CH 1: INTRODUCTION

1.1 MOTIVATION AND LECTURE OVERVIEW

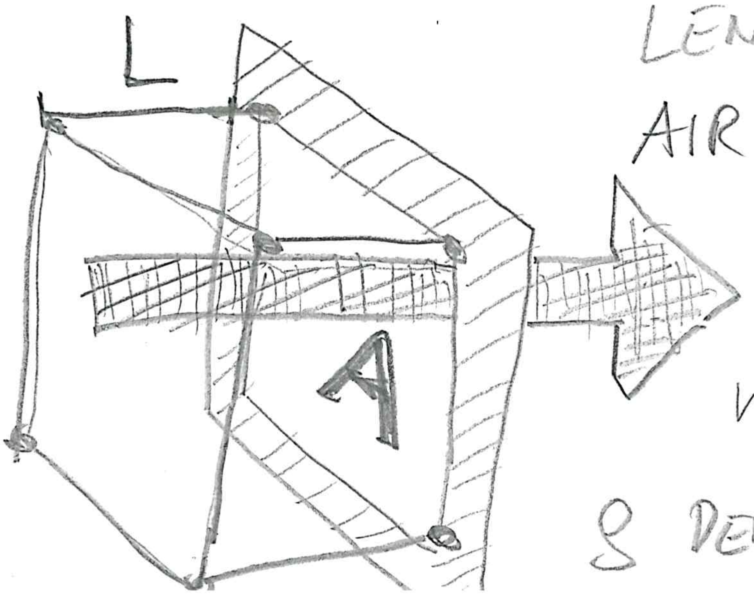
(ON SLIDES)

1.2 ENERGY CONTENT OF WIND

QUESTION: HOW MUCH POWER IS "IN THE WIND"?

ANSWER: REGARD A CYLINDRICAL VOLUME OF AIR FLOWING THROUGH A "WINDOW" OF AREA A $[m^2]$, WITH LENGTH L $[m]$.

AIR VELOCITY IS v $[\frac{m}{s}]$.



MASS OF THE AIR IS $m = \rho \cdot L \cdot A$ WITH ρ DENSITY OF AIR. $\rho \approx 1.2 \frac{kg}{m^3}$

KINETIC ENERGY IN THE VOLUME OF AIR IS

$$E = \frac{1}{2} m v^2 = \frac{1}{2} \rho L \cdot A \cdot v^2$$

POWER P [W] IS GIVEN BY

$$P = \frac{E}{T}$$ WITH T [s] THE

TIME IT TAKES TO MOVE THE VOLUME THROUGH THE WINDOW, GIVEN BY

$$T = \frac{L}{v}$$

THUS

$$P = \frac{\frac{1}{2} \rho L A v^2}{L/v} = \frac{1}{2} \rho A v^3$$

CUBIC IN v !

<u>POWER DENSITY</u> IS "POWER PER CROSS-SECTIONAL AREA" AND GIVEN BY

$$\boxed{\frac{P}{A} = \frac{1}{2}\rho v^3}$$

SI-UNIT OF THIS EXPRESSION IS

$$\frac{kg}{s^3} = \underbrace{\left(kg \cdot \frac{m}{s^2}\right)}_{=N} \cdot \left(\frac{1}{m \cdot s}\right) = \underbrace{(N \cdot m)}_{=J}\left(\frac{1}{m^2 s}\right)$$

$$= \underbrace{\left(\frac{J}{s}\right)}_{=W}\left(\frac{1}{m^2}\right) = \frac{W}{m^2}$$

FOR $v = 10\ m/s$, WE GET

$$\frac{P}{A} = \frac{1}{2} \cdot 1.2 \cdot (10)^3 \ \frac{W}{m^2} = 600 \ \frac{W}{m^2}$$

$v = 10 \frac{m}{s}$ IS A GOOD STRONG WIND.

AT $v = 20 \frac{m}{s}$ WE HAVE $\frac{P}{A} = 2.4 \frac{kW}{m^2}$

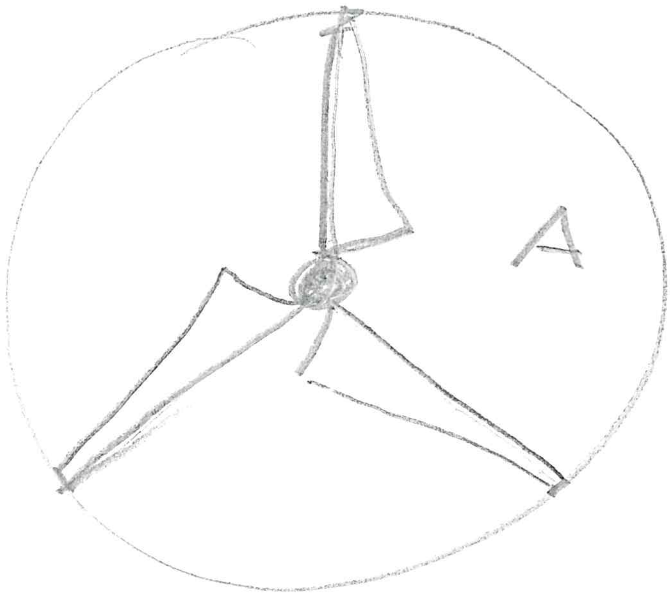
COMPARE THIS WITH THE AVERAGE EUROPEAN'S POWER NEED OF 5 kW:

$\boxed{2\ m^2}$ OF CROSS-SECTIONAL AREA IN VERY STRONG WIND, OR $\boxed{16\ m^2}$ OF AREA IN GOOD WIND (OF $v = 10 \frac{m}{s}$) OR $\boxed{128\ m^2}$ OF AREA IN WEAK WIND OF $v = 5 \frac{m}{s}$ CONTAIN ABOUT 5 kW.

(NOT ALL OF THIS CAN BE HARVESTED, DUE TO THE SO CALLED "BETZ-LIMIT" WE DERIVE & DISCUSS IN CHAPTER 3).

THUS, STRONG WINDS CONSTITUTE A FAIRLY CONCENTRATED FORM OF SUSTAINABLE ENERGY, OF A SIMILAR POWER DENSITY AS SOLAR POWER.

NOTE THAT THE CROSS-SECTIONAL AREA OF WIND TURBINES IS GIVEN BY THE WHOLE DISC OVER WHICH THE ROTOR BLADES SWEEP:



THUS, WIND TURBINES HARVEST THE AREA WITH RELATIVELY LITTLE BLADE AREA; THIS IS THE REAL REASON WHY WIND POWER IS COMPARABLY CHEAP & COMPETITIVE.