D-Lab: Energy

Week 5: Wind, Micro-Hydro, & catch-up

AGENDA

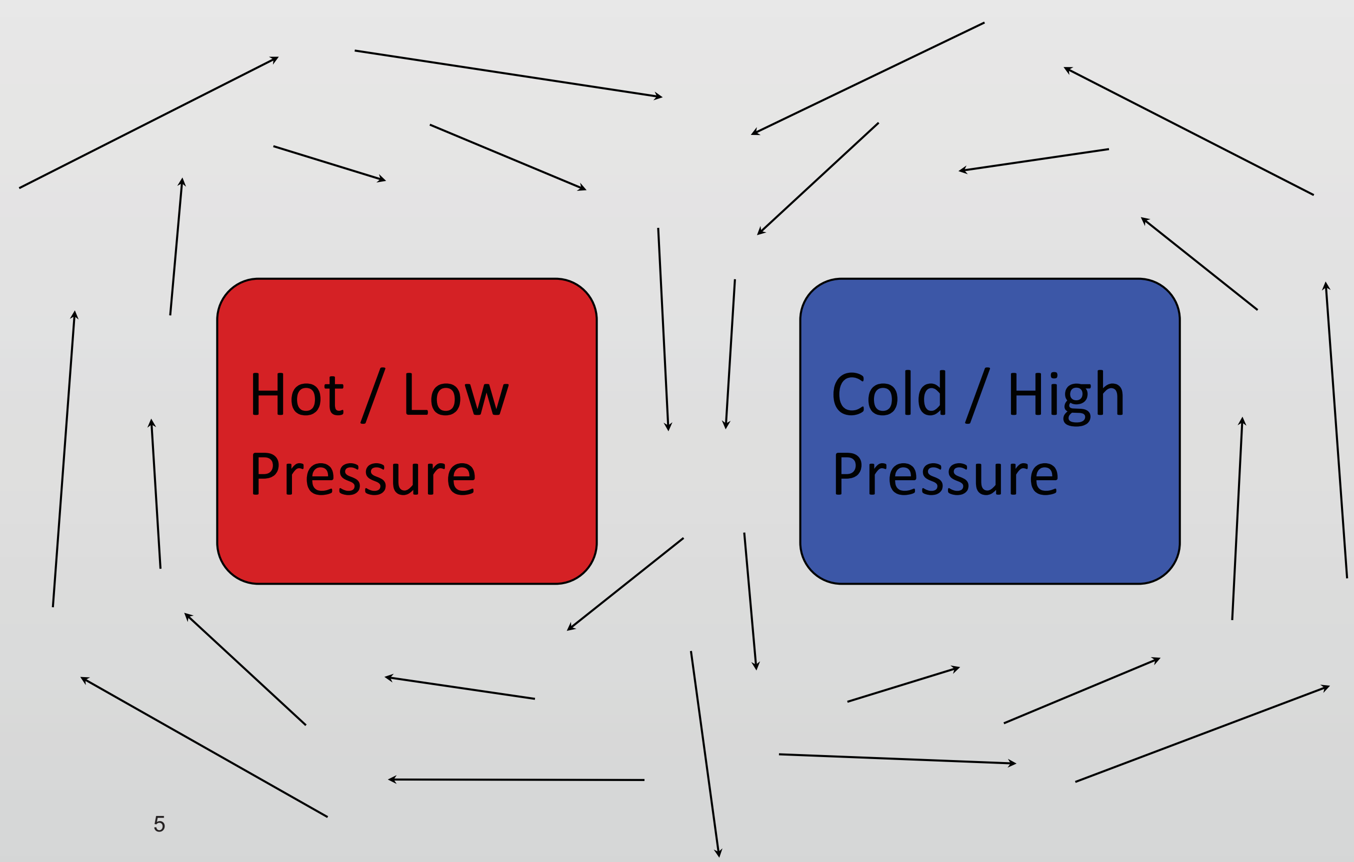
- Where are we?
- Muddy Card review
- Wind
- Micro-hydro
- Project Development
- Complete Muddy Card

Week	Class	Lab
Feb 2	Introduction: Energy, Units, Esti-mation, Energy Usage Worldwide, Class Overview	Human Power Lab
Feb 9	Energy Storage & Micro Grids Initial Trip Planning	Energy Storage Lab
Feb 16	Lighting Community Partner Introduction	Biogas & biodiesel lecture & construction
Feb 23	Solar Thermal & PV **Quiz I**	Solar Panel Construction, Installation, and Operation
Mar 2	Wind & Micro-Hydro Trip Planning	Savonius Wind Turbine Construction & Testing
Mar 9	Cooking, Stoves, & Fuel Biogas digester testing	Charcoal Making & Stove Testing
Mar 16	**Trip Plan Presentations** **Quiz II**	Trip Prep
Mar 23	Trip	Travel, Learn, Apply

MUDDY CARD REVIEW

Wind Energy

- indirect solar energy
- Uneven heating of earth = uneven heating of atmosphere
- Hot air ↑ causing Pressure ↓
- Cold air rushes in
- The result is **Wind** !



Evolution of wind energy extraction

- **Windmills**
  - Mechanical power
  - In operation since 1000BC (Persia)
  - Used to pump water/ grind stuff
  - High solidity - high torque favored


Courtesy of net_efekt and cwwycoff1 on Flickr.

Courtesy of SustainableDevelopment on Flickr.

Wind turbines

- Electrical power
- In operation since 1888
- Used to generate electricity
- Low solidity - High speed favored

Solidity: proportion of the swept surface covered by the rotor blades

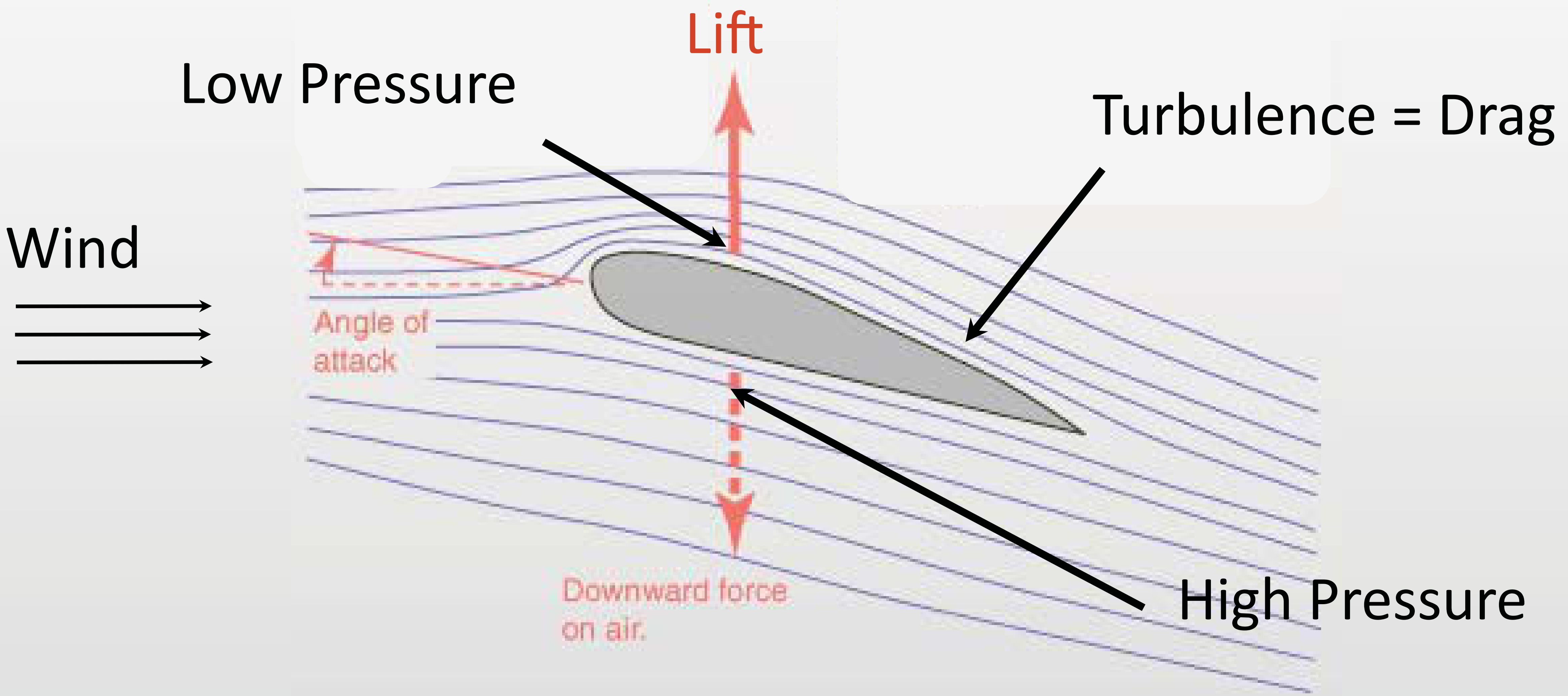
Horizontal Axis Wind Turbines (HAWTs)

- Rotor and motor at top
- Needs to be pointed into the wind
- Height reaches stronger wind
- Variable blade pitch for maximum efficiency
- Are now up to 126 m in diameter = 7 MW (and 10MW on its way)

Horizontal Axis Wind Turbines (HAWTs)

This could power ~ 2000 American Homes

How They Spin



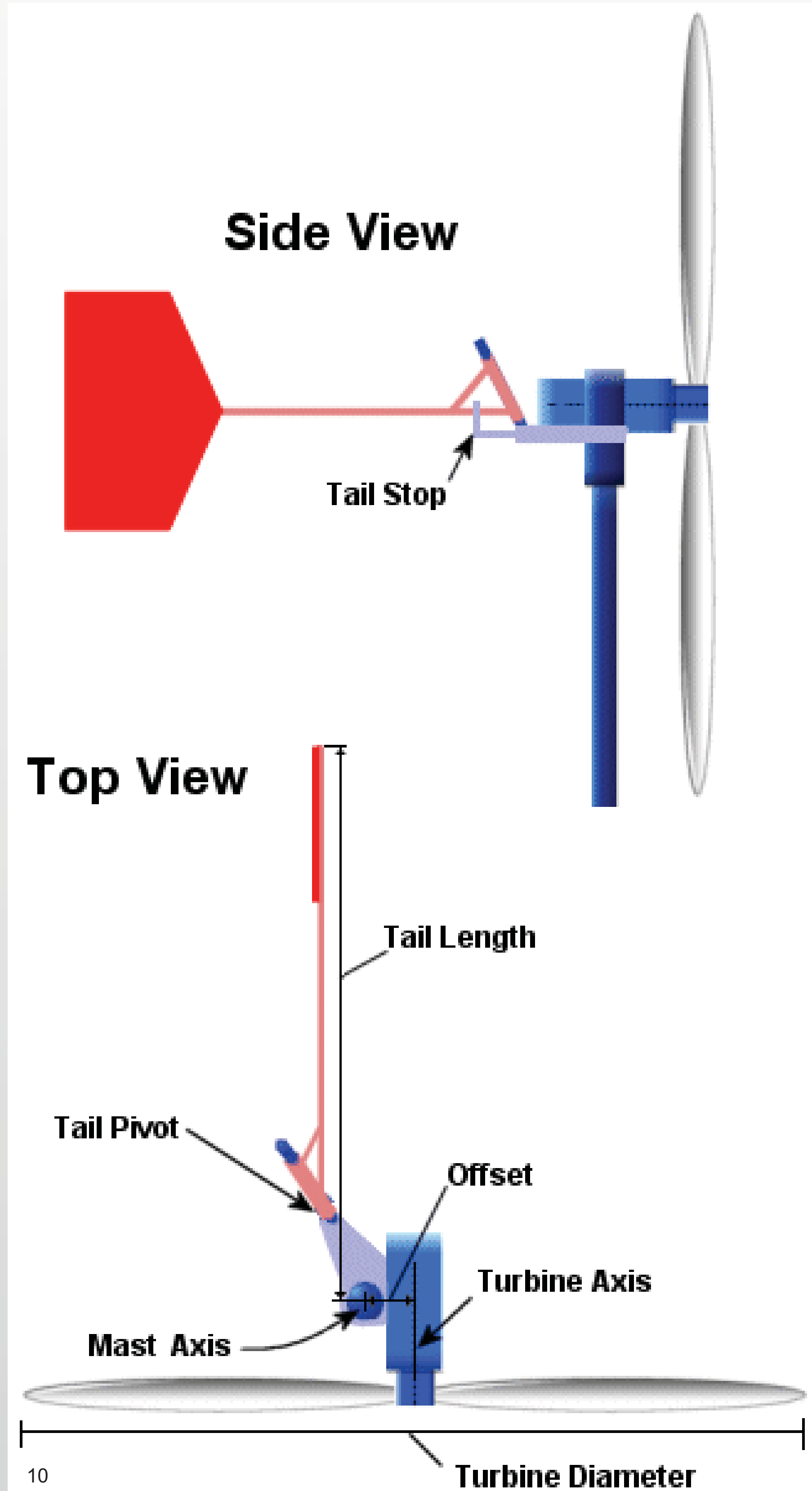
Motion dominated by LIFT forces, not DRAG forces

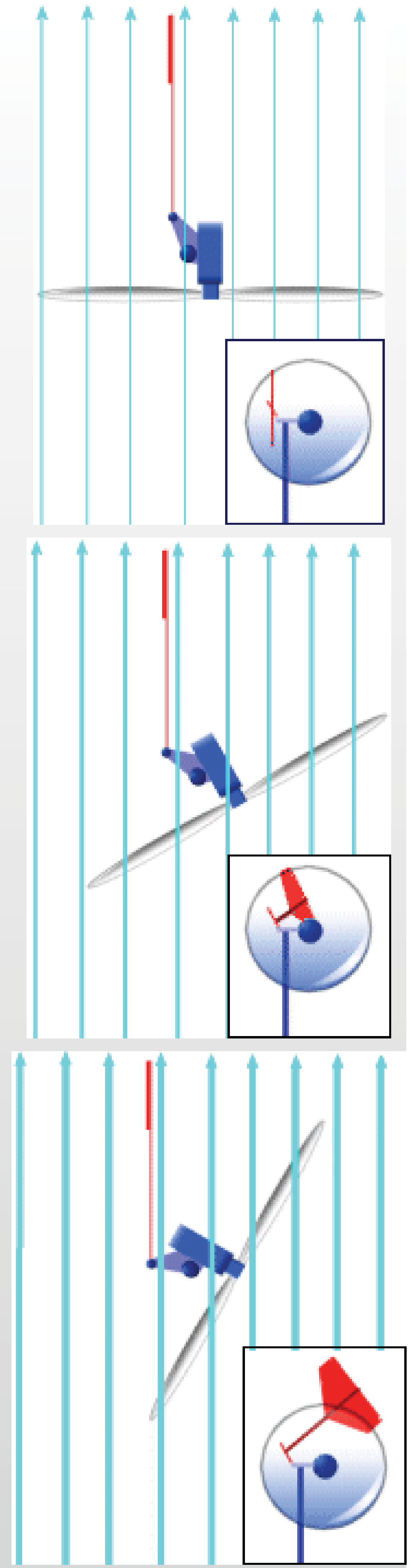
Base image: http://hyperphysics.phy-astr. gsu.edu/Hbase/fluids/angatt.html#c1

Furling:
method to control spin rate

Why Control Wind Speed?

http://www.youtube.com/watch?v=7nSB1SdVHqQ



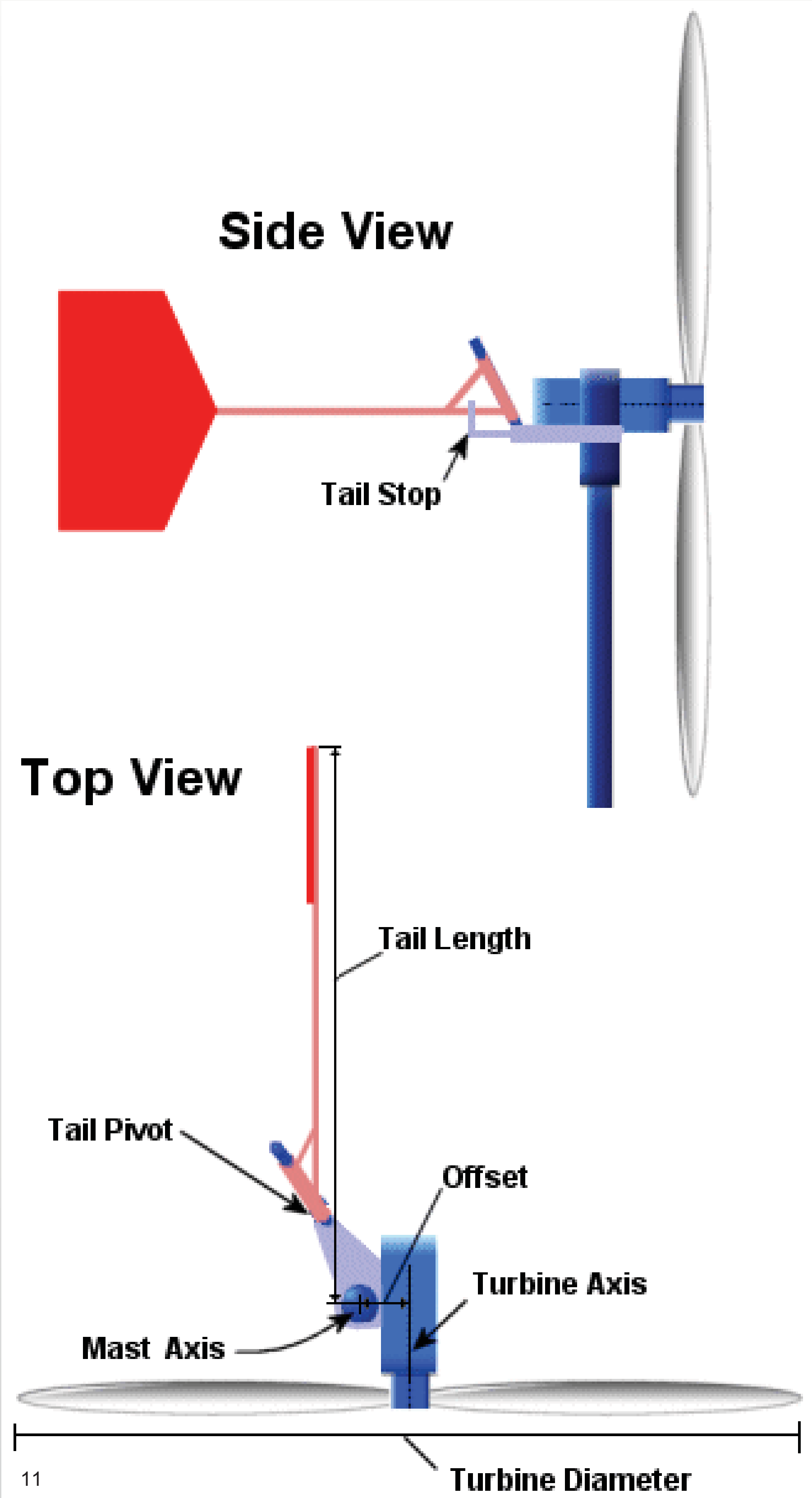


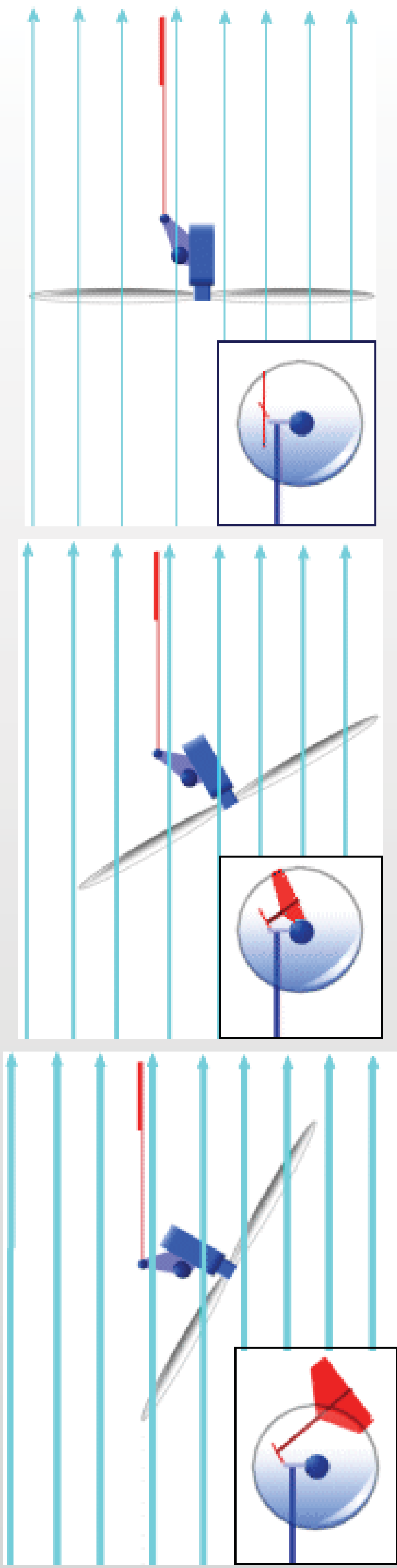
Courtesy of The Back Shed, http://www.thebackshed.com. Used with permission.

Furling:
method to control spin rate

Why Control Wind Speed?

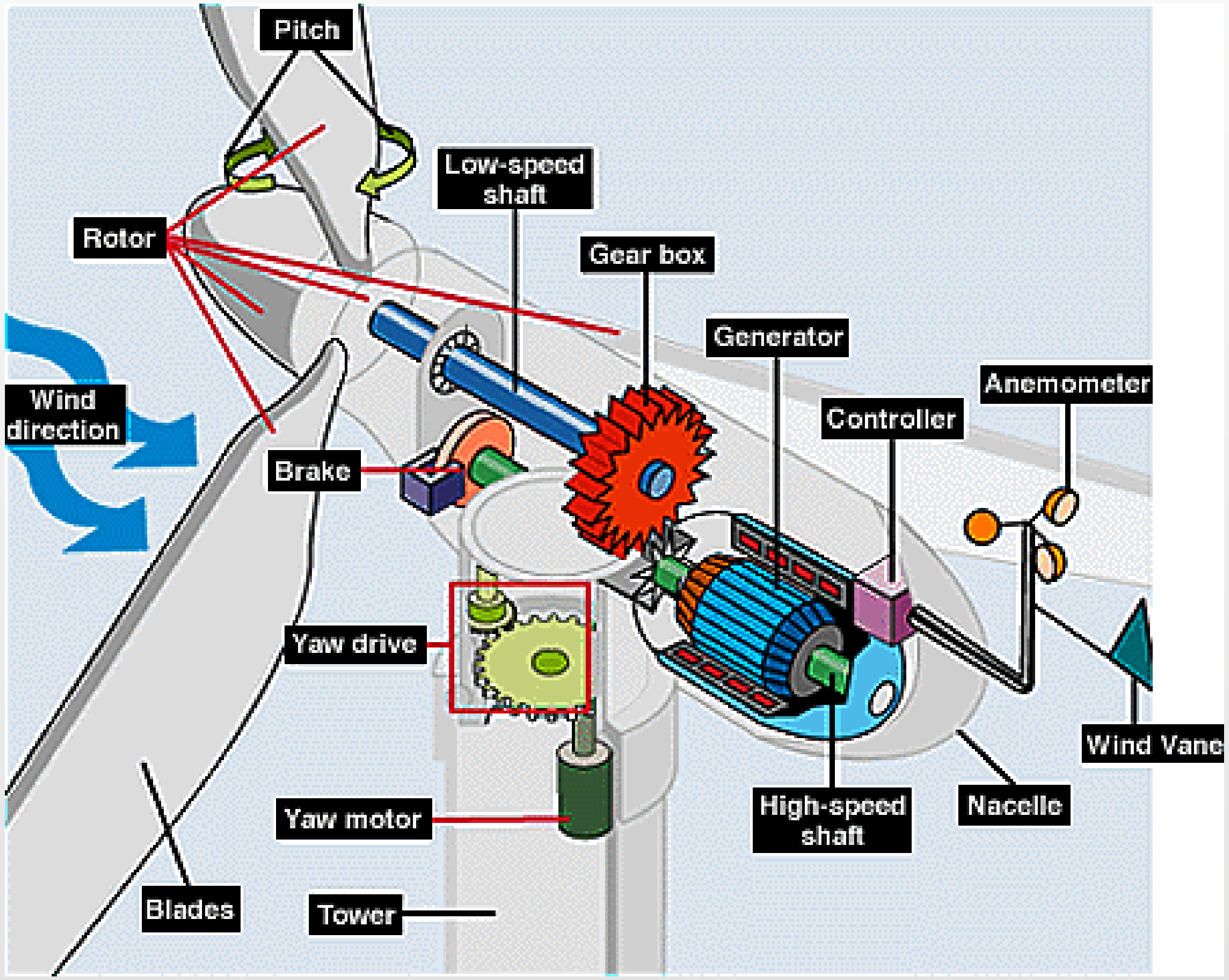
- Generators are designed for a specific magnetic flux
- Too fast: overload & destruction





Courtesy of The Back Shed, http://www.thebackshed.com.Used with permission.

HAWT Components



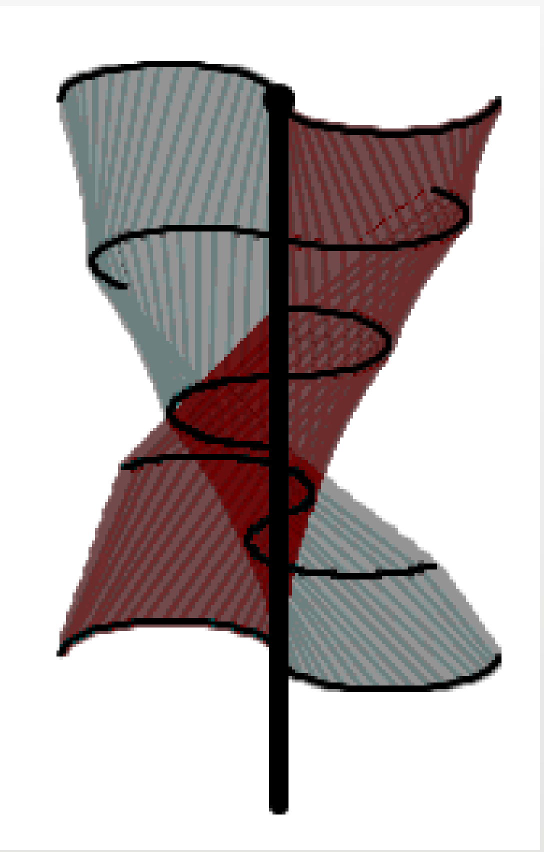
Public domain image (source: US DOE).

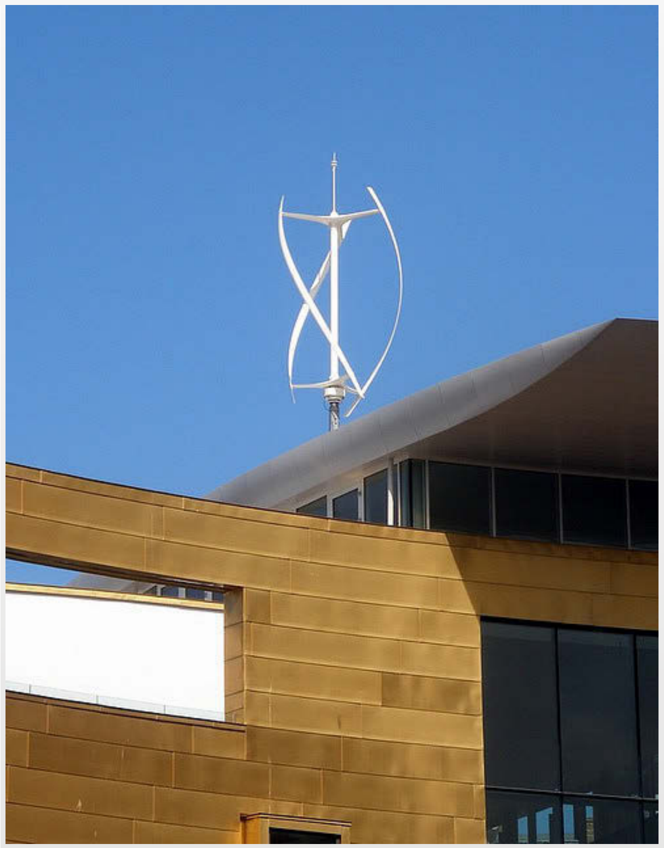
Yawing: turning blades into the wind

Installation Considerations

30 feet above any obstruction within 300 feet

Vertical Axis Wind Turbines





Photos courtesy of archer10, Arenamontanus and AIDG. Diagram is public domain.

Vertical Axis Wind Turbines

Advantages:

- Generator closer to the ground
- No need for yaw or pitch control
- Good for lower wind speeds / lower heights
- Less Noise
- Can often start at lower wind speeds

Disadvantages:

- Hard to scale up
- Generally less efficient
- More prone to fatigue

Defining Equations

Force of wind

$F = 0.5\rho A v^2$ ρ= density of wind,

A= cross sectional Area swept
v= velocity of wind

Maximum possible power extraction of a specific wind turbine

$P_{ideal} = 0.5 C_p \rho A v^3$ (Watts)

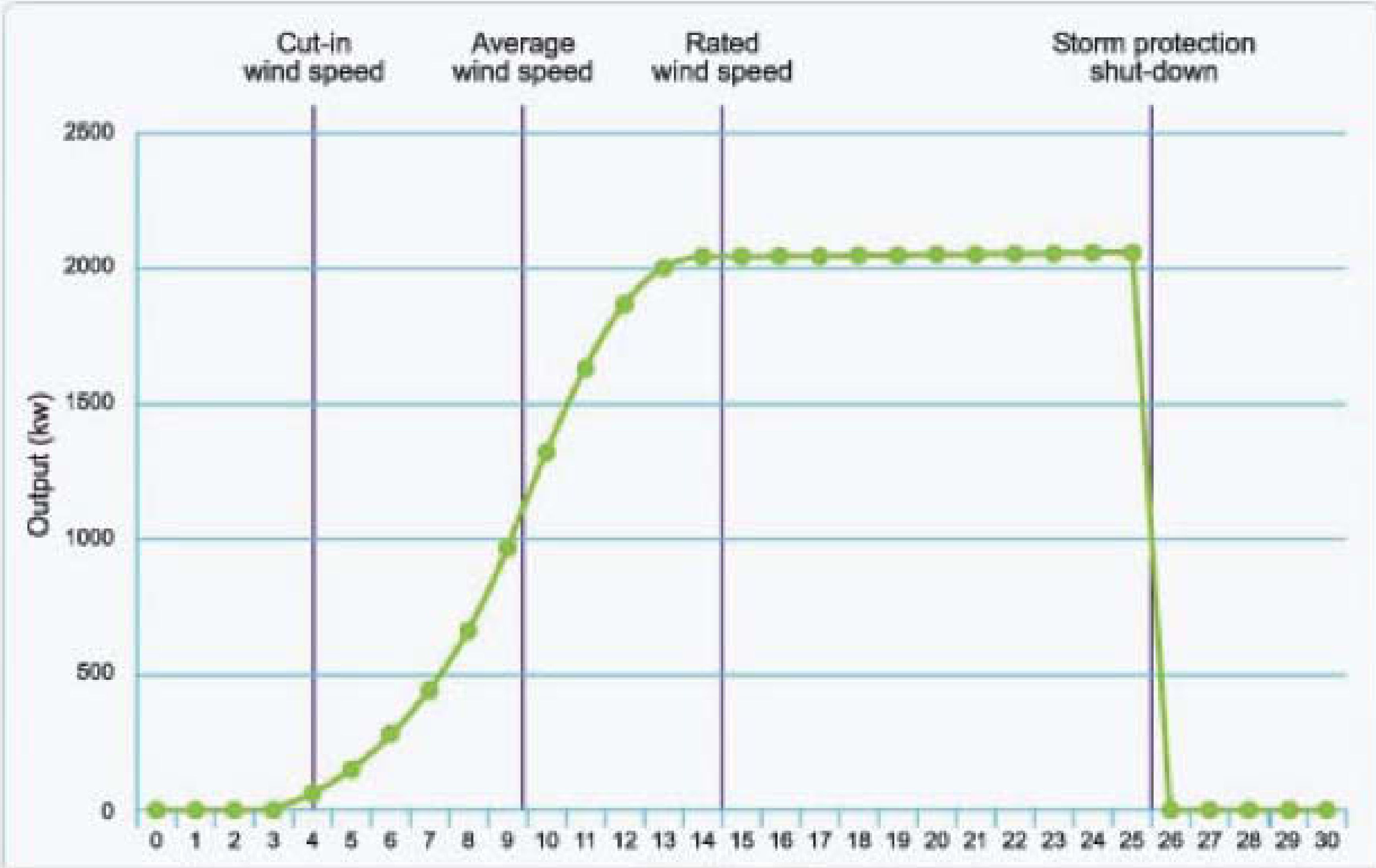
Coefficient of Performance= proportion of the power in the wind that the rotor can extract.
$C_{p\ max} = .593$ = Betz Limit; $0.1 < C_{p\ typical} < 0.5$

Defining Equations

$$\textbf{Capacity Factor} = \frac{\text{Actual amount of power a turbine puts out over time}}{\text{Rated amount if working at full capacity all the time}}$$

Usually around 20%-40%

A typical power curve



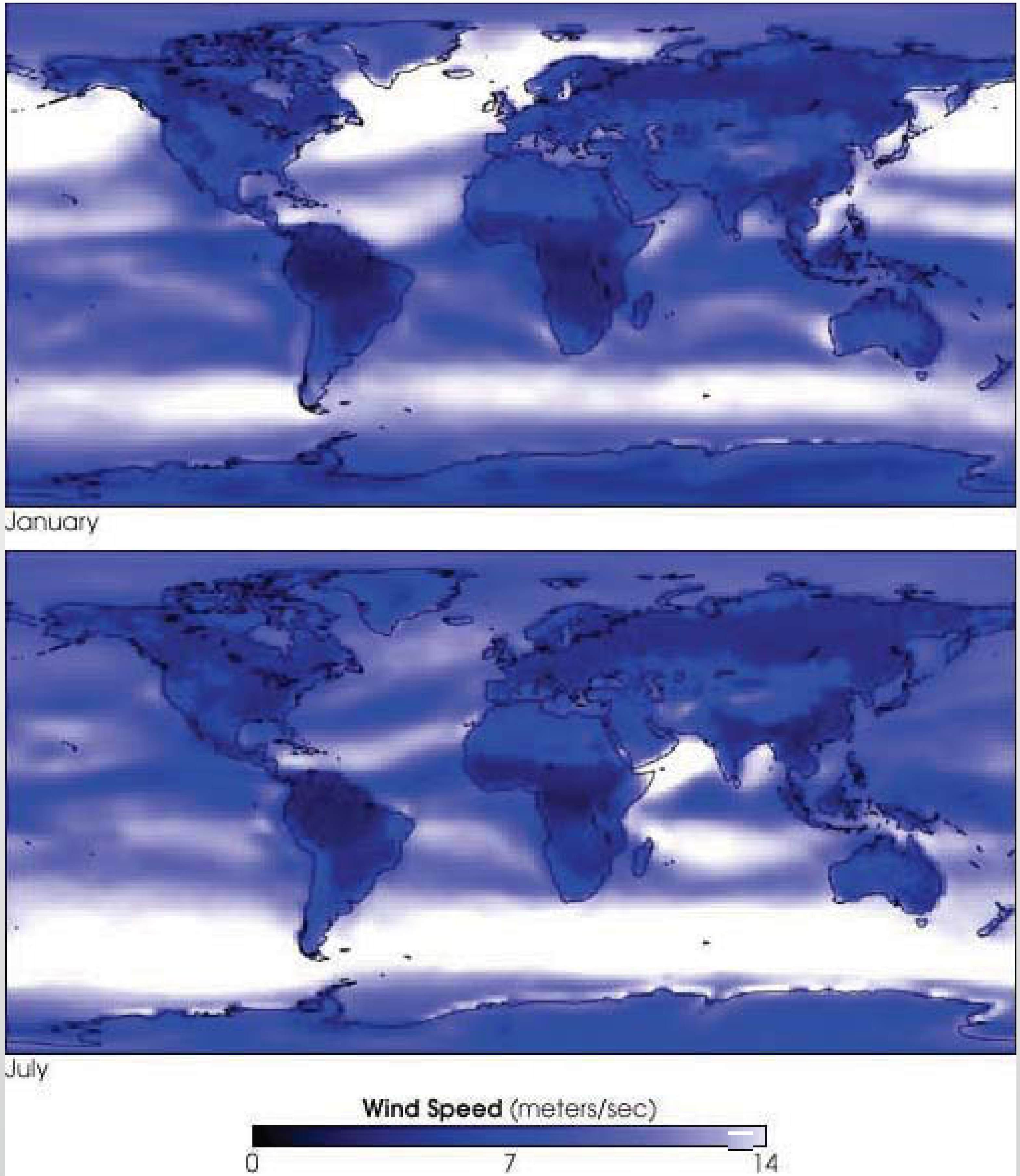
Characteristics of a typical power curve

- Zero output below the cut-in speed (commonly around 5 m/s)
- Constant power output above a certain speed (commonly around 10 m/s)
- The constant power output is where the speed control has been implemented
- Zero output above the cut-out speed (commonly around 25 m/s)

Wind speed

$P_{ideal} = 0.5C_p\rho Av^3$

5 m/s minimum (HAWT)



Public domain image (source: NASA).

Estimating Wind Speed: Beaufort Scale

- 1 mph = 0.45 meters / second

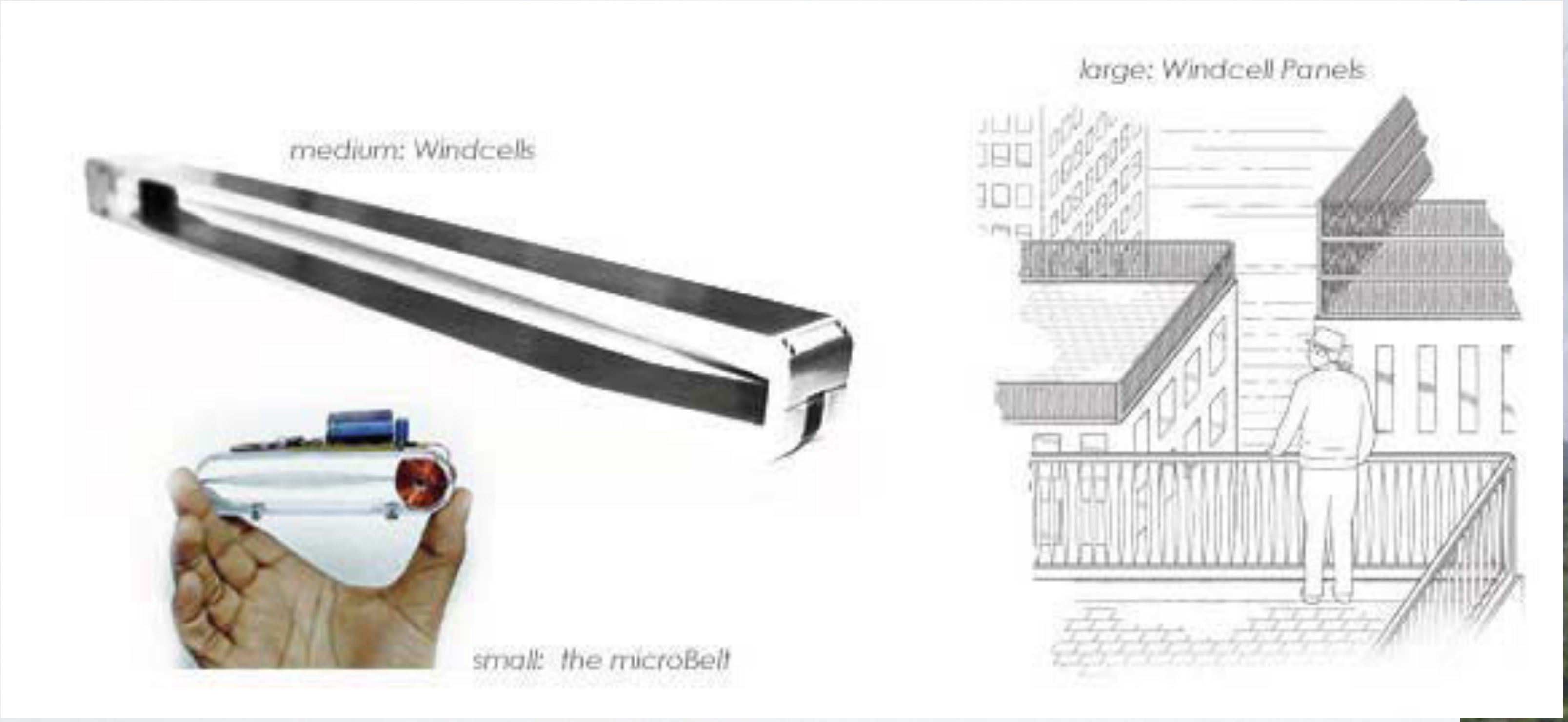
Beaufort number	Description	Speed	Visual Clues and Damage Effects
0	Calm	Calm	Calm wind. Smoke rises vertically with little if any drift.
1	Light Air	1 to 3 mph	Direction of wind shown by smoke drift, not by wind vanes. Little if any movement with flags. Wind barely moves tree leaves.
2	Light Breeze	4 to 7 mph	Wind felt on face. Leaves rustle and small twigs move. Ordinary wind vanes move.
3	Gentle Breeze	8 to 12 mph	Leaves and small twigs in constant motion. Wind blows up dry leaves from the ground. Flags are extended out.
4	Moderate Breeze	13 to 18 mph	Wind moves small branches. Wind raises dust and loose paper from the ground and drives them along.
5	Fresh Breeze	19 to 24 mph	Large branches and small trees in leaf begin to sway. Crested wavelets form on inland lakes and large rivers.
6	Strong Breeze	25 to 31 mph	Large branches in continuous motion. Whistling sounds heard in overhead or nearby power and telephone lines. Umbrellas used with difficulty.
7	Near Gale	32 to 38 mph	Whole trees in motion. Inconvenience felt when walking against the wind.

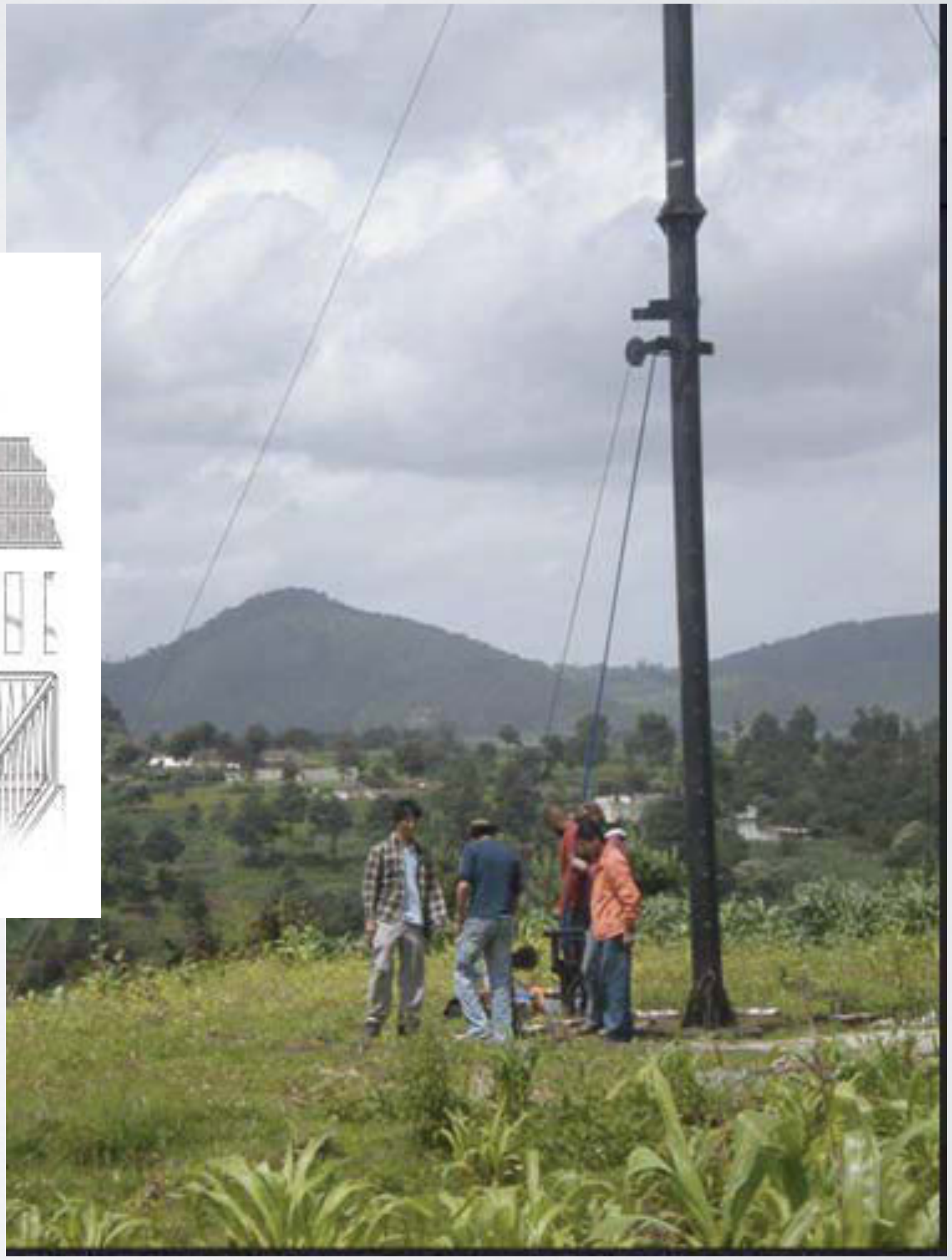
Global wind (and solar) data

http://eosweb.larc.nasa.gov/cgi-bin/sse/sse.cgi?+s01#s01

EXAMPLES OF WIND POWER IN DEVELOPING COUNTRIES

HUMDINGER WINDBELT
0.1 W - 100W





Courtesy of Humdinger Wind Energy LLC. Used with permission.

BLUE ENERGY
1 KW TURBINE

Photos removed due to copyright restrictions. See lecture video.

Hugh Piggott and Otherpower.com.

WILLIAM KAMKWAMBA

AFRICA WINDMILL PROJECT: PANEMONE WIND PUMP

Courtesy of Africa Windmill Project. Used with permission.

SO MANY OTHERS




http://www.windstuffnow.com

MICRO HYDRO POWER

HYDROPOWER: using gravitational water flow to generate power

- full scale: > 2 MW
- mini: 100 kW - 2MW
- micro: 5kW-100kW
- pico: 200W-300kW

SAME AS WIND: MILLS & TURBINES

- mill: low velocity, high torque, generate mechanical work

- turbine: high velocity, low torque, generate electricity

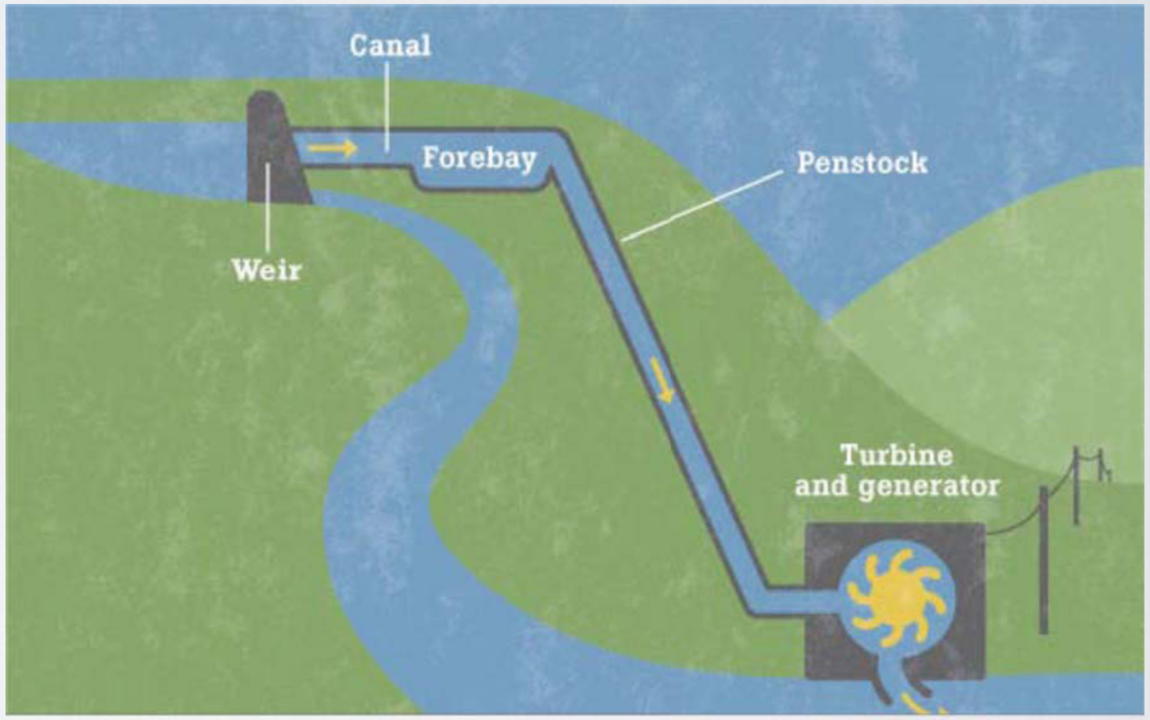
METHOD 1: RUN OF THE RIVER

Divert part of the river into a channel

- relative simplicity
- can be built locally
- low environmental impact
- relatively affordable

but

- no control over water supply variation



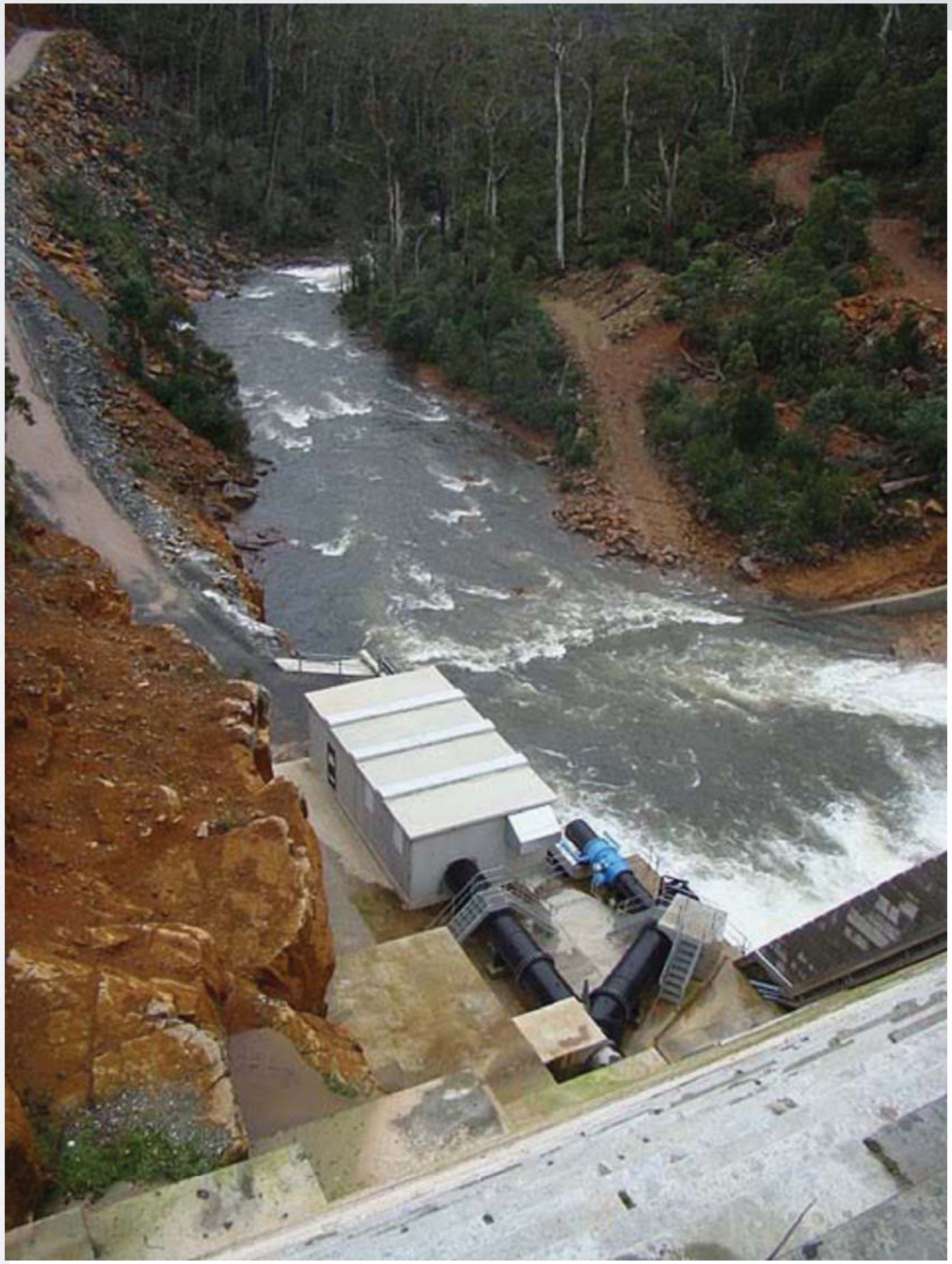
METHOD II: STORAGE (DAM)

Dam the river to store head; release water as needed to turbine

- rainfall accumulation possible

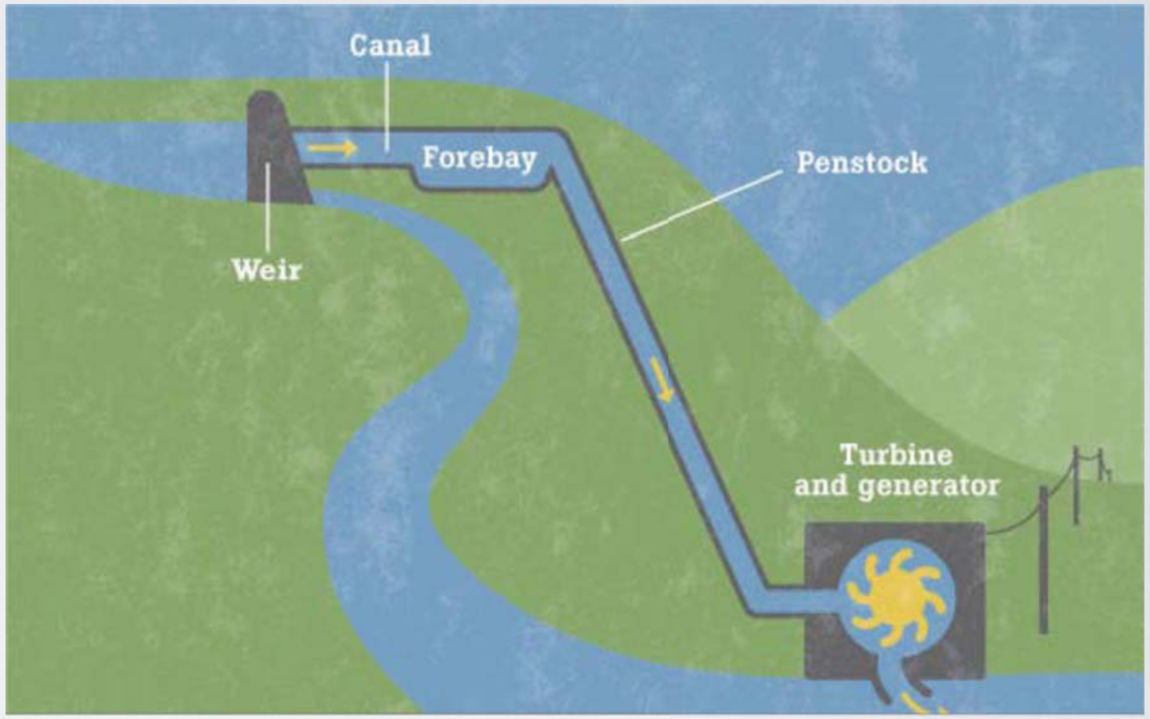
but

- comparatively complex & expensive
- greater environmental impact



COMPONENTS

- weir: diverts the river water
- settling basin: removes debris
- forebay: holding tank
- penstock: closed pipe flowing downhill
- turbine/electric generator: power production



A FEW TURBINE TYPES

- **Pelton** (high head, low flow) a set of small buckets arranged around a wheel onto which one or more jets of water are arranged to impact; very efficient

- **Francis** (lower head, higher flow) a spiral casing that directs the water flow through vanes on a rotor

Diagram of Francis turbine removed due to copyright restrictions.
See lecture video.

A FEW TURBINE TYPES

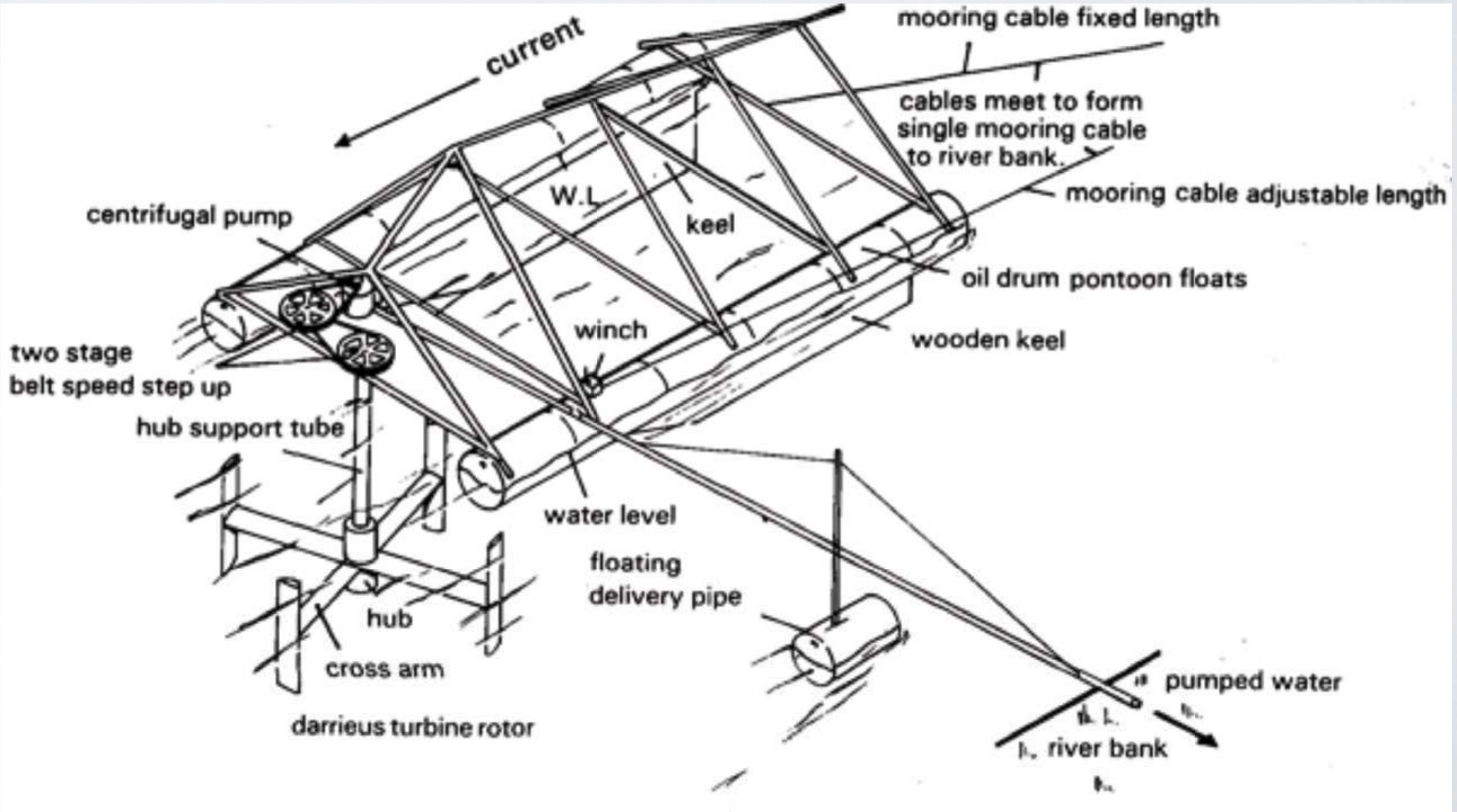
- **Cross-flow** (even lower head, higher flow) series of curved blades fixed between the perimeters of two disks to make a cylinder. The water flows in at one side of the cylinder and out of the other, driving the blades around. much easier to make than most other designs.

- **Propeller** (very low head and large flow) fixed blades, like a boat propeller

Diagrams of cross-flow and propeller turbines removed due to copyright restrictions.
See lecture video.

A FEW TURBINE TYPES

River current, which is like a wind-turbine immersed in water, can be used to extract power from with a large flow in a river, where there is virtually no head.



Source: Food and Agriculture Organization of the United Nations, 1986, P.L. Fraenkel, *Water Lifting.* http://www.fao.org/docrep/010/ah810e/AH810E12.htm. Used with permission.

CONSIDERATIONS

rule of thumb: 3 feet of head & 20 gallons per minute of flow (or equivalent with greater head):

$P = C_e \rho g h Q$

P: power (Watts)

C_e: efficiency (generally 0.4-0.7)

ρg: water density (kg/m^3) * gravity (m/s^2) = ~10 for SI units

h: height (m)

Q: flow rate (m^3/s)

pipeline diameter sufficient to minimize friction loss

HYDROLOGIC SURVEY: FLOW

Float method

- mark off ~100 ft along a length (ideally straight with uniform length and depth)
- calculate cross-sectional area, **A**
- place floats upstream of markers, in center of stream, record time to go from start to finish, repeat 5-10 times, find average)
    - good floats: tennis balls, fruit, etc.
- use conversion factor to calculate mean channel velocity **V** (flow is higher at surface than at the center)
- **V*A=Q**, flow rate

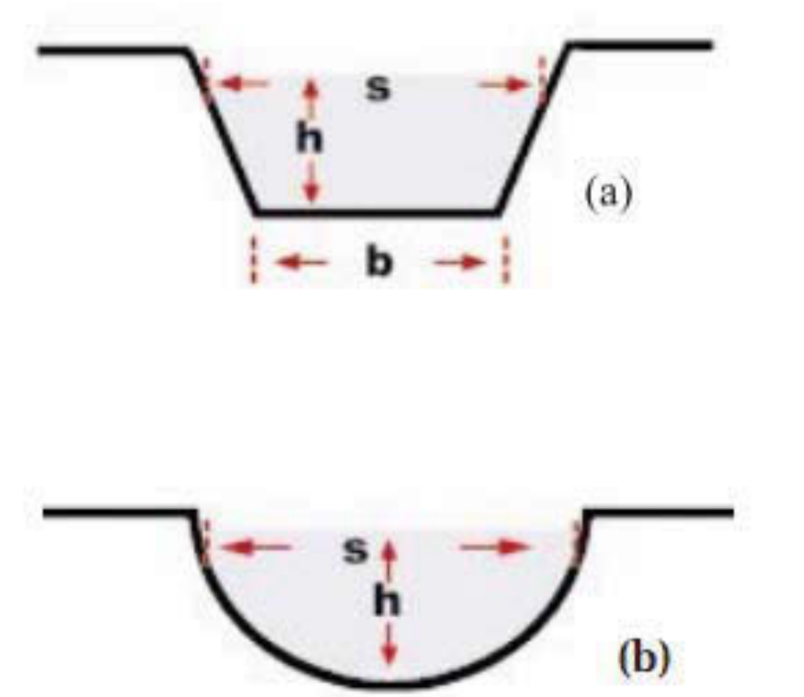


Figure 1. Cross-sectional dimensions for trapezoidal (a) and elliptical (b) ditches. (Diagram by J.S. Jones, 2003)

Table 1. Coefficients to correct surface float velocitie to mean channel velocities. (from "Water Managemen Manual, USDI/BOR, 1997).

Average Depth (ft)	Coefficient
1	0.66
2	0.68
3	0.70
4	0.72
5	0.74
6	0.76
9	0.77
12	0.78
15	0.79
20	0.80

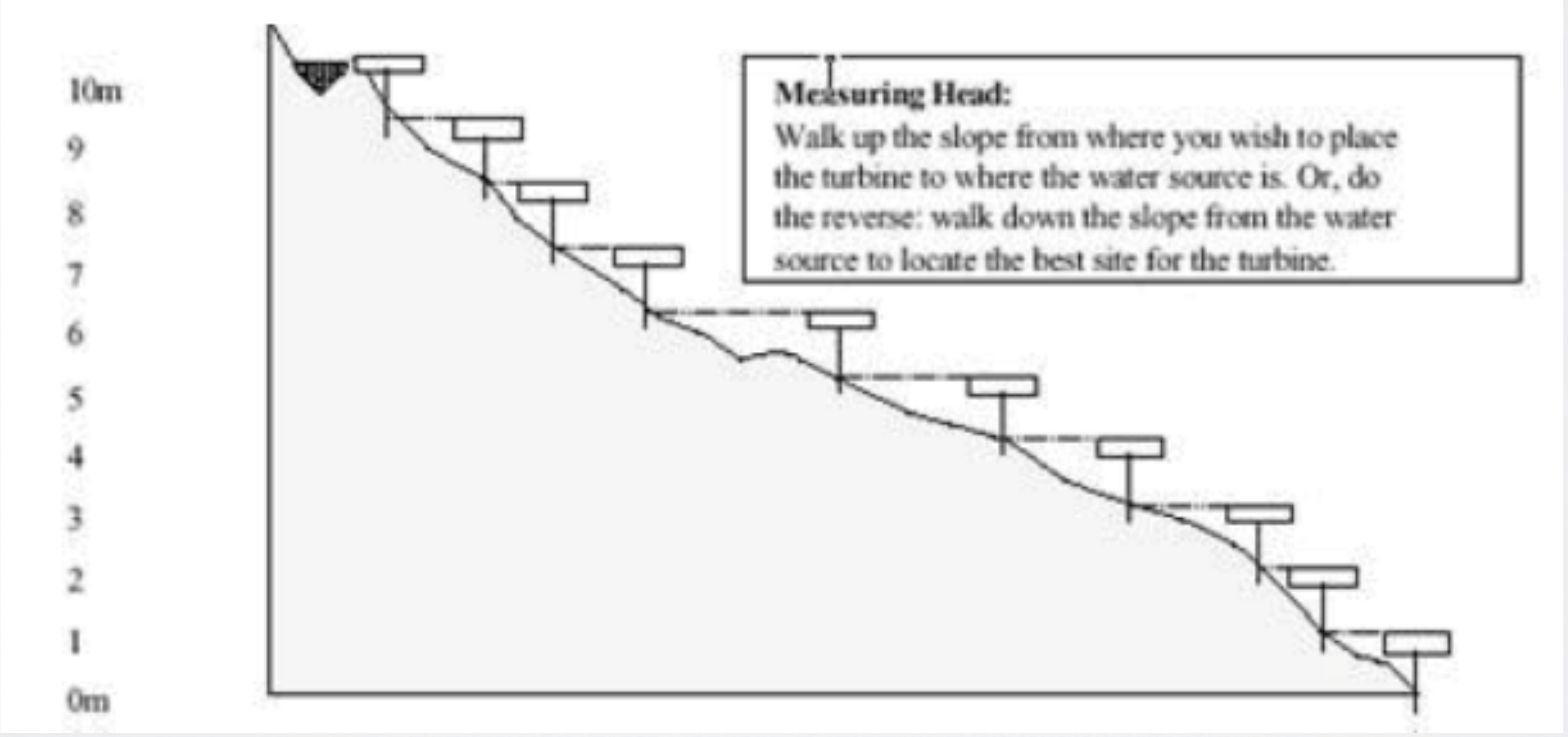
Courtesy of Arizona Cooperative Extension, University of Arizona College of Agriculture and Life Sciences. Used with permission.
Source: Martin, Edward C. "Measuring Water Flow in Surface Irrigation Ditches and Gated Pipe." University of Arizona Cooperative Extension, 2006.

HYDROLOGIC SURVEY: HEAD

Water filled tube

•use a level (can use clear tube half-full of water) horizontally on top of a 1m stick.

•two people alternate using stick to measure head



Courtesy of Asian Phoenix Resources Ltd., Canada. Used with permission.
Source: PowerPal T5 Turgo Generator manual.

Trip Teams

AsoFenix

http://asofenix.org/

Projects:

0. delivery of OJ bag sealer project

1. Bio-digester: mixing of the slew. Our bio-digesters lose a lot of usable fuel because the slew is not mixed. Jaime wants some sort of mechanism to mix the slew (mechanical, not electrical) using hand or bicycle power. This would be used on concrete and plastic bio-digester designs. One of our interns, Erika, has her masters in bio-digesters and will be a great resource

2. Feed chopper mechanization using bicycle power

3. Washing machine. hand or bicycle powered. It would need to improve on the current method of hand washing in water usage, effort, and time

https://sites.google.com/site/worldtechforpeople/human-powered-washing-machine

GrupoFenix http://www.grupofenix.org/

Projects:

1. Charcoal -- practice charcoal-making and review charcoal stove making and usage.

2. Solar cell phone chargers -- develop more affordable version for production

3. Solar cooker -- more affordable and more aesthetically pleasing (looking like it's a real product), making sure the wind can't damage, insulation considerations

ASAPROSAR http://www.asaprosar.net/

Description: ASAPROSAR is dedicated to empowering the poor in El Salvador. Numerous efforts in health, nutrition, family planning, child development, care of environment & sustainable agriculture.

Possible Projects:

0. Charcoal Training

1. better ventilation for smoke for cooking in the home

2. charcoal stoves, believed that most people cook with wood now and only have adobe stoves

3. better lighting fixtures/arrangements so that families with electricity but few light sockets/bulbs

Project Assignment

1. Right now
    a. talk to Amy for 10 minutes
    b. brainstorm ideas
    deliverable: 2 annotated pictures from each team member for each project by 3/4

2. literature search on topics
    a. what exists
    b. how it functions/is made
    deliverable: ~2 page annotated bibliography per project by 3/4
    http://owl.english.purdue.edu/owl/resource/614/01/
    (focus writing on summarize & reflect, not assess -- only include sources that pass the assessment)

3. develop project specifications
    how: http://web.mit.edu/2.009/www/lectures/15_specifications.pdf
    examples: http://web.mit.edu/2.009/www/lectures/15_fruitSpec/specExamples.html
    deliverable: specs for each project using 2.009 format (attribute, metric, unit, value)
    (it is likely you won't be able to fill in all the values until your trip) by 3/11, revised by 3/18

Project Assignment

4. second brainstorm

    deliverable: 2 annotated pictures for each project by 3/11, revised by 3/18

5. questions list for trip (deliverable) 3/16

6. materials list for trip (deliverable, also to project partners) 3/11

7. 15-minute presentation on 3/16
    a. literature search findings
    b. project specifications
    c. annotated pictures
    d. key questions
    e. key expected activities

READING ASSIGNMENT

http://bopreneur.blogspot.com/2010/01/ending-poverty-period.html

http://www.greenempowerment.org/blog/wp-content/uploads/2010/05/practical-action-technical-brief-final-charcoal1.pdf

Effective (and Fun) Brainstorming

Clear Problem Statement

Project ideas for community partner project

4 weeks of building

~ $500 budget

References: Professor David Wallace, IDEO

Effective (and Fun) Brainstorming

How it's done

Generate as many ideas as you can in 15 minutes

pictures..few words

give it a (short) name

quickly describe the idea

post on wall

practice improves idea generation

References: Professor David Wallace, IDEO

Effective (and Fun) Brainstorming

Rules of the Game

DEFER JUDGEMENT

one at a time

build on ideas ("theft" is encouraged)

stay focused

be visual

encourage wild ideas

References: Professor David Wallace, IDEO

Effective (and Fun) Brainstorming

Sort the pile

group divides the ideas in to themes

name the themes

do the themes make sense?

refine & combine the best

References: Professor David Wallace, IDEO

Muddy Cards!

please include hours/week you spend outside of class on this class

EC.711 D-Lab: Energy
Spring 2011