A Highly Efficient Wind and Water Turbines With Wind-Lens Technology & Offshore Floating Renewable Energy Farm

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Part 1. What is the Wind-Lens Turbine?

Part 2. Ongoing Projects and Future Plans
If one can accelerate the local wind speed by capturing and concentrating the wind with some mechanism, there appears hope for utilizing the wind power in a more efficient way. This concept of accelerating the wind was named the “WindLens” technology.
Part 2A. Development of a collection-acceleration device for wind

Concentration of wind energy

A structure which shrouds a wind turbine

Typical configurations of hollow-structure models
Concentration of wind (Increase in wind velocity)

- Nozzle type → Wind is decelerated at the entrance
- Diffuser type → Wind is accelerated at the entrance
Development of a wind turbine with brimmed diffuser for shorter shroud

Improvement of acceleration performance by the addition of periphery appendages

② Idea of a ring-type plate which forms strong vortices (It is called “brim”)

A collection-acceleration device for wind (Inlet shroud + Diffuser + Brim)

WindLens

A wind turbine with windlens
Flow around a diffuser shroud with brim

Vortex field and streamlines by a 2-D numerical simulation

The role of brim is to make vortex behind a shroud
The mechanism of acceleration of wind using a wind lens

Low-pressure region due to strong vortices
Wind flows into this region

Wind flow
Brim
Wind turbine
Diffuser shroud
Field experiment for a 500W windlens wind turbine

Conventional (bare) wind turbine

four times increase

Power Curve of Cw=1.4
Field Data (10min. ave.)
W.T. only
The features of a wind turbine with brimmed diffuser (windlens):

- Two to five times increase in output power as compared to conventional wind turbines
- Brim-based yaw control
- Significant reduction in wind turbine noise
- Improved safety
- Improved cut-in velocity
- Reduction in interference with Doppler radar
Aerodynamic noise → Tip Vortex

Red area indicates noisy portions

Tip vortex
Longitudinal vortex

Generate noise and drag
Trace of tip vortices in wind tunnel exp.

Vortex strength: **Red** and **Blue**

**Upper:** Windlens turbine

**Lower:** Wind turbine only

- Z=48mm
- Z=128mm
- Z=208mm
Conventional wind turbine (rotor only)

- Tip vortices flow in the downstream direction
- Tip vortices are longitudinal vortices and remain in the far downstream

Origin of aerodynamic noise
Numerical Simulation by DNS

Long Diffuser Windlens Turbine

- Diffuser Shroud
- Tip Vortex
- Induced Vortex
- Interference
Field Experiment for Windlens Turbine Noise

Almost the same sound levels in both operation and rest for weak and strong winds

Test site in Momochi-hama park in Fukuoka
With almost 30 million inhabitants and a frenzied pace of life, Tokyo could easily lay claim to the title of the world’s most stressful city. But help is now at hand for Tokyoites who feel their energy levels have become dangerously depleted. The centrally situated Royal Park Hotel has two rooms where the lighting, the temperature, and the music all work in concert to send guests off into a deep, revitalizing sleep.

It’s no surprise to find that the rooms are fully booked. What is startling is the fact that the technology behind this system originated with research on sleep-quality measuring sensors funded by Japan’s New Energy and Industrial Technology Development Organization (NEDO). Established in 1980, after the second oil shock, NEDO’s original mission was to promote research into alternative energy and reduce Japan’s dependency on imported oil. Since 1988, NEDO has been promoting international joint research, through grants of over ¥100 million for some 190 plus projects.

Solar technology is one field where NEDO’s backing has made a clear difference. Of the world’s top five manufacturers of solar panels, four are Japanese, and Japan installed more solar cells than Germany and the U.S.A., each year from 1997 to 2004, with a total of almost 200,000 Japanese households now using them. In 2005 Japan generated 1.42 gigawatts of electricity from solar power—equivalent to burning 348,000 kiloliters of oil. Not only is solar clean, but a whole industry has sprung up to produce the technology and materials for solar cells. There have also been some unexpected spin-off effects. “An amorphous solar cell is basically a layer of silicon spread over a sheet of glass, and similar procedures can be applied with liquid crystal display TVs,” says Masamichi Hashiguchi, NEDO’s director general of R&D promotion. “Then there’s wire saw technology. Originally created to slice the silicon used in solar cells, it’s now used in the semiconductor production process.”

Unlike conventional wind turbines, the wind lens is small and quiet so it can be placed in densely inhabited areas.

In Ota City in Japan’s Gunma Prefecture, 550 households get a proportion of their energy needs from solar power. But Japan faces a unique set of problems. “The majority of wind turbines are made in Europe,” explains Hashiguchi. “And weather conditions there are different from Asia. Here we have not just typhoons, but lightning storms.”

So rather than fund wind-turbine research, a technology which has already been successfully commercialized, NEDO is developing standards to help adapt wind turbines to Asia’s unique climatic needs. It’s also researching better battery storage and improved grid connections—both essential with an energy source as inherently unstable as wind.

Together with Kyushu University and Torishima Pump Manufacturing, NEDO is working on a promising new source of wind power: wind lens microturbines, so-called because they gather wind as a lens collects and focuses light. Although much smaller than giant turbines, wind lenses have the benefit of being able to swivel to face the wind, and produce none of the noise that is so stressful for people living near wind farms. “The number of suitable places—empty spaces with strong winds—where large-scale turbines can be installed is limited,” explains Hashiguchi. “So the wind lens is about to come into its own. It’s small and can be used in cities where wind turbines are out of the question.”

Producing one kilowatt of energy (the average family uses four kilowatts), measuring about a meter across, and costing around ¥9,000, Hashiguchi sees wind lenses—in combination with solar cells—supplying the energy needs of the household of the future.

As our supply of fossil fuels dwindles, we can all sleep that much sounder knowing that NEDO is working on practicable energy solutions for the 21st century.
Part 2B: Development of very compact “windlens” (Compact brimmed diffuser shroud)

Problems in the application to larger wind turbines

- Increase in structural weight
- Shorter windlens
- Increase in wind load
- Smaller brim
Output performance with compact brimmed diffuser length \( L_t/D \)

Performance Curves for C-type diffusers with different length 
\((h=0.1D, U_o=8m/s)\)
$C_{w_{\text{max}}} \text{ with C-type diffuser length } Lt/D$

If $Lt/D > 0.1$

2-3 times as large as a bare wind turbine is expected

W.T. only

- $C_{w_{\text{max}}}$ with $h=0.05D$
- $C_{w_{\text{max}}}$ with $h=0.10D$
- $C_{w_{\text{max}}}$ with $h=0.15D$
- $C_{w_{\text{max}}}$ with $h=0.20D$

2.1 times
2.3 times
2.6 times
2.8 times
Wind speed distribution in front of the rotor (acceleration factor $K(=u_x/U_0)$)

- Long diffuser (prototype)
- Compact diffuser (B ii)
- Wind turbine only
3kW WindLens Turbine (Field Test)
(Rated Wind Speed 10m/s, Rotor dia. of 2.5m)

Cw* = 0.54 based on the lens diameter

2.5 times Increase & Very quiet

Conventional Wind Turbine

Windlens turbine
Mechanism of Wind-lens Turbine

Concentration of Wind Energy

1. Brimmed diffuser surrounding rotors
2. Strong vortices generated
   - The vortices cause low pressure region
3. Low pressure draws wind
   - 1.4 times increase in wind speed

Power output is proportional to wind speed by cubed \( (P \propto V^3) \)

1.4 times increase in wind speed leads to 3 times increase in power output
Birds Striking Free

6cm mesh size and the diameter of 5mm

Wind speed (m/s)

Power output (W))

Mesh

Without mesh

Mesh in front

Mesh in back
For the purpose of the practical application to small to mid-size wind turbines, we developed a very compact brimmed diffuser shroud (compact windlens structure).

- Two-threefold increase in output power as compared to conventional (bare) wind turbines due to concentration of wind energy.

- Quiet and safe
Part 2: Ongoing Projects

Small WindLens turbine projects (1-3kW)
- Wind energy utilization in a city which faces the sea

Larger WindLens turbine projects (>100kW)
- 100kW mid-size windlens turbine
- Offshore wind farm using windlens turbines
Micro-siting of windlens turbines in Fukuoka city which faces the sea using Riam-Compact (LES)

Fukuoka city
- faces the sea in the north
- has a long seashore which is suitable for wind energy utilization
Wind Pattern at a height of 15m
By RIAM-COMPACT (LES Numerical Tool)

Horizontal resolution of 2.5m

Momochi-hama Seaside Park, Fukuoka City
Installation of wind measurement pole
Fukuoka city

3kW Windlens turbines on the seashore

Momochi-hama park

2009.12.7
Small WindLens turbine (3kW)

Annual Electric-Generating Capacity

<table>
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<tr>
<th>Average Annual Wind Speed [m/s]</th>
<th>Power [kWh/year]</th>
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<tbody>
<tr>
<td>2.0</td>
<td>393</td>
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<tr>
<td>3.0</td>
<td>1,325</td>
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<td>4.0</td>
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<td>7.0</td>
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<tr>
<td>8.0</td>
<td>16,825</td>
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3600kWh/year for a standard family home

Adaptable to the surroundings

Rotor dia. of 2.5m
1kW Small Windlens Turbine

NHK Robot Camera System

Robot camera system equipped with windlens turbine and solar panel. 2012.8.1

A building remains in Sendai Watari-tyo after Tsunami disaster

1kW Windlens turbine

Solar panel (1.1kW)
New Windlens Turbine (3kW rated at 12m/s)
Project supported by Mnist. Environ. (2010-2012)

Structure
- Less weight & more strength
- Long durability

For strong wind
- Stall control
- Tilt-up pole

Certification
FIT

Creating jobs for small & medium-sized manufactures in Japan
Mid-size WindLens Turbine (100kW): Next Generation Energy Project at Ito Campus, KU

- 4 m/s average expected
- 100kW
- Rotor dia. of 13m
- 2/3 rotor diameter size
- Quiet

Installation site
100 kW WindLens at Kyushu-U

Merit:
- Passive yaw
- Very quiet
- Small consumption of operation electricity
- 2/3 blade diameter
- Lightning conductor
- Adaptable to the surroundings

Demerit:
- Large wind load
- Lens cost

Movie

Rotor diameter of 12.8m, Lens diameter of 15.4m
100kW Mid-size WindLens Turbine at Kyushu-U (Rotor diameter of 12.8m)

Can be fed to 30 standard family homes

Annual Power Generation (estimated)

Total Annual Power (kWh)

Annual Average Wind Speed (m/s)

Power Curve Estimated for 100KW Windlens Turbine

Power Output (kW)

Wind Speed (m/s)
Noise comparison: Windlens turbine is quiet!

<table>
<thead>
<tr>
<th></th>
<th>100kW WL</th>
<th>Conventional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotor D</td>
<td>13 m</td>
<td>22 m</td>
</tr>
<tr>
<td>Hub height</td>
<td>25 m</td>
<td>24 m</td>
</tr>
<tr>
<td>Rated Power</td>
<td>100 kW</td>
<td>100 kW</td>
</tr>
</tbody>
</table>
Adaptable to the surroundings TV [television] commercial by Fujitsu Corp.

Round Lens structure can blend into nature.
Japan is sometimes mentioned with its small land and lack of natural resources, but the total area of territorial waters and exclusive economic zone (EEZ) is the 6th largest in the world.

Kyushu University is currently challenging for development of new energies including WindLens.

The challenge is on-going with an outlook on realizing High Density Offshore Electric Power Generation Farm utilizing very wide Japanese EEZ.
Multi-purpose

Integrated Offshore Renewable Energy Farm

- means an offshore energy farm on floating bodies with combined power generation systems such as wind, solar, tidal, wave, current and with storage systems.
- *Multi-purpose*: Energy farm, Marine farming, the base for exploring resources, etc.
Current, Tidal, and Mini-Hydro in Rivers

- Very highly efficient compared with conventional ones
- Water Lens Turbine
  - Density 840 times than the air
  - The streams always flow in the rivers and in the sea
- Very high availability

Tidal flow and Current

Water flow exp.

Rivers: Mini-Hydro

- Generator

Diagram with water flow exp. graph showing 2.5 times enhancement.
Off-shore Energy Farm project

Scaled model in test pool

CG model

A floating structure for future ~MW type

Movie
1st stage: Installation in Hakata Bay (2011 Winter)

18m Hexagon floating body

18m floating body and two 3kW WindLens turbines and solar panels

Site

Fukuoka City

Hakata Bay
1st Stage: Windlens turbines on a floating body

18m hexagon floating body, two 3kW windlens turbines and 2kW solar panels in total 8kW energy farm
Under the floating body in Hakata Bay

Realizing a floating energy farm with multi-purpose
In cooperation with fishery

Provided by RKB TV

Provided by Shibuya Corp.
Wind-lens turbine

- High power output: 2-3 times larger than conventional turbines
- Quiet
- Bird strike free
- Increased tolerance against lightning strikes
- Environment friendly design

Off-shore floating energy farm in cooperation with fishery

Hakata-bay, Fukuoka Japan (Google map)
2nd stage (planned): Multiple 60m-class Floating Bodies and 1MW Renewable Energy Farm

Prospective site: Uwaumi Fisherman’s union agrees with our project.

Annual mean wind speed on the sea is larger than that on land of 1-2 m/s
Twofold total power output will be expected
A new system of a marine farm will be developed.

- Electricity is provided to the marine farm.
- Automatic feeder (self-feeder)
- New corf (up and down)
Offshore Floating Integrated Energy Farm

Keyword: Multi-purpose

① Energy Farm
- Wind, Solar, Tidal, Wave
- Energy conversion
- Shipping or Undersea cables

② Cooperation with Fishery Industry
- Marine farm
- Plant factory (seaweed bed)

③ Transportation, Resources exploration base, EV base, etc.
- Offshore artificial island
- Electrical ship & airplane base
- Resource exploration in the sea

④ Natural Disaster Prevention

contribute to the creation and development of industry!
The WindLens has a compact diffuser shroud with a broad-ring rim at the exit periphery, generating vortices and low pressure.

This system has demonstrated power augmentation by a factor of about 2 to 3, due to focusing the wind energy.

The further significant features of the WindLens technology include, improved safety, reduction of acoustic noise and Doppler radar interference.

We also showed the latest development on 100kW type WindLens turbine and future prospects on floating farm.
Thank you for your kind attention!