Generating Clean Sustainable Energy from Urban Wind Flows

A Break Through Approach to Achieving IRENA's 2030 Global Targets

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Background

Rapid urbanisation is occurring across the globe, leading to increasingly dense city environments and the concentration of growing populations within urban centres. This demographic transformation is placing greater pressure on existing energy infrastructure and driving up the demand for innovative energy solutions that can adequately support the evolving needs of city residents.

In response to these challenges, cities are presented with a unique opportunity to implement renewable Distributed Energy Resources (DER). These systems are particularly well suited to urban settings, as they have the capacity to harness the distinctive wind flows that arise from the complex, built environment. By effectively leveraging these urban wind patterns, cities can address their escalating energy requirements in a way that prioritises sustainability and environmental responsibility.

Furthermore, the adoption of urban wind energy solutions contributes directly to global renewable energy targets, including the International Renewable Energy Agency's (IRENA) goal of increasing renewable generation capacity by 6,000 GW before 2030. Through the strategic deployment of DER technologies tailored to the urban context, cities can play a pivotal role in advancing the global transition towards clean, sustainable energy.

Urban Wind Flows

As urban populations continue to grow, cities are increasingly characterised by the presence of numerous tall residential, commercial, and recreational buildings. These high-rise structures have a pronounced impact on local wind conditions, influencing the way air moves through and around the urban landscape. The interaction between wind and built environments creates significant variations in wind speeds, which can be harnessed for renewable energy generation.

Influence of Tall Buildings on Wind Patterns

Scientific research has highlighted three primary effects that tall buildings exert on wind flows within cities:

- Corner Acceleration: As wind encounters the corners of buildings, it is forced to accelerate as it splits and moves around the structure. This effect can lead to wind speeds increasing by 50% to 100% in the immediate vicinity of building corners.
- Venturi Effect: When wind is channelled through narrow passageways or spaces between buildings, it undergoes a funnel-like acceleration. This Venturi effect can result in a 25% to 44% increase in wind speeds within these constricted areas.
- Down Draught Effect: As wind strikes the face of a tall building, it is often deflected downwards towards street level. This downward movement can cause local wind speeds to rise by 40% to 120% near the base of the structure.

Combined Effects

In some areas where both the corner acceleration and down draught effects occur simultaneously, wind speeds can experience particularly significant increases. Combined, these phenomena can result in wind speeds rising by 30 to 45 kilometres per hour (equivalent to approximately 8.3 to 12.5 metres per second), presenting a valuable opportunity for micro-scale wind energy generation within urban environments.

Transport Wind Flows

Highspeed Intercity Trains

Electrified rail transportation networks are becoming increasingly common across the globe, offering improved efficiency and greater opportunities for sustainable energy integration. Currently, there are approximately 6,000 highspeed intercity trainsets in operation worldwide, with this number continuing to increase each year. These trains operate at average velocities of around 250 kilometres per hour (69 metres per second). The significant speeds achieved by these trainsets generate substantial wind flows as they move along their routes. This dynamic presents a promising opportunity for harnessing these wind flows for energy production within transport corridors.

City Commuter Trains

Alongside highspeed trains, city commuter trains also contribute to the generation of usable wind flows. Presently, around 30,000 electric trainsets are in operation globally, a figure that is steadily rising as urban and regional travel demands increase. These commuter trains are integral to modern public transport networks, typically travelling at average speeds between 50 and 80 kilometres per hour (14 to 22 metres per second). Although these speeds are lower than those of highspeed trains, the wind flows produced are still sufficient to support economic energy generation. As such, both highspeed and commuter train operations provide consistent and reliable sources of wind within urban and transit environments, which can be utilised to advance micro-scale renewable energy initiatives.

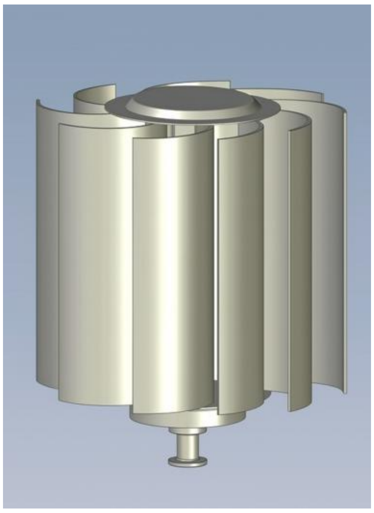
Solution

Micro Wind Turbines

Vertical axis wind turbines (VAWTs) specifically developed to capture and utilise wind speeds produced by both urbanisation and modern transportation systems. This innovative approach leverages urban wind phenomena, including downdraught and corner acceleration effects, as well as the increased wind flows generated by highspeed and commuter electric trains. By targeting these reliable and consistent wind sources within urban and transit corridors, these turbines present a practical micro-scale energy generation solution for densely built environments.

EW Turbines has patented a VAWT designed to operate effectively in these conditions. The turbine is tailored for the unique wind patterns found in built-up areas and along transport routes, providing a dependable means of generating renewable energy at the micro scale.

Turbine Technology



9 Blade Vertical Axis Turbine

The turbine technology features several advanced attributes aimed at optimising performance in urban and transport corridor settings. A key advantage is its self-starting capability, allowing the turbine to operate reliably even at very low wind speeds. This characteristic is essential for environments where wind conditions can be highly variable and unpredictable.

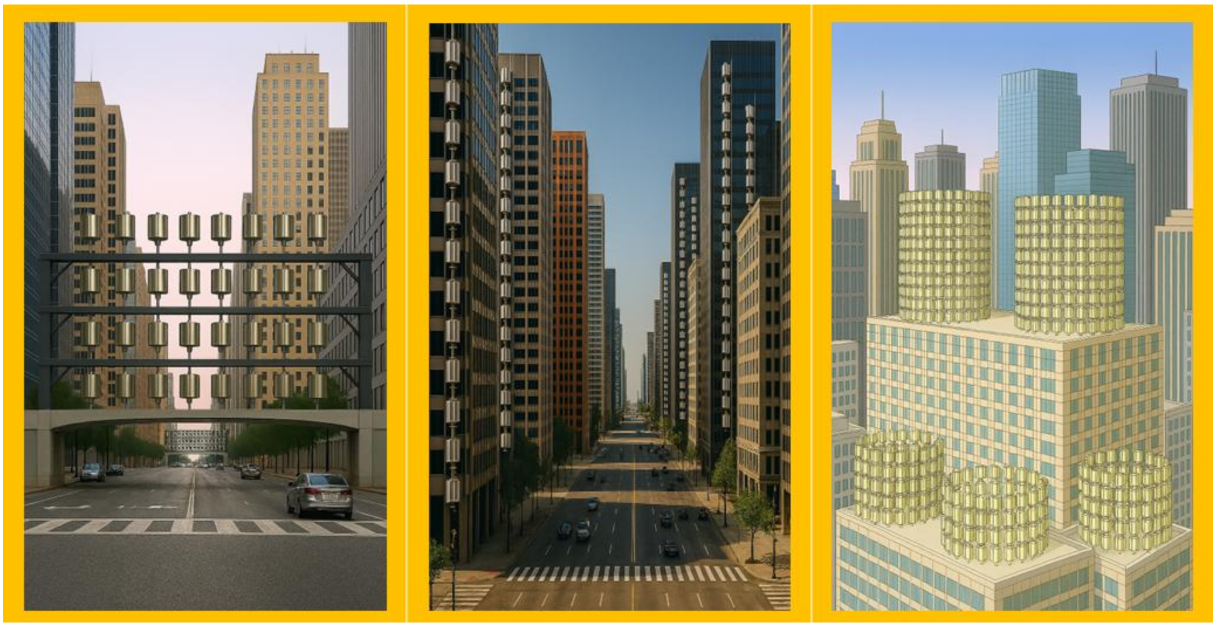
The patented blade design is engineered to maximise torque output while minimising aerodynamic drag, resulting in improved efficiency across a variety of operational scenarios. The turbine's lightweight construction and omni-directional operation further enhance its suitability for urban sites, enabling it to respond efficiently to winds from any direction—an important consideration in areas where wind direction frequently shifts.

Turbine Parameters

EWT600 mm	EWT900 mm	EWT1200 mm
350w @ 300rpm	500w @ 200rpm	1200w @ 200rpm
500w @ 350rpm	750w @ 250rpm	1500w @ 220rpm

For comprehensive technical specifications and further details, refer to https://ewturbines.com/turbines/

Urbanisation



Wind Energy Optimisation in Urban Environments

Optimising wind energy generation in urban settings requires careful consideration of the unique environmental dynamics that emerge in densely populated, high-rise precincts. Factors such as downdraughts, venturi acceleration, and funnelling effects, all arising from the architectural layout, can be leveraged to enhance energy extraction. Strategic placement of either cylindrical or bridge arrays using EW Turbines 1200mm VAWT turbines harness these synergistic effects.

Installing turbine arrays on buildings with heights ranging from 10 to 200 metres, urban wind energy systems can realise significant improvements in their capacity factor. This approach maximises the potential for energy capture by targeting locations where wind flows are naturally intensified by the built environment.

Generation Capacity

Micro turbines, with a nameplate size of 1.5kw, can deliver substantial energy output when deployed across an urban envelope. The table below presents the nameplate capacity, measured in gigawatts (GW), for four-tier arrays distributed throughout a 5km square urban area. The further tables represent the contribution of these systems towards meeting larger renewable energy targets, such as those set by IRENA's 6,000 GW goal.

Urban Envelope Coverage	Nameplate Capacity (GW)
25%	3.75
20%	3.00
15%	2.25
10%	1.50
5%	0.75

Percentage Contribution to IRENA Targets

25% Envelope

No. Cities	50	100	250	400	600	800
IRENA %	3%	6%	16%	25%	38%	50%

20% Envelope

No. Cities	50	100	250	400	600	800
IRENA %	3%	5%	13%	20%	30%	40%

15% Envelope

No. Cities	50	100	250	400	600	800
IRENA %	2%	4%	9%	15%	23%	30%

10% Envelope

No. Cities	50	100	250	400	600	800
IRENA %	2%	3%	6%	10%	15%	20%

5% Envelope

No. Cities	50	100	250	400	600	800
IRENA %	1%	1%	3%	5%	8%	10%

Capacity Factors

Urban Wind Speed Data Analysis Methodology

The analysis utilises population and wind speed data to assess the potential for wind energy generation in urban environments. Specifically, data was sourced from WorldPopulationReview.com, targeting the 800 most populated cities worldwide, with further detail provided in Appendix 1 – City Wind Speeds.

To ensure robust and accurate insights, the city dataset was cross-referenced with average annual wind speed figures from globalwindatlas.info, focusing on the top 500 cities by population. This process enabled a comprehensive comparison of urban locations with significant wind energy potential.

Recognising the unique characteristics of urban landscapes, an adjustment was made to account for the combined effects of corner acceleration and downdraught (CA/DD). These phenomena, caused by high-rise buildings, can significantly impact local wind speeds and, consequently, the capacity factors achievable by wind turbine installations. Applying the CA/DD adjustment provides a more realistic representation of the wind resource available within densely built-up city environments.

Current Utility Scale Capacity Factors

The operational efficiency and energy output of utility-scale renewable energy sources can be assessed by examining their capacity factors. These capacity factors represent the ratio of actual energy output over compared to the maximum possible output under continuous full-power operation. Notably, different renewable technologies exhibit varying capacity factors due to their inherent characteristics and the influence of environmental conditions.

Onshore Wind

Onshore wind installations display capacity factors that typically range from 22% to 45%. The variation within this range is primarily determined by local wind conditions, advancements in turbine technology, and the careful selection of installation sites. Locations with favourable wind resources and optimised turbine placement tend to achieve higher capacity factors, resulting in more efficient energy generation.

Offshore Wind

Offshore wind farms generally achieve higher capacity factors compared to their onshore counterparts, with values ranging from 29% to 52%. This increase is largely attributed to the more consistent and stronger wind resources available over open water, which contribute to steadier and more reliable energy production.

Solar

Utility-scale solar power plants commonly operate with capacity factors between 24% and 26%. These figures reflect the variability of solar resources, including fluctuations in sunlight due to weather, seasonal changes, and other environmental factors. As a result, solar capacity factors tend to be lower and less variable than those observed in wind energy installations.

Micro Turbine Capacity Factors

Wind Speed (m/s)	9	10	11	12	13	14	15
600mm	21%	29%	39%	51%	65%	81%	100%
900mm	21%	29%	39%	51%	65%	81%	100%
1200mm	21%	29%	39%	51%	65%	81%	100%

Analysis of Capacity Factors at Different Installation Heights

The analysis conducted examines the average capacity factors for 1200 mm, 1.5kw wind turbine arrays when installed at various heights. This assessment specifically focuses on installations across the 500 most populous cities, ensuring that the results reflect a broad and representative sample of urban environments.

A key aspect of this evaluation is the application of the CA/DD (Corner Acceleration/Down Drought) effect, which accounts for the unique wind acceleration phenomena observed in densely built-up areas. By incorporating this factor, the resulting capacity factors provide a realistic measure of the efficiency gains that can be expected from urban wind acceleration.

In summary, these findings present a comprehensive understanding of how installation height influences the potential performance of wind turbine arrays in large urban centres, highlighting the impact of urban wind acceleration on overall efficiency.

Largest 500 Global Cities Average

Installation Height (metres)	10	50	100	150	200
Ave Wind Speed (m/s)	2.18	3.89	4.75	5.32	5.75
CA/DD Effect (m/s)	12.50	11.46	10.42	9.37	8.33
Adjusted Wind Speed (m/s)	14.68	15.35	15.17	14.69	14.08
Capacity Factor (%)	90%	100%	100%	90%	80%

Tokyo, Japan (Most Populated City) Average

Installation Height (metres)	10	50	100	150	200
Ave Wind Speed (m/s)	3.62	5.26	5.91	6.49	6.84
CA/DD Effect (m/s)	12.50	11.46	10.42	9.37	8.33
Adjusted Wind Speed (m/s)	16.12	16.72	16.33	15.86	15.17
Capacity Factor (%)	100%	100%	100%	100%	100%

Micro Turbine Annual Generation Analysis

Overview

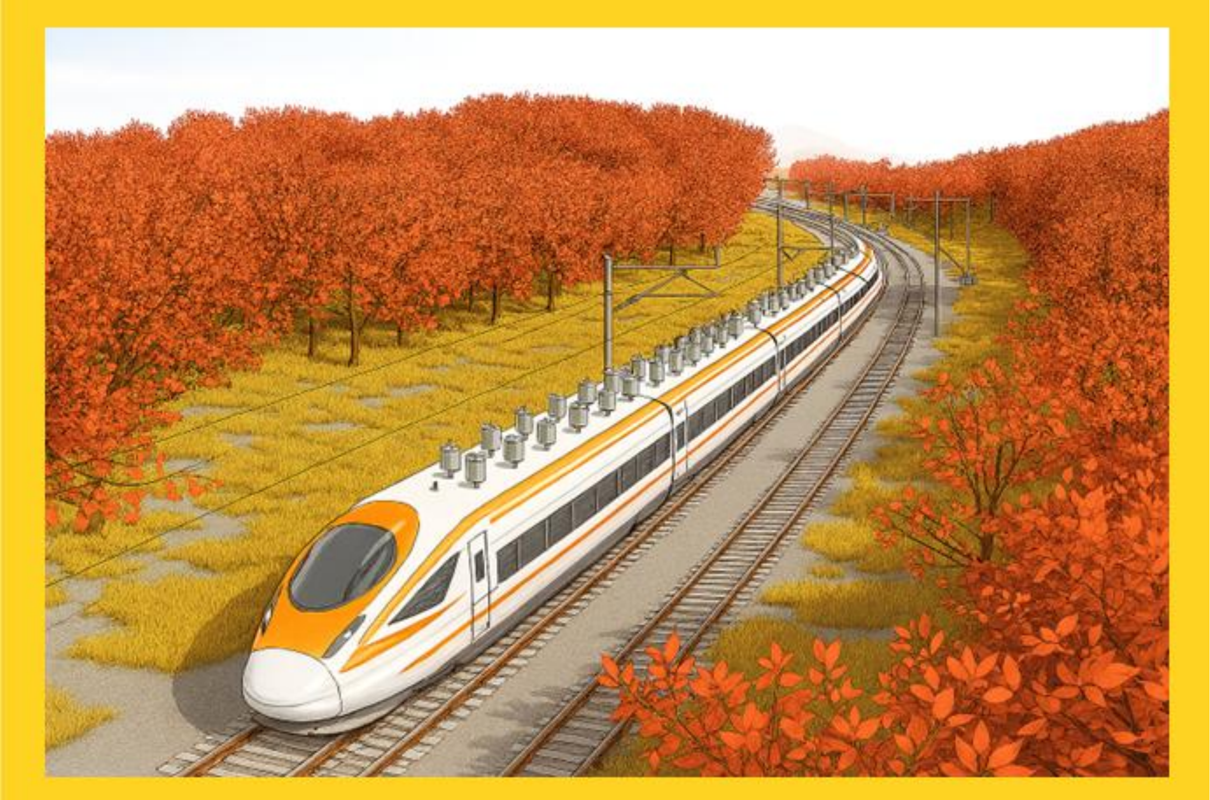
The following section provides an overview of the annual energy generation for micro turbines with a rotor diameter of 1200mm and 1.5kw, specifically within a 5km square urban envelope. The data is presented in gigawatt-hours (GWh) and illustrates how energy output varies according to urban envelope coverage and generation capacity factors.

Annual Energy Generation Metrics

The table below summarises the total electricity produced over the course of a year. The figures are based on the proportion of the urban envelope covered and the percentage of time the generation asset operates at the specified capacity factor. This approach enables a clear understanding of the relationship between operational performance and spatial deployment in urban settings.

Urban Envelope Coverage	Capacity Factor							
	30%	40%	50%	60%	70%	80%	90%	100%
25%	9,855	13,140	16,425	19,710	22,995	26,280	29,565	32,850
20%	7,884	10,512	13,140	15,768	18,396	21,024	23,652	26,280
15%	5,897	7,862	9,828	11,794	13,759	15,725	17,690	19,650
10%	3,942	5,256	6,570	7,884	9,198	10,512	11,826	13,140
5%	1,971	2,628	3,285	3,942	4,599	5,256	5,913	6,570

Transportation



Highspeed Electric Rail Overview

Highspeed electric rail systems have become an increasingly prominent feature in transportation infrastructure across the globe. Presently, there are approximately 6,000 highspeed trainsets in operation, with this figure steadily growing each year. These trainsets are integral to contemporary transport networks, contributing to improved efficiency while facilitating sustainable energy practices.

Operational Characteristics

On average, a highspeed trainset comprises 10 carriages, each measuring 25 metres in length. These trainsets typically operate for around 1,250 hours per year, maintaining speeds of 250 kilometres per hour or higher. This combination of extended service hours and high operational velocity underscore their importance in meeting modern travel demands efficiently.

Energy Generation Capabilities

Each highspeed trainset can be equipped with an installed capacity of 165 kilowatts. Operating at a capacity factor of 100%, a single trainset will generate 210 megawatt-hours (MWh) per annum. When considered collectively, all 6,000 trainsets worldwide have the potential to generate a total of 1,260 gigawatt-hours (GWh) per year. This substantial energy generation further highlights the role of highspeed electric rail in supporting sustainable transportation solutions.

Commuter Electric Rail Overview

Commuter electric rail networks play a vital role in meeting the daily transport needs of urban and regional populations across the globe. At present, there are approximately 30,000 commuter electric trainsets in operation worldwide, a figure that continues to grow each year in response to increasing demand for efficient and reliable public transport solutions. These trainsets form the backbone of many modern public transport systems, facilitating seamless connections within cities and metropolitan regions, as well as linking outlying suburbs and communities.

Operational Characteristics

Typically, each commuter electric train is comprised of six carriages, with each carriage measuring 20 metres in length. These trains are designed for frequent service, operating for an average of 2,250 hours annually. Maintaining average speeds of 50 kilometres per hour or greater, they are well-suited to the stop-start nature of urban and regional routes. The consistent and extended operational hours reflect their essential function in accommodating the high volume of passengers who rely on public transport for daily commuting and travel.

Energy Generation Capabilities

Each commuter electric trainset can be equipped with an installed capacity of 60 kilowatts. When operating at a capacity factor of 80%, a single trainset generates 1,800 megawatt-hours (MWh) of electricity per year. On a global scale, the combined output of all 30,000 commuter trainsets amounts to a substantial 5,310 gigawatt-hours (GWh) annually. This significant electricity generation potential further underscores the contribution of commuter electric rail to sustainable energy practices and the broader transition towards environmentally responsible transportation systems.

Other Generation Scenarios

Deployment of Individual Wind Turbines

Individual turbines are well-suited for placement in coastal and mountainous regions, where prevailing wind conditions support efficient energy generation. These sites are selected to ensure that average wind speeds are consistently high enough to make electricity production economically viable.

The strategic location of turbines in these areas allows operators to take advantage of natural wind flow enhancements. In mountainous settings, the passage of airstreams over peaks and ridges increases wind velocity, thereby boosting the turbines' energy output. Similarly, coastal zones benefit from wind speed variations that occur due to differences in surface temperatures between bodies of water and adjacent land. These effects combine to maximise the potential generation from each installation, contributing to the overall efficiency and effectiveness of wind energy infrastructure.

Cost Comparison and LCOE Advantages

Levelised Cost of Energy (LCOE) Comparison

Recent surveys conducted by the International Renewable Energy Agency (IRENA) provide insight into the average Levelised Cost of Energy (LCOE) for various utility scale renewable technologies. The LCOE represents the average cost per megawatt-hour (MWh) of electricity generated over the lifetime of a power plant, incorporating both capital and operational expenses.

Utility Scale Renewable Energy

- Onshore Wind: The average LCOE for onshore wind projects is between USD$33 and USD$48 per MWh.
- Offshore Wind: Offshore wind installations have a higher average LCOE at approximately USD$89 per MWh, reflecting the increased engineering and maintenance challenges of offshore environments.
- Solar: Large-scale solar projects demonstrate an average LCOE ranging from USD$39 to USD$44 per MWh, making solar one of the more cost-effective options among utility scale renewables.

Micro Turbine Installations

Micro turbine solutions, such as the 1.5 MW system evaluated by EW Turbines, offer distinct advantages due to their design features. These systems have a projected operational life exceeding 20 years, utilise omni-directional operation, and employ direct drive mechanisms to reduce maintenance requirements. Additionally, their ability to function efficiently at higher capacity factors—especially in areas with increased urban wind speeds—further enhances their cost-effectiveness.

As a result, the LCOE for micro turbine installations can be up to 50% lower than that of utility scale generation. This significant reduction in energy cost is particularly notable when the micro turbines capitalise on higher capacity factors.

Forecasts for the LCOE of micro turbine solutions at varying capacity factors are provided in the following section.

Capacity Factor	30%	40%	50%	60%	70%	80%	90%	100%
LCOE (USD)	$51	$41	$35	$31	$28	$25	$24	$21

Additional LCOE Benefits

The turbine system is designed to connect directly to the distribution grid, which eliminates the need for high voltage transmission networks. By removing the necessity for these networks, further reductions in the Levelised Cost of Energy (LCOE) become possible.

Transmission Losses

Transmission losses typically account for 5 to 10 percent of total energy output. By eliminating these losses, the amount of required generation capacity is reduced, which in turn lowers the capital costs needed for comparable energy production.

Transmission Network Costs

Eliminating the transmission network results in significant cost savings, both in construction and ongoing maintenance. The typical construction costs for transmission networks are as follows:

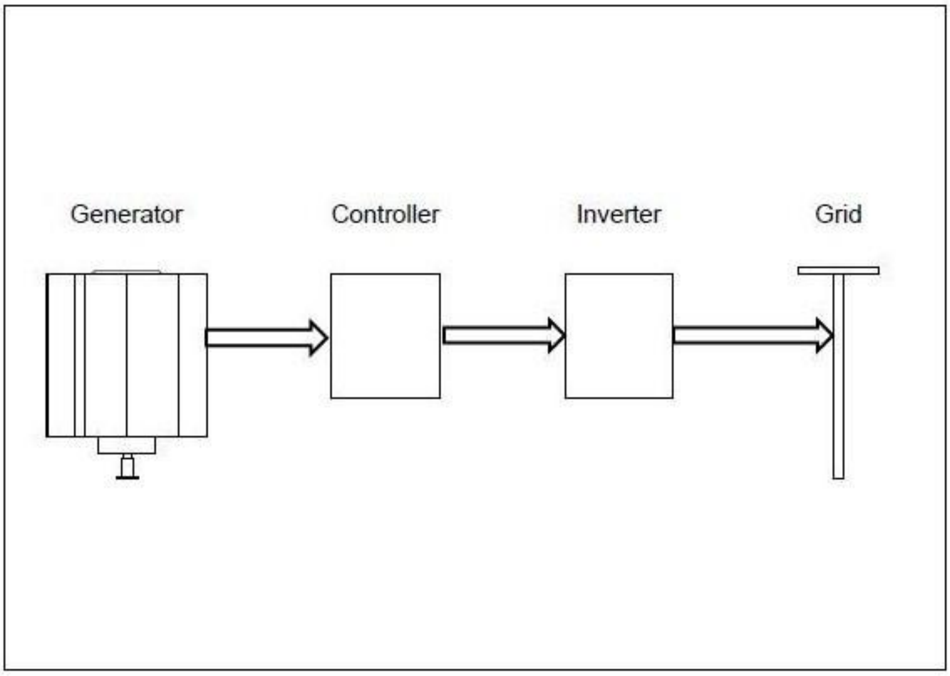
- Overhead network: $150,000 per kilometre
- Underground network: $1.5 million per kilometre
- Subsea network: $2.5 million per kilometre

Maintenance costs are also reduced, with typical figures outlined below:

- Overhead network: $3,000 per kilometre
- Underground network: $7,000 per kilometre
- Subsea network: $10,000 per kilometre

Further Development

The current technological configuration, as depicted in the accompanying diagram, employs a one-to-one-to-one ratio between the generator, controller, and inverter. This means that for each generator installed, there is a dedicated controller and inverter, resulting in a direct and exclusive relationship among these three key components.



Research Directions for Improving LCOE

To further reduce the Levelised Cost of Energy (LCOE) and enhance system efficiency, two primary fields of research have been identified as priorities:

1. Development of Combined Controller/Inverter Systems
    - Investigating the integration of the controller and inverter functions into a single unit could streamline operations, potentially reducing both hardware costs and system complexity. This research direction aims to eliminate redundancies, simplify maintenance, and improve overall reliability.
2. Implementation of Multiple Turbines per Controller/Inverter
    - Exploring the feasibility of connecting multiple turbines to a single controller/inverter unit may allow for more efficient use of resources. This approach could lead to cost savings through economies of scale, reduce the number of components required, and optimise the management of turbine arrays.

Conclusion

Global Wind Energy Potential for Urban Environments

Meeting international targets for mitigating global warming requires a substantial increase in renewable energy deployment. According to the International Renewable Energy Agency (IRENA), an additional 6,000 GW of renewable energy capacity needs to be installed worldwide by 2030. This underscores the urgency and importance of scaling up clean energy solutions across the globe.

Role of Urban Wind Energy

Urban environments present a significant opportunity to contribute to this renewable energy target. Analysis indicates that if all 800 cities listed in Appendix 1 – City Wind Speeds were to each install 3.75 GW of wind energy capacity, these urban installations would collectively provide half of IRENA's projected additional capacity. The total capital investment required for this effort is estimated at USD$5 trillion.

Importantly, achieving this level of urban wind energy deployment would deliver this capacity at a lower Levelised Cost of Energy (LCOE), demonstrating both the efficiency and cost-effectiveness of leveraging wind energy within city settings.

Author

About the Author

Owen Ebbutt is the founder of EW Turbines, a company dedicated to advancing technology and solutions in the renewable energy sector. EW Turbines places a particular emphasis on reducing the Levelised Cost of Energy (LCOE) and promoting sustainable practices within its operations.

Collaboration and Strategic Partnerships

EW Turbines actively seeks collaboration opportunities with organisations and government bodies that possess a deep understanding of renewable energy technology and the capability to fully realise its potential. Through strategic partnerships, EW Turbines aims to encourage the widespread adoption of its renewable energy solutions and maximise their overall impact.

Contact Details

For further information regarding EW Turbines' technology and collaboration opportunities, contact Owen via email at owen@ewturbines.com

Annexures

Appendix 1 – City Wind Speeds

Appendix 1 - City
WInd Speeds.xlsx