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Renewable Energy Sources and Modern Technologies

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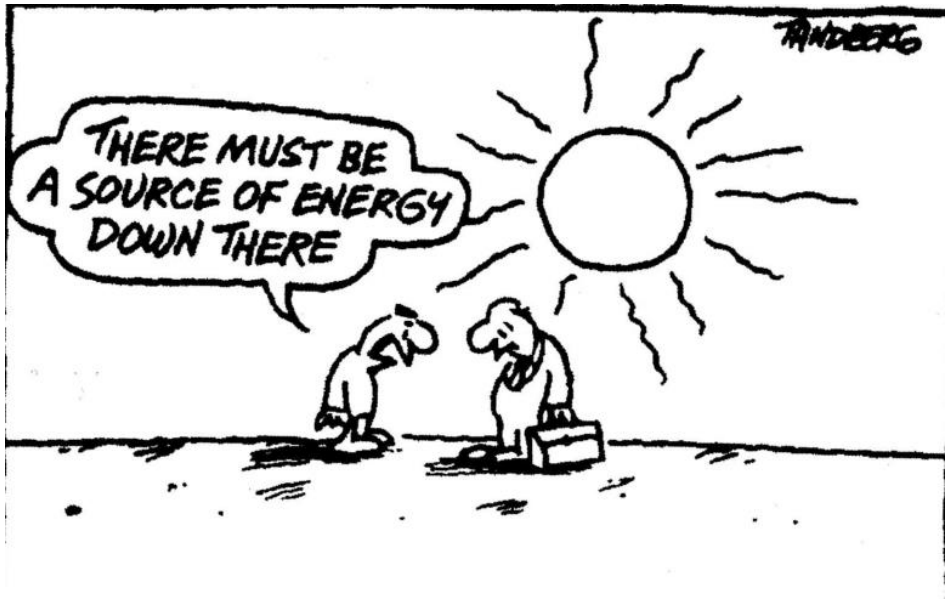
Renewable Energy Policies

- The oldest energy sector on Earth vs. new wave of development
- New sector, probably the most dynamic one

Why?



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Renewable Energy Policies

- The sector responds to the global trend of combating climate change, protecting the environment, reducing greenhouse gas emissions and decrease imports of energy resources especially after 1989.

  - Rapid growth in consumption of energy resources
  - Interdependence in the relationship with foreign suppliers
  - Contradictory an effort to retain as much autonomy from foreign countries using nuclear power, domestic coal and, increasingly, renewable energy
  - First symptoms caused by lack of coal
  - Probable end of the hydrocarbon age in the 21 Century (exhaustion of coal, oil and natural gas)
  - Fighting the climate change
  - Emissions reduction efforts
  - UN and EU commitments to those organizations
  - The process of liberalization of the electricity market
  - Rising energy costs

Renewable Energy Policies

- Natural energy that does not have a limited supply. Renewable energy can be used again and again, and will never run out.
- Any energy resource that is naturally regenerated over a short time scale and derived directly from the sun (such as thermal, photochemical, and photoelectric), indirectly from the sun (such as wind, hydropower, and photosynthetic energy stored in biomass), or from other natural movements and mechanisms of the environment (such as geothermal and tidal energy). Renewable energy does not include energy resources derived from fossil fuels, waste products from fossil sources, or waste products from inorganic sources.
- Any naturally occurring, theoretically inexhaustible source of energy, as biomass, solar, wind, tidal, wave, and hydroelectric power, that is not derived from fossil or nuclear fuel.
- Renewable energy is from an energy resource that is replaced by a natural process at a rate that is equal to or faster than the rate at which that resource is being consumed. Renewable energy is a subset of sustainable energy.

Renewable Energy Policies

- Two attitudes to REP:

- **Low-carbon economy**
  - a priori does not reject various fossil energy sources
  - the aim is to adapt the existing economy to low-carbon principle as much as possible, i.e. minimum production of CO2 as the main greenhouse gas
  - this approach does not exclude (on the contrary - supports) the use and development of nuclear energy as an emission-free source
  - renewables may have different meanings, but they are always more or less complementary to the primary sources

- **Environmental**
  - focuses on the word "renewable" and refuses basically any fossil fuel
  - the target is complete transition to renewable energy
  - there are currently many limits for complete transition to renewable energy, such as the condition of human knowledge and technology, technical aspects and financial costs

Renewable Energy Sources

- Who do you think are

the top countries in renewable energy

generation?

Renewable Energy So

- Who do you think are the top countries in renewable energy generation?

Renewable Energy By Country

Rank	Country	Total Renewable Energy (GWh)
1	China	1,398,207
2	United States	572,409
3	Brazil	426,638
4	Canada	418,679
5	India	195,242
6	Germany	193,735
7	Russia	170,077
8	Japan	169,660
9	Norway	140,240
10	Italy	109,962
11	Sweden	103,067
12	Spain	95,660
13	France	90,940
14	United Kingdom	87,083
15	Turkey	81,911
16	Venezuela	74,240
17	Vietnam	55,742
18	Paraguay	55,190

Renewable Energy Sources

- What sources of RES do you know?

Renewable Energy Sources










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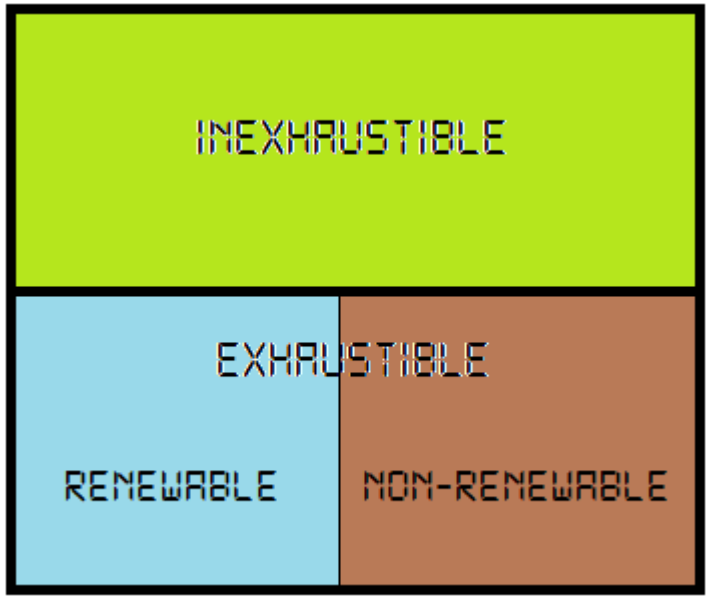
Renewable Energy Sources

- **Libor Krajíček**
- late 1960s, geographer at Faculty of Science, Charles University in Prague
- creation of a scheme that shows the distribution of raw materials and resources independent of human activity and only resulting from what our planet and the surrounding universe provide



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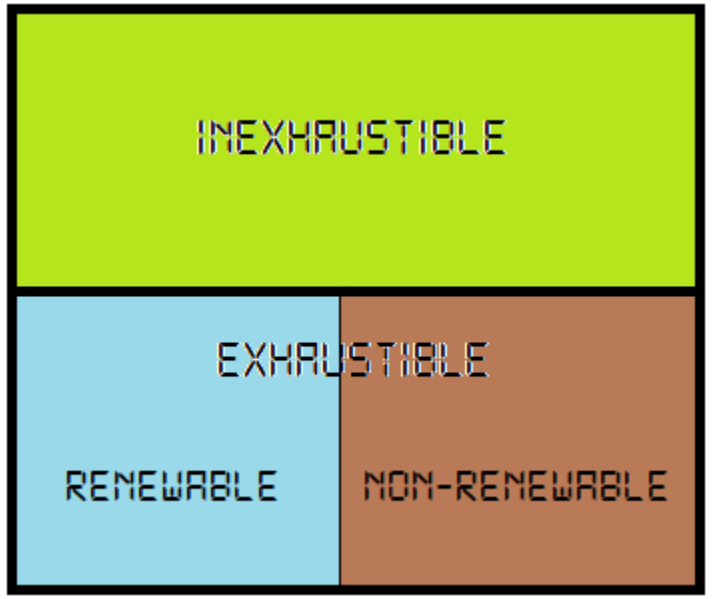
Renewable Energy Sources

- **solar energy** - formally exhaustible, but 9-21 billion years are **inexhaustible** from the perspective of humans
- **Hydroenergy, tidal energy** - water is exhaustible and non-renewable (a mere carrier of energy, not a source, an intermediary between *gravity* and electricity; gravity is **inexhaustible**)
- **biomass** - exhaustible but renewable independent of human activity
- **wind** – **inexhaustible**, product of **climate** and rotations of Earth
- **geothermal energy** – **inexhaustible**, product of Earth‘s core
- **coal, gas, uranium, oil etc**. - exhaustible and non-renewable



Solar Energy

3,288 Wh/m2/day
= 137 Wh/m2/hour
= 137 W/m2 * 0,15
= 20,55 W/m2 * 24 * 365
= 180018 Wh/m2/year
= 180 kWh/m2/year

Yearly production of a square meter of solar panels in Brno is approximately **180 kWh**.

The Amount of Solar Energy in the Czech Republic which Stroke a Square Meter of Surface Bent at an Angle of 40° Southwards (Wh/m²/day)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Rok
Praha	1228	2027	3034	4149	4846	4644	4930	4577	3475	2729	1140	833	3141
Brno	1247	2111	3163	4262	4953	4877	5211	4774	3679	2918	1309	872	3288
Plzeň	1238	2087	3036	4147	4755	4618	4975	4604	3587	2735	1182	828	3155
Ostrava	1321	2138	2990	3890	4689	4556	4916	4471	3370	2858	1372	976	3135
Břeclav	1343	2204	3315	4429	5046	5100	5411	4925	3990	2975	1441	935	3433
Aš	1255	2215	2941	4180	4662	4431	4837	4459	3544	2639	1327	840	3115
Ústí n. L.	1231	2080	2956	4063	4788	4507	4751	4405	3365	2677	1207	841	3078

Source: European Commission - Joint Research Centre, n.d.

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Solar Energy

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Solar Energy

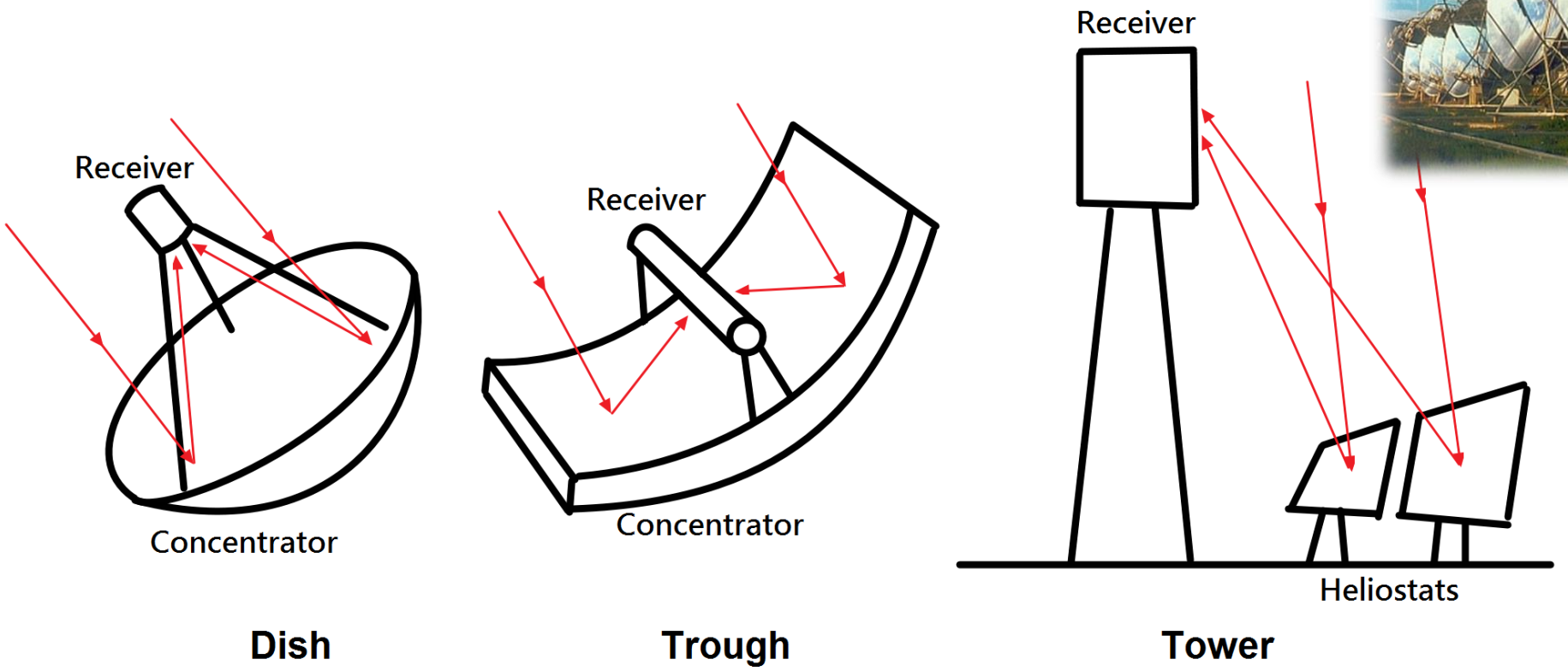
PS20, Abengoa, Spain (20 MWe, 44 GWh)

Molten salt is heated to 565 ºC, pumped to a steam generating system to drive turbines that are coupled with generators which produce electricity

Ivanpah I, II, III Solar Electric Generating System, Ivanpah, California, USA (123 + 133 + 133 MWe)

Ashalim Power Station, Negev Desert, Israel (259 MWe)

Solar Energy



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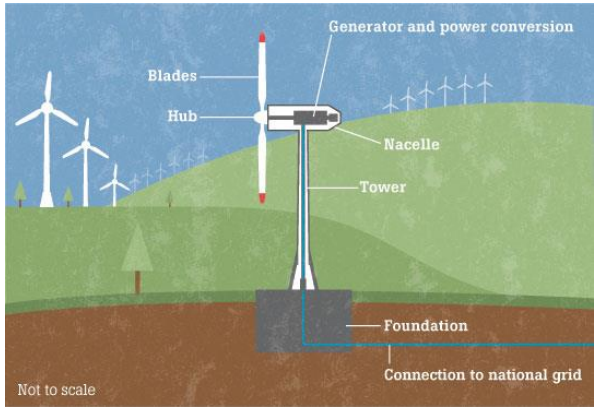
Wind Energy



- produce electricity by utilizing the flux of air
- the flux of air spins propeller blades, which then spin electrical power generator
- wind power plants for their operating require a region with an average speed of wind between 6 and 25 m/s
- all wind turbines are designed for a maximum wind speed, called the survival speed
- in conventional wind turbines, the blades spin a shaft that is connected through a gearbox to the generator
- gearless wind turbines get rid of the gearbox completely, problem is weight and rare elements used for permanent magnets

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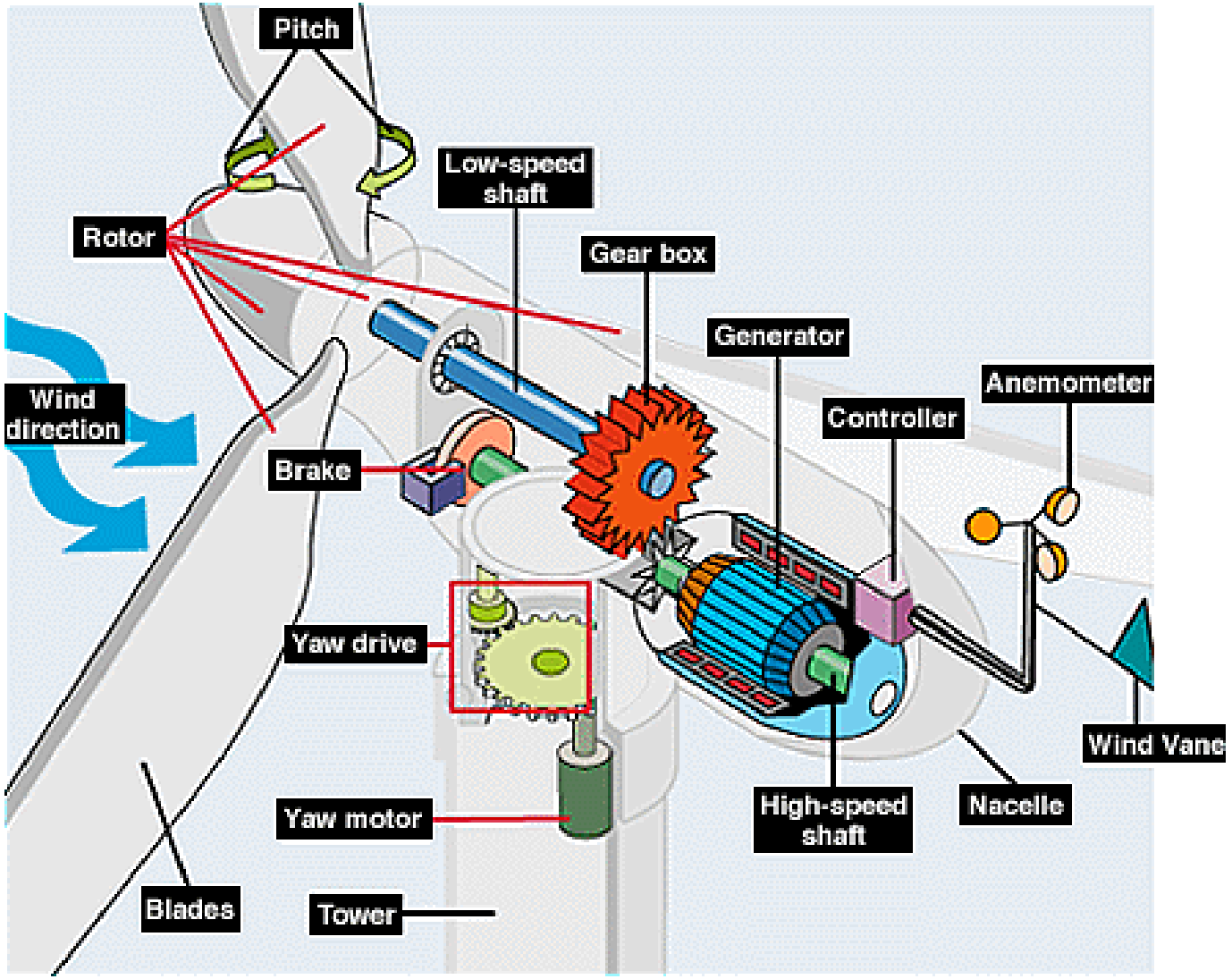
Wind Energy



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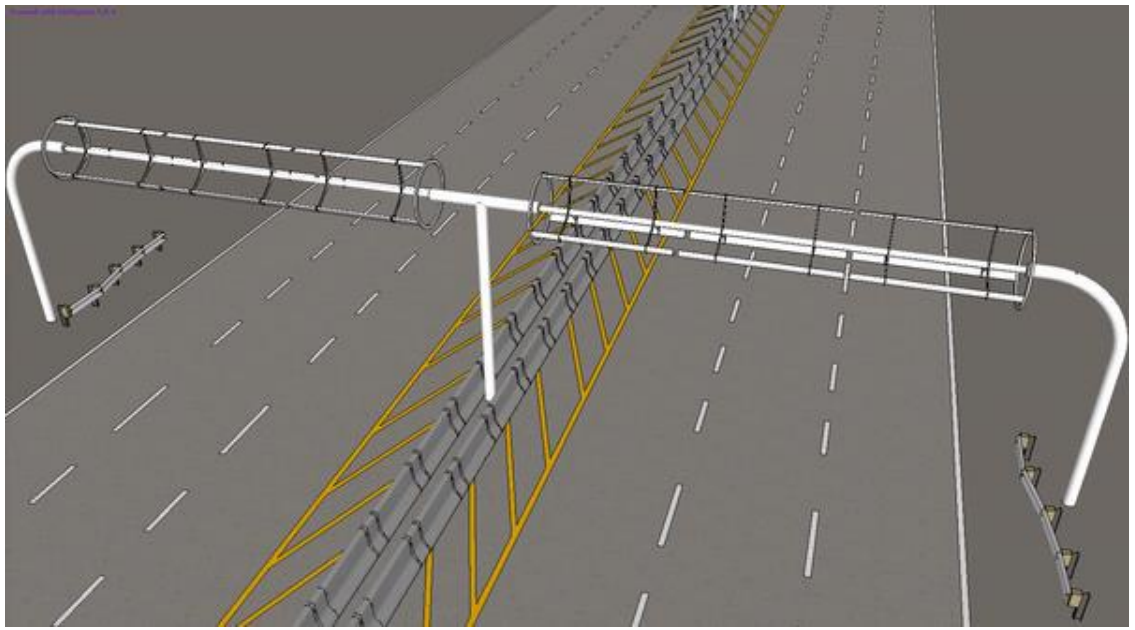
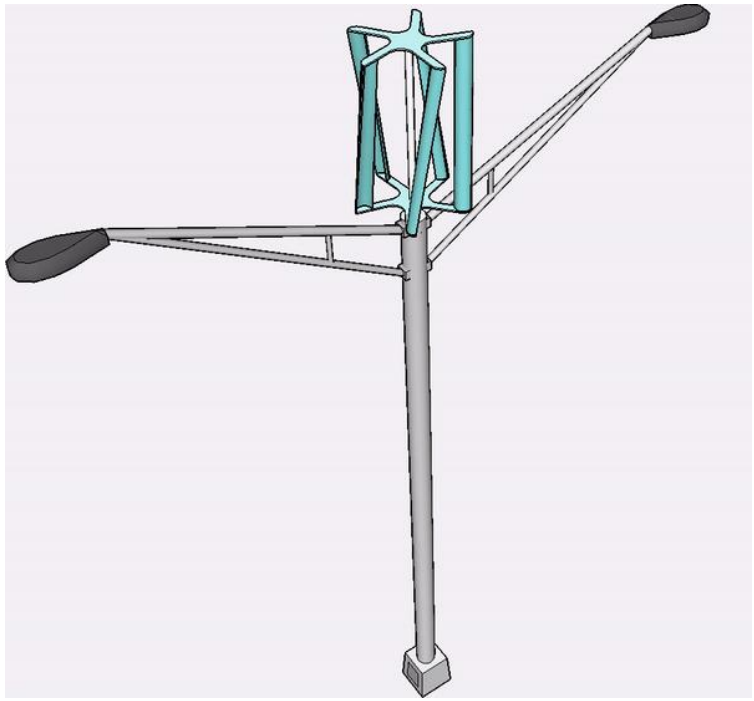
Unconventional Wind Turbines





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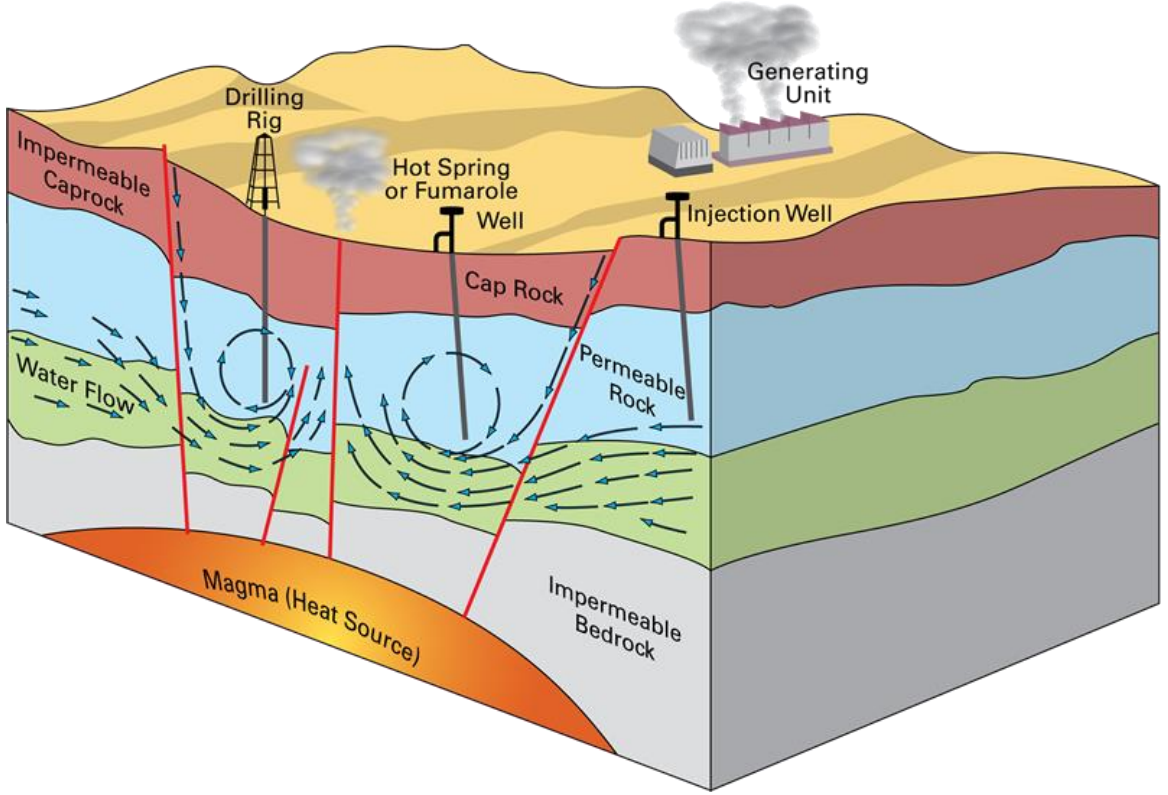
Geothermal Energy



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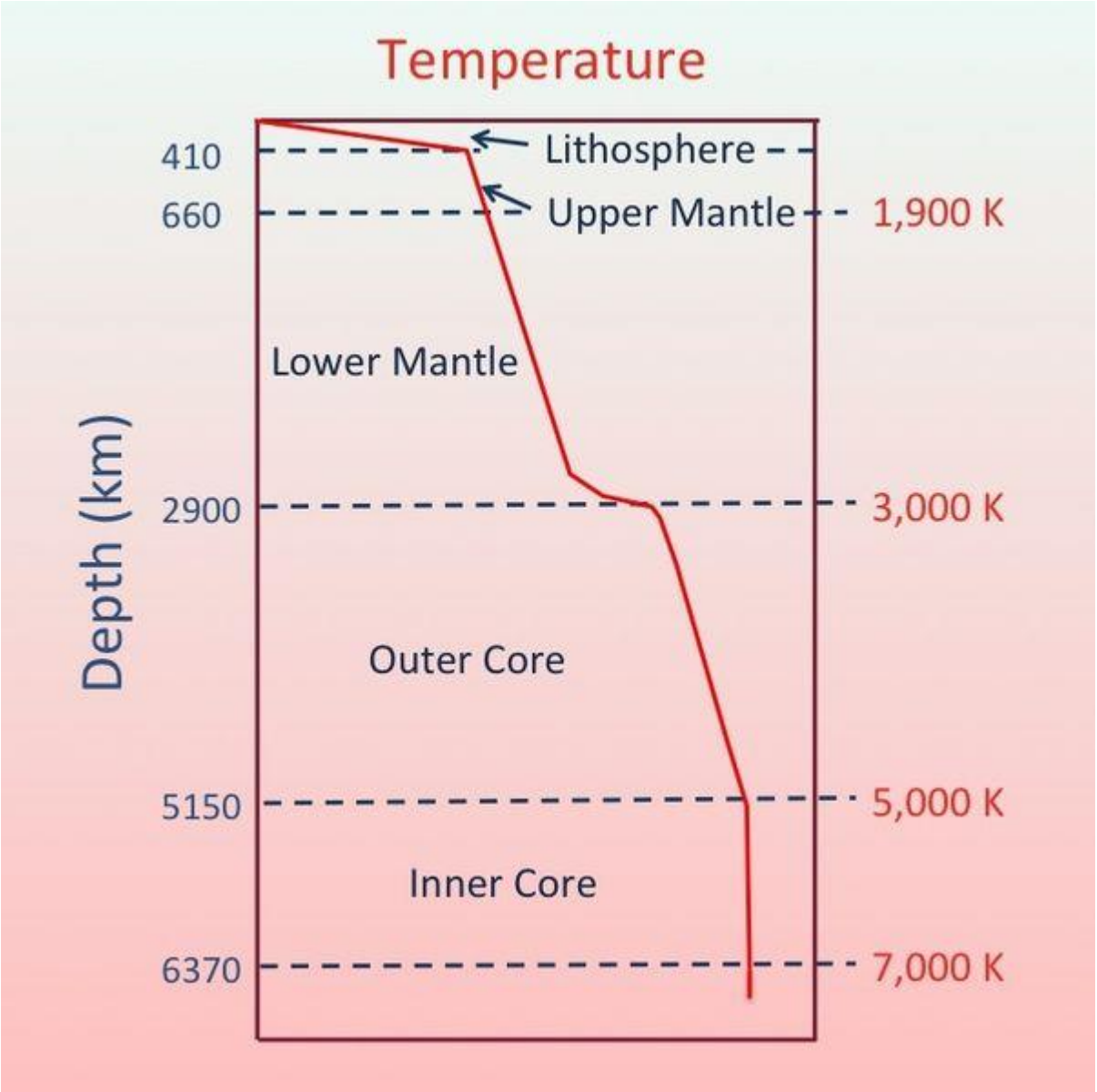
Geothermal Energy

- geothermal gradient is the rate of increasing temperature with respect to increasing depth in the Earth's interior

- it is about 25–30 °C/km of depth near the surface in most of the world



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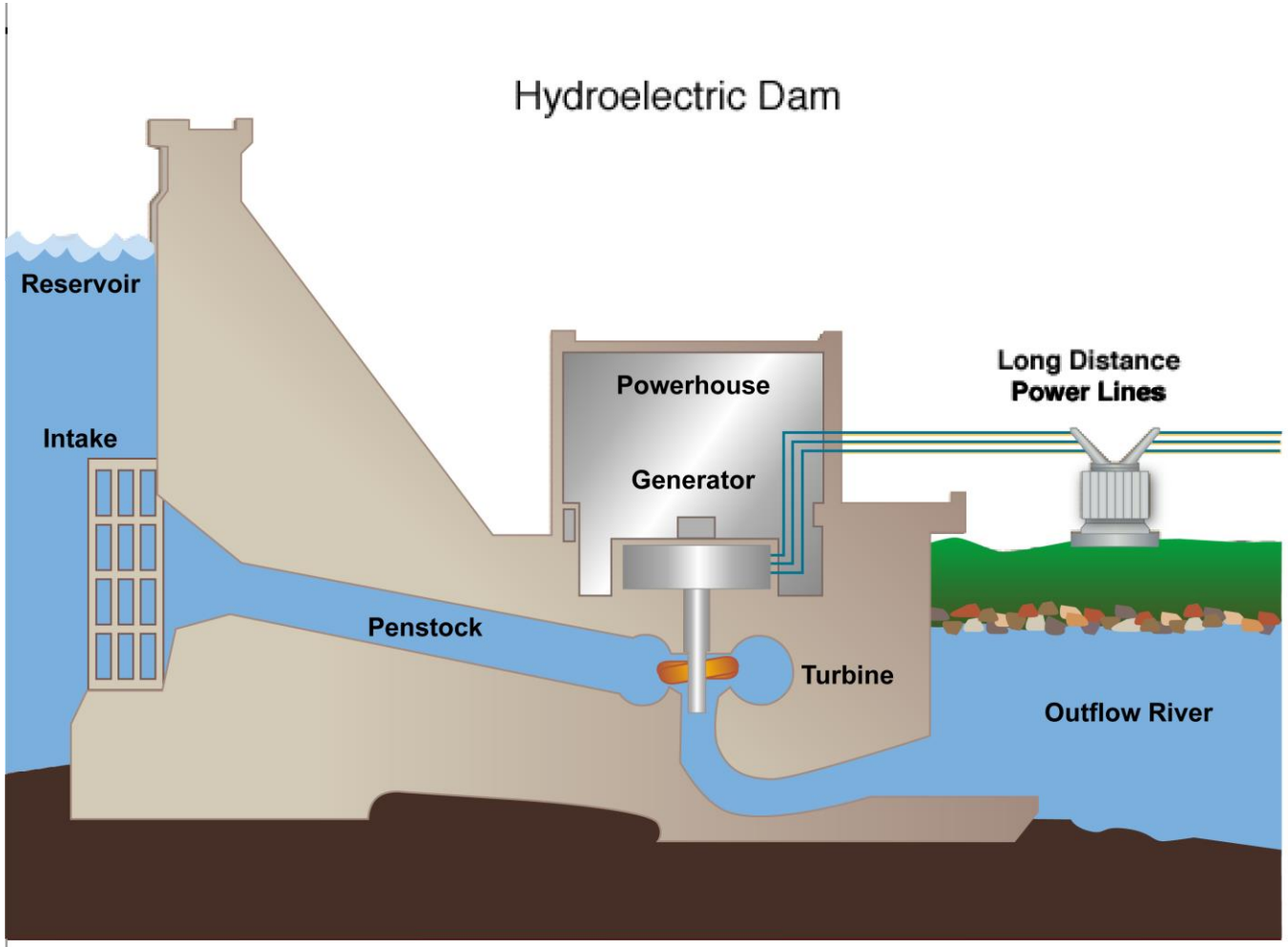
Hydroenergy

- Hydroelectricity is electricity generated by hydropower, i.e., the production of power through use of the gravitational force of falling or flowing water. It is the most widely used form of renewable energy.
- Once a hydroelectric complex is constructed, the project produces no direct waste. Small scale hydro or micro-hydro power has been an increasingly popular alternative energy source, especially in remote areas where other power sources are not viable. Small scale hydro power systems can be installed in small rivers or streams with little or no discernible environmental effect or disruption to fish migration.
- Most small scale hydro power systems make no use of a dam or major water diversion, but rather use water wheels to generate energy. This was approximately 19% of the world's electricity (up from 16% in 2003), and accounted for over 63% of electricity from renewable sources.
- There are several types of hydroelectricity power production facilities:
  - Falling Water
  - Flowing Water
  - Pumping Storage Systems
  - Tidal Energy Systems
  - Wave Energy Systems

Hydroenergy – Falling Water



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Hydroenergy – Falling Wat

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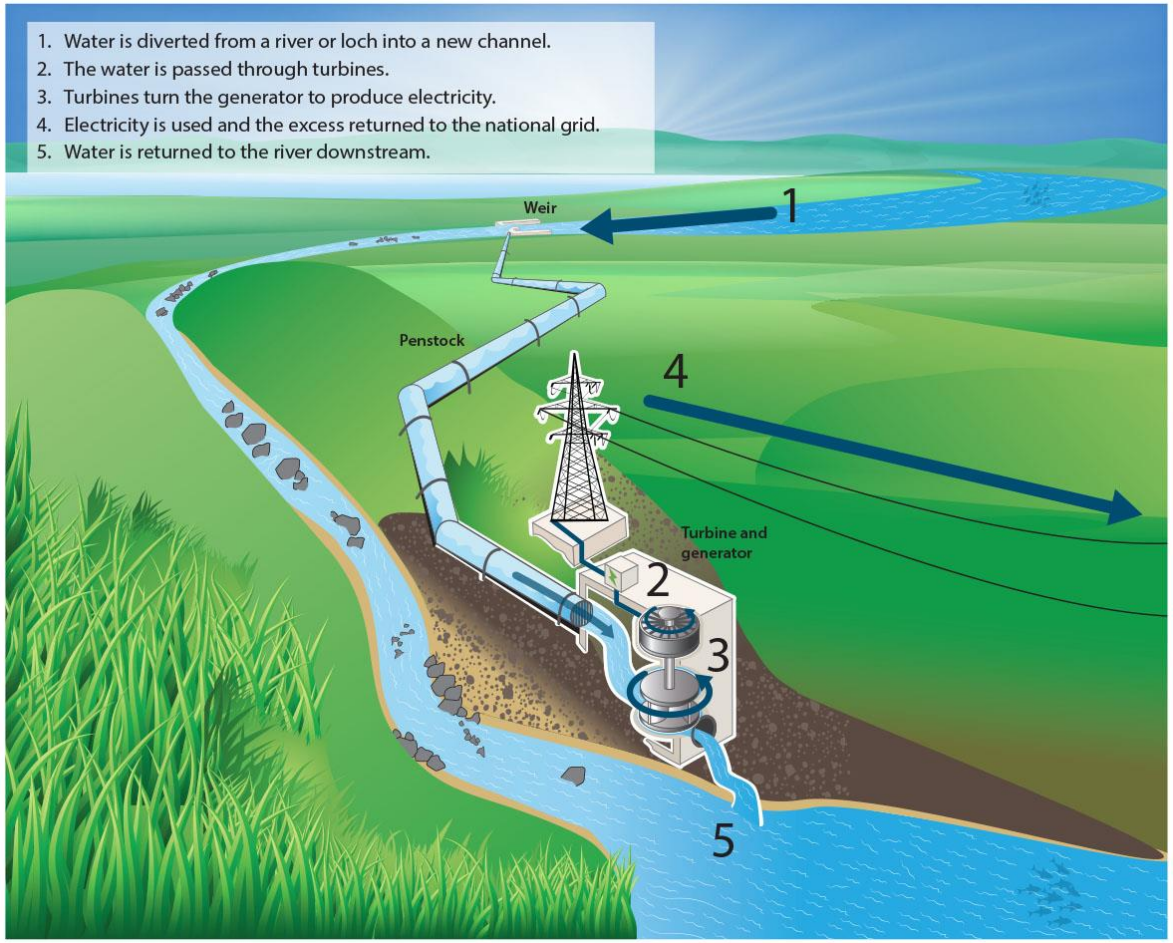
Hydroenergy – Flowing Water



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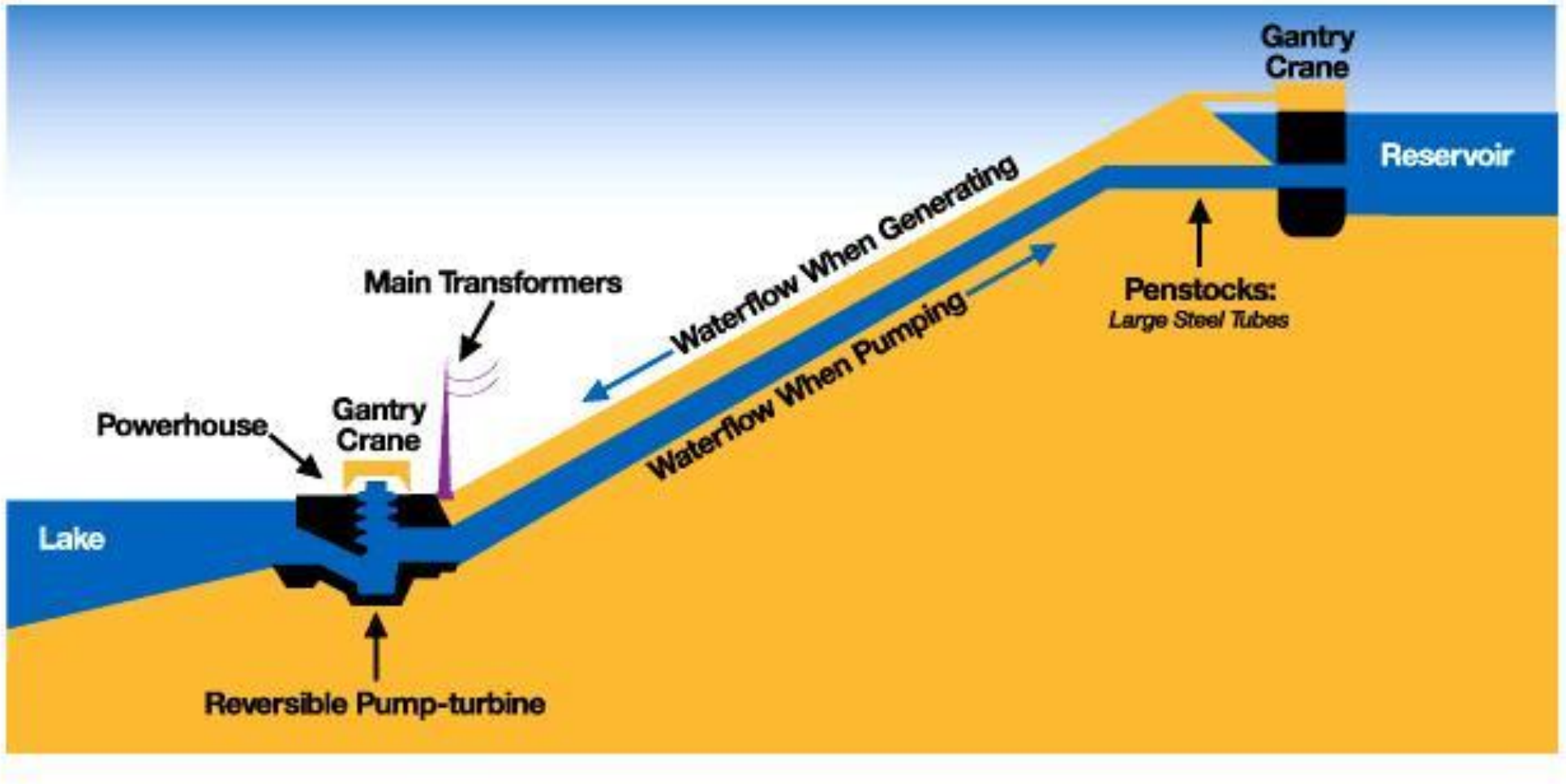
Hydroenergy – Pumping Storage System



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Hydroenergy – Pumping Storage System

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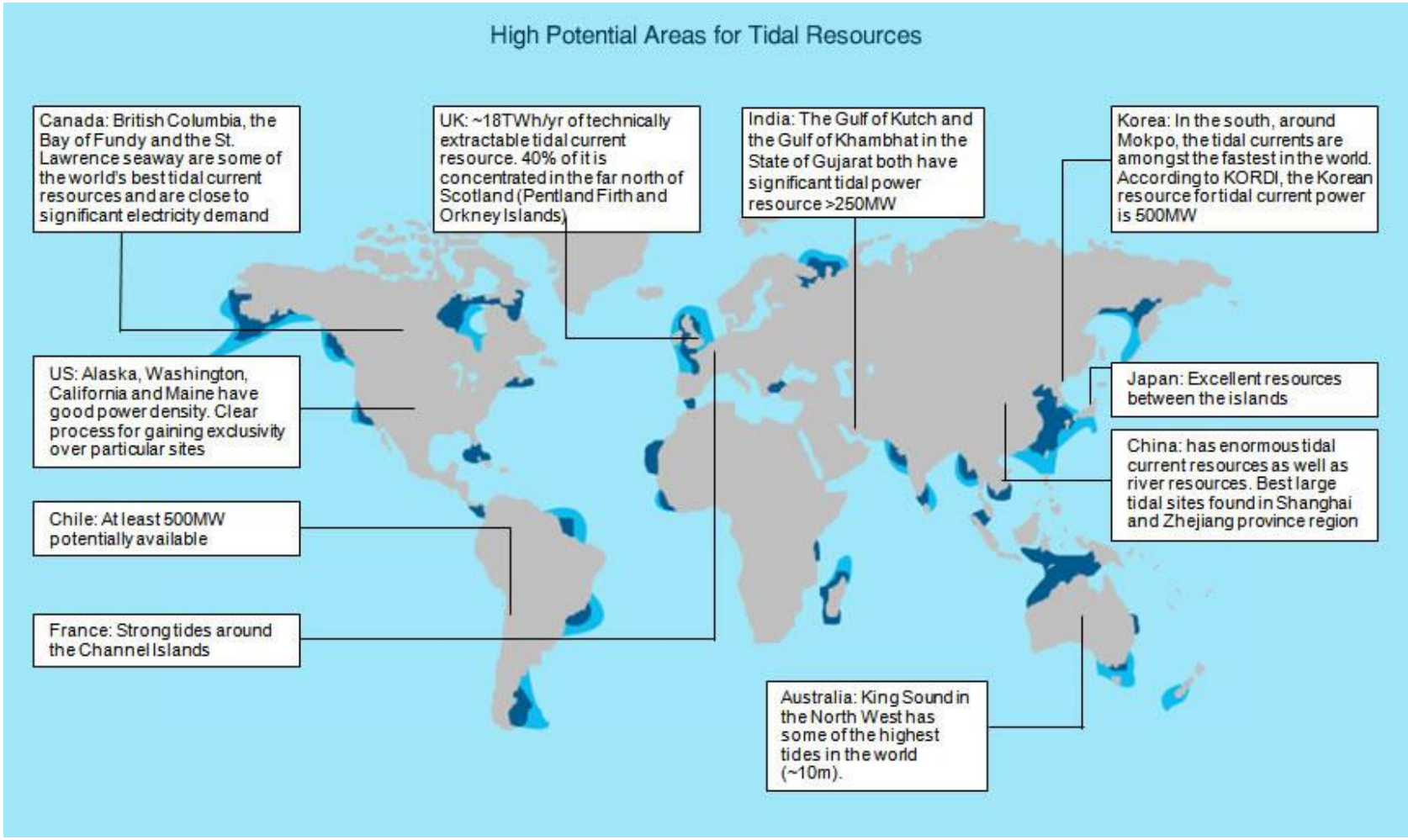
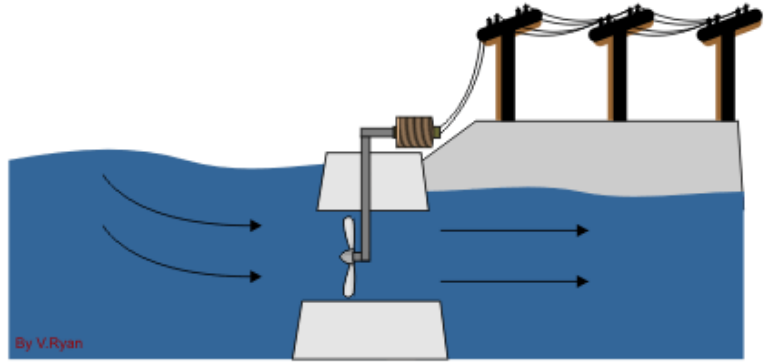
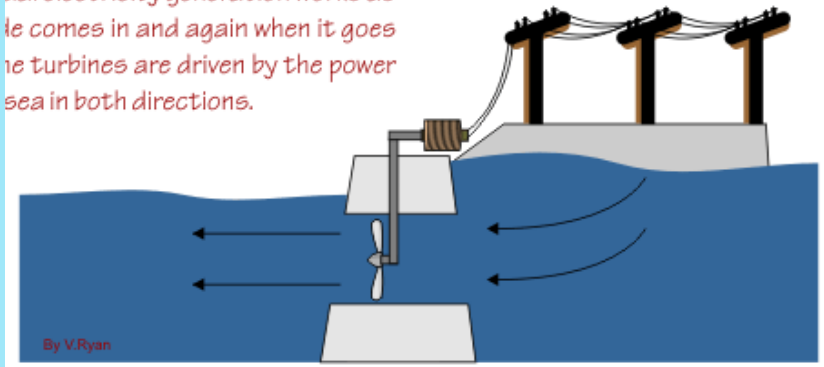
Hydroenergy – Tidal Energy





TIDE COMING IN

dal electricity generation works as
le comes in and again when it goes
ne turbines are driven by the power
sea in both directions.



TIDE GOING OUT

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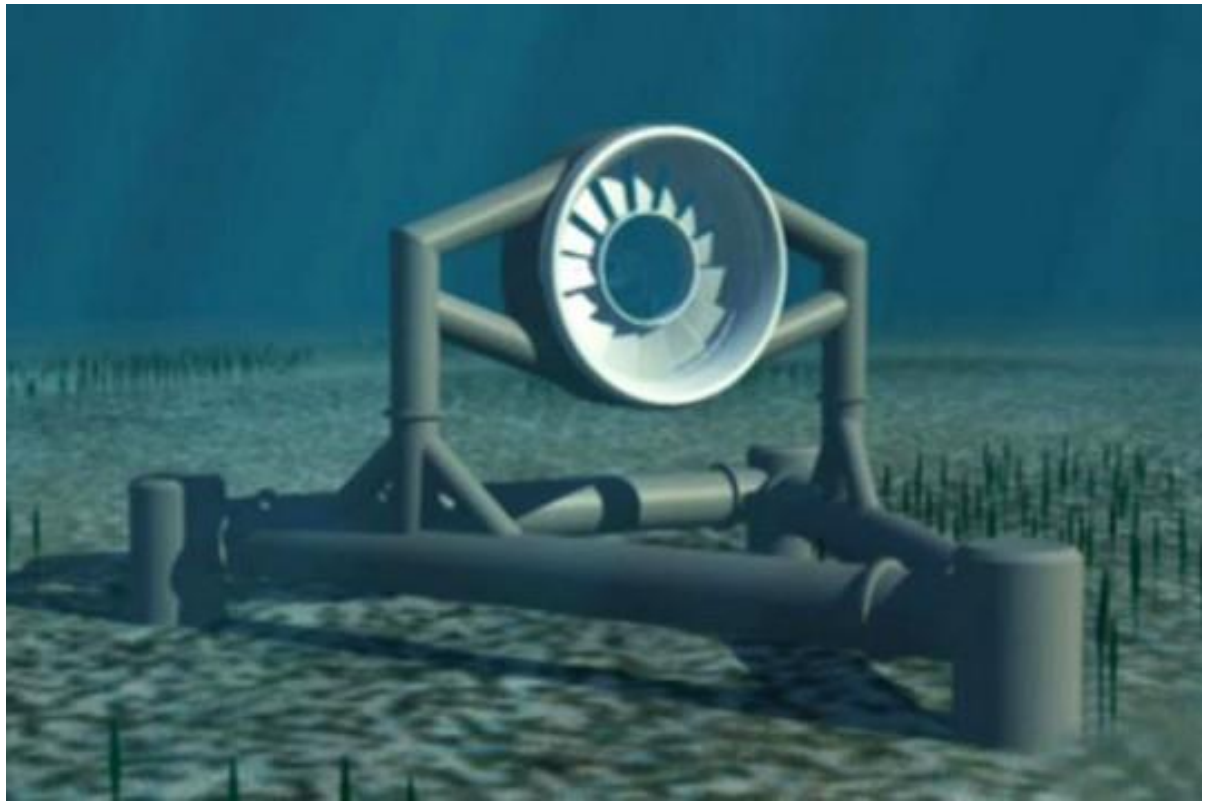
Hydroenergy – Tidal Energy



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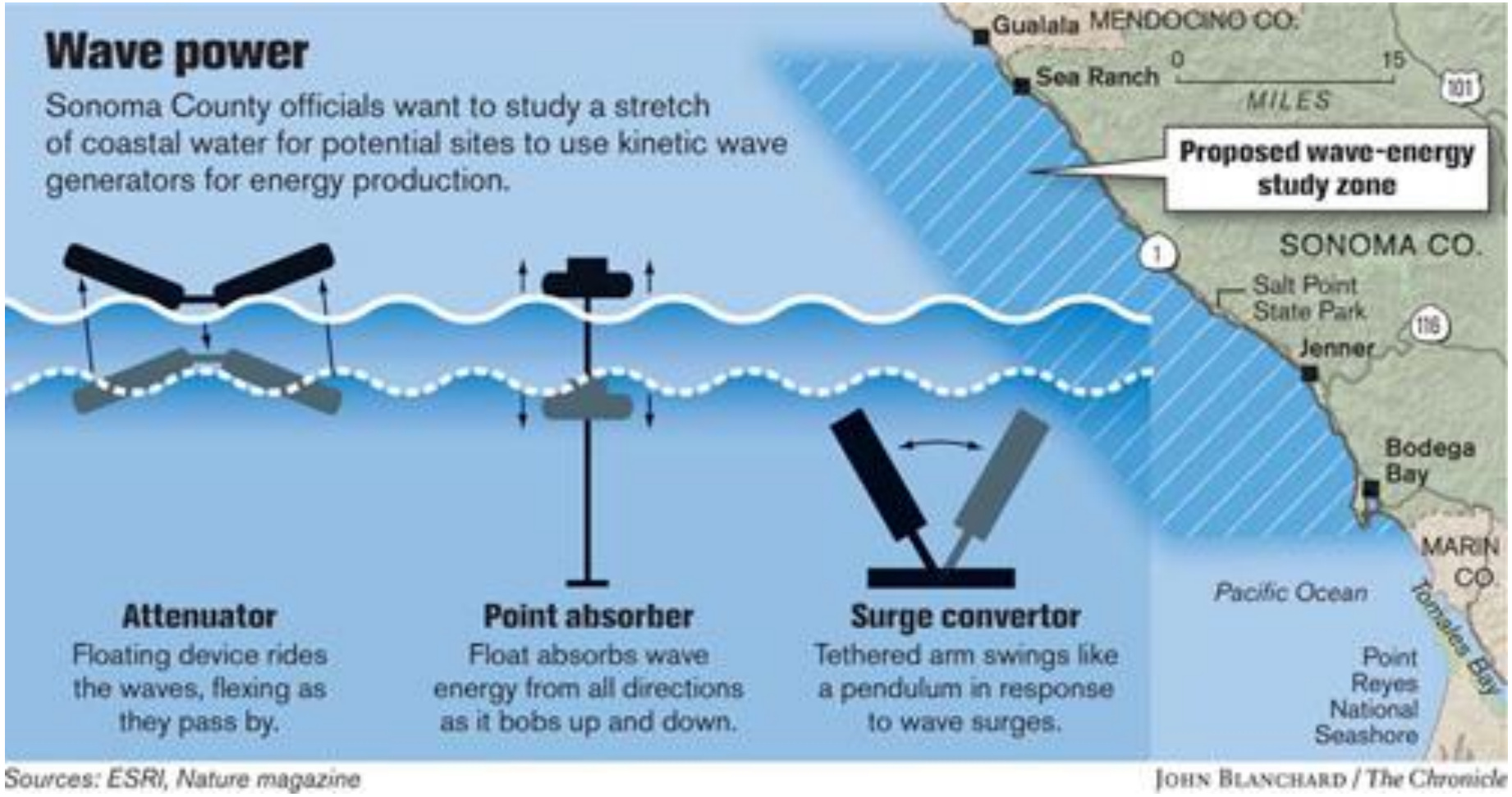
Hydroenergy – Wave Energy Systems



Biomass

- Developed countries: a renewable source of energy, neutral emissions
- Developing countries: the source of 90% of the daily energy consumption for 2.5 billion people

- Fuel and energy:
- Incineration - direct, indirect (biogas), indirect parallel (steam)
- The thermal decomposition (pyrolysis) - solid and liquid fuels (charcoal, pyrolysis oil, 16 MJ / kg)
- Gasification - oxidation at high temperatures, 5-20 MJ / m3
- Esterification, hydrogenation
- Biochemical transformation - fermentation, digestion (biogas, 18-29 MJ / m3)

Biomass

- Generation I
  - Ethanol – easier combustion but lowe calorific value (by 25-30 %)
- Generation II
  - Fast growing trees
  - plants that can be grown more than once in one place
- Generation III
  - Marine plants: algae - 80% lipids
  - yield up to 30% greater than in oilseed

	GJ/ha
Barley	34 – 50
Wheat	59 – 67
Corn	63 – 71
Sugar beet	138 – 146
Sugarcane	147 - 167

Biomass

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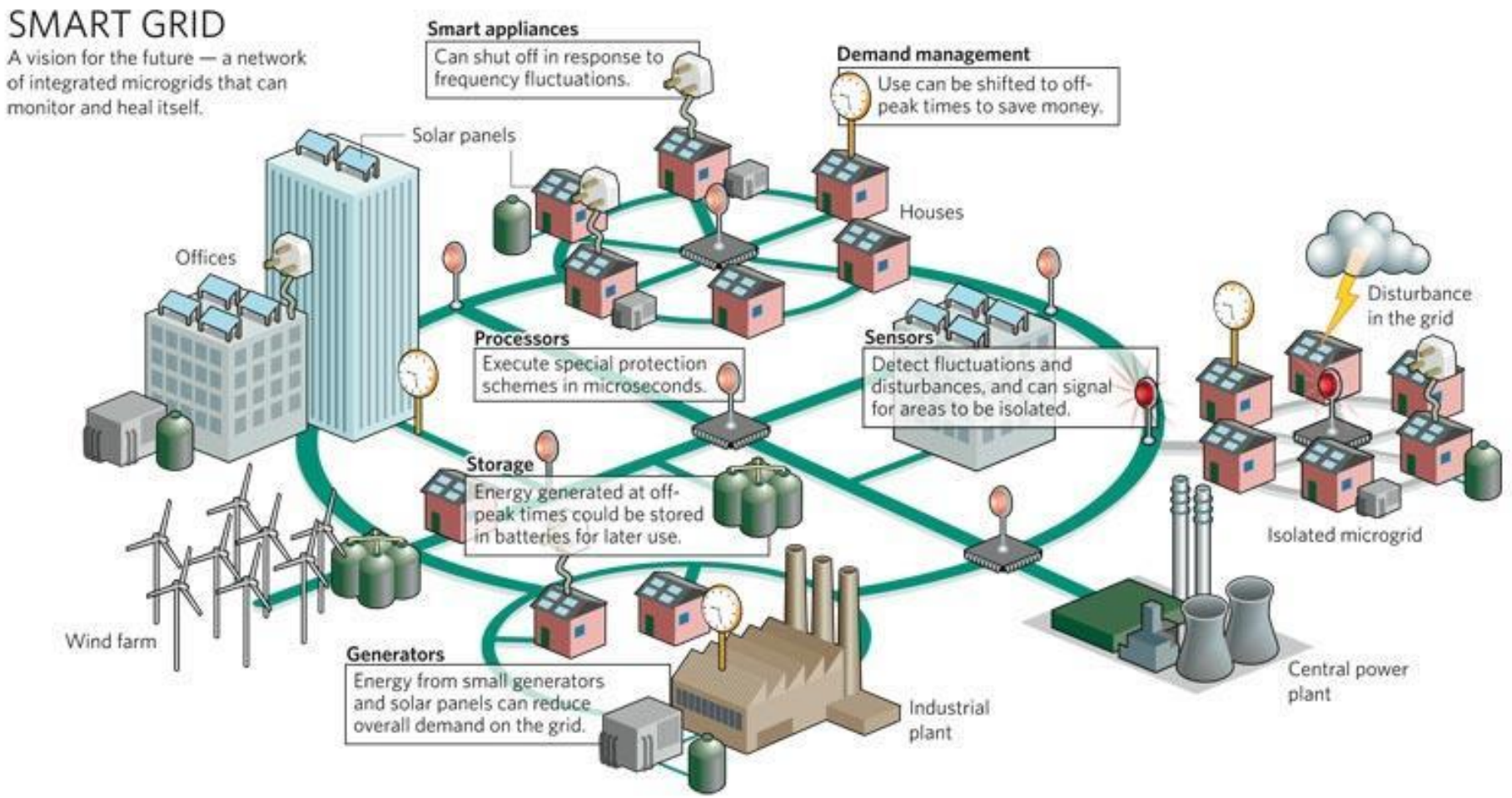
Smartgrids

- „A smart grid is a modernized electrical grid that uses analogue or digital information and communications technology to gather and act on information, such as information about the behaviours of suppliers and consumers, in an automated fashion to improve the efficiency, reliability, economics, and sustainability of the production and distribution of electricity. “ (U.S. Department of Energy.)

- Goals:
  - More efficient use of energy
  - Limitation of crisis situations in the network
  - Integration of alternative sources
  - Integration of new appliances
  - Providing online information about the price of electricity and the subsequent management of the network

Smartgrids



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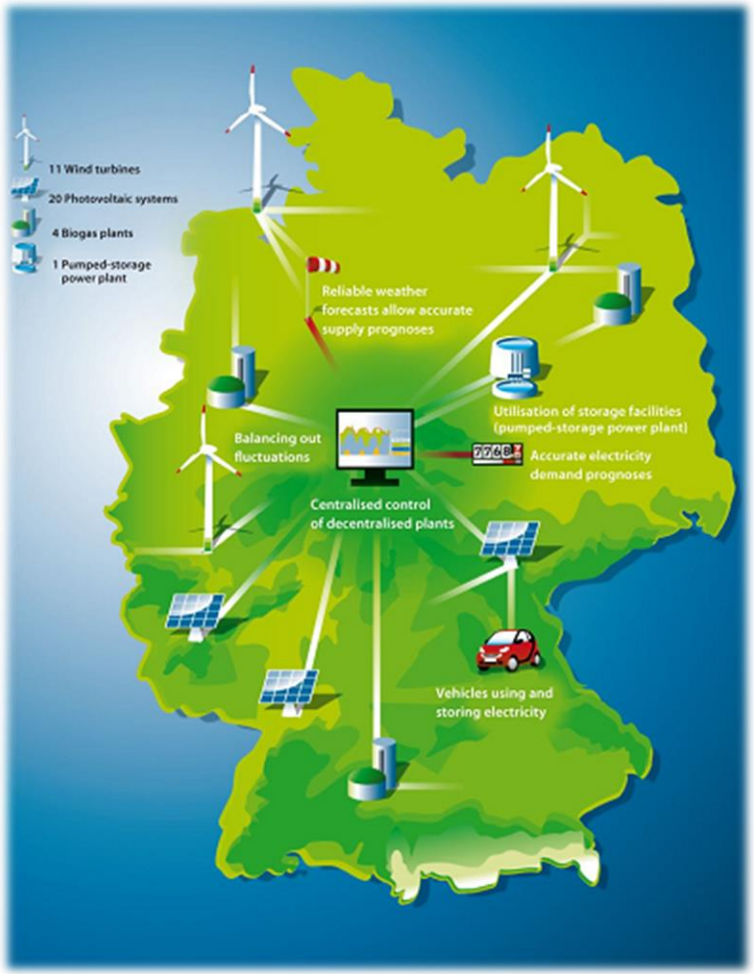
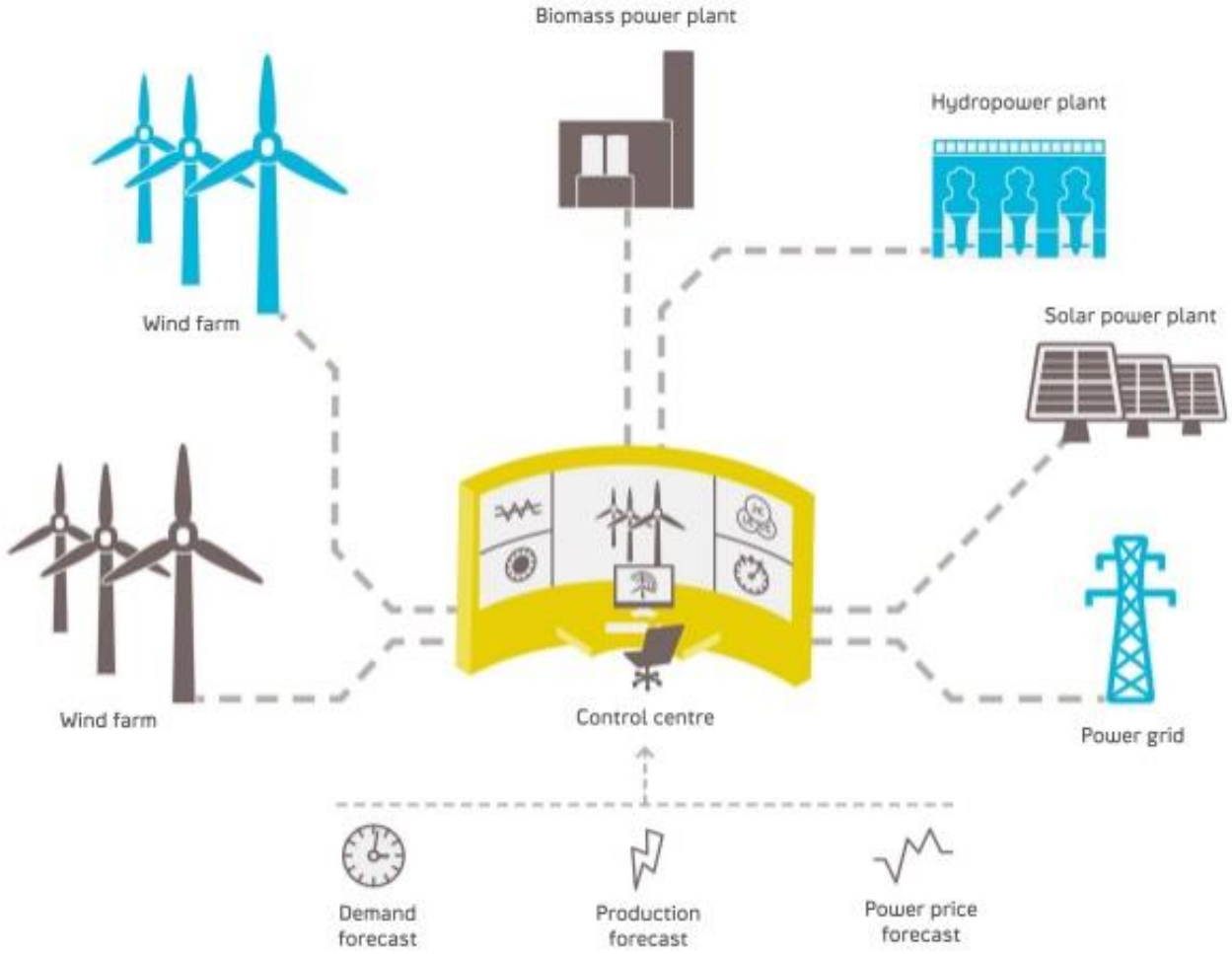
Smartgrids

- Critique:
  - High pressure on both the supply (joining the production units to the so-called virtual power plants) and demand (consumers programming appliances for time or cost)
  - Ensuring a sufficient number of actors
  - Investment costs for operators and traders (benefits tends to rest with customers)
  - The modernization of the electricity grid
  - The potential to monitor and susceptibility to abuse the technology by thieves
  - Privacy protection
  - Relinquishing control over the use of electricity in favor of the operator

Virtual Power Plant





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Storage of Electricity

Current System	With Storage
Costs	Costs
Capacity	Capacity
Startup Speed	
Capacity Variablity	

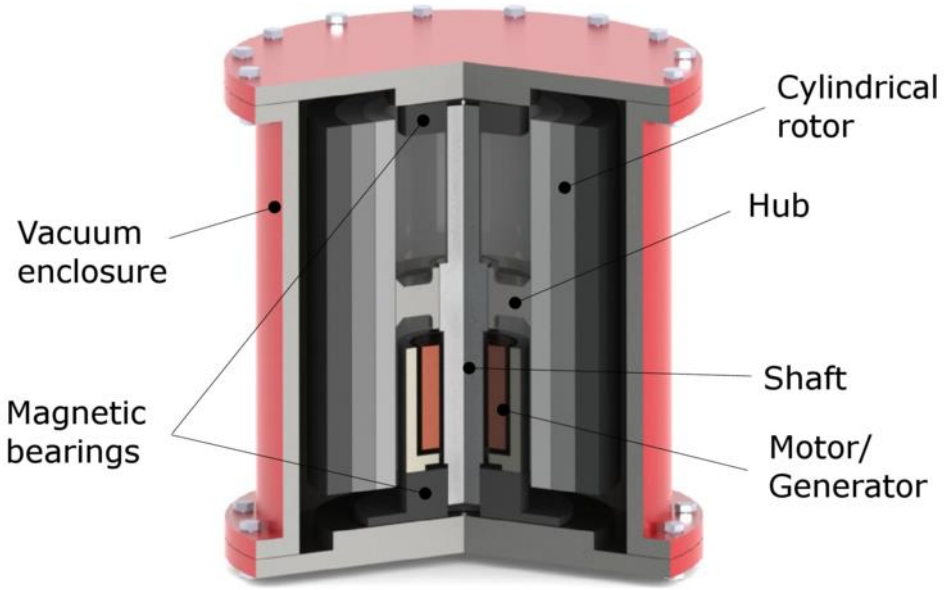
- Storage could:
  - Help in wiring RES
  - Efficient use of existing resources (plants today are used on average about 55% of the time)
  - Increase the reliability of electricity supply (US 79 billion losses annually due to network outages)
  - Reduce the need for new power plants
  - Reduce the need for additional transport capacity
  - Electricity storage would reduce price volatility of fossil fuels and transport capacity
  - Reduce the dependency on weather

Storage of Electricity

- Possibilities:
  - Electromechanical (flywheels, compressed air, pumping hydro stations…)
  - Eletrochemical (fuel cells, batteries)
  - Chemical (hydrogen, biofuels, power-to-gas)
  - Thermal
  - Etc.

https://en.wikipedia.org/wiki/Energy_storage

Storage of Electricity - Electromechanical



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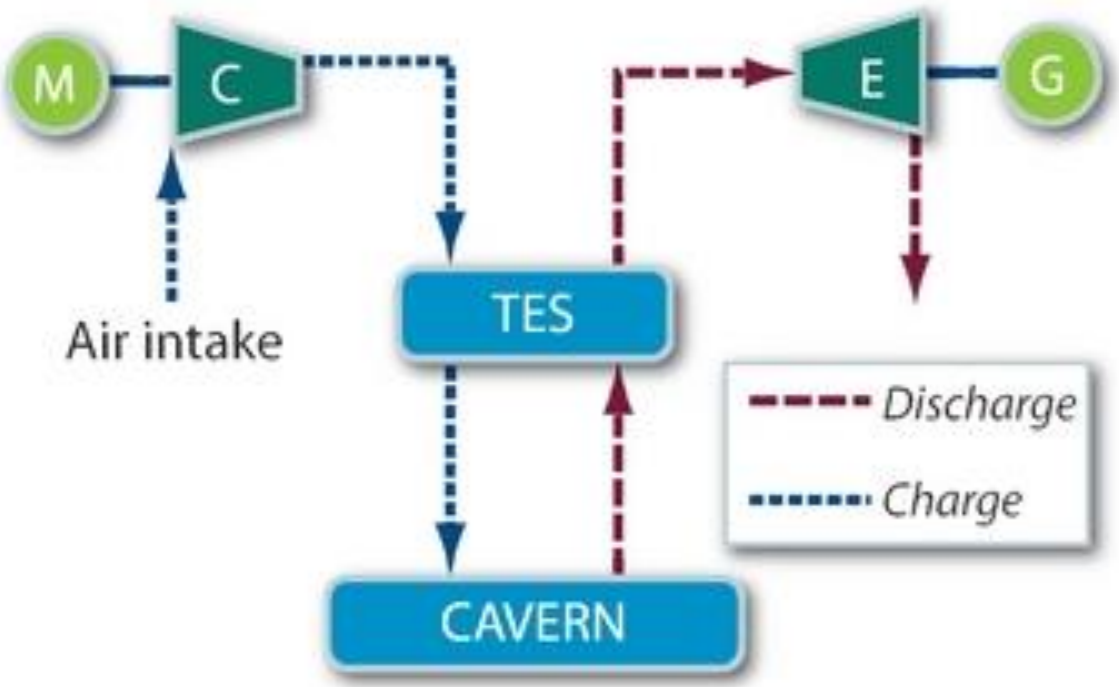
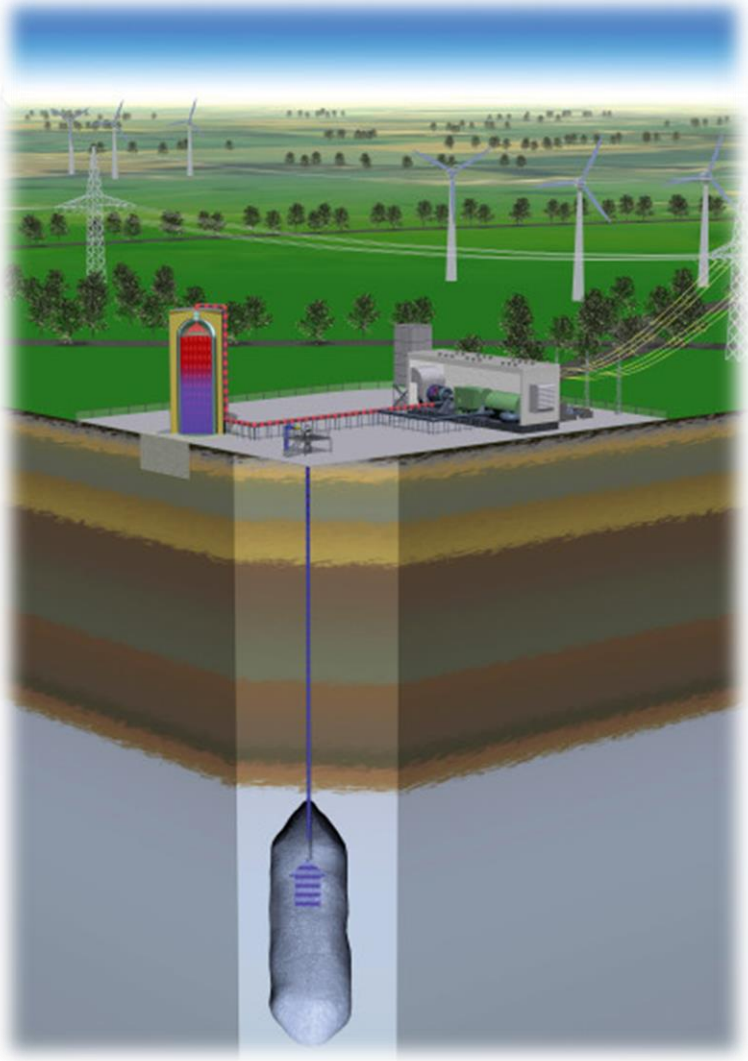
Storage of Electricity - Electromechanical





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Storage of Electricity - Electromechanical

– Dinorwig, Wales

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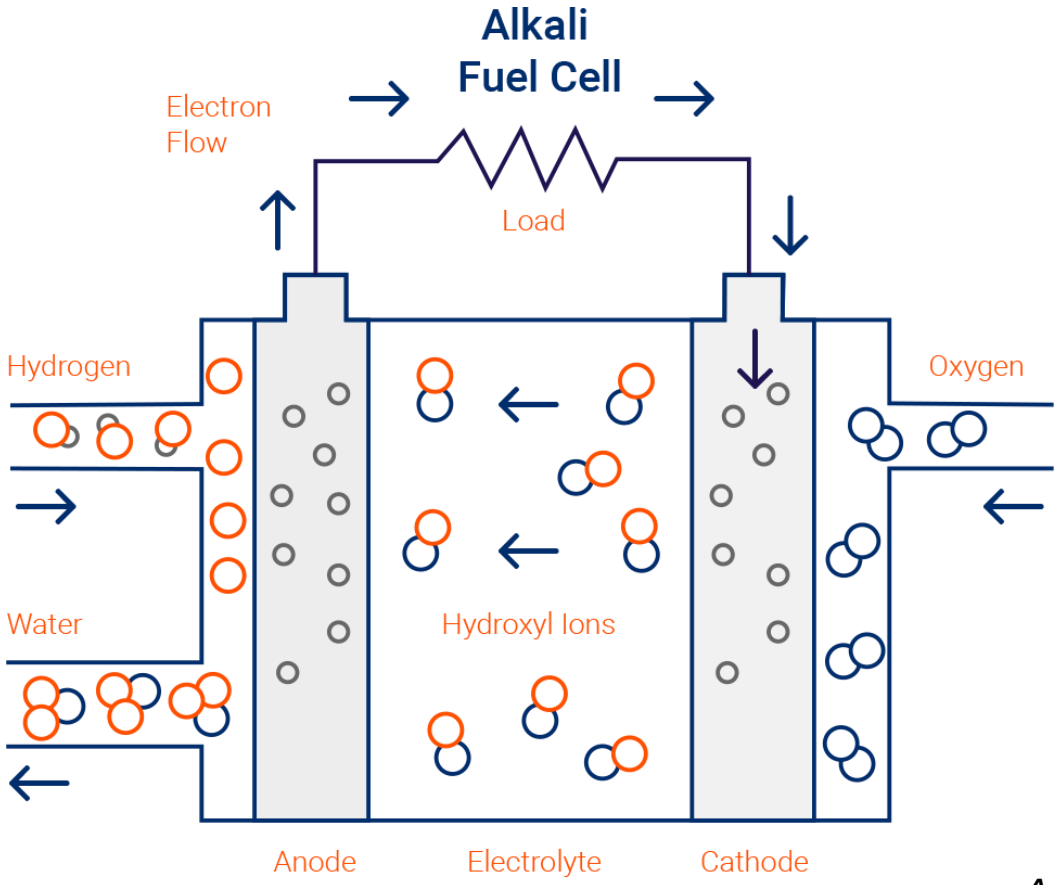
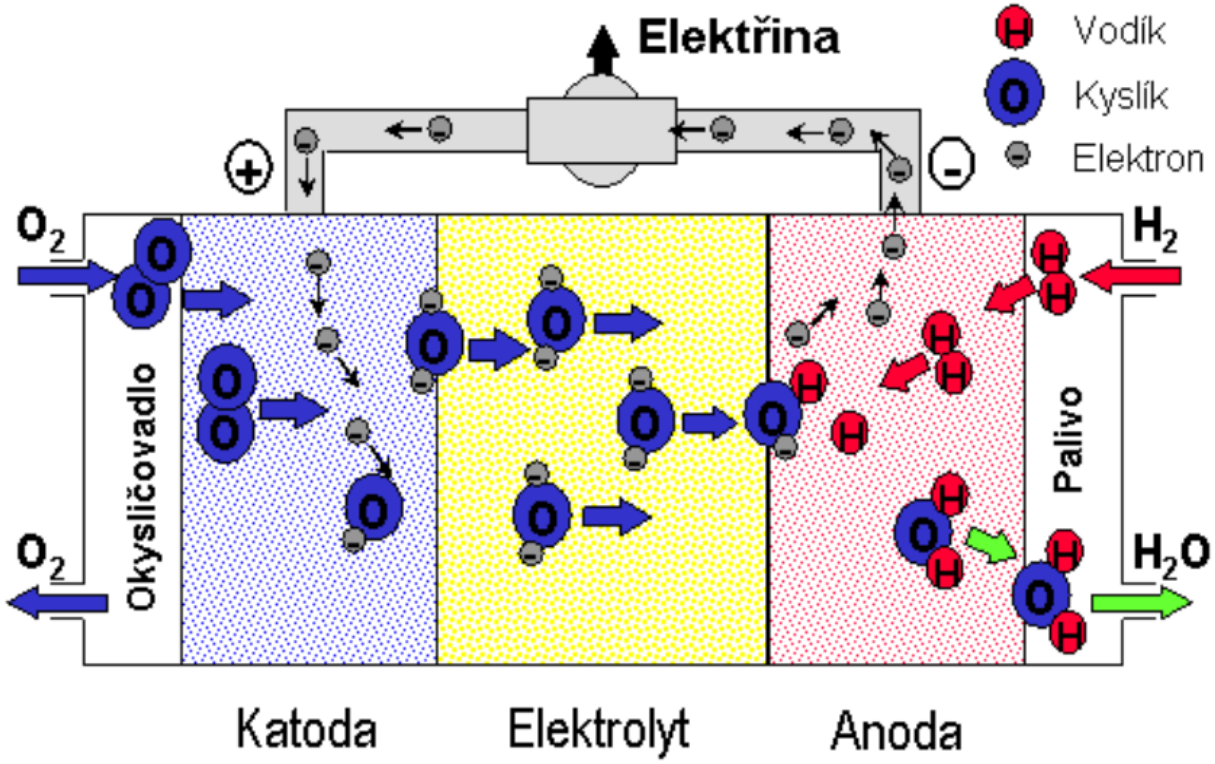
Storage of Electricity - Electrochemical

- Fuel Cells
  - A fuel cell is an electrochemical device directly converting chemical energy of fuel and oxidant into electrical energy
  - The principle has been known since the mid-19th century, their commercial deployment is still at the planning stage
  - They are an alternative to the current small and medium sources of fossil fuels; gas engines, dieselaggregates, gas microturbines, small cogeneration units, it is counted with their deployment in the automotive industry
  - In the future, it should replace the larger electricity supply units. It can be used also as a replacement for batteries and accumulators
  - For some special applications (space projects, undersea research) they are already widely used (1960s Apollo and Gemini)
  - Today cca 60 companies manufacturing fuel cells (32 in USA, 7 Canada, 6 GB, 5 India, 2 Singapur, 1 international) + car companies

Storage of Electricity - Electrochemical





Anode Reaction: $2H_2 + 2O^{2-} \rightarrow 2H_2O + 4e^-$
Cathode Reaction: $O_2 + 4e^- \rightarrow 2O^{2-}$
Overall Cell Reaction: $2H_2 + O_2 \rightarrow 2H_2O$

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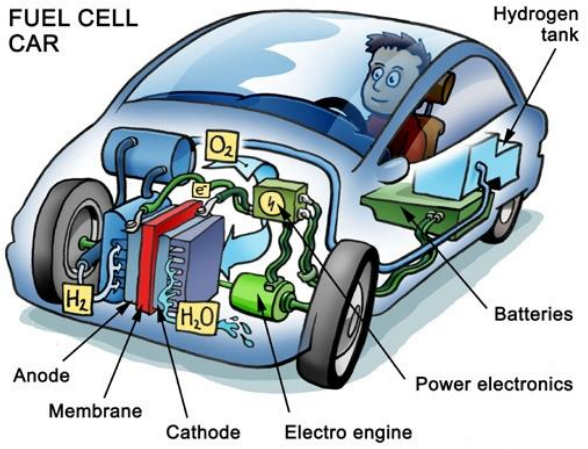
Storage of Electricity - Electrochemical

- Advantages:
  - High efficiency power conversion due to direct conversion of chemical energy of fuel into electrical energy (total efficiency in automobiles 50-60%)
  - Modular concept - the possibility to construct fuel cells in a wide range of performances with nearly the same efficiency.
  - The possibility of using a variety of gaseous fuels (after adjustments)
  - Almost silent operation due to the absence of moving parts (except the accompanying equipment - blowers, compressors, ...).
  - Low wear
  - Efficiency for power plant electricity production is 40-45%



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Storage of Electricity - Electrochemical

- Disadvantages:
  - High investment costs
  - Still too low service life
  - The effectiveness decreases with time
  - The necessity of continuously removing fumes from chemical reactions whose quantity depends on the size of the current drawn (for H2-O2 cells pumping out of water or water vapor, other cells oxidation products)
  - Commissioning (PEM operating temperature is 70-85 C, it may take a few minutes and the cell must be warmed up to operating temperature, likely from an external source)

  - Industrial production of hydrogen

Storage of Electricity - Electrochemical

Hydrogen is produced in large thermal decomposition of methane (natural gas) at 1000 °C.

$$CH_4 \rightarrow C + 2\ H_2$$

In the future, the production of hydrogen using nuclear energy is likely, either thermochemically (high temperatures) or by means of electric current (nuclear power plants could then be used at the times, when demand is low).

Steam reforming	Electrolysis	High-temperature electrolysis
Reforming reaction: $CH_4 + H_2O \rightarrow CO + 3H_2$	$2H_2O \rightarrow 2H_2 + O_2$	
CO conversion: $CO + H_2O \rightarrow CO_2 + H_2$		
Effectivity 80 %	Effectivity 80-92 %	Effectivity up to 45 %

Storage of Electricity - Electrochemical

Barcelona, Hydrogen buses

Toyota Mirai Fuel Cell Sedan

12/2014 in Japan; 8/2015 in USA; 6/2016 in EU

Honda FCX Clarity Fuel Cell

Hyundai ix35 FCEV

Mercedes-Benz F-Cell

Alstom Coradia iLint

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Storage of Electricity - Chemical

- Power-to-gas (P2G)
  - technology that converts electrical power to a gas fuel, typically electrical power from wind turbines
  - electricity is used to split water into hydrogen and oxygen by means of electrolysis
  - hydrogen is either used directly or combined with CO2 and converted to methane (or eventually to LPG) or converted to biogas
  - overall efficiency around 40%

Falkenhagen, Brandenburg, Germany

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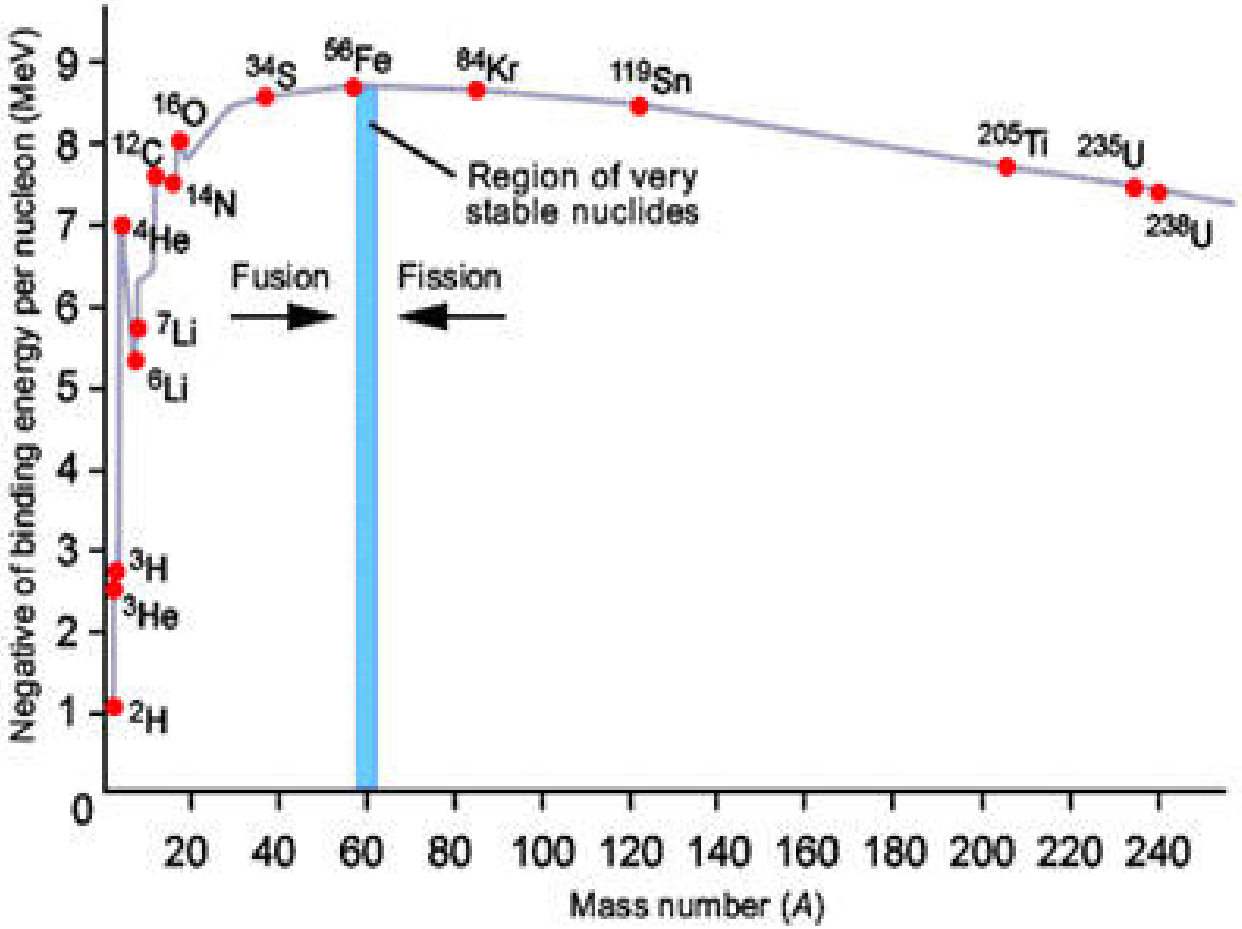
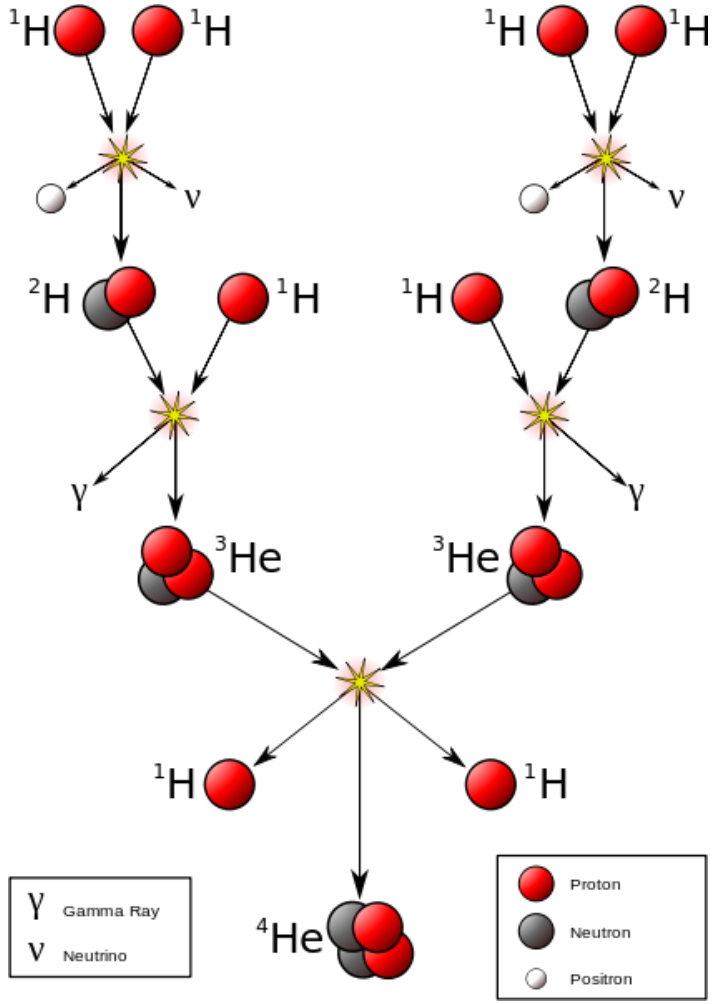
Nuclear Fusion





- A process, during which lighter atomic nuclei are fused and energy is released
- The Sun: 15 M °C
- 1H + 1H => He + energy
- Hydrogen consumption: 600 Mt/s

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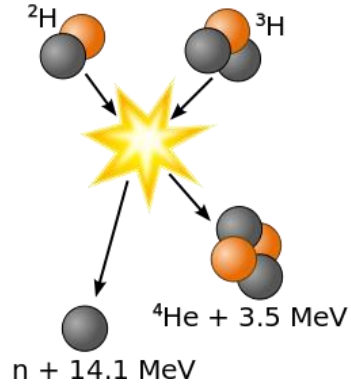
Nuclear Fusion



- one-off nuclear fusion reaction is not difficult to recall
- it is difficult to keep it in the reactor for a longer time and ensure a positive balance of energy obtained to energy delivered
- fusion reactor, unlike fission reactors, is basically safe, cannot explode and leaves almost no radioactive residues
- troubles are rather of opposite nature - it is the problem to hold the fusion reaction stable for a period of time
- the most simple reaction is a synthesis of deuterium and tritium:

150 M°C 2H (D) + 3H (T) => He + n + energy

- "fuel" is considered to be a mixture of deuterium and tritium
- when merging takes place, helium arises and high-energy neutrons are released
- the advantage is that these neutrons penetrate deeply into the material of the inner wall of the reactor so that it is technically easier to divert the heat recovery
- the disadvantage is that the material of the reactor becomes radioactive

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Nuclear Fusion

Possible Fuel Combinations

Deuterium-Tritium

(0.1 billion ˚C, most probable)

Deuterium-Helium 3

(fuel not radioactive, Helium 3 only on Moon)

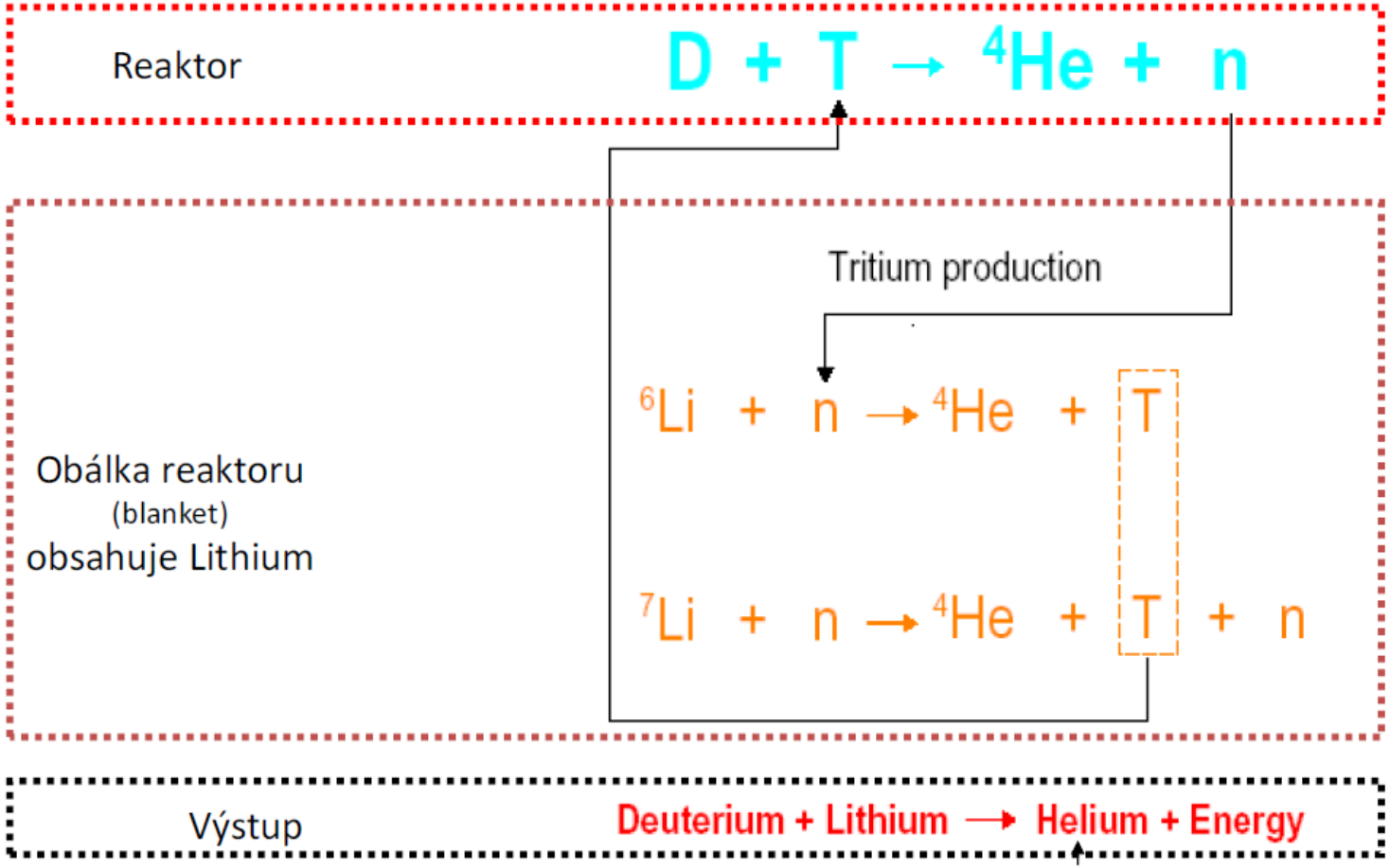
Deuterium-Deuterium

(1-10 billion ˚C)

Proton-Proton

(occurs only in the Sun)

Fusion reactor fuel cycle



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Nuclear Fusion

– Jamie Edwards, thirteen year old schoolboy at Priory Academy in the British Penwortham is the youngest person in history who was able to induce nuclear fusion

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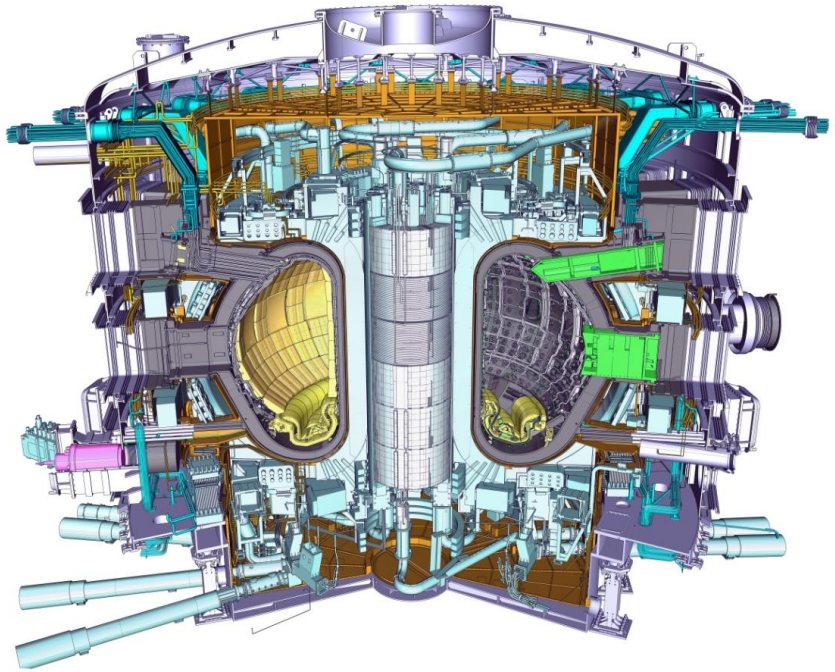
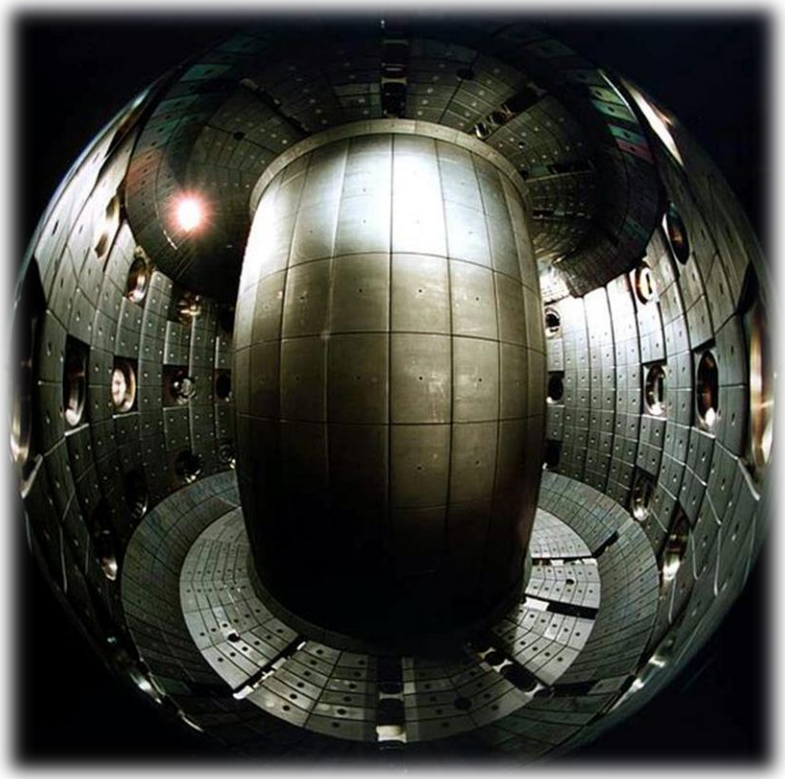
Nuclear Fusion

- one of the ways to achieve nuclear fusion is the tokamak, a device that prevents contact with the plasma with the wall of the chamber by a magnetic field
- тороидальная камера с магнитными катушками (Thoroid Chamber in Magnetic Coils), TOKAMAK





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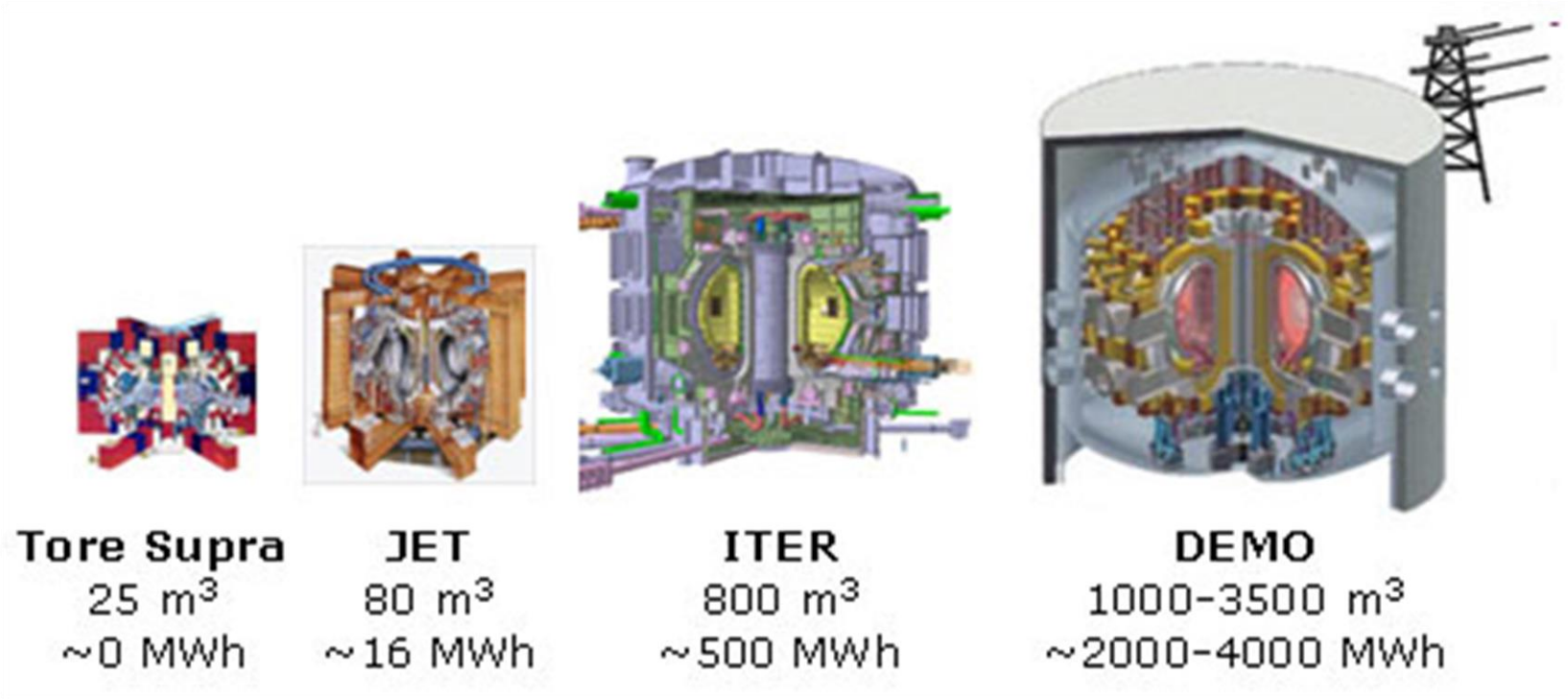
Nuclear Fusion

- the idea of tokamak was born in the 1950s by Igor Tamm and Andrei Sakharov
- the international project ITER in Cadarache, France, is the most advance



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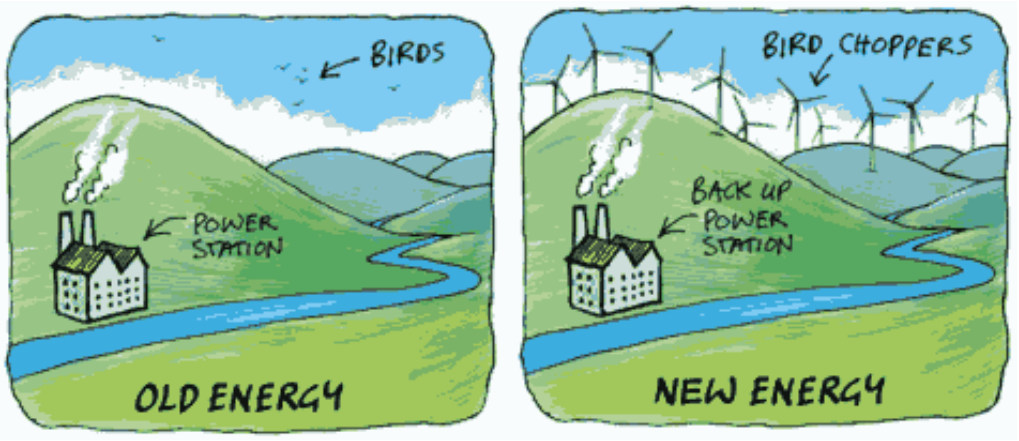
Thank you for your attention.



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