Renewable Energy

Whitepaper

Investment Analyst:
Sunniva Bratt Slette

Table of Contents

Executive summary

The 2030 Agenda for Sustainable Development, a set of 17 Sustainable Development Goals (SDGs), creates an opportunity for investors to allocate capital to help accelerate a more sustainable development.

Renewable energy is defined as "energy that is produced by natural resources, such as sunlight, wind, rain, waves, tides and geothermal heat, that are naturally replenished within a timespan of a few years"[6]. These natural resources do not emit CO_2 or other pollutants to air or soil during energy production, resulting in improved air quality and less water pollution. Furthermore, freshwater consumption is significantly reduced with renewable energy, compared to fossil-based power generation.

In physics, the law of conservation of energy states that energy can never be created or destroyed, only converted from one form of energy to another. Waste of high-quality energy leads to unnecessary high energy production. Striving to reduce energy loss is therefore fundamental to a sustainable energy system.

Access to clean energy is necessary for human prosperity. The overall global energy system needs a significant shift to get to net zero Greenhouse Gas (GHG) emissions. Renewable energy production is the single common denominator of a wide range of leading forecasting and scenario models towards 2050. There seems to be a consensus around anticipated increase of solar and wind energy. The pressing need to conserve water, clean the air and reduce GHG emissions makes the business case for future growth in renewables. The numerous positive crossovers can strengthen the outlook for renewable energy as an attractive investment segment. This whitepaper focuses on two central sub-themes that lay the foundation of successful expansion of renewable energy: Renewable Energy Technologies and Energy Storage and Distribution.

Renewable Energy Technologies

The most common renewable energy sources are wind, solar and hydro. Wind energy is one of the fastest-growing renewable energy technologies, while solar energy is the most abundant and accessible energy resource on planet Earth. A cost reduction from lower prices in system components, higher efficiency, and matured industries on both the supply and demand side, has made both solar and wind energy economically viable, and hence the technologies have become commercially available in markets across the globe. Hydropower is one of the most cost-effective methods of producing electricity. Small-scale or micro hydropower generates energy with minimal interference of a river's natural water flow. This is generally perceived to be more environmentally friendly because it causes less methane emissions from biodegrading submerged vegetation, less stress on biodiversity and surrounding ecosystems.

Other renewable energy sources are bioenergy, geothermal energy and ocean energy. Bioenergy is the combustion of biological materials. Geothermal is derived from heated water or steam from within the sub-surface of the Earth. Ocean energy is premature in the sense that it is not yet commercially available. It refers to wave energy, tidal energy by dams or barrier construction, tidal-current or underwater turbines that turn with the tidal flows, salinity gradient energy that exploits variations in salt concentration or ocean thermal energy conversion that utilizes temperature differences.

Energy Storage and Distribution

Energy storage costs have declined across most storage technologies, especially for short-term storage. Long duration energy storage technologies are attractive, but unfortunately in various stages of technical maturity rates and degrees of commercialization.

A major source of concern with mainstream renewable energy is intermittency. Wind and solar power can only be generated when sunlight or wind is present. A stable power grid with sufficient backup storage can prevent grid outages. Smart grids are designed to optimize the electricity supply network through digital monitoring.

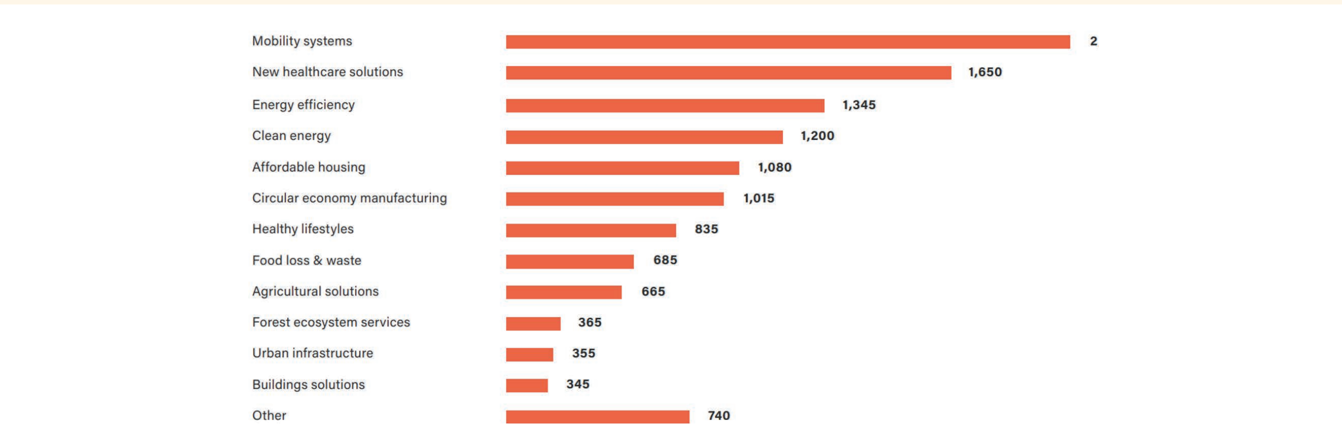
Distributed Energy Systems (DES) amplify a dynamic system which can shave peak loads off a centralized grid. Over-dimensioned grids are built do deliver peak energy demand, but this is expensive. Improved energy management, locally produced renewables, storage, monitoring and control solutions can help delivering a more stable and flexible grid. Energy access to remote areas is another major advantage of DES. Energy independence can be gained without the need to invest in a massive transmission line upfront. A competitive advantage can be expected in cost effectiveness, rapid installation, less material use, and a reasonable operational cost due to the low price of renewables.

The SDGs as an Investment Theme

The UN Sustainable Development Goals (SDGs) were adopted by all United Nations member states in 2015. The SDGs represent a shared blueprint for global peace and prosperity towards 2030. The 17 goals highlight how ending poverty and conflicts can be realized alongside strategies that improve health and education, reduce inequality, contribute to economic growth while safeguarding natural habitats, oceans and tackling climate change[1]. With the global effort to transition to sustainable societal development comes investment opportunities when new solutions need to be financed. The World Business Council for Sustainable Development (WBCSD) has identified SDG investment opportunities across four economic systems: food and agriculture; cities; energy and materials; health and wellbeing. The economic gains of SDG investments can be significant. Predictions by the Copenhagen Consensus show that 19 of the 169 SDG targets can deliver more than $15 of good for society, environment and economy for every $1 spent[2].

The SDGs provide a common target and language of action to achieve sustainable development. This facilitates business opportunities when finance flows towards sustainable projects. The UN Roadmap for SDG investing calls on the financial industry to disclose and incorporate long-term risk into investment decision making, implement sustainable investing strategies, scale up green financial instruments, as well as measuring and reporting on impact3. Estimates show that a USD 12 trillion market value could be opened up by 2030 if the SDGs are realized, creating 380 million jobs in the process[4]. An estimate by WBCSD of the distribution of these investment themes is found in the figure below.

Value of Incremental Opportunities in 2030 US$ billions: 2015 values*



*Based on estimated savings or project market sizings in each area. Rounded to nearest US$ billion. Source: Literature search; AlphaBeta analysis

Figure 1: The 12 largest business themes in a world economy heading for the SDGs.
Source: Business and Sustainable Development Commission[5]

Solutions Theme: Renewable Energy

Renewable energy is defined as ”energy that is produced by natural resources—such as sunlight, wind, rain, waves, tides, and geothermal heat—that are naturally replenished within a time span of a few years”[6]. Renewable energy does not emit CO_2 or other pollutants to air or soil during energy production. The result is improved air quality and less water pollution, which in turn benefits the health of humans and the eco-systems that rely on clean air and water. Health concerns related to air pollution have been a major driver for the uptake of renewable energy, particularly in large cities that incur serious air pollution due to fossil-based energy and transport systems. Furthermore, freshwater consumption is dramatically reduced with renewable energy, in particular solar photo-voltaics (PV) and wind. A Finnish study in the research journal Nature Energy estimates that a global energy system based on 100 percent renewable energy would consume 95 percent less water that conventional power generation[7]. Freshwater is a scarce resource, and increasingly so, following droughts caused by the global climate crisis. The pressing need to conserve water, clean the air and reduce greenhouse gas (GHG) emissions underscores the business case for future growth in renewables. The numerous positive crossovers can strengthen the outlook for renewable energy as an attractive investment segment.

Main SDGs Linked to Solutions Theme

13 CLIMATE ACTION

Take urgent action to combat climate change and its impacts
Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries; Integrate climate change measures into national policies, strategies and planning; Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning.

7 AFFORDABLE AND CLEAN ENERGY

Ensure access to affordable, reliable, sustainable and modern energy for all
Increase substantially the share of renewable energy in the global energy mix; double the global rate of improvement in energy efficiency; enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology; expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries.

There are many linkages to other SDGs, which will be described in the subsequent sub-categories. Other relevant SDGs with crossovers will be described in different thematic white papers.

Investment Potential in Renewables Towards 2050

The Intergovernmental Panel on Climate Change (IPPC) issued a report in 2018 on the pathway to keep global temperatures below 1.5 degrees Celsius. "In 1.5°C pathways with no or limited overshoot, renewables are projected to supply 70–85% (interquartile range) of electricity in 2050"[8]. The rise of renewables is the single common denominator of a wide range of leading forecasting and scenario models towards 2050. Examples of models that are commonly used are developed by the IPCC, Bloomberg New Energy Finance (BloombergNEF), International Energy Agency (IEA), International Renewable Energy Agency (IRENA) and DNV (previously DNV GL). While the various scenarios and models vary in means of reaching GHG emission mitigation and adaptation, there seems to be consensus around the anticipated increase of solar and wind energy. In part this relates to unprecedented cost reductions in the unsubsidized levelized cost of energy in wind and solar power. Technology efficiency, reasonable energy storage, economies of scale, learning curves and more stable and mature market developments all accelerate the demand. The Paris Agreement commitments of all UN nations has already contributed to shift financial flows towards climate mitigation and adaptation measures. In the coming decades, the scale of such investments is expected to increase drastically.

Historical Global Power Generation NEO 2020 global power

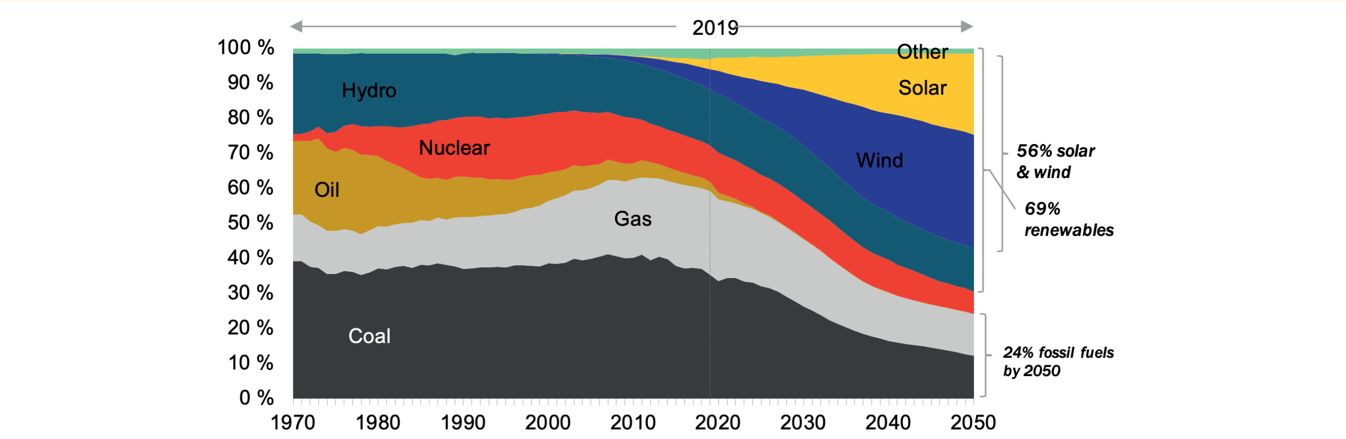


Figure 2: Historical and scenario modelled global electricity generation mix. Wind and solar energy are estimated to take the largest share of global power production in 2050. Investments in these sectors contribute to accelerate the rapid development. Source: BloombergNEF (2020)[9].

The rapidly accelerating uptake of renewables in electricity production is visible in both historical and future predictions, as shown in Figure 2 from Bloomberg New Energy Finance. Investment in renewables has increased steadily over the past decade. The main drivers are political regulations, significant cost reductions, and public health benefits in the form of reduced pollution and higher energy independence. However, the weight of renewables versus fossil fuels scale quite differently when considering the energy system as a whole.

The upper part of figure 2 illustrates that only 11 percent of global primary energy was derived from renewables in 2019.

The overall global energy system needs a significant shift to get to net zero emissions. The illustration of how primary energy consumption has changed since 1800 is illustrated in figure 3. While renewables have expanded exponentially, they have started from miniscule levels compared to fossil-based sources.

Global Primary Energy Consumption by Source

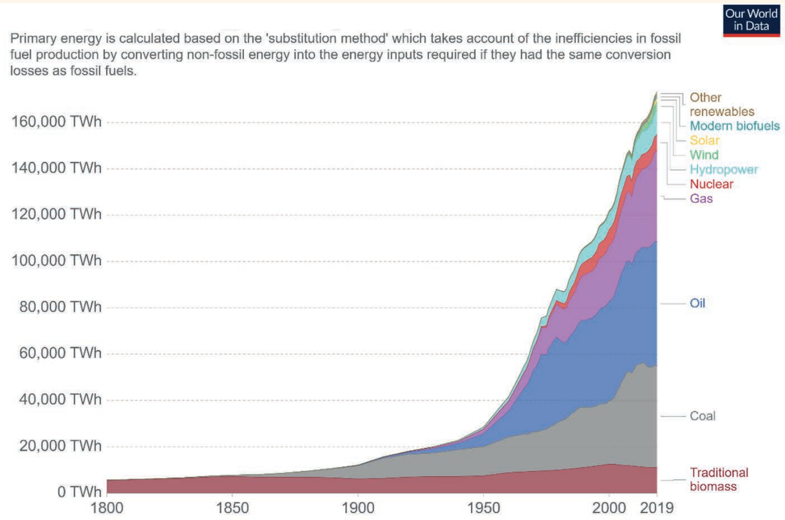
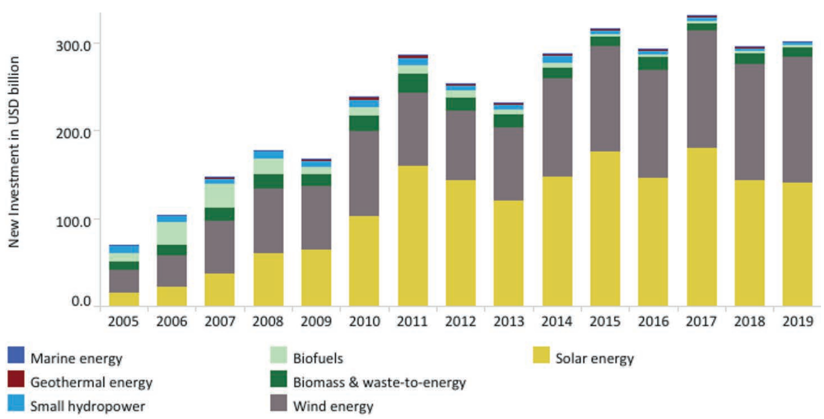


Figure 3 shows how the world's energy system has changed since the 1800s. Renewable energy is still a miniscule part of the total energy system. The graph is corrected for the inefficiencies (energy wasted as heat during combustion) in fossil fuel and biomass conversion. Source: Our World in Data (2021)[10].

While the overall energy system may be dominated by fossil fuels, investments are on a trajectory to shift the trend. Although global investment in clean energy has been stable throughout the Covid-19 pandemic, figure 4 shows that the trend has been broadly flat since 2015.



Source: Frankfurt School-UNEP Centre/BNEF. 2020. Global Trends in Renewable Energy Investment 2020, http://www.fs.unep-centre.org. Note: Investment volume adjust for re-invested equity. Total values include estimates for undisclosed deals.

Figure 4: Global trends in renewable energy investments show that solar and wind energy have dominated the share of new investments in renewables since 2005. Source: IRENA (2020)[11].

Clean electricity production is a prerequisite for the full effect of electrification in transport sectors and industry. Though electric vehicles (EVs) have no tailpipe emissions, the upstream emissions from electricity production must be taken into account to reduce life cycle emissions. For example, EV charging from residential solar roofs with integrated batteries and smart metering is preferable to centralized coal-powered electricity. Figure 5 shows a BloombergNEF overview of how renewables investment has been complemented by supporting infrastructure investment since 2004. Investments in electrification, energy storage, carbon capture and storage (CCS) and hydrogen have all increased notably.

Global Investment in Energy Transition by Sector

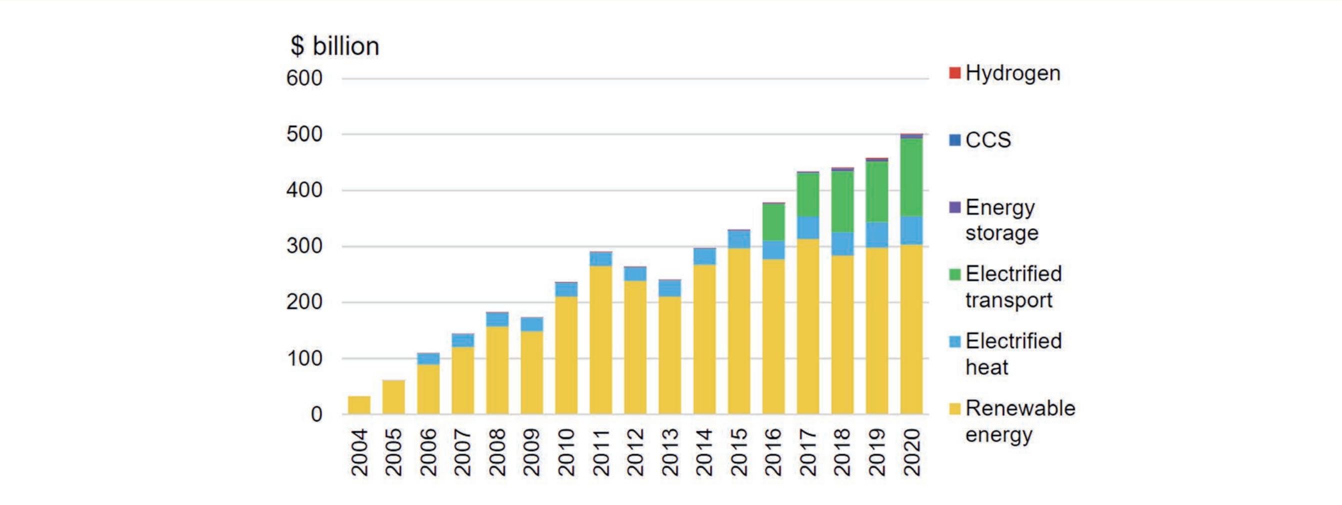


Figure 5: Global investment in energy transition by sector, of which renewables and electric transport is most notable. Source: BloombergNEF (2021)[12].

A positive takeaway from the IEA's graph in figure 6 is the considerable investments in energy efficiency in parallel with renewables investments. The most environmentally friendly energy is the energy which is never consumed, and thereby not produced. The win-win nature of energy efficiency is measurable in monetary savings with immediate effect. To illustrate, companies and nations that prioritize upgrades in energy efficient solutions and distribution systems will experience a reduced electricity bill instantly.

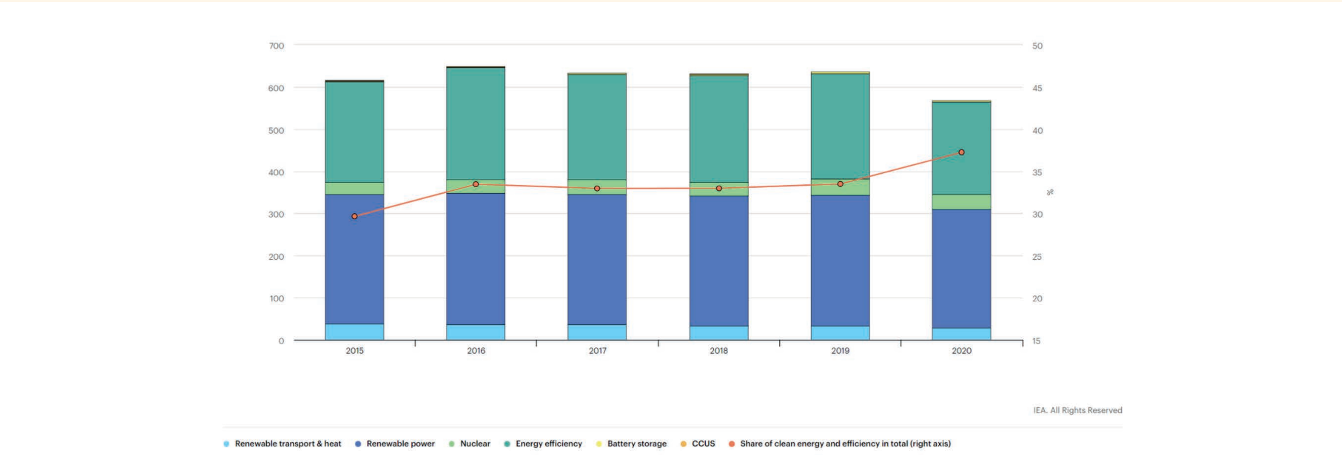


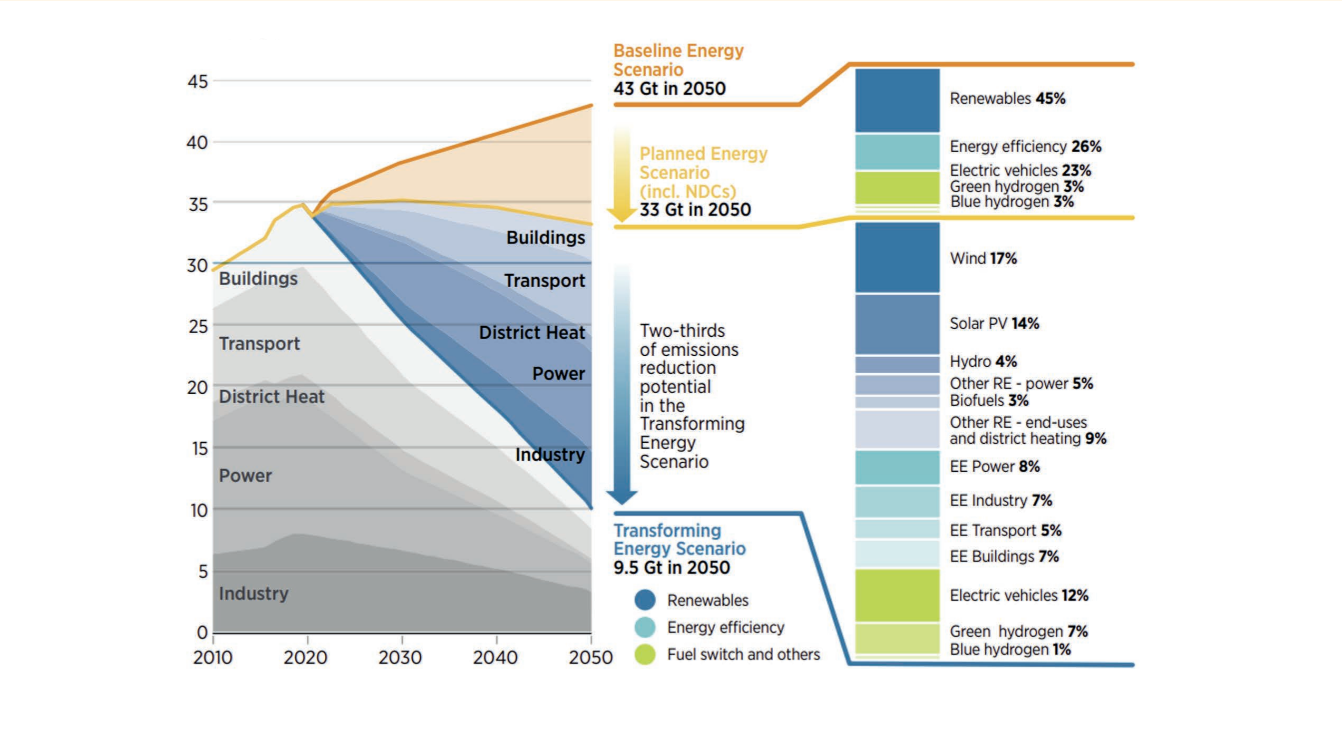
Figure 6 shows the IEA's overview of global investment in clean energy and efficiency in USD billion (left axis) and its percentage share of total energy investment (right axis) from 2015-2020. Source: IEA (2020)[13].

Companies in the commercial and industrial sectors account for approximately half of the world's end users of electricity[14]. RE100 is an initiative to switch these companies' demand to renewables, as the members have committed to use 100 percent renewable electricity in the company's operations. From the supply meets demand model of economic theory, the general idea that what private consumers, companies and nations demand and invest in matter for the supply of desirable products or services at a reasonable price.

Scenario analysis has been used to outline what it takes to get to different outcomes. A paradigm shift in the finance sector was the 2017 Task Force on Climate-related Financial Disclosure (TCFD) recommendation. The TCFD report was driven by G20 countries and designed to help companies provide better information to support informed capital allocation15. Using scenarios to make investment decisions has fueled the turnaround of expectations in the business world.

A scenario example is given in figure 7, where IRENA showcases how the emissions of CO_2 per year can be reduced towards 2050. They use a baseline scenario, which means business along today's trajectory without extra efforts for emission mitigation. Secondly, a planned energy scenario including Nationally Determined Contributions (NDCs) from the Paris Agreement. NDCs refer to efforts by each country to reduce national emissions and adapt to the impacts of climate change[16]. The last scenario is an energy transformation scenario, with a controlled shift of the entire energy system. The combined tools of increase in renewables, energy efficiency and fuel switch lead to various emission reductions.

Investment potential in renewables in three scenarios towards 2050 in CO_2 (Gt/yr)



Note: The Transforming Energy Scenario includes 250 Mt/year in 2050 of carbon capture, utilisation and storage for natural gas-based hydrogen (blue hydrogen). RE = renewable energy; EE = energy efficiency. Based on IRENA analysis.

Figure 7: Investment potential in renewables in three scenarios towards 2050. Source: IRENA (2020)[17].

Facts and Figures

13%
of the world's population do not have access to electricity[18]

28%
of renewables in global electricity in Q1 2020[19]

82%
cost decline of photovoltaics from 2010-2019[20]

11%
of global primary energy came from renewables in 2019[21]

40%
of the world, 3 billion people, lack access to clean fuels for cooking[22]

$501.3bn
was invested in low-carbon energy transition in 2020, up from $458.6 bn in 2019[23]

56%
increase in global offshore wind capacity from 2019-2020[24]

99%
of the global electricity demand increase during 2020-2025 is expected to be covered by renewables[25]

$303.5bn
was invested in global renewable energy capacity in 2020[26]

Supporting Laws and Regulations

EU Green Deal - Finance and Industry Reforms

The European Commission established a Technical Expert Group (TEG) on sustainable finance in 2018 to make a guide for financing sustainable growth. In December 2019, the European Commission presented the European Green Deal, a framework and action plan to transform the European economy. The TEG's recommendations are designed to support the development of climate change mitigation and climate change adaptation. The result is the EU Taxonomy on Sustainable Finance, which is a classification system for approved sustainable business activities. The regulation was implemented by autumn 2020 and required to be disclosed by companies and investors by 2022[27].

Finance Reform	Economic Reform
• Sustainable Europe Investment Plan • Renewed Strategy on Sustainable Finance	• **Rapid decarbonization of energy systems** • Innovation in sustainable industry • Large-scale renovation of existing buildings • Development of cleaner public and private transport • Progress towards sustainable food systems

Decarbonization of energy systems is highlighted as a central topic in economic reforms in the EU Taxonomy on Sustainable Finance[28]. This theme will be explored further in this white paper.

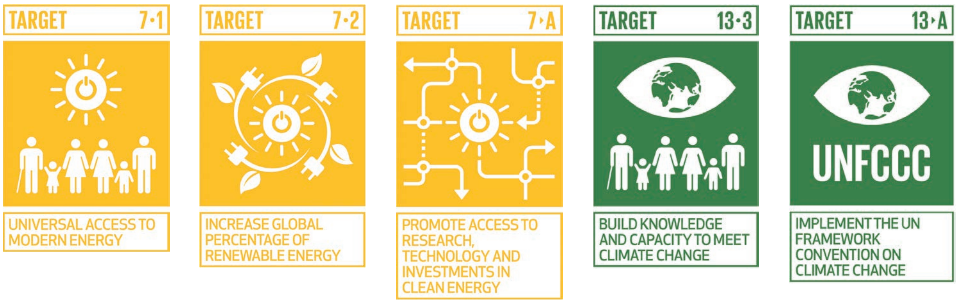
The Paris Agreement
Economic Activities That Contribute to Substantial Climate Change Mitigation
Article 2.1: "This Agreement, in enhancing the implementation of the Convention, including its objective, aims to strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty, including by (a) Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and **pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels**, recognizing that this would significantly reduce the risks and impacts of climate change; (b) Increasing the ability to **adapt to the adverse impacts of climate change** and foster climate resilience and low greenhouse gas emissions development, in a manner that does not threaten food production; and (c) Making **finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development**."[29].
The commitment is adopted by all nations on Earth. As of December 2020, 197 UNFCCC members have signed the agreement and 189 nations remain party to it.

Sub Themes

This white paper focuses on two central sub-themes that lay the foundation of success for the expansion of renewable energy. Renewable energy technologies and energy storage & distribution. The energy is preserved through energy efficient transmission.

Renewables

Renewables – Examples of key SDG Targets



This section will introduce the sub themes' connection to the SDG targets and EU Taxonomy on Sustainable Finance. Cross-cutting themes like IT systems and financing are highly relevant to accelerate renewable capacity, but these investment themes are not specifically included in this white paper.

Access to clean energy is necessary for human prosperity. According to BloombergNEF, global energy demand is expected to grow by 60 percent from today until 2050[30] given the expected increase in global population and rising living standards in non-OECD economies. Developing countries have the opportunity to leapfrog directly to cost-efficient clean energy solutions. Financing needs to ensure the deployment of stable, accessible, and renewable energy in these countries. An unprecedented shift in global energy systems is required to provide enough energy and simultaneously keep global warming below 1.5 degrees Celsius. This section gives an introduction to renewable energies that are part of the solution.

Wind Energy

Wind energy is one of the fastest-growing renewable energy technologies. The global installed capacity of wind electricity generation has increased by a factor of almost 75 in the past two decades[31]. To reach the Paris Agreement targets, the global annual capacity of offshore wind needs to grow ten-fold, from 4.5 gigawatts (GW) in 2018 to 45 GW per year by 2050. In comparison, onshore wind power needs to increase more than four-fold, to more than 200 GW per year, compared to 45 GW added in 2018[32]. There are two main categories of wind energy technologies: macro wind turbines, which are built for large-scale energy generation such as wind farms, and micro wind turbines used for local electricity production[33]. Wind turbine types include horizontal turbines, the classical turbine suitable for large scale production; vertical, often suitable for urban areas and multi-directional wind speeds at the cost of lower power efficiency; and innovative shapes like tree-shapes, kite-shapes, O-shapes and building-integrated wind turbines.

Solar Energy

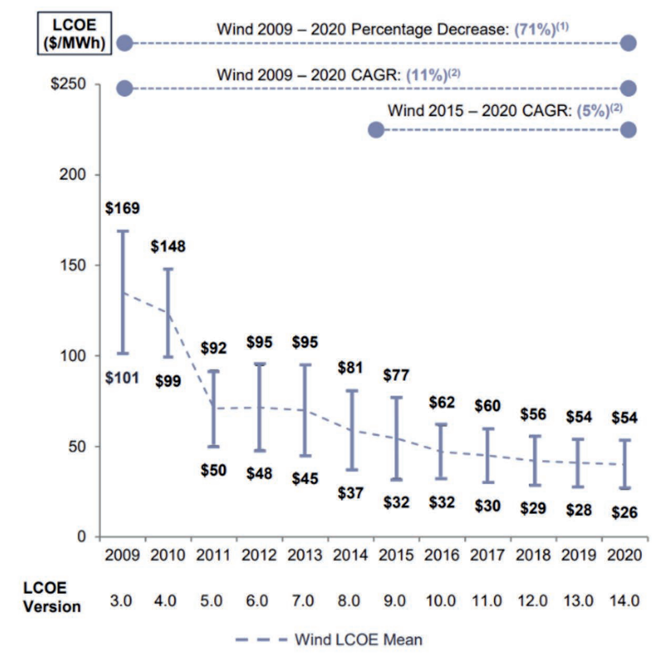
Solar energy is the most abundant and accessible energy resource on planet Earth. It is mainly used to generate electricity, heating or desalinate salt water. Solar power is generated in two main ways: PV or solar cells, which convert solar energy to electricity directly; or concentrated solar power (CSP), which uses mirrors to concentrate sunlight to heat fluids. The fluid creates steam, which in turn drives a turbine that generates electricity. Another type is the solar thermal collector, that heats water or air directly for residential use. An increasingly popular variety of the PV technology is the Floating Solar Photovoltaic, or "Floatovoltaics", where solar panels are installed on water. The upside of floatovoltaics is the increased energy efficiency, which is estimated to be 8-10 percent higher than land-based solar plants, because the water cools the panels and improves the overall energy yield[34]. Furthermore, the use of lakes or ocean areas is less controversial than using precious land space for energy production. It can also be combined with aquaculture or hydro power, which makes a dual-use-case.

Another solar panel type is bifacial solar modules that produce energy from both panel sides and thereby increase the energy production. Bifacial modules were first introduced in the 1960's, yet it has been the development of passivated emitter rear cell (PERC)[35] technology that has significantly increased their efficiencies and created the potential for them to be a disruptive player in the solar PV market[36]. The cost gap between the more expensive bifacial modules and the conventional monofacial modules has converged for the past decades.

The combination of the fact that bifacial modules can produce additional power between 10-20 percent over monofacial panels[37] and lower costs, has made the technology increasingly attractive. The Norwegian solar company Scatec operates a 390 MW solar plant using bifacial solar modules in Egypt, including what was in 2019 the world's largest one-site project[38].

The cost reduction of solar and wind energy has contributed to its rapid expansion. Figure 8 shows how the unsubsidized cost of wind and solar PV has fallen for the past decade. The cost decline has made solar and wind energy economically viable, and hence the technologies have become commercially available in markets across the globe. The decreased cost mainly stems from lower prices in system components, higher efficiency, and matured industries on both the supply and demand side.

Unsubsidized Wind LCOE



Unsubsidized Solar PV LCOE

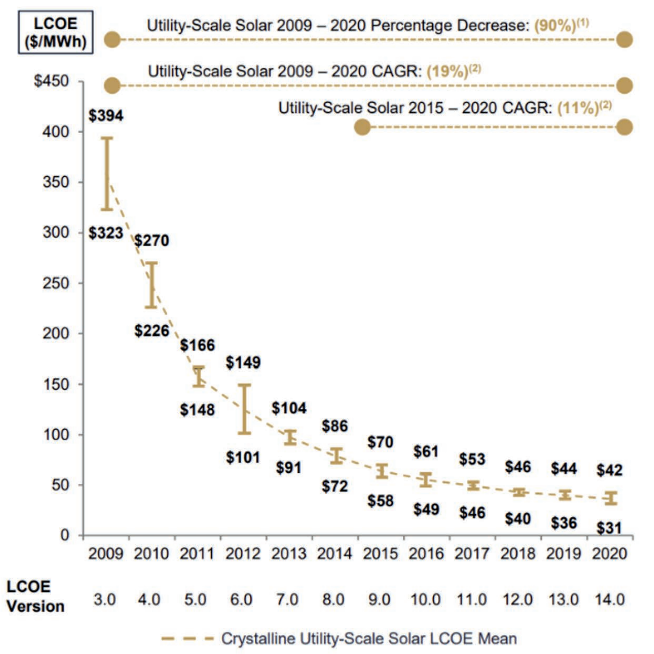


Figure 8: The graph shows how the levelized cost of energy (LCOE), or unsubsidized cost of renewable wind and solar energy, has decreased radically since 2008. Lazard estimates. (1) Represents the average percentage decrease of the high end and low end of the LCOE range. (2) Represents the average compounded annual rate of decline of the high end and low end of the LCOE range. Source: Lazard (2020), printed with permission[39].

Hydropower

Hydropower is one of the most cost-effective methods of producing electricity. Water in motion drives turbines, either from great heights or as run-of-river hydropower. Dams and reservoirs give a flexible and stable grid since it opens up for energy storage. Small-scale or micro hydropower generates energy without interfering with a river's natural water flow. This is generally perceived to be more environmentally friendly because it causes less methane emissions from biodegrading submerged vegetation, less stress on biodiversity and surrounding ecosystems.

Geothermal Energy

Geothermal energy is derived from heated water and/or steam from within the sub-surface of the Earth40. The energy source is mainly exploited by countries located near tectonic plate cracks, like Iceland, El Salvador, New Zealand, Kenya, and the Philippines. The global installed geothermal energy capacity was 13.9 GW in 2019[41].

Ocean, Wave and Tidal Energy

Ocean energy is generally premature in the sense that it is not yet commercially available. The global cumulative installed capacity for ocean energy technologies was only 535 megawatts (MW) in 2020, which is negligible in comparison to the global installed capacity for all renewables (around 2,600 GW)[42]. Wave energy can be harvested by transferring wave motion to electricity. Tidal energy can be utilized by dams or barrier construction, tidal-current or underwater turbines that turn with the tidal flows. Salinity gradient energy can be generated through exploiting the different salt concentration where rivers meet the ocean. Membranes capture the energy through pressure retarded osmosis or reverse electro dialysis[43]. Lastly, ocean thermal energy conversion (OTEC) utilizes the temperature difference between deep and shallow waters. The principle resembles a water-based heat pump.

Bioenergy

Traditional bioenergy means the combustion of wood, animal waste and charcoal. It is generally a fairly polluting process due to the gases and particles produced in the process. Modern bioenergy, on the other hand, refers to liquid biofuels, biogas, wood pellets and bio-refineries. Approximately three-quarters of the world's renewable energy use involves bioenergy[44].

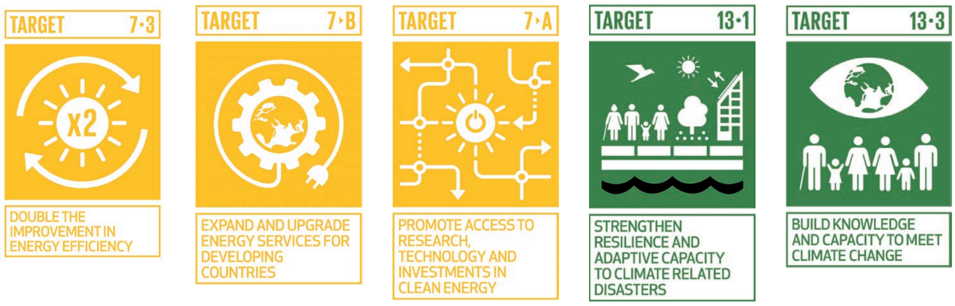
EU Taxonomy Technical Screening Criteria Linked to Renewable Energy - Electricity, Gas, Steam and Air Conditioning Supply

Code	Economic activities that contribute to substantial climate change mitigation and adaptation	
D.35.1.1	4.1 Production of Electricity from Solar PV	Construction and operation of electricity generation facilities that produce electricity from Solar Photovoltaic
D.35.1.1	4.2 Production of Electricity from Concentrated Solar Power	Construction and operation of electricity generation facilities that produce electricity from Concentrated Solar Power
D.35.1.1	4.3 Production of Electricity from Wind Power	Construction and operation of electricity generation facilities that produce electricity from Wind Power
D.35.1.1	4.4 Production of Electricity from Ocean Energy	Construction and operation of electricity generation facilities that produce electricity from Ocean Energy
D.35.1.1	4.5 Production of Electricity from Hydropower	Construction and operation of electricity generation facilities that produce electricity from Hydropower. DNSH criteria and further guidance applies for typical sensitivities.
D.35.1.1	4.6 Production of Electricity from Geothermal	Construction and operation of electricity generation facilities that produce electricity from Geothermal
D.35.1.1	4.8 Production of Electricity from Bioenergy (Biomass, Biogas and Biofuels)	Construction and operation of electricity generation facilities that produce electricity from Bioenergy. DNSH criteria particularly stringent.
D.35.21	4.13 Manufacture of Biomass, Biogas or Biofuels	Manufacture of Biogas or Biofuels

Source: EU TEG Taxonomy Report - Technical Annex, p 456 – 517[45]

Energy Storage and Distribution

Energy Storage and Distribution – Examples of key SDG Targets



In physics, the law of conservation of energy states that energy can never be created of destroyed, only converted from one form of energy to another[46]. This law is the most evident argument for energy efficiency. Waste of high quality energy leads to unnecessary high energy production. In turn, this causes strain on natural resources, natural habitat and usable land areas. Striving for reducing energy loss is therefore fundamental to a solid energy system. A sustainable energy system must be energy efficient, which ensures as high useable energy share as possible, with minimal losses from production to consumption and based on renewable energy sources.

According to IRENA, there are two pathways to reach zero emission world in 2050: sourcing all heat and electricity from renewables: 1) use green hydrogen as a reducing agent in iron production and electric arc furnaces in steel production; or 2) apply carbon capture, usage and storage (CCUS) to existing iron and steel production[47]. In other words: The world needs energy systems based on 100 percent renewables, with zero emission industrial processes and storage systems to scale.

Batteries

A battery is a device with electrochemical cells that can power electrical devices. Batteries provide the opportunity to store excess renewable energy at times of abundance, to be used for instance after sunset or when the wind decreases. The capacity of different types of batteries varies greatly, from small scale electronics to residential to commercial scale use.

The downside of batteries includes the extensive mining activities that are necessary to source minerals that are used in the battery technology. Rare minerals like cobalt, lithium, copper, zinc, and cadmium are usually found in small concentrations mixed with rock formations. Mining and separation of the desirable minerals require significant amounts of energy. Rare minerals can be geographically limited, and if the occurrence is mainly found in developing countries with political instability there is a risk of both natural and human cost. These environmental, social and governance (ESG) risks need to be accounted for. ESG risks in the value chain of batteries emphasise the importance of using as little energy as possible in the first place. Electrification and energy storage is a solution, but on the condition that sound ESG standards are implemented across the entire value chain from mining to battery recycling.

Long duration storage technologies are attractive, but unfortunately in various stages of technical maturity rates and degrees of commercialization. According to Lazard, the three most common long duration storage methods are flow, thermal and mechanical storage[48]. Flow storage usually refers to energy from chemical reactions like zinc bromine and vanadium. Chemical storage entails no degradation but is expensive and has a low energy density. Thermal storage refers to latent heat or sensible heat, by storing thermal energy in a heating or cooling medium. This inexpensive technology is scalable but has a comparatively low energy density and a limited track record at larger scales. Lastly, mechanical energy storage means gravity energy storage or compressed air energy storage (CAES). In this case, energy is stored as kinetic, gravitational potential or in a compression medium. Pumped hydro power is an example. This storage form is economically viable, but usually leads to a larger physical footprint and lower efficiency than the other technologies.

While the cost of investments in energy storage is useful, the future lifetime cost of different storage technologies is just as important. This is often measured in the levelized cost of storage (LCOS), which enables cost comparison across technologies. Unsubsidized levelized cost of storage even adjusts for governmental subsidies. A study published in Joule estimates that LCOS will be reduced by 30 percent in 2030 and 50 percent in 2050. Lithium-ion batteries are likely to become most cost efficient for nearly all stationary applications from 2030, while pumped hydro, compressed air and hydrogen are best for long term energy storage[49].

Figure 9 shows how the levelized cost of energy storage is becoming economically viable across different storage solutions. The Lazard analysis shows that energy storage costs have declined across most storage technologies, especially for short-term storage which is driven by battery chemistry evolution. The analysis is split between front-of-the-meter (utility scale energy storage) and behind-the-meter (residential solar, storage and microgrid). The difference lies in the energy system's position in relation to an electric meter. Typically, a front-of-the-meter system provides power to off-site locations through a distribution system, while a behind-the-meter system provides power that can be used on-site without passing through a meter[50]. The figure shows that behind-the-meter storage systems remain relatively expensive without subsidies, while utility-scale in-front-of-the-meter solar PV and storage systems are becoming commercially attractive even without subsidies.

For reference, a megawatt represents one million basic units of power (1 watt). Measures in watt represent how much energy there is in an electrical circuit and how much work this energy can perform. A megawatt-hour (MWh) measures how much electrical energy that has been used over a set period of time. 1 MWh is thereby equivalent to one million watts of electricity used for one hour. Energy storage capacity is usually measured in MWh or kWh, as a measure for how much energy can be discharged from the battery before it must be recharged again. Another example is the largest utility-scale solar power plant in 2020, Bhadala Solar Park in India, which has the capacity to produce over 2.2 gigawatts (GW) of electricity[51]. The energy output of the powerplant would be measured in GWh. Figure 9 represents energy storage costs over one kW-year.

Unsubsidized Levelized Cost of Storage Comparison–Capacity ($/kW-year)

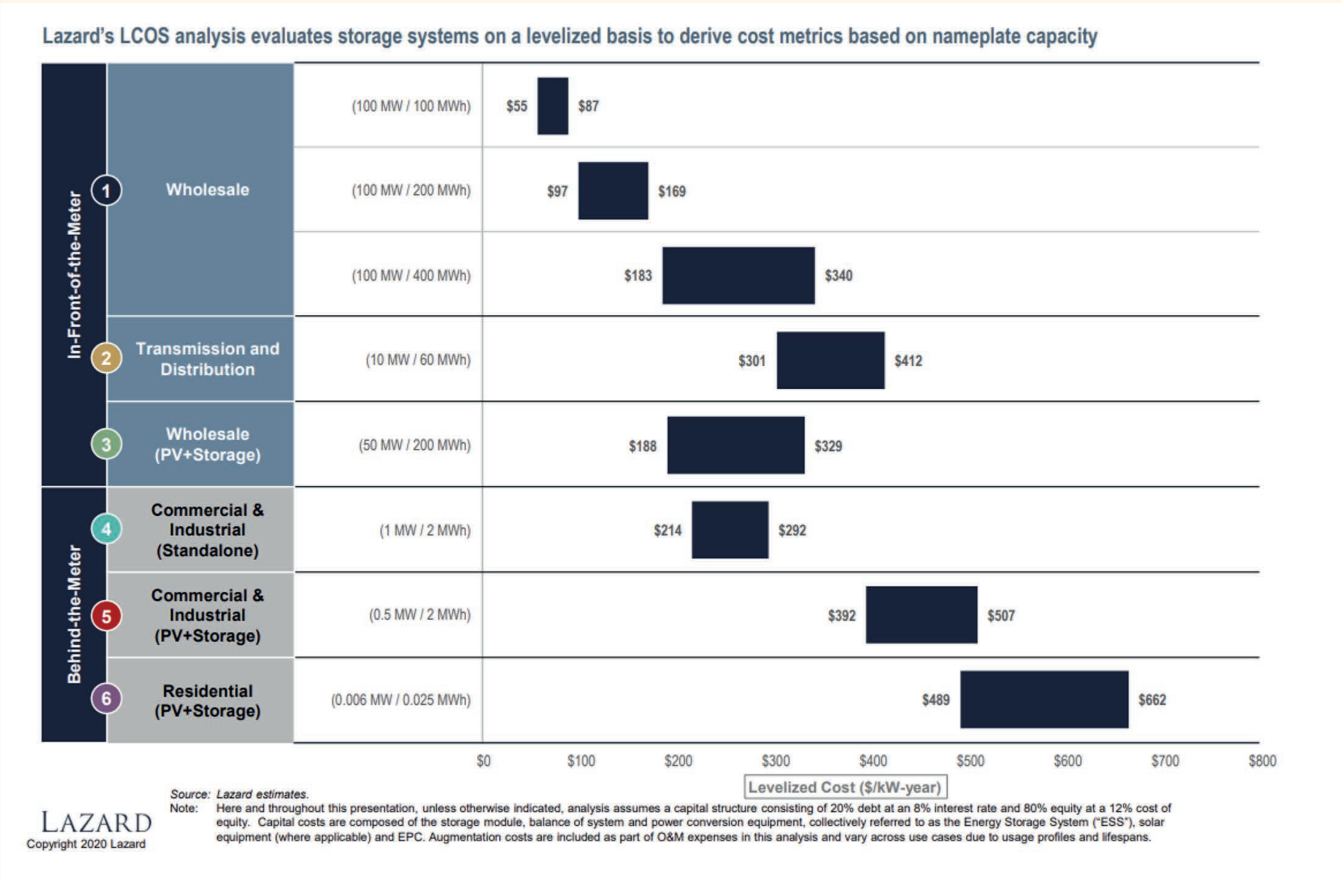


Figure 9: Lazard's estimates of the levelized cost of storage capacity for different energy storage systems. The graph shows cost in US dollars per kW-year. Source: Lazard (2020)[52].

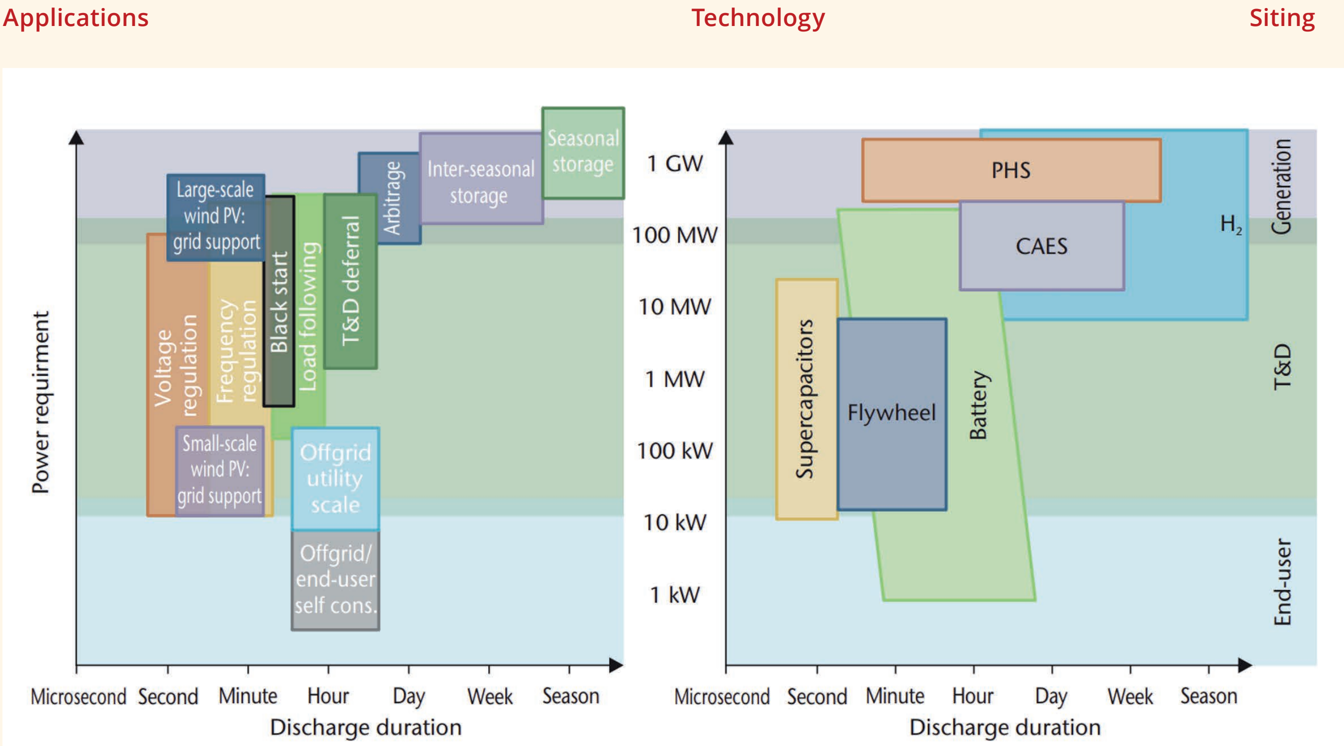
Energy Carriers

Energy carriers are defined as "secondary energy sources… that are derived from the transformation of primary energy sources. They move energy in a useable form from one place to another"[53]. The most well-known energy carriers are electricity, petrol, and hydrogen. To make electricity or hydrogen, primary energy sources can be used, like renewable energies, nuclear power, or fossil fuels.

Hydrogen is the most abundant element on Earth but is highly reactive so it is rarely found in its pure form. It can be used to move and store energy between different locations. There are three main methods to produce hydrogen: Green, blue, and grey hydrogen. Green hydrogen refers to electrolysis using renewable energies. Today green hydrogen only accounts for 5 percent, though the global ambition is to increase this share in the future. Blue hydrogen is produced using fossil fuels, but with carbon capture. Grey hydrogen is produced using fossil fuels and with direct air emissions. Today, hydrogen is mostly produced using natural gas with significant carbon emissions.

A fuel cell functions like a battery. It generates electricity from an electrochemical reaction based on hydrogen and oxygen, usually from air.

Electricity storage systems can be classified by size according to their input and output power capacity (MW) and their discharge duration (hours). These three parameters finally determine energy capacity (MWh)[54]. Figure 10 shows how different energy storage systems and technologies provide energy for various segments. Hydrogen is for instance suitable for large-scale electricity storage in megawatt scale and covers storage times ranging from hours to whole seasons.



Note: CAES = compressed air energy storage; PHS = pumped hydro energy storage.

Figure 10: Hydrogen-based electricity storage covers large-scale and long-term storage applications. Source: IEA (2015)[55].

The major downside to hydrogen is the energy inefficiency; useful energy output from the total hydrogen-based energy storage is only 24-29 percent due to energy losses in the chemical energy conversion[56].

Grids and Infrastructure

Power grids can be segmented into macrogrids, minigrids and microgrids. A macrogrid serves a large population in a centralized structure with electricity supply and voltage management. Minigrids are geographically limited utility networks for small-scale electricity distribution, suitable for rural communities in remote locations without access to a macrogrid. Lastly, a microgrid is a decentralized and flexible grid which delivers short-traveled electricity from local energy sources. Microgrids are easily compatible with renewable energy and distributed energy resources. Mini and microgrids can be structured as standalone systems but can also be linked to a macrogrid for increased flexibility.

A major source of concern with mainstream renewable energy is intermittency. Wind and solar power can only be generated when sunlight or wind is present. This presents a low level of predictability, and the energy is not necessarily abundant when consumers need the energy. The mismatch in supply and demand requires a stable baseload energy source, which is flexible and readily available. A stable grid with sufficient backup storage can prevent grid outages and sudden energy blackouts. Even better, a smart grid is designed to optimize the electricity supply network though digital communications and monitoring. It can combine micro and mini grids. Local changes in electricity consumption can be detected and the supply adjusted accordingly. A smart grid is thereby a common term for a "system that allows for monitoring, analysis, control and communication within the supply chain to help improve efficiency, reduce energy consumption and cost, and maximize the transparency and reliability of the energy supply chain"[57]. A major advantage of smart grids is the possibility to reduce the load that strains the grid infrastructure during the bottleneck peak hours of energy demand. Hence, lower cost can incentivize well-informed "prosumers" to reduce or delay their energy consumption to get a better price when the demand is lower. Lastly, a smart grid is ideal for decentralized power generation. On-site electricity reduces loss in power transmission and reduces peak load on a centralized system. An example is integrated rooftop solar, batteries and charging facilities for residential areas, both in cities or remote locations.

Distributed Energy Systems

In the advent of energy production, distributed energy was taken for granted. Accessible rivers were prerequisites to build a water mill, and the energy was used instantly on site. Windmills were literally mills, grinding corn whenever the wind blew. The advance of the modern wind turbines and electricity grids enabled energy transmission in the form of electricity across vast distances. Today, Distributed Energy Systems (DES) are set for an impressive comeback because they are fundamentally logical. Locally produced and consumed energy makes sense because it uses cheap, regenerative, and abundantly available energy. DES amplify a dynamic system which can shave peak loads off a centralized grid. Over-dimensioned grids are built to deliver peak energy demand, but this is expensive. Improved energy management, locally available renewables, storage, monitoring and control solutions can help delivering a more stable and flexible grid. The need for massive high voltage transmission masts can be downscaled. This reduces investment costs and the need to build so-called "Monster Masts" that tend to cause public dismay.

The energy losses are miniscule when electricity is used on site compared to long distance transmission. One cause of energy loss is the corona effect. Corona in the context of electricity refers to the unwanted phenomenon of partial discharges of visible light, heat, and cracking noise from the transmission cables[58]. Lost electrons mean lost income.

Energy access to remote areas is another major advantage of DES. For example, rural villages in countries with poor infrastructure can get electricity access overnight. Energy independence can be gained without the need to invest in a massive transmission line upfront. Not to mention bearing the cost of maintenance and repair. A competitive advantage can be expected in cost effectiveness, rapid installation, less material use, and a reasonable operational cost due to the low price of renewables.

Energy Efficiency

Energy efficiency generally refers to materials and processes that prevent energy loss. Because of entropy, the increasing disorder of molecules in a system over time, energy has higher value in its primary form when it can be fully utilized. Mechanical energy and electricity provide a higher energy quality than heat, in particular low temperatures where the energy per unit temperature is unavailable for doing useful work. Entropy can therefore be regarded as a measure of the effectiveness of a specific amount of energy, or the energy quality, which decreases as the entropy of a system increases[59].

Energy is usually lost through heat energy, light energy, or sound energy, all of which prevent processes from being 100 percent efficient[60]. BloombergNEF reports that as much as "55 percent of the world's primary energy is wasted either in the production of electricity, refined fuels, or in end-use machines. The vast majority of these losses come from the use of coal, gas and oil. The difference between final and useful energy shows how end-use electrification reduces energy demand for the same output"61. In other words, electrification in general will reduce energy losses, which enables more useful work with less energy. Electricity is considered to be exceptionally useful because of its low entropy, or highly ordered nature. Low entropy means that it can easily and efficiently be converted into other energy forms.

Another example of energy efficiency is found in the transport sector. Energy is required to make a car move forward. Losses incur in the conversion from fuel or electricity to kinetic energy that enables movement, expressed in the form of heat and noise. Few movable parts are beneficial to reduce heat generation. The average EV engine has around 20 parts, whereas combustion engines can have more than 2,000 parts[62]. The useful energy that makes a car move is often expressed as the total well-to-wheel efficiency (WTW). The WTW of gasoline-driven vehicles ranges between 11-27 percent, while diesel-driven vehicles ranges from 25-37 percent. In contrast, electric vehicles will have a WTW efficiencyof 40-70 percent if renewable energy is used to charge its batteries, depending on the source and location of the renewable energy system[63]. High energy efficiency and no tailpipe emissions is therefore a common argument for electrification in the transport sector.

EU Taxonomy Technical Screening Criteria Linked to Energy Storage and Distribution - Electricity, Gas, Steam and Air Conditioning Supply		
Code	Economic activities that contribute to substantial climate change mitigation and adaptation	
D.35.12, D.35.13	4.9 Transmission and Distribution of Electricity	Construction and operation of transmission and distribution Systems that transport electricity on high-voltage, medium-voltage and low-voltage distribution Systems. Construction and operation of interconnections that transport electricity between separate Systems. Further guidance for typical sensitivities apply.
No NACE code	4.10 Storage of Electricity	Construction and operation of facilities that store electricity and return it at a later time, in the form of electricity.
No NACE code	4.11 Storage of Thermal Energy	Construction and operation of facilities that store thermal energy, and return it at a later time, in the form of thermal energy or other energy vectors.
No NACE code	4.12 Storage of Hydrogen	Construction and operation of facilities that store hydrogen, and return it at a later time, in the form of hydrogen or other energy vectors.
D.35.30	4.15 District Heating/Cooling Distribution	Construction and operation of pipelines and associated infrastructure for distribution of heating and cooling, ending at the sub-station or heat exchanger.
D.35.11 D.35.30	4.17 Cogeneration of Heat/Cool and Power from Concentrated Solar Power	Cogeneration of Heat/Cool and power from concentrated solar power
D.35.11 D.35.30	4.18 Cogeneration of Heat/Cool and Power from Geothermal Energy	Construction and operation of a facility used for Construction and operation of a facility used for cogeneration of heat/cooling and power from Geothermal Energy
D.35.11 D.35.30	4.20 Cogeneration of Heat/ Cool and Power from Bioenergy (Biomass, Biogas, Biofuels)	Construction and operation of a facility used for cogeneration of heat/cooling and power from Bioenergy. The TEG interprets DNSH to mitigation as avoidance of activities which would compromise the EU's net zero by 2050 climate mitigation targets. We have determined that activities which operate below the 100g threshold provide a significant contribution, and that activities that operate above the regional average of 262g (as per the IEA) would cause significant harm.
D.35.30	4.23 Production of Heat/Cool from Geothermal	Production of heating and cooling from Geothermal Energy. The TEG interprets DNSH to mitigation as avoidance of activities which would compromise the EU's net zero by 2050 climate mitigation targets. We have determined that activities which operate below the 100g threshold provide a significant contribution, and that activities that operate above the regional average of 262g (as per the IEA) would cause significant harm.
D.35.30	4.22 Production of Heat/Cool from Concentrated Solar Power	Production of Heat/Cool from concentrated solar power
D.35.30	4.25 Production of Heat/Cool from Bioenergy (Biomass, Bio-gas and Biofuels)	Production of heating and cooling from Bioenergy. The TEG interprets DNSH to mitigation as avoidance of activities which would compromise the EU's net zero by 2050 climate mitigation targets. We have determined that activities which operate below the 100g threshold provide a significant contribution, and that activities that operate above the regional average of 262g (as per the IEA) would cause significant harm.
D.35.30	4.26 Production of Heat/Cool using Waste Heat	Production of Heat/Cool using waste heat

EU TEG Taxonomy Report - Technical Annex, p 456 – 517[64]

Solutions Company Highlight

ENPHASE

About

Enphase Energy is a US-based residential solar and energy storage provider. The company has solved a major issue for home-owners: To combine an easily accessible smart metering app, energy storage for solar energy and installation of solar panels all in one service. The functional design and energy efficient technology is topped with the integration of a modular design that ensures smooth energy delivery even if one solar panel or battery unit gets an outage.

Enphase: Integrated Solar Pioneer

The functional integration of renewable energy in more distributed energy systems plays an integral part of the global movement towards a low carbon economy. Well-run solar energy and storage, EV charging and delayed energy use outside peak hours enables smart grids to optimize energy distribution. Enphase Energy contributes to household's energy independence and a reduced load on the power grid.

Impact on SDG Targets

Enphase Energy has installed over 30 million microinverters on more than 1.3 million homes65. With 300+ issued patents, the innovative technology has updated client experience. The solar systems are designed to deliver stable energy even in tough weather like storms, rain, snow and ice. SDG 7 on increased renewable share and energy efficiency. It impacts SDG 13 on climate mitigation and adaptation through its climate resilient solar and storage systems.

Appendix

EU Taxonomy on Sustainable Finance

The IT sector is an EU Taxonomy Technical screening criteria which is important, but have not been included in the investment theme renewable energy and will be addressed as a cross-cutting theme.

EU Taxonomy Technical Screening Criteria – Information and Communications		
Economic Activities That Contribute to Substantial Climate Change Mitigation		
J63.1.1	Data processing, hosting and related activities	Storage, manipulation, management, movement, control, display, switching, interchange, transmission or reception of diversity of data through data centres, including edge computing.
J61 J62 J63.1.1	Data-driven solutions for GHG emission reductions	Development and/or use of ICT solutions that are aimed at collecting, transmitting, storing data and at its modelling and use when these activities are exclusively aimed at the provision of data and analytics for decision making (by the public and private sector) enabling GHG emission reductions.
EU TEG Taxonomy Report - Technical Annex, p 363 - 366[67]		

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Photo Attributions

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Andreas Gücklhorn
Karsten Würth
Mark Merner
Vivint Solar

SDG Target Icons: Global Goals, available at https://www.globalgoals.org/resources
SDG Icon grid: UN, available at https://www.un.org/sustainabledevelopment/news/communications-material/

Team Solutions

Philip Ripman

- Portfolio Manager & Head of Solutions, *Storebrand Asset Management*
- MA in Chinese Studies, and MA in Politics

Philip Ripman specializes within the areas of politics, climate change, the commercialization of sustainability and how to integrate the Sustainable Development Goals as investment themes.

Philip has held numerous positions within the company including Group Head of Sustainability. Through his engagement with Sustainability he has advised several governments and institutions on topics ranging from coal exclusions, environmental impacts of human activities to policy requirements to achieve international climate agreement targets.

Sunniva Bratt Slette

- *Investment Analyst, Storebrand Asset Management*
- MSc in Industrial Economics and Technology Management (NTNU, 2016 and Ajou University, South Korea, 2014)

Sunniva joined Storebrand in 2017 as a Sustainability Analyst. In this role, her main focus areas were sustainability assessments related to the UN Sustainable Development Goals. She was responsible for the carbon footprint of investments and following up green bonds, and worked with the team on topics like corruption, human rights and environment. As an Investment Analyst for the Solutions team she focuses on research and portfolio construction of solution companies, companies with products and services that significantly contributes to the UN Sustainable Development Goals.

Ellen Grieg Andersen

- Investment Analyst, *Storebrand Asset Management*
- Master's degree in International Economics (Lund University, 2018) and a BSc in International Business in Asia from Copenhagen Business School (2017), including a semester at Fudan University in Shanghai (2016)

Ellen joined Storebrand Asset Management's funds team in 2019 as a Project Manager trainee. In this role, she was involved in the project planning of internal processes and communication of the company's sustainability work. She also participated in the graduate program "Future Impact". As Solutions team Investment analyst she focuses on research and portfolio construction of solution companies, which means companies with products and services that significantly contributes to the UN Sustainable Development Goals.

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Investment Analyst: Sunniva Bratt Slette
Storebrand Asset Management