A Work Project, presented as part of the requirements for the Award of a Master's degree in Finance from the Nova School of Business and Economics.

Market research on energy generation regarding sustainable energy transition

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Work project carried out under the supervision of: Professor Miguel Pita

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NOVA SCHOOL OF BUSINESS & ECONOMICS

In light of a sustainable energy transition, what are the key changes across the multiple sectors and what opportunities will emerge?

Abstract

1 **Demand**

Demand for energy and renewable sources is increasing. The buildings segment has the potential to have the largest share of renewable-produced energy followed by industry, yet transport can face the highest growth. Greater investment opportunities will emerge in buildings and transport with new technology and low-carbon policies unlocking new business models in areas like demand flexibility, efficiency and e-mobility

2 **Transmission**

Transmission development comes as a result of the rise in demand, generation capacity and the distance that separates these two. These constraints can be addressed through a set of solutions which complemented, meet the requirements of a flexible integrated transmission

3 Generation

The generation energy market once dominated by massive oil companies is experiencing changes that allow new types of players. The 2050 scenarios show large increases in renewable technologies total installation capacities and power generation mainly in wind and solar power as well as a great investment opportunity in wind power

4 **Investment Opportunities**

A cleaner energy market will diversify the ecosystem and change the nature of factors to succeed across demand, transmission and generation. Investment opportunities will be greater in energy demand and the total investment of the three areas combined represents 3.1% of the World GDP. This new ecosystem will allow new players to emerge and fragment a former highly concentrated market with increased uncertainty, encouraging partnerships

Keywords: renewable energy generation, energy market, wind power, solar power

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Executive Summary: Generation

3.1 Market and costs

Renewable sources of energy show a historical trend of increasing generating capacity and reducing costs of installation and production, projections for the future show that all these trends are likely to continue

3.1.1 A third of global power capacity is now based on RE. From the annual increase of 7.9% solar PV and wind are the leaders of this addition

3.1.2 With installation and production costs declining most renewable sources of energy already reached grid parity with fossil fuels in 2018

3.2 Prominent Renewable Energies

3.2.1 Solar

- Between the Solar Power technologies Solar PV is on track and CSP is off-track to reach a sustainable future scenario
- If solar PV keeps on track until 2050 it can increase its installed capacity in 17 times and its power generation in 24 times
- To keep on track solar PV needs to tap off-grid systems not covered by national grids as well as continue the cost drop trajectory

3.2.2 Wind

- More efforts are required in both onshore and offshore wind in order to achieve the expected sustainable scenario
- Wind power will increase its installed capacity in 6 to 10-fold and its power generation between 8 to 15 times until 2050
- Supportive policies are key to enable wind market growth, but also distribution technologies to create a reliable grid integration

3.2.3 Hydro

- Hydropower reached its peak in 2013, more efforts needed to reach the sustainability goals and luckily a new horizon can be explored
- Hydropower shows a much more limited space to grow compared to solar and wind, PHS, however, shows a better growth opportunity
- Pumped-storage diffusion, digitalization, improving turbine technology, and reducing civil works costs are inevitable in this industry

Because solar, wind and hydropower will increase their generating capacity and power generation the intermittency issue needs to be tackled, a solution is the implementation of a hybrid system comprised of the three sources together

3.2.4 The hybrid system will help to reduce intermittency and energy waste while improving system stability and reliability with a faster response time

3.3 Investments

Smaller companies are the ones leading the renewables market. Wind power shows the largest investment among all renewable technologies

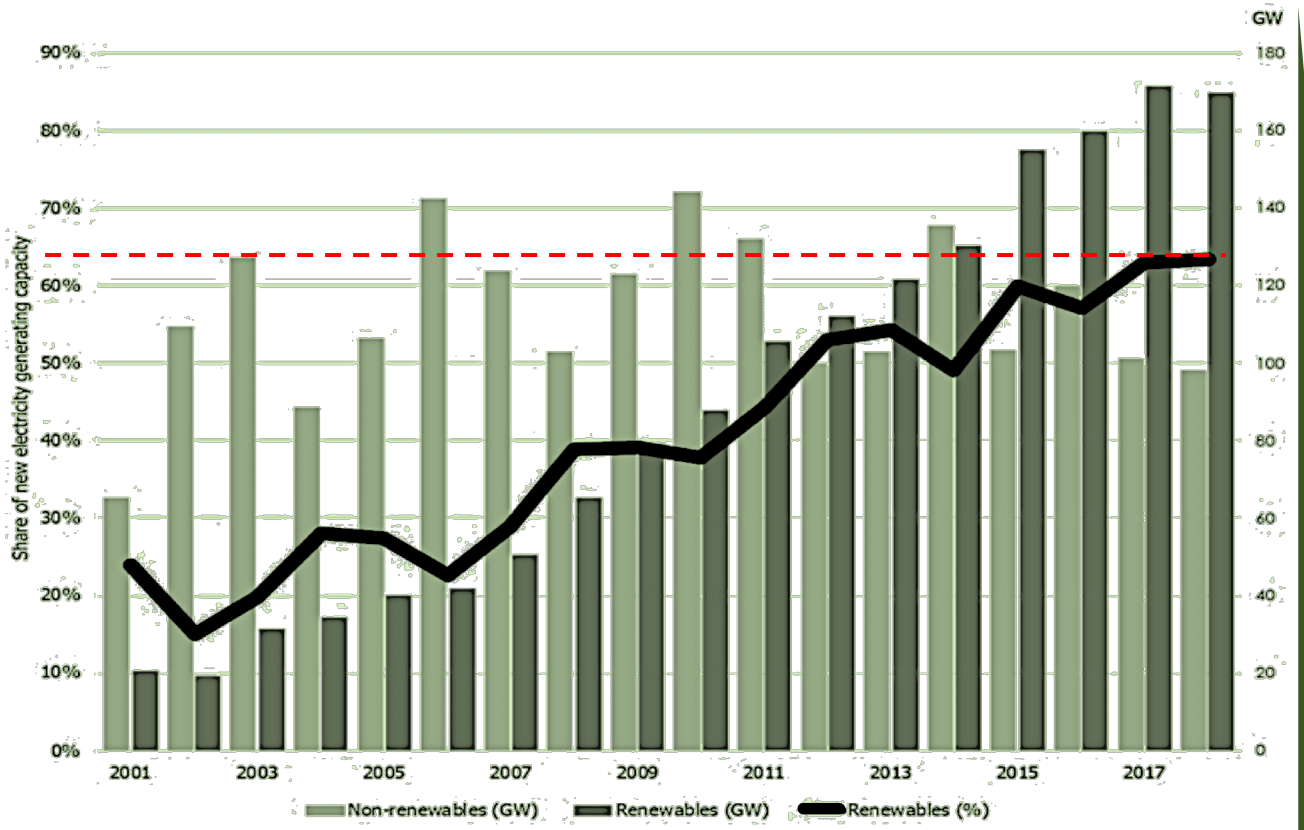
3.3.1 Dealing with the variable nature of its resources as well as keeping producing solar panels and wind turbines are the main plays in this industry

3.3.2 Unlike the oil industry, wind and solar markets have more space for new and smaller players, hydropower still depends on bigger companies

3.3.3 The yearly average investment ranges from USD 354 - 382 bn in the conservative and USD 587 - 794 bn in the optimistic scenarios

Nearly two-thirds of new global power generation capacity in 2018 is based on Renewable Energy, solar and wind accounted for 84% of the 7.9% annual increase

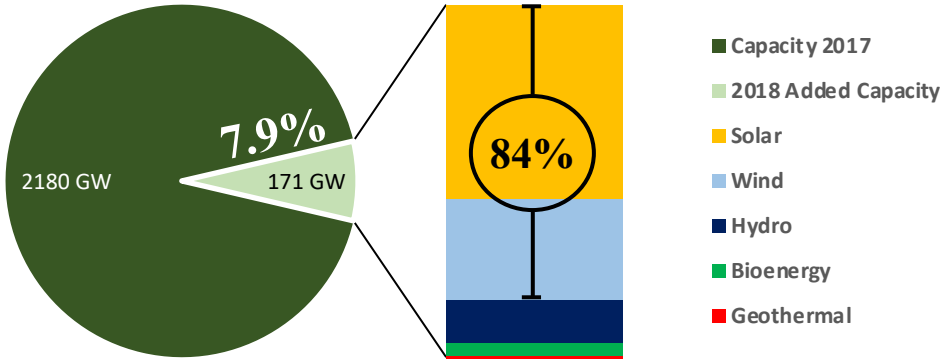
Since 2000 the non-renewable sources present an average new capacity of 115 GW/year with no clear trend upwards or downwards



1. Share of new electricity generating capacity of non-renewables and renewables, 2001-2018 in GW

Solar, wind and hydro are the major segments of RE

2. New RE capacity added in 2018 (GW)



3. Renewables total accumulated global installed capacity in 2018 by technology (GW)

Hydropower	1,172 GW*
Wind Power	564 GW
Solar Power	486 GW
Bioenergy	115 GW
Geothermal	13 GW
Marine	0.5 GW
Total	**2,351 GW (+ 8.8 GW off-grid)**

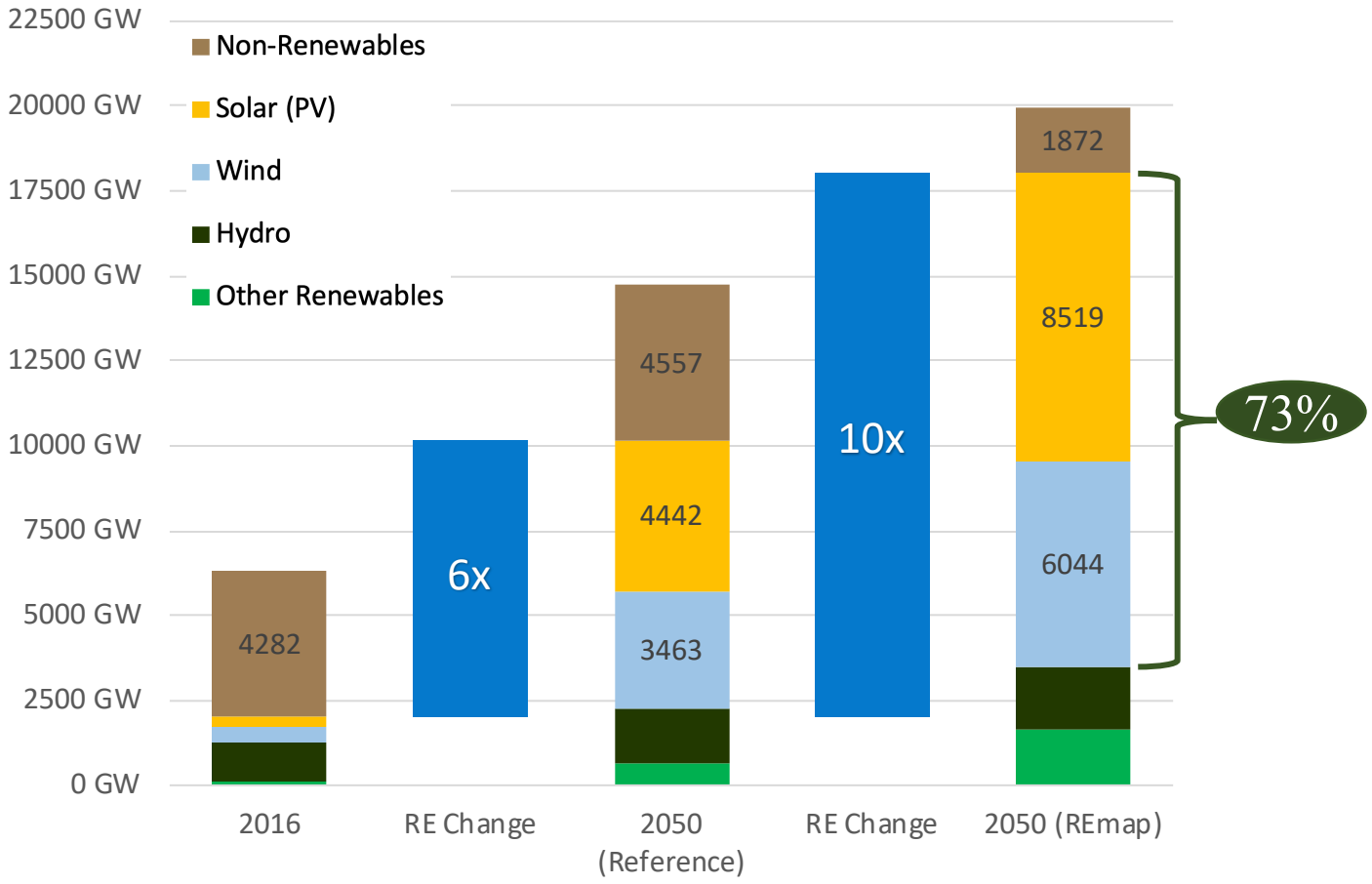
* Does not include PHS

1. Source: International Renewable Energy Agency 2019

By 2050*, solar PV and wind would account for 73% of global total installed power capacity leading the 10-fold increase in renewables total global installed capacity

Fossil fuels loses market share to renewables: from 68% to 9 or 31%

4. Total global installed power capacity 2016-2050 (GW)



The sector will need greater flexibility to accommodate the daily and seasonal variability of solar and wind power

- **Fossil-fuel** based energy present a limited growth of 6.4% in the reference case** while showing a **decline** of **56.3%** in the REmap
- In the **Reference** case **wind and solar PV** would still account for **54%** of total capacity
- **Interconnections** between national and regional grids will be required to help **balancing supply and demand**

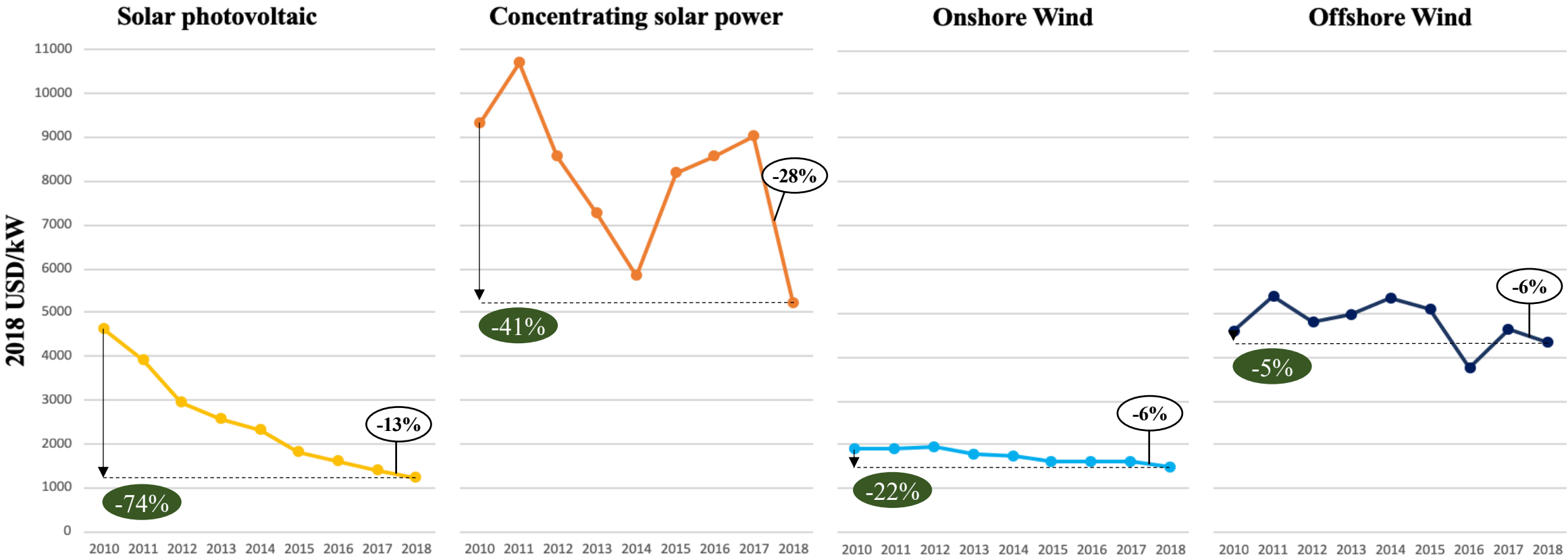
*The REmap scenario considers the deployment of low-carbon technologies that limit the rise in global temperature to well bellow 2 degrees Celsius above pre-industrial levels

** The Reference case considers current and planned policies, it is a "business-as-usual" perspective

2. Source: International Renewable Energy Agency 2019

Total installation costs have been dropping in most RE sources with solar PV falling 74%, CSP down 41%, onshore and offshore wind down 22% and 5% respectively since 2010

Solar PV module prices have been fallen by 90% since the end of 2009[3] and are expected to fall another 34% until 2030[4]. Due to its thin market CSP's cost decrease is being driven by projects in China, Morocco and South Africa

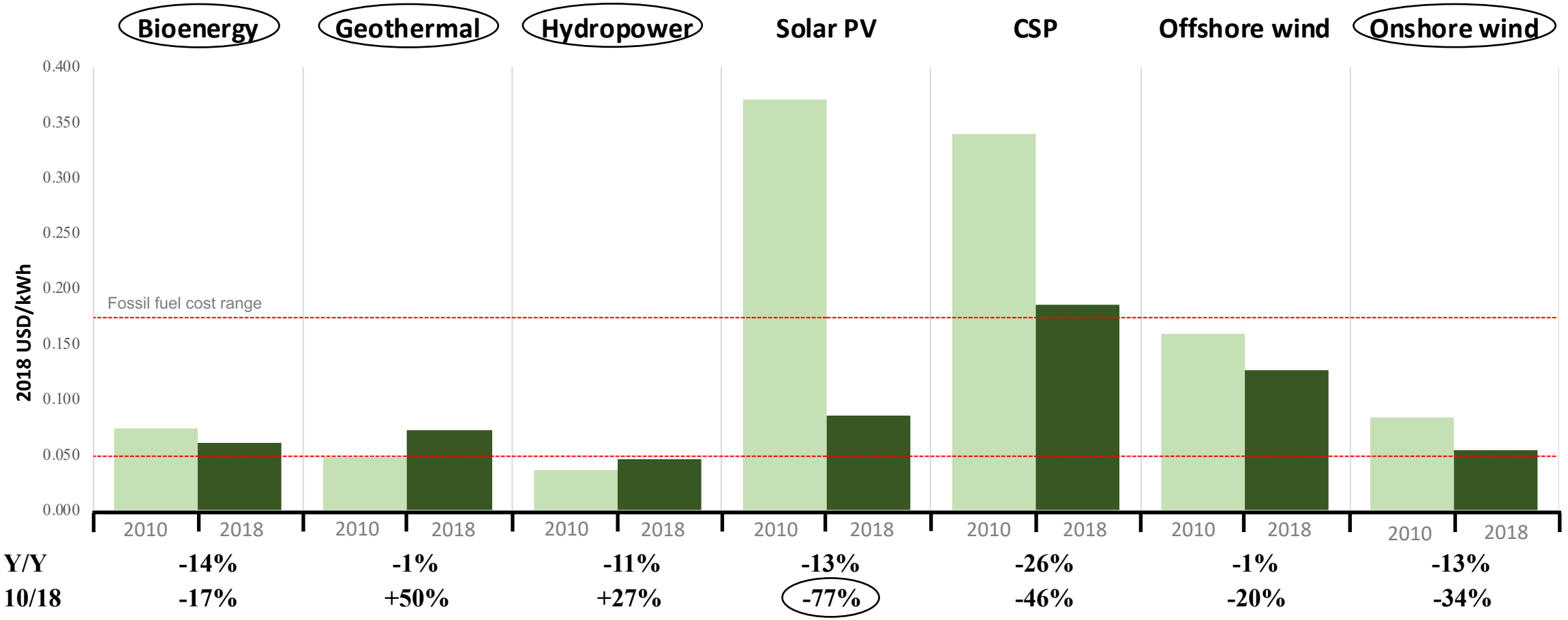


5. Global weighted average total installed costs for solar PV, CSP, onshore and offshore wind, 2010-2018 (2018 USD/kW)

3. Source: International Renewable Energy Agency 2019
4. Source. Wisniewska 2019

In 2018, bioenergy, geothermal, hydropower and onshore wind have already reached grid parity globally, competing with fossil fuels even without subsidies

The production costs for all commercially available renewable technologies declined from 2017 to 2018



6. Global weighted-average LCOE of utility-scale renewable power generation technologies, 2010-2018 (2018 USD/kWh)

3. Source: International Renewable Energy Agency 2019

Between the Solar Power technologies Solar PV is on track and CSP is off-track in the goal to reach a sustainable future scenario[5]

Even though CSP can more easily store energy in the form of heat, solar PV is much more diffused globally

On Track

Solar PV

- Generation increased **31%** in 2018 (requires 16% average annual growth)
- Share in global generation passed **2%** for first time
- Current theoretical conversion efficiency of 15% to 20%
- Theoretical conversion[4]: Next 3-5 years: 24% - 25% Next generation: **~30%**

Not On Track

CSP

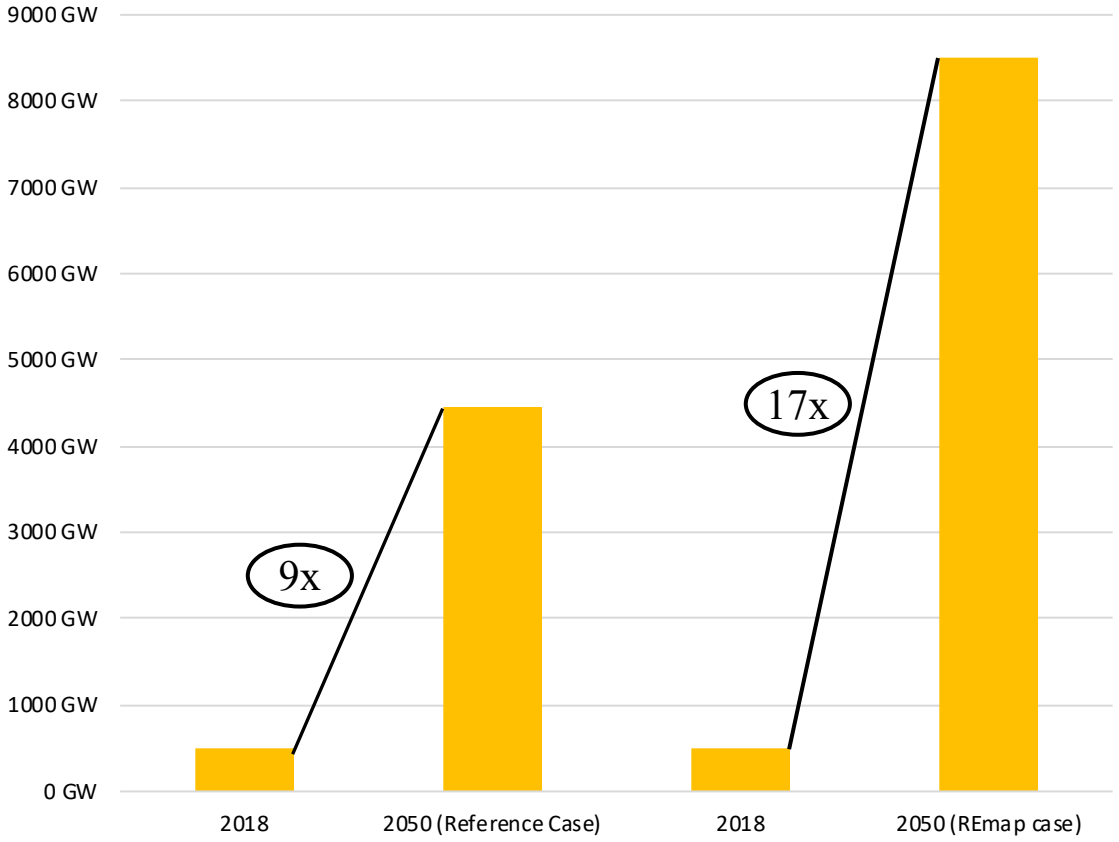
- Generation increased **8%** (requires 26% annual average through 2030)
- Share in global generation is less than **0.05%**
- Theoretical conversion efficiency ranges from 23% to 35%
- CSP requires direct solar radiation to operate (more sensitive to cloudy weather)

4. Source. Wisniewska 2019
5. Source: International Energy Agency 2019

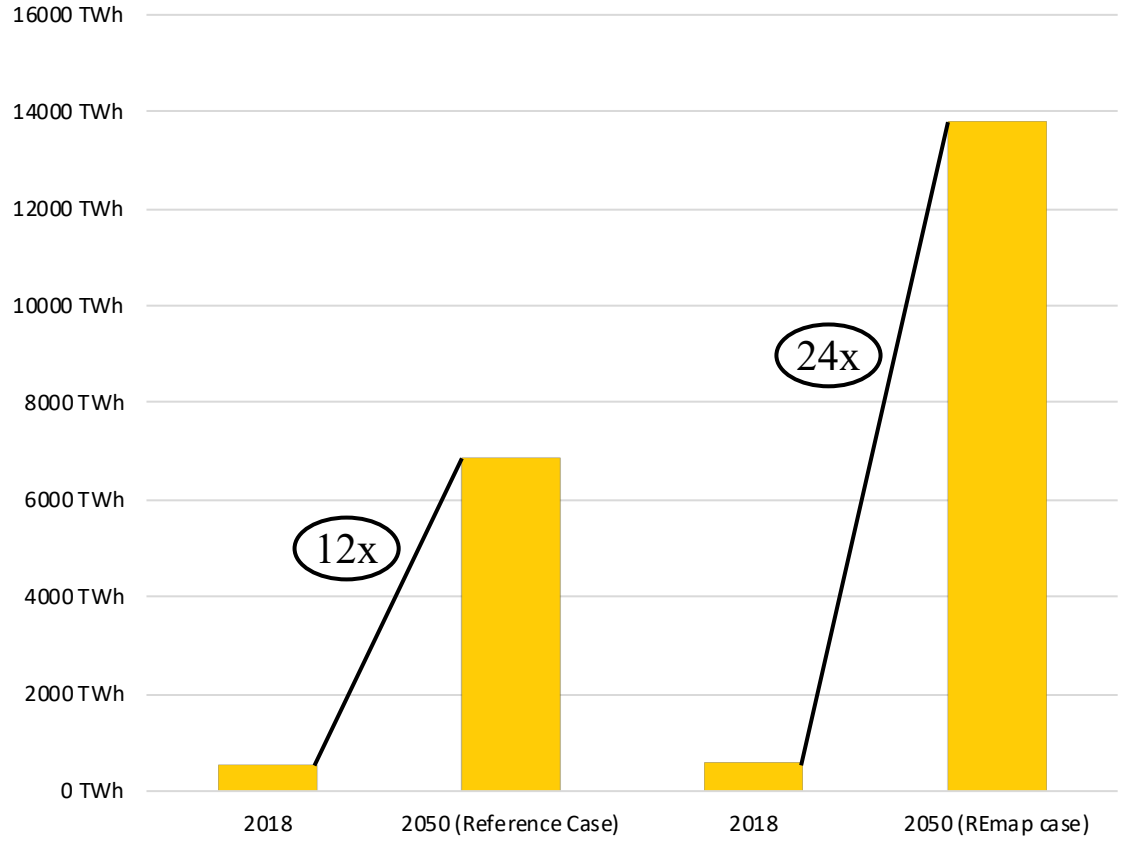
If solar PV keeps on track until 2050 it can increase its installed capacity in 17 times and its power generation in 24 times

The growth in installed capacity can be up to 51.6% year while for power generation it can be 72.3% year

7. Solar PV Installed Capacity 2018-2050 Reference and REmap cases (GW)



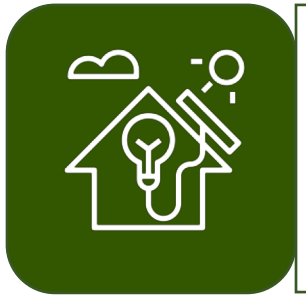
8. Solar PV Power Generation 2018-2050 Reference and REmap cases (TWh/year)



2. Source: International Renewable Energy Agency 2019
5. Source: International Energy Agency 2019

To keep on track until 2050 solar PV needs to tap off-grid systems not covered by national grids as well as continue the cost drop trajectory in panels and in balance-of-system

Innovation is needed to increase performance of PV systems and the access in developing countries[5]:



Increased integration of off-grid electrification systems

- Provide electricity access to remote areas where grid connections are too expensive to reach
- Pay-as-you-go (PAYG) financing helps consumers overcome the high upfront costs
- Data gathered can be used to improve the deployment of new modules

Maintaining the cost reduction trajectory of Solar PV

- Market share: ¾ = crystalline silicon; ¼ = Passivated Emitter Rear Cell (PERC)
- Advancing n-type technologies (not subjected to light-induced degradation)
- Improved cleaning, passivated contacts, interconnection, embedding, new metallization pastes

Smarter inverter systems and balance-of-system (BOS) cost reduction

- New ways to inject power into the grid and to manage generation from solar PV systems
- Communication equipment that interacts in real time with house utilities
- BOS cost has fallen by over 90% since the end of 2009[3] (make up to 10% - 50% of the installation costs)

3. Source: International Renewable Energy Agency 2019
5. Source: International Energy Agency 2019

Even though onshore and offshore wind reached the required generation increase, more efforts are required to achieve the expected sustainable scenario[5]

The unitary power and the rotor size of turbines have advanced from 0.75MW and 50m in 2000 to 5MW and 125m between 2015-2020, expectations are of reaching 20MW and 250m in the future[6]

More Efforts Needed

Onshore wind

- Generation increased **12%** in 2018 (requires 12% average annual growth)
- IEA forecasts a 9% average annual growth through 2023
- Theoretical maximum efficiency (On and Off): ~60%
- Best modern turbines operate at (On and Off): 35% - 45%[4]

More Efforts Needed

Offshore wind

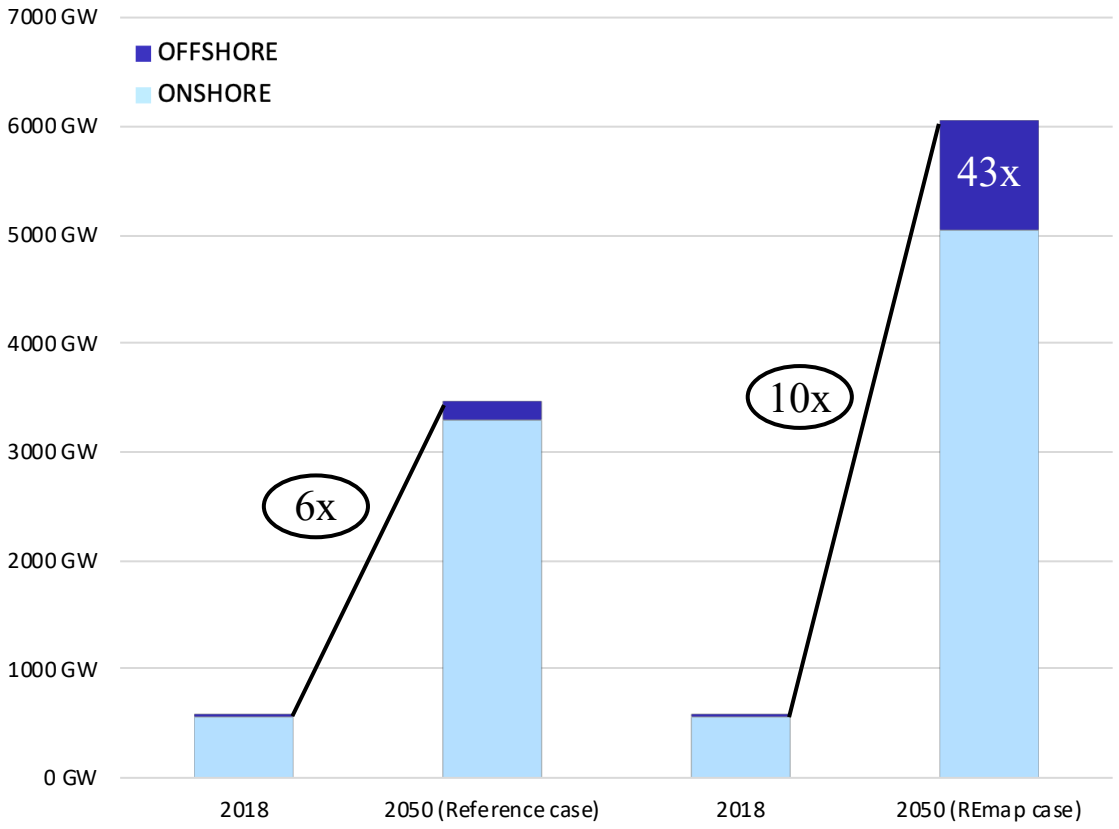
- Generation increased **20%** (requires 20% annual average through 2030)
- IEA forecasts a 15% average annual growth through 2023
- Positioning wind turbines in the sea provide better wind resources than onshore
- Drawback is the difficulty in installing offshore turbines, requiring large vessels

4. Source. Wisniewska 2019
5. Source: International Energy Agency 2019
6. Source: International Energy Agency 2013

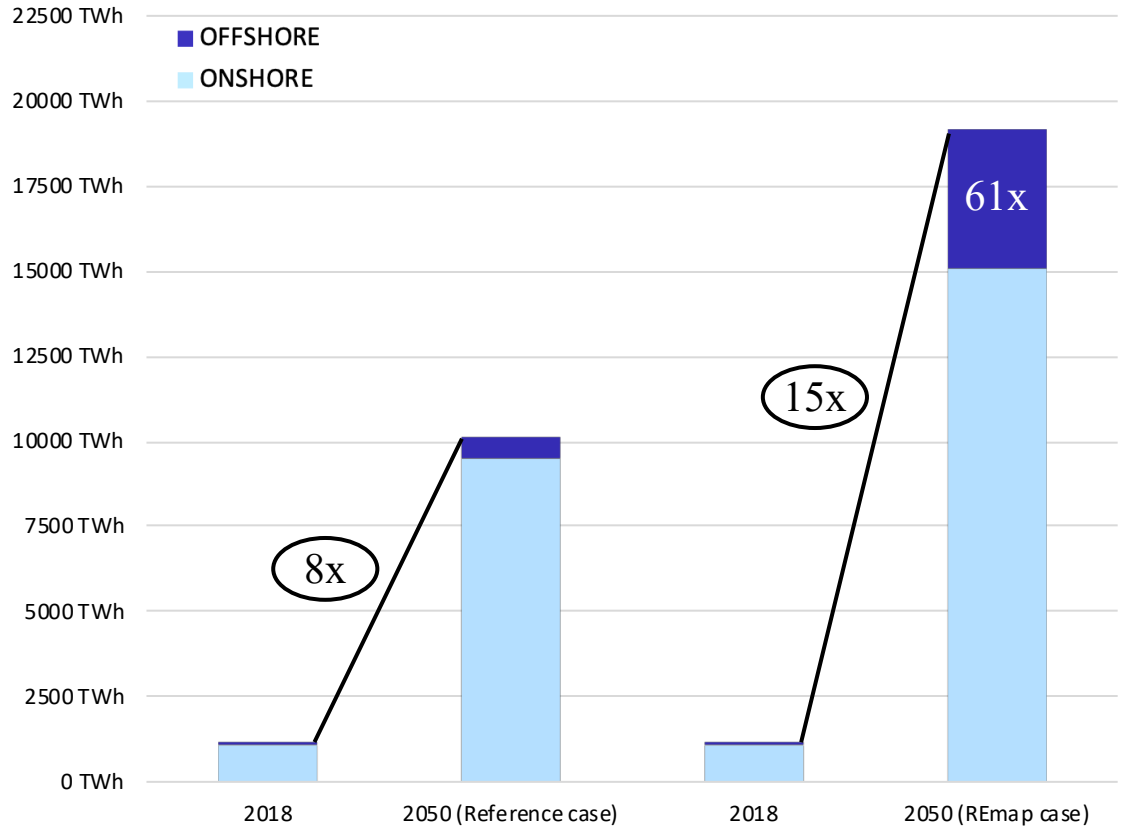
Wind power installed capacity will increase in 6 to 10-fold and its power generation will increase between 8 to 15 times until 2050 with offshore showing more growth potential

Currently 8% of the new installations in wind power are offshore, by 2023 this share is expected to increase to 22%[7]

9. Wind Power Installed Capacity 2018-2050
Reference and REmap cases (GW)



10. Wind Power Electricity Generation 2018-2050
Reference and REmap cases (TWh/year)



2. Source: International Renewable Energy Agency 2019
5. Source: International Energy Agency 2019
7. Source: Global Wind Energy Council 2019

Supportive policies are key to enable faster wind energy market growth, but also there is a need to improve distribution technologies to create a reliable and cheaper grid integration

Governmental support in auction/tender programs as well as policies aiming to reach renewable targets can push the wind power market[7]. Improvements in technology are also needed in order to increase annual capacity additions more quickly[5]:

Onshore Wind Power:

- Advanced contribution of wind power to grid integration
  - Due to its variability and uncertainty solutions are required in what is related to dispatchability
- Improve resource assessment and spatial planning (also applies for offshore)
  - Enhance sensitivity assessment of the surrounding environment ensuring long term efficiency
- Next generation turbine, power-train and system management technology
  - Larger rotor diameters and higher hubs (higher upfront costs ⟷ higher production, less variability)

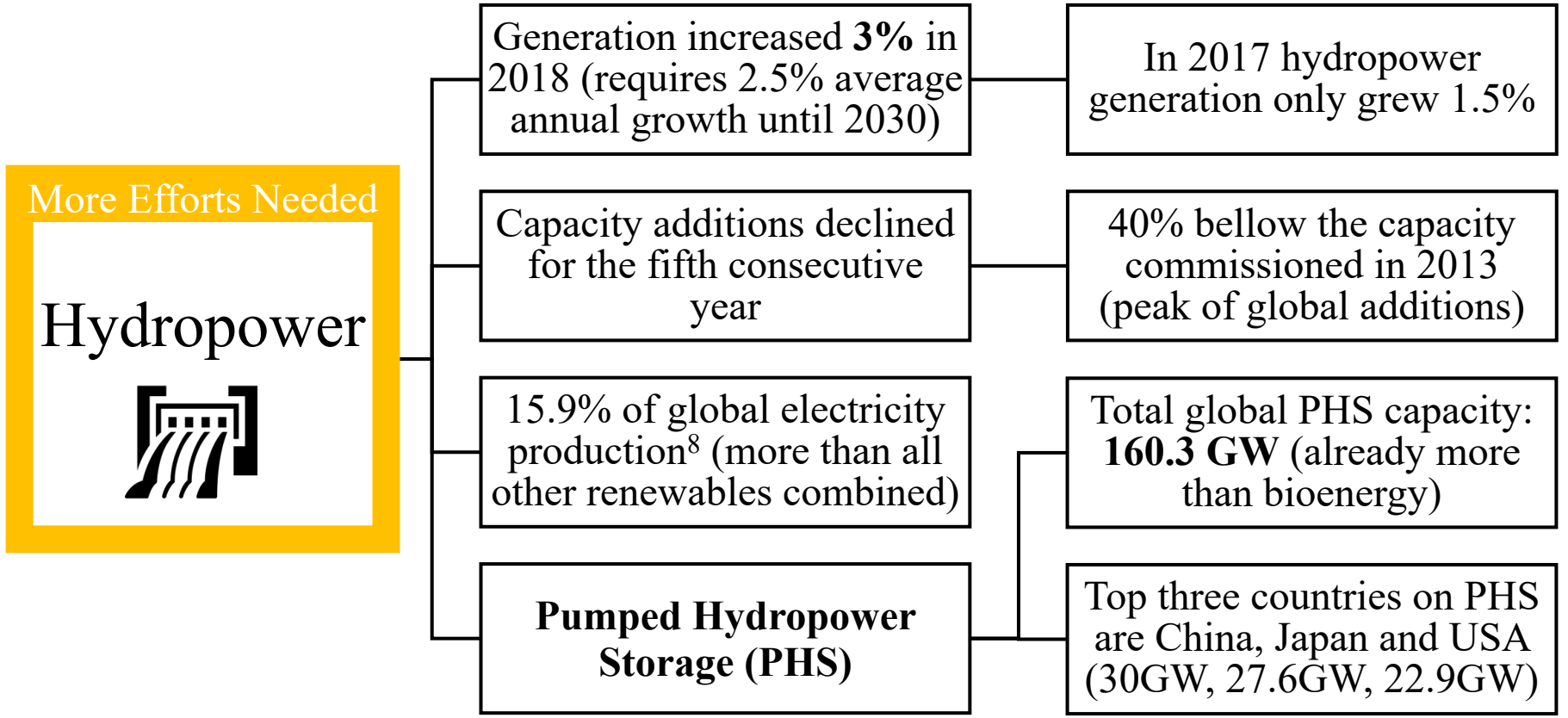
Offshore Wind Power:

- Innovation in installation processes for offshore wind plant
  - Offshore farms need higher levels of resilience (stronger winds, long-term exposure to seawater)
- Reducing cost and risk of transmission and distribution of electricity from offshore wind
  - Transmission losses need to be reduced (increasing voltages in offshore farms / low frequency)
- Tapping deeper offshore resources through floating wind turbines
  - Deeper waters (depths more than 50m to 60m) = richest wind resource and more areas to explore

5. Source: International Energy Agency 2019
7. Source: Global Wind Energy Council 2019

Hydropower seems to have reached its peak in 2013, this technology requires more efforts to reach the sustainability goals[5] and luckily PHS systems can be better explored

With a downward trend in China and Brazil hydropower is struggling to keep its growth level up. The solution can be to focus on Pumped Hydropower Storage a "water battery" system that can support other variable renewable energy sources

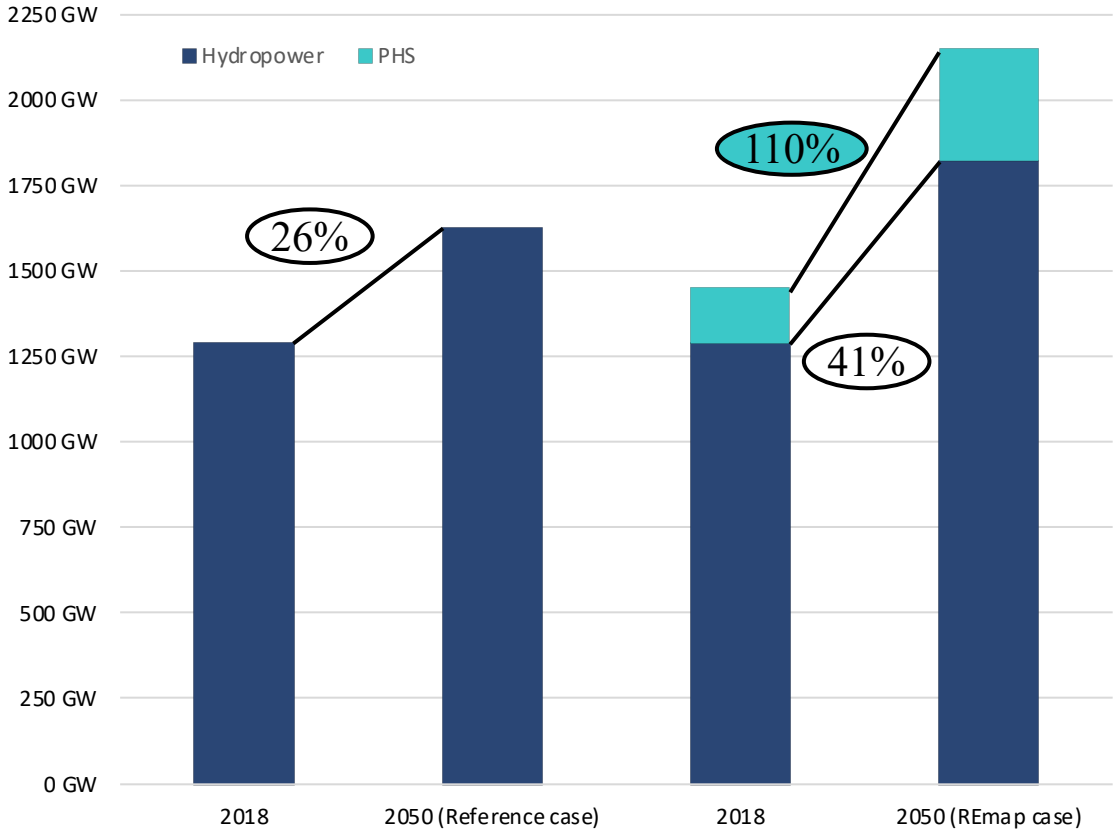


5. Source: International Energy Agency 2019
8. Source: International Hydropower Association 2019

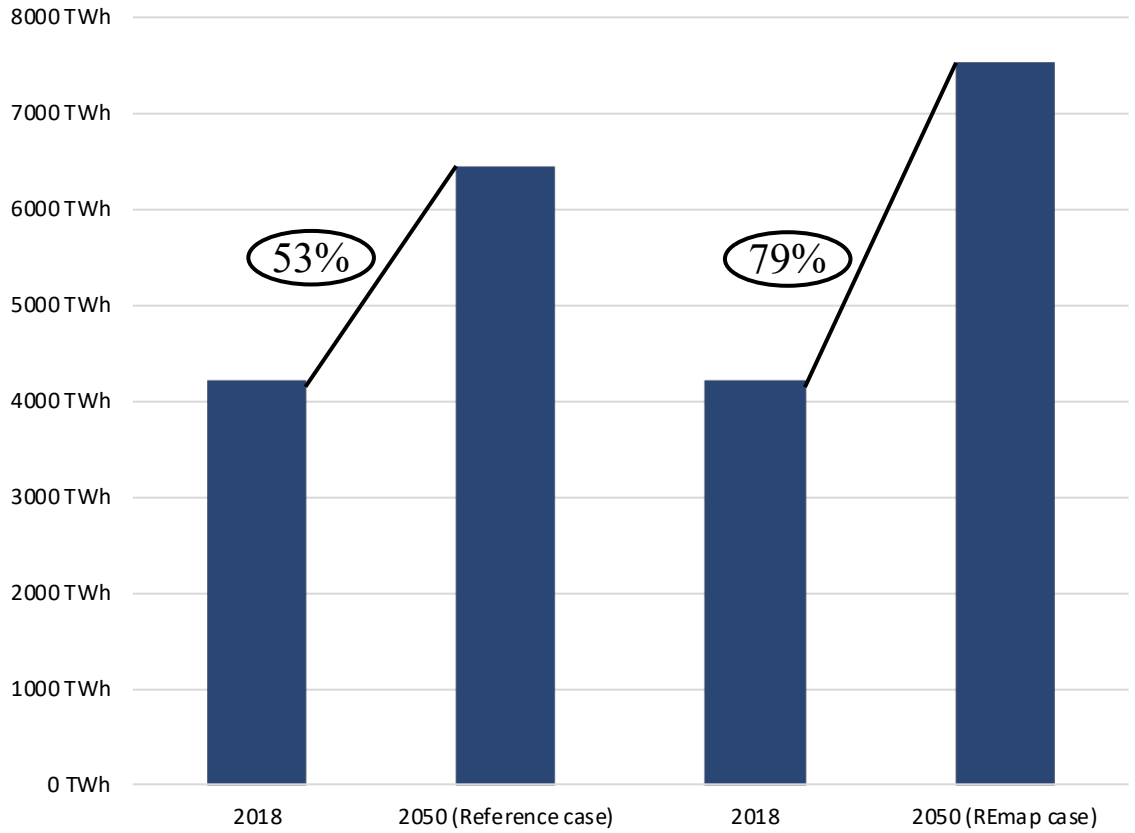
Because hydropower is a mature technology it has a much more limited space to grow compared to solar and wind, PHS, however, shows a better growth opportunity

Pumped hydropower storage installed capacity can grow 110% until 2050 in a REmap case[9]

11. Hydropower and PHS Installed Capacity 2018-2050 Reference and REmap cases (GW)



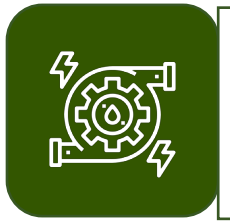
12. Hydropower Power Generation 2018-2050 Reference and REmap cases (TWh/year)



2. Source: International Renewable Energy Agency 2019
8. Source: International Hydropower Association 2019
9. Source: International Renewable Energy Agency 2018

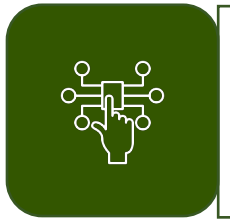
Pumped-storage diffusion, digitalization, improving turbine technology, and reducing civil works cost and impact are inevitable in the hydropower industry of the future

To put hydropower back on track there is a need to expand the generation growth as it has been losing speed:



Increasing the use of pumped-storage hydroelectricity

- Work to change regulatory and policy frameworks to liberalize markets and incentivize PHS development
- Developing the feasibility of underwater pumped-hydro energy storage

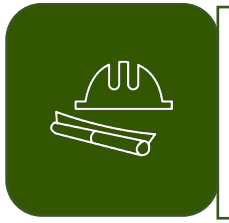


Digitalization of hydropower operation (rehabilitation/upgrading old equipment)

- Data collection/analysis, detecting anomalies → deciding on the proper actions
- Savings from increasing annual production as well as significant reduction of GHG emissions

Innovative hydropower designs

- Flow control techniques, variable speed generation, improving mechanical and hydraulic turbine designs
- Alternatives that don't require damming or the resettlement of populations



Reducing the cost and impact of civil works

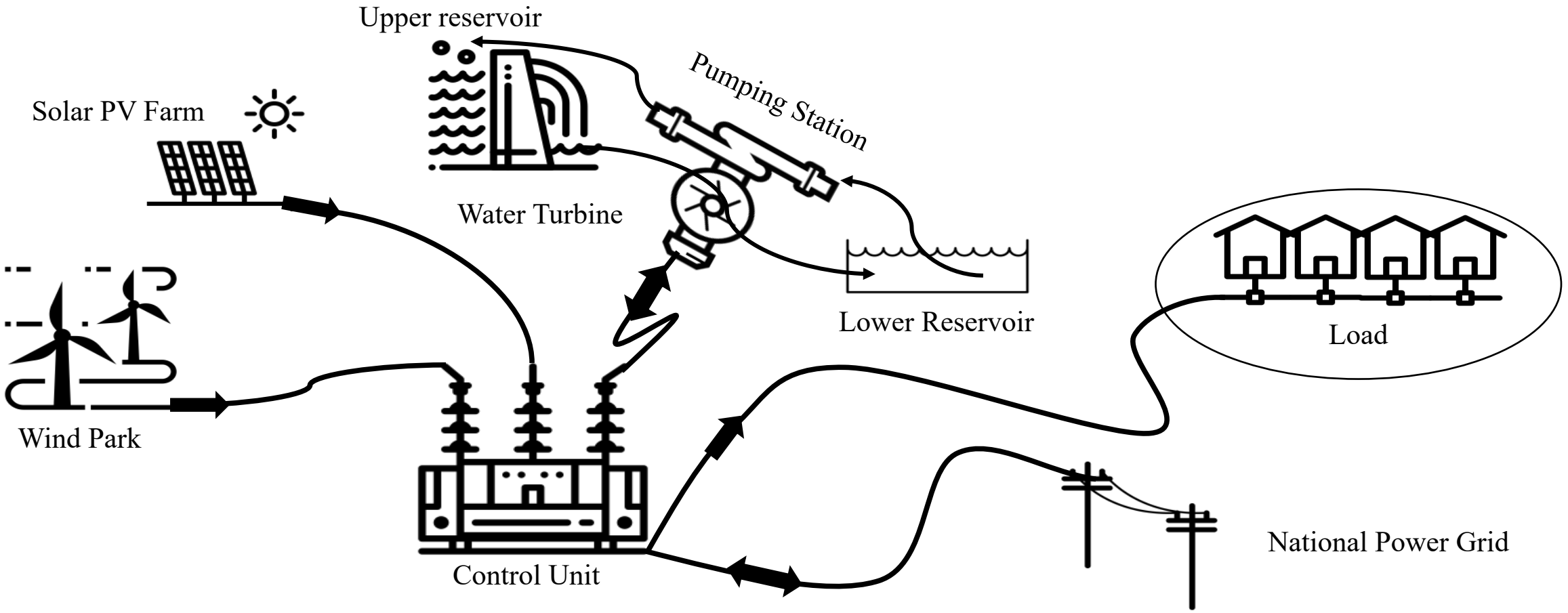
- Project construction can take up to 70% of total project costs
- Improved methods, technologies and materials for planning, design and construction are required

5. Source: International Energy Agency 2019
10. Source: Kougias et al. 2019

The best alternative is to have a hybrid system combining the three energy sources allowing to store unused energy with a PHS system

Reduce intermittency and energy waste while improve system stability and reliability with faster response time

13. Illustration of a hybrid system using solar power, wind power and pumped hydropower storage systems interconnected



The most important play in renewable energy generation is to deal with the the variable nature of its resources as well as keeping producing solar panels and wind turbines

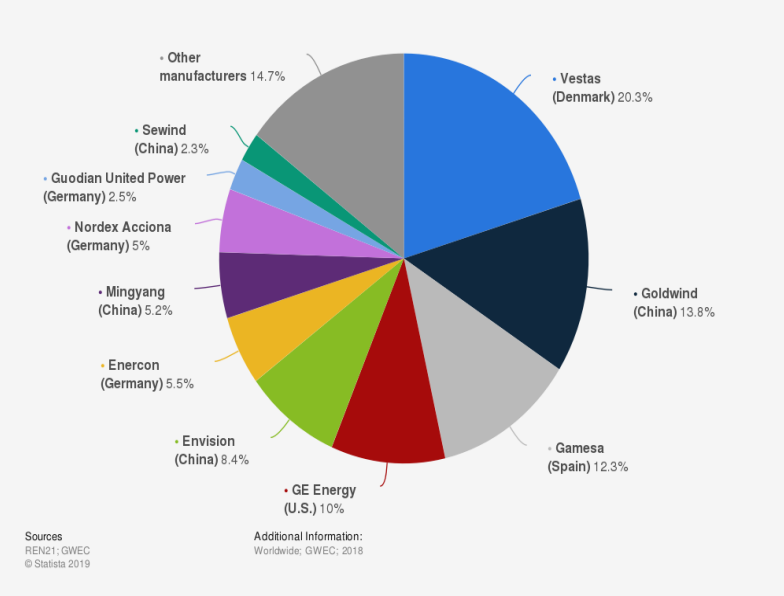
Improving grid technology as well as the use of hybrid systems are the best options to tackle the intermittency issue

Mismatch between generation/consumption	• Work on the mismatch between energy generation and consumption will prevent curtailment from happening avoiding further energy generation losses ➢ Digitalization and data gathering can help on tracking and predicting energy flows
System integration of renewables	• Using hybrid systems with more than one renewable energy source creates a safer, more reliable, and more efficient grid ➢ Different resources have different patterns and are not affected in the same ways
Fast response to fluctuations	• Developing technologies that have a fast response to fluctuations in source availability for renewable energy generation lead to system stability and grid reliability ➢ Have a backing up generation plant (perhaps one that is not fully renewable)
Continuing to produce solar panels and turbines	• With the solar panels cost reduction going full speed and wind turbines also dropping the obvious play is to keep producing them as it will become less expensive to do it ➢ Cheaper products allow more people to own them expanding its market size

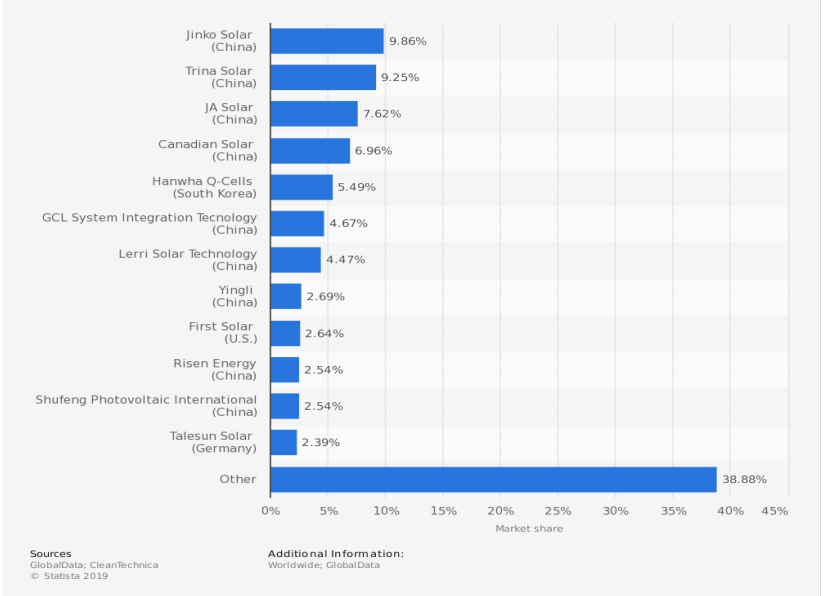
Smaller players are the ones moving the renewable energy market, wind and solar markets have more space for new entrants, hydropower still depends on bigger players

Unlike in the oil industry the renewable energy market is less concentrated and has space for smaller players

14. Global market share of wind turbine manufacturers in 2018[11]



15. Global market share of PV manufacturers based on revenue 2017[12]



16. Construction costs among the biggest hydroelectric dams in the world (USD bn)

Three Gorges Dam	$ 31.765 billion
Itaipu Dam	$ 19.6 billion
Belo Monte Dam	$ 18.5 billion
Yaciretá Dam	$ 15 billion

17. Total assets and market cap of the companies with higher market share (solar and wind), biggest dam (hydro), and highest total assets (oil) in USD bn

	Vestas	Jinko Solar	China Yangtze Power Co	China Petroleum & Chemical Corp.
Total Assets	$9.5 bn	$5.2 bn	$41.8 bn	$426 bn
Market Cap	$130.89 bn	$3.21 bn	$394.68 bn	$574.07 bn

11. Source: Statista 2019
12. Source: Statista 2019

By using sheep for vegetation control and foxes to hunt rodents Prosolia Energy is an example of a new player that the present energy market permits to play the game

Case In Point

The solar farm in Ourique was done through a joint venture between Prosolia Energy and Solaer, later sold to Allianz. Now Prosolia is only in charge of the Operation and Maintenance of the solar park

Concept	140,000 solar panels giving 48MW of installed capacity were installed in a 100 hectares area, producing 80.4 GWh annually
How it works	The O&M is charge of generation forecasts and monitoring as well as vegetation control and equipment and panel repair
Pros	Provide clean energy to 25,000 families avoiding 45,000 tons of CO_2 and increasing the energy independence
Investment	€35Million without any subsidies

18. Ourika solar farm

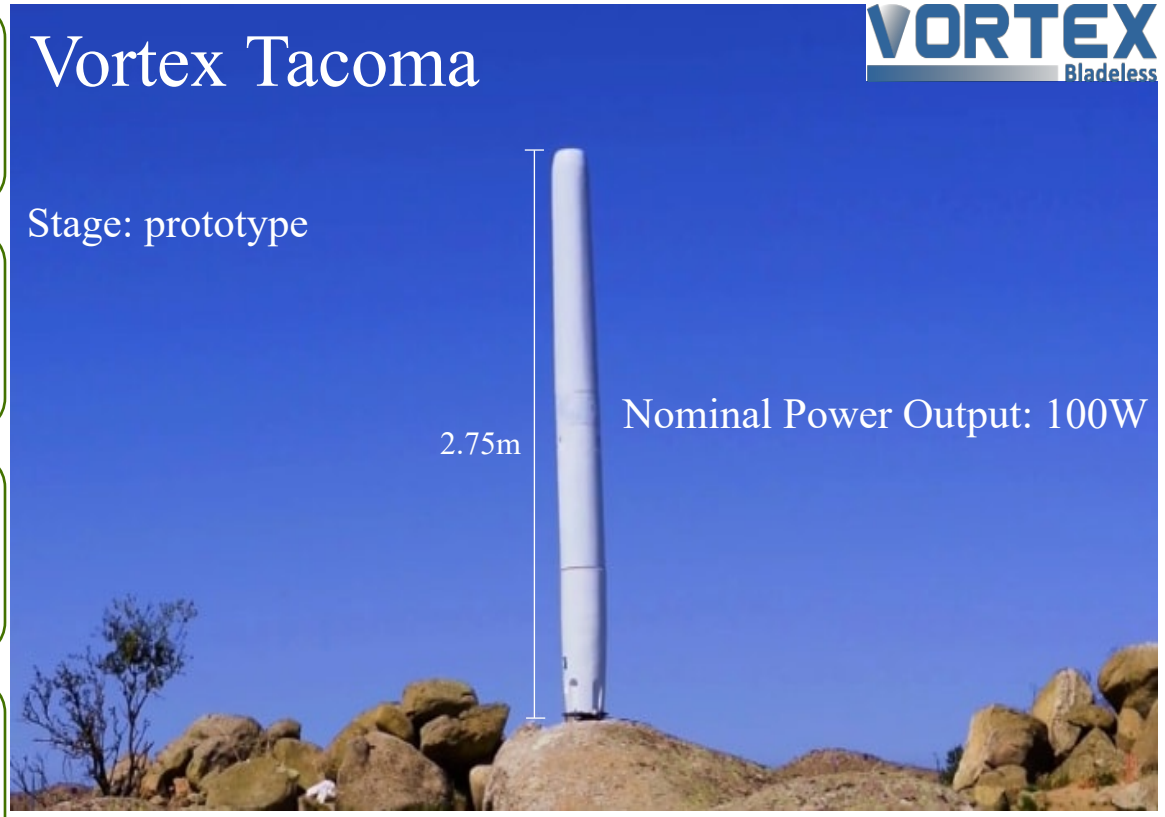
13. Source: Prosolia Energy 2019
14. Source: Prado 2018

In the technology front Vortex Bladeless is a new player that invests in technology in order to create an innovative product able to harvest wind power

Case In Point

Vortex induced vibration resonant wind generator can work on-grid and off-grid, or along with regular wind and solar panels or other generators

Concept	Operates at low wind speeds, between 3-8m/s. Stops at 11-12m/s where regular wind turbines keep going (can be complementary to regular)
How it works	Harness wind from the Vortex Shedding phenomenon, the vibration is converted to energy using an alternator
Pros	Turbines are 80% lighter, foundation is 50% smaller, it doesn't require any oil, and more bladeless turbines can be installed in the area
Investment	Although not yet commercially available (expected to be in 2021), vortex bladeless cost-effectiveness is more similar to solar PV than to regular wind turbines



19. Vortex Tacoma device

15. Source: Vortex Bladeless 2019

Valhalla Energy has the best resources at hand to create a hybrid solar-PHS system, the Atacama desert irradiation and the altitude difference from the Andes to the sea

Expected to start the construction in 2020 with commercial operation starting in 2025 this project will be able to generate electricity 24/7

Concept	A hybrid system using solar PV in the Atacama desert (highest level of radiation on Earth) along with a PHS (sea → mountains)
How it works	Daytime power generation of 600MW from solar park. Nighttime power generation of 300MW from PHS
Pros	Has a reservoir storage capacity enough for 5 to 11 days. The project can help avoid 35 million tons of CO_2
Investment	~ USD 1.1 billion

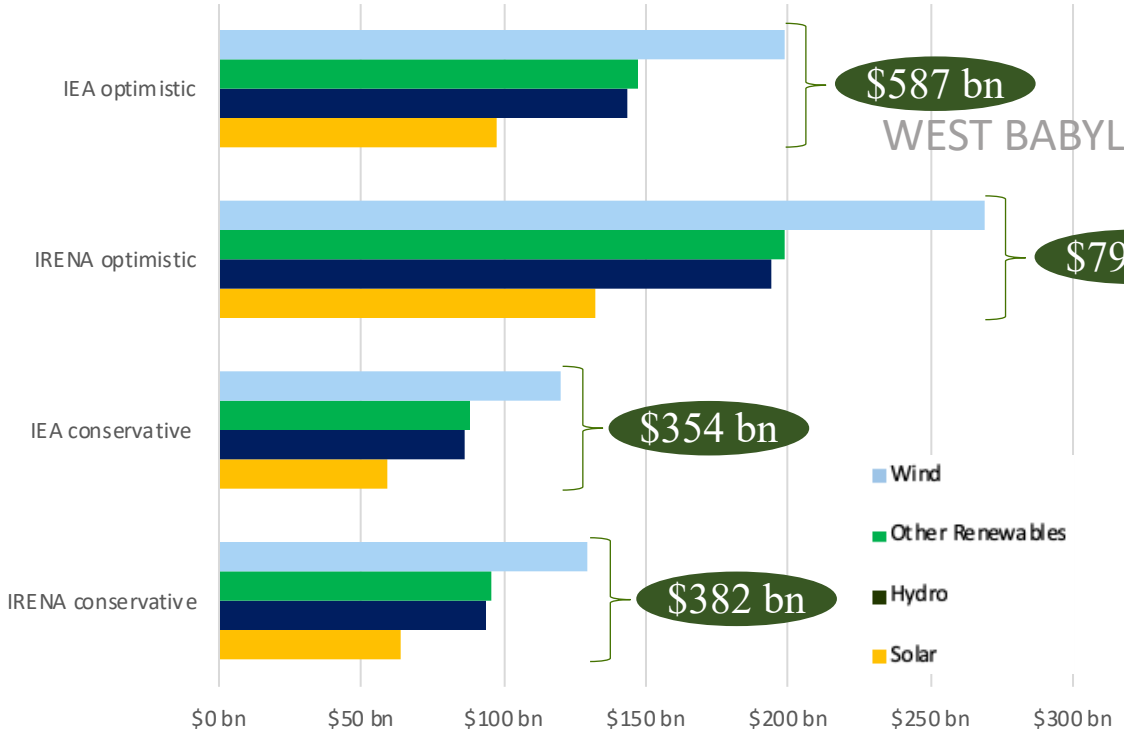
20. Photo and map of where Valhalla Energy projects take place

16. Source: Martín 2019
17. Source: Chile Energías 2015

The total yearly investments range from $354-$382 bn in the conservative scenarios and from $587-$794 bn in the optimistic scenarios, wind leads the investments in all of them

Wind is the technology expecting the most investment in all scenarios and solar is the one with the least investments

21. Renewable energies average investment per year until 2050 (USD bn, optimistic and conservative scenarios)



Even though in 2050 solar power will represent a much higher market share in terms of capacity and generation than hydropower its cost drop will lower the investments required from this technology

Hydropower:

- Costs increasing (smaller projects)
- Heavy upfront construction costs
- Smaller share of power generation
- More investments required to get back on track of sustainable goals

Solar Power:

- Costs decreasing
- Panels in a fast cost cut trajectory
- Bigger share of power generation
- Less investments required as it is already on track

WEST BABYLON, NY 11704

2. Source: International Renewable Energy Agency 2019
18. Source: International Energy Agency 2018

A Work Project, presented as part of the requirements for the Award of a Master's degree in Economics / Finance / Management from the Nova School of Business and Economics.

Investment Opportunities

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In light of a sustainable energy transition, what are the key changes across the multiple sectors and what opportunities will emerge?

Abstract

1 Demand

Demand for energy and renewable sources is increasing. The Buildings segment has the potential to have the largest share of renewable-produced energy followed by Industry, yet Transportation can face the highest growth. Greater investment opportunities will emerge in Buildings and Transportation with new technology and low-carbon policies unlocking new business models in areas like demand flexibility, efficiency and e-mobility

2 Transmission

Transmission development comes as a result of the rise in demand, generation capacity and the distance that separates these two. These constraints can be addressed through a set of solutions which complemented, meet the requirements of a flexible integrated transmission

3 Generation

The generation energy market once dominated by massive oil companies is experiencing changes that allow new types of players. The 2050 scenarios show large increases in renewable technologies total installation capacities and power generation mainly in wind and solar power as well as a great investment opportunity in wind power

4 Investment Opportunities

A cleaner energy market will diversify the ecosystem and change the nature of factors to succeed across demand, transmission and generation. Investment opportunities will be greater in energy demand and the total investment of the three areas combined represents 3.1% of the World GDP. This new ecosystem will allow new players to emerge and fragment a former highly concentrated market with increased uncertainty, encouraging partnerships

Keywords: diversify, demand, ecosystem, fragmentation

A cleaner energy market will diversify the energy ecosystem and change the nature of plays and factors to succeed across the three main stages of the energy market

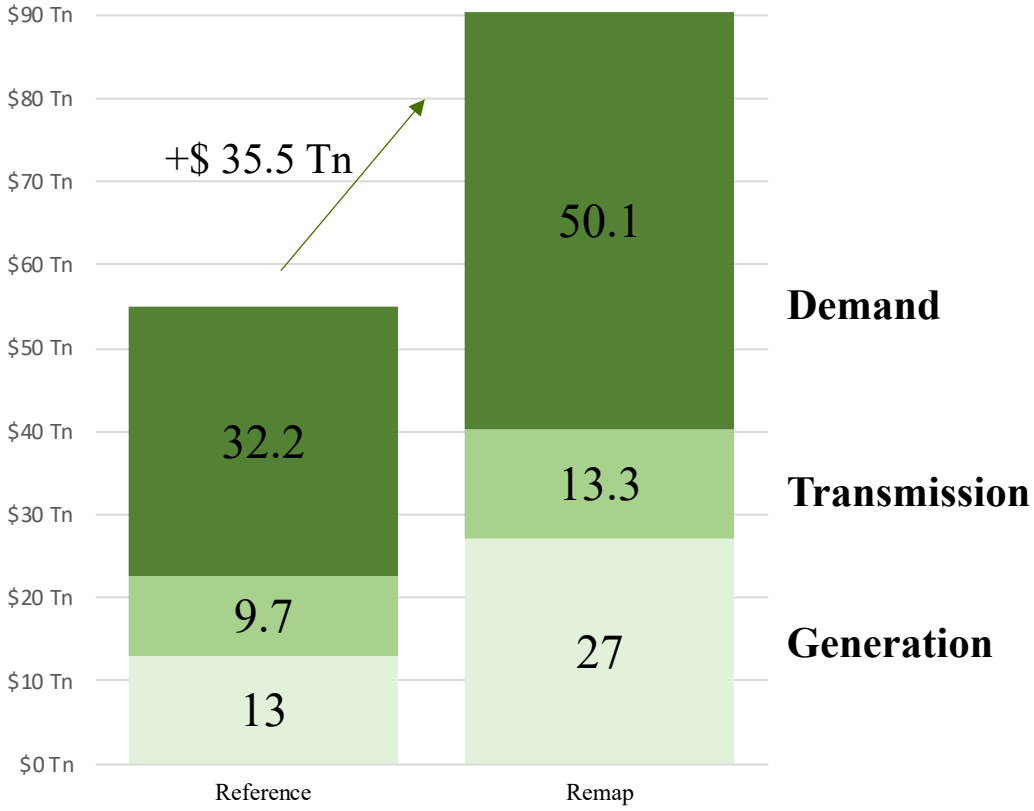
	Energy Demand	Transmission	Generation
Nature	• Virtual Power Plants • Efficiency Energetic Consultancy • E-Mobility Services	• Grid connection • Connect farms • Storage	• New plays/players • Innovative Technologies • Hybrid Systems
KSFs	• (F) High initial investments incentivise partnerships to lower costs down the line • (T) Rapid deployment of smart meters, smart grids and electric mobility technology • (R) Subsidies to electric mobility and incentives for buildings to adopt efficiency standards	• (F) Public private partnership to finance the high costs of projects such as power storage batteries • (T) Reduce CSP installation costs • (R) International and intercontinental cooperation	• (F) Pay-as-you-go: reducing upfront costs for the consumers • (T) Smarter Balance-of-System technologies • (R) Support regulatory and pricing policies to allow consumers to become prosumers and sell electricity

(F) Financial (T) Technological (R) Regulatory

Investment opportunities will be greater in energy demand, meanwhile total investment per year in the three areas combined represents 3.1% of the World GDP

Regardless from the scenario, **demand** investments will be far superior than the other two and the REmap scenario will require almost $35.5 Trillion more

Total investment in USD Trillion from 2016-2050 in 2 Scenarios



- **Demand**

Includes efficiency measures deployed across the end-use sectors – buildings, transport and industry

Investment per year (Remap): $**1.47 Trillion**

- **Transmission**

Includes investments made for transmission and distribution grid extensions as well as storage

Investment per year (Remap): **$391 Billion**

- **Generation**

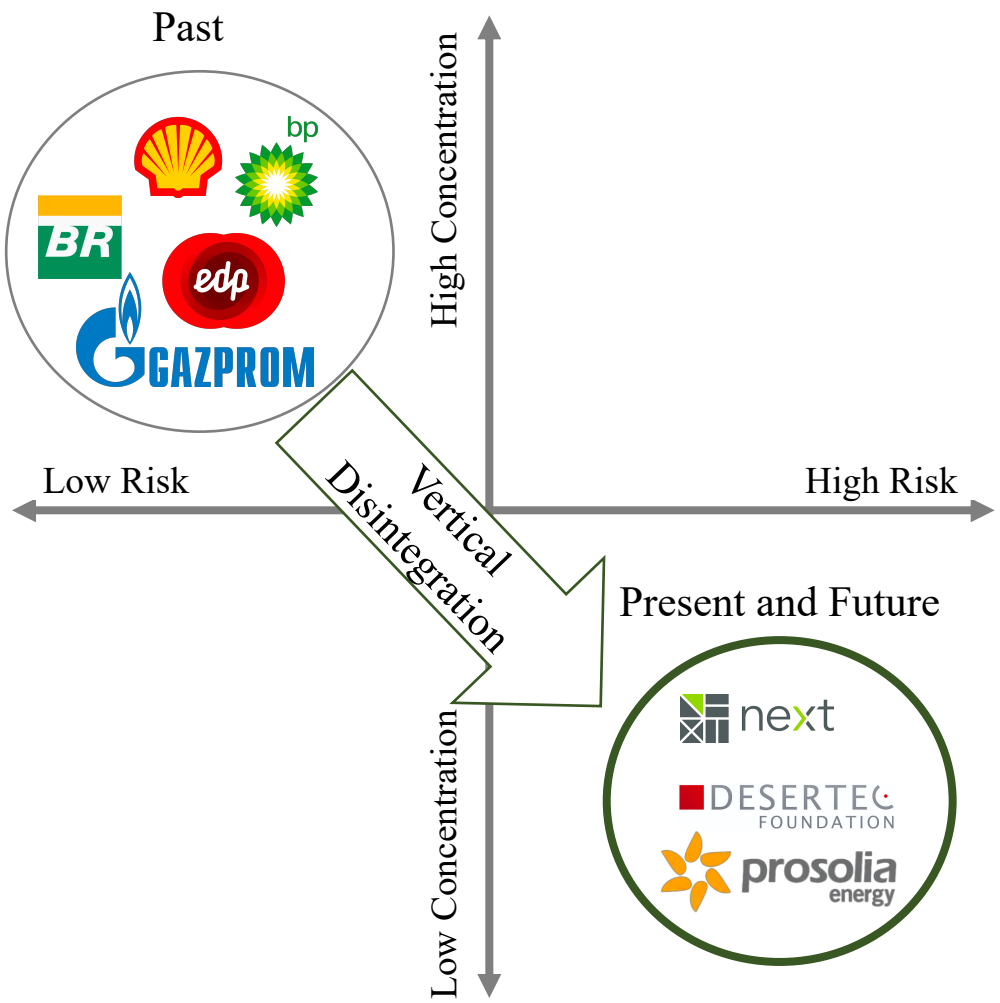
Includes investments for the deployment of renewable technologies for power generation such as capacity construction, operation and management

Investment per year (Remap): **$794 Billion**

Total combined investment per year = **$2.655 Trillion** which represents **3.1%** of the **World GDP** ($85.909 Trillion in 2018)

1. Source: IRENA 2019
2. Source: World Bank 2019

The new ecosystem will allow new players to emerge and fragment the former highly concentrated market encouraging partnerships to split risks and costs due to uncertainty



1. For the past century, **large players have dominated the energy ecosystem**, funded solely by public markets and governments

2. Technology and sustainability concerns are spawning **new business models and types of players** funded by pension funds and private-equity firms

3. This **fragmentation** is diminishing the power of scale to shape market

4. With so many players interacting in different ways and locations, **uncertainty and risk** are higher than ever

Recommended Strategy

- Companies should make smaller initial investments and be flexible in adjusting strategies as circumstances change
- Partnerships can help companies splitting the cost and risk of large capital projects under high risk and uncertainty

3. Source: McKinsey & Company 2017

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