Renewable Energy Engineering

Sustainable - Alternative Energy Engineering

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The Good News and the Bad News

- Good news, Conservation of energy holds.
- Bad news, so does the 2nd Law of Thermodynamics
- Patterson's Theory of Doom (plagiarised)

Tom Stoppard, Arcadia

- Septimus:-“So the improved Newtonian Universe must cease and grow cold, Dear me”.

- Thomasina :-"Yes, we must hurry if we are going to dance.”

- The time scale

The hard reality

- No energy is “renewable”
- The best aim is for sustainability
  - Hydrocarbon fuels store solar energy
  - We are using in centuries energy stored over aeons
    - the threat of shortage
    - Urban air pollution
    - Greenhouse gas
    - Thermal load on globe

Energy - Power - Lord Kelvin

- Energy has the ability to do work, units
  - Scientific - joule
  - Electrical - kilowatt hour, LES ~7c/kWh
- Power is rate of delivering energy, units
  - Scientific / everyday, watt, (1 joule/second)

Tutorial on Power

- Human being, on bike 200 W
- Small Automobile 60,000 W
- Jet aircraft engine 30,000,000 W (F*V)
- Nebraska Utilities 4,563,000,000 W
- Solar Panel 50 W

Costs

- If we are to spend $200, we could buy a 50 W solar panel, OR, at 7c /kWh from LES, 10.3 GJ.
  - (2860 kWh, 3.6 MJ per kWh)
- At 50 watts, 4.5 hours per day from a solar panel, it would take 35 years to get this much energy!
- Plus, if we want to read at night, $40 every three years for a battery …….
  - Plus power electronics ……..

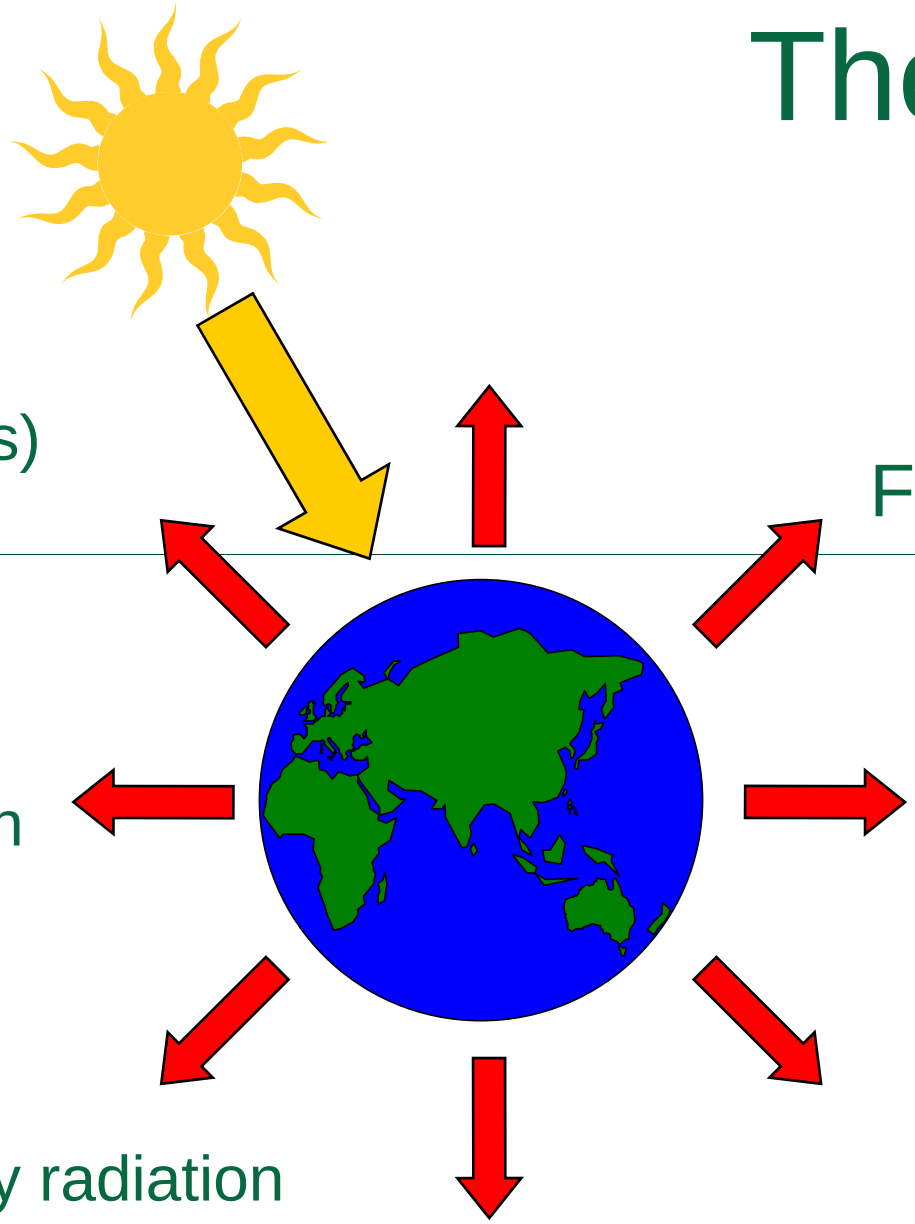
2 Lessons

- 1. Alternative energy is relatively expensive.
- 2. Everybody admires those who use it, even if they don’t themselves, because of lesson 1

Charles Dickens, David Copperfield

- Annual income twenty pounds, annual expenditure nineteen nineteen and six, result happiness.
- Annual income twenty pounds, annual expenditure twenty pounds ought and six, result misery.

The Budget



$1.75*10^{17}$ W
($3*10^{34}$J in
5 billion years)

20 days to
get the
hydrocarbon
number

Black body radiation
at 5 degrees C
$1.75*10^{17}$ W

Stored energy

Hydrocarbons	$3*10^{23}$ J

Fissionable material

Uranium 235,	$0.2*10^{23}$J
Uranium breeder	$10*10^{23}$J
Thorium Breeder	$3*10^{27}$J
Fusion	$7*10^{30}$J

Geo-thermal	>> $3*10^{30}$J
Kinetic of rotation, own axis,	$5*10^{28}$ J
Kinetic of rotation, around sun	$3*10^{33}$J

Sustainability

- Solar energy is our input
- falls on vegetation, photosynthesis (1.2%, ethanol)
- falls on oceans, evaporation, rain, (hydro)
- Falls on land masses, air convection, winds (wind turbines)
- Apart from photosynthesis, and lakes in mountains, it all ends up as low grade heat in a very short time frame -
  - aim:- get it to do “useful” work on its way there

Photovoltaics

- Mono - poly crystalline ~15%
  - embodied energy
- Amorphous ~ 8%
  - already available as roofing material
  - Cu In Se, thin film, 12%
- Titania - Organic - Polymers
  - window coatings – wearable PV ~4- 5%
- Concentrator systems, large area, small amount of photovoltaics

Multi layer cells, > 30% efficient, parabolic dishes or Heliostat arrays

PS, Aust Govt announced Oct 06 154 MW PV Heliostat! $AUD 10^8


15

Wind Power

- Viable in large grid systems where good regimes exist - large scale
- An integral part of small remote area power supplies where good regimes exist (fuel saving)
- Concerns:- visual and acoustic pollution, bird strikes

1997 350 kW, Induction generator

A 20km stretch of the north coast of Gujarat, a north-western state of India which is the site of a 136 MW wind farm ~ 500 wind turbines

Enercon E-126

6 (7+) MW,

126 meter diameter hub

height 138 meter

Gearless

DC link

Blades in 2 parts!

12,500 m^2

480 W/ m^2

Economies of scale, large engineering effort

Tidal Power

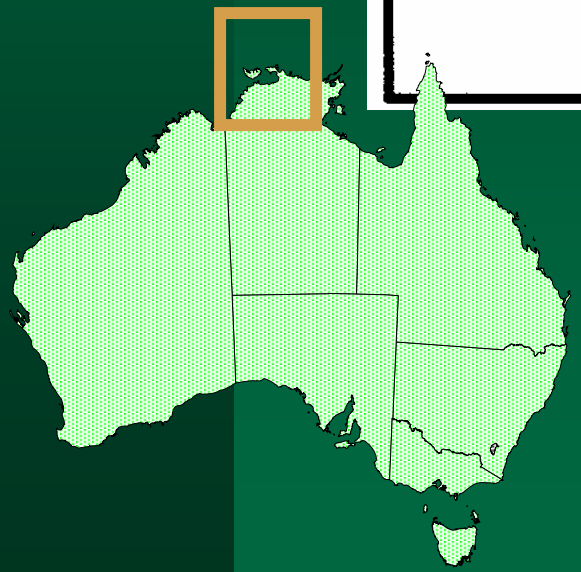
- Not even sustainable
- Using KE of moon and KE of rotation of earth, hastening the departure of the moon from orbit, and slowing down the earth

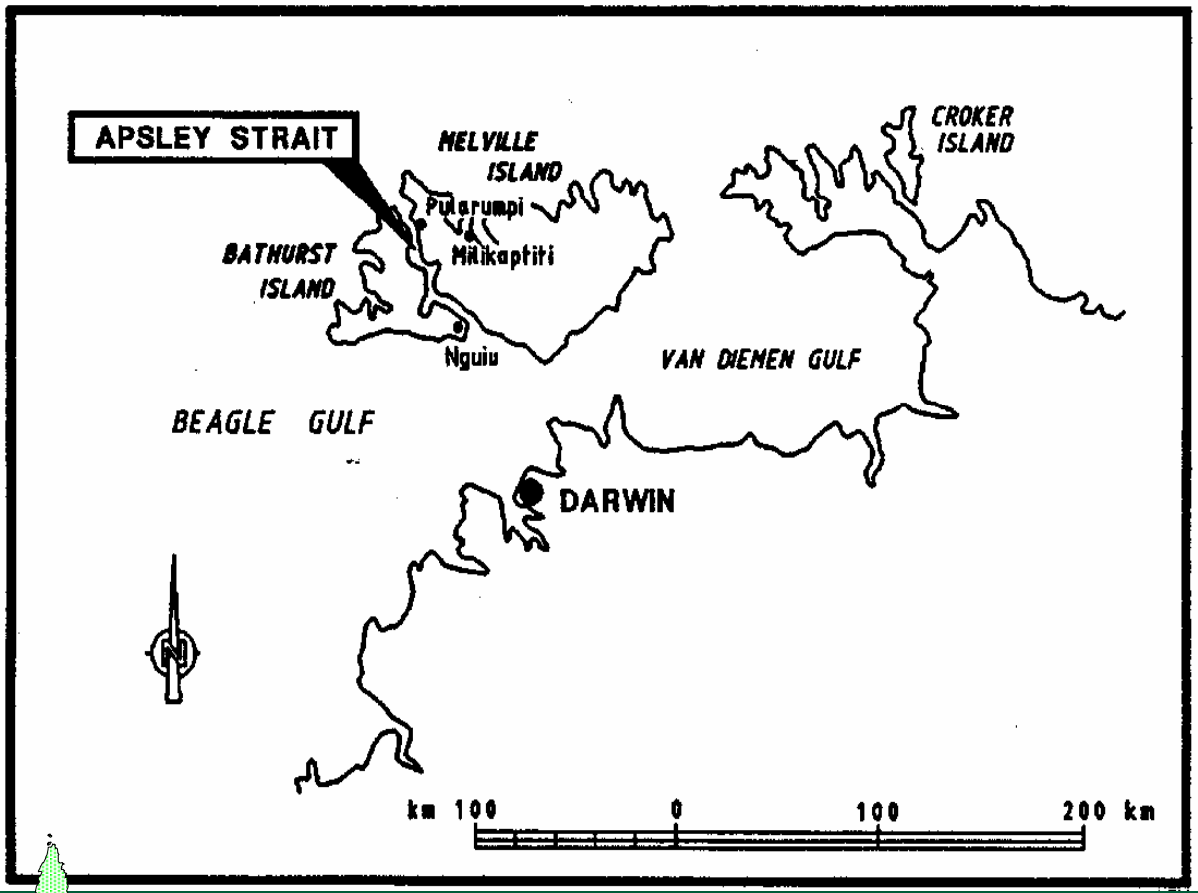
The Numbers

- Friction of water flowing over the ocean bottom due to tides has retarded the rotation of the earth so that 365 rotations takes about one second longer than it did a century ago
- The KE of rotation of the earth is $5.3*10^{28}$Joules.

The numbers cont

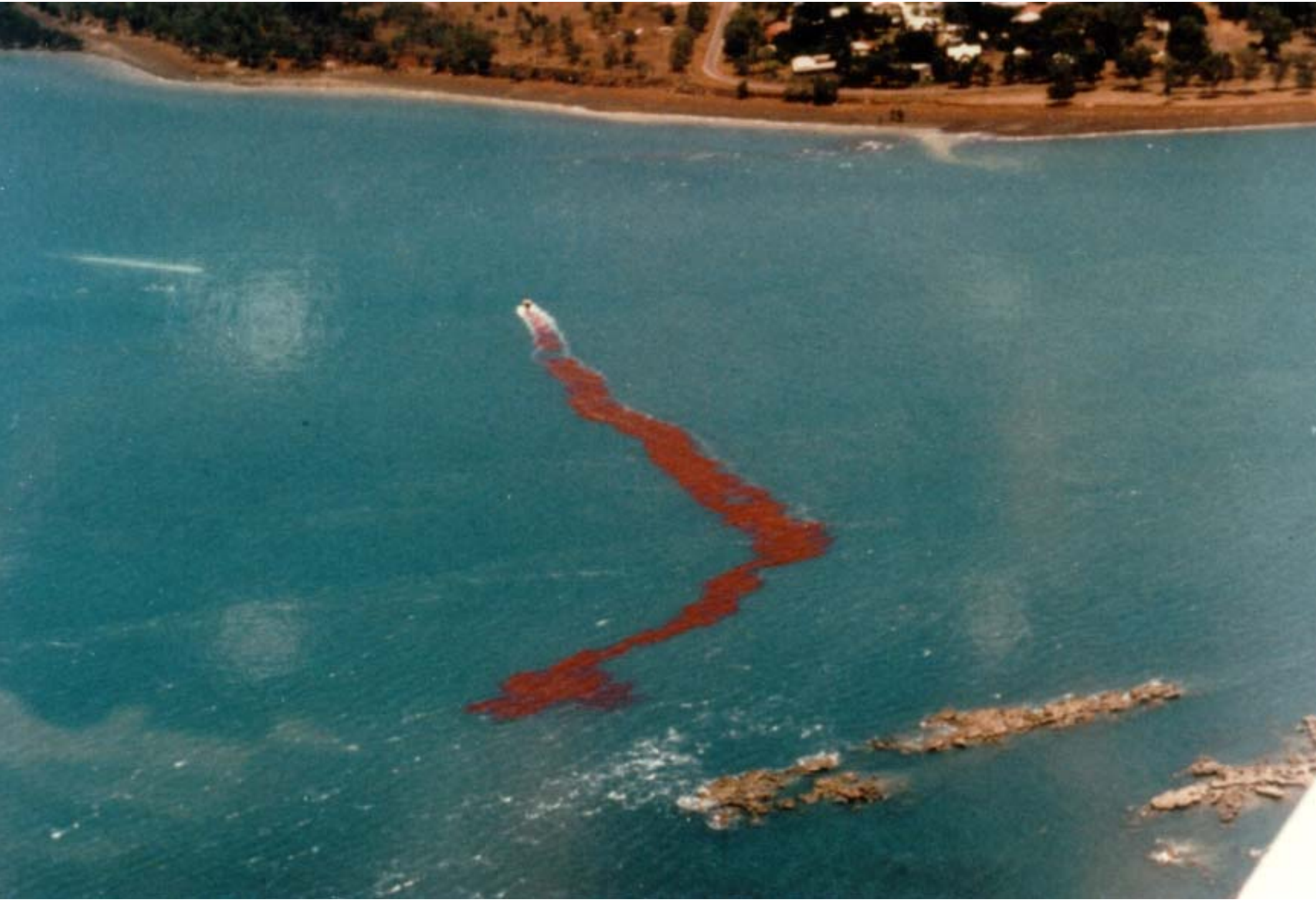
- La Rance in France, 240 MW
- proposed Severn , UK, 9000 MW
- assume max 30,000 MW,
- 200,000 years to make 365 rotations take 1 sec longer




APSLEY STRAIT
MELVILLE ISLAND
CROKER ISLAND
Pularumpi
Milikapiti
BATHURST ISLAND
Nguiu
VAN DIEMEN GULF
BEAGLE GULF
DARWIN
N
km 100 0 100 200 km

Older systems

- Trap water at high tide
- use potential energy
- problems, large scale civil works, environmental impact
- economies of scale
- there is also kinetic energy in the flow, captured using “underwater windmill”



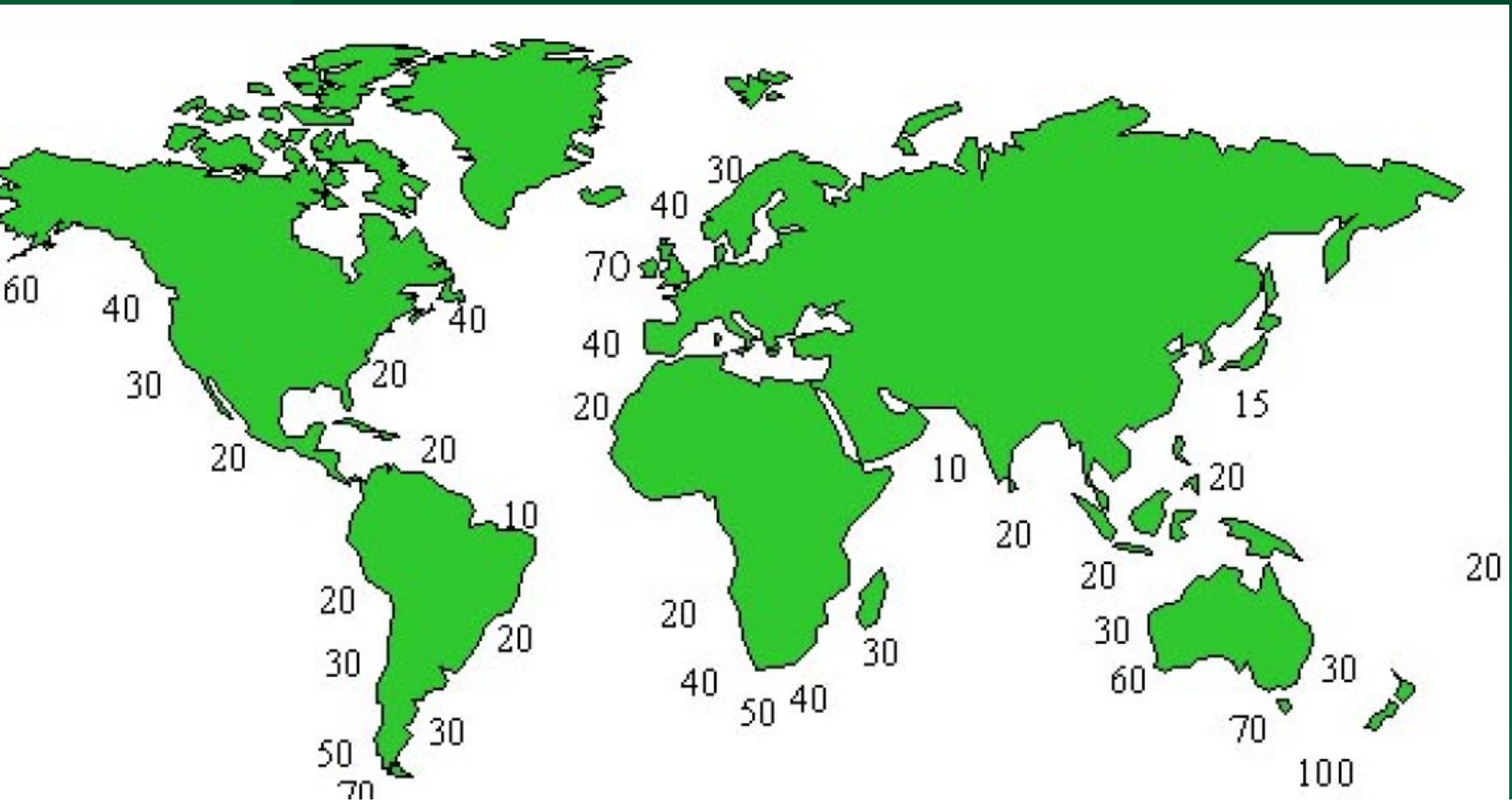
2 kW at 2 m/s, 2 meter diameter turbine, Cp ~ 0.4

Also run of river, needs same engineering effort as wind turbines, Congo

Ocean Wave Energy

A “concentrated” form of solar energy, sun-wind-waves.
There,s a lot of it, and conversion systems needn’t be huge.

More “dense” than solar or wind



Units are kW/meter of wave crest, takes wavelength and frequency into account

Wave energy II

- Wind turbines run at rated power 25% of the time
- Wave generators 40%
- Not as variable, swells travel long distances
- Correlation wind – sea swell not as high as you might expect, predictions days before are good

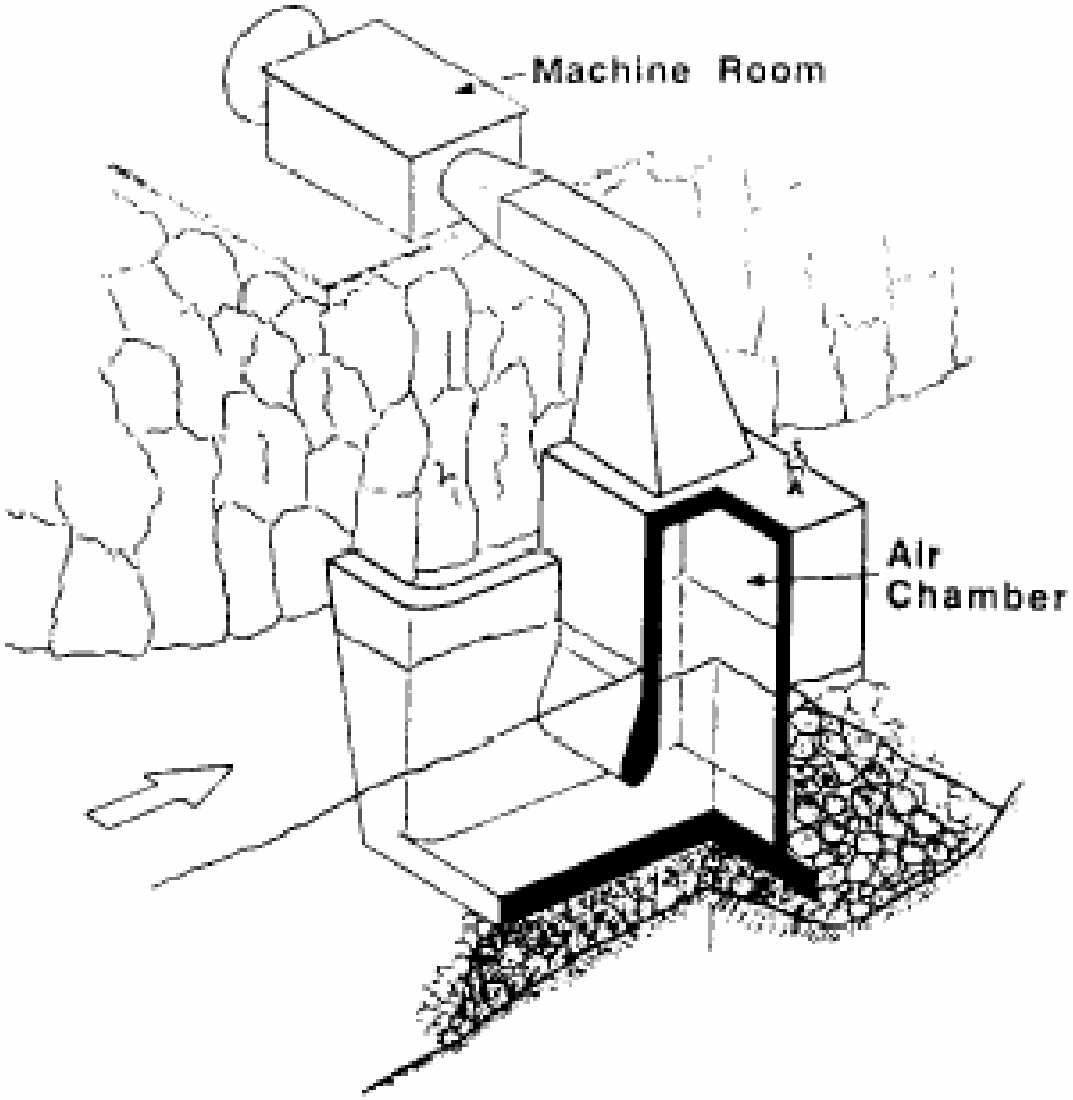
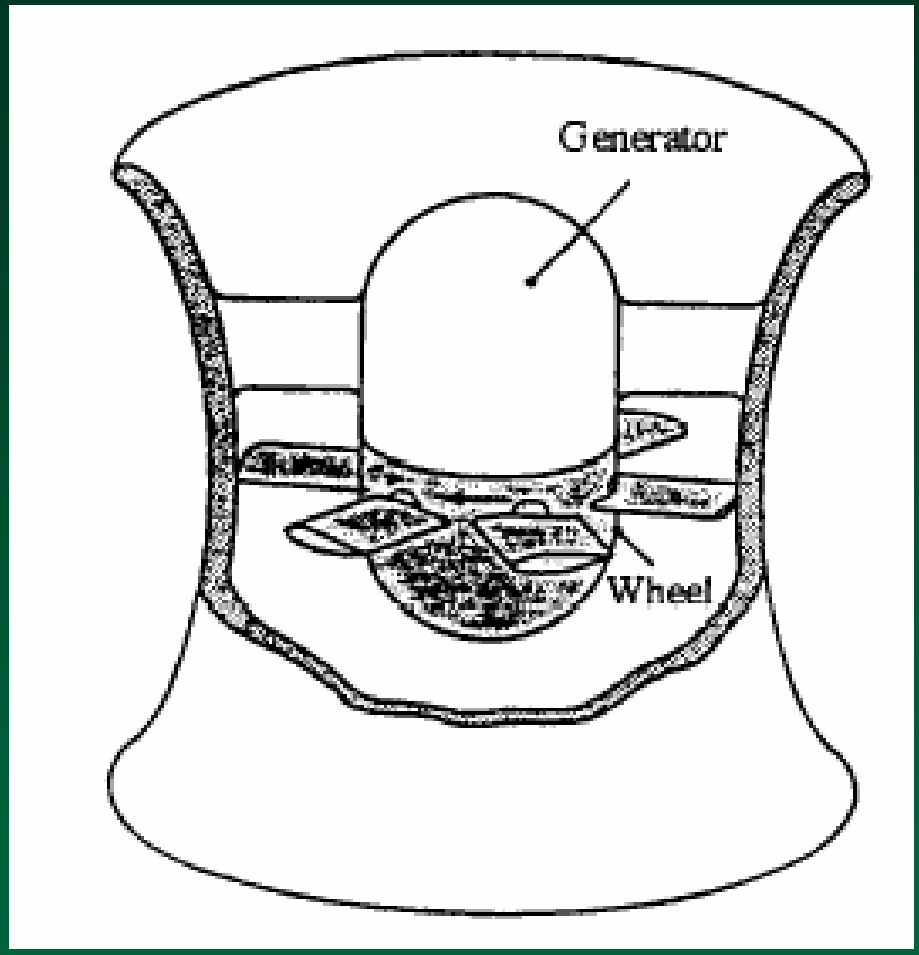


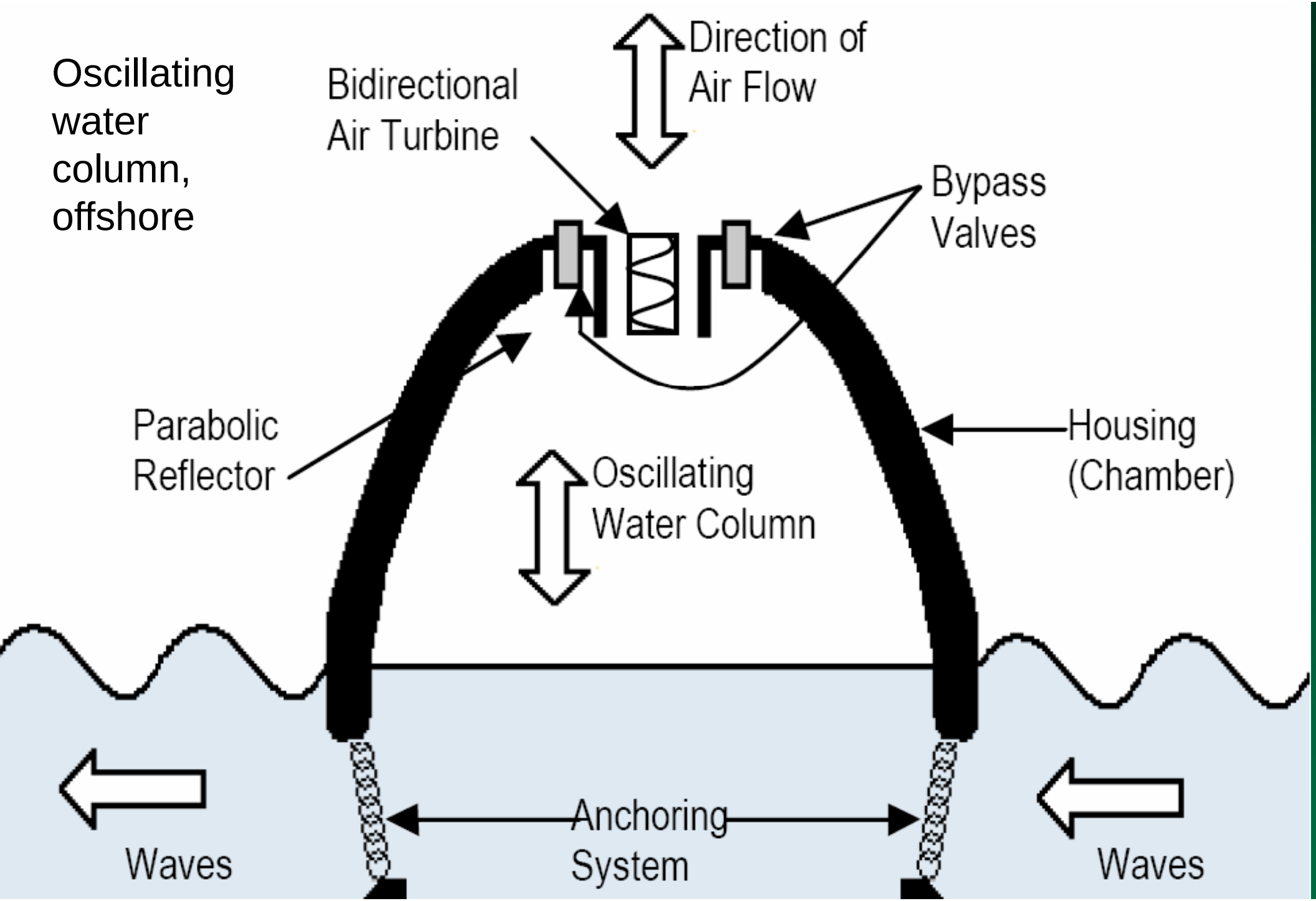
Fig. 1: Oscillating water column device for Azores.



Bidirectional Wells Turbine

Oscillating water column, shore based (1992)

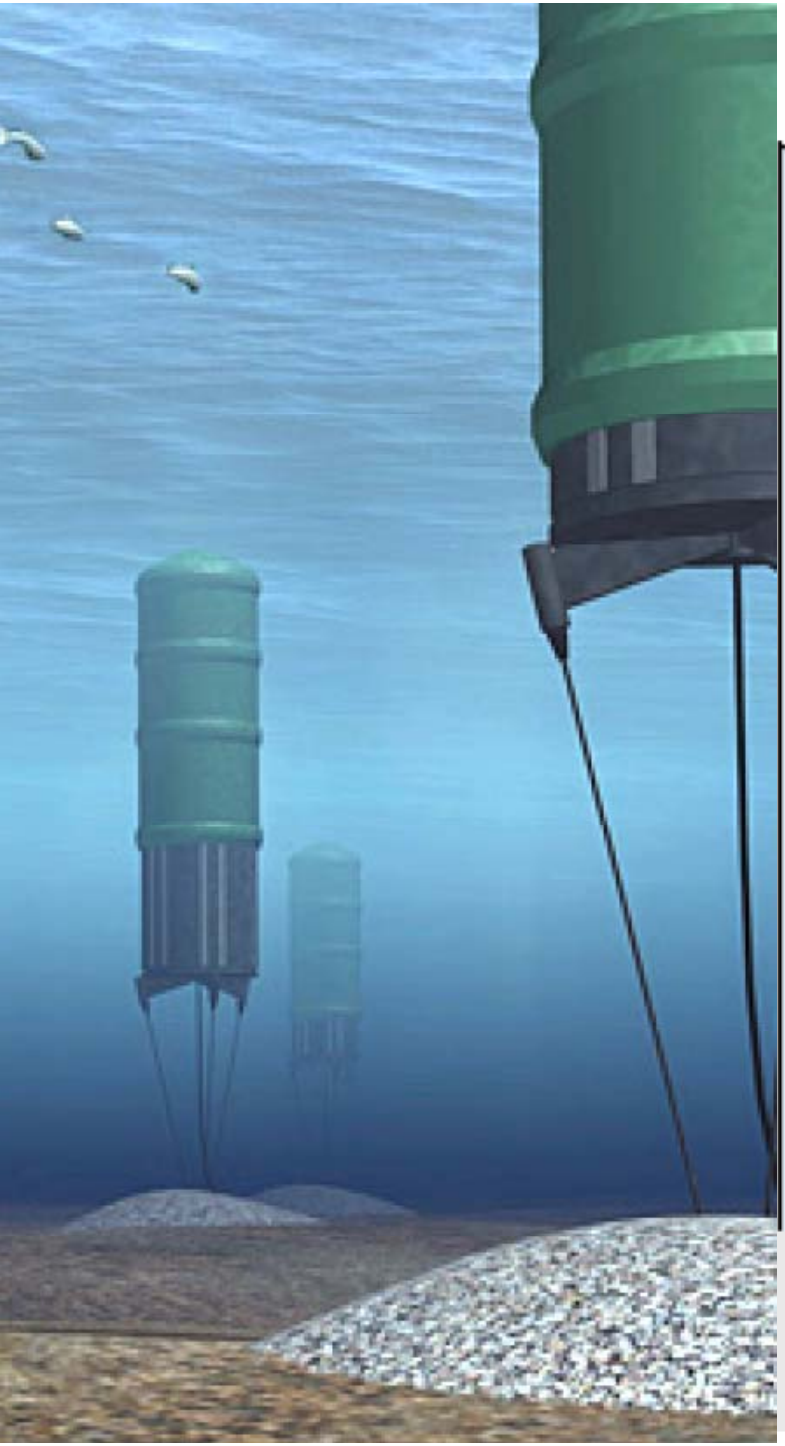
Oscillating water column, offshore

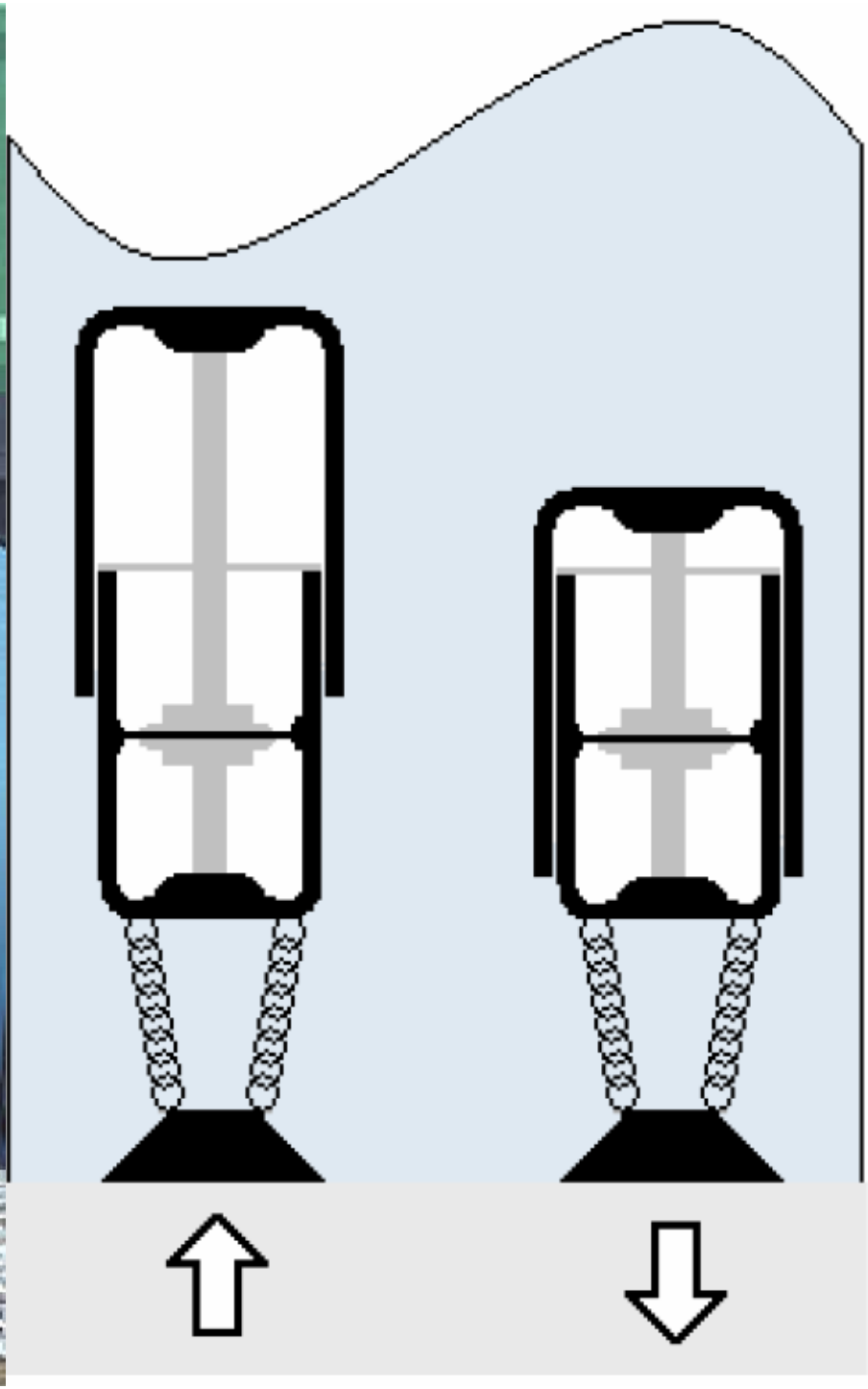


Heaving bouy.

Fixed part anchored to bottom, or to a large horizontal plate deep in water to provide stable reference.

Linear generator, or hydraulic pump





Archimedes wave swing.

(Dutch)

Fully submerged

Large, high force, slow, linear PM generator.

Planned, over 1 MW per unit.

Pelamis, 4 sections, 150 m long, hydraulic pumps. Next model, 180 m

750 kW apiece, 3 in farm off Portugal.

Wavedragon have commercialised this!

Wave energy The next big thing? Already quoting 6.25 eurocents/kWh!!

Solar Thermal

- A workable answer
- needs courage
- Technology exists

Australian National University “big dish”

2 MW for Tennant creek, 27 dishes, large scale study, 9c/kWh

Capture – Storage - Use

Storage - Some Numbers

	Specific Energy MJ/kg	Energy Density MJ/liter
Refined Gasoline,	43	39
Liquid Hydrogen (<20K)	120	13
Ammonia Dissociation	4	
Fused Silica Fiber flywheel	3.6	
Li – ion Battery	0.5	
Steel Flywheel	0.18	
Lead acid Battery	0.12	
Ultra capacitor	0.005	
Steel clockwork	0.000038	
Rubber	~0.000005	

Energy Use Issues, efficiency AND entropy match

- Domestic Water Heating
- Domestic Refrigeration
- Electric Motors
- Lighting, Air-conditioning, buildings
- Automobiles

Conclusions

- It is worth worrying about
- Definition of life. Humans will organise
- “We must hurry if we are going to dance."

Automobiles, A Solar Powered Car

Photovoltaic cells

Battery

Electric Motor in wheel

Electric system delivers 96% of electrical energy to the road

Efficiency Opportunities

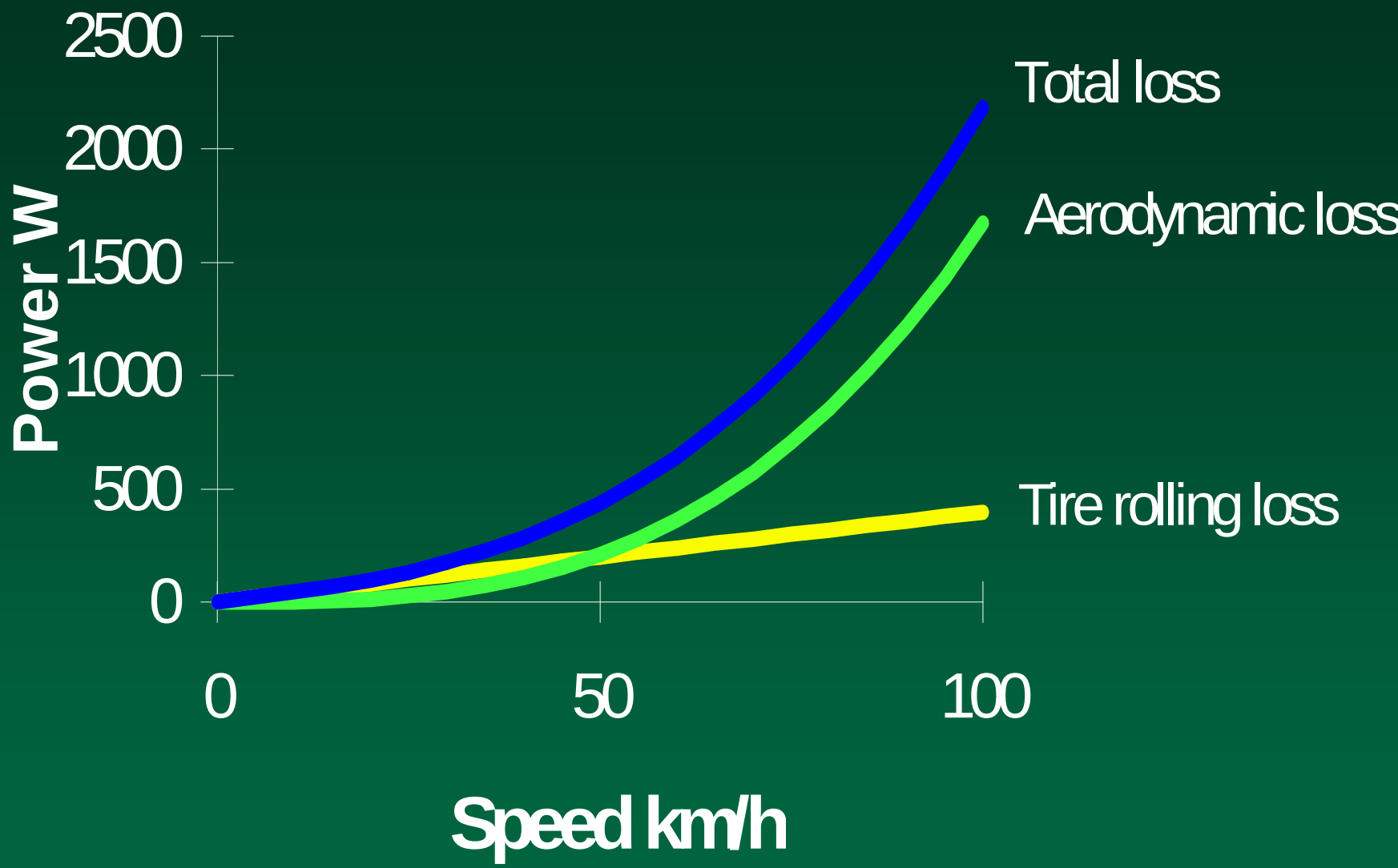
- Current heat engine in auto 12%-14%
  - Of energy in gasoline gets to the road
- Tightly controlled best heat engine 35%- 40%
  - Fundamental limit for heat engines, 2nd law!
- Fuel Cell (PEMFC) 60%
  - Beats the Carnot cycle for heat engines
  - Plus
- typical energy use, city driving, 1/3 energy wasted braking
  - 60% of braking energy - recovered - electric machine regeneration
- Altitude change also provides opportunity for regeneration
  - Solar cars, Golf carts, hilly cities

Power use, any wheeled vehicle, steady speed, level ground, no wind

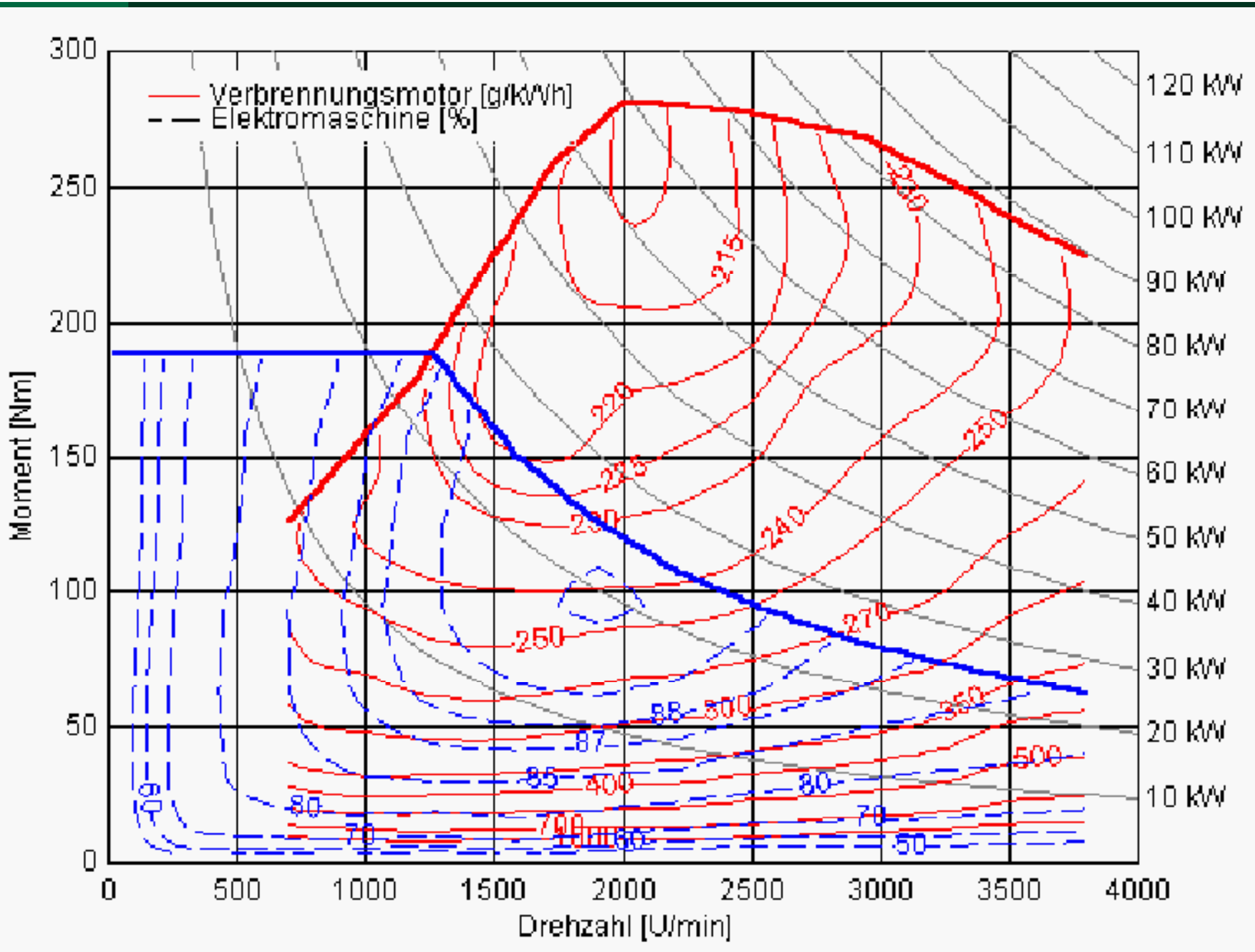
- Power is used in two ways only
- 1 Compressing the tires!
  - Rolling loss - proportional to weight and speed
- 2 Pushing the air out of the way!
  - Aerodynamic loss -related to speed, and vehicle shape

$$P = MC_{rr1}v + \frac{1}{2}\rho v^3 C_d A \quad watts$$

Tires, 1900, 30 kg/t, 1946, radial 11 kg/t, now 8.5, 6, 2.5 kg/t



Link:car comparison


Verbrennungsmotor [g/kWh]
Elektromaschine [%]
Moment [Nm]
Drehzahl [U/min]
0
50
100
150
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300
0
500
1000
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2000
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110 kW
120 kW
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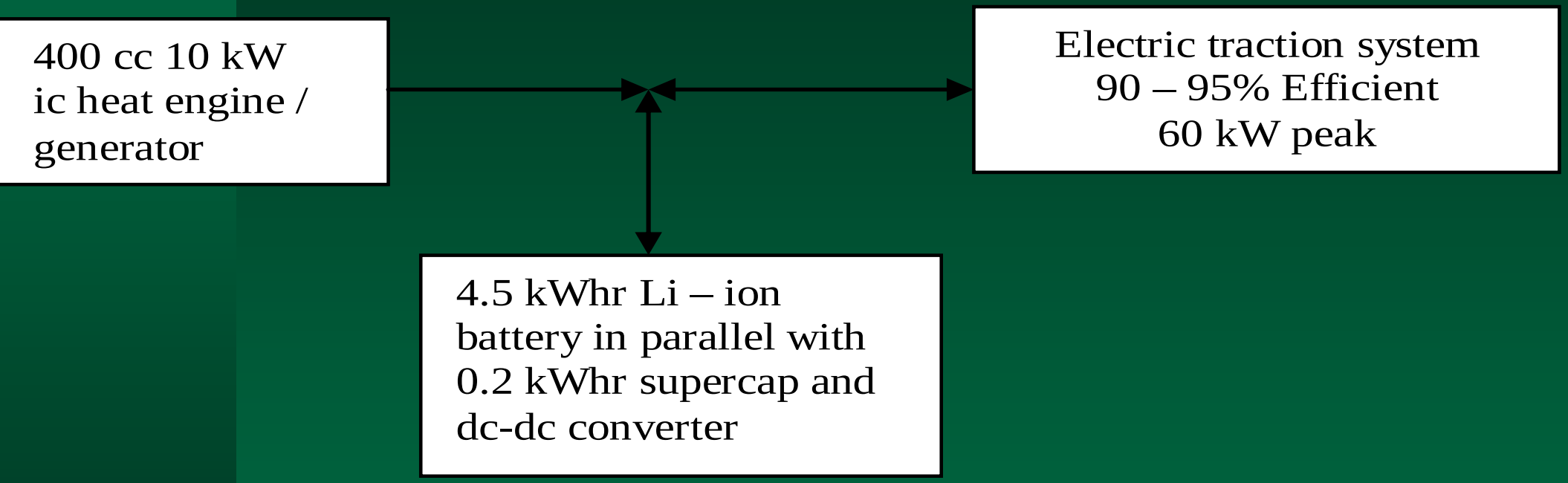
The Series Hybrid

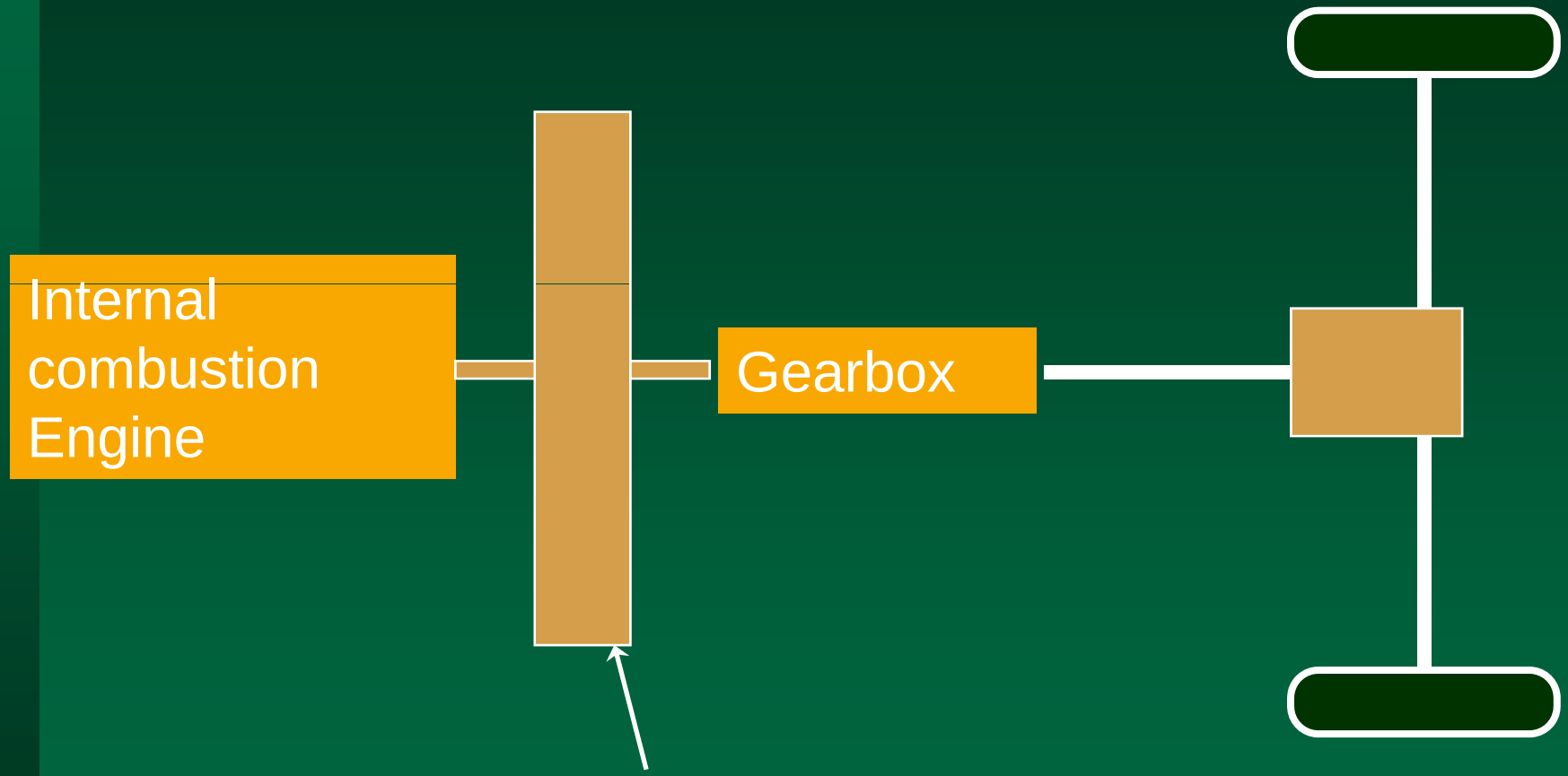


Heat engine runs at optimum speed
and power rating, or not at all

Comments, series hybrid

- None in Market yet
- Ultimately the best – Like Diesel Electric Locomotive, or ship (QE II)
- All power gets converted to electricity and back, double conversion
- No “Limp home” capability

Mild Parallel Hybrid, Insight



The future, fuel cell vehicles ?

- Still coming
- Ultimately may win, (more efficient) fully electric drive, as for series
- challenges –
- Getting the hydrogen – much early talk of on board reforming of eg methanol
- Storing the hydrogen, if not produced on board
- Finding economic catalysts, non Pt
- Preventing poisoning of catalyst by CO