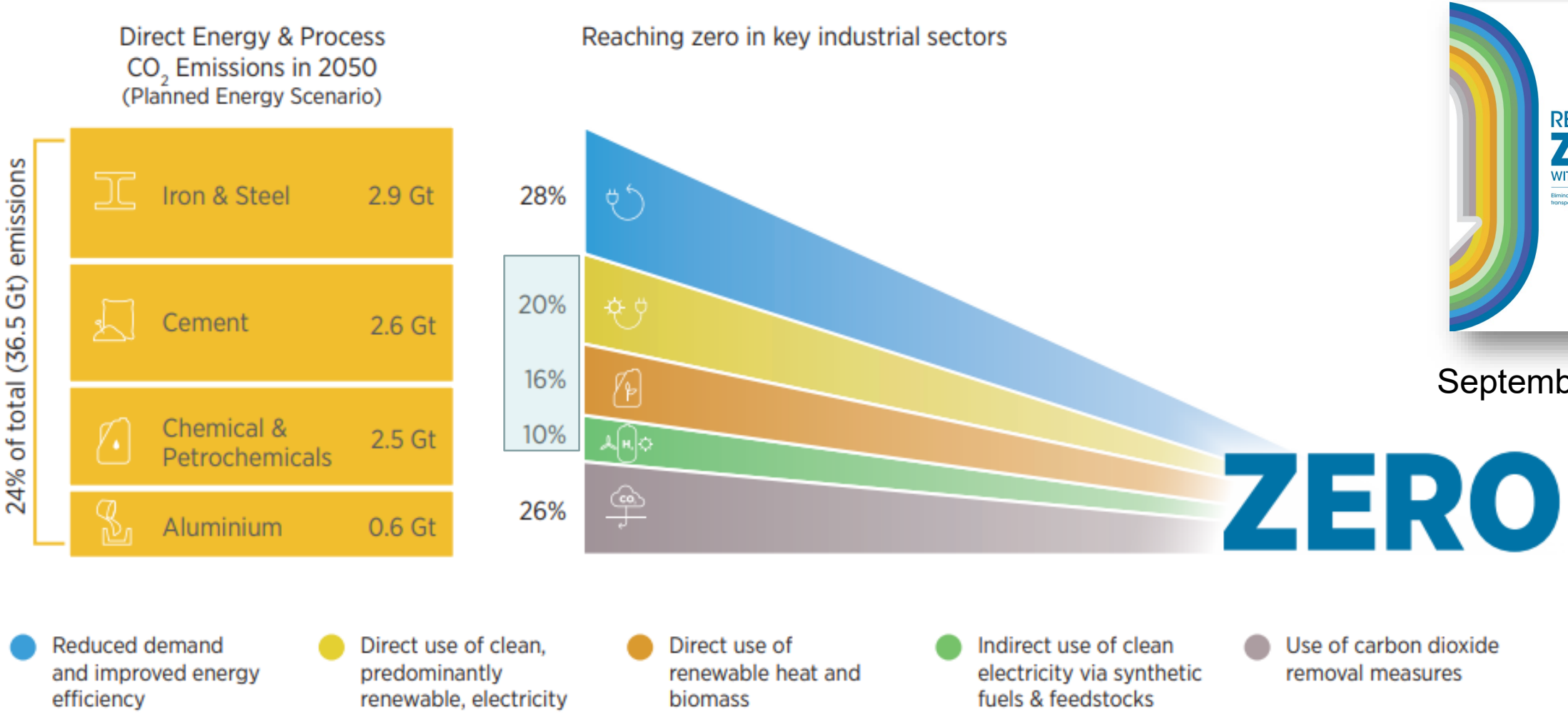
- REDUCE – Energy efficiency and circular economy
- REDUCE - Renewable electricity and electrification
- REDUCE – Green hydrogen and other PtX
- RECYCLE – Biomass feedstock and bioenergy
- REUSE – CCUS, also BCCUS
- REMOVE – CCS, also BECCS

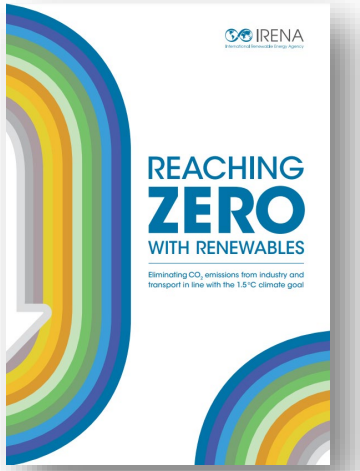
- Energy intensive commodities account for 2/3 of industrial energy use
  - Energy intensive materials can shipped, recycled, substituted etc

Decarbonisation solutions for the industry sector

Each industry is different but renewable energy can play a key role in all sectors

IRENA
International Renewable Energy Agency





September 2020

Today's steel industry

Steel production technologies (2021):

- 70.8% BF-BOF steel
- 28.9% EAF steel

Iron supply (2021):

- 1354 Mt pig iron (BF)
- 114 Mt DRI
- 500 Mt scrap (approx.)

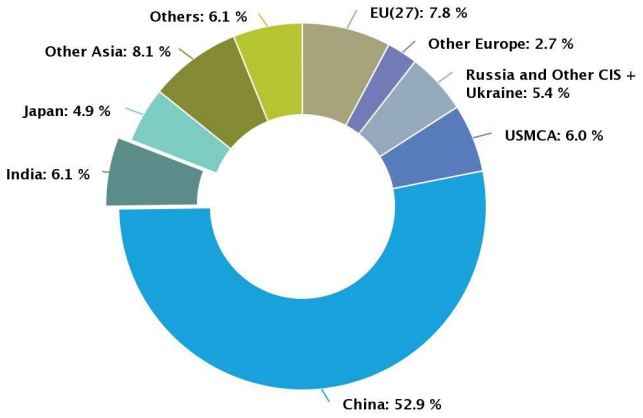
Capital stock

- Approximately 1950 steel plant worldwide
- Of which 474 plant 1.83 Gt capacity
- Numerous databases exist

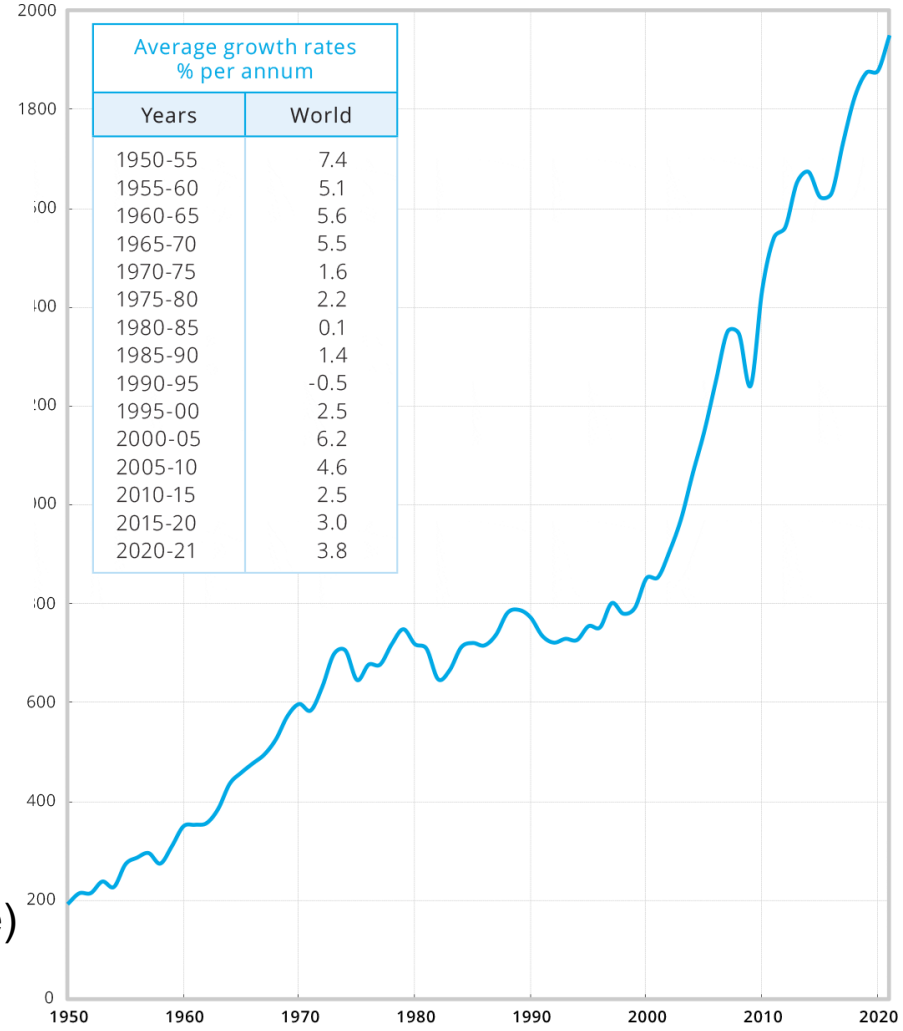
Decarbonization options

- Energy efficiency
- CCS for blast furnace (ULCOS studies, pilot ARCELORMittal Dunkerque France)
- DRI – natural gas – CCS (Emirates Steel UAE)
- DRI – hydrogen (about 10 pilot projects)
- Electro-steelmaking (SIDERWIN - labscale)

Production shares 2021



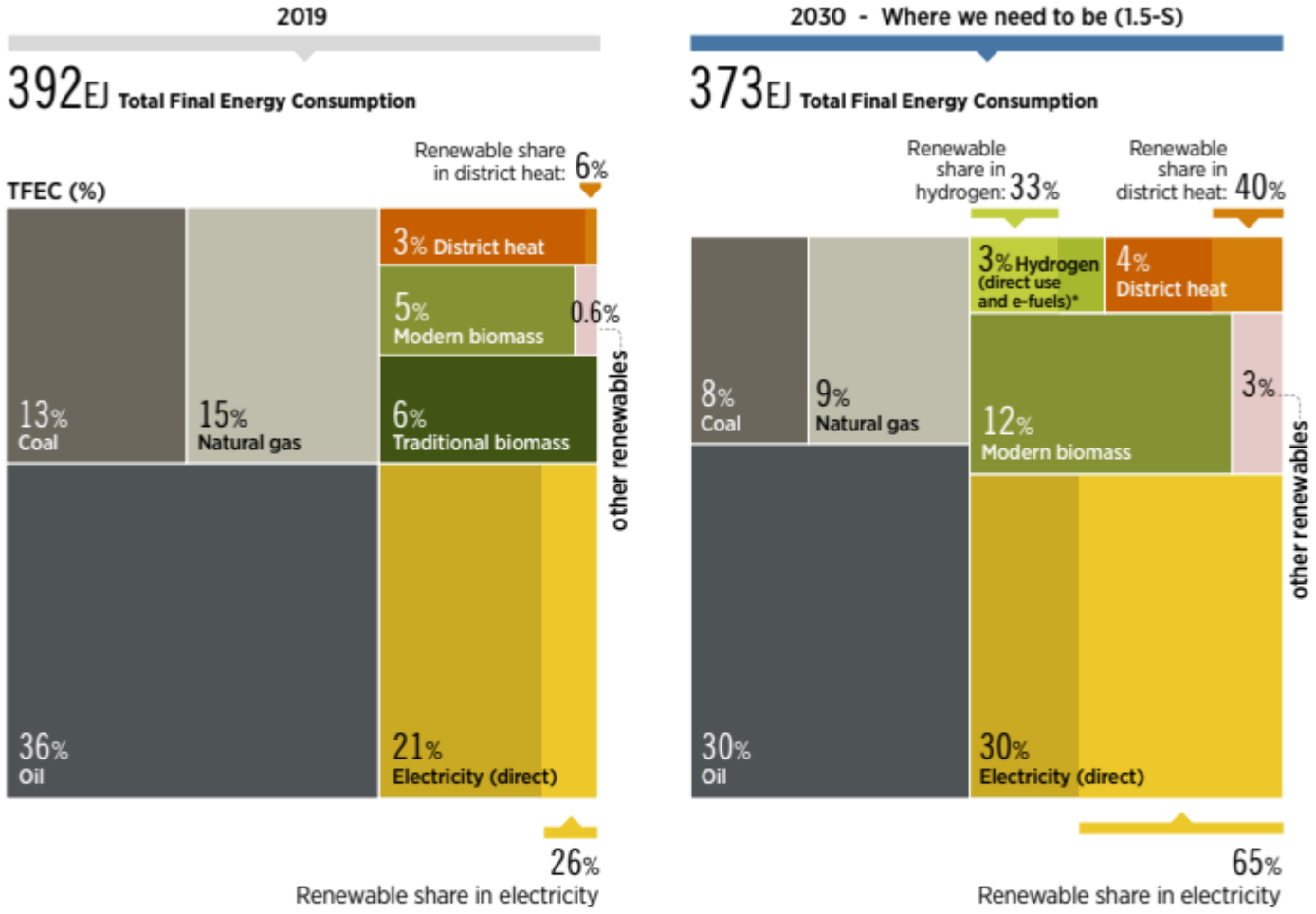
Source: World Steel Association, 2022



Average growth rates % per annum

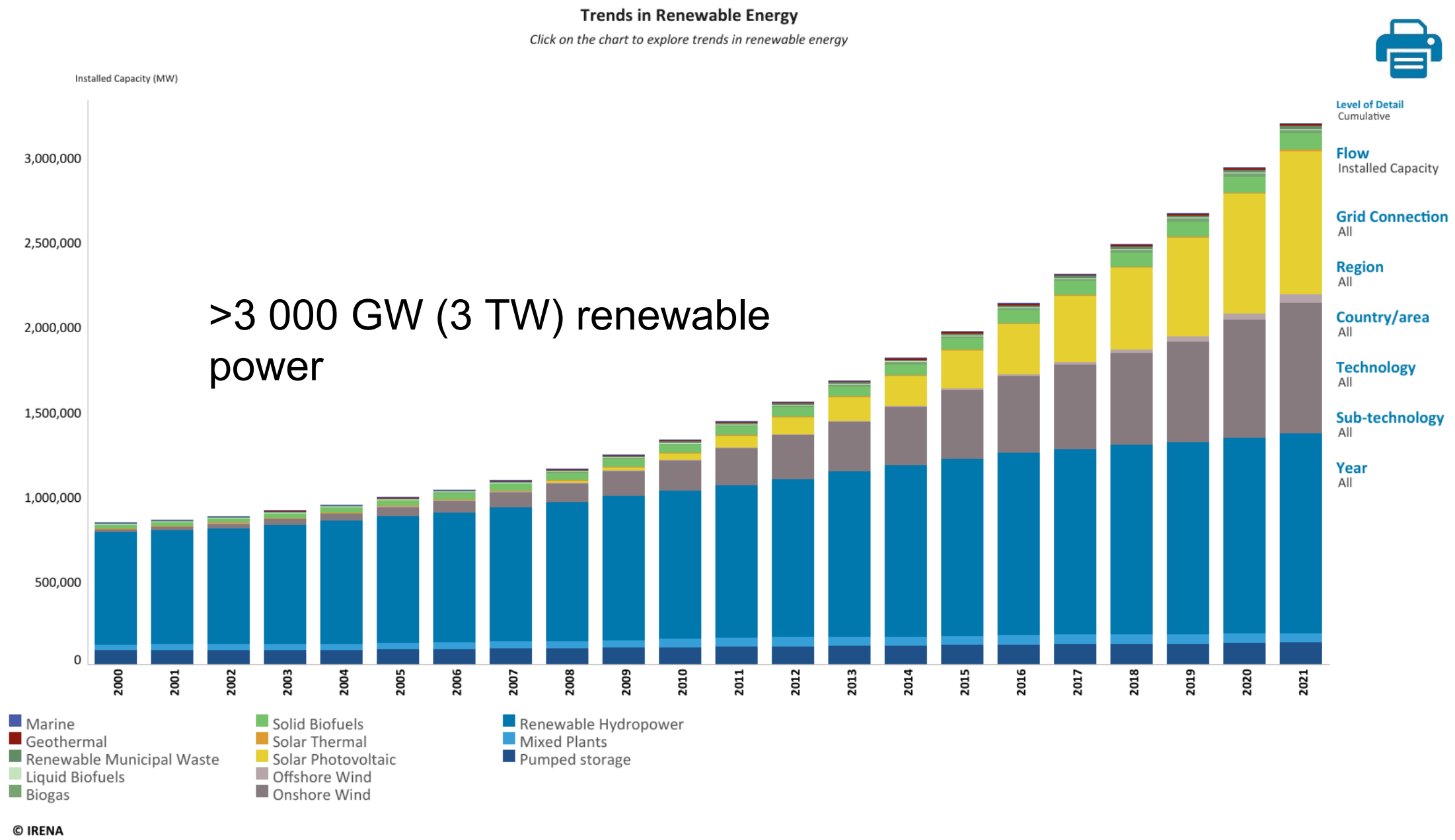
Years	World
1950-55	7.4
1955-60	5.1
1960-65	5.6
1965-70	5.5
1970-75	1.6
1975-80	2.2
1980-85	0.1
1985-90	1.4
1990-95	-0.5
1995-00	2.5
2000-05	6.2
2005-10	4.6
2010-15	2.5
2015-20	3.0
2020-21	3.8

Breakdown of TFEC by energy carrier in 2019 and 2030 (EJ)



- Electricity will become by far the dominant energy carrier in future clean energy systems
- Direct electrification shares of final energy consumption would reach 30% by 2030 and exceed 50% by 2050, up from just 21% in 2019
- Transport and hydrogen production will emerge as new and noteworthy markets for electricity

Note: The figures above include only energy consumption, excluding non-energy uses. For electricity use, 26% in 2019, 65% in 2030 and 90% in 2050 are sourced from renewable sources; for district heating, these shares are 6%, 40% and 90%, respectively; for hydrogen (direct use and e-fuels), the renewable energy shares (*i.e.* green hydrogen) would reach 66% by 2050. The category "Hydrogen (direct use and e-fuels)" accounts for total hydrogen consumption (green and blue) and other e-fuels (e-ammonia and e-methanol). Electricity (direct) includes all sources of generation: renewable, nuclear and fossil fuel based. 1.5-S = 1.5°C Scenario; EJ = exajoule.

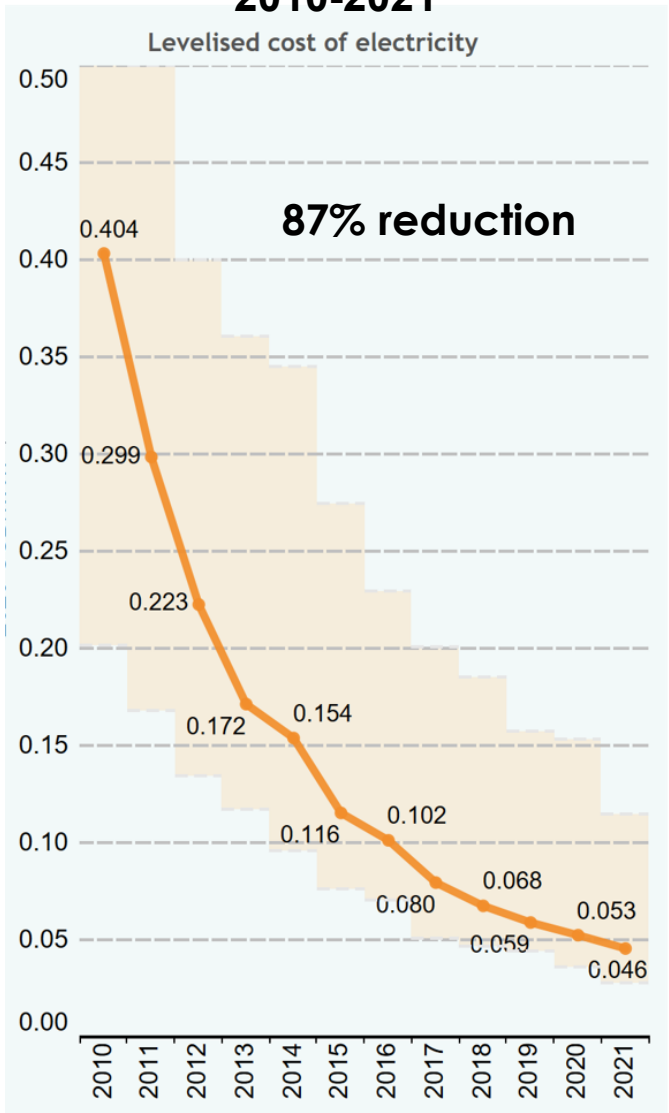


>3 000 GW (3 TW) renewable power

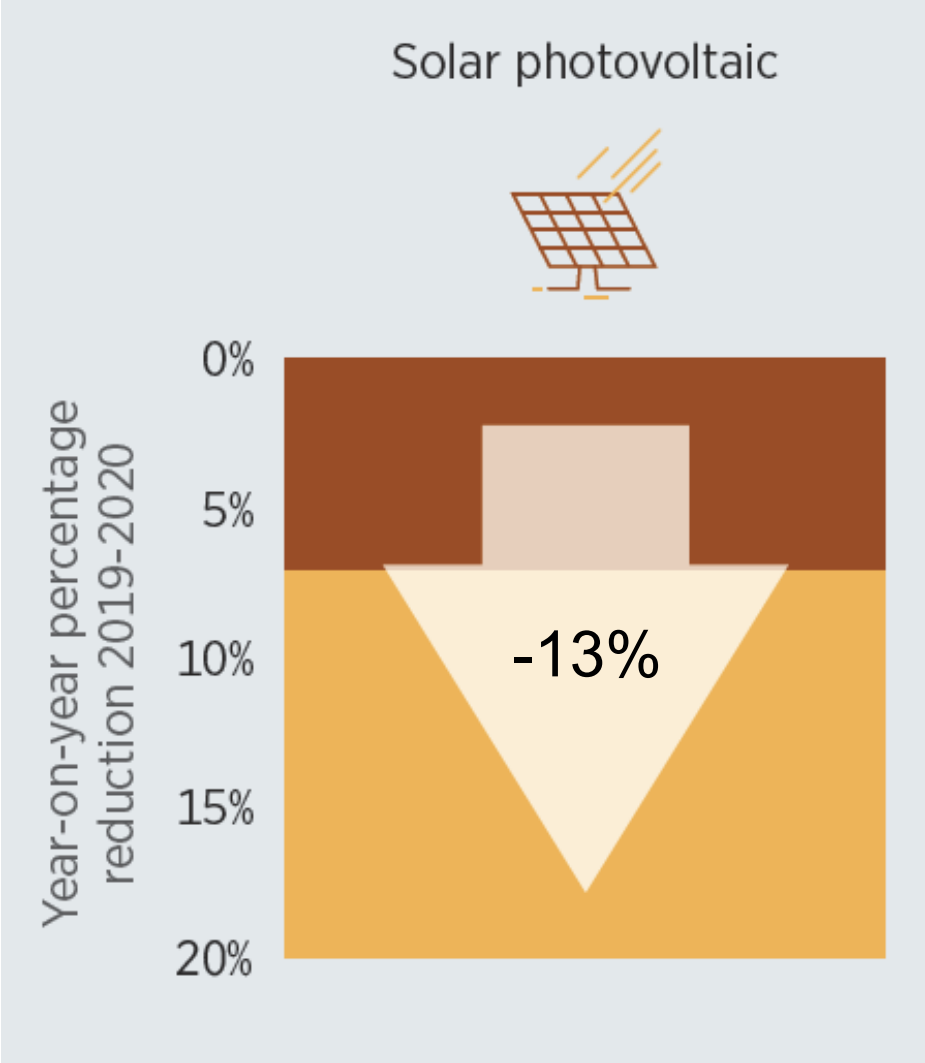
Solar PV industry propelled by its cost competitiveness

IRENA
International Renewable Energy Agency

2010-2021



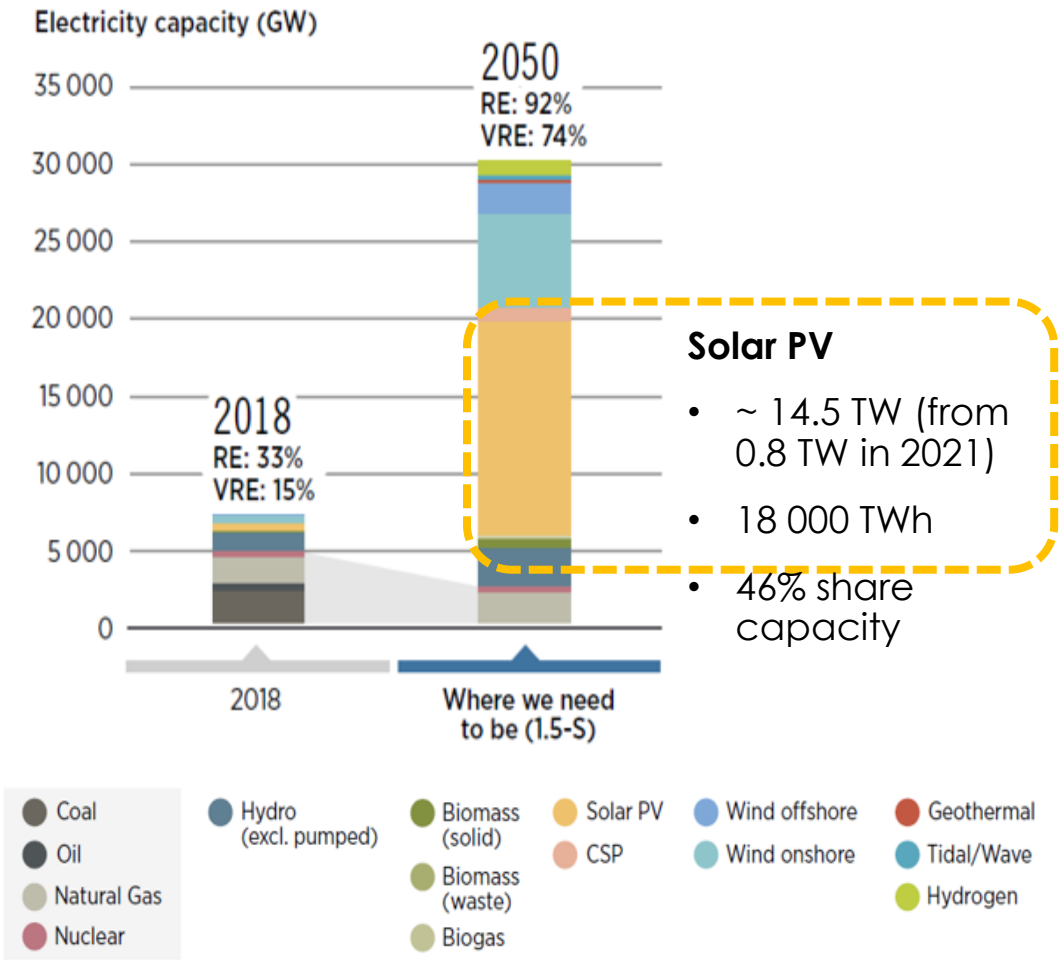
2010-2021



- Brazil < 2 USD ct/kWh
- Portugal < 1.4 USD ct/kWh
- Middle East < 1.2 USD ct/kWh

Source: IRENA Renewable cost database, 2022 and https://www.irena.org/publications/2021/Jun/Renewable-Power-Costs-in-2020 Data for 2021 is preliminary

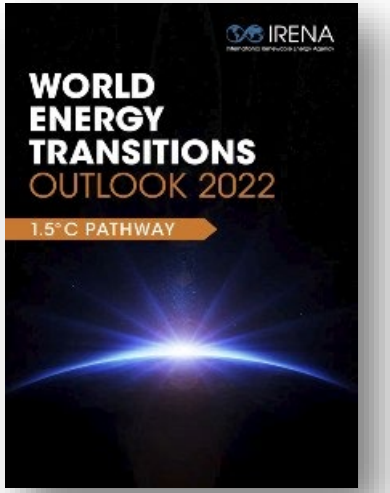
Electricity sector transformation in a 1.5°C scenario



Solar PV

- ~ 14.5 TW (from 0.8 TW in 2021)
- 18 000 TWh
- 46% share capacity

- Global renewables capacity additions need to increase four-fold this decade.
- The share of renewables in power generation would grow to 90% in 2050 from 25% in 2018.
- VRE like wind and solar would grow to 63% of all generation in 2050, compared to 10% in 2018.
- Such power systems will require increased flexibility.
- Industry can provide flexibility and that can create economic benefits.



March 2022

Source: https://www.irena.org/publications/2022/Mar/World-Energy-Transitions-Outlook-2022

Global power supply projections in a 1.5C scenario

Growing electricity demand for green hydrogen production

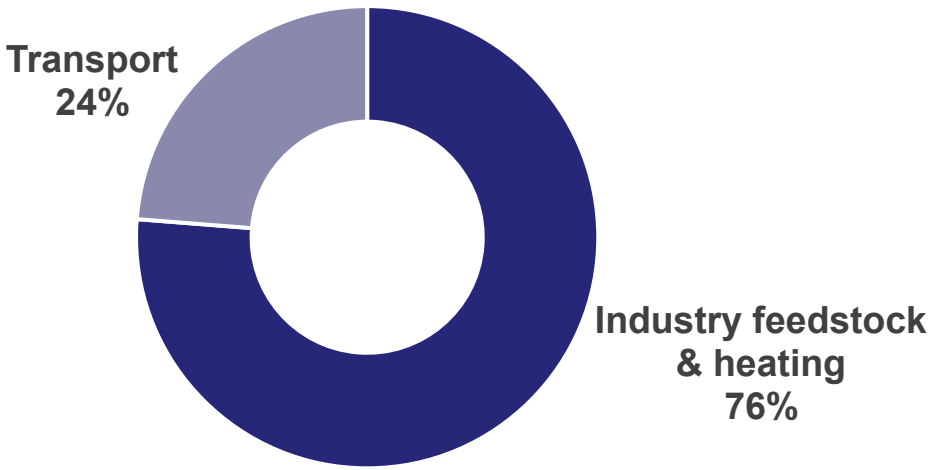
IRENA
International Renewable Energy Agency

By 2050, most hydrogen will be consumed in hard-to-decarbonise sectors

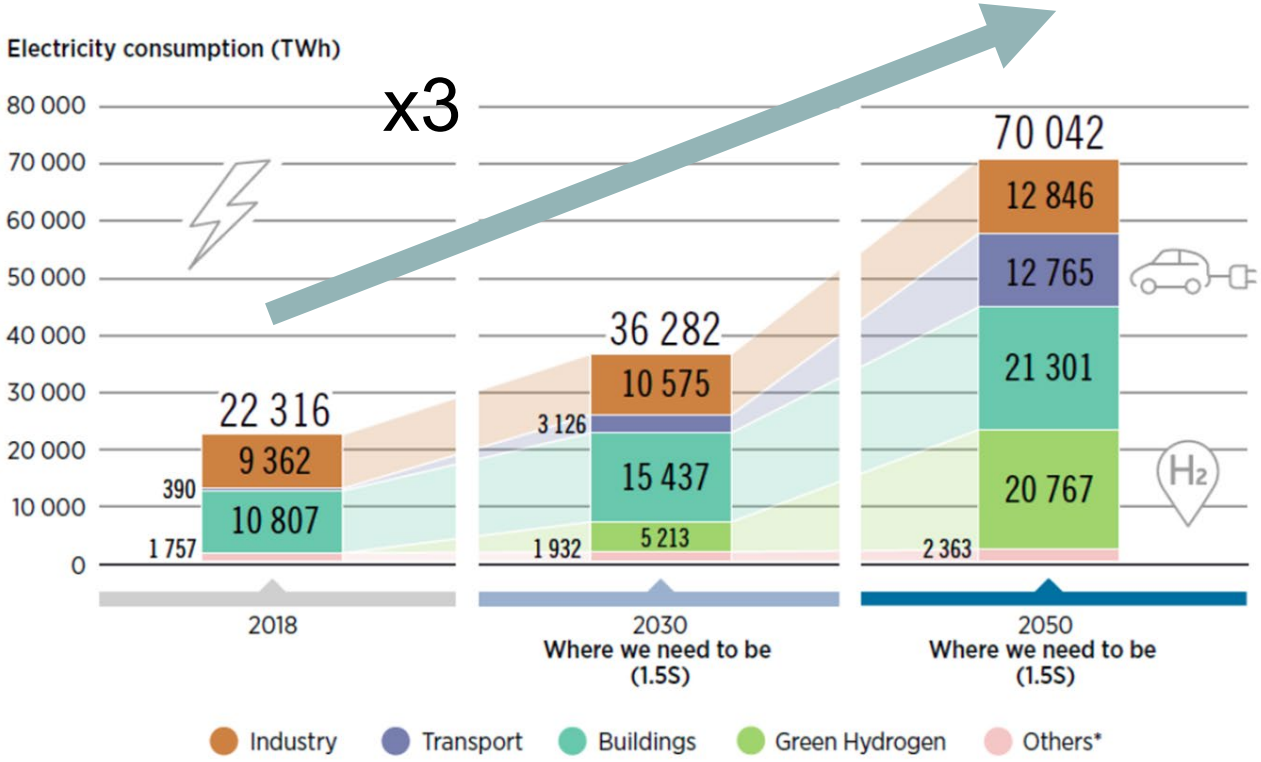
1/3 blue, 2/3 green hydrogen supply

Total hydrogen demand increase 5-fold from today

Clean hydrogen consumption in 1.5C Scenario in 2050



Electricity consumption by sector, 2018, 2030 and 2050 (TWh/yr) in the 1.5°C Scenario



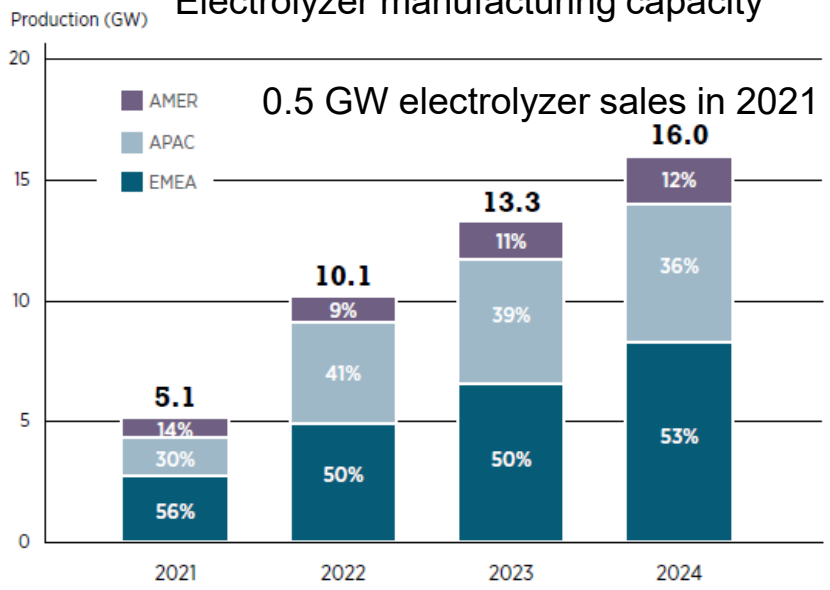
Growing commitment to develop green hydrogen

Green hydrogen compact dialogue

Over 30 UN Energy Compacts for green hydrogen from governments, subnational governments, intergovernmental organizations, private sector companies and coalitions

268 GW new renewable capacity by 2030 and 129 GW of new electrolyzer capacity by 2030 committed

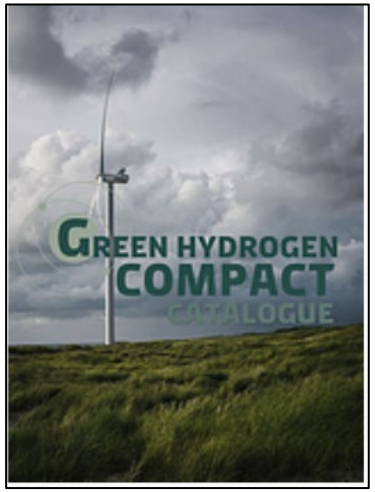
Electrolyzer manufacturing capacity



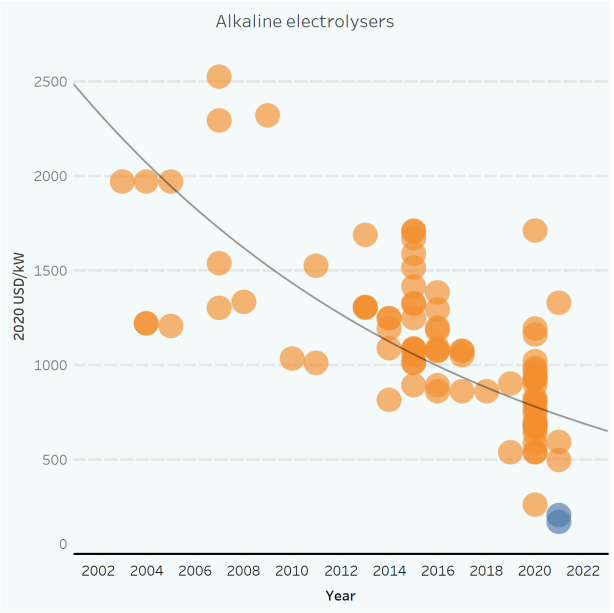
1.5C pathway:

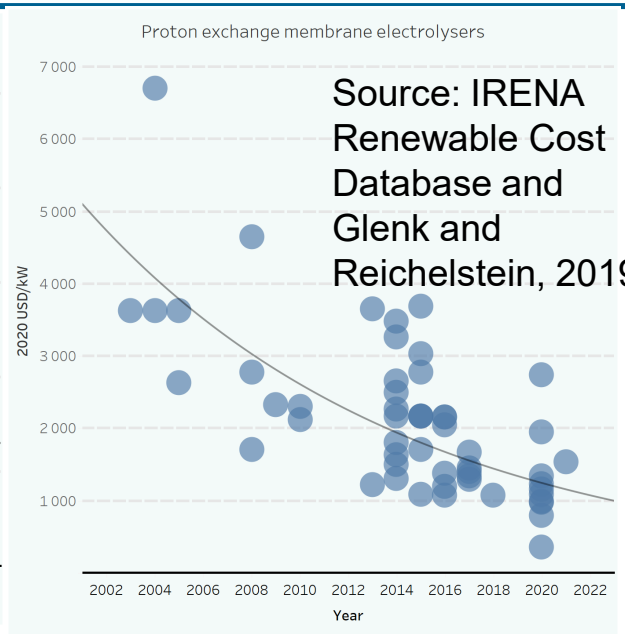
Electrolyzer needs: 350 GW in 2030, 5 000 GW in 2050

1 Mt hydrogen = 10 GW electrolyzers = 20 GW renewable power



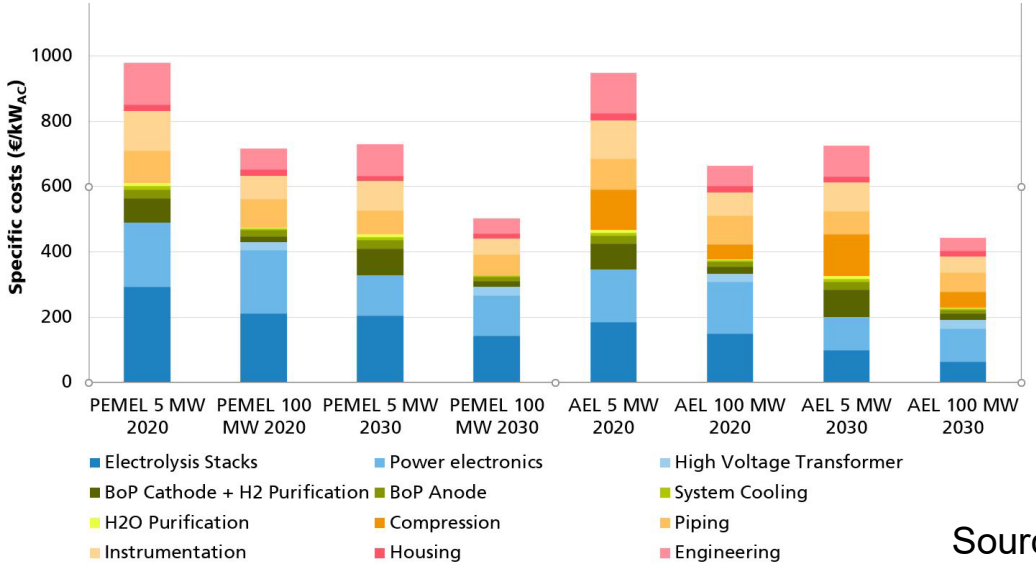
Hydrogen economics
3 USD/kg hydrogen = 25 USD/GJ. Coking coal today 20 USD/GJ





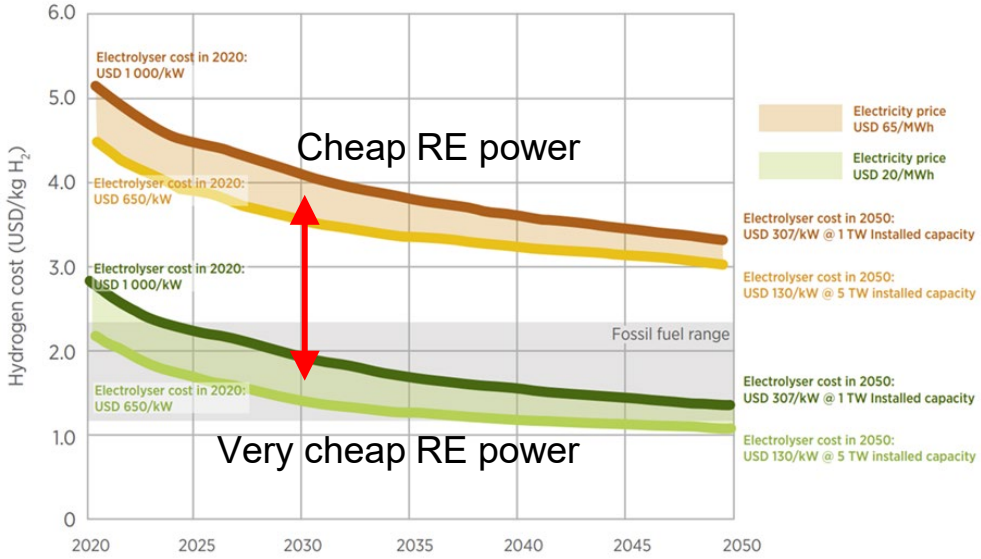
Source: IRENA Renewable Cost Database and Glenk and Reichelstein, 2019

Electrolyzers – 800-1200 USD/kW today; USD 500-600 by 2030



Source: FhG ISE, 2022

Green hydrogen will become cheaper than blue hydrogen



Source: IRENA (2019)

2050 (1.5C scenario):

- Need to reduce production cost substantially to 1.5 USD/kg hydrogen
- Plus 1.5 USD/kg for transport

Profound energy and investment implications

IRENA
International Renewable Energy Agency

- 1 Mt hydrogen/yr requires 10 GW electrolyzers and 20 GW renewable power generation
- This equals approximately 30 bln USD investments

- 1 Mt DRI requires 80 kt hydrogen
- 1500 Mt DRI require 120 Mt hydrogen – todays worldwide hydrogen production volume
- 360 bln USD investments in hydrogen production needed

- Ship hydrogen or ship DRI/HBI ?
- Hydrogen trade requires likely further processing into ammonia
- Ammonia loading terminals and ammonia tankers needed

- Implications for iron ore quality (fines/pellets, purity)
- Land use 5 km2/GW (PV) – approximately 100 km2/Mt hydrogen
- 1 Mt hydrogen production requires 9 Mt pure water

Cross-sectorial industrial transition challenges
Need to think beyond technology

IRENA
International Renewable Energy Agency

- Net zero ambitions yes, but how fast will net zero implementation follow ?
- Access to renewable energy – enabling infrastructure
  - Competition for certain scarce resources (cheap renewable electricity, green hydrogen, sustainable biomass)
- Additional cost, competitiveness and carbon leakage – CBAM etc.
  - Industry location choice may be affected by access to cheap & clean energy
- Mitigation technologies exist but they are often not yet mature, scaling challenges
- Social acceptance challenges – sustainable biomass, CCS
- Standards and certification needed for green commodities
- Off-take risk – secure demand for green commodities can reduce financing cost
- Stranded assets and retrofit potentials for integrated production processes

Ship hydrogen or move iron making ?

IRENA
International Renewable Energy Agency

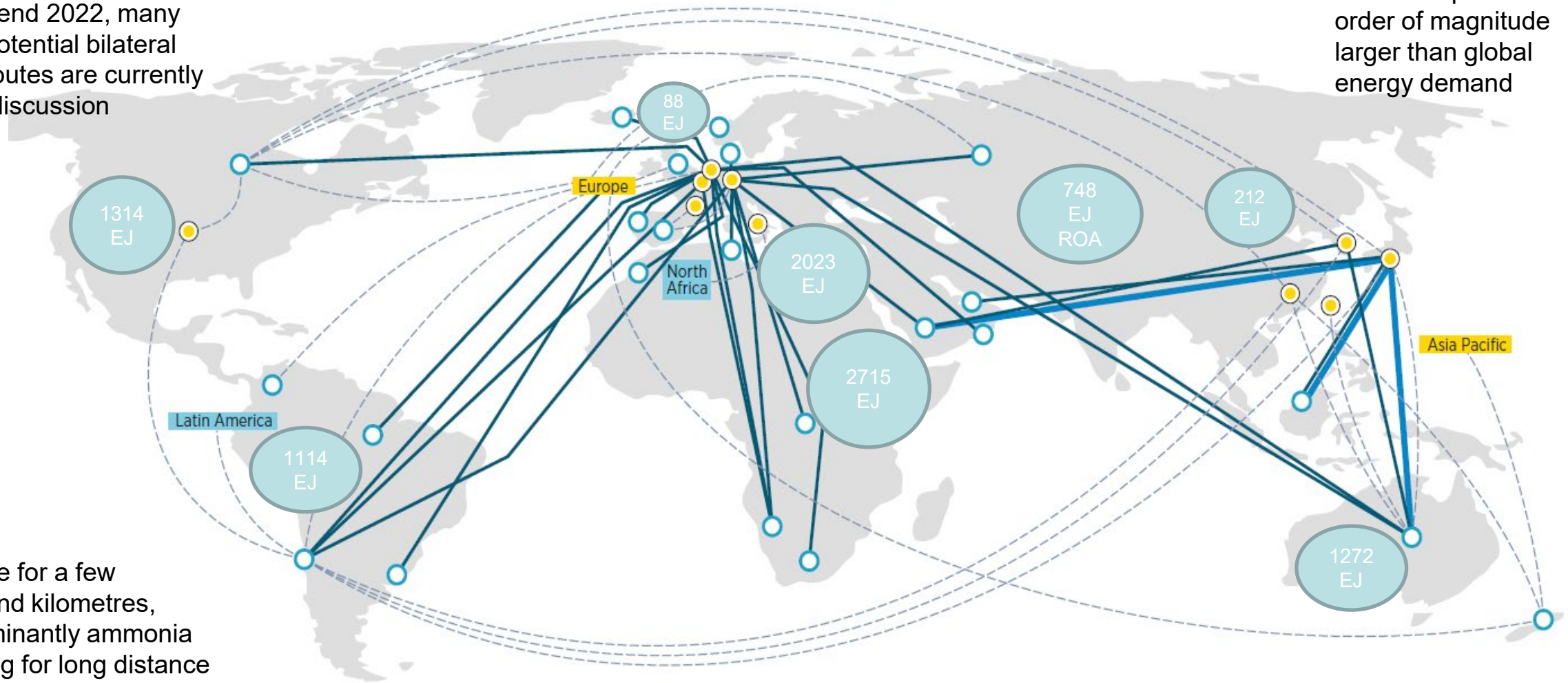
- Hydrogen supply cost and availability will vary by location
- Remote locations may have lower hydrogen production cost
- Iron ore mining areas may have low hydrogen production cost
- Shipping HBI is cheaper than shipping iron ore and fuel/feedstock
- Interest from iron ore mining companies Fortescue, Vale etc
- Separate iron making and steel making/finishing steps ?
- Hybrit is exceptional case
- Mauritania project under development
  - Arcelor – SNIM announcement Mauritania DRI prefeasibility study 25 May 2022

Hydrogen trade routes, plans and agreements - IRENA analysis suggests 25% internationally traded H2, 50/50 pipeline and shipping

IRENA
International Renewable Energy Agency

Status end 2022, many more potential bilateral trade routes are currently under discussion

Technical potential order of magnitude larger than global energy demand



Pipeline for a few thousand kilometres, predominantly ammonia shipping for long distance intercontinental trade

Source: IRENA

Technical potential 2050 at <1.5 USD/kg

Exporter | Exporting region

Importer | Importing region

New routes in place or under development

MoUs in place establishing trade routes

Potential trade route explicitly mentioned in published strategies

The need for standards and certification of clean and green steel

Demand

- Important to drive demand for adoption for bulk consumers reduce Scope 3 emissions.
- Allow product differentiation making choices clearer for buyers

Supply

- Drive investments in cleaner forms of production from low carbon supply chains

Policy implications

- Support policy implementation for energy efficiency and emission intensity schemes

Breakthrough Agenda report highlights the importance of international cooperation to decarbonize steel

- Companies and governments to **create standard definitions for low and near-zero carbon steel**, to adopt standards by the mid-2020s
- Companies and governments to increase shares of **public sector procurements** to send strong demand signals to producers.
- Creating a **strategic dialogue between producing and consuming nations** to ensure the competitiveness of near-zero emission steel.
- Companies and governments to identify deployment of commercial-scale **pilots for near-zero emission steel** in large steel-producing regions.
- Donor countries and MDBs to **increase funding for near-zero emission steel** technologies in emerging and developing countries.


HYDROGEN:
A RENEWABLE ENERGY PERSPECTIVE
SEPTEMBER 2019
HYDROGEN FROM RENEWABLE POWER
TECHNOLOGY OUTLOOK FOR THE ENERGY TRANSITION
REACHING ZERO WITH RENEWABLES
WORLD ENERGY TRANSITIONS OUTLOOK 2022
1.5°C PATHWAY
DEMAND-SIDE FLEXIBILITY FOR POWER SECTOR TRANSFORMATION
Analytical Brief
GREEN HYDROGEN FOR INDUSTRY
A GUIDE TO POLICY MAKING
GREEN HYDROGEN COST REDUCTION
SCALING UP ELECTROLYSERS
TO MEET THE 1.5°C CLIMATE GOAL
RENEWABLE POWER-TO-HYDROGEN
INNOVATION LANDSCAPE BRIEF
Geopolitics of the Energy Transformation
The Hydrogen Factor
Innovation trends in electrolysers for hydrogen production
GLOBAL HYDROGEN TRADE TO MEET THE 1.5°C CLIMATE GOAL
PART II
TECHNOLOGY REVIEW OF HYDROGEN CARRIERS
INNOVATION OUTLOOK
RENEWABLE METHANOL
METHANOL INSTITUTE
INNOVATION OUTLOOK
RENEWABLE AMMONIA
AMMONIA ENERGY ASSOCIATION
GLOBAL HYDROGEN TRADE TO MEET THE 1.5°C CLIMATE GOAL
PART III
GREEN HYDROGEN COST AND POTENTIAL

Thank you !

Why hydrogen ?

- H2 – contains no carbon so not combustion CO2
- It is an energy carrier NOT an energy source
- You need some other form of primary energy to produce hydrogen, which entails losses and causes upstream CO_2 emissions
  - Hydrogen is today produced from natural gas and coal
- Hydrogen contains a lot of energy per unit of weight: 120 GJ/t (LHV) which equals 140 GJ/t (HHV) – three times the energy density of natural gas per unit of weight
- It is a gas, liquefies only at very low temperatures near absolute zero
- The molecular mass is 2, so 1 m3 of hydrogen gas contains 89 grams of hydrogen at room temperature
  - 1 m3 of natural gas contains 714 grams of methane
  - Natural gas contains nearly three times more energy per unit of volume
- So not easy to handle but clean
- Today certain industrial processes require hydrogen (eg whitening the barrel in refineries, ammonia production)
- Hydrogen or hydrogen energy derivatives can be used more widely to substitute fossil fuels