Types of Wind Power Plants (WPPs) can be categorized based on location, grid integration, scale, technology, and purpose. Here's a structured breakdown:

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1. By Location & Foundation

Type	Description	Key Features
Onshore WPPs	Installed on land (hills, plains, coasts).	• Lower installation/maintenance costs. • Shorter development time. • Subject to land use conflicts and noise regulations.
Offshore WPPs	Installed in oceans/lakes (shallow to deep water).	• Stronger/steadier winds → higher capacity factors (40–60%). • Higher CAPEX but larger turbines (6–15+ MW). • Minimal visual impact on communities.
◦ *Fixed-Bottom*	Mounted on seabed (monopiles, jackets, gravity bases).	• Viable for depths < **50–60m**. • Dominates current offshore market.
◦ *Floating*	Turbines on buoyant platforms (semi-submersible, spar, TLP) anchored to seabed.	• For depths > **60m** (80% of offshore potential). • Emerging technology (e.g., Hywind Scotland).

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2. By Grid Integration

Type	Description	Applications
Grid-Connected WPPs	Feed electricity directly into the main power grid.	• Utility-scale power generation (most common). • Requires robust grid infrastructure.
Off-Grid WPPs	Operate independently (often with storage/diesel backup).	• Remote communities/islands. • Telecom towers, rural

Type	Description	Applications
		electrification. • Paired with batteries/generators.
Hybrid WPPs	Integrated with other renewables (solar, hydro) and/or storage.	• Stabilizes intermittent output. • Microgrids or large-scale plants (e.g., wind-solar farms).

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3. By Scale & Capacity

Type	Capacity Range	Use Cases
Utility-Scale	20 MW – 2,000+ MW	National/regional power supply.
Community Wind	1 MW – 20 MW	Local ownership (towns/cooperatives).
Distributed/Small-Scale	< 1 MW	Farms, businesses, residential (<100 kW).

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4. By Technology & Design

Type	Description	Example
Horizontal-Axis (HAWT)	Rotor shaft parallel to ground (standard design).	95% of modern turbines (e.g., Vestas, Siemens).
Vertical-Axis (VAWT)	Rotor shaft perpendicular to ground (less common).	Niche applications (urban/off-grid sites).
Repowered WPPs	Old turbines replaced with modern, higher-capacity units.	Extends project life; boosts output 2–3x.

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5. Specialized Types

Type	Description	Purpose
Microgrids with Wind	Wind + solar/storage/diesel forming a self-contained grid.	Resilience for campuses/military bases.
Wind-Diesel Hybrids	Wind paired with diesel generators.	Reduces fuel costs in remote areas.
Floating Hybrids	Floating wind + wave/solar/ocean energy.	Maximizes ocean space utilization.

Comparison Table: Onshore vs. Offshore vs. Floating WPPs

Feature	Onshore	Offshore (Fixed)	Offshore (Floating)
Avg. Turbine Size	3–5 MW	8–15 MW	10–15 MW
Capacity Factor	25–45%	45–55%	50–60%+
Installation Cost	Lowest ($1.3–2.2M/MW)	High ($3–5M/MW)	Highest ($4–7M/MW)
Development Time	2–5 years	5–10 years	7–12 years
Challenges	Land access, noise	Seabed surveys, corrosion	Dynamic stability, cables

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Key Trends

- Floating Wind: Rapid growth (15+ projects underway globally).
- Repowering: Replacing 1990s/2000s turbines with >5x capacity models.
- Green Hydrogen WPPs: Dedicated offshore wind farms powering electrolyzers.
- Cross-Border WPPs: Shared offshore plants (e.g., Denmark-Germany Kriegers Flak).

Understanding these types helps optimize project design, economics, and integration into t