Wind turbines: technology and theories

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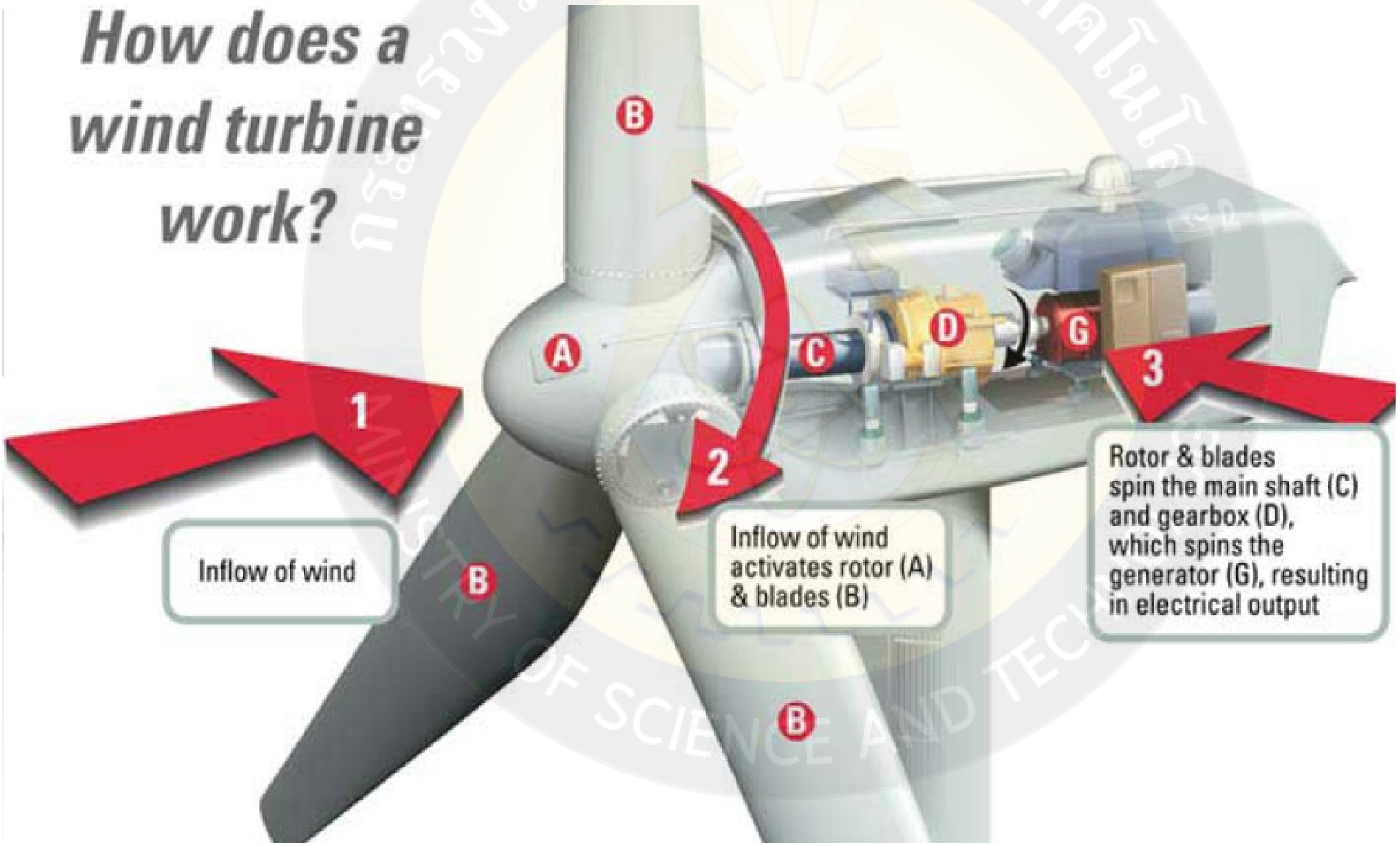
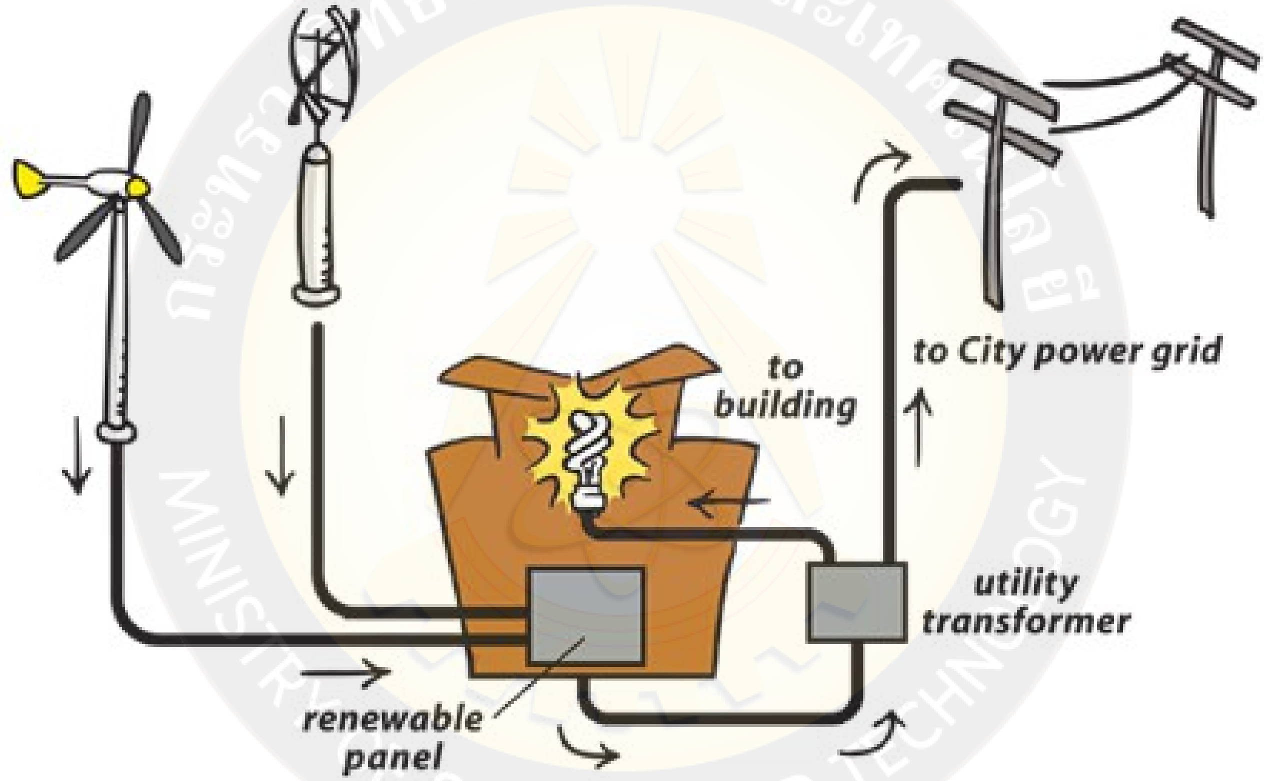
Outline

- Basic principles
- Horizontal-axis wind turbines
- Vertical-axis wind turbines
- Wind turbine industry in Thailand

I. Basic principles

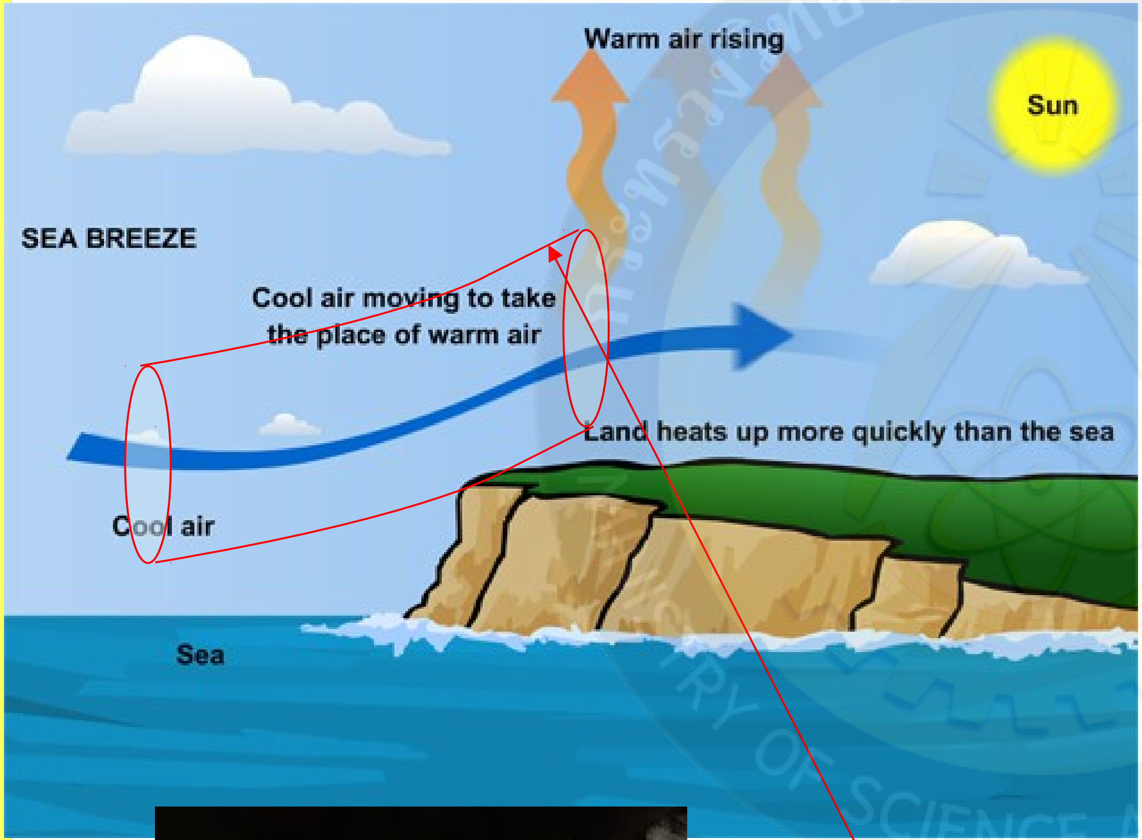


I. Basic principles



One of the important components is the turbine blade which transforms the kinetic energy to mechanical energy

I. Basic principles: power available



streamtube

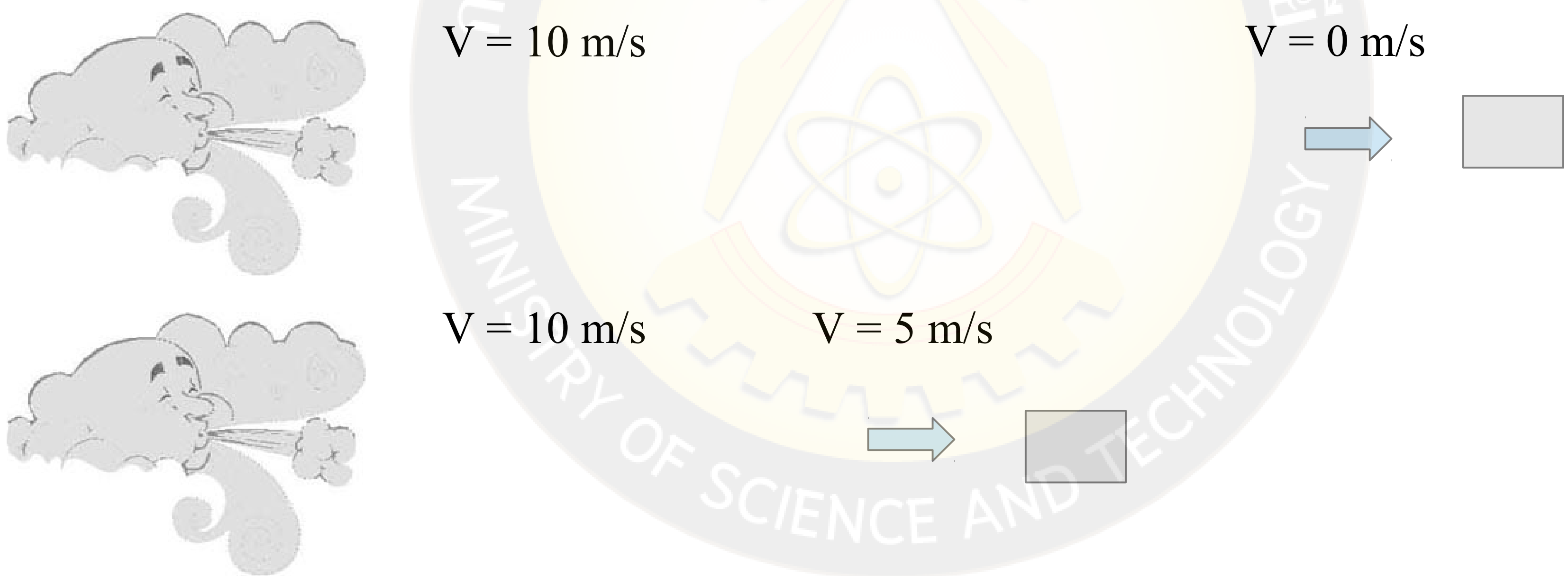
$$P=\frac{dW}{dt}=\frac{d\left(1/2\,mV^2\right)}{dt}$$

$$P=mV\frac{dV}{dt}+\frac{1}{2}V^2\frac{dm}{dt}$$

$$P=\frac{1}{2}V^2(\rho A V)=\frac{1}{2}\rho A V^3$$

I. Basic principles: maximum power

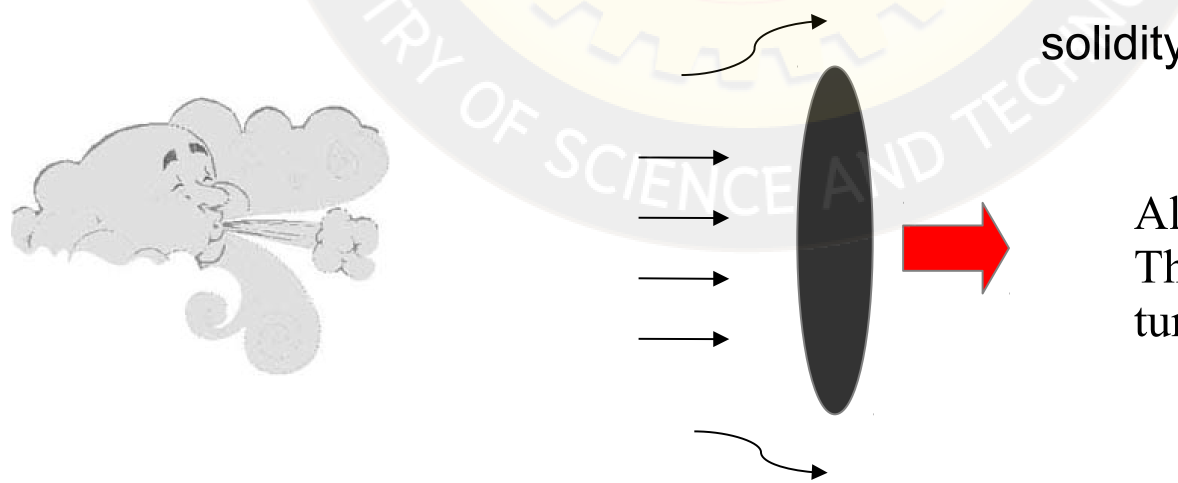
1) All energy will be extracted when the air comes to standstill



I. Basic principles: maximum power

Two extreme cases

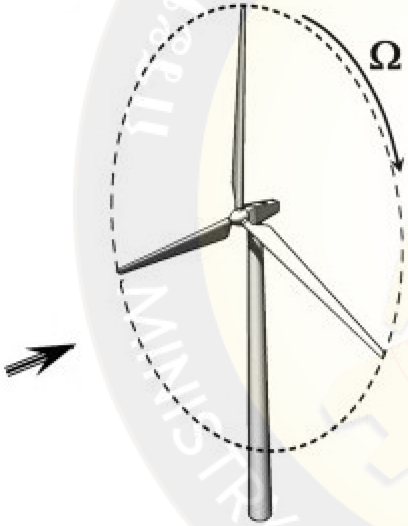
No power is extracted!



All power is transformed into Thrust which tries to bend the turbine

I. Basic principles: maximum power

1) The effective Different solidity

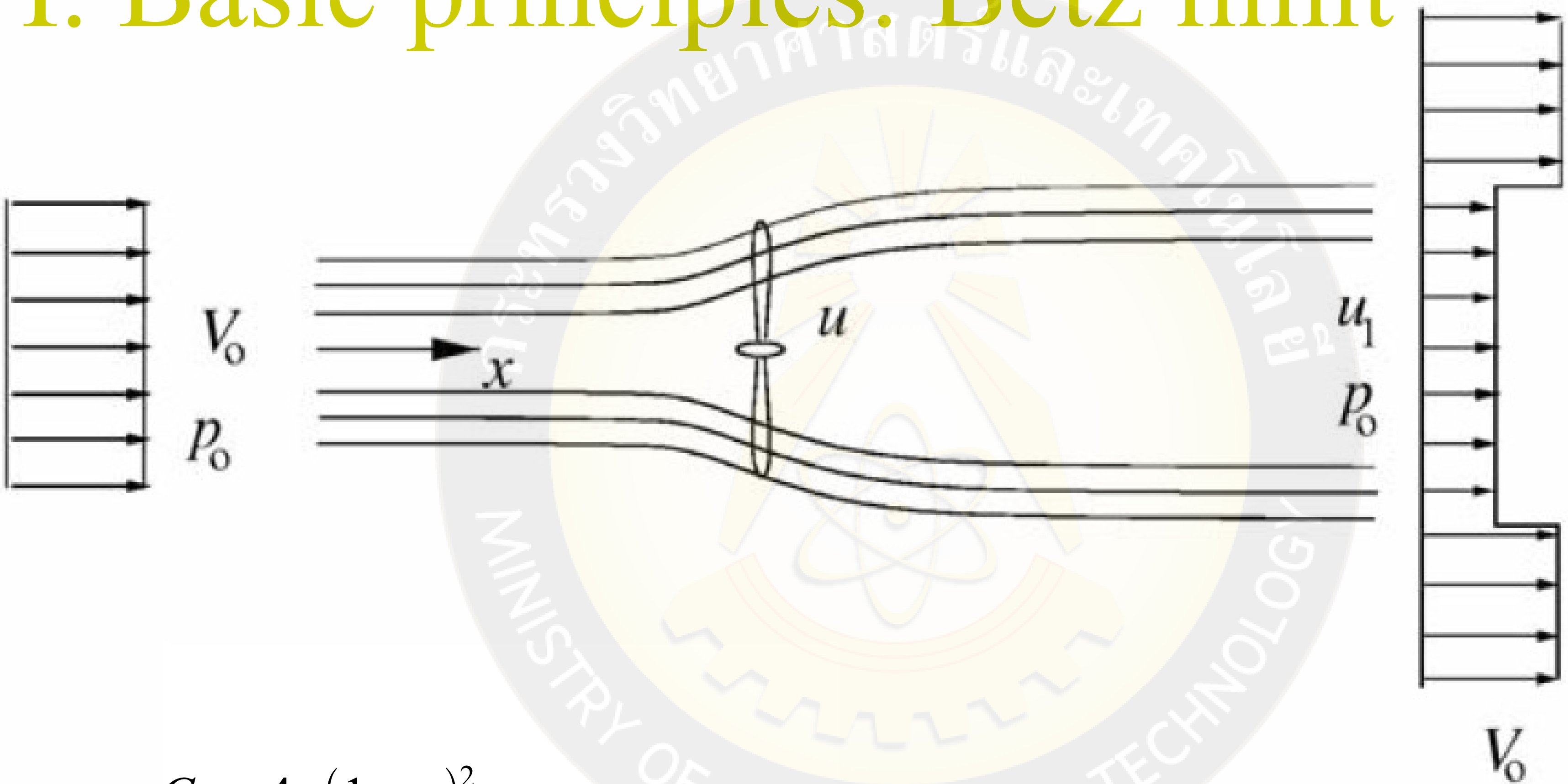


Modern wind turbine

American wind turbine

2) Effective solidity increases with increasing tip speed ratio

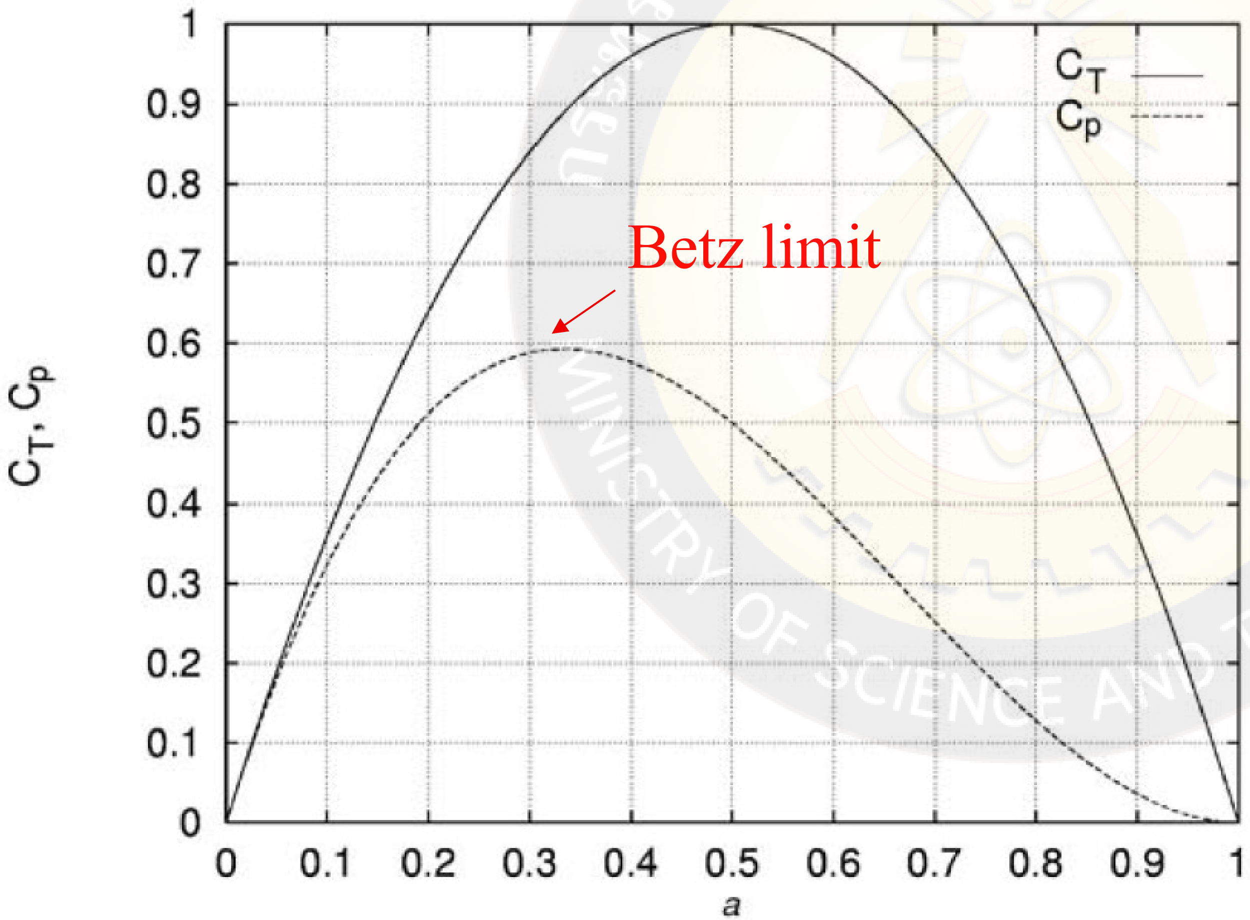
I. Basic principles: Betz limit



$$C_P = 4a(1-a)^2$$

$$C_T = 4a(1-a)$$ where $$a = \frac{V_0 - u}{V_0}$$

I. Basic principles: Betz limit



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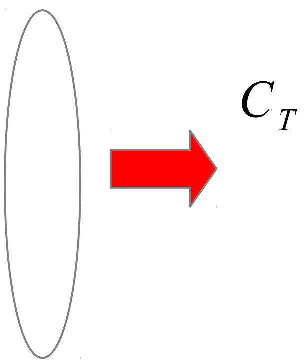
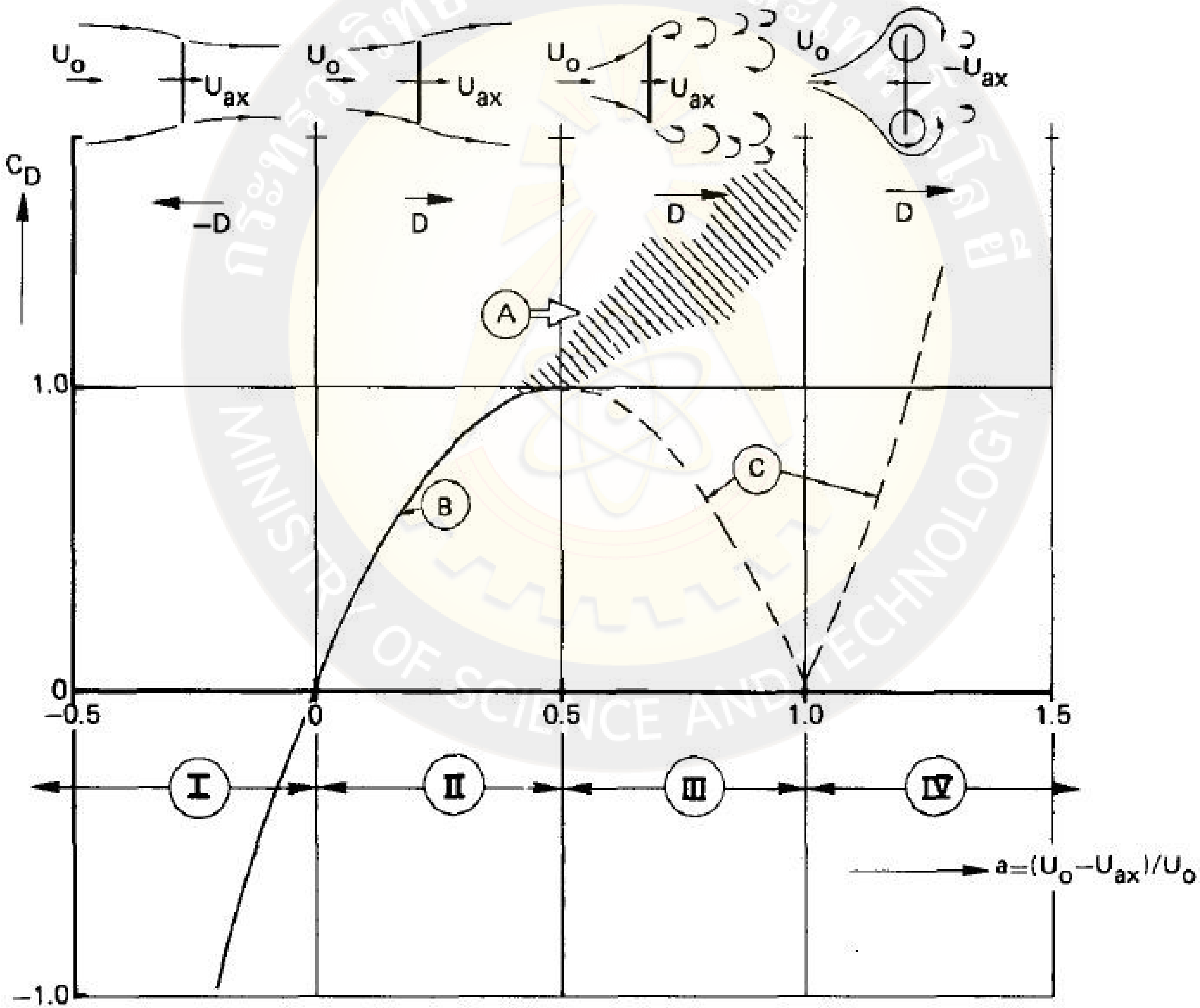


I. Basic principles: Betz limit



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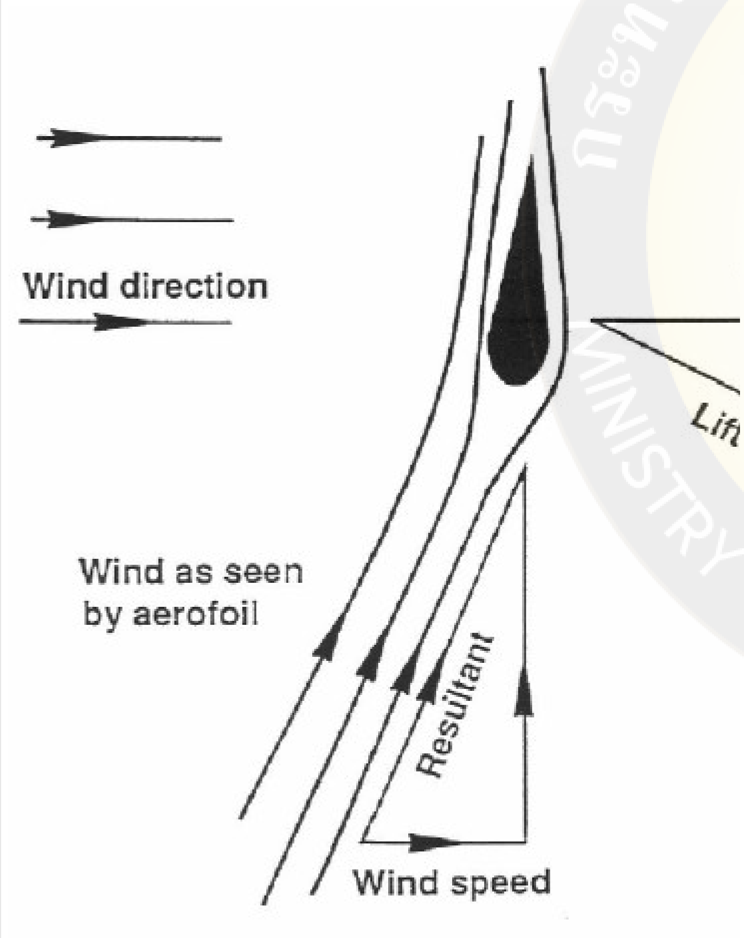
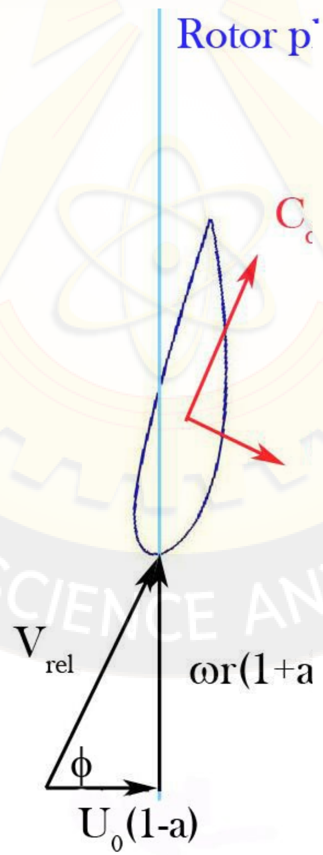
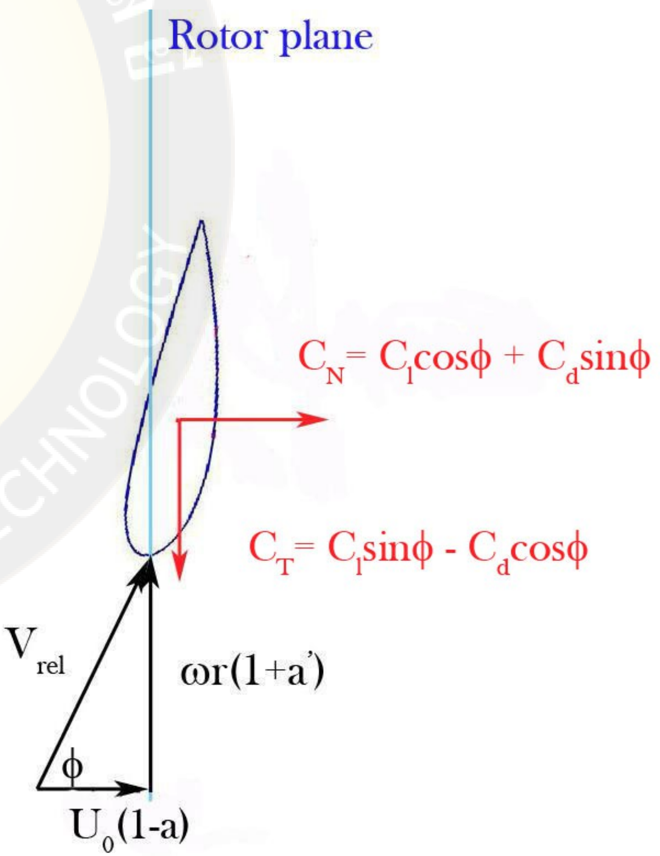
I. Basic principle: performance







I. Basic principle: performance

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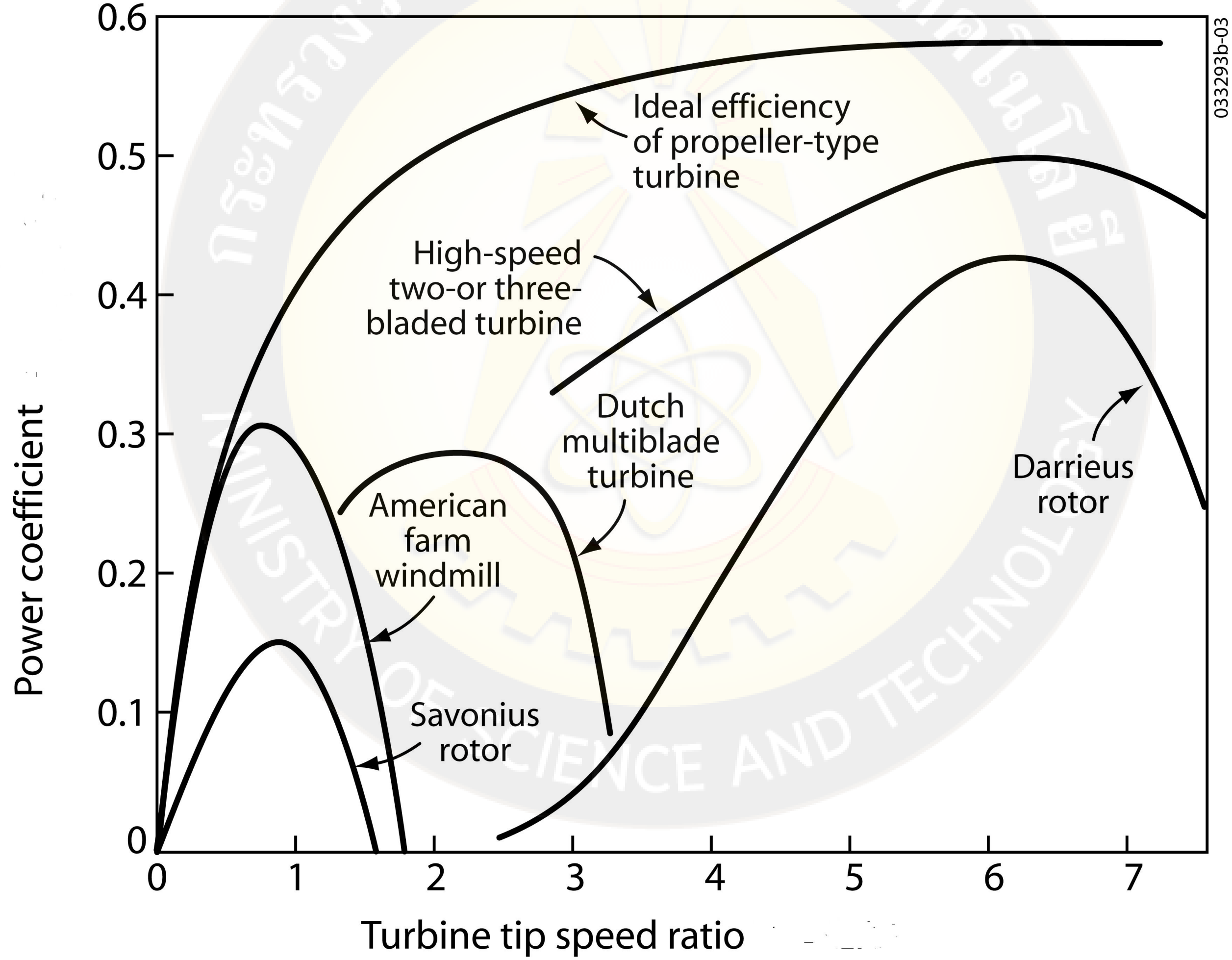


I. Basic principles: operations

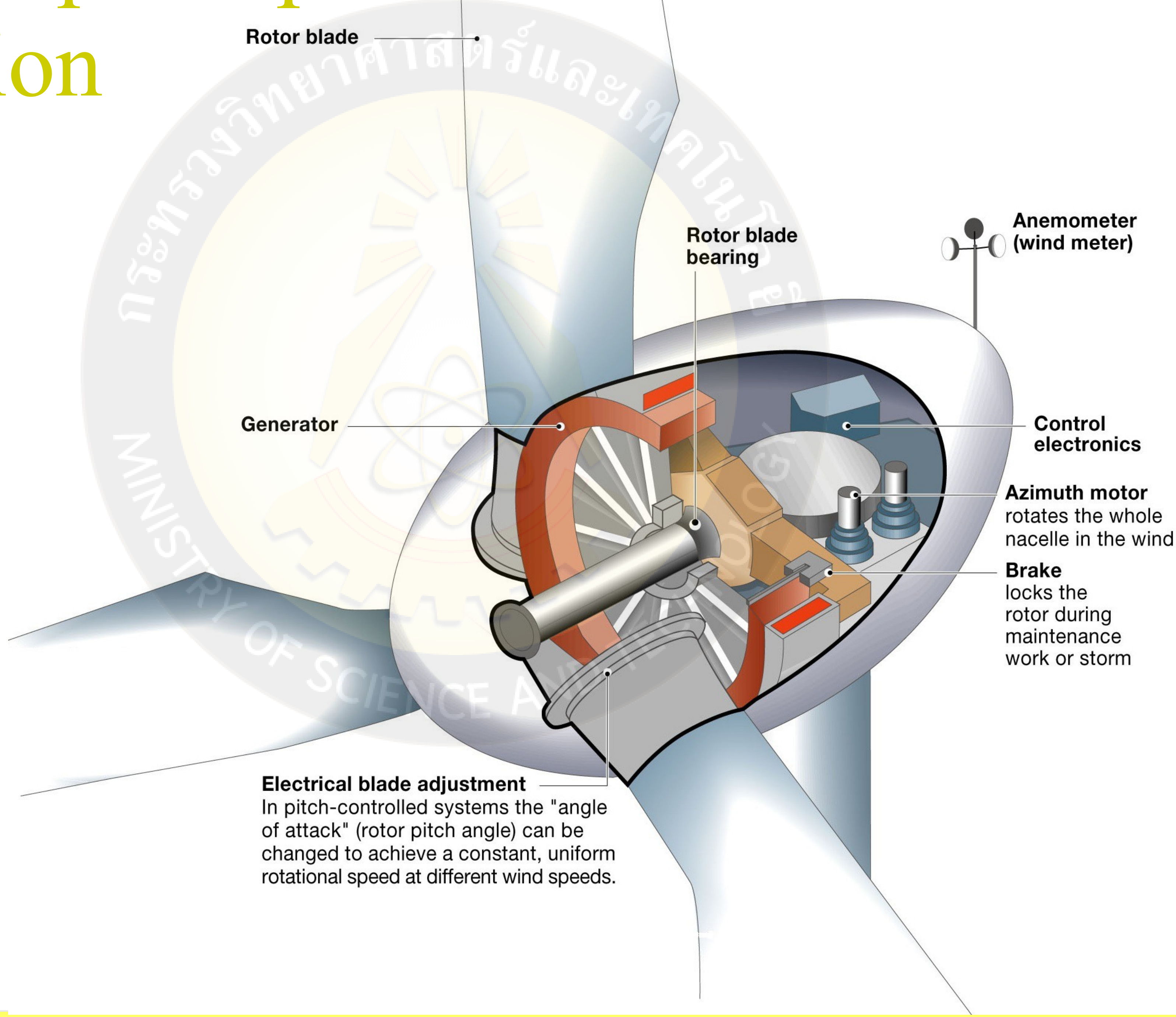
1) Speed control

- Fixed speed configuration – connected to the grid where the frequency is fixed
- Variable speed configuration – varying the rotor speed to achieve a constant tip speed ratio (power inverter is needed to connect to the grid)

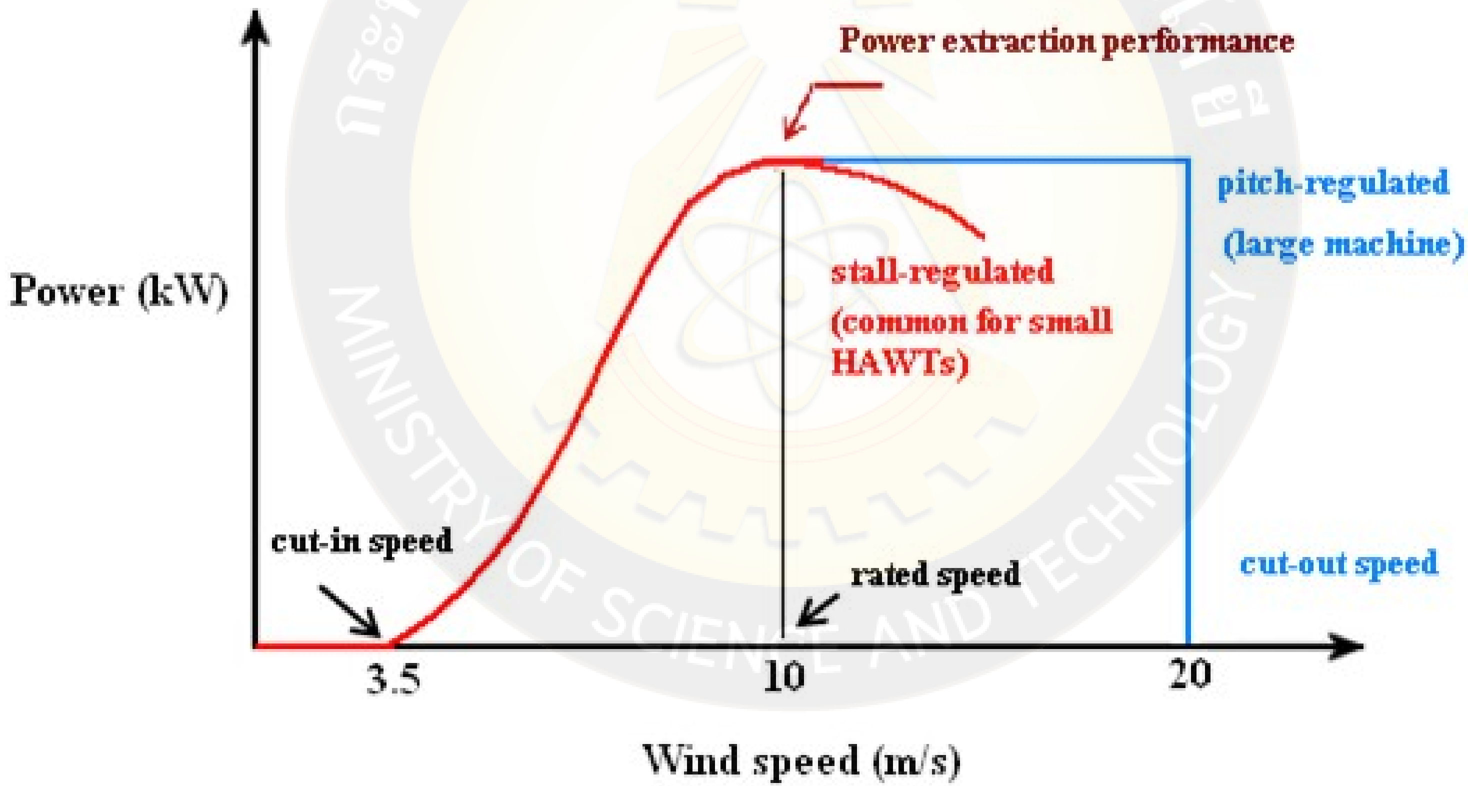
2) Torque control

- Stall-regulated (passive) – the blade is fixed and cannot adjusted
- Pitch-regulated (active)

I. Basic principle: wind turbine operation



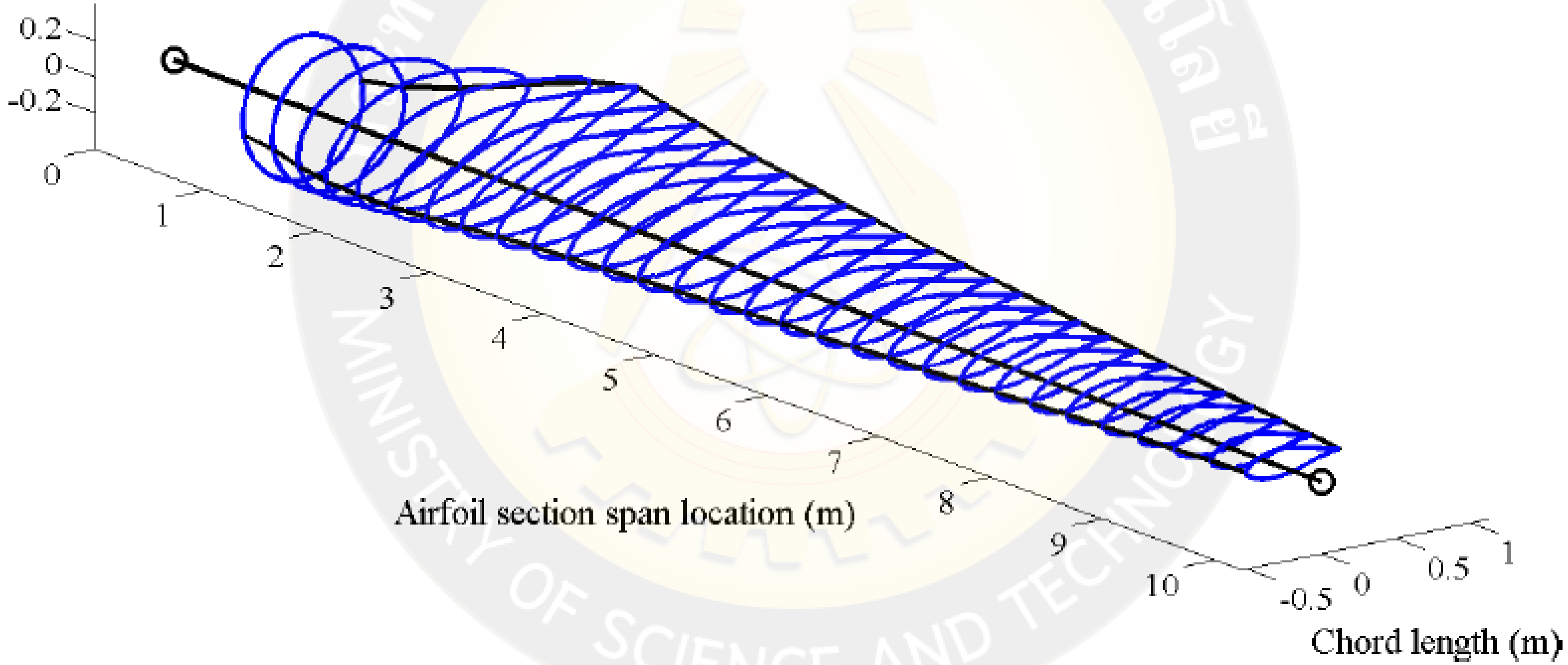
I. Basic principle: wind turbine operation



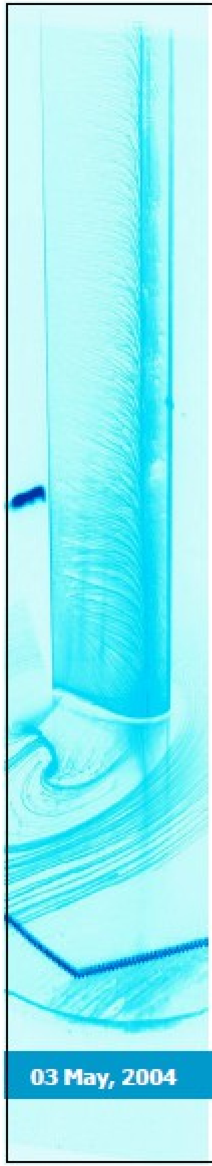
I. Basic principles: design criteria

1) Power required → rotor and blade size
2) Operational speed → solidity, chord size
3) Stall-regulated, fixed speed → soft-stall aerofoil characteristics
4) Pitch-regulated, variable speed → narrower range of incidence angle, maximising lift-to-drag ratio
5) different blade section → Reynolds number
6) Strength → aerofoil thickness

I. Wind turbine blades



I. Aerofoils for HAWTs



Design goals HAWT airfoils

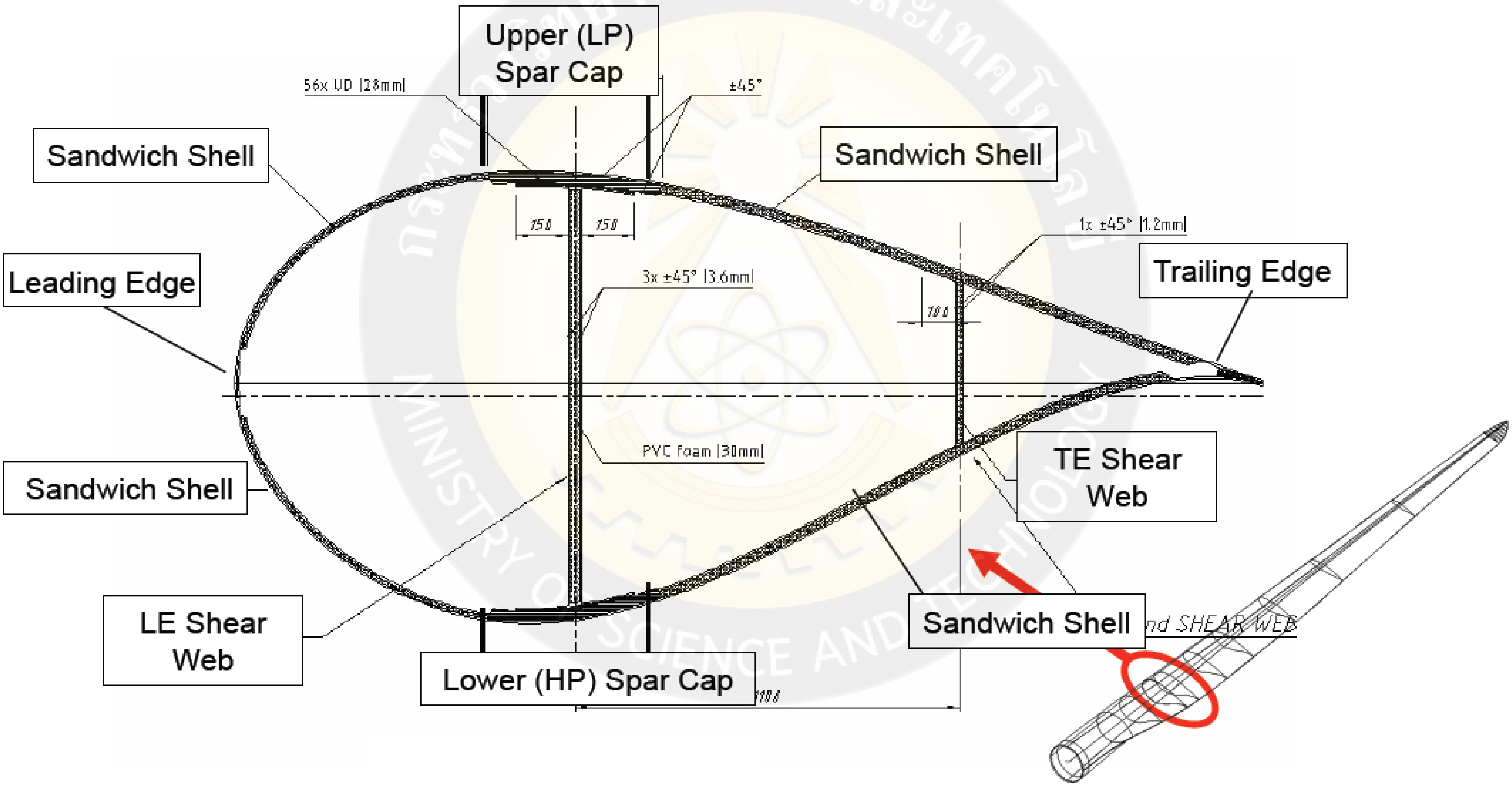
steady

Thickness-to-chord ratio	> .28	.28 - .21	.21 >
High maximum lift-to-drag ratio	●	●●	●●●
Low max. and benign post stall			●●
Insensitivity to roughness	●	●●	●●●
Low noise		●	●●●
Geometric compatibility	●●	●●	●●
Structural demands	●●●	●●	●

I. Blade manufacturing

-Fiberglass-reinforced
epoxy

I. Blade anatomy



III. Vertical-axis wind turbines

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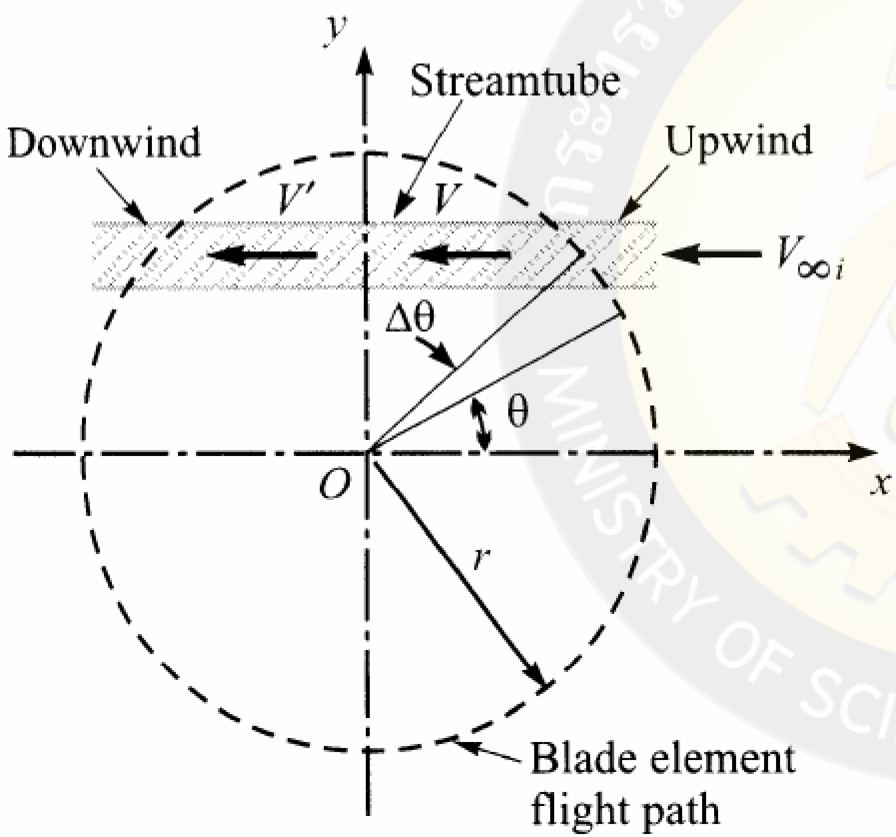
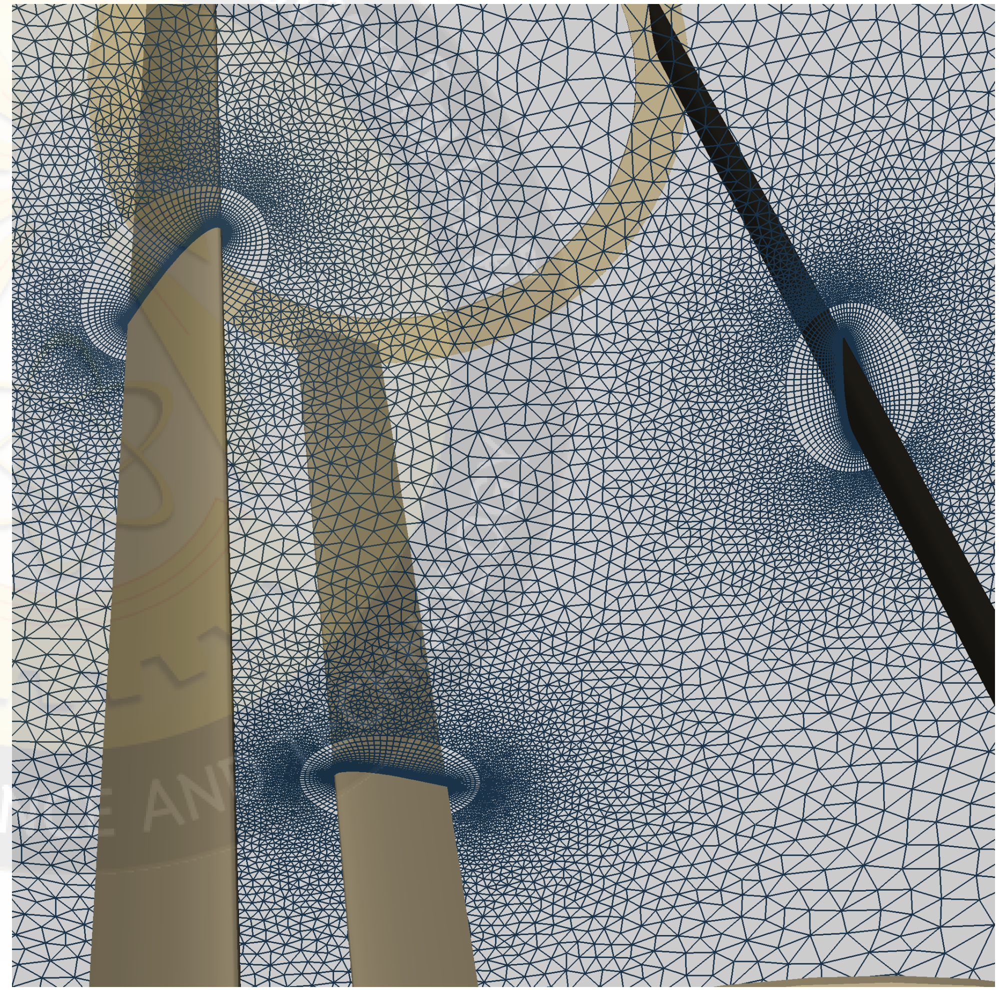
III. Vertical-axis wind turbines





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III. Vertical-axis wind turbines

Curved blades to reduce centrifugal stress

Straight blades which are easier for manufacturing

Twisted blades to spread the torque evenly

III. Vertical-axis wind turbines

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IV. Wind Turbine industry

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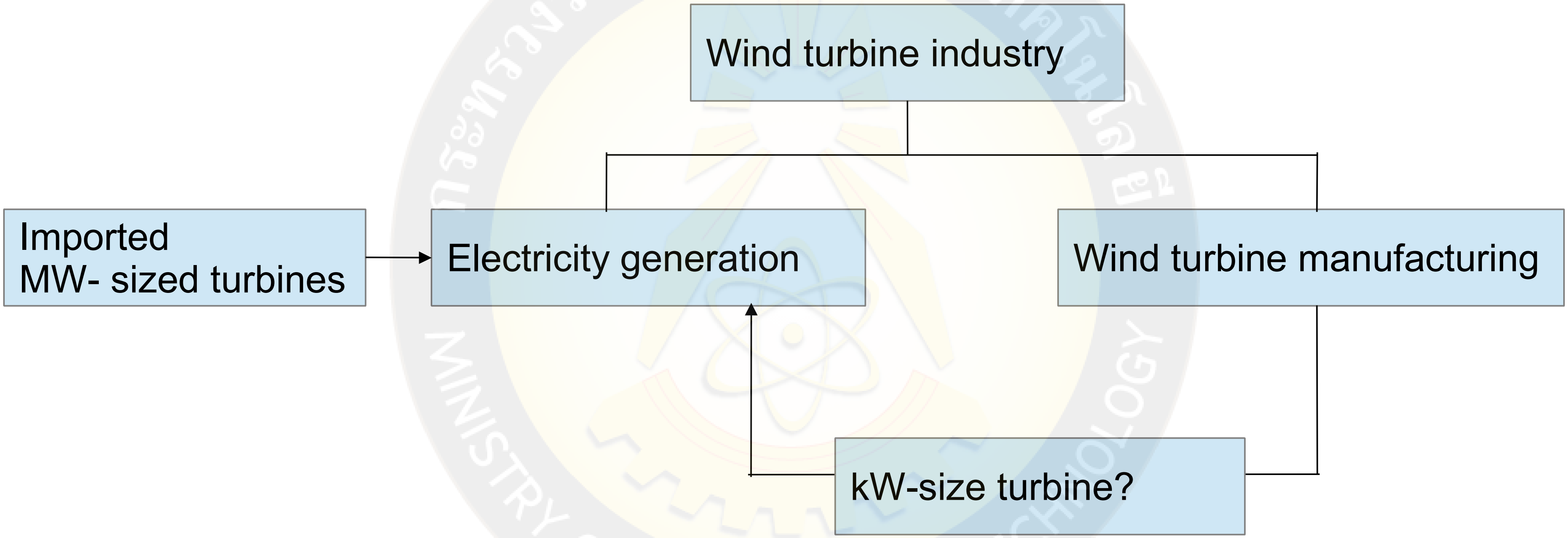
Huangbong wind projects,
Nakhon Ratchasima

IV. Wind Turbine industry



IV. Large or small wind turbines

Focus on a smaller scale (kW)?

Lamchabang port

- 10 kW machines
- 84 units

IV. Large or small wind turbines

- Turbines cannot produce power as claimed by the manufacturers, giving a bad name to the wind turbines

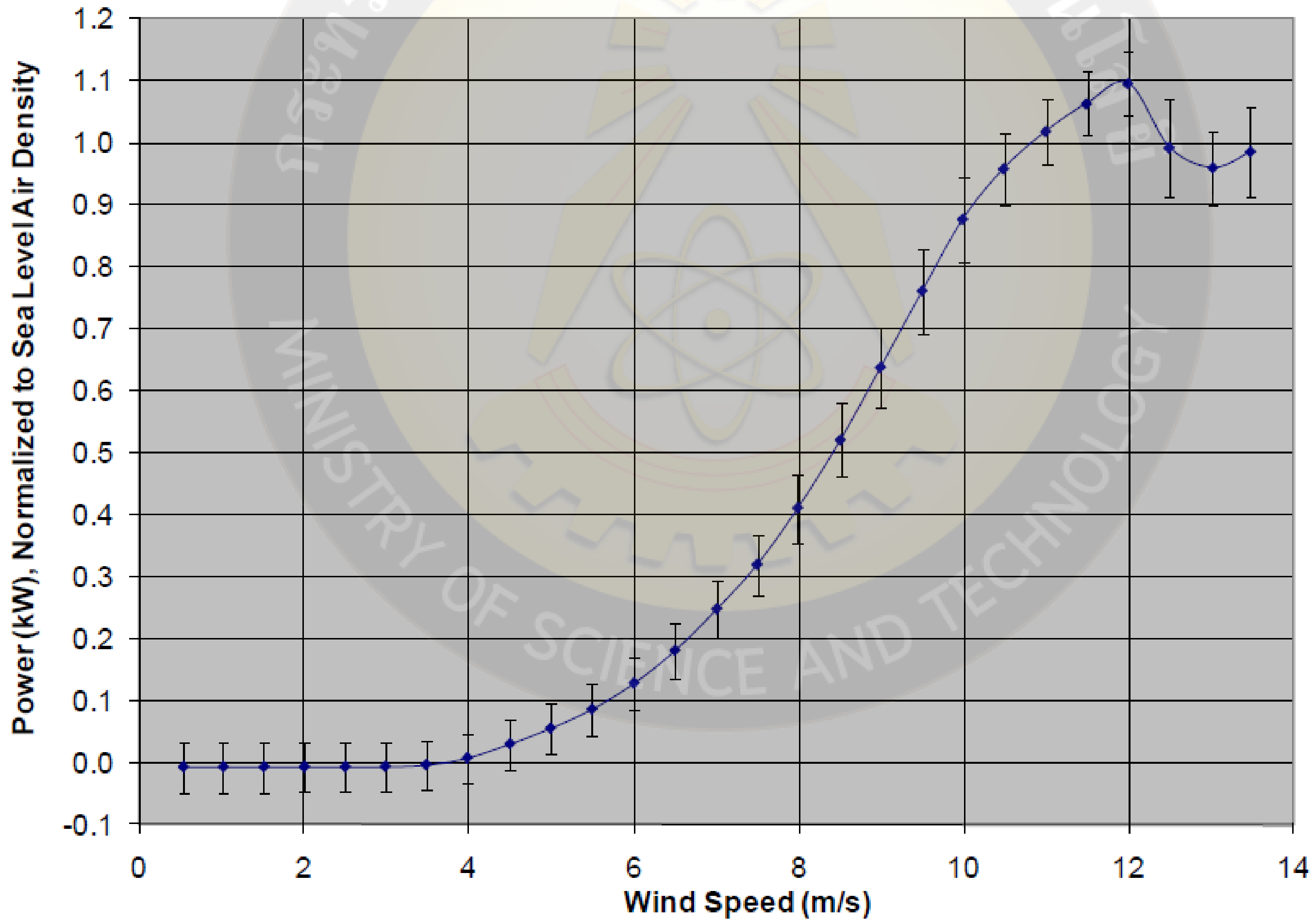
- Needs a certification body

Are the turbines certified?

- US: National Renewable Energy Laboratory (NREL)
  – Performance test
  – Noise test
  – Duration test
  – Safety test
- UK: Microgeneration Certificate Scheme (MCS) accredited wind turbines

IV. Certification body

- Accurate power curve



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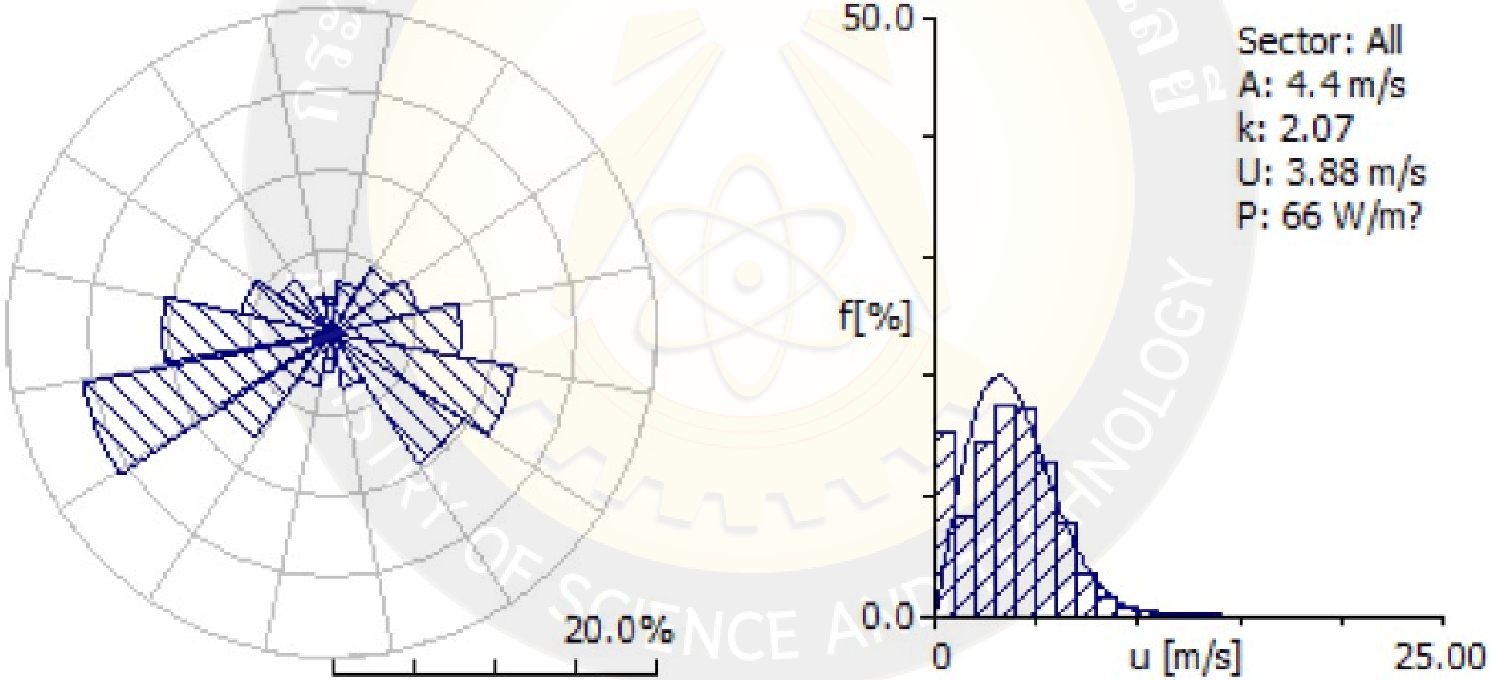
IV. Certification body

- Wind data (Weibull distribution, wind rose)



- Annual energy yield → Cost effectiveness

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