DECARBONISATION AND EMISSIONS TRADING:
HOW COMMODITIES RISE AND DIE

***Tutor**: Octavian TRIFAN*

***Team:** Alexandra MURSALOVA*

Natalya RAVELEVA

Anda-Georgeta STANCIU

Raluca-Liliana TEODORESCU

TABLE OF CONTENTS:

EXECUTIVE SUMMARY

Commodities are basic goods and materials that are widely used in commerce, are interchangeable with other goods of the same type and are not meaningfully differentiated from one-another across a market. A commodity remains constant no matter where it is sold and there are no significant differences among products within a commodity group. Although trading commodities sometimes involves the physical trading of goods, more often trading commodities happens through futures contracts, derivatives, or other financial products.

As a general rule, commodities tend to be the most volatile asset class. Amongst the main reasons for commodity price volatility we mention liquidity, climate conditions and natural disasters, supply and demand, geopolitics, ability to store a commodity. However, certain commodities show more stability than others, some even being considered 'safe-haven' assets, such as gold and silver.

Throughout history, there have been four main categories of commodities trading, including energy commodities (*e.g*. crude oil, natural gas, gasoline), metal commodities (*e.g*. gold, silver, platinum), livestock and meat commodities (*e.g*. pork bellies, live cattle, feeder cattle), agricultural commodities (*e.g*. corn, soybeans, wheat, rice, cocoa, coffee, cotton, sugar).

As commodity markets have expanded, the need for other commodity categories has emerged, including the need for man-made commodities, such as steel. An example of such commodities artificially created by man may be the environmental commodities, that constitute non-tangible energy credits. The need for such products emerged as a means to decrease greenhouse gas emissions (GHGs) and stimulate clean energy production and consumption. The value of these commodities derives from the needs of market participants to produce and consume cleaner forms of energy.

Thus, a new commodity was created in the form of emission reductions or removals. Since carbon dioxide is the principal greenhouse gas, people speak simply of trading in carbon. Carbon is now tracked and traded like any other commodity, which is known as the "*carbon market*."

Anthropogenic carbon dioxide emissions have not ceased to increase since the Second Industrial Revolution, which we know thanks to the changes in the sea ice in the Antarctic or since they have been measured in the Mauna Loa observatory. In May 2021, once again the record figure of 419.05 ppm of CO2 (parts per million of carbon dioxide) was recorded[1]. The aim of decarbonization is to return as soon as possible to the atmospheric carbon values prior to the Industrial Revolution, which began in the late 1700s and marked the beginning of gradual rise in greenhouse gas emissions.

Fueled by renewables' proliferation, and customers' increasing sustainability awareness, the energy sector has embarked on an unstoppable decarbonization journey. What started as an emission-reduction mission in power supply is rapidly evolving into a much broader vision towards sustainable value chains, this being a great challenge the energy sector and the global economy – both still largely fossil-fuel-based.

By taking a global view across sectors, the main drivers for a transition towards a clean energy future include[2]:

- Customer, employee, and community demands.

[1] Global Monitoring Laboratory. *Trends in Atmospheric Carbon Dioxide*. URL: https://gml.noaa.gov/ccgg/trends/graph.html.
[2] Deloitte. *The 2030 decarbonization challenge. The path to the future of energy*. URL: https://www2.deloitte.com/content/dam/Deloitte/global/Documents/Energy-and-Resources/gx-eri-decarbonization-report.pdf.

- Investor pressure.
- Policy and government targets.
- Technology and operational cost reduction.

In regard to policy and government targets, with demands of actions coming from the public on climate change, many governments have to set carbon-reduction targets and enact green legislation.

As an example, the European Union aims to be climate neutral by 2050, by pursuing an economy with net-zero greenhouse gas (GHG) emissions and aligned with its commitment to global climate action under the Paris Agreement. China has also announced ambitious carbon-reduction goals, having set 2030 as a target for peak emissions as part of the Paris Agreement.

Even though China's near-term goal is to reduce emissions intensity: energy use and carbon emissions for every unit of gross domestic product, according to recent developments, China is one of the five Asian countries that are jeopardizing global climate ambitions by investing in 80% of the world's planned new coal plants[3].

The investments in one of the most environmentally damaging sources of energy could generate a total of 300 gigawatts of energy – enough to power the UK more than three times over – despite calls from climate experts at the UN for all new coal plants to be cancelled.

Beyond setting reduction targets, in some cases governments are using carbon pricing schemes to accelerate progress toward their goals for decarbonization. More than 40 governments worldwide have adopted a price on carbon, either through direct taxes on fossil fuels or through cap-and-trade programs.

The carbon tax increases fuel costs in general, the base cost of new power plants, and impacts industrial production levels based on changes in the base cost of capital equipment according to its carbon content.

These programs have produced mixed results. Some are perceived to be wildly successful while others are viewed as ineffective and expensive at a time when energy customers cannot bear the added costs. That may be why some governments are choosing to tax carbon indirectly through subtler methods such as renewable portfolio standards, energy efficiency mandates, emissions regulations, and carbon-offset pricing.

The technical and socio-economic transformation implied by decarbonization amounts to a new Industrial Revolution, where there is a clear need to steer the process of innovation towards zero-carbon solutions.

In this process digitalization is likely to have a strong impact on energy use and GHG emissions, but the direction of change is still unclear. The core power sector has been undergoing digitalization over the past decade and the COVID-19 pandemic exacerbated the trend as many power companies sought to digitalize processes to mitigate pandemic-related disruptions. It has proved to be a catalyst for many power companies to rethink the workplace and rearchitect the work by deploying digital technologies in concert with human capabilities to transform the way work gets done. An accelerated decarbonization timeline will only expedite the digitalization.

Businesses and other organizations from all over the world develop and implement a growing number of initiatives and partnerships contributing to the reduction of GHG emissions in various sectors such as

[3] Jillian Ambrose. *Five Asian countries account for 80% of new coal power investment*. URL: https://www.theguardian.com/environment/2021/jun/30/five-asian-countries-80-percent-new-coal-power-investment.

renewable energy, clean hydrogen, energy efficiency, sustainable cities and low-carbon mobility. Enel Group being at the forefront of the energy transition and business sustainability also sets its priorities in the development of initiatives and projects that contribute to the decarbonization, renewable energy and the fight against climate change.

The drive towards decarbonization gave us new technologies, new markets, new ways of doing business and new environment related commodities, and that drive it does not look that it is slowing down – on the contrary. This drive will expand the new created commodities, and it is likely to create new ones or "resurrect" old ones.

Although rather difficult to predict the commodities of the future, considering that the green and digital transitions are to accelerate in the coming years, specifically the electric vehicle market is expected to grow exponentially in the next 20 years, it appears that so will various commodities linked to electric vehicles. In this respect we mention lithium, cobalt, graphite and also copper and high-grade nickel.

Out of the energy sector, low-carbon hydrogen, a relatively new commodity, is set to boom. While fossil fuel-derived hydrogen (grey hydrogen) is not new, blue hydrogen (natural gas-derived and with carbon capture and storage) and green hydrogen (renewable energy-derived) are entering commercialization and are only just becoming established in energy commodity markets.

1. COMMODITIES. GENERAL CONSIDERATIONS.

What are commodities?

Commodities are basic goods and materials that are widely used in commerce, are interchangeable with other goods of the same type and are not meaningfully differentiated from one-another across a market. Hence, a commodity remains constant no matter where it is sold and there are no significant differences among products within a commodity group. The most frequent examples of commodities include grains, metal (*e.g*. silver, gold), beef, oil, natural gas, cocoa, coffee, wheat and sugar.

How are they traded?

Commodities trading is the buying and selling of these basic goods and materials. Although sometimes it involves the physical trading of goods, more often trading commodities happens through futures contracts, derivatives or other financial products. With futures contracts one agrees to buy or sell a commodity for a certain price at a specified date, betting on how the commodity's price will rise/ fall. If traders think the price will go up, they'll buy futures. On the other hand, if traders think the price will drop, they'll sell futures. Thus, a future contract lets you avoid market volatility by selling future commodities at a fixed price today. The need for these types of financial products emerged from the unpredictability of the commodity markets. By locking into one price today, you avoid the risk associated with commodities markets.

Futures contracts are typically traded on commodity exchanges, for example, in Romania, there is the Romanian Commodities Exchange. A commodities exchange refers both to a physical location where the trading of commodities takes place and to legal entities that have been formed in order to enforce the rules for the trading of standardized commodity contracts and related investment products. The majority of exchanges trade various different commodities, although certain exchanges specialize in a single group (*e.g.* on the London Metal Exchange one can only trade metals).

However, commodity trading isn't the only means of investing in commodities. One can also choose to invest in stocks of companies that produce commodities or in exchange-traded funds (ETFs) or mutual funds that track the commodity. It is to be noted that a commodity-producing company won't necessarily rise or fall in line with the commodity it produces.

History of commodity trading

Trading commodities is an ancient profession with a longer history than the trading of stocks and bonds. Although modern commodities trading typically refers to trading futures contracts, derivatives, and other financial products, being exchanged across the world, in ancient history, however, commodities trading was as simple as trading wheat for copper and primarily involved farmers and merchants.

In the early days of civilization, **gold and silver** were valued for their beauty and were associated with royalty, having an intrinsic worth. Thus, gold and silver became a means of exchange used to pay for different goods, thus becoming a form of money. Gold was one of the first forms of commodity trading in history.

In time, commodity markets became the best way to distribute goods, labor, land and capital across the region. Merchants would accept gold in exchange for other goods. In turn, they could then use this gold throughout most of the world for the same purpose (to purchase goods).

As time passed, regions began to make their own forms of coinage, along with scales to allow people to weight different forms of coinage[4].

It was only in the 1500s that stock exchanges were formed. **The Amsterdam Stock Exchange** emerged in 1530, being known to be the world's first stock exchange. However, prior to becoming a stock exchange, it operated as a market for the exchange of commodities.

Over the 1500s and 1600s, a growing number of cities would add their own commodity exchanges where they sold similar products.

In 1864, the US initiated **the Chicago Board of Trade (CBOT)**, an exchange that used commodities such as wheat, corn, cattle, and pigs as standard instruments.

The CBOT expanded its commodity trading in the 1930s by adding new items to the list, including rice, mill feeds, butter, eggs, soybeans and potatoes.

However, certain difficulties arose from forming a common understanding on what the goods actually are and the differences between them.

In 1940, the US created **the Commodity Price Index**, consisting of a computation of 22 commodity prices. Most countries around the world today have their own version of the commodity price index.

In 1990s, **the Commodity Index Fund** was created as a fund where the assets are invested into financial instruments based on a commodity index.

Nowadays, the addition of online trading systems has led to a heightened interest in commodities and futures and, thus, to the expansion of the commodity markets.

Futures and Commodities Markets can be found all over the world, specializing in different goods, such as[5]:

- Chicago Mercantile Exchange (CME): Energy, precious metals, industrial metals, livestock, and financials
- Chicago Board of Trade (CBOT): Agriculture and livestock
- New York Mercantile Exchange (NYMEX): Energy and precious metals
- New York Board of Trade (NYBOY): Agriculture
- BM&F Bovespa (Including the Brazilian Mercantile and Futures Exchange): Agriculture and financials
- London Metal Exchange (LME): Industrial metals
- Australian Stock Exchange (ASE): Energy, environmental, financial, agriculture
- NYSE Euronext (ASE): Energy, environmental, financial, and agriculture (based in France)
- Tokyo Commodities Exchange (TOCOM): Energy, precious metals, industrials metals, and rubber

[4] Johnson Hur. *History of Commodities Trading*. URL: https://bebusinessed.com/history/history-commodities-trading/.
[5] Ibid.

- Korea Exchange (KRS): Financials and precious metals

As the developing world continues to grow, commodity futures markets have also appeared throughout third world countries, such as India (*e.g.* the National Commodity & Derivative Exchange (NCDEX), the Multi Commodity Exchange (MCX), the National Multi Commodity Exchange of India (NMCE))

The NMCE is popular for trading spices and plantation crops that are not traded on other exchanges over the world.

As a general conclusion, the growth in the global economy has also spurred the growth of the commodity market. With financial markets becoming more accessible, many traders have turned to the commodity markets to look for new trading opportunities.

What determines commodity prices?

Like all assets, commodity prices are ultimately determined by supply and demand. Hence, commodity prices often fluctuate wildly because of changes in supply and demand, such as:

(i) **commodity prices will rise** when faced with increasing demand or decreasing supply;

(ii) **commodity prices will fall** when faced with decreasing demand or increasing supply.

As a general rule, commodities tend to be the most volatile asset class. Commodity prices exhibit variability for many reasons, but some price changes may be more predictable than others. For example, agricultural prices tend to be lowest during and soon after harvest, and highest immediately before harvest.

Furthermore, we present below a list with the main reasons for commodity price volatility[6]:

(i) ***Liquidity***

Liquidity generally occurs when an asset has a high level of trading activity and buying or selling an asset can be easily done without disrupting its price in a market. Generally, investing in a liquid asset is safer than investing in an illiquid one because of the ease of getting into and out of positions.

As regards commodities, liquidity is a key concern for many investors and traders. Many commodities offer much less liquidity or trading volume than other renown assets (*e.g.* stocks, bonds, currencies). While oil and gold are the most liquidly traded commodities, these markets can also become highly volatile at times, given the potential for endogenous or exogenous events.

(ii) ***Climate conditions and natural disasters***

Although seasonal changes are often similar from one year to the next and somewhat predictable, weather shocks, on the other hand, are typically unpredictable. Adverse weather conditions may lead to unpredictable changes in demand and supply for certain commodities and hence, cause massive volatility in commodity prices, especially if stocks are low to begin with. For example, a cold winter season will increase demand for natural gas, hence increasing the prices for the energy commodity.

[6] Andrew Hecht. *Why Are Commodities More Volatile Than Other Assets?* URL: https://www.thebalance.com/why-commodities-are-volatile-assets-4126754.

(iii) ***Supply and Demand***

Almost every human being is a consumer of commodities, which are the staples of everyday life. Therefore, the supply and demand equation for raw materials is what often makes them some of the most volatile assets in the world when it comes to prices.

In the short term, both supply and demand are relatively price inelastic. Increasing commodity production takes time if new crops must be grown, mineral exploration undertaken or oil wells drilled. Similarly, it can take considerable time to change consumption habits, such as shifting from coal-fired electricity generation to gas or altering the share of more fuel-efficient cars. This sluggish response means that supply and demand shocks, whether it is an adverse weather event or a natural disaster, can result in large price movements. If demand grows faster than supply, then stock levels will run down, perhaps alongside higher commodity prices.

(iv) ***Geopolitics***

Considering that commodity reserves exist in specific areas of our planet, political issues in one region often affect prices. For example, wars or violence in one area of the world can close off logistical routes, like the Panama Canal, which makes it hard or impossible to transport commodities from production areas to consumption zones around the world. Tariffs, government subsidies, or other political tools often change the price dynamics for a commodity, which adds to the volatility.

Global economic development and technological advances can also have an impact on commodity prices. For example, the emergence of China and India as significant manufacturing players (therefore demanding a higher volume of industrial metals) has contributed to the declining availability of metals, such as steel, for the rest of the world.

Also, the prosperity of a country influences the price of a commodity, considering that the economic prosperity of a country determines the purchasing power of its population.

(v) ***Ability to store the commodity***

When commodities cannot be stored for immediate delivery, such as electricity, prices are the most volatile. In terms of natural gas and oil, which can be stored but require specialized infrastructure, volatility is low when inventories are available, but spikes occur when infrastructure constraints are approached. Metals and agriculture stand in contrast to energy because they do not run into storage capacity constraints as quickly. As a result, the volatility of non-energy commodities is generally lower.

2. HISTORY OF COMMODITIES

The most important commodities throughout the ages

Throughout history, there have been four main categories of commodities trading, including the following:

- Energy Commodities (*e.g*. crude oil, natural gas, gasoline)
- Metal Commodities (*e.g*. gold, silver, platinum)
- Livestock and Meat Commodities (*e.g*. pork bellies, live cattle, feeder cattle)
- Agricultural Commodities (*e.g*. corn, soybeans, wheat, rice, cocoa, coffee, cotton, sugar)

As commodity markets have expanded, the need for other commodity categories has emerged, such as, but not limited to the following list of the most common commodities traded nowadays:

- Agriculture: Corn, oats, soybeans, rice, soybean meal, soybean oil, wheat, orange juice
- Livestock: Hogs, frozen pork bellies, live cattle, feeder cattle
- Energy: Crude oil, heating oil, ethanol, natural gas, gasoline, propane, uranium, electricity
- Precious Metals: Gold, platinum, palladium, silver
- Industrial Metals: Aluminum, steel, copper
- Financial: bonds, indexes, currencies
- Soft Commodities: Sugar, cocoa, coffee, cotton
- Pulp: Lumber

Man-made commodities

Aside from the natural commodities presented above (*e.g.,* oil, minerals), the need for man-made commodities, such as steel, also emerged.

An example of such commodities artificially created by man may be the environmental commodities[7], that constitute non-tangible energy credits. The need for such products emerged as a means to decrease greenhouse gas emissions (GHGs) and stimulate clean energy production and consumption. Note is to be made that most environmental commodities evolved as a result of government environmental policies.

The value of these commodities derives from the needs of market participants to produce and consume cleaner forms of energy.

Nowadays, many governments across the world have been placing restrictions on the rights of entities to produce GHGs and hence, pollute the environment. Since many companies produce GHGs in their day to day activity, environmental commodities emerged as a way to buy and sell these rights. In other words, if you place strict limits on individuals' and institutions' rights to pollute, then those rights become

[7] Lawrence Pines. *Environmental Commodities: What Are They & How Can You Trade Them?* URL: https://commodity.com/environmental/#What_Are_Environmental_Commodities.

scarce and valuable. Without any such limitations, the right to pollute would have no economic value since its "production" and "supply" would be theoretically unlimited. Some governments have chosen to reward green energy producers by providing them certificates that serve as a type of subsidy. These certificates have economic value and are another form of environmental commodity.

Rise and fall of commodities

As presented above, because the supply and demand characteristics change frequently, volatility in commodities tends to be very high. Sharp fluctuations in commodity prices are creating significant business challenges that can affect production costs, product pricing, earnings and credit availability.

However, certain commodities show more stability than others, some even being considered 'safe-haven' assets (*i.e.* they are expected to retain, or even gain value during periods of economic downturn).

Amongst the characteristics that make assets safe-haven, there are[8]:

- ***Liquidity***: the asset is easily convertible to cash, at any time;
- ***Functionality***: the asset has a use that will continually provide long-term demand;
- ***Limited supply***: the growth of supply should never outweigh the demand;
- ***Certainty of demand***: the asset is unlikely to be replaced or become outdated;
- ***Permanence***: the asset should not decay or rot over time.

However, not all safe-haven assets have all the above characteristics. What makes a good safe-haven for one market downturn may not show the same results in another.

Volatility in commodity prices can impact market players differently depending on where they lie on the value chain. Profitability of these players is also determined based on the variant of the commodity that the entity is dependent on within the value chain[9].

A. **A fall in commodity prices** can:

- Decrease sales revenue for producers, potentially decreasing the value of the company and/or lead to change in business strategy;
- Reduce or eliminate the viability of production — mining and primary producers may alter production levels in response to lower prices;
- Decrease input costs for businesses consuming such commodities, thus potentially increasing profitability, which in turn can lead to an increase in value of the business;
- Affect inventory management solutions as there is a direct impact on earnings in case of fall in the value of inventory. Inventory is valued at cost or net realizable value whichever is lower.

[8] IG. *What are safe-haven assets and how do you trade them?* URL: https://www.ig.com/en/trading-strategies/what-are-safe-haven-assets-and-how-do-you-trade-them--181031.
[9] Deloitte. *Commodity Price. Risk Management. A manual of hedging commodity price risk for corporates.* URL: https://www2.deloitte.com/content/dam/Deloitte/in/Documents/risk/in-risk-overview-of-commodity-noexp.PDF.

Accordingly, where net realizable value falls below cost, there is a real impact to cash flows *i.e.,* sales will realize a lower value.

B. **A rise in commodity prices** can:

- Increase sales revenue for producers if demand is not impacted by the price increase. This in turn can lead to an increase in the value of the business;
- Increase competition as producers increase supply to benefit from price increases and/or new entrants seek to take advantage of higher prices;
- Reduce profitability for businesses consuming such commodities (if the business is unable to pass on the cost increases in full), potentially reducing the value of the company.

***Potential factors affecting the demand for a commodity*[10]**

- **Changes in the Price of the Commodity:** As a general rule, at a low market price, market demand for the commodity tends to be high and vice-versa.
- **Changes in the consumer's income:** A rise in the consumer's income may raise the demand for a commodity and a fall in his income may reduce the demand for it.
- **Change in habit, taste and fashion:** When there is a change in the tastes of consumers in favour of a commodity, say due to fashion, its demand will rise. On the other hand, change in tastes against a commodity leads to a fall in its demand. For example, when a large section of population shifts its preference from vegetarian foods to non-vegetarian foods, the demand for the former will tend to decrease and that for the latter will increase.
- **Change in climate and season:** Demand for certain products are determined by climatic or weather conditions. For example, in summer there is a greater demand for cold drinks, fans, coolers etc. Similarly, demand for umbrellas and raincoats are seasonal.
- **The growth of population/ number of buyers:** A high growth of population over a period of time tends to imply a rising demand for essential goods and services in general.
- **Innovations:** Introduction of new goods or substitutes as a result of innovations in a dynamic modern economy tends to adversely affect the demand for the existing products, which as a result of innovations, definitely become obsolete. For example, the advent of electronic calculations has made adding machines obsolete.
- **Social customs and festivals:** Demand for certain goods are determined by social customs, festivals etc. For example, during Christmas, decorations and traditional food are in more demand.
- **Taxation:** A progressively high tax rate would generally mean a low demand for goods in general and vice-versa, while a highly taxed commodity will have a relatively lower demand than an untaxed commodity if that happens to be a remote substitute.

---

[10] Saqib Shaikh. *12 Main Causes of Changes in Demand for a Commodity*. URL: https://www.economicsdiscussion.net/law-of-demand/12-main-causes-of-changes-in-demand-for-a-commodity/13623.

- **Age and sex ratio of the population:** If the population of a country has a larger proportion of juvenile population, then the market demand for toys, schools etc.—goods and services required by children will be much higher than the market demand for goods needed by the elderly people.

  Similarly, sex ratio has its impact on demand for many goods. An adverse sex ratio, *i.e.*, females exceeding males in number would mean a greater demand for goods required by the female population than by the male population or the reverse.

- **Advertisement and sales propaganda:** Market demands for many products in the present day are influenced by the seller's efforts through advertisements and sales propaganda. Demand is created through selling efforts. When these factors change, the general demand pattern will be affected, causing a change in the market demand as a whole.

Potential factors affecting the supply for a commodity[11]

- **Price of the Commodity:** Price is the most important factor influencing the supply of a commodity. More is supplied at a lower price and less is supplied at a higher price.
- **Seller's expectations about the future price:** If a seller expects the price to rise in the future, he will withhold his stock at present and so there will be less supply now.
- **Nature of goods:** The supply of perishable goods is perfectly inelastic in a market period because the entire stock of such goods must be disposed of within a very short period, whatsoever may be the price. However, if the stock of goods can be easily stored its supply would be relatively elastic and vice-versa.
- **Climate conditions:** The supply of certain commodities, such as agricultural products depends on the natural environment or climatic conditions, such as rainfall, temperature etc. A change in the natural conditions will cause a change in the supply.
- **Transport conditions:** Difficulties in transport may cause a temporary decrease in supply as goods cannot be brought in time to the market place.
- **Production cost:** If there is a rise in the cost of production of a commodity, its supply will tend to decrease.
- **Technology:** The supply of a commodity depends upon the methods of production. Advance in technology and science are the most powerful forces influencing productivity of the factors of production. Most of the innovations in chemistry, electronics, atomic energy etc. have greatly contributed to increased supplies of commodities at lower costs.
- **Government policies:** If the industrial licensing policy of the government is liberal, more firms are encouraged to enter the field of production, so that the supply may increase. A tax on a commodity or a factor of production raises its cost of production, consequently production is reduced. A subsidy on the other-hand provides an incentive to production and augments supply.

Commonly traded commodities and price fluctuations

For exemplification purposes, the most commonly traded commodities and their price fluctuations are:

[11] Saqib Shaikh. *Supply of a Commodity: Meaning, Factors Affecting and Types.* URL: https://www.economicsdiscussion.net/law-of-supply/supply-of-a-commodity-meaning-factors-affecting-and-types/13695.

- ***Gold***

  Gold is widely considered to be a ‘safe-haven’ asset, as it tends to hold its value or rise in times of economic and political uncertainty. Moreover, gold also serves as a reserve asset for central banks to buffer against volatility.

- ***Silver***

  Such as gold, silver is also considered a ‘safe haven’ asset, so its price will often rise during times of economic uncertainty. However, gold is often seen as a more reliable investment because its price is less dependent on demand from industry, which often takes a hit when economic output falls. On the supply side, silver is most often extracted from the ores of other metals – particularly copper – so fluctuations in demand for these other elements can affect silver’s price.

- ***Crude oil***

  Crude oil is one the world’s most in-demand commodities as it can be refined into products including petrol, diesel and lubricants, along with many petrochemicals that are used to make plastics, medicines, linoleum, shingles, ink, cosmetics, synthetic fibers, solvents, fertilizer, asphalt, and thousands of others. Historically, demand for oil has been correlated with global economic performance. Prices generally rise during boom periods – as more oil is needed to manufacture and transport products – and fall during economic slowdowns.

- ***Copper***

  Copper is an important base metal because it is an exceptionally good conductor of both heat and electricity and is also corrosion resistant and weatherproof. It is primarily used to manufacture electrical wire, pipes, roof tiles and industrial machinery. However, it is also used to produce alloys including brass and bronze.

  Because of its many uses in industry and electronics, the price of copper can fluctuate significantly in line with economic output. Supply, on the other hand, can be affected by trade disputes, seasons and infrastructure concerns – particularly within key South American suppliers such as Chile and Peru.

- ***Aluminum***

  The price of oil and electricity can affect the price of aluminum, as separating the element from ores is very energy intensive. Demand is driven by manufacturing and construction, so economic developments in economies such as China can have a big effect on its price.

3. DECARBONIZATION

3.1. How Carbon emissions become a commodity. Global Objectives.

Carbon emissions are the most significant type of greenhouse gas (GHG) emissions generated by any human activity or process.

The role of absorption of solar radiation by carbon dioxide and methane and the potential for global temperature rise as a result of industrial activities releasing carbon dioxide were first recognized by Fourier, Tyndale and Arrhenius in 1827, 1859 and 1896 respectively in France, the UK and Sweden.

But it was not until the late 1970s that the World Meteorological Organization (WMO) began to express concern that human activities-particularly emissions of carbon dioxide-could lead to serious warming of the lower atmosphere. In the 1980s, scientific concern about global warming grew, and in 1988 (a year in which North America faced an intense heat wave and drought) these concerns spilled over into policy, and the WMO and United Nations Environment Program (UNEP) established the International Panel on Climate Change (IPCC) to examine and report on the scientific evidence about climate change and possible international responses to it.

The IPCC's first assessment report in 1990 fed into the drafting of the United Nations Framework Convention at Climate Change (UNFCCC) in 1991.

The UNFCCC was signed by 166 nations at Earth Summit in Rio de Janeiro in 1992 and entered into force in 1994. It should be noted that the UNFCCC did not contain specific national or international greenhouse gas (GHG) emission reduction targets, but key points or principles that have been fundamental in subsequent international debates and processes on climate change.

The key points[12] consist of the following:

- The goal of stabilizing the climate to prevent "dangerous anthropogenic interference with the climate system" in a timeframe that allows natural systems to adapt without major damage to food systems and economic development.
- The need for countries to monitor and limit their greenhouse gas emissions and for different national limits that consider countries' different responsibilities and capacities.
- Concerns for developing countries - and especially those most vulnerable to the harmful effects of climate change, such as small island states.
- The importance of precautionary measures to respond to the severity of climate change threats, despite real scientific uncertainties about climate change processes and impacts.
- In the absence of specific targets, and recognizing the need for an important step in establishing basic principles to guide subsequent negotiations on national reductions in greenhouse gas emissions, the Conference of the Parties (COP) in Kyoto, Japan, in 1997 adopted the UNFCCC Kyoto Protocol, which established emissions targets for industrialized countries for the period 2008-2012 and three main mechanisms[13] for meeting them:

[12] UN Climate Change. Intergovernmental Negotiating Committee for a Framework Convention on Climate Change. *Preparation of a framework convention on climate change – Set of informal papers provided by delegations, related to the preparation of a framework convention on climate change. Addendum*. URL: https://unfccc.int/sites/default/files/resource/docs/1991/a/eng/misc01a01.pdf.

[13] Eurostat. *Glossary: Kyoto Protocol*. URL: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Kyoto_Protocol.

- An Emissions Trading Scheme (ETS, which allows international trading of emissions allowances).
- Clean Development Mechanism (CDM), which allows developed country signatories to earn carbon credits to invest in emissions reductions in developing countries. The only Kyoto mechanism that allows investment in developing countries is the CDM.
- Joint Implementation (JI), which allows investment in emissions savings in other developed countries, including emerging economies, to be credited to signatory developed countries, thereby promoting more cost-effective emissions reductions than could otherwise be achieved.

These mechanisms ideally encourage greenhouse gas reductions to begin where they are most cost-effective, for example, in developing countries. It does not matter where emissions are reduced as long as they are removed from the atmosphere. This has the parallel benefit of stimulating green investment in developing countries and engaging the private sector in the effort to reduce GHG emissions and keep them at safe levels. It also makes leap-frogging - the ability to leapfrog the use of older, dirtier technology for newer, cleaner infrastructure and systems, with obvious longer-term benefits - more economical.

The idea behind carbon trading is very similar to trading securities or commodities in a marketplace. Carbon is assigned an economic value that allows people, companies, or nations to trade it. When a nation buys carbon, it buys the rights to burn it, and a nation that sells carbon gives up its rights to burn it. The value of carbon is based on the nation's ability to store it or prevent it from being released into the atmosphere (the better you can store it, the more you can charge for it).

The carbon trading market facilitates the buying and selling of greenhouse gas emission rights. The industrialized nations, for whom reducing emissions is a daunting task, buy the emission rights from another nation whose industries do not produce as much of these gasses.

The carbon market became possible because the goal of the Kyoto Protocol was to reduce emissions as a collective. On one hand, carbon trading seems like a win-win situation: Greenhouse gas emissions can be reduced while some countries benefit economically. On the other hand, critics of the idea believe that some countries take advantage of the trading system and the consequences are negative.

While emissions trading may have its merits, a debate about this type of market is inevitable, as it is about finding a compromise between profit, equity, and environmental concerns.

Global objectives:

The COVID-19 pandemic has underscored the need for international cooperation to address these interconnected problems. At the recent Climate Ambition Summit and One Planet Summit, many countries announced impressive actions. This is an important first step in ensuring that this year's UN climate and biodiversity summits develop the necessary ambition and reinforce countries' commitment to sustainable recovery.

The UN Secretary-General, António Guterres, has set a goal of building a Global Coalition for Carbon Neutrality. The UK is also making the goal of achieving net zero emissions by 2050 a priority for its COP26 presidency. More than 100 countries have already committed to carbon neutrality by around mid-century, including Argentina, Brazil, Chile, Colombia, Costa Rica, Ecuador, Grenada, Jamaica, Panama, and Uruguay.

Decarbonization will require transformations that complement development goals, including job creation. These transformations, such as the provision of electric public transport, have important co-benefits such as reducing air pollution. Countries must also continue to embrace renewable energy, promote electrification of energy use at home and in industry, and support low-carbon agriculture and forest conservation.

Formulating long-term strategies requires a national conversation to create a shared vision for decarbonization that addresses emissions reductions and development priorities. This conversation is key to promoting understanding and transparency around key sectoral decisions, such as where to create new jobs and how to support affected communities. From there, governments can work with stakeholders to set a roadmap of actions to achieve net zero emissions, such as how many electric buses are needed.

- ***European Union***

  The EU has adopted ambitious new targets to curb climate change and pledged to make them legally binding.

  Under a new law agreed by member states and the EU parliament, the bloc will cut carbon emissions by at least 55% by 2030, compared to 1990 levels, and aims to be climate neutral by 2050.

  The EU Climate Law sets a limit on the amount of CO2 removal that can be counted towards the 2030 target to ensure states are actively cutting emissions rather than removing them from the atmosphere, for example through forests.

  A 15-member independent council has been set up, the European Scientific Advisory Board on Climate Change, which will be will be tasked, among other things, with providing scientific advice and reporting on EU measures, climate targets and indicative greenhouse gas budgets and their coherence with the European climate law and the EU's international commitments under the Paris Agreement.

  The target to cut emissions by 55% by 2030 was originally announced by EU leaders in December 2020, but there was pressure from the EU Parliament and environmental groups for the law to go further. Previous EU targets had called for a 40% reduction.

- ***U.K.***

  In 2019, the UK government and the devolved administrations committed to the net zero target as recommended by the Climate Change Committee. These changes are unprecedented in their overall scale, but large-scale conversions have been successfully implemented in the UK before, such as the switch to natural gas in the 1970s and the switch to digital broadcasting in the 2000s.

  UK emissions in 2018 were 44% below 1990 levels, largely due to progress in reducing emissions from electricity generation, waste, and the industrial sector. The first (2008-2012) and second carbon budgets (2013-2017) have been met, and the UK is on track to meet the third carbon budget (2018-2022), but not on track to meet the fourth, covering 2023-2027, or the fifth, covering 2028-2032. Crucially, these budgets are set against the previous target of an 80% emissions reduction by 2050. The new target Net-Zero (100%reduction by 2050) means that progress must be accelerated.

The UK government announced in April 2021 that it would adopt a much tougher climate change target of reducing carbon emissions by 78% by 2035 to become the global leader on climate change.

The target of 78% isn't randomly determined - it represents a milestone on a carefully researched pathway that stretches from today's emissions levels to net zero in 2050. This pathway includes a timed roll-out of policies and technologies, and expected behavioral changes, that might be considered realistic over the next three decades and that can lead the UK to climate neutrality at a reasonable cost.

Achieving net zero targets in 2035 or 2050 depends on policy decisions and public and private investment made in 2021. Governments tend to like flashy projects like zero-carbon aircraft or nuclear fusion, but these are no substitute for a fully funded, comprehensive strategy to transform society within a strict timetable.

- ***China***

China's plan coincided with Japan's official zero-carbon agenda for 2050, and South Korea followed suit. Beijing's plan, however, will be far more difficult to implement. Japan and South Korea are both developed economies where total energy demand is unlikely to grow much, making decarbonization easier. China, on the other hand, still must meet growing energy demand, which could be the reason why the target will probably not be reached until 10 years later, in 2060.

China's stance on carbon emissions puts the country's next 14th Five-Year Plan, which begins in 2021, in the spotlight as the main policy tool to pursue its climate goals.

For fossil fuel markets, the domino effect of China's energy policy cannot be underestimated, as China is the world's largest energy consumer and producer. Thus, to achieve a 1.5 C scenario by 2050, total energy demand will have reach 5 billion tce, with non-fossil fuels accounting for over 85% in the energy mix. In the power sector, over 90% of the electricity will be generated by non-fossil fuels, and less than 5% by coal. The end-use sectors will see the increased use of electricity to replace direct combustion of fossil fuels. The share of primary energy for electricity generation will increase from the current 45 % to about 85 % by 2050, and the share of electricity in end-use energy consumption will increase from the current 25 % to about 68%, according to ICCSD (Institute of Climate Change and Sustainable Development), from Tsinghua University[14].

The scenarios outlined by ICCSD outline four different trends:

– coal has almost peaked in China and will plateau for about a decade before dropping off sharply

– oil follows a similar trend to coal, but with some scope - though not much - for additional demand growth over the next decade

– natural gas still has until 2030 to peak before it starts to decline, but still has a larger share of the energy mix than oil by 2050

[14] He Jiankun. *Launch of the Outcome of the Research on China's Long-term Low-carbon Development Strategy and Pathway*. URL: https://www.efchina.org/Attachments/Program-Update-Attachments/programupdate-lceg-20201015/Public-Launch-of-Outcomes-China-s-Low-carbon-Development-Strategies-and-Transition-Pathways-ICCSD.pdf.

– a steady but undeniable growth path for non-fossil fuels.

- ***Japan***

Japan has revised upward its 2030 greenhouse gas (GHG) emissions reduction target, now aiming for a 46% reduction from 2013 levels, up from 26% previously.

Tokyo has been considering a possible increase in its previous target, which called for a 26% reduction by 2030 from 2013/14 levels, to bring it in line with its goal of a decarbonized society by 2050.

In October 2020, Prime Minister Suga declared that by 2050, Japan aims to reduce greenhouse gas emissions to net-zero. The administration will focus on realizing a “green society,” because “proactive climate change measures bring transformation of industrial structures as well as our economy and society, leading to dynamic economic growth,” Suga stated.

Various industries have expressed support for Tokyo's 2050 decarbonization target and have committed to making their operations carbon neutral. However, the more ambitious GHG reduction target for 2030 is expected to force high-emitting industries, such as the power and steel sectors, to accelerate their decarbonization process.

- ***Russia***

The Russian Federation submitted its 2030 Intended Nationally Determined Contribution (INDC) proposing to reduce emissions by 25% to 30% below 1990 levels by 2030 (UNFCCC, 2015). The Russian government officially signed the Paris Agreement on April 22, 2016, and formally adopted the agreement in October 2019, three and a half years later (United Nations, 2019).

The best estimate of the targeted emission levels that Russia's NDC entails is 2.4 GtCO2e to 2.6 GtCO2e in 2030 (19-24% below 1990 levels, excluding LULUCF - Land Use, Land Use Change, and Forestry sector). However, Russia's NDC includes a statement that the 2030 target is "under the maximum possible crediting of the absorption capacity of forests" (UNFCCC, 2015).

If Russia formally adopts its proposed updated 2030 target of a 33% reduction below 1990 levels, this would imply an emission level of 2.3 GtCO2e for 2030 (27% below 1990 levels, excluding LULUCF). Given the latest emissions projections from Russian Government, which show an emissions level of 2.3 GtCO2e (excluding LULUCF) for 2030, this does not represent a real reduction in emissions.

In contrast to the required peak and decline in emissions needed to meet the target Paris Agreement, emissions at Russian Federation are expected to either stagnate or continue to grow from 2021, after the expected increase due to economic recovery, until at least 2030.

However, Russia's emissions targets, which use 1990 as a reference, allow for further increases in national emissions without falling short of international commitments. According to latest estimates, currently implemented measures will result in emissions of between 2.0 and 2.2 GtCO2e in 2030 (excluding LULUCF), which is only 3-9% below 2018 emission levels. This represents a 32-37% decrease in emissions below 1990 levels, a level below the NDC targets of a 19-24% decrease below 1990 levels (excluding LULUCF).

In March 2020, Russia published its draft long-term climate strategy, which included emissions projections to 2050. Both the "baseline" scenario and the more ambitious "intensive" emissions projection scenario fail to achieve a reduction in emissions below 2017 levels by 2050, representing a serious lack of intent on the part of the Russian government. According to the IPCC Special Report on 1.5°C, the world needs to achieve net zero CO2 emissions by 2050 to limit warming to the long-term temperature target of 1.5°C (Paris Agreement).[15] This shows the extent to which Russia's projected emissions pathways fall short of the required level of ambition, particularly for large emitters such as Russia.

Russia's draft long-term strategy includes a list of policy actions needed to achieve the stated priority of aligning Russia with Paris Agreement. Currently, there is little to no action taken on these policy requirements. If Russia is to align with the Paris Agreement targets, as it has stated, significant action is needed in these and other areas.

Legislation introduced in December 2018 was originally intended to introduce a cap-and-trade system for large carbon emitters by 2025 and require companies to report their emissions. It would have allowed the government to introduce GHG emissions targets and charge companies for excess emissions, which would be included in Emissions Reduction Support Fund.

- ***US***

The U.S. recently rejoined the Paris Climate Agreement and decarbonization is back on the minds of government officials and companies alike.

Though every sector plays a major role on the path to net zero carbon emissions, none are as impactful as the energy sector. In 2016, almost three-quarters of global GHG emissions came from energy consumption. With organizations looking to either curb energy consumption or transition to cleaner forms of energy, the pressure is on utilities to decarbonize and offer green alternatives.

For each state, after narrowing down from 3,328 different entities and subsidiaries, the final list of 60 utilities accounted for 60% of U.S. energy sales in 2019 at just under 1.93 trillion MWh (megawatt hours).

Many companies on the list have multiple goals spread across different timeframes, but they can be grouped into a few distinct categories:

- Reducing carbon dioxide (CO2) or greenhouse gas (GHG) emissions: These measures are either percentage-based or flat reductions, and include becoming carbon neutral or “net zero” by balancing reduced emissions with carbon offsets.
- Reducing carbon intensity: These measures work on reducing the impact of electricity generated by fossil fuels, rather than reducing the amount directly.
- Increasing renewable energy production: These measures focus on adding renewable energy with a lower carbon footprint to the production mix and can be either percentage-based or flat additions.

[15] IPCC. *Summary for Policymakers of IPCC Special Report on Global Warming of 1.5°C approved by governments*. URL: https://www.ipcc.ch/2018/10/08/summary-for-policymakers-of-ipcc-special-report-on-global-warming-of-1-5c-approved-by-governments/.

- Increasing clean electricity production: These measures are centered around ensuring that electricity produced is 100% carbon free.

Utilities with decarbonization targets set for 2035 and earlier vary wildly in scope, from completely carbon neutral to minimal reductions.

3.2. Policies (carbon taxes versus cap-and-trading schemes)

Globally, 39 national and 23 sub-national jurisdictions have implemented or are scheduled to implement carbon pricing instruments, including emissions trading systems and taxes. The world's largest carbon market is the European Emissions trading scheme (EU-ETS), covering sectors that emit over 2 billion tons of carbon dioxide each year. In comparison, Korea's ETS covers sectors that emit over half a billion tons of GHG and the program in California and Quebec covers sectors emitting nearly half a billion tones. The seven Chinese pilot emission trading systems collectively cover sources emitting over one billion tons of CO22.

The fundamental principle on which the Kyoto Protocol is based—setting "targets and timetables" for reducing greenhouse gas emissions—is both economically flawed and politically unrealistic. To ratify the protocol, a developed country had to be willing to agree to reduce its emissions to a specified level—typically about 5% below the country's emissions in 1990-by 2008 to 2012 regardless of cost. Because costs could be huge, most developed countries never ratified the treaty or insisted, as a precondition, that their targets be diluted through an accounting adjustment that allows credit for activities that absorb carbon (called sinks).

A comprehensive carbon pricing mechanism is set to help reduce emissions while balancing growth and environmental objectives.

The Paris Agreement

The Paris Agreement is a legally binding international treaty on climate change. It was adopted by 196 Parties at COP 21 in Paris, on 12 December 2015 and entered into force on 4 November 2016.

The Paris Agreement is a landmark in the multilateral climate change process because, for the first time, a binding agreement brings all nations into a common cause to undertake ambitious efforts to combat climate change and adapt to its effects.

Its goal is to limit global warming to well below 2°C, preferably to 1.5°C, compared to pre-industrial levels. To achieve this long-term temperature goal, countries aim to reach global peaking of greenhouse gas emissions as soon as possible to achieve a climate neutral world by mid-century.

These ambitious objectives must be achieved through the cyclic upgrading of nationally determined contributions (NDCs) to climate action, reviewed every five years to ensure convergence towards the goals.

This provision requires the "linkage" of various carbon emissions trading systems—because measured emissions reductions must avoid "double counting", transferred mitigation outcomes must be recorded as a gain of emission units for one party and a reduction of emission units for the other. Because the NDC's, and domestic carbon trading schemes, are heterogeneous, the ITMO's (Internationally Transferred Mitigation Outcomes) will provide a format for global linkage under the auspices of the UNFCCC. The provision thus also creates a pressure for countries to adopt emissions management systems — if a country wants to use more cost-effective cooperative approaches[16] to achieve their NDCs, they will need to monitor carbon units for their economies.

The Paris Agreement speaks of the vision of fully realizing technology development and transfer for both improving resilience to climate change and reducing GHG emissions. It establishes a technology framework to provide overarching guidance to the well-functioning Technology Mechanism. The mechanism is accelerating technology development and transfer through its policy and implementation arms.

Under the Paris Agreement, countries must increase their ambition every five years. To facilitate this, the Agreement established the Global Stocktake[17], which assesses progress, with the first evaluation in 2023. The outcome is to be used as input for new nationally determined contributions of parties. The Talanoa Dialogue in 2018 was seen as an example for the global Stocktake.[18] After a year of discussion, a report was published and there was a call for action, but countries did not increase ambition afterwards.

The Stocktake works as part of the Paris Agreement's effort to create a "ratcheting up" of ambition in emissions cuts. Because analysts agreed in 2014 that the NDCs would not limit rising temperatures below 2°C, the Global Stocktake reconvenes parties to assess how their new NDC's must evolve so that they continually reflect a country's "highest possible ambition".

While advancing up the ambition of NDC's is a major aim of the Global Stocktake, it assesses efforts beyond mitigation. The 5-year reviews will also evaluate a country's adaptation, climate finance provisions, and technology development and transfer.

After the first exercise at COP21, it was clear that the NDC's proposed by countries were highly insufficient to achieve the targets and are likely to lead to global warming between 2.7°C and 3.0°C, or even more. Most of modelling work around this issue shows that the world's greenhouse gas emissions should peak as soon as possible and rapidly decrease afterward in hope of remaining within the estimated carbon budgets leading to 1.5°C or 2°C. Every further year of emissions at today's level of about 42 GtCO2/y will make the Paris Agreement goals more difficult to achieve as the remaining carbon budget is low and not precisely known.

In the Paris Agreement policy framework, R&I (Research & Innovation) play a major role by providing the technological and non-technological solutions for a rapid decarbonization of the world's economy. Climate action can, and must, start and progress with latest available solutions, but these will soon be insufficient for the pace of decarbonization required unless accompanied by climate policies of politically difficult stringency. The development of cheaper and more effective mitigation solutions is therefore essential to increase the speed and the ambition of decarbonization.

In this context, the success of rapid and deep decarbonization depends largely on the effective development of portfolios of low- and zero carbon, cost-efficient and high-performance technological and nontechnological solutions, and on their integration in economy and society.

---

[16] Federal Ministry for the Environment, Nature Conservation and Nuclear Safety of the Federal Republic of Germany. *Carbon Mechanisms. Market-based climate policy instrument. Cooperative action under Article 6*. URL: https://www.carbon-mechanisms.de/en/introduction/the-paris-agreement-and-article-6.

[17] UN Climate Change. *Global Stocktake*. URL: https://unfccc.int/topics/science/workstreams/global-stocktake.

[18] IISD: SDG Knowledge Hub. *UNFCCC Publishes Summary of Talanoa Dialogue Inputs*. URL: https://sdg.iisd.org/news/unfccc-publishes-summary-of-talanoa-dialogue-inputs/.

These include key productive sectors, such as industry, energy, agriculture, and transport, but are also more generally related to the way of living of European citizens, which can be changed through social innovation promoting moves towards zero-carbon, sustainable cities.

Horizon Europe

In the light of the latest available science and of the need to step up global climate action, the European Council endorses the objective of achieving a climate-neutral EU by 2050, in line with the objectives of the Paris Agreement. One Member State, at this stage, cannot commit to implement this objective as far as it is concerned.

The transition to climate neutrality will bring significant opportunities, such as potential for economic growth, for new business models and markets, for new jobs and technological development. Forward-looking research, development and innovation policies will have a key role.

A set of thematic and cross cutting recommendations have been produced by the High-Level Panel (HLP) of the European Decarbonization Initiative, for the orientation of the new EU Framework Program for R&I 2021-2027, Horizon Europe. These recommendations include:

a. the need for sustained R&I activities on decarbonization across all sectors, including a robust program on climate change science;

b. the establishment of large mission-oriented programs of a cross-cutting nature for the deployment of system-level transdisciplinary innovation;

c. the development of partnerships with industry to address together the most difficult aspects of decarbonization, on which industry alone would not invest enough and with the necessary urgency;

d. the launch of 'Transition Super-Labs', very-large-territory initiatives of real-life management of the transition from typical fossil-fuel-based local economies to zero-carbon ones.

Putting decarbonization at the heart of Horizon Europe and of other national R&I programs in the EU may be the starting point of the change of pace in mitigation that is required to achieve the Paris Agreement goals.

A mission-oriented approach is needed for those complex societal challenges which require solutions within the medium term (5 to 15 years) that cannot simply be achieved by relying on independent developments driven by market conditions or by current innovation trends. Missions, currently being debated in the design phase of Horizon Europe, allow the achievement of difficult goals in a focused way. Particularly for challenges with a profound cross-sectoral dimension that requires the contribution of different stakeholders, and where public engagement is of high importance.

This Panel formulates three proposals[19] for missions which are synthesized, as follows:

- A mission that could be called 'the Internet of Electricity', meaning the transformation of the power system based on renewables, integrating storage, transmission, dispatchment, and through

[19] European Commission. *Final Report of the High-Level Panel of the European Decarbonization Pathways Initiative*. URL: https://ec.europa.eu/info/sites/default/files/research_and_innovation/research_by_area/documents/ec_rtd_decarbonisation-report_112018.pdf.

smartness and digitalization. This being a fundamental step towards the full integration and decarbonization of the energy system;

- A mission on European soils as carbon sinks, addressing the need for structural and management changes capable of making EU agriculture, forestry and land use contribute to the overall carbon neutrality of the continent, as needed by 2050;
- A mission on climate-neutral, 'circular' and liveable cities (including energy, mobility, waste, construction, urban planning, etc.), that may well be formulated as the one presented in a recent paper of Mariana Mazzucato (Mazzucato, 2018) and entitled '100 carbon-neutral cities by 2030'.

Carbon pricing mechanisms (carbon taxes versus cap-and-trade schemes)

Carbon pricing is an approach to reducing carbon emissions (also referred to as greenhouse gas, or GHG, emissions) that uses market mechanisms to pass the cost of emitting on to emitters. Its broad goal is to discourage the use of carbon dioxide–emitting fossil fuels in order to protect the environment, address the causes of climate change, and meet national and international climate agreements.

A key aspect of carbon pricing is the "polluter pays" principle. By putting a price on carbon, society can hold emitters responsible for the serious costs of adding GHG emissions to the atmosphere; these costs include polluted air, warming temperatures, and various attendants ills (threats to public health and to food and water supplies, increased risk of certain dangerous weather events). Putting a price on carbon can likewise create financial incentives for polluters to reduce emissions.

As a policy instrument, carbon taxes have so far been more widely adopted and therefore there is a wider empirical experience of policy effectiveness to review. While taxes appear to have been more successful at reducing emissions, recent adaptations of ETS systems may overturn this conclusion soon.

Carbon taxes have been favored by governments because of their lower cost of implementation, the comparative ease of implementation, the potential to increase government revenue, and the potential for offsetting reductions in income taxes. Among the countries with mature carbon pricing policies, those with carbon tax policies demonstrated greater reductions in greenhouse gas (GHG) emissions than countries with only ETS. However, reforms to the EU ETS, the New Zealand ETS, and the California cap and trade likely improved ETS effectiveness in reducing emissions.[20]

A well-designed carbon pricing mechanism can spur innovation and investments in low-carbon technologies that offer competitive advantage. But achieving the right design can also entail certain challenges[21]:

- **Carbon leakage.** Some schemes have had the effect of hindering business competitiveness. When there is an inconsistent patchwork of carbon pricing policies and regulations at the regional and global levels, the result can be carbon leakage—that is, the phenomenon by which carbon-intensive industries or firms shift operations to lower-cost jurisdictions. However, this practice can be discouraged through targeted and well-designed policies—such as product or investment tax credits, research and development support, and business support services.

[20] Enel Foundation, The Earth Institute – Columbia University. *Carbon Pricing as a Policy Instrument to Decarbonize Economies*. URL: https://www.enelfoundation.org/content/dam/enel-found/Carbon%20Pricing%20Report%20July%2019%202019%20FINAL1.pdf.
[21] Carbon Pricing Leadership Coalition. *What Is Carbon Pricing?* URL: https://www.carbonpricingleadership.org/what.

- **Policy overlap or inconsistency.** Carbon pricing instruments can be significantly more effective if they are properly aligned with complementary policies, such as energy efficiency policies, emissions performance standards, and research and technology policies, among others. Policy makers must work carefully and deliberately to avoid potential overlap of and interaction between policy instruments, which could undermine the effectiveness of carbon pricing mechanisms.

- **Ineffective use of revenues.** Carbon pricing instruments can raise significant revenues, but the effectiveness of many carbon pricing initiatives depends on how these revenues are spent. Revenues can be recycled to reduce other conventional taxes, protect lower-income households, support cleaner technologies, address fairness and competitiveness concerns, or channel public funds toward other public policy objectives. But each of these approaches has costs as well as benefits, and some are better suited to specific policy environments than others.

As research suggests, there will always be a tradeoff between the scope of the pricing policy and the effective rate or price. As the second oldest ETS, the New Zealand ETS provides a context for analyzing the potential benefits and challenges of linking national, subnational, or international carbon markets. Evidence suggests that despite early theoretical support for linking carbon 42 systems – with the intention to reduce marginal abatement costs and prevent "carbon leakage" – the import of offsets determines prices more than fundamentals such as energy prices or economic conditions (Diaz-Rainey and Tulloch, 2018).

In the long term, economy-wide carbon pricing will be an essential element of any policy that can achieve meaningful reductions of CO2 emissions cost-effectively in many countries.

In view of the two major approaches to carbon pricing on relevant dimensions, including efficiency, cost-effectiveness, and distributional equity the following key similarities have appeared[22]:

- the two instruments are perfectly equivalent in regard to: incentives for emission reduction, as both can be set upstream on the carbon content of fuels; aggregate abatement costs, as both can be cost-effective and provide the same incentives for technological change; and their effects on competitiveness, as both can lessen such impacts via appropriate border adjustments.

- carbon taxes and cap-and-trade are nearly equivalent in regard to possibilities for raising revenue. (Cap-and-trade can employ an auction.)

- these instruments are similar in terms of: costs to regulated firms, because cap-and-trade can freely allocate allowances, and a tax system can provide inframarginal exemptions below a specified level of emissions; and distributional impacts, as they can be designed to be roughly equivalent.

Turning to differences and distinctions between the two carbon-pricing instruments, the following have been identified:

- there are distinctions in terms of transaction costs, because volume discounts from brokers in a cap-and-trade system can violate the key property of the independence of costs and effectiveness of performance from the initial allocation of the allowances.

[22] Robert N. Stavins. *Carbon Taxes vs. Cap and Trade: Theory and Practice*. URL: https://seors.unfccc.int/applications/seors/attachments/get_attachment?code=TJQGYTI096K3J33ANM1HDWYEU51VRXNC.

- there are subtle differences in regard to: performance in the presence of uncertainty, as the Weitzman rule, which would seem to favor taxes because of the stock externality nature of the problem, can be overwhelmed by the correlation of benefits with costs, due to the persistence of technology shocks; and possibilities for linkage with other jurisdictions, since heterogeneous linkage is eminently possible.
- there are significant differences in regard to: carbon-price volatility, an issue only in cap-and-trade systems, although this can be somewhat ameliorated with price collars and banking of allowances; interactions with complementary policies, which is less of an issue with carbon taxes, which eliminate the so-called waterbed effect; market manipulation; and complexity and administrative requirements, which would seem to favor taxes, although whether a tax remains simple as it works its way through a legislature is an empirical question.

The table below summarizes the main features of ETS and Carbon Tax[23]:

	ETS	Carbon Tax
Policy Effectiveness	Provides certainty of abatement quantity but renders the price per unit of abatement uncertain. ETS are effective in reducing carbon emissions, but the instrument is yet to be proven in all sectors. The advent of a market stability reserve in the EU ETS and permit import restrictions in the New Zealand ETS demonstrate the feasibility of efforts to maintain market stability.	Does not guarantee abatement quantity, but the certain price per unit of abatement ensures a stable price to spur decarbonization efforts. Carbon taxes are effective in reducing carbon emissions and often replace or complement existing excise taxes, particularly in the energy sector.
Regulatory Stability	Reform efforts and increasingly efficient ETS policies will improve the likelihood that a stable regulatory environment can be maintained. The investment required in institutional infrastructure needed for ETS implementation helps consolidate political will for regulatory stability.	Phased introduction of new taxes and regulations are necessary to ensure taxpayer support and investor confidence.

[23] Enel Foundation, The Earth Institute – Columbia University. *Carbon Pricing as a Policy Instrument to Decarbonize Economies*. URL: https://www.enelfoundation.org/content/dam/enel-found/Carbon%20Pricing%20Report%20July%2019%202019%20FINAL1.pdf.

Cost and Distributional Effects	Costs associated with effective ETS include investment in capacity for monitoring and verification.	Lacking political will and the potential for regressive impact can hamper political vetting, implementation, and continuation. Revenue neutral carbon taxes are increasingly viewed as more equitable, a view that helps consolidate wide political and public support.
Policy Coherence	Overlapping polices, along with the economic downturn, undermined the effectiveness of the EU ETS. Reform efforts have targeted strategies to safeguard against an allowance surplus by improving policy coherence with the Renewable Energy Directive and the Energy Efficiency Directive.	Carbon tax policy must be considered in the context of both environmental policies and taxes as well as fiscal policy and taxation, including individual and corporate tax rates.
Impact on Trade	Carbon leakage, though theoretically important has not been critical empirically.	Border carbon adjustments have been proposed as supplements to a carbon tax to address possible competitive disadvantage and emissions leakage, but many details remain to be worked out to address scope and compatibility of BCAs with international trade agreements.

In all these efforts to achieve meaningful reductions of CO2 emissions cost-effectively, one major conclusion stands out: The specific designs of carbon taxes and cap-and-trade systems may be more consequential than the choice between the two instruments. These two approaches to carbon pricing are perfectly or nearly equivalent in regard to some issues and attributes, while significantly different in regard to some others. But many of these differences fade with specific implementation choices, as elements of design foster greater symmetry. Indeed, what appears at first to be a dichotomous choice between two distinct policy instruments often turns out to be a choice of design elements along a policy continuum[24].

[24] Robert N. Stavins. *Carbon Taxes vs. Cap and Trade: Theory and Practice*. URL: https://seors.unfccc.int/applications/seors/attachments/get_attachment?code=TJQGYTI096K3J33ANM1HDWYEU51VRXNC.

3.3. The Global rise of Emission Trading

Countries and regions around the world are developing emissions trading systems as a means to place a price on greenhouse gas (GHG) emissions. Such programs are now in place in Europe, North America, and parts of Asia – they are being considered in South America and several other regions. Given the difficulties of achieving consensus on climate change mitigation measures through the multilateral climate negotiations, momentum appears to have shifted from the international level to that of nation states and regions. A particularly strong dynamic is visible in rapidly developing economies, with new trading systems under discussion or already being established in Brazil, China, India, and South Korea. The aim of this article is to provide an overview of existing and selected emerging GHG trading schemes worldwide.

Globally, 39 national and 23 sub-national jurisdictions have implemented or are scheduled to implement carbon pricing instruments, including emissions trading systems and taxes. The world's largest carbon market is the European Emissions trading scheme (EU-ETS), covering sectors that emit over 2 billion tons of carbon dioxide each year. Korea's ETS covers sectors that emit over half a billion tons of GHG and the program in California and Quebec covers sectors emitting nearly half a billion tons. The seven Chinese pilot emission trading systems collectively cover sources emitting over one billion tons of CO2.

Additional carbon pricing initiatives are being put in place to help jurisdictions reach more ambitious regional or national climate goals[25]. In Europe, the EU Green Deal, and its commitment to reach carbon neutrality by 2050 strengthened the case for more ambitious climate action and a wider application of carbon pricing. Several countries announced new climate targets and plans to start exploring national carbon pricing initiatives to complement the EU ETS by covering new sectors. Germany intends to launch a domestic carbon market for heat and road transport in 2021. Luxembourg is also planning to introduce a carbon tax in 2021 for sectors not included in the EU ETS. Similarly, Austria presented plans to introduce a carbon price for non-ETS sectors with the form of the carbon pricing initiative yet to be determined.

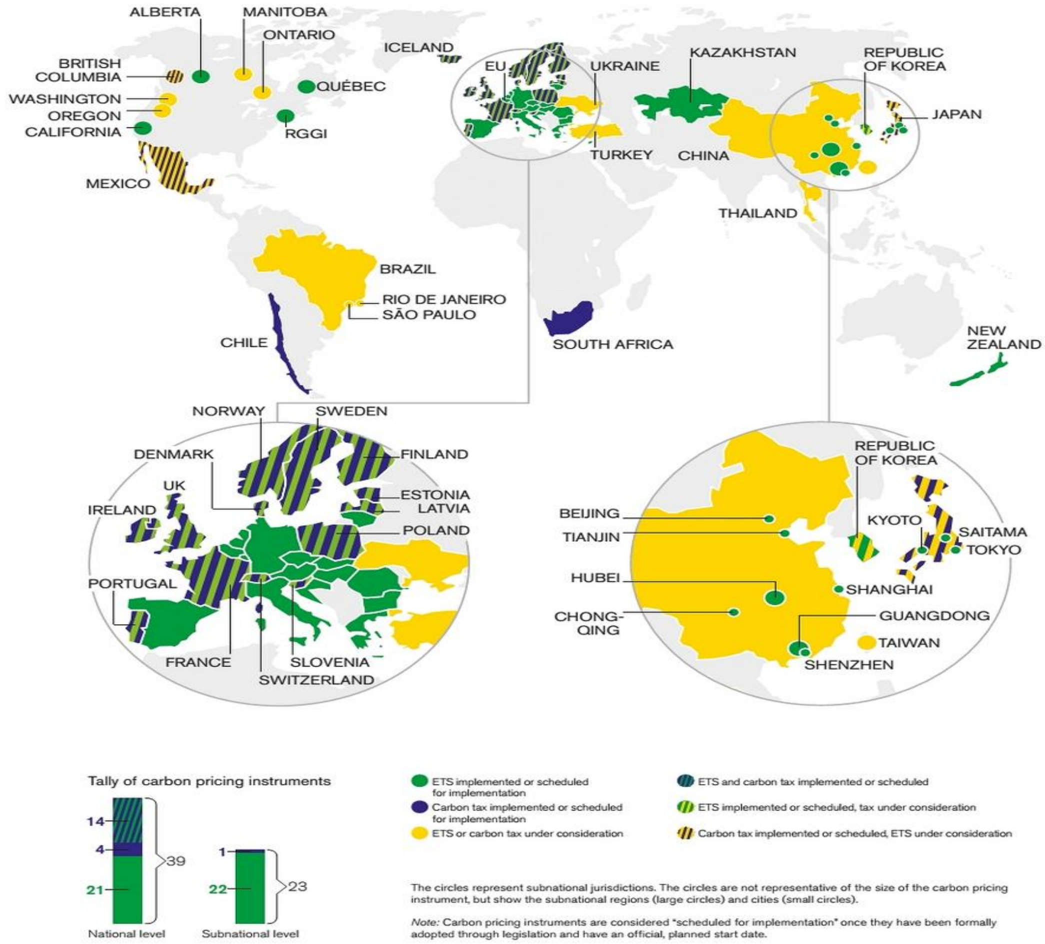
National emission trading programs have been discussed in the US and Canada, but have so far failed to receive the necessary political support. Instead, North American carbon trading systems have emerged at the regional level: nine US States have joined forces in a joint trading system called the Regional Greenhouse Gas Initiative (RGGI), and the Canadian province Quebec linked with California's emissions trading program in January 2014.

Asia has seen a strong dynamic toward emission trading recently, with five Chinese cities and two provinces starting pilot carbon markets – together, those regions account for about one-fourth of Chinese GDP and CO2 emissions. Chinese leaders are considering a national emission trading scheme, possibly beginning in 2016. South Korea's emission trading program entered into force in January 2015.

In other parts of the Asia Pacific region, the picture is mixed. The Tokyo Metropolitan Government has been operating a trading scheme for indirect CO2 emissions since 2010. However, Japan is not planning to implement a national emission trading system. While New Zealand's small ETS has been

[25] World Bank Group. *State and Trends of Carbon Pricing 2020*. URL: https://openknowledge.worldbank.org/bitstream/handle/10986/33809/9781464815867.pdf?sequence=4&isAllowed=y.

operating since 2008, Australia abandoned a long-planned national ETS in 2013 after a change in government.



Snapshot of existing schemes[26]:

The EU-ETS: In operation since 2005, the European Union Emissions Trading System (EU ETS) has faced a number of challenges resulting from the creation of the largest market for an environmental commodity in history. Currently, the EU ETS operates in 31 countries – all 28 EU Member States as well as Iceland, Liechtenstein and Norway – and covers CO2 emissions from emitters in the power sector, combustion plants, oil refineries and iron and steel works, as well as installations producing cement, glass, lime, bricks, ceramics, pulp and paper. More than 10 000 covered entities account for around 2 gigatons or 40% of EU total greenhouse gas emissions.

- **The New Zealand Emissions Trading Scheme (NZ ETS)** entered into force in 2008 and is the only ETS to include forestry as a covered sector.
- **The Regional Greenhouse Gas Initiative (RGGI)** is a carbon market among states in the northeastern and mid-Atlantic US that entered into force on January 1, 2009. It covers only CO2 emissions from electricity generation.

[26] The image has been taken from the official website of Climate Policy Info Hub. *The Global Rise of Emissions Trading.* URL: https://climatepolicyinfohub.eu/global-rise-emissions-trading.html.

- **The Western Climate Initiative (WCI)** is an initiative of US states and Canadian provinces to jointly develop climate change policies. Currently only California and Quebec have implemented emission trading systems, which entered into force on January 1, 2013;
- **The Tokyo Metropolitan Government Emissions Trading System (TMG ETS)** was established in 2010. The targets energy-related CO_2 emissions from industrial facilities as well as public and commercial buildings;
- **The Korean ETS** began in January 2015 and covers over 60% of the country's emissions. Over 500 companies (thousands of individual facilities) are covered in the power and industry sectors, but also waste and domestic aviation..
- **The Kazakhstan Emissions Trading Scheme** started with a pilot phase in 2013 covering CO_2 emissions. Energy, mining and metallurgy, chemicals, cement and the power sector are included.
- **The Australian state of New South Wales (Australian NSW ETS)** includes greenhouse gas (GHG) emissions from electricity generation and use and allows the use of project-based measures to reduce GHG emissions from other sectors. Benchmarking establishes the per head of population CO_2 emissions from electricity consumption that need to be reduced by purchasing emission reduction project certificates. Permitted projects include switching to low-carbon energy production, energy conservation and carbon storage in forests. In 2009, certificates representing 34 million tons of emission reductions (34 $MtCO_2$) were realized at a total value of $117 million.
- **In Alberta State**, Canada a domestic ETS covers 100 of the largest sources of GHGs (more than 100 000 tons of CO_2 per year), such as oil sands developers and coal-fired power plants. These sources account for about 70% of Alberta's industrial GHG emissions. ETS members are obliged to reduce their emission intensity (emissions per unit of output) by 12% starting from 01.07.2007. As this scheme is based on relative values, the absolute values of emissions may still increase. A further reduction of 2% per year is necessary in the following years. To meet the requirements, ETS member companies can improve their energy efficiency, invest in projects that reduce emissions, purchase allowances from companies that exceed their targets or pay a penalty of 15 CAD/tCO_2 into funds for investments in technologies that reduce GHG emissions.
- **In Switzerland** ETS was set for the period from 2008 to 2012 to coincide with the commitments under the first period of the Kyoto Protocol. Companies that have made a legal commitment to reduce energy-related CO_2 emissions could obtain an exemption from the heating-related CO_2 tax, which was set at CHF 36/tCO_2 (€26/tCO_2 eq.). Targets were negotiated on a case-by-case basis, using information on the technical and economic potential of companies to reduce emissions. Approximately 350 companies fell under the scheme. Emissions allowances were free of charge up to the level of their negotiated target and every year companies submitted a request for allowances that corresponded to their CO_2 emissions. Additional allowances were purchased to cover any emissions that exceed the target - either by trading with other companies that have reduced emissions below the target, or by purchasing reduced emissions from offset projects, which could be used to cover no more than 8% of the reduction plan. In case of non-compliance, a full CO_2 tax had to be paid on each ton of emissions from the date of the tax exemption.
- **The Chinese pilot trading schemes -** in 2011, the National Development and Reform Commission (NDRC) announced its plan to develop seven official ETS pilot programs in five cities

(Beijing, Shanghai, Tianjin, Chongqing and Shenzhen) and two provinces (Guangdong and Hubei). Implementation of this plan began in 2013. In 2015 all programs had entered into force – the Chinese national government's plans to implement a national ETS will be informed by the experiences of these pilot programs.

The Chinese pilot programs vary in terms of caps and targeted sectors. For example, Beijing is the only pilot that requires annual absolute emission reductions (quantifying the amount of carbon dioxide and other greenhouse gases reduced) for existing facilities in the manufacturing and service sectors. The other ETS require reductions in emissions intensity, a ratio of emissions per unit of product. Shenzhen and Tianjin allow individual investors and entities that are not covered in the ETS, such as financial institutions, to participate in trading, resulting in higher trading frequency and potentially larger price fluctuations.

Allowances in the Chinese ETS pilots are generally given out for free, based on grandfathering. Apart from power and heat, benchmarking (an allocation method by which emitters receive allowances based on measures related to their size) has not been deployed at a large scale. However, two of the ETS pilots, Shenzen and Guangdong, started to experiment with a small amount of auctioning. As for offset credits (emission reductions resulting from projects undertaken by entities NOT covered by the ETS cap) all of the Chinese programs are required to accept federally approved offsets known as "*Chinese Certified Emission Reductions*" or CCERs. These mostly come from previous Chinese Clean Development Mechanism (CDM) projects under the Kyoto Protocol's CDM. Indirectly, this opens a link between the pilots, as they have at least one type of compliance unit in common.

Comparison of design features of ETS worldwide:

Sectoral coverage: While the EU-ETS focuses on industry and large energy producers and ETS schemes in the US and Canada have similar coverages (with the exception that the linked California/Quebec program also includes transport emissions), some of the emerging schemes in Asia involve smaller facilities, buildings, and indirect emissions from energy consumption.

Type of targets: While schemes in the US and Europe have absolute caps, the Chinese pilot ETS largely use an intensity metric for required reductions.

Allocation method: Only few ETS worldwide have a significant share of auctioning from the beginning. Similar to the EU-ETS where grandfathering (an allocation method by which emitters receive permits on the basis of their past emissions) was used in the beginning, the Chinese ETS pilots allocate most allowances for free.

Although neither the US nor Canada have national emission trading systems, they are home to regional carbon markets. At the same time various ETS are emerging at regional and national level are in Asia. Some of these differ from the *'traditional'* schemes in industrialized countries (such as RGGI and the EU ETS), which mainly address emissions from heavy industry and the power sector. In contrast, some of the newer schemes involve smaller facilities or buildings and include indirect emissions from energy consumption. Given the current dynamics in Asia, the future of global emissions trading will depend on developments in Asia and, to a lesser degree, other parts of the developing world. If this dynamic continues, emerging economies could eventually overtake the European Union and other OECD countries as centers for emissions trading, which in turn would significantly shift the style, nature and challenges of a future international carbon market.

3.4. Digitalization. The innovation challenges.

Digitalization is key to deploying innovation at system level across all traditional sectors. Electrification is a sine qua non for the decarbonization of a large part of the mobility system, of energy-intensive industries and of heating needs. Electricity needs will increase substantially, but smart grid technology and a wise management of future diffused energy storage systems — such as batteries for electric vehicles ("EVs") — and of diffused production may very much help to flatten peak demand.

An '**Internet of Energy'** will need to be developed.

Huge amounts of data are already being collected in various areas. Better management of this data can allow big data to become a tool in decarbonization making electricity smart grids more accurate or through improving life-cycle assessments (LCA) of products and their value chains. Similarly, AI and machine learning can support the design of more sustainable products by learning from previous experiences and obtaining the optimal result at a higher speed then previously.

Most oil and gas companies have initiated reductions in their carbon intensity and are evaluating which technologies are best suited for their operations. One of the practical ways to achieve near net zero emissions is to adopt technologies that remove carbon by sequestering carbon into noncombustible products like plastics or by capturing and injecting carbon into the reservoirs with CCUS (Carbon capture, utilization and storage) or using carbon dioxide for EOR (Enhanced oil recovery) methods.

The digital initiative is focused on the deployment of various technology, such as robots and drones, predictive analytics, and automated remote operations. The blend of these technologies will greatly facilitate real-time, data-driven decision making. Leveraging capabilities of Internet of Things (IoT) could connect end-to-end operations to ensure that all systems, equipment, sensors, and data are in communication for immediate remedial actions.

Oil and gas companies already have incorporated many of the tools important to address their operational challenges, such as equipment maintenance and reliability, remote operations and asset integrity. Industries can leverage the strength of disruptive digital technologies such as machine learning, digital twins, augmented reality, AI, integrated data platforms, and other solutions to optimize their production and reduce emissions including identifying and recording fugitive emissions in both upstream and downstream sectors.

AI-based diagnostics and predictive and prescriptive analytics are going to play a major role in identifying emission sources, tracking equipment health, and alerting operations in advance in order to reduce downtime and limit emissions.

In addition to optimizing production processes, AI and machine learning can support the decarbonization of the energy sector by predicting the output of wind and solar farms (see Google's Deepmind subsidiary for an interesting initiative on predicting wind and solar capacity). AI also holds large potential in providing services to consumers as energy generators and personalization of energy devices. Increased use of Internet of Things (IoT) can lengthen the lifespan of products by monitoring their functioning through predictable maintenance or contribute to a more resource efficient energy use through the increased use of smart-meters or application in electric vehicles ("EVs").

Blockchain as a distributed ledger technology can facilitate a secure and transparent peer-to-peer transaction in a future energy system where all households act as prosumers in a highly complex and integrated grid system. Blockchain can also enable better and safer traceability of products and materials needed to support circularity in value chains.

While digital and technological solutions at times seem like the obvious solution, there are barriers that need to be overcome and possible rebound effects to be aware of. There is still a long way to go for digital infrastructure to fully harness the potential of digital solutions. In addition, increased use of IoT and AI raises issues related to privacy, trust and security that must be addressed to gain the acceptance of citizens and the public sector. For example, the 'black box' nature of machine learning for automatization can be problematic when it affects energy access to thousands of homes.

Given the magnitude of the decarbonization challenge and the need to ensure that competitiveness and job co-benefits fully materialize through decarbonization, R&I efforts should be intensified. It is also required to develop innovative ways to overcome other significant barriers to technology diffusion, such as system integration, infrastructures that lock in high-carbon behavior, transitional costs, non-technical and behavioral barriers, and difficulties in accessing and securing financing and increasing market reach.

Furthermore, there is a clear need to steer the process of innovation towards zero-carbon solutions. Historically, technological innovation has not necessarily brought about improved material, cleaner energy or input efficiency. For instance, innovation in the Industrial Revolution or many aspects of the Internet Revolution increased the use of materials and energy. The implementation of a set of policy and institutional incentives thus becomes a necessary pre-condition to foster zero-carbon innovation and the diffusion of low- and zero-carbon business models. In this respect, digitalization — if properly steered — can become a means to support decarbonization.

Digitalization of energy use and energy supply promotes the growing interdependence of the different types of energy use that until now were quite separated, *e.g.* for transport, heating, or appliances. Digitalization is starting to penetrate activities, products and services related to 38 smart homes and other smart energy-efficient solutions. Digitalization could help to enhance the management of energy demand, improve grid reliability, and reduce energy costs, but it could potentially also have a number of negative effects.

Digitalization itself requires additional energy (data centers for big data), and digitalization-enabled services could lead to substantial additional energy demand — as, for example, seen with the blockchain-based cryptocurrency bitcoin. Digitalization, once combined with the vast possibilities of social innovation, can also create a new situation of information asymmetry for prosumers. With the increase in data availability and use, as in other sectors of the European economy, concerns over data collection, data control, data integrity and data ownership, etc. arise. To get the full benefits of these developments in digital technologies in the energy sector, concerns over privacy and data security remain. All in all, digitalization is likely to have a strong impact on energy use and GHG emissions, but the direction of change is still unclear. Accordingly, R&I is required in all aspects of energy digitalization.

This favors the emergence of novel, potentially disruptive business models alongside new job profiles and skill requirements. The respective industries no longer just sell goods or deliver energy as a commodity. Instead, they offer integrated solutions extending into areas such as home comfort, entertainment, or personal security. European energy policies and regulation are largely based on a distinction between parts of the energy supply chain that can benefit from competition, on the one hand, and natural monopolies that stem from network effects, on the other.

In terms of rebound effects stemming from increased digitalization, there is the risk that the efforts to decarbonize sectors though digitalization will lead to a higher use of energy and resources. As an example, the indication that the ICT (Information and communication technologies) sector itself needs to undergo "*a green transformation*" has been highlighted in the EU's digital strategy[27]. The environmental footprint related not only to electronic and electrical equipment, but also data centers and cloud services is significant and needs to be decoupled from emission and waste.

It is estimated that 5-9% of global electricity consumption is consumed by the ICT sector, making up over 2% of global emissions[28]. As an example, estimations show that Bitcoin technology's energy consumption is at a similar level as that of Switzerland[29]. The need for the ICT sector to lower their environmental footprint is however growing on the agenda with tech companies announcing net-zero emission targets. Microsoft, as another example, have partnered with the Swedish energy company Vattenfall in the procurement of renewable energy for their data centers in Sweden and the Netherlands[30] and is one of the largest purchasers of renewable energy in the world.

The state of Europe in 2050 will be the result of the efforts to make the continent both green and fit for the digital age. As the EU's digital strategy acknowledges: "Digital technologies, as advanced as they may be, are just a tool". They are however tools that hold the enormous potential to accelerate the green transition.

[27] Josephine Andersen. *Digitization for Decarbonization*. URL: https://www.internetjustsociety.org/digitize-decarbonize.
[28] European Commission. *Communication from The Commission to The European Parliament, The Council, The European Economic and Social Committee and The Committee of The Regions*. URL: https://ec.europa.eu/info/sites/default/files/communication-shaping-europes-digital-future-feb2020_en_3.pdf.
[29] Annika Hedberg, Stefan Šipka. *The circular economy: Going digital*. URL: https://wms.flexious.be/editor/plugins/imagemanager/content/2140/PDF/2020/DRCE_web.pdf.
[30] Esat Dedezade. *Building for the future: Microsoft's new Swedish datacentres have sustainability firmly in mind*. URL: https://news.microsoft.com/europe/2019/05/29/building-for-the-future-microsofts-new-swedish-datacentres-have-sustainability-firmly-in-mind/.

4. RECENT DEVELOPMENTS AND LESSONS LEARNED

Over the past decades, many companies have incrementally adopted strategies for better management of natural resources and emissions. Cost minimization, compliance optimization and eco-efficiency thinking are now being replaced by more ambitious approaches. The movement built up steadily over the years, gained momentum after the Paris Agreement and has greatly accelerated since the outbreak of Covid-19. The business community has now reached a point of no return.

One way of keeping track of the growing number of companies that have committed to become carbon neutral is by using transparency and science-based targets. When the UN Global Compact, in collaboration with other organizations, launched the Science Based Targets Initiative (SBTI) in 2015, the aim was to enlist 100 companies for the Paris Climate Summit. Over 1,000 companies have joined the SBTI and many of these corporations have committed to the SBTI's "Business Ambition for 1.5°C".

Committing to decarbonizations often involves major process and product changes, technology shifts and the phasing out of fossil fuels. The business case for decarbonizations is not always apparent, as carbon emissions are still not priced high enough. But it is now commonly understood that the reduction of emissions and the material footprint of products, such as plastics, correlates with increased brand value, competitiveness, and market access. Decarbonizing business activities across the lifecycle of products and along supply chains has already led to massive relocation of capital, innovation and new business models across all sectors of the economy.

In the past couple of years, the energy landscape in Europe and the world has become more aware of the need for sustainability. The massive investments in new low-carbon energy technologies in China, the US and Europe, as well as the switch from coal to gas in the US since the shale revolution, are affecting the growth path of CO2 emissions in the world. Since 2010, CO2 emissions growth has been tapering off and was even flat from 2014-2016, in part because of the downturn in economic growth. However, the recent increase in 2017 shows that CO2 emissions have not yet peaked (IEA, 2018).

The changes in recent energy landscape in Europe are the result of several interdependent mega-trends, both pushed and pulled by the EU's 2020 and 2030 climate and energy plans and the recent Clean Energy for All Europeans package. These trends[31] are:

- greater renewable energy sources (RES) production and (potential of) increasing electrification;
- greater energy efficiency;
- new energy technologies (such as distributed energy technologies) and governance structures;
- digitalization as a key driver and enabler of greater integration and service orientation;
- active consumers.

Up to now, these changes have taken place neither at a sufficient pace nor homogeneously throughout the EU. For instance, while overall energy-related CO2 emissions decreased on average by 2 % annually from 2005 to 2015, transport-related emissions reduced by only 0.6 % per year (European Commission, 2018).

[31] European Commission. *Final Report of the High-Level Panel of the European Decarbonization Pathways Initiative*. URL: https://ec.europa.eu/info/sites/default/files/research_and_innovation/research_by_area/documents/ec_rtd_decarbonisation-report_112018.pdf.

In order to deeply decarbonize the economies, zero-carbon molecules as well as increased use of zero-carbon electrons are needed. More concretely, there is a need for new technologies to produce, convert, store and use zero carbon electrons and molecules. These technologies will enable new systems integration across different types of energy demand and the management of intermittent supply and demand of all types (CIEP, 2017).

The European Battery Alliance, launched in October 2017, is an important first step towards the next generation of battery storage technologies. Further such initiatives, targeting both other storage technologies (including chemical and thermal) as well as other building blocks of the future energy supply system, are necessary.

A certain trade-off between the extent of decarbonization and short-term emission reductions exists. For most processes and technologies, implementing a zero-emission solution requires higher investments than going for only partial decarbonization. Furthermore, many zero-carbon solutions, such as hydrogen trucks, are not yet market ready. Thus, these technologies will require substantial R&I funding and will certainly not be implemented on a large scale for at least a decade, meaning that they will not contribute to the emission reductions that are necessary over the next decade to stay within the emission budgets for 1.5 °C or 2 °C of warming.

On the other hand, cheaper intermediate solutions exist that will bring down emissions in the short term, such as natural-gas-fueled trucks. While being cheaper to implement and closer to market, these technologies can potentially create lock-ins into partially decarbonized processes that prevent the full decarbonizations required to meet the Paris Agreement targets.

This trade-off cannot be solved in general — it needs to be weighed separately for each specific case, factoring in the differential costs of additional abatement, the expected R&I timeline of a technology, the danger of lock-ins into unsustainable pathways, and the adaptability towards future zero-carbon solutions, e.g. injecting hydrogen and biogas into gas grids.

In several practical cases, given the very ambitious target of full decarbonizations by the mid-century, public R&I money should be focused on processes that achieve close-to-zero or even negative emissions, and not on processes that only reduce emissions, especially if solutions take 10-20 years to go from the laboratory stage to high market shares.

Carefully designed R&I policies will ensure that reducing one externality (e.g. greenhouse gases) does not create new externalities, *e.g.* new material scarcities or increased land use. Although new energy technologies are coming to maturity, it cannot be assumed that the low-carbon character of the new energy technologies means that they are perfect on all accounts. We need to look at the energy system in a dynamic and integrated manner, rather than a static one, if we want to understand fully all the impacts of existing and proposed policy measures. This requires a fundamental update of current energy system models to include the necessary dynamic representation of links between the energy system, land and

In the past decade, renewables have attracted a growing share of new energy investment. Global investment in renewables has dropped in the recent past as a result of declining specific investment costs for renewables, but there has been a record installation of renewable power capacity (UNEP-FS, 2017; IRENA, 2017).

The rapid expansion of renewables brings manifold challenges and opportunities: knowledge growth, massive grid requirements, storage and capacity mechanisms, to name a few. Further sustained deployment of these technologies will result in more efficiency gains, greater economies of scale and additional cost reductions through processes such as automation and learning by-doing. However, the variable (but forecastable) generation profile of solar and wind energy is starting to pose integration challenges in some states. To address these challenges, many potential options exist, *e.g.* building extensive high voltage connections to demand centers, developing energy storage through batteries or conversion to molecules (for instance hydrogen), or making demand flexible.

Also, variability implies that (extended) periods of low wind and solar generation occur and may in fact coincide. As a result, alternative capacity is required, either renewable or conventional in the short run, which is only needed for limited amounts of time. While electricity systems presently rely on (legacy) conventional power plants, it remains to be seen whether operators and investors are willing to put their resources into capacity given this kind of risk/reward profile. Finally, while the costs of wind and solar can now be competitive with newly constructed fossil fuel power plants, the current oversupply of fossil capacity in combination with long-lived capital stocks means that the decarbonization of the EU power supply will happen much too slowly without additional policy action.

5. CASE STUDY

Enel sets its priorities in the development of decarbonization, renewable energy and the fight against climate change.

Enel action platforms and partnerships in "green" field

Enel actively participates in industry associations and organizations to promote issues related to the energy transition.

Alliance of CEO Climate Leaders. The CEO of Enel is a member of the Alliance of CEO Climate Leaders, organized by the World Economic Forum. In 2017, Enel co-signed a declaration that supports effective climate solutions that are promoted by the business, expressing strong support for the recommendations of the TCFD.

Carbon Pricing Leadership Coalition. Enel is a member of the Carbon Pricing Leadership Coalition (CPLC) launched in 2014 by the World Bank, with the aim of bringing together public and private players to speed up the adoption of effective carbon pricing solutions worldwide.

"A more ambitious EU-wide renewable energy target for 2030" declaration. The "*A more ambitious EU-wide renewable energy target for 2030*" declaration was signed by six European companies in the energy sector: EDP, Enel, EnBW, Iberdrola, Ørsted and SSE. In this joint declaration, the signatories set a more challenging goal for renewable energy, rising from a 27% share to 35% by 2030. This goal is to be achieved through greater electrification of the transport and heating sectors, together with a redesigned electricity market for renewable energies, in line with the decarbonization targets set by the Paris Agreement.

Electrification Alliance. The Electrification Alliance is an initiative of the leading European associations that promote the key role of electricity in the decarbonization process. In 2017, a statement was published reiterating the role of electricity and the commitment to support the reduction of climate-altering emissions, as well as the increase in investments in non-issuing technologies such as renewable energy, energy storage and smart grids, while promoting integration with the heating, cooling and transport sectors.

In the early months of 2018, the Alliance focused on defining the EU's post-2020 budget (the Multi-Annual Financial Framework - MFF) and the Mobility Package. With regard to the MFF, the Alliance has requested that public spending in the EU reflects the strategy of the Paris Agreement and is intended to support the related commitments on climate and energy in all EU countries, including the objective of carbon neutrality for infrastructures and the wider EU target for 2030 on renewable energy, as well as the electrification of consumption for smart and efficient use of energy. As for the Mobility Package, the Alliance calls for recognition of the importance of transport electrification as a key factor for achieving road-travel decarbonization in the EU and highlights the need for a more stringent commitment in that regard.

Platform for Electro-Mobility. The Platform for Electro-Mobility is a joint initiative of companies, associations and NGOs (non-governmental organizations) committed to promoting electric mobility and to collectively developing solutions for the electrification of European transport. Enel was the first utility to participate in the platform.

Eurelectric New Industry Vision. Under Enel's leadership, eurelectric has repositioned itself in order to accelerate the energy transition by investing in the production of clean energy and in solutions enabling the change to reduce emissions and to reach the goal of becoming carbon-neutral well before the middle of the century. Thanks to this new vision, the electrical sector reaffirms its commitment to leading the transition towards a future of the energy sector in a fully sustainable EU, creating value for customers and for society. The new Vision received the unanimous support of eurelectric members and a significant number of Managing Directors of the EU electricity companies.

Enel launched its second green bond on the European market

On January 9, 2017, Enel Finance International (EFI) successfully placed on the European market its first green bond. The issue totals 1,250 million euro and provides for repayment in one instalment at maturity on September 16, 2024, as well as the payment of a fixed-rate coupon of 1%, payable annually in arrears in the month of September. The issue price has been set at 99.001% and the effective yield to maturity is equal to 1.137%.

On January 9, 2018, EFI carried out a new issue, successfully placing its second green bond on the European market. The issue amounts to a total of 1,250 million euro, to be repaid in a single instalment at maturity on September 16, 2026, and the payment of a fixed-rate coupon equal to 1.125%, payable annually in arrears in the month of September as from 2018. The issue price has been set at 99.184% and the effective yield at maturity is equal to 1.225%.

The green bond was listed on the regulated market of the Irish Stock Exchange and on the regulated market of the Luxembourg Stock Exchange and was admitted to trading on the multilateral trading system "ExtraMOT PRO" organized and managed by Borsa Italiana. The transaction has received subscriptions amounting to more than 3 billion euro, with the significant participation of Socially Responsible Investors ("**SRI**").

The net proceeds of the issue – carried out under Enel and EFI "Euro Medium-Term Note Program" – will be used to finance and/or refinance, in whole or in part, the eligible green projects of the Enel Group identified and/or to be identified in accordance with the "Green Bond Principles" published by the International Capital Market Association (ICMA). The transaction is consistent with:

- the financial strategy of the Enel Group set out in the 2018-2020 Strategic Plan, which among other things envisages the refinancing of 10 billion euro through 2020, including the issue of green bonds as instruments dedicated to the financing of projects to spur the transition to the low-carbon economy;

- the commitment made by Enel on December 11, 2017, on the Paris 2017 Climate Finance Day, together with 8 other industrial companies issuing green bonds, to continue to develop the green bond market, today one of the most dynamic segments of sustainable finance.

It should be noted that the Enel Group has prepared and published a new Green Bond Framework in order to facilitate transparency and the commitments made by the Group with regard to green bonds. In addition, in June 2017 the Enel Group set up a Green Bond Committee to oversee the implementation of the Green Bond Framework and the process of allocating the proceeds of green bond issues.

Enel development of renewable capacity and reduction of thermal capacity

At the end of December 2017, the Group's net installed capacity was around 85 GW, up compared to 2016 by around 2 GW, mainly due to the entry into operation of new renewable hydroelectric, wind and solar plants in Brazil, solar plants in Peru and wind farms in the United States.

The additional capacity from renewable sources (renewables and hydroelectric) amounts to about 2.8 GW. Today, the Group has, all over the world, plants powered by renewable sources for around 38 GW of installed capacity, which is about 45% of the Group's total power generation capacity.

Enel has also worked as operator in joint ventures with both the BSO model (Build, Sell and Operate) and through acquisitions of company shares. The managed capacity includes renewable plants in Italy, the United States and Canada. Considering a managed capacity of 2.6 GW, the total capacity is thus equal to around 88 GW (32% hydroelectric, 15% other renewables, 14% oil & gas, 17% CCGT, 18% coal and 4% nuclear).[32]

E.g. Russian expertise

- *Sale of Reftinskaya GRES*. In 2019, a transaction on the sale of one of the main Enel Russia PJSC assets – 3 800 MW Reftinskaya power plant - took place. As of October 1, 2019, it is in full possession of the buyer - JSC Kuzbassenergo. The cost of the transaction amounted to 20.7 billion roubles. The sale of Reftinskaya GRES took place within the framework of the long-term strategy for the complete decarbonization of Enel Group's energy production by 2050 and the transition to environmentally friendly production methods, as the main fuel at the power plant was coal. After its sale, only natural gas-fired power plants remain at the company's disposal. The company is gradually seeking to transform its portfolio of assets in favour of renewable energy sources.[33]
- *Construction of 3 wind farms in Russia*. In 2017 Enel Russia PJSC received the right to build a wind power plant in Azov, Rostov region, with an installed capacity of 90 MW, under the tender for the construction of wind power generation facilities with a total installed capacity of 1.9 GW held by the Russian government. In 2021 PJSC Enel Russia has been awarded the right to put it into commercial operation. The construction of the wind farm was carried out by Enel Green Power, a division of Enel Group responsible for the development and operation of renewable energy facilities around the world. The initial investments of Enel Russia PJSC in Azov WPP were estimated at EUR 132 million. This project is included in the list of the "Governor's Hundred" of priority large-scale investment projects in Rostov Oblast. The wind farm will be able to generate around 320 GWh per year and avoid the emission of around 260,000 tons of carbon dioxide into the atmosphere. The wind farm is equipped with 26 turbines and is located on a total area of 133 hectares. Apart from Azov wind farm, PJSC Enel Russia is implementing two other wind power projects: Kola wind farm (201 MW) in Murmansk region and Rodnikovsky wind farm (71 MW) in Stavropol region. The Company's total investment in the three wind farms will amount to about EUR 495 million. These investments are also in line with Enel Group's goal to fully decarbonize its assets by 2050.[34]

[32] *Enel Sustainability Report 2017*. URL: https://www.enel.com/content/dam/enel-com/documenti/investitori/sostenibilita/2017/sustainability-report_2017.pdf.
[33] Enel Russia PJSC. *Enel Russia completes the transition of Reftinskaya GRES to Kuzbassenergo.* URL: https://www.enelrussia.ru/en/media/press/d202007-01072020.html.
[34] Enel Russia PJSC. *Enel Russia received a right to put into commercial operation its first wind farm Azovskaya 90 MW*. URL: https://www.enelrussia.ru/en/media/press/d2021-enel-russia-received-a-right-to-put-into-commercial-operation-it.html.

EU-Japan industrial cooperation for decarbonization

Businesses and other organizations from Europe and Japan develop and implement a growing number of partnerships contributing to the reduction of greenhouse gases emissions, in sectors such as renewable energy, clean hydrogen, energy efficiency, sustainable cities and low-carbon mobility.

These projects bring together the best of European and Japanese technologies, expertise and know-how. They take place in Japan, Europe, and other regions, helping set the world on the pathway towards carbon neutrality. They contribute to innovation, economic growth and decarbonization. They involve recently created startups, small and medium enterprises developing their international footprint, and long-established major corporations.

- **HYDROGEN TAXIS | HYPE X AIR LIQUIDE X IDEX X TOYOTA MOTOR.** Three French companies – hydrogen taxi company Hype, industrial gas supplier Air Liquide, and energy supplier Idex – joined forces with Japanese car manufacturer Toyota Motor in 2019 to form HysetCo, a joint-venture determined to bring a change to the mobility landscape. Together, they deploy in Paris the world's largest fleet of hydrogen taxis.
- **SOLAR ENERGY DEVELOPMENT IN JAPAN | JUWI X SHIZEN ENERGY.** In 2013, two years after the nuclear accident of Fukushima, the recently founded Japanese renewable energy developer and supplier Shizen Energy established a joint venture with juwi, a German leader that started building wind and solar farms in 1996. Together, the companies developed nearly 70 renewable energy plans in Japan, and are working on increasingly ambitious projects, adapting their model to the geographic conditions of Japan and the evolution of the local market.
- **ON-DEMAND PUBLIC TRANSPORT | SHOTL X ODAKYU ELECTRIC RAILWAY.** Odakyu Electric Railway, a major public transport company in Japan, established in 2019 a partnership with Spanish mobility start-up Shotl. Together, they are testing new on-demand transport services in the suburb of Tokyo, in order to reduce the need for individual cars and thus the emissions of greenhouse gases and air pollutants.
- **OFFSHORE WIND FOUNDATIONS | SIF X KAJIMA CORPORATION.** In 2020, Kajima Corporation, one of Japan's largest construction firms, selected Dutch manufacturer Sif to provide the monopile foundations for the Akita Noshiro offshore wind farms, the first commercial-scale offshore wind project in Japan. This is both the first contract in Japan for Sif, and the first major offshore wind construction project for Kajima. The wind farms, that will provide the energy equivalent to 130000 households, are set to begin operation in 2022.
- **OFFSHORE WIND TURBINES | VESTAS WIND SYSTEMS X MITSUBISHI HEAVY INDUSTRIES.** Vestas Wind Systems, a Danish leader in wind turbines manufacturing, and Mitsubishi Heavy Industries, one of the world's largest industrial firms, joined forces in 2014 to establish MHI Vestas, a joint venture aiming at becoming a leading player in the offshore wind industry. MHI Vestas now hires more than 3000 people, has offshore turbines in operation in several European countries, and registered its first orders in Asia. Late 2020, the partnership evolved with new perspectives in wind energy and green hydrogen.[35]

[35] EU-Japan Centre for Industrial Cooperation. *Case Studies: Eu-Japan Industrial Cooperation for Decarbonization*. URL: https://www.eu-japan.eu/climate.

6. COMMODITIES OF THE FUTURE

Pursuant to an analysis by Fitch Solutions Country Risk and Industry Research[36], it is expected that oil, iron-ore, conventional steel, zinc, sugar and beef to broadly stagnate, demand-wise, in the next 20 years.

Also, in terms of agricultural commodities set to boom, these include poultry, dairy, fish and crustaceans, soybean, corn, cocoa, fruits and vegetables and new agribusiness areas such as marijuana.

An overview of the predictions of Fitch Solutions regarding commodities is presented in the table[37] below:

Source: Fitch Solutions

The "*commodities of the future*", including copper, nickel, aluminum, lithium, cobalt, tin, rare earths, metal scraps and green steel, are likely to experience a boom in demand over a two-decade horizon.

Although rather difficult to predict the commodities of the future, considering that the green and digital transitions are to accelerate in the coming years, specifically the electric vehicle market is expected to grow exponentially in the next 20 years, it appears that so will various commodities linked to electric vehicles[38]. In this respect we mention lithium, cobalt, graphite — the demand for these essential components in electric vehicle cars and batteries is already starting to spike. Also, a demand growth is now being forecast for copper and high-grade nickel.

This boom in electric vehicles promises to have a seismic impact on miners. Lithium, cobalt, graphite—the demand for these essential components in electric vehicles and batteries is already starting to spike. And let's not forget the demand growth that is now being forecast for copper and high-grade nickel. Consider the following:

---

[36] Donna Slater. *Commodities of the future to boom over 20-year horizon*. URL: https://www.miningweekly.com/article/commodities-of-the-future-to-boom-over-20-year-horizon-2021-04-21.

[37] The image has been taken from the official website of Fitch Solutions. *Which Are The Commodities Of The Future?* URL: https://www.fitchsolutions.com/commodities/which-are-commodities-future-19-04-2021.

[38] Deloitte. *Commodities of the future: Predicting tomorrow's disruptors*. URL: https://www2.deloitte.com/ca/en/pages/energy-and-resources/articles/commodities-of-the-future-predicting-tomorrows-disruptors.html.

- Most analysts predict that global demand for lithium will double or even triple by 2030.[39]
- Analysts predict that demand for battery-grade graphite will triple by 2020.[40]
- Cobalt is facing a global supply deficit that may grow from 885 tons in 2018 to 5,340 tons in 2020.[41]
- Electric vehicles are expected to contain four times as much copper as combustion-powered engines.[42]
- Demand for battery-grade nickel is expected to increase 50 percent by 2030.[43]

Out of the energy sector, low-carbon hydrogen, a relatively new commodity, is set to boom. While fossil fuel-derived hydrogen (grey hydrogen) is not new, blue hydrogen (natural gas-derived and with carbon capture and storage) and green hydrogen (renewable energy-derived) are entering commercialization and are only just becoming established in energy commodity markets. Low carbon hydrogen has numerous potential industrial applications to decarbonize multiple sectors including power, or as fuel for manufacturing, transportation and more.

The technology used for obtaining green hydrogen would save the 830 million tons of CO_2 that are emitted annually when this gas is produced using fossil fuels. Likewise, replacing all grey hydrogen in the world would require 3,000 TWh/year from new renewables — equivalent to current demand of Europe. However, there are some questions about the viability of green hydrogen because of its high production cost; reasonable doubts that will disappear as the decarbonization of the earth progresses and, consequently, the generation of renewable energy becomes cheaper.

Many advocates for a hydrogen economy believe “green” hydrogen, which is produced through electrolysis using renewable energy, will eliminate the need to curtail wind and solar generation. However, there are many reasons why “blue” hydrogen, which is produced from natural gas while using carbon capture technology to reduce or eliminate greenhouse gas emissions, could be a better long-term option for hydrogen production.

In this regard, it is considered that the “hydrogen as a commodity” narrative has just started to unfold, with a notable rise in interest since 2020. As such, the hydrogen sector will evolve at a fast pace in the coming years amid an ever-expanding project pipeline. Green hydrogen production will rapidly accelerate and gain increasing market share at the expense of traditional grey hydrogen, rising from less than 1% of current global market supply to a forecasted 10% by 2030.

This rapid acceleration has been brought forward by declining renewable costs, wide geographical scope, short development times and its zero-carbon footprint.

In contrast, it is expected that blue hydrogen production growth will remain highly focused in several key markets and will be slower to gain market share owing to long development times, resource dependency and high levels of capital investment.

---

[39] David Fickling. *Peak Lithium? Not so fast*. URL: https://www.bloomberg.com/opinion/articles/2017-09-27/take-peak-lithium-forecasts-with-a-pinch-of-andean-salt.
[40] Benchmark Mineral Intelligence. *Graphite Demand from Lithium Ion Batteries to More Than Treble In 4 Years*. URL: https://www.benchmarkminerals.com/graphite-demand-from-lithium-ion-batteries-to-more-than-treble-in-4-years/.
[41] CISION. *Cobalt Prices to Rocket as Tesla and Apple Scramble for Supplies*. URL: https://www.prnewswire.com/news-releases/cobalt-prices-to-rocket-as-tesla-and-apple-scramble-for-supplies-620374383.html.
[42] The Economist. *Mining companies have dug themselves out of a hole*. https://www.economist.com/news/business/21718532-electric-vehicles-and-batteries-are-expected-create-huge-demand-copper-and-cobalt-mining.
[43] Mark Burton, Jack Farchy. *One metal will be transformed by the electric car boom*. URL: https://www.theglobeandmail.com/globe-investor/investment-ideas/nickel-forecast-charges-ahead-on-electric-car-battery-demand/article36784954/.

CONCLUSIONS

Fully decarbonizing is a central part of achieving climate stabilization, and reaching net zero emissions by 2050–2070 is necessary in order to remain on-track with the Paris Agreement's goal of limiting warming to well below 2°C.

The move from fossil fuels to renewables is one of the keystones in the battle against climate change and in the transition to a sustainable world. However, it also involves a paradigm shift from a completely plannable model of power generation to a scenario that is intrinsically unplannable. This is a journey that involves technical and infrastructural challenges in part because we cannot allow power grids to become unstable, or blackouts or power outages to occur.

A sustainable energy supply implies optimized use of energy, minimized pollution and reduction in fossil fuel energy consumption. These aspects have led to an increasing focus on the short-term stored energy resources, which could be derived from wind power, hydro power, solar power, biomass, and geothermal heat power. The fastest growing segment of sustainable energy is the wind; however, the other mainstream forms such as hydro power and solar power are in the prototype form or at the research and development stage.

Three trends have already started shaping utilities' decarbonization opportunities[44]:

- a fossil fuel fade is underway, as all fossil fuel emissions will need to be phased out if the power sector is to completely decarbonize and reach its stated goal of net-zero emissions by 2050.
- a solar and wind sweep is rapidly increasing the share of variable renewable resources on the grid.
- infrastructural innovation is helping to enhance the electric and gas system's ability to support decarbonization.

Solar and wind power have become the preferred energy resources to replace coal. Power and utility executives responding to our energy transition survey stated that cleaner energy sources and fuels including renewables are one of the leading enablers of their clean energy strategy. Not only have renewables become the lowest-cost source of new generation in many areas on an unsubsidized basis, but their deployment is also propelled by customer demand and state renewable portfolio standards that set renewable generation targets.

Smoothing the transition to zero net emissions also includes helping businesses reinvent themselves for a cleaner world. The energy system is rapidly transforming, driven by political, economic, environmental, technological and consumer pressures.

Emission trading played a major role is this and is continuing to play an ever-increasing role, in a so far successful combination of regulation and market forces.

These changes include the rise in renewable electricity generation and the use of electric vehicles (EVs) and substantial further changes will need to take place to meet the decarbonization goals by 2050.

In this regard EVs can help decarbonize both transport and electricity supply. This is both *via* reduced tailpipe emissions and due to the flexibility in charge and discharge that EV batteries can offer to the

[44] Stanley Porter. *The future of energy: Decarbonization in power and utilities*. URL: https://www2.deloitte.com/global/en/blog/energy-resources-industrials/2021/decarbonization-in-power-and-utilities.html.

electricity system.[45] For example, automakers started down that path as they improved gas mileage to meet performance standards and developed electric and low-emissions vehicles to meet demand. Also, smart charging of EVs could enable the storage of the solar generation for when this energy is needed. However, to do this, the market needs to align vehicle charging behavior to complement renewable generation and meet system needs.

Faced with the staggering number of vehicles currently on the roads, competition from the secondhand market, and the cost of infrastructures and electric vehicles, promoting this type of mobility is a strategic choice to encourage the transition from combustion-powered engines to electric mobility. Government incentives for plug-in electric vehicles have been established around the world to support policy-driven adoption of plug-in electric vehicles. These incentives mainly take the form of purchase rebates, tax exemptions and tax credits, and additional perks that range from access to bus lanes to waivers on fees (*e.g.*, charging, parking, tolls).

E-fuels should be prioritized also for ships and planes, most of which cannot use batteries to decarbonize and will generate huge demand for e-fuels. While some small ships and planes may be able to be powered by a battery, for longer journeys, planes and ships will need hydrogen or hydrogen-based ammonia.

Given that hydrogen is one of the keys to the energy transition, it is not only important to make it economically viable, but also to maximize the decarbonization impact and minimize its resource requirements. As the hydrogen momentum accelerates, it is increasingly clear that decision makers must put the focus on decarbonization to ensure hydrogen can fulfil its potential as a key solution in the global clean energy transition, making a significant contribution to net zero emissions.

Different sustainability aspects have been considered in the life cycle of hydrogen production and supply[46], such as:

- As an energy source for hydrogen production, both renewable power for water electrolysis and natural gas with very high shares of CCS ("**Carbon Capture and Storage**") can achieve marginal to low greenhouse gas (GHG) emissions, respectively, when considered well to use, including end-of-life emissions.
- Biogenic feedstock for hydrogen production can result in a wide range of GHG emissions. While energy crops are between natural gas-based and renewable electricity-based pathways, GHG emissions from biogenic wastes can be as low as the best renewable power-to-hydrogen pathways (or even negative in case of bio + CCS) but with waste streams somewhat limited at global scale.
- The impact of selected metal recycling on the GHG emissions balance well to use is somewhat limited. GHG reductions from recycling of selected metals is most pronounced with solar and wind power pathways, where recycling tends to yield GHG savings of about 30% for the manufacturing of photovoltaic plants and 40% for wind power plants in 2030 versus using virgin material). Recycling is of wider strategic relevance for deep decarbonization in the context of a circular economy.

[45] Archie Corliss. *Electric Vehicles and Their Role in the Energy System*. URL: https://www.technology.matthey.com/article/64/3/307-319/.
[46] Hydrogen Council. *Hydrogen decarbonization pathways. Introduction to the two reports: "Hydrogen Decarbonization Pathways: A Life-Cycle Assessment" and "Hydrogen Decarbonization Pathways: Potential Supply Scenarios"*. URL: https://hydrogencouncil.com/wp-content/uploads/2021/01/Hydrogen-Council-Report_Decarbonization-Pathways_Executive-Summary.pdf.

In reality, the decarbonized supply scenario will combine a range of different renewable and low-carbon hydrogen production pathways that are optimally suited to local conditions, political and societal preferences and regulations, as well as industrial and cost developments for different technologies.

Going forward, digital transformation will be key to decarbonization and helping electricity ecosystems deliver clean energy to connected consumers in safe and reliable ways. Digital solutions that apply AI, IoT and blockchain will support new energy marketplaces, while enabling more resilient physical infrastructure, more efficient and reliable utility operations, and better customer service.[47]

Sustainable energy management is most conveniently conducted in practice by using tools and techniques that arrange and observe the process, in its essence complex, as a sum of operations that are to be performed at certain time and in a specific way. Analyzing, planning, directing, implementing, and control phases of sustainable energy management implementation are performed according to goals that are above all focused on providing sustainability as well as preserving positive economic business effects.

A combination of reduced energy consumption from non-renewable resources, increased energy consumption from renewable resources, and increased energy efficiency on one side and creating positive economic and non-economic effects on the other, create the definition of modern sustainable energy management.

[47] Mahesh Sudhakaran. *Sustainably fueling the future: accelerating decarbonization through clean electrification*. URL: https://www.ibm.com/blogs/internet-of-things/sustainably-accelerating-decarbonization/.

BIBLIOGRAPHY

1. Global Monitoring Laboratory. *Trends in Atmospheric Carbon Dioxide*. URL: https://gml.noaa.gov/ccgg/trends/graph.html.
2. Deloitte. *The 2030 decarbonization challenge. The path to the future of energy*. URL: https://www2.deloitte.com/content/dam/Deloitte/global/Documents/Energy-and-Resources/gx-eri-decarbonization-report.pdf.
3. Jillian Ambrose. *Five Asian countries account for 80% of new coal power investment*. URL: https://www.theguardian.com/environment/2021/jun/30/five-asian-countries-80-percent-new-coal-power-investment.
4. Johnson Hur. *History of Commodities Trading*. URL: https://bebusinessed.com/history/history-commodities-trading/.
5. Andrew Hecht. *Why Are Commodities More Volatile Than Other Assets*? URL: https://www.thebalance.com/why-commodities-are-volatile-assets-4126754.
6. Lawrence Pines. *Environmental Commodities: What Are They & How Can You Trade Them*? URL: https://commodity.com/environmental/#What_Are_Environmental_Commodities.
7. IG. *What are safe-haven assets and how do you trade them?* URL: https://www.ig.com/en/trading-strategies/what-are-safe-haven-assets-and-how-do-you-trade-them--181031.
8. Deloitte. *Commodity Price. Risk Management. A manual of hedging commodity price risk for corporates*. URL: https://www2.deloitte.com/content/dam/Deloitte/in/Documents/risk/in-risk-overview-of-commodity-noexp.PDF.
9. Saqib Shaikh. *12 Main Causes of Changes in Demand for a Commodity*. URL: https://www.economicsdiscussion.net/law-of-demand/12-main-causes-of-changes-in-demand-for-a-commodity/13623.
10. Saqib Shaikh. *Supply of a Commodity: Meaning, Factors Affecting and Types.* URL: https://www.economicsdiscussion.net/law-of-supply/supply-of-a-commodity-meaning-factors-affecting-and-types/13695.
11. UN Climate Change. Intergovernmental Negotiating Committee for a Framework Convention on Climate Change. *Preparation of a framework convention on climate change – Set of informal papers provided by delegations, related to the preparation of a framework convention on climate change. Addendum.* URL: https://unfccc.int/sites/default/files/resource/docs/1991/a/eng/misc01a01.pdf.
12. Eurostat. *Glossary: Kyoto Protocol.* URL: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Kyoto_Protocol.
13. He Jiankun. *Launch of the Outcome of the Research on China's Long-term Low-carbon Development Strategy and Pathway*. URL: https://www.efchina.org/Attachments/Program-Update-Attachments/programupdate-lceg-20201015/Public-Launch-of-Outcomes-China-s-Low-carbon-Development-Strategies-and-Transition-Pathways-ICCSD.pdf.
14. IPCC. *Summary for Policymakers of IPCC Special Report on Global Warming of 1.5°C approved by governments*. URL: https://www.ipcc.ch/2018/10/08/summary-for-policymakers-of-ipcc-special-report-on-global-warming-of-1-5c-approved-by-governments/.
15. Federal Ministry for the Environment, Nature Conservation and Nuclear Safety of the Federal Republic of Germany. *Carbon Mechanisms. Market-based climate policy instrument. Cooperative action under Article 6.* URL: https://www.carbon-mechanisms.de/en/introduction/the-paris-agreement-and-article-6.

16. UN Climate Change. *Global Stocktake*. URL: https://unfccc.int/topics/science/workstreams/global-stocktake.
17. IISD: SDG Knowledge Hub. *UNFCCC Publishes Summary of Talanoa Dialogue Inputs*. URL: https://sdg.iisd.org/news/unfccc-publishes-summary-of-talanoa-dialogue-inputs/.
18. European Commission. *Final Report of the High-Level Panel of the European Decarbonization Pathways Initiative.* URL: https://ec.europa.eu/info/sites/default/files/research_and_innovation/research_by_area/documents/ec_rtd_decarbonisation-report_112018.pdf.
19. Enel Foundation, The Earth Institute – Columbia University. *Carbon Pricing as a Policy Instrument to Decarbonize Economies*. URL: https://www.enelfoundation.org/content/dam/enel-found/Carbon%20Pricing%20Report%20July%2019%202019%20FINAL1.pdf.
20. Carbon Pricing Leadership Coalition. *What Is Carbon Pricing*? URL: https://www.carbonpricingleadership.org/what.
21. Robert N. Stavins. *Carbon Taxes vs. Cap and Trade: Theory and Practice*. URL: https://seors.unfccc.int/applications/seors/attachments/get_attachment?code=TJQGYTI096K3J33ANM1HDWYEU51VRXNC.
22. World Bank Group. *State and Trends of Carbon Pricing 2020*. URL: https://openknowledge.worldbank.org/bitstream/handle/10986/33809/9781464815867.pdf?sequence=4&isAllowed=y.
23. Climate Policy Info Hub. *The Global Rise of Emissions Trading.* URL: https://climatepolicyinfohub.eu/global-rise-emissions-trading.html.
24. Josephine Andersen. *Digitization for Decarbonization*. URL: https://www.internetjustsociety.org/digitize-decarbonize.
25. European Commission. *Communication from The Commission to The European Parliament, The Council, The European Economic and Social Committee and The Committee of The Regions*. URL: https://ec.europa.eu/info/sites/default/files/communication-shaping-europes-digital-future-feb2020_en_3.pdf.
26. Annika Hedberg, Stefan Šipka. *The circular economy: Going digital*. URL: https://wms.flexious.be/editor/plugins/imagemanager/content/2140/PDF/2020/DRCE_web.pdf.
27. Esat Dedezade. *Building for the future: Microsoft's new Swedish datacentres have sustainability firmly in mind*. URL: https://news.microsoft.com/europe/2019/05/29/building-for-the-future-microsofts-new-swedish-datacentres-have-sustainability-firmly-in-mind/.
28. *Enel Sustainability Report 2017.* URL: https://www.enel.com/content/dam/enel-com/documenti/investitori/sostenibilita/2017/sustainability-report_2017.pdf.
29. Enel Russia PJSC. *Enel Russia completes the transition of Reftinskaya GRES to Kuzbassenergo*. URL: https://www.enelrussia.ru/en/media/press/d202007-01072020.html.
30. Enel Russia PJSC. *Enel Russia received a right to put into commercial operation its first wind farm Azovskaya 90 MW.* URL: https://www.enelrussia.ru/en/media/press/d2021-enel-russia-received-a-right-to-put-into-commercial-operation-it.html.
31. EU-Japan Centre for Industrial Cooperation. *Case Studies: Eu-Japan Industrial Cooperation for Decarbonization*. URL: https://www.eu-japan.eu/climate.
32. Donna Slater. *Commodities of the future to boom over 20-year horizon*. URL: https://www.miningweekly.com/article/commodities-of-the-future-to-boom-over-20-year-horizon-2021-04-21.
33. Fitch Solutions. *Which Are The Commodities Of The Future?* URL: https://www.fitchsolutions.com/commodities/which-are-commodities-future-19-04-2021.

34. Deloitte. *Commodities of the future: Predicting tomorrow's disruptors*. URL: https://www2.deloitte.com/ca/en/pages/energy-and-resources/articles/commodities-of-the-future-predicting-tomorrows-disruptors.html.
35. David Fickling. *Peak Lithium? Not so fast*. URL: https://www.bloomberg.com/opinion/articles/2017-09-27/take-peak-lithium-forecasts-with-a-pinch-of-andean-salt.
36. Benchmark Mineral Intelligence. *Graphite Demand from Lithium Ion Batteries to More Than Treble In 4 Years*. URL: https://www.benchmarkminerals.com/graphite-demand-from-lithium-ion-batteries-to-more-than-treble-in-4-years/.
37. CISION. *Cobalt Prices to Rocket as Tesla and Apple Scramble for Supplies*. URL: https://www.prnewswire.com/news-releases/cobalt-prices-to-rocket-as-tesla-and-apple-scramble-for-supplies-620374383.html.
38. The Economist. *Mining companies have dug themselves out of a hole*. https://www.economist.com/news/business/21718532-electric-vehicles-and-batteries-are-expected-create-huge-demand-copper-and-cobalt-mining.
39. Mark Burton, Jack Farchy. *One metal will be transformed by the electric car boom*. URL: https://www.theglobeandmail.com/globe-investor/investment-ideas/nickel-forecast-charges-ahead-on-electric-car-battery-demand/article36784954/.
40. Stanley Porter. *The future of energy: Decarbonization in power and utilities*. URL: https://www2.deloitte.com/global/en/blog/energy-resources-industrials/2021/decarbonization-in-power-and-utilities.html.
41. Archie Corliss. *Electric Vehicles and Their Role in the Energy System*. URL: https://www.technology.matthey.com/article/64/3/307-319/.
42. Hydrogen Council. *Hydrogen decarbonization pathways. Introduction to the two reports: "Hydrogen Decarbonization Pathways: A Life-Cycle Assessment" and "Hydrogen Decarbonization Pathways: Potential Supply Scenarios"*. URL: https://hydrogencouncil.com/wp-content/uploads/2021/01/Hydrogen-Council-Report_Decarbonization-Pathways_Executive-Summary.pdf.
43. Mahesh Sudhakaran. *Sustainably fueling the future: accelerating decarbonization through clean electrification*. URL: https://www.ibm.com/blogs/internet-of-things/sustainably-accelerating-decarbonization/.