



**WHITE PAPER
ON THE POSSIBILITY TO OVERCOME BETZ LIMIT IN WIND POWER EXTRACTION**

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The energy in the wind has two components:

- the kinetic energy
- the heat energy

The current wind technologies are able to extract only a fraction of the kinetic energy. The maximum theoretical value of kinetic energy extraction from the wind was demonstrated in 1919 by Albert Betz and it is known as Betz's Law.

According to Betz Law, the maximum coefficient of performance (Cp) in wind kinetic energy extraction is 59.3%, which is known as the Betz Limit. The current wind technologies have in reality a much lower Cp than the Betz Limit.

What if the wind technologies would be able to extract a portion of the heat energy from the wind in addition to its kinetic energy?

Assuming that there is an ideal wind turbine able to extract the wind kinetic energy at the Betz Limit Cp of 59.3%, that the above ideal turbine has a frontal surface area of 100 square meters (10mx10m), that the wind speed is 10m/s and the exterior temperature is 15 degrees Celsius, the energy extracted by such an ideal wind turbine is:

$$E = 0.5 * \text{air_density} * \text{frontal_surface_area} * \text{cubic_power_of_wind_speed} * C_p$$

$$E = 0.5 * 1.225 * 100 * 1000 * 0.593$$

$$E = 36,321.25 \text{ joules} = 36.32125 \text{ kj}$$

Let's assume now that would exist a device that, if integrated with the above ideal turbine, it will be able to extract a portion of the thermal energy in addition to the above calculated kinetic energy. Assume that with that device a portion of the airflow that exits from the turbine it is at slightly lower temperature than the input airflow.



For the purpose of this paper, let's assume that 50% of the input airflow will exit at 0.1 degree Celsius lower temperature.

In such case, the thermal energy calculation is:

$E_{thermal} = \text{air_density} * \text{air_volume_exhaust_per_second} * \text{temperature_difference} * \text{air_specific_heat}$

$E_{thermal} = 1.225 * (100\text{m}^2 * 10\text{m/s} * 1\text{s} * 50\%) * 0.1 * 1.005\text{kJ/kg}$

$E_{thermal} = 61.55\text{kJ}$

The corresponding thermal energy was transferred to the wind turbine as rotational kinetic energy.

Consequently the turbine in the above theoretical example having integrated a device that lowers the temperature of the exit airflow with only 0.1 degree Celsius will be able to produce a total of:

$E_{total} = E_{kinetic} + E_{thermal} = 97.877\text{kJ}$, which is 2.69 times more than the Betz Limit.

Conclusion

In theory the wind power extraction can go beyond the Betz Limit, without contradicting in any way Betz's Law. The ability of wind turbines technologies to go beyond the Betz Limit will result in future powerful wind turbines having much smaller dimensions compared to the current large windmills.

Our recent patent application discloses a device able to tackle into the thermal energy as described above.