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The Green Energy 2023 White Paper

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GREEN ENERGY

Historically, energy has been essential for humanity. In fact, some scientific theories state that most of the universe itself is and comes from energy[1]. Throughout the years, ancient and modern civilisations have leveraged energy for powering, heating, feeding, and lighting purposes, among others. Undoubtedly, technology has represented an opportunity to make energy increasingly useful, scalable, and efficient. Energy has allowed global economies to become more productive and interconnected.

However, the energy sourced from fossil fuels such as oil and coal has proven to be significantly harmful for the environment due to its large contribution of CO_2 emissions. Certainly, the climate crisis has shown that the dependence on fossil fuels cannot be sustained throughout time and new solutions are needed in this sector. Thus, the transition towards an economy based on low-carbon sources of energy is a key lever for mitigating the climate crisis.

A brief history of the green energy transition

790,000 years ago
The first tracks of fire used for cooking and heating appear in Israel[2].

1700 - 1869
The Industrial Revolution relies heavily on coal energy[3].

1839
Edmond Becquerel discovers how to convert light into electricity[4].

1882
North America's first hydroelectric power plant opens[7].

1866
Augustin Mouchot invents the first solar energy system[6].

1860s
The start of the age of oil and the start of electric power distribution[5].

1956
Solar cells become commercially available[8].

2009
The International Renewable Energy Agency (IRENA) is founded[9].

2020
The world's largest offshore wind energy plant opens in the UK[10].

"Energy is central to nearly every major challenge and opportunity the world faces today." – UN[11]

Key facts

- As of **2020**, the global per capita CO_2 emissions were 1.81 trillion (tn) in coal, 1.43tn in oil, and 0.96tn in gas, as the three main energy sources of CO_2 emissions.[16]
- In **2021**, the global energy consumption was 94.3 EJ. In this year, 134 countries (65%) generate most of their electricity from fossil fuels, 66 countries (31%) from renewables, and seven countries (4%) from nuclear energy.[13]
- In **2022** in the European Union (EU), 42% of the consumed electricity was produced from fossil fuels and biomass, 22% from nuclear, 22% from wind and solar, and 10% from hydro.[17]
- At the current rate of progress in terms of energy accessibility, 670 million (m) people will remain without electricity by **2030**, 10m more than projected in 2022.[14]
- By **2050**, the world is expected to consume 760 exajoules (EJ) of energy combining 247 EJ of renewables, 181 EJ of natural gas, 154 EJ of oil, 103 EJ of coal, 48 EJ of hydroelectricity, and 27 EJ of nuclear energy.[12]

Green energy sources

As displayed in the timeline, several types of green energy have been discovered by scientists, biologists, and chemists. Nowadays, we know that the supply of renewable energy sources is unlimited and that this type of energy sources can be naturally replenished while producing low amounts of or no CO_2 emissions. On the other hand, non-renewable energy sources cannot be naturally replenished and produce high amounts of CO_2 emissions. The following table describes both types of energy sources, where the shaded boxes represent renewable energy sources:

Type	Short definition	Facts
Solar	• Solar energy technologies convert sunlight into electrical or thermal energy through photovoltaic (PV) panels. Solar energy can be used to power electric devices or to store energy in batteries or thermal storages.[18]	• The amount of sunlight that hits the Earth's surface in an hour and a half is enough to handle the entire world's energy consumption for a full year.[18] • The global renewable energy capacity is expected to increase by almost 2,400 GW (almost 75%) between 2022 and 2028.[19]
Wind	• Wind is used to produce electricity by converting the kinetic energy of air in motion into electricity. This is achieved through wind turbines that use air force to spin and power an energy generator.[20]	• 6.6% of global electricity comes from wind power. Global wind power capacity is now at over 743 GW.[21] • It would take around 2.4m onshore wind turbines to provide enough electricity to power the world in 2023.[21]
Hydro	• Hydropower uses the power of moving water to generate electricity. This energy production method is among the oldest renewable energy generation processes.[22]	• Hydropower has helped to avoid more than 100 billion (bn) tonnes (t) of carbon dioxide in the past 50 years alone, exceeding even the emissions averted by nuclear power. That is roughly equivalent to the total annual carbon footprint of the United States for 20 years.[23]
Biomass	• Biomass energy is energy generated or produced by living or once-living organisms like plants. The energy from these organisms can be burned to create heat or to be transformed into electricity.	• The biomass electricity market is expected to grow to $61.3bn in 2027 at a CAGR of 7.9%.[24]
Nuclear	• Nuclear energy originates from a process called fission where uranium atoms are split. This generates heat to produce steam, which is used by a turbine generator to generate electricity.[25]	• Nuclear energy now provides about 10% of the world's electricity from about 440 power reactors.[17]
Coal	• Coal is a combustible dark sedimentary rock with a high amount of carbon and hydrocarbons. Coal is classified as a non-renewable energy source because it takes millions of years to form and releases carbon into the atmosphere when used for powering purposes.	• Due to an increase in electricity demand during COVID-19, both Europe and North America showed an increase in coal consumption in 2021 after nearly ten years of back-to-back declines.[26]
Oil	• Petroleum, also called crude oil, is a naturally occurring liquid found beneath the Earth's surface that can be refined into fuel and transformed into non-renewable energy.[27]	• China is the world's largest oil importer, but the U.S. remains as the biggest consumer of internationally-traded oil.[28]
Natural Gas	• Natural gas is a fossil fuel formed by layers of decomposing plants and animals combined with heat from the Earth and pressure from rocks. Natural gas is considered a type of non-renewable energy.[29]	• Russia's share of the EU's gas market was around 50% until the second half of 2021. The EU's REPowerEU plan aims to reduce its economic dependence on Russia due to the Russia-Ukraine war.[30]

Deep dive: Hydrogen

What is it and why is it impactful?

Hydrogen is the simplest and most abundant element on Earth. Each atom of hydrogen has only one proton. All hydrogen matter constitutes **75% of matter on Earth**.[31] This element can be produced and separated from a variety of sources including water, fossil fuels, or biomass and used as a source of energy or fuel. Its abundance, paired with green energy production sources like solar energy, make hydrogen an attractive asset for the energy sector.

Hydrogen has a major role to play in the transition towards a carbon-neutral global economy since it has a great capacity to decarbonise hard-to-decarbonise sectors, including transportation, heavy-industry, aviation, and shipping. Therefore, its impact potential is significant at scale. The European Commission has created the EU Hydrogen Strategy that is a key element of Europe's transition to an economy powered by green energy.

How is hydrogen produced?

The methods listed below are used to manufacture different types of hydrogen as displayed in the table:

1. **Electrolysis** uses an electric current to split water into hydrogen and oxygen.

2. **Gasification** converts carbonaceous raw materials at high temperatures into fuel.

3. **Pyrolysis** modifies organic matter into energy in the absence of oxygen.

4. **Steam Methane Reforming** reacts methane with steam to produce a mixture of carbon monoxide and hydrogen.

Hydrogen type	Hydrogen carrier	Manufacturing method	Carbon footprint
Brown	Coal	Gasification	High
Grey	Natural gas / Methane	Steam reforming	High
Blue	Coal / Natural gas / Methane	Steam reforming with carbon capture	Medium
Green	Water	Electrolysis via renewables	Low
Pink	Water	Electrolysis via nuclear power	Low

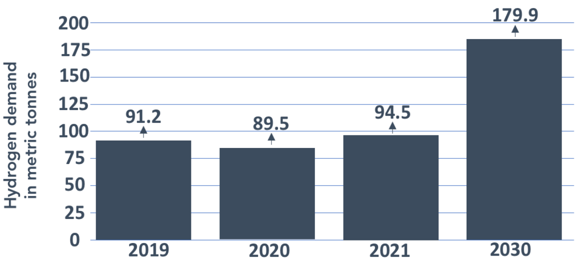
Why now?

As a result of the Russia-Ukraine war, the EU has an urgency to reduce its high dependency on imported Russian natural gas, which accounted for **over 40% of the EU's demand for gas in 2021**.[30] As a result, the European Commission is deploying its Hydrogen Strategy and REPowerEU plan. One of the main goals of this strategy is to domestically produce 10 megatonnes (mt) of renewable hydrogen and to import 10mt more by 2030.[32]

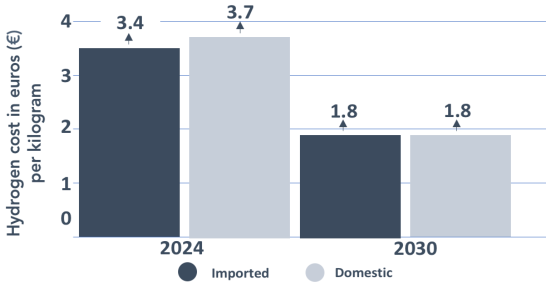
To achieve those goals, **total investment needs are estimated between €335bn and €471bn** including between **€200bn and €300bn** needed for additional renewable energy production. According to Goldman Sachs, decarbonisation and reaching net-zero carbon emissions will require **€4.5tn** of cumulative investments, which for hydrogen generation alone could mean a total available market of nearly **€1tn by 2050**.[33]

Given the improved regulatory framework, the high economic incentives for investors, and the impactful effect of hydrogen innovation and investments, this sector is at a promising and unprecedented moment. To reach a net zero greenhouse gas emission scenario by 2050, it is crucial that both supply and demand sides of the market become actively involved through R&D, strategic partnerships, innovation, and impact investments.

Hydrogen demand worldwide[34]



Hydrogen cost in per kilogram in Europe[35]



Investment opportunities

Green hydrogen carriers

Disruptive electrolysers

Green hydrogen storage units

Deep dive: Green ammonia

What is it and why is it important?

Ammonia (NH3) is an organic chemical made of nitrogen and hydrogen atoms. It is found in air, water, plants, and animals. Although it is found in these organic sources, it can also be artificially produced. Green ammonia is made with hydrogen that comes from water electrolysis powered by renewable energy. Therefore, green hydrogen and green ammonia are closely related to one another and are key contributors for the energy transition at a global scale.

Nowadays, the EU is confronted with the challenge of cutting the energy system's GHG emissions by 55% until 2030.[36] In different sectors, energy reduction measures are needed to reduce the consumption and production of fossil fuels. As it has the capacity to transport hydrogen or alternative fuels, ammonia may play a major role in the energy industry. Ammonia is currently produced from natural gas and used primarily as fertilisers or construction materials in the chemical industry. The International Renewable Energy Agency (IRENA) estimates that by 2050, the total ammonia market will be about four times as big as it is today.[37]

Why green ammonia?

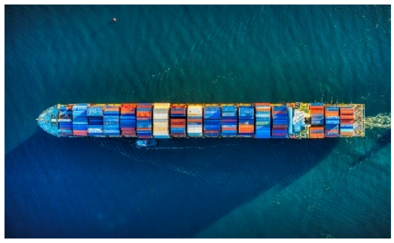
Ammonia is crucial to build the hydrogen economy that the EU aims to develop. Due to the need for a high temperature and limited energy density, hydrogen is difficult to store and transport. On the contrary, due to its three times higher energy density and less extreme heat, ammonia is a more suitable material to transport. Besides, there is the advantage that ammonia already has an existing infrastructure with over 120 ports having ammonia terminals. [38]

Green ammonia: functions and figures[39]

Its three main functions are:

1. Fertilise crops

2. Transport energy



3. Fuel ships

Between 80% and 90% of ammonia produced is used for agricultural fertilisers, but as the world moves toward sustainability, a growing proportion of ammonia will be used for alternative fuels and for hydrogen transportation.

Did you know that…

- Ammonia holds nine times the energy of lithium batteries
- Ammonia has 1.8 times higher density than hydrogen
- In the long term, green ammonia is expected to be the main renewable energy carrier

The non-renewable global ammonia production emits 500mt of CO_2, per year, which equals:

- 75% of Germany's annual emissions
- 100 m flights from Berlin to San Francisco
- Emissions from a cattle made of 180 m cows

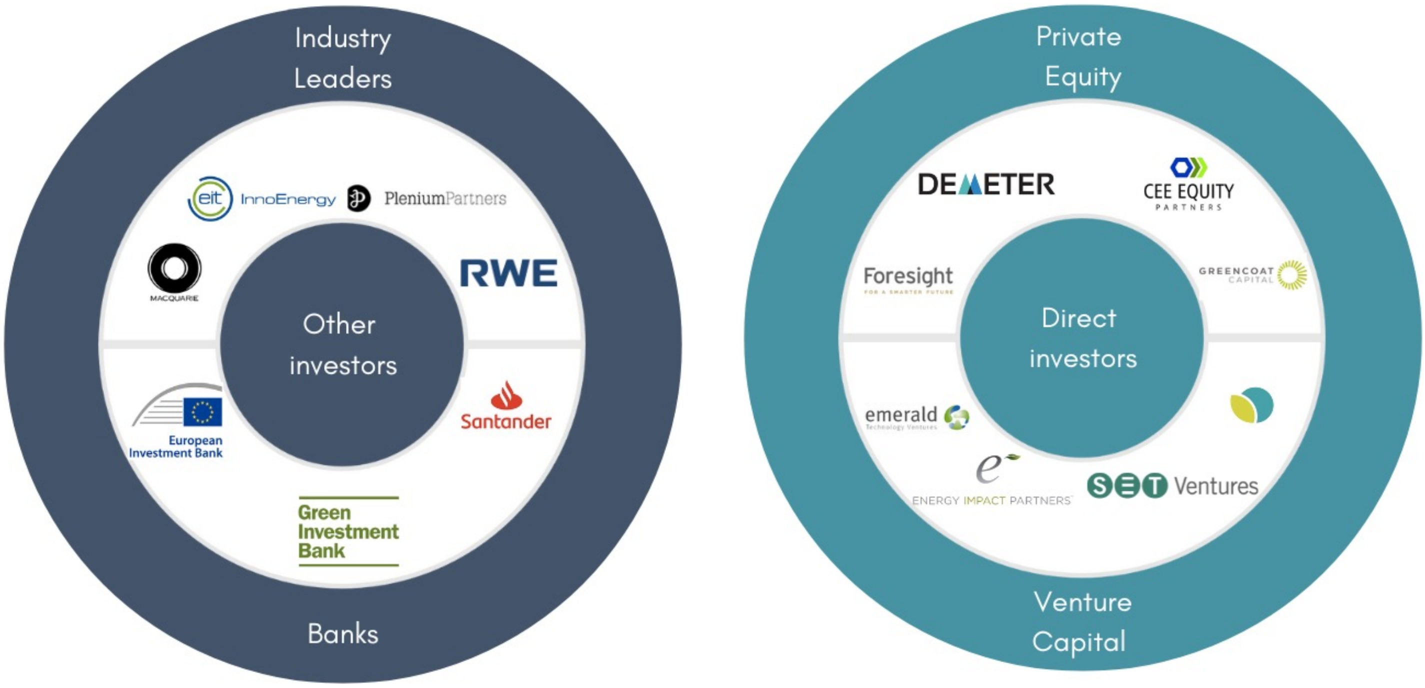
«By switching to renewable electricity to make ammonia, we could save over 40mt of CO_2 each year in Europe alone, or over 360mt globally»

SIEMENS Energy[40]

Investment opportunities

- Green ammonia-based fertilisers
- Ammonia-based sustainable fuels
- Sustainable heat pumps

Key players in the industry



Challenges for the green energy sector

The objectives for an European Net Zero economy have been set by the Net Zero Coalition where both national and regional strategies are being deployed. However, certain challenges such as high production costs, incomplete policy frameworks, underfunded sectors, and technology readiness represent significant barriers for the transition towards a green energy economy. Some of the most notable challenges include:

Grid System Integration

The current energy system is still built on fragmented vertical energy value chains that are managed and operated in silos for different energy resources with specific end-use sectors. The EU argues that this model cannot deliver a climate neutral economy and that it is technically and economically inefficient, and leads to substantial losses in the form of wasted heat and low energy efficiency.[41]

As the EU claims: "Energy system integration – the coordinated planning and operation of the energy system 'as one', across multiple energy carriers, infrastructures, and consumption sectors – is the pathway towards an effective, affordable, and deep decarbonisation of the European economy."[41]

Energy efficiency, economics, and public policy

One of the main challenges of the green energy sector is associated with the cost effectiveness of the production and distribution costs of green energy sources. On the other hand, energy efficiency has come a long way but it still needs to improve in certain developing sectors such as hydrogen to attract private investment and develop a robust market infrastructure. For example, hydrogen fuel cells were identified to reach an overall of 30% of fuel efficiency compared to 77% of directly chargeable batteries. For energy efficiency and cost effectiveness to improve, public policy and R&D funding will be crucial components in this sector.[42]

The road ahead

In the years to come, advancements in the newly implemented public policies, the maturity of technologies, and the mobilisation of capital will lead the development of the green energy sector. For example, the EU's Hydrogen Strategy has five main policy action points that are already driving development and investment in this sector. The five main areas are: investment support, support in production and demand, creating a hydrogen market and infrastructure, research and cooperation, and international cooperation.

On the other hand, maturing technologies such as nanotechnology, green hydrogen technologies, nuclear fusion and fission will become more scalable, feasible, and affordable. This will allow us to deploy solutions that contribute to our energy transition objectives. Certainly, research centres, impact investors, governmental institutions, project managers, and impact entrepreneurs have all a central role to play in this sector.

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