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Global Energy Transition Outlook

Moving to a cleaner, more electrified world

March 2024

By 2035, the ***majority (~60%+) of global electricity generation*** will be from ***clean sources***

Solar PV & Wind

- Solar PV and Wind will be the predominant modes of clean electricity generation as their economics continue to improve; by 2030 the LCOE* of both Solar PV and Wind installations will be less than 50% of the LCOE of natural gas turbine installations
  - By 2030, Solar PV will account for at least 15% of global electricity generation, up from 4% in 2022, a 20% CAGR
  - By 2030, Wind will account for at least 15% of global electricity generation, up from 7% in 2022, a 12% CAGR
- For Solar PV, utility scale installations will dominate given their scale and economic advantages; by 2030, 55% of global solar PV electricity generation will come from utility scale installations
- For Wind, onshore installations will dominate with over 75% of new installed capacity through 2030

APAC & China Lead

- The Asia-Pacific region, and especially China, will lead the way in clean electricity development, especially in solar PV
  - Over 50% of global clean electricity generation, and over 60% of solar PV electricity generation, will be in the Asia-Pacific Region;
  - China alone will account for over 1/3 of global clean energy and solar PV electricity generation.

Ducker Carlisle Market Research, Ducker Carlisle Analysis

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7 Clean Energy Sectors Evaluated in the Outlook

Solar PV

Electricity produced from solar photovoltaic cells including utility-scale and small-scale installations

Bioenergy

Energy content in solid, liquid and gaseous products derived from biomass feedstocks and biogas; includes solid bioenergy, liquid biofuels and biogases

Wind (Onshore + Offshore)

Use of wind energy to do useful work, especially generate electricity typically generated with wind turbines

Marine (Tidal + Wave)

Represents the mechanical energy derived from tidal movement, wave motion or ocean currents and exploited for electricity generation

Hydropower

Electricity produced from hydropower installations (dams, etc.)

Geothermal

Geothermal energy is heat from the sub-surface of the earth and can be used for heating and cooling purposes or be harnessed to generate electricity

Hydrogen

Hydrogen is used in the energy system as an energy carrier or is combined with other inputs to produce hydrogen-based fuels

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Outlook hinges on **government policy driving technology advancements** and **favoring clean energy sectors**

Government Policy
- Regulations favoring clean energy & electrification
- Subsidies for clean energy sectors
- R&D investments or incentives to drive technology advancements

Technology Advancements
- Battery storage
- Grid capacity & resiliency
- Energy management

Favored Clean Energy Sectors
- Mandates for clean energy sectors
- Cost advantages for clean energy sectors
- Taxes on traditional energy sources

Energy Transition Future State
- Economically viable clean energy sectors
- Consistent & reliable clean energy
- Electrification

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As such, 3 forecast scenarios are modeled based on different levels of government policy effects

Stated Policies Scenario
(most likely)

- Reflects current policy based on a sector-by-sector and country-by-country assessment of the energy-related policies that are in place as of 2023, as well as those that are under development
- Scenario also considers currently planned manufacturing capacities for clean energy technologies

Most Conservative

Follows Actual Policies

No Pledges or Aspirational Goals

Announced Pledges Scenario

- Assumes all climate commitments made by governments and industries around the world as of 2023 will be met in full and on time, including…
  - Nationally Determined Contributions (NDCs)
  - Longer-term net zero targets
  - Targets for access to electricity and clean cooking, will be met in full and on time

Net Zero Emissions by 2050 Scenario

- Pathway for the global energy sector to achieve net zero CO_2 emissions by 2050
- Does not rely on emissions reductions from outside the energy sector to achieve its goals
- Scenario was fully updated in 2023

Source: IEA

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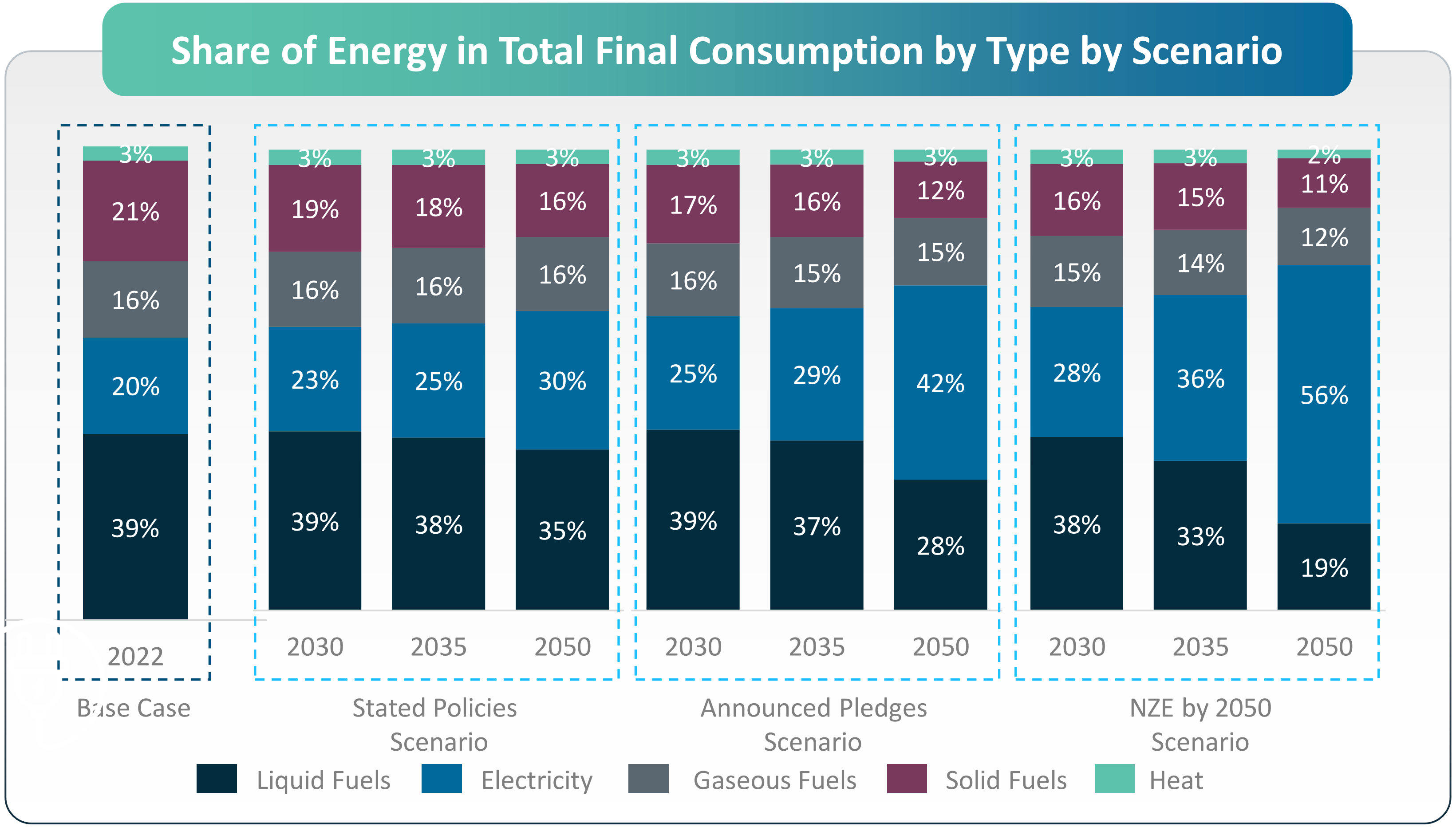
Transitioning to a More Electrified World



In each scenario examined, ***electricity's share of total energy*** *generation and consumption* ***increases significantly***

Electricity's share gain is mostly at the expense of liquid fuels

IEA World Energy Outlook 2023, Ducker Carlisle Analysis
Liquid Fuels – biofuels, ammonia, synthetic oil, oil
Gaseous Fuels – biomethane, hydrogen, synthetic methane, natural gas
Solid Fuels – solid bioenergy, coal

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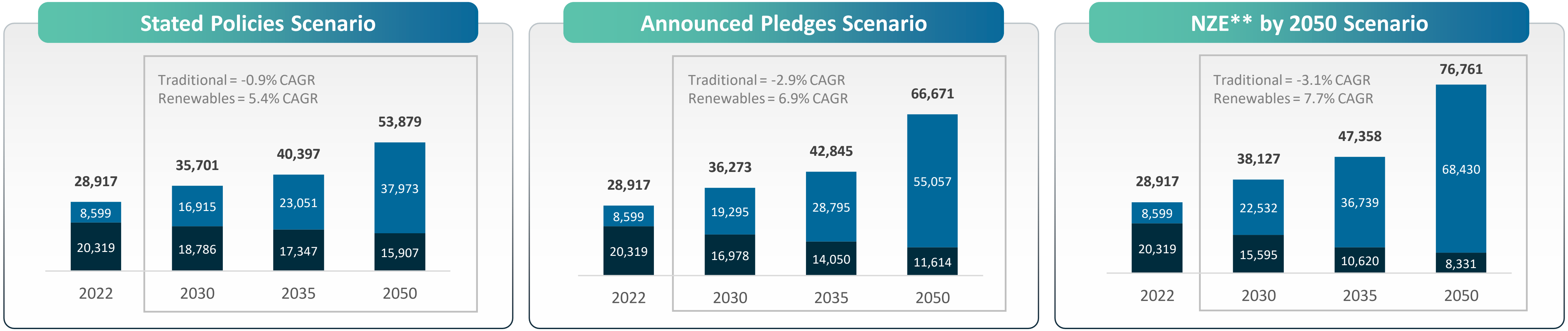
Electricity generation will both grow and shift from traditional to clean sources

Growth of Electricity Generation by Source by Scenario, TWh*



Key Drivers of Clean Electricity Generation Growth:

- Supportive government policies as governments across the globe are pledging to increase spending on clean sources to reduce greenhouse gas emissions
- Energy security considerations amidst escalating geo-political tensions are favorable for clean electricity generation; wind and solar are localized, while fossil fuels like oil and gas are supplied globally
- Cost profile and economics of clean energy generation, especially solar and wind, are expected to be at par or better than traditional fossil fuel sources by 2030

IEA World Energy Outlook 2023, Ducker Carlisle Analysis
** TWh – Terawatt-hours*
***NZE – Net Zero Emission*

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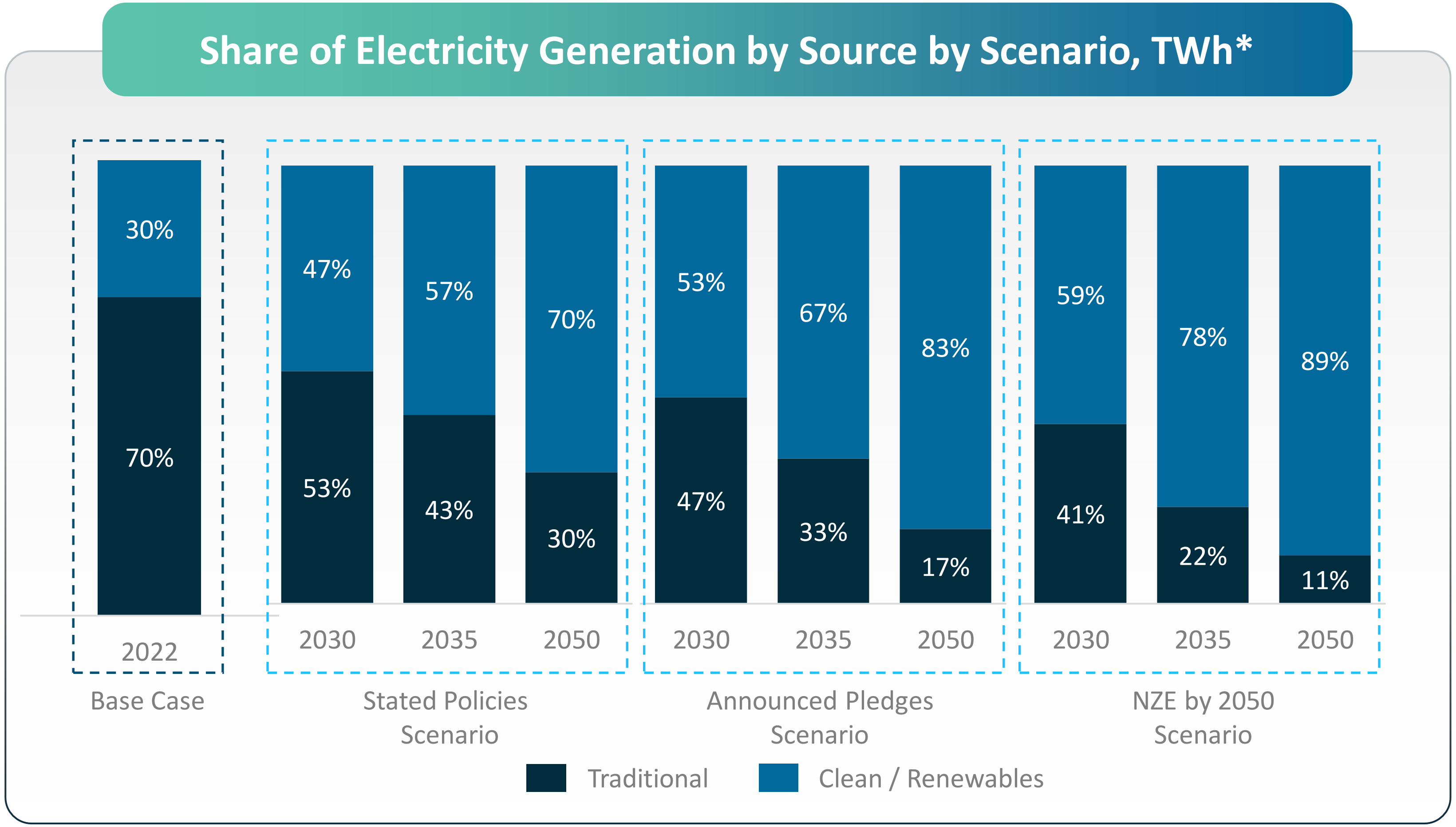
Clean Electricity Sources Will Surpass Traditional Sources by 2035 at the Latest



In any scenario, ***clean electricity sources are expected to dominate*** traditional sources by the 2030s

IEA World Energy Outlook 2023, Ducker Carlisle Analysis
** TWh – Terawatt-hours*

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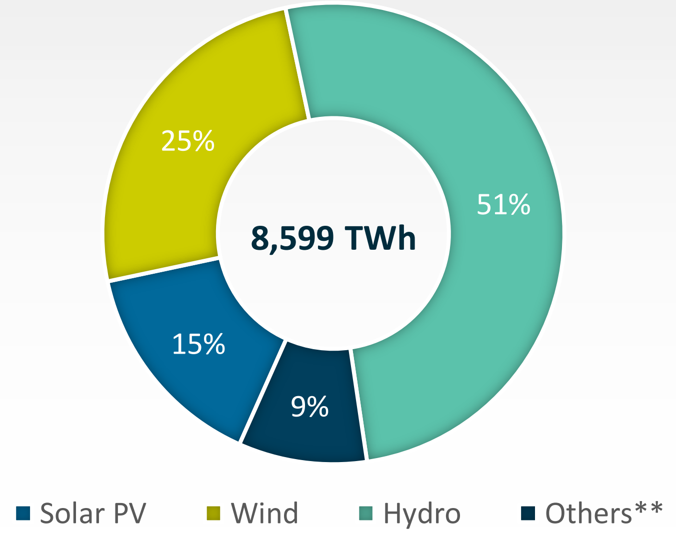
The Stated Policy Scenario

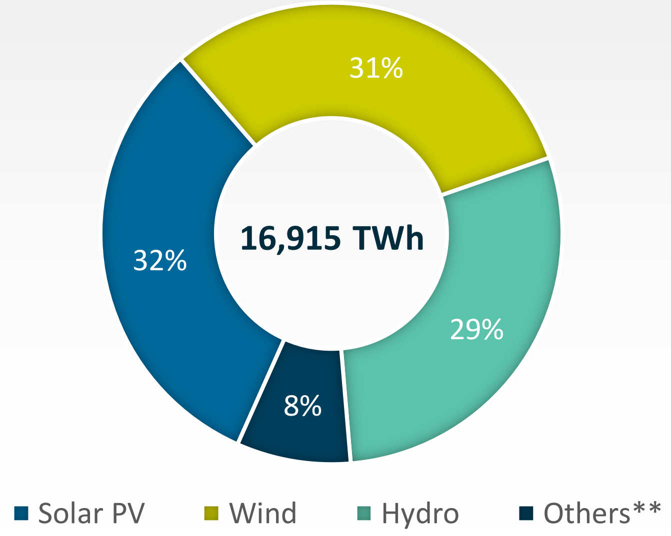
Focusing on the "Most Likely" Scenario

Solar PV will be the leading clean electricity source, followed by wind

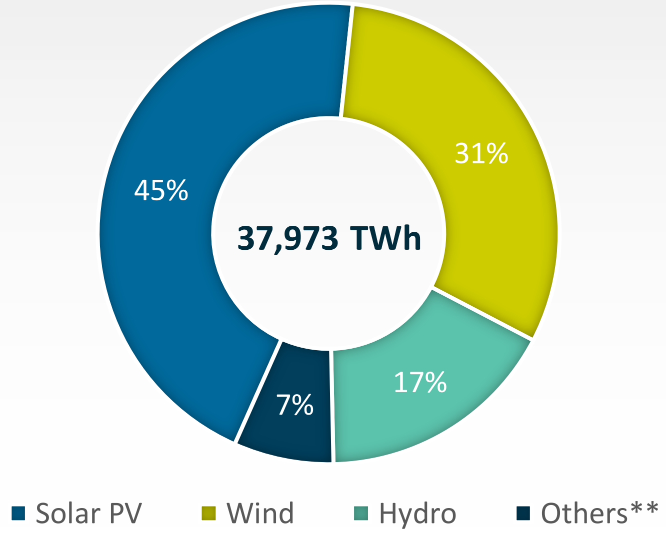
2022



2030



2050



Key drivers of solar PV and wind power growth:

- China eased project permitting process and has identified areas for large scale deployment of utility scale solar PV as well as onshore and offshore wind
- US inflation reduction act (IRA) 2022 provides policy support & tax credits for solar PV and wind power until 2030
- REPowerEU plan in Europe for accelerated transition to clean energy aims to accelerate the rollout of solar PV with a dedicated EU solar energy strategy
- Improving cost economics relative to traditional sources

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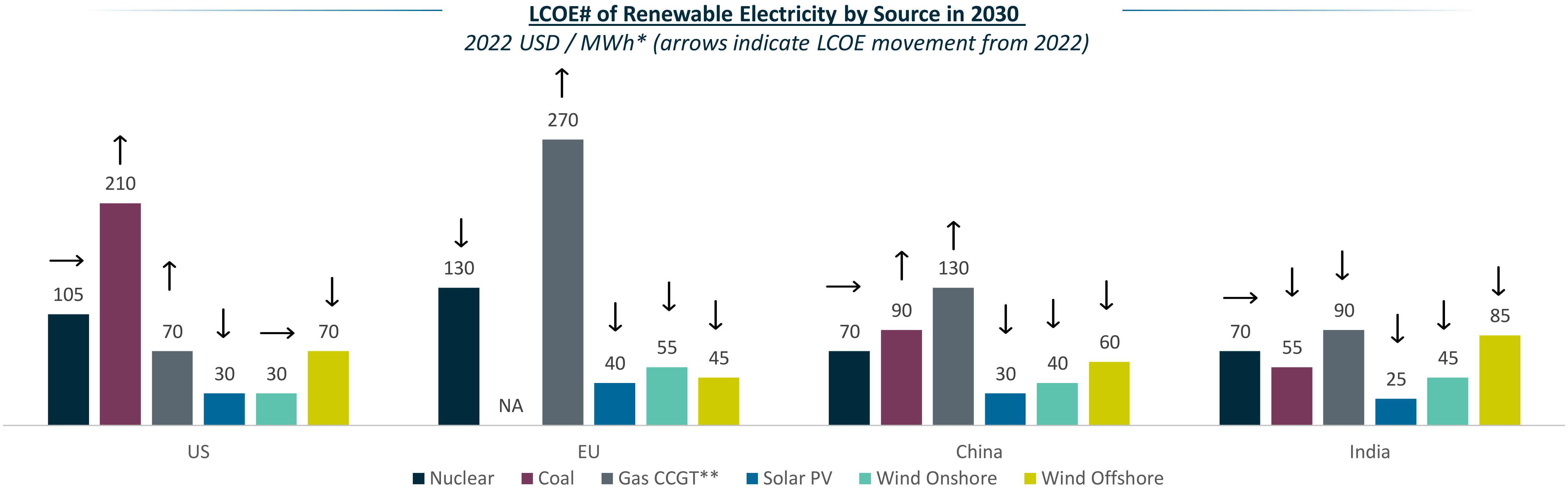
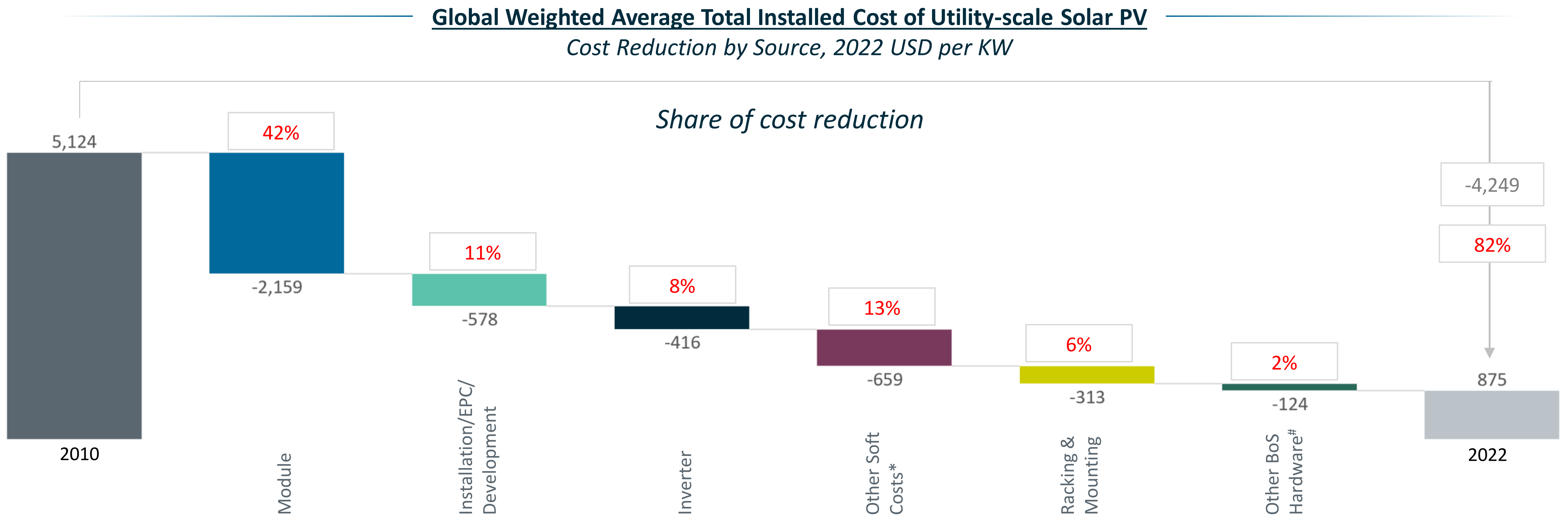
Cost of solar PV and wind generation is declining and will be cheaper than traditional sources by 2030



Supportive government policies and improved technological efficiency are driving down solar and wind costs and will drive the growth and expansion of these electricity sources

IEA Global Energy and Climate Model Documentation 2023, Ducker Carlisle Analysis
Levelized Cost of Electricity, * MWh: Megawatt-hour, ** combined-cycle gas turbine
Under stated polices scenario

PV module cost reduction is the main driver of the declining cost of solar PV electricity generation



82% reduction in utility-scale solar PV systems between 2010 and 2022; cost reduction trend is expected to continue and is mainly driven by solar PV module cost reduction

IRENA, Ducker Carlisle Analysis
* Soft costs, like, financing costs, system design, permitting, margins, etc.
# Other BoS, like, cabling, safety and security, structures and components for grid connection, etc.

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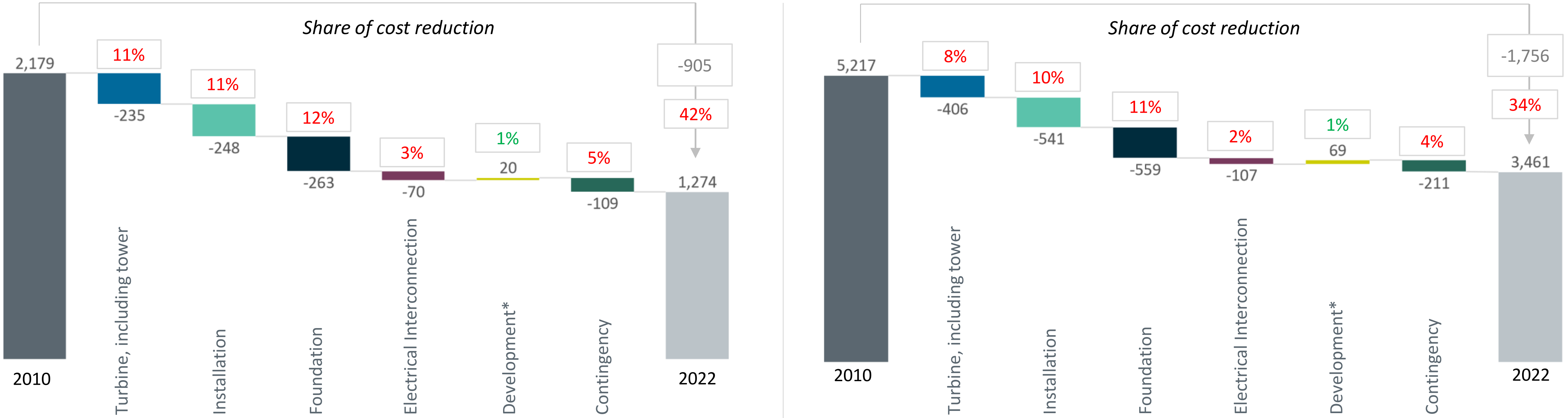
Reduction in turbine, foundation, and installations costs are the main drivers of the declining cost of wind electricity generation

Global Weighted Average Total Installed Cost of Utility-scale Solar PV

Cost Reduction by Source, 2022 USD per KW

Onshore Wind **Offshore Wind**



42% and 34% reduction in onshore and offshore systems respectively between 2010 and 2022; cost reduction trend is expected to continue

IRENA, Ducker Carlisle Analysis

* Development costs include planning, project management and other administrative costs

NOTE – due to large variation in costs between onshore and offshore wind projects as well as between various projects and geographic locations, these values should only be treated as indicative.

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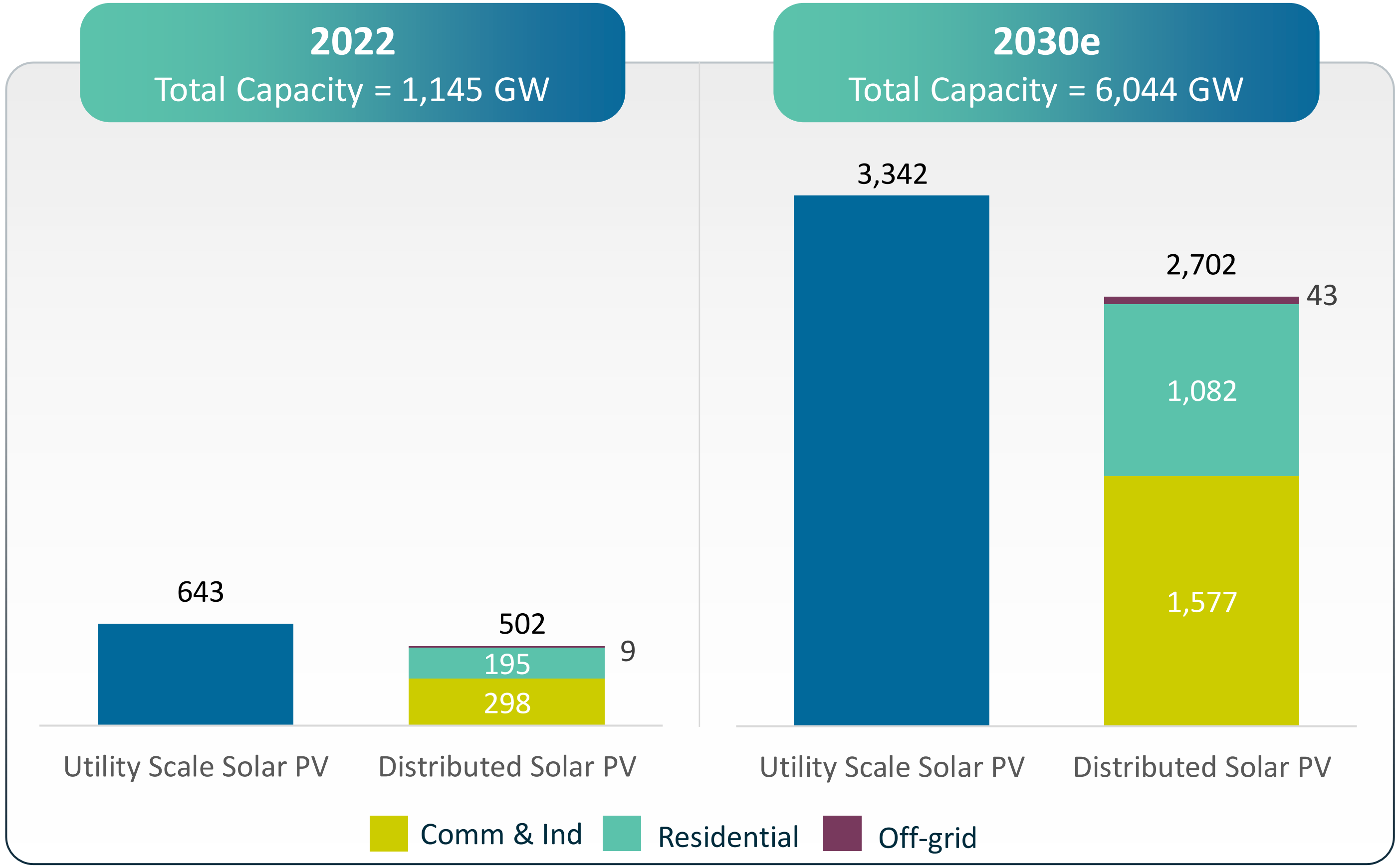
Utility-scale solar PV will provide the majority share of solar PV generation going forward

Global Grid Connected Vs. Distributed Solar PV Cumulative Capacity, GW



Utility-scale solar PV will continue to provide majority of solar PV generation

Within distributed solar PV deployment, commercial & industrial will provide 59% of capacity, and residential 39% of capacity

IEA, Ducker Analysis
* Grid connected = utility scale + distributed commercial & industrial + distributed residential
Utility-scale solar PV – large scale solar power plants, sell directly to the utility market (T&D companies), usually ground mounted
Distributed solar PV – small scale solar power plants, for on-site use / supply to grid, usually roof-top mounted

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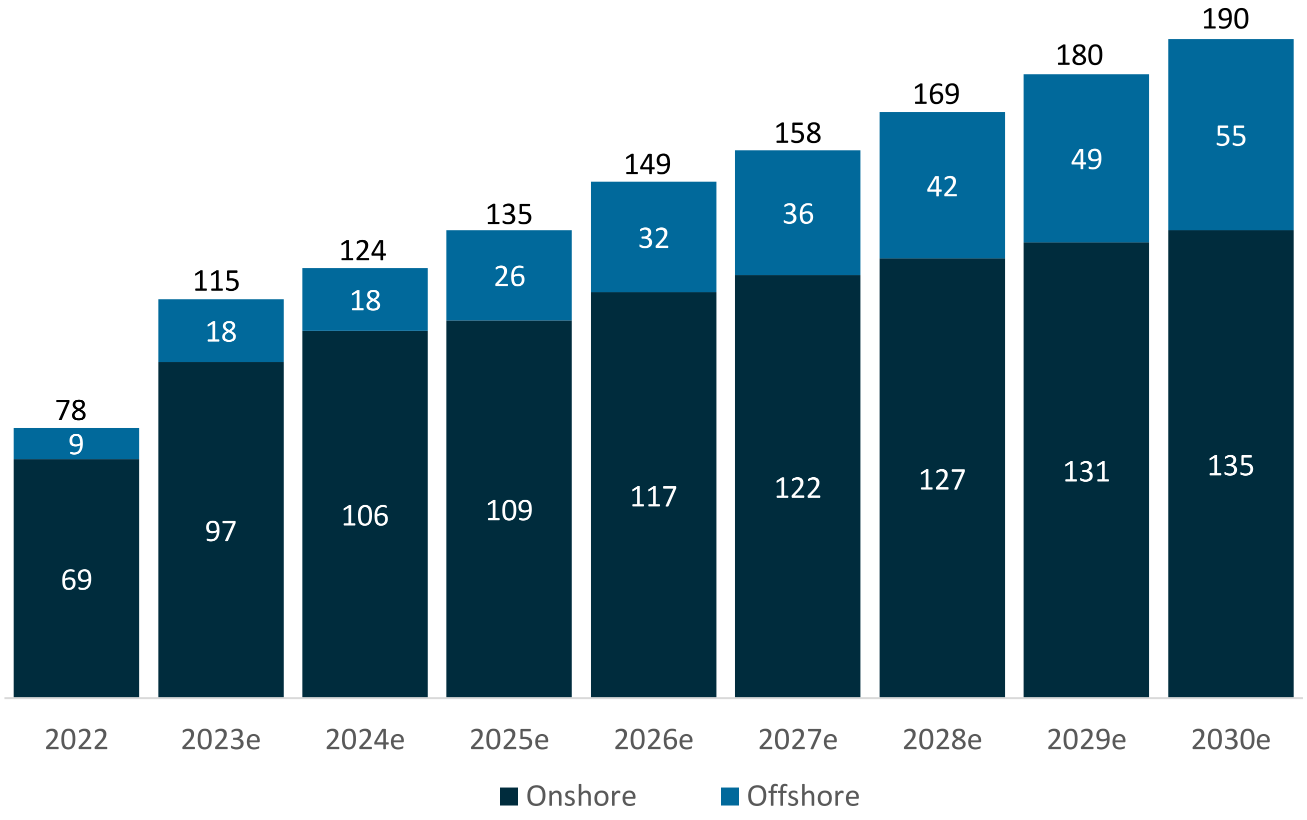
New wind power installations will grow over the coming decade, with **onshore installations accounting for the majority of GW installed**

Global Annual New Wind Power Installation, GW



Share		CAGR
2023	2030	2023-2030
16%	29%	25%
84%	71%	9%

While a smaller share, offshore wind installations are growing faster than onshore installations and will account for *29%* of GW installed in 2030

GWEC, Ducker Carlisle Analysis

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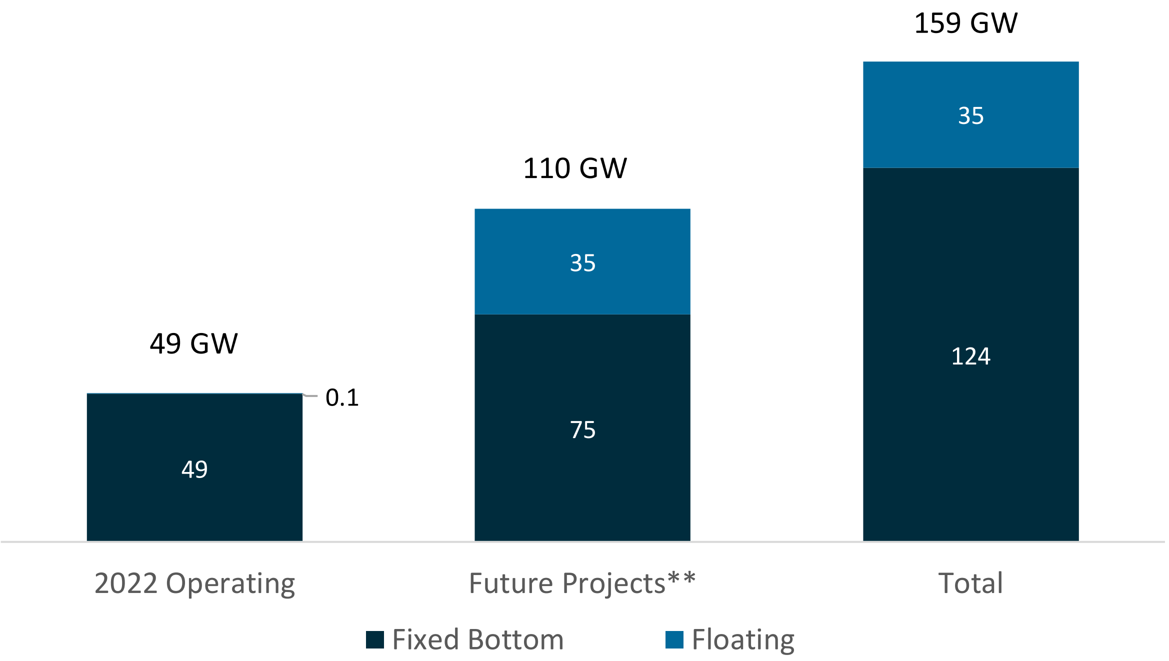
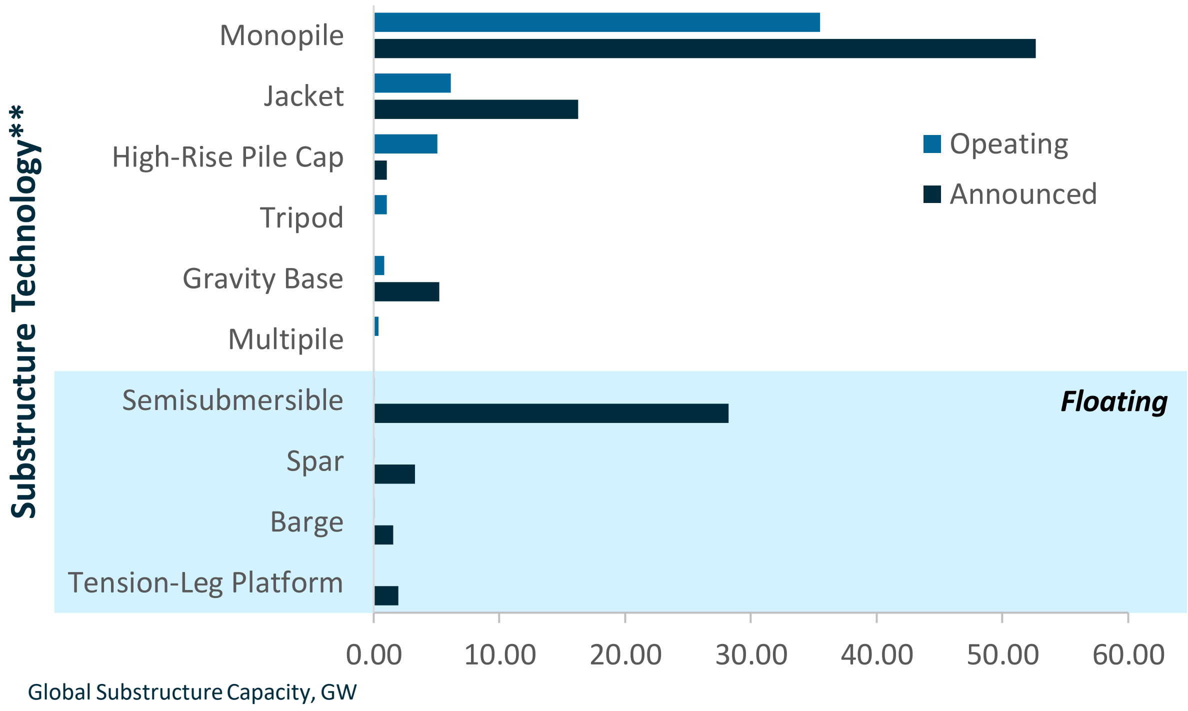
Offshore Wind: While fixed bottom substructure will remain dominant, floating substructure is expected to gain significant share going forward

Global Offshore Wind Capacity* Substructure Share, 2022



*** Proposed projects with / without commercial operation dates (CODs)*

Global Offshore Wind Capacity* by Substructure Technology, 2022



- While there is very little floating substructure today, it is ~32% of the announced future offshore wind power capacity globally
- For fixed substructure, monopile technology is most common, accounting for 72% of current capacity and 70% of announced capacity
- For floating substructure, semisubmersible is expected to be the most common technology, accounting for 81% of announced capacity

The National Renewable Energy Laboratory, US DOE, Ducker Carlisle Analysis
* Excludes unreported capacity
**See appendix for details on various offshore wind substructure technologies
Footnote: Descriptions of various offshore wind substructures are in the appendix.

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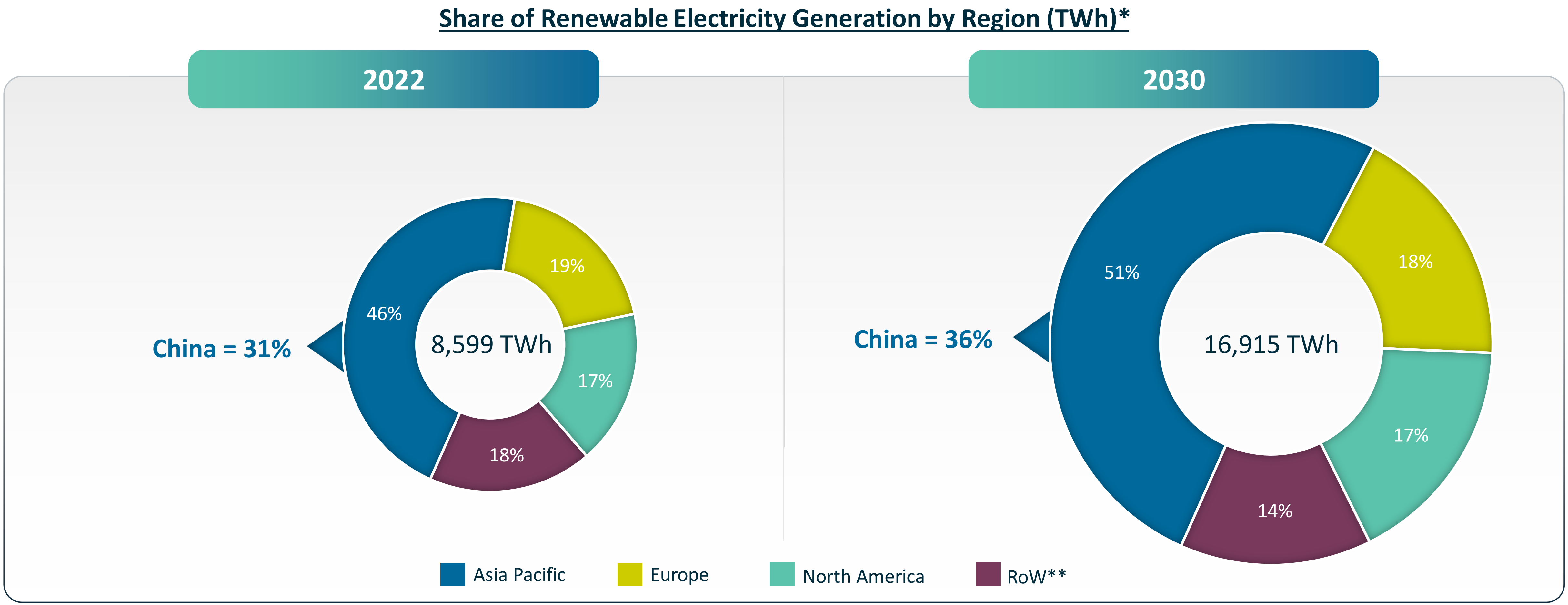
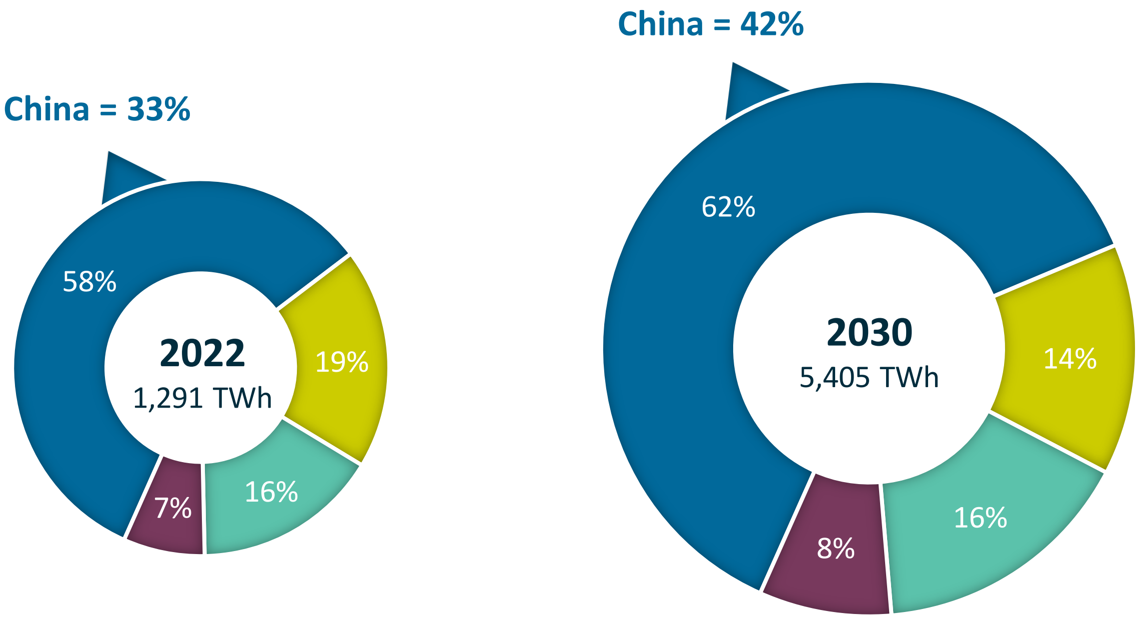
Asia Pacific region, especially China, will lead global clean electricity generation growth



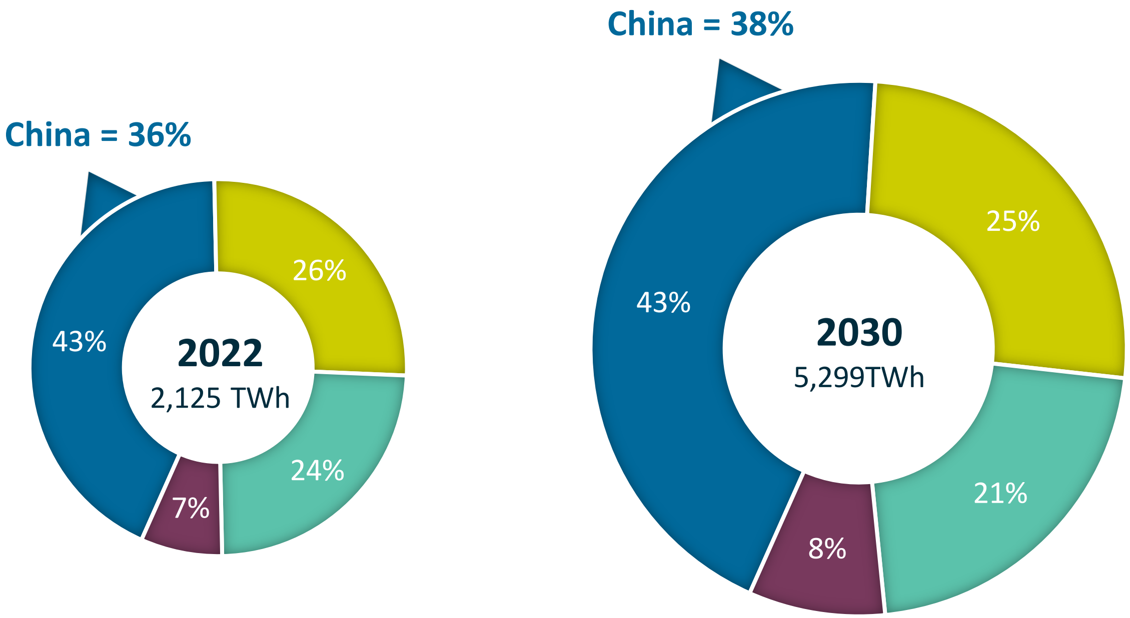
IEA World Energy Outlook 2023, Ducker Carlisle Analysis
RoW – Africa, Middle East, Eurasia, Central & South America
* Under stated policies scenario

Asia Pacific region, led by China, will dominate solar PV and wind generation

Share of Solar PV Electricity Generation by Region (TWh)*



Share of Wind Electricity Generation by Region (TWh)*



Asia Pacific | Europe | North America | RoW**

Solar PV and wind growth in Asia Pacific will be driven by rapid electrification and strong growth in new economy sectors such as high-tech manufacturing, along with government policy guidelines and ambitious clean energy targets

IEA World Energy Outlook 2023, Ducker Carlisle Analysis
* Under stated policies scenario
RoW – Africa, Middle East, Eurasia, Central & South America

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Summary Table – Stated Policies Scenario

<table>
<tr><th>Region</th><th>Sector</th><th>2030 TWh</th><th>CAGR ‘22-’30</th><th>Drivers</th><th>Headwinds</th></tr>
<tr><td rowspan="2">China</td><td>Solar PV</td><td>2,294</td><td>23%</td><td rowspan="2">• Eased project permitting process
• Identified bases for large scale deployment
• Power market reforms and green certification systems enabling utility-scale developers to command higher prices than under regulated contracts, improved project economics</td><td rowspan="2">• Grid development and integration challenges for new utility scape solar PV and wind power projects
• Economic growth concerns</td></tr>
<tr><td>Wind</td><td>1,963</td><td>13%</td></tr>
<tr><td rowspan="2">Rest of Asia Pacific</td><td>Solar PV</td><td>1,042</td><td>16%</td><td rowspan="2">• Improved grid access to commercial distributed solar PV projects in India
• Introduction of closed-envelope bidding process for wind projects in India
• Vietnam’s new electricity development plan with significant wind power capacity deployment
• Ambitious auction program of Philippines to boost utility-scale solar PV and onshore wind power growth</td><td rowspan="2">• Policy uncertainties and delayed policy responses
• Lack of access to affordable financing
• Complex and lengthy permitting process
• Grid development and integration challenges</td></tr>
<tr><td>Wind</td><td>464</td><td>15%</td></tr>
<tr><td rowspan="2">North America</td><td>Solar PV</td><td>868</td><td>20%</td><td rowspan="2">• Policy and tax credits through IRA 2022 for utility scale solar PV and wind power deployment
• Federal, state and utility level incentives for distributed solar PV deployment
• Federal lease auctions and state-level tenders to enable growth in offshore wind deployment</td><td rowspan="2">• Supply chain constraints leading to rising costs and project delays of solar PV and wind power projects
• Higher financing costs for developers with PPAs signed under low equipment and financing costs scenario
• Slow project permitting process resulting in delayed deployment</td></tr>
<tr><td>Wind</td><td>1,107</td><td>10%</td></tr>
<tr><td rowspan="2">Europe</td><td>Solar PV</td><td>753</td><td>15%</td><td rowspan="2">• Streamlined auction process, raised ceiling costs to account for higher investment costs
• Contract indexation, helping developers to hedge against inflation during the project implementation
• Alterative routes to market for developers, like, corporate PPAs</td><td rowspan="2">• Rising costs led by supply chain constraints
• Higher financing costs for developers with PPAs signed under low equipment and financing costs scenario
• Slow and complex permitting process for solar PV and wind power projects</td></tr>
<tr><td>Wind</td><td>1,304</td><td>11%</td></tr>
</table>

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Keys to Realizing the **Clean Energy, Electrified Future**

How can your company position itself in these 3 areas to create value?

Battery/Storage Technology

- Current battery storage technology is not sufficient
- Various newer and innovated technologies in consideration, including hydrogen storage and flow batteries
- Government regulation and incentives needed in short term to get new technologies off the ground

"We don't see LI ion as the longer-term solution. We've looked at flow batteries as a longer-term solution. The future will probably be a mix of LI ion, flow batteries, thermal storage, or hydrogen storage."

– VP Global BD, Major Wind Manufacturer

Grid Capacity & Resiliency

- Aging grid and related components, especially in transmission, cannot handle higher loads and more fluctuating loads in a future cleaner, more electrified world
- Investment in grid capacity and resiliency will be required

"Majority of the circuits are 30-40 years old, and as load increases and fluctuates, you have to account for the transmission level to connect the load."

– Sr. Power Systems Design Consultant

Energy Management

- Monitoring & controls for load balancing and management
- Hybrid, integrated systems including wind/solar plus storage to balance load
- Artificial Intelligence (AI) may have a significant role

"Next markets to be developed will be storage, grid, and energy management system markets. That is where complex system integration will have to come as complexity increases in the grid."

– VP Global BD, Major Wind Manufacturer

Ducker Carlisle Market Research, Ducker Carlisle Analysis

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Key Questions for Industry Leaders Affected by the Energy Transition

FOCUS

Where can and should my company play in the clean energy value chain?

Where are our capabilities the best fit, and where is the strongest opportunity for profitable growth?

VALUE PROP

What should be our offering and value proposition where we choose to play in the clean energy value chain?

PRODUCT

How should product management and new product development be directed to develop products & solutions for our differentiated offering in the clean energy value chain?

COMMERCIAL

Is our commercial organization set up to capture share and growth in the clean energy ecosystem?

How do we build awareness of our differentiated offering in the space?

What sales & commercial skills, expertise, and structure are needed to sell our value proposition?

OPERATING MODEL

What additional operating model elements need to be designed/refined to support our growth in the clean energy ecosystem?

RISK TO CORE

How does the energy transition affect our core business?

Does it create risks for our core business, and how can these risks be mitigated?

Does our core business need to be repositioned in the growing and evolving clean energy ecosystem?

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Contact Us

Kevin G. Sarb | Managing Director
Industrials Practice Lead

Kevin is a Managing Director at Ducker Carlisle, leading the Industrials Practice. He has nearly 20 years of management consulting experience and has led a multitude of engagements focused on profitable revenue growth across several industrial sectors, including building products, chemicals, climate technologies, electrical products and services, manufacturing equipment, materials processing, security solutions, and water management. Clients value Kevin's capabilities devising market- and customer-backed growth strategies and building leading commercial capabilities to maximize profitable growth and market share gains. Kevin holds a B.S. in Medical Science and History from the University of Notre Dame, an M.A. in Applied Economics from the University of Michigan, and an MBA from the University of Chicago Booth School of Business. Kevin is an active member of the Association for Corporate Growth (ACG).

For additional inquiries and further research & analysis on the global energy transition, please contact **Kevin Sarb**

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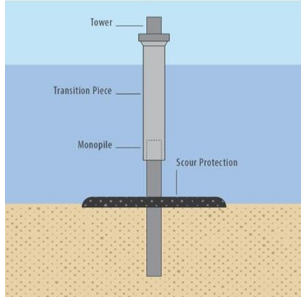
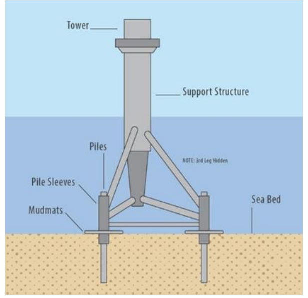
Appendix

Fixed Bottom (Nearshore) Wind Substructure Overview



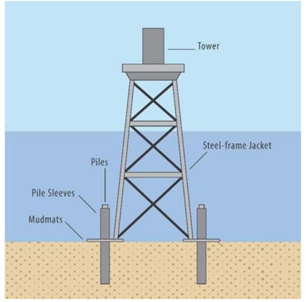
Monopile

- A single, large diameter steel pipe, known as a pile, driven into the seabed to provide vertical and lateral support.
- Monopiles are typically prefabricated and transported to the site as a single structure.



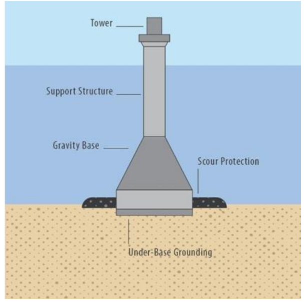
Tripod

- Tetrahedral (pyramid-shaped) space frame constructed from tubular steel members.
- The tripod base and the central column constructed onshore as a single unit, transported to the site, and lowered to the seabed.



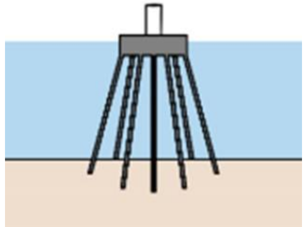
Jacket

- Lattice-truss structures, like, the offshore oil platforms.
- Built onshore and transported to the site on a flat-top barge or specialty transport vessel. Jackets can also be floated and towed to the site.



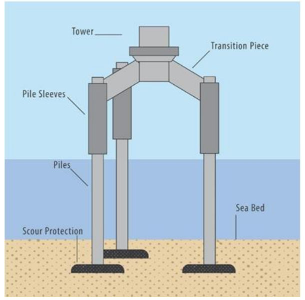
Gravity Base

- Has a wide, heavy base sitting on the sea floor and supports the cylindrical central column raising above the waterline.
- Requires more seabed preparation compared to others, is prefabricated, built onshore, and towed to the site.



High-rise Pile Cap

- Usually, made of concrete or a combination of steel and concrete.
- The cap is supported by large number of piles.



Tri-Pile / Multi-pile

- Has more than one pile, smaller in size compared to monopile leg, connected to the structure above water,
- Built onshore as separate components and transported to the site,

Bureau of Ocean Energy Management, U.S. Department of the Interior , National Renewable Energy Laboratory, U.S. Department of Energy (DOE)

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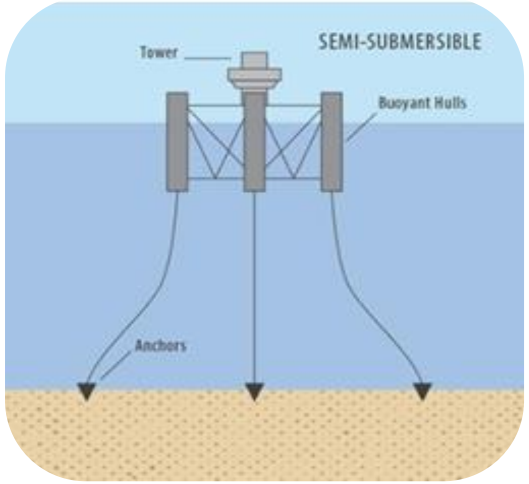
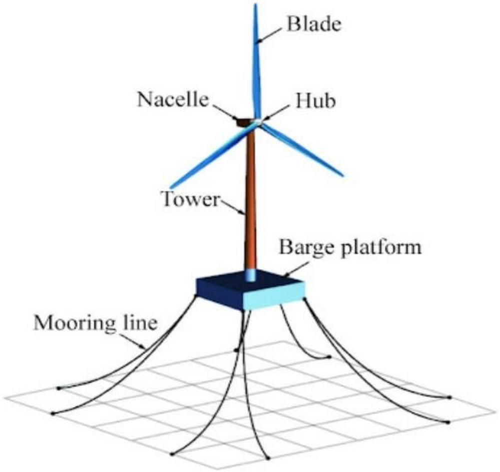
Floating Wind Substructure Overview



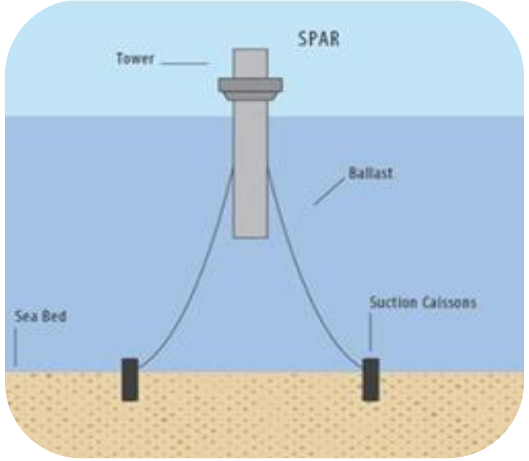
Semi-Submersible

- Have multiple columns or hulls submerged and attached together with connecting braces.
- The submerged ballast keeps the structure upright.



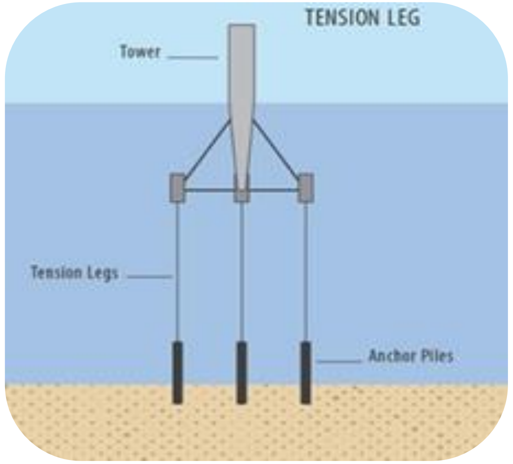
Barge

- Concept is like a ship, beam and length are larger than draught (height)
- Has a large surface area in contact with the water, which gives it stability



Spar

- A single ballasted cylinder, supporting the tower and extends below water
- Also called as spar buoys



Tension Leg Platform

- Multihull floating platform vertically moored to the seafloor by a group of tendons
- Tendons stabilize the platform, minimizes vertical movement of the structure.

Bureau of Ocean Energy Management, U.S. Department of the Interior , National Renewable Energy Laboratory, U.S. Department of Energy (DOE), China Ocean Engineering, Iberdrola

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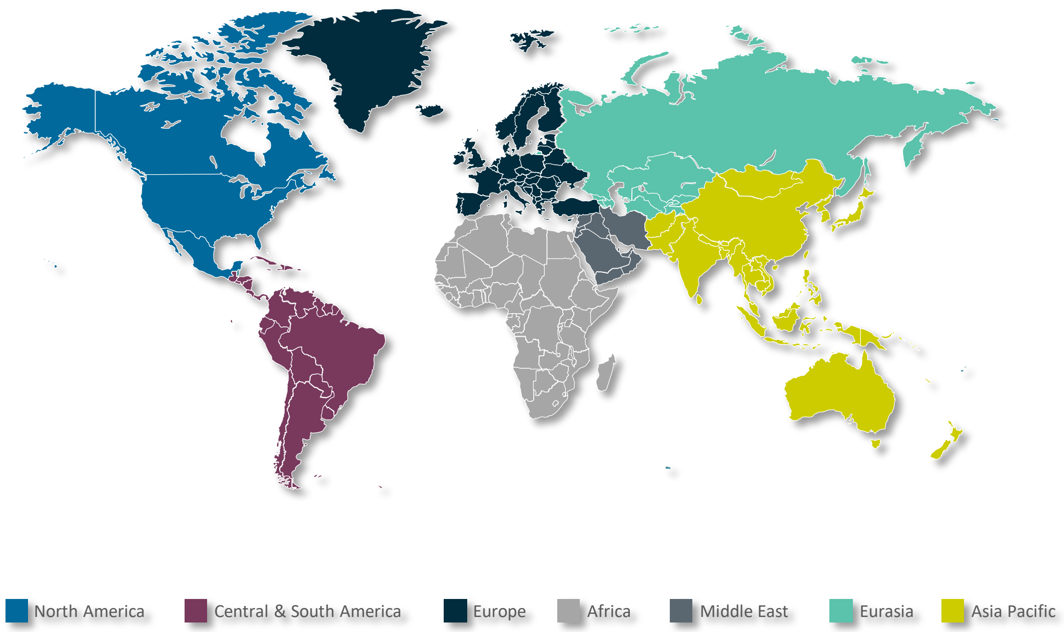
Regions



Regions	Countries Included
Asia Pacific	**Australia, Bangladesh, Democratic People's Republic of Korea (North Korea), India, Japan, South Korea, Mongolia, Nepal, New Zealand, Pakistan, The People's Republic of China (China), Sri Lanka, Southeast Asia** *(Brunei Darussalam, Cambodia, Indonesia, Lao People's Democratic Republic (Lao PDR), Malaysia, Myanmar, Philippines, Singapore, Thailand and Viet Nam)*, **Chinese Taipei**, and **other Asia Pacific countries and territories** *(Afghanistan, Bhutan, Cook Islands, Fiji, French Polynesia, Kiribati, Macau (China), Maldives, New Caledonia, Palau, Papua New Guinea, Samoa, Solomon Islands, Timor-Leste, Tonga and Vanuatu).*
Europe	**European Union** *(Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain and Sweden)*, **Albania, Belarus, Bosnia and Herzegovina, Gibraltar, Iceland, Israel, Kosovo, Montenegro, North Macedonia, Norway, Republic of Moldova, Serbia, Switzerland, Türkiye, Ukraine and United Kingdom.**
North America	Canada, Mexico and United States
Rest of the World (RoW)	**Africa** *(North Africa and sub-Saharan Africa regional groupings (Angola, Benin, Botswana, Cameroon, Côte d'Ivoire, Democratic Republic of the Congo, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Ghana, Kenya, Kingdom of Eswatini, Madagascar, Mauritius, Mozambique, Namibia, Niger, Nigeria, Republic of the Congo (Congo), Rwanda, Senegal, South Africa, South Sudan, Sudan, United Republic of Tanzania (Tanzania), Togo, Uganda, Zambia, Zimbabwe and other African countries and territories))*, **Central and South America** *(Argentina, Bolivia, Venezuela, Brazil, Chile, Colombia, Costa Rica, Cuba, Curaçao, Dominican Republic, Ecuador, El Salvador, Guatemala, Guyana, Haiti, Honduras, Jamaica, Nicaragua, Panama, Paraguay, Peru, Suriname, Trinidad and Tobago, Uruguay and other Central and South American countries and territories)*, **Eurasia** *(Caspian regional grouping and the Russian Federation (Russia))*, **Middle East** *(Bahrain, Islamic Republic of Iran (Iran), Iraq, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syrian Arab Republic (Syria), United Arab Emirates and Yemen)*.

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Scenarios Details

Stated Policies Scenario

Definition: A scenario which reflects current policy settings based on a sector-by-sector and country-by-country assessment of the energy-related policies that are in place as of the end of August 2023, as well as those that are under development. The scenario also considers currently planned manufacturing capacities for clean energy technologies.

Objectives: To provide a benchmark to assess the potential achievements (and limitations) of recent developments in energy and climate policy. The differences between the STEPS and the APS highlight the "implementation gap" that needs to be closed for countries to achieve their announced decarbonization targets.

The Stated Policies Scenario (STEPS) are exploratory, in that they define a set of starting conditions, such as policies and targets, and see where they lead based on model representations of energy systems that reflect market dynamics and technological progress.

Announced Pledges Scenario

Definition: A scenario which assumes that all climate commitments made by governments and industries around the world as of the end of August 2023, including Nationally Determined Contributions (NDCs) and longer-term net zero targets, as well as targets for access to electricity and clean cooking, will be met in full and on time.

Objectives: To show how close current pledges get the world to the target of limiting global warming to 1.5 °C. The differences between the APS and the NZE Scenario highlight the "ambition gap" that needs to be closed to achieve the goals of the Paris Agreement adopted in 2015. It also shows the gap between current targets and achieving universal energy access.

The Announced Pledges Scenario (APS) is exploratory, in that they define a set of starting conditions, such as policies and targets, and see where they lead based on model representations of energy systems that reflect market dynamics and technological progress.

Net Zero Emissions by 2050 Scenario

Definition: A scenario which sets out a pathway for the global energy sector to achieve net zero CO2 emissions by 2050. It does not rely on emissions reductions from outside the energy sector to achieve its goals. Universal access to electricity and clean cooking are achieved by 2030. The scenario was fully updated in 2023.

Objectives: To show what is needed across the main sectors by various actors, and by when, for the world to achieve net zero energy-related CO2 emissions by 2050 while meeting other energy-related sustainable development goals such as universal energy access.

The Net Zero Emissions by 2050 Scenario (NZE Scenario) is normative, in that it is designed to achieve specific outcomes – an emissions trajectory consistent with keeping the temperature rise in 2100 below 1.5 °C (with at least a 50% probability) with limited overshoot, universal access to modern energy services by 2030 and major improvements in air quality – and shows a pathway to reach them.

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