# Short summary “Energy facts”

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The increase of the world population = 200 000 people per day

In this story, the energy yield of all kinds of energy sources is always compared with the output of a **600 megawatts** medium-sized power plant.

# Some definitions and fundamental laws

**Power**

**power = energy / time**

- power is a measure of the **speed** at which energy **can** be generated or used
- power shows what is **possible** at most
- the commonly used unit for power is **kilowatts**

For example
the **power** of a car engine is 70 **kilowatts** (even when the vehicle is stationary).

**Energy**

**energy = power x time**

- energy is generated or used **during** a certain **time**
- energy will **always generate something:** electricity, movement, light, heat, sound, etc
- the commonly used unit for energy is **kilowatt-hours**

For example
the **energy** provided by a car engine of 70 kilowatts during 2 hours = 140 **kilowatt-hours** (at full power)

**In the shop** one pays for the **power** (for example: the power that is stated on a vacuum cleaner)
**At home** one pays for the **energy** (the energy used during vacuuming)

**Law of conservation of Energy**

- Energy cannot be lost
- Energy cannot come from nothing
- Energy can be converted from one form to another, but the sum of the energies cannot change

**Law of conservation of Mass** (mass = the amount of matter)

- Mass cannot be lost
- Mass cannot come from nothing
- Mass can be converted from one form to another, but the sum of the masses cannot change

**So Energy and Mass will never be "consumed"**
In normal language, people usually talk about "consumed".
For example, when the fuel in a car is low, petrol has been consumed.
But then also the "Law of conservation of Energy" and the "Law of conservation of Mass" apply.

**At combustion no energy is lost**
During the combustion of petrol in an engine, chemical energy converts into mechanical energy (= work) and thermal energy (= heat)
**the chemical energy = the mechanical energy + the thermal energy**

**At combustion no mass is lost**
Petrol is a chemical compound of the elements carbon and hydrogen. The combustion of petrol with oxygen, results in carbon dioxide and water.
**the mass of petrol + oxygen = the mass of carbon dioxide + water**

**Efficiency**

**efficiency = useful energy / energy supplied**

For example: a petrol engine

- suppose, a petrol engine provides **50** kilowatt-hours **useful** mechanical **energy**
- suppose, the amount of **energy supplied** is **200** kilowatt-hours (= 22 litres of petrol)
- then the **efficiency** will be (50 / 200) × 100% = 25%
- so 150 kilowatt-hours disappears in the form of useless heat

**Efficiencies are always less than 100%     So Perpetual Mobile does not exist**

**Production factor**

**production factor = actual annual yield / theoretical annual yield**

For example: wind energy

- suppose, the power of a windmill is 3 megawatts
- the **theoretical annual yield** is 3 megawatts x 24 hours x 365 days = **26 280** megawatt-hours
- suppose, the **actual annual yield** is **8 000** megawatt-hours
- then the **production factor** is (8 000 / 26 280) x 100% = 30%

**Efficiency and production factor are 2 completely different concepts**

- the **efficiency** is a property of a solar panel or a wind mill
- the **production factor** is determined by the location of the solar panel or the wind mill

For example: wind energy

- the **efficiency** of a wind mill is **50%**
- at sea the wind is blowing more and more often than on land
- therefore the **production factor** of wind energy will be greater at sea than on land
- the production factor at sea = **45%** and on land = **30%** (rounded up)
- the useful energy of a windmill at **sea** = 50% x 45% = **22,5%** of the theoretical annual yield
- the useful energy of a windmill on **land** = 50% x 30% = **15%** of the theoretical annual yield

**Mechanical equivalent of heat**

The mechanical equivalent of heat shows the relationship between thermal energy (= heat) and mechanical energy (= work)

**1 kilocalorie is equivalent to 427 kilogram-metres**

An example

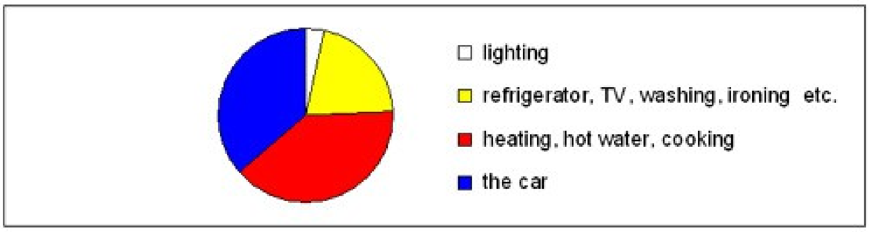
- 1 kilocalorie is the amount of energy needed to raise the temperature of 1 kilogram (= 1 litre) of water with 1 degree celsius
- if one put one's hand in 1 litre of cold water during 1 minute then the temperature of the water has risen approximately with 1 degree celsius.
- this corresponds with a quantity of mechanical energy of 427 kilogram-metres.
- that will be sufficient energy to lift a cow for 1 metre

**Newton's laws of motion**

1. Every object continues in its state of rest, or of uniform motion in a straight line, unless compelled to change that state by external forces acted upon it (the mass is **not** an issue here)
2. The acceleration **a** of a body is parallel and directly proportional to the net force **F** acting on the body, is in the direction of the net force, and is inversely proportional to the mass **m** of the body
   **F = ma**
3. When two bodies interact by exerting force on each other, these forces of action and reaction are equal in magnitude, but opposite in direction

These laws are clearly visible in billiards

# The energy consumption of a household (2008)




In a year a **car** consumes **one and a half times** as much energy as needed for lighting, refrigerator, TV, washing, ironing, vacuuming etc. The total energy consumption per year equals the energy content of **4000 litres of petrol**

It makes little sense to save on lighting as it is only 4% of the total energy consumption. But lowering the heating will help. All energy fed to lighting and devices is fully converted into heat. A living room will not be noticeably warmer when the TV or the lights are switched on. Apparently the energy consumption of the lighting and the TV is negligible compared to the energy needed for heating.
Many people think: "all tiny bits will help". The "tiny bits" will contribute very little and give the misleading sense, that one does quite a lot for the environment and that therefore one can carry onas one is doing way. (with the heating and the car)
**If everyone is doing a little bit, we'll only achieve a little bit**.
As soon as comfort is at stake, people are no longer "at home".

# Green energy

1 solar panel of 1,6 square metres provides **0,2** megawatt-hours per year
1 wind mill of 3 megawatts (on land) produces **8 000** megawatt-hours per year

The total electricity consumption of the Netherlands is **115 000 000** megawatt-hours per year.
So that would require:

| | |
|---|---|
| or 115 000 000 / 0,2 | = 575 000 000 solar panels of 1,6 square metres |
| or 115 000 000 / 8 000 = | 14 375 wind mills of 3 megawatts |

# Solar energy

**Almost all energy on Earth comes from the Sun**

- almost all energy resources on Earth (oil, natural gas, coal, biomass, wind and hydro power) find their origin in solar energy.
- exceptions are: geothermal energy, nuclear energy and energy from the Moon (tidal energy).
- the most direct source of energy is the light and heat radiation from the Sun. This energy source is clean and inexhaustible and in the distant future we will be largely dependent on it.
- the energy that is radiated by the Sun is generated by nuclear fusion

The amount of energy the Sun radiates in **1 second** is almost **1 billion** times as much as the total use of electricity in **1 year** in the Netherlands

The annuel amount of solar energy that is irradiated on Earth is **7000 times** as much as the world consumption of energy

Some people conclude that there is no energy problem.
However, one must bear the following: in mind

- 71% of the Earth's surface consists of water, so the irradiation on the remaining 29% is **2000 times** the world supply of primary energy
- a large part of the irradiated solar energy is stopped by the clouds
- gigantic surfaces are needed for the generation of electricity by solar energy,
- there is no efficient large-scale system yet for the storage of solar energy
- the efficiency of the conversion of solar energy to electricity is low

**Some possibilities to use solar energy are:**

**1.** production of electricity with **solar panels**
**2.** production of electricity with **concentrated solar power**
**3. heating of water** (solar water heater)
**4. photosynthesis** (bio fuel)

**1. Solar panels**
With a solar panel, the irradiated solar energy is directly converted into electricity

**Waldpolenz Solar Park**

- the Waldpolenz Solar Park is a large plant with solar panels, located near Leipzig
- electricity is generated by 550 000 solar panels
- a 600 megawatts power plant produces **80 times** as much energy in 1 year

**2. Concentrated solar power**
The solar radiation is concentrated on a small surface by means of mirrors. The resulting heat is used to generate electricity. The advantage of "concentrated solar radiation" is that part of the heat can be stored temporarily. Thus sunless periods can be bridged
An example of concentrated solar power is the **Andasol Solar Power Station**

**Conditions for concentrated solar power**

- a sun-tracking system
- only usable in places where the sun shines all day
- at a cloudy sky, concentrated solar power does not work
- therefore it cannot be applied in the Netherlands

**Andasol Solar Power Station**

- a solar trough is a trough-shaped mirror, with a parabola shaped cross-section.
- the longitudinal-axis is in North-South direction and the solar trough revolves around this axis in the same position as the Sun, so every day from East to West.
- the concentrated solar power heats oil in a tube in the fire line
- with this water is heated in a heat exchanger to hot steam.
- electricity is generated with the hot steam
- the ground area of this solar trough power station is 6 square kilometres
- a 600 megawatts power plant produces almost **9 times** as much energy in 1 year

**3. Heating of water** (solar water heater)
Usually this is done with panels on the roof of a house. They look like solar panels, but they are filled with water. The conversion of solar energy to heat is done with an efficiency of about **65%**, but the temperature is limited and therefore no electricity can be generated. The hot water can be used as pre-heated water for a washing machine, shower, under floor heating or as a heat source for a heat pump

**4. Photosynthesis** (bio fuel)
Under the influence of sunlight, bio fuels can be grown, such as rapeseed, sugar cane, corn and trees. The efficiency of the conversion of sunlight to chemical energy in the bio fuels will be at most **!%**

# Wind energy

**The efficiency of a windmill**

- the efficiency of a modern windmill is about **50%**
- theoretically the maximum efficiency is **59%**

**The world's largest wind mill is the Enercon E-126**

- the hub height is 135 metres
- the diameter of the blades is 126 metres
- so the highest point of the blades is 198 metres
- the annual yield is 21 000 megawatt-hours at a production factor of 32% (on land)
- a 600 megawatts power plant produces **200 times** as much energy in 1 year

**The largest Dutch offshore wind farm is Borssele 1&2**

- the wind farm contains 94 wind turbines of 8 megawatts
- the surface area is 128 square kilometres
- the annual yield is 3 210 000 megawatt-hours
- a 600 megawatt power station supplies **1,3 times** as much energy per year

# Storage of solar and wind energy

Large-scale application of solar and wind energy is only possible, if a solution will be found for storing very large amounts of electrical energy. The problem occurs especially with solar energy, where the need for energy usually is greatest, when the Sun has gone down.

**Some possibilities for storage of electrical energy**

- **Storage in a reservoir**
  Using electricity,  water can be pumped up into a higher situated reservoir. When there is a shortage of electricity, water can return electricity through a hydroelectric power station.
- **Storage in Hydrogen**
  Using electricity, water can be decomposed into oxygen and hydrogen. The hydrogen can generate electricity in a fuel cell or via a gas turbine
- **Storage in the grid**
  For the time being, we can use the grid for the temporary storage of "green" energy. For example, if you want to run an electric car on the solar energy generated by your own solar panels, then the grid is almost always used for the temporary storage of the solar energy.

# Hydro power

Because the energy consumption has increased in recent years even in Switzerland, Hydro power is of limited significance

- in Switzerland **40%** of electrical energy is generated by nuclear power plants nowadays
- only in Norway virtually all electrical energy is generated by hydro power
- worldwide **16%** of all electrical energy is generated by hydro power  (in 2009)

**In China the largest hydroelectric power plant in the world has been build, the Three Gorges Dam**

- the energy yield is **85 000 000** megawatt-hours per year
- that equals **3%** of the electricity consumption in China
- which is **20** times as much energy as a 600 megawatts power plant. produces in 1 year

# Geothermal energy

**Geothermal energy is extracted from the heat in the Earth**

- the temperature from the Earth’s surface rises with increasing depth by roughly 30 degrees celsius per 1000 metres
- at a depth of 5000 metres the average temperature is about 150 degrees celsius

Geothermal energy may play a (modest) role in future energy supply.

**Qualities of geothermal energy**

- clean, durable and inexhaustible
- independent of weather conditions seasons and time of the day
- no CO2 emission
- the energy is constantly available, so there is no storage problem

# Tidal energy

The energy generated by a tidal power plant is indirectly derived from the moon.
The largest tidal power plant in the world is in France in Bretagne

- there the difference in height between ebb and flood tide is very large, up to 13 metres.
- the annual energy generated is **540 000** megawatt-hours
- a 600 megawatts power plant produces 8 times as much energy in 1 year

# Bio fuel

With bio fuels, for example wood, the solar energy is converted into chemical energy. The return of this conversion is at most **1%**. The idea when using bio fuel is that during the growth, oxygen is produced and carbon dioxide ($CO_2$) is absorbed from the atmosphere.
At combustion, the reverse process takes place. Net this so-called “short cycle” does not pollute the environment. ($Co_2$ neutral).
The great advantage of using bio fuel is that there is no storage problem. The bio fuel can be mixed with the fuel of the coal-fired power plant, which are reviled by environmental activists. The extra $CO_2$ released then will be “green”.

In the Netherlands the share of bio fuel in the production of electricity is 7%. This equals approximately about 80 000 freight wagons with 50 tons of wood each year. A train with a length of 800 kilometres.
For a “$CO_2$-neutral” use of this amount of wood, an area of 63 x 63 kilometres of trees must be cut and replanted every year. That will **never** work.

**Comparison of the amount of electricity that can be generated with wood or solar panels**

- with wood **3,2** kilowatt-hours of electricity can be generated, per square metre per year
- in the Netherlands a solar panel generates **150** kilowatt-hours, per square metre per year
- so solar panels are almost **50 times** more efficient than wood

# Combined Heat and Power

- the efficiency of electricity production in a power plant is approximately 40%
- therefore 60% of primary energy is lost through the cooling water.
- many plants are using this "waste heat" nowadays for district heating and the heating of greenhouses.
- often the heat must be transported and distributed over great distances, which obviously yields quite a few losses.
- nevertheless the overall efficiency of the power plant will be increased significantly.

At Combined Heat and Power the generation of heat and electricity (power) is linked directly. Then heat and electricity are exited at the consumer. The main issue is the heat production while electricity is a by-product. The total efficiency is very high, because there is virtually no heat being lost and all electricity is being used.

Combined Heat and Power is widely applied in hospitals, swimming pools, factories and horticulture In horticulture the $CO_2$ released is very welcome, because it stimulates the growth of the plants (carbon dioxide assimilation). The total efficiency of Combined Heat and Power is about **90%**

# Heat pump

- A heat pump transfers heat from a low temperature level to a higher level.
- For example, the lower level is the ground heat which is approximately 12 degrees during the whole year at any depth. Also heat can be extracted from the air.
- The heat pump works according to the same principle as a refrigerator, but the goal is different.
- In a refrigerator the interior is chilled and the temperature outside is of no importance
- In a heat pump, the heat is important. A room can be heated with it.
- The useful heat that arises is the sum of the heat from the ground or from the air and the energy fed to the compressor (pump)

# Battery

**The lithium-ion battery**

This type of battery is usually used in electric cars and electric bicycles

- the energy content is 160 watt-hours per kilogram
- the service life is 1000 charge cycles

**The lifetime of a rechargeable battery**

- the lifetime of a rechargeable battery will be strongly influenced by the depth of discharge
- the end of lifetime is reached, when the capacity is only 70% of the replacement value
- the lifetime is expressed in the number of charge cycles consumed

**Fast charging of a battery**

At the fast charging of a battery from the mains, massive charge currents will be needed.

- to charge 9,1 kilowatt-hours (= 1 litre of petrol equivalent) in 1 hour from 230 volt, a current of 9100 / 230 = 40 amperes will be needed.
- if this amount of energy will be charged in a battery in 3 minutes then the current from the mains will be 20 times as large, so 800 amperes.

# Walking and cycling

For a person of 75 kilograms the basal metabolism will be about 300 kilojoules per hour. This amount of energy will continuously be needed for heartbeat, breathing, maintaining the constant body temperature, digestion etc.

- 1 kilometre walking costs 300 kilojoules extra
- 1 kilometre cycling costs 60 kilojoules extra

So walking will take **5 times** as much energy as cycling over the same **distance**

Now the calculation for walking and cycling during the same time:

- 1 hour walking = 4 kilometres = 4 × 300 = 1200 kilojoules
- 1 hour cycling = 20 kilometres = 20 × 60 = 1200 kilojoules

So walking will take **the same** amount of energy as cycling during the same **time**

The amount of energy necessary for cycling depends heavily on the bike speed and the wind. In this example no headwind is assumed and the cyclist is seated upright. The above figures show how much energy is consumed in the form of food

**Walking:**

- the mass of a walker is lifted up and down a few centimetres at every step, for which a lot of energy will be needed
- the energy used is proportional to the mass (weight) of the walker

**Cycling:**

- a cyclist is fixated on the saddle and his centre of gravity always remains at the same height. When one leg goes down, the other goes up
- energy is only used for overcoming the air resistance and rolling friction when cycling on a flat road with constant speed. The rider's weight is not an issue (Newton’s 1st Law)
- acceleration and driving up a slope costs extra energy. Then the required energy is proportional to the weights of rider + bicycle.

**One can cycle 100 kilometres on the energy content of 2 litres of whole milk**

- at a speed of 20 kilometres per hour, a power of 75 watts must be supplied
- that is an amount of energy of 375 watt-hours in 5 hours
- with an efficiency of 25%, the energy content of 2 litres of full milk
- from cycling 100 kilometres one will not lose any weight, onr will lose weight when swimming, because of the heat loss (and especially by eating less)

# Electric bicycle

- on an electric bicycle the cyclist is supported by an electric motor
- this motor gets its energy from a rechargeable battery
- the degree of support is automatically controlled by a pedal sensor
- the pedal sensor measures the force that is being exercised on the pedals
- the motor gets energy proportional to that force
- with the result that on a slope or with headwind, support will increase (automatically)

Ideally, climbing a slope or cycling against wind will be as easy as cycling on a flat road without wind But of course that will cost a lot of energy. Therefore it is possible on most electric bicycles, to adjust the extent of support more or less progressively by using a switch on the bicycle's handlebar. For example, one can choose between the modes "normal" or "power". The range of the support is determined by the energy content of the battery and the energy consumption of the motor. The legally permitted power of the motor is 250 watts. The support is only active up to a speed of 25 kilometres per hour.

**The energy consumption of an electric bicycle**

The energy consumption is highly dependent on the wind, tailwind or headwind
The average energy consumption from the battery = **5 watt-hours** per kilometre
With a battery of 400 watt-hours, for example, the action radius will be 400 / 5 = 80 kilometres

**Pedal sensor or rotation sensor?**

Recently more and more electric bicycles have been launched equipped with a rotation sensor instead of a pedal sensor. Advantages are the lower price and the simple construction. The smaller range and the insecurity however are a disadvantage. The application of a rotation sensor, enables immediately support once the pedals are rotating. Also when little force is pursued, the motor will be enabled and will then deliver virtually all energy needed for the propulsion. If one wants to cycle faster, one must pedal disproportionately harder, because then the cyclist himself has to deliver the extra energy needed.
In practice one usually cycles with the speed of the maximum support. A great solution for people who do not want to work, but this is at the expense of the range. If one stops pedalling, the support usually still goes on for a while. Therefore, these bikes are often equipped with a switch at the brake handle If one brakes, the circuit to the motor is switched off immediately
Electric bicycles with a rotation sensor are potentially dangerous in traffic, especially for older cyclists But one get used to anything. On electric bikes with a pedal sensor, said problems are entirely absent

**Does it take more exercise to cycle an electric bicycle without support than a regular bicycle?**

It is a widespread misunderstanding, that when support is disabled it will be (a lot) more work on an electric bicycle than on a regular bicycle. Only the rolling resistance of an electric bicycle is a bit more compared to a regular bicycle, due to more weight of the bicycle. The air resistance will be the same of course. On a flat road with constant speed the mass (weight) of the bicycle + rider is (virtually) not an issue. (Newton's 1st Law).
The rolling resistance is negligible compared to the air resistance, especially with moderate or strong headwind. Ofcourse the larger weight will play an important role during acceleration and on a slope.
But during a long bicycle ride slopes will not be present very often. (in the Netherlands)

**The benefits of an electric bicycle are:**

1. the energy consumption of an electric bicycle is 10 times less than that of a moped
2. the support over 80 kilometres costs less than 10 euro cents (= 0,5 kilowatt-hour)
3. one hour of electric cycling consumes as much electrical energy as watching TV for one hour
4. an electric bicycle requires virtually no maintenance
5. a helmet is not obligatory on an electric bicycle
6. insurance is not compulsory for an electric bicycle
7. an electric bicycle is much sportier and healthier than a moped, because one always has to pedal
8. an electric bicycle does not smell, makes no noise and does not leak oil
9. **one can also just cycle on an electric bicycle**
10. with an electric bicycle one cycles more often, further and faster

# Electric trains

### The Double Decker

The Double Decker is the most modern and efficient train of the Dutch Railways

- the train runs on 1500 volts DC
- the maximum speed is 140 kilometres per hour
- the basic implementation of the train is 4 wagons with **372** seats.
- the energy consumption is **48 watt-hours** per passenger per kilometre

### The Thalys

The Thalys, which runs on the **H**igh **S**peed **L**ine, consumes much more energy than an ordinary train

- the train runs on 25 000 volts AC
- the maximum speed is 300 kilometres per hour
- the Thalys has a fixed composition of 10 wagons with **377** seats
- that is **151 watt-hours** per passenger per kilometre

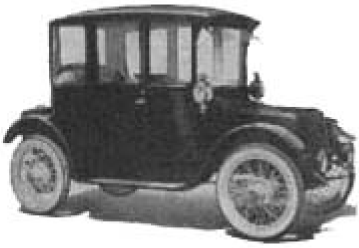
# Aircraft

### The Boeing 747    “Jumbo"


Some global data and calculations:

- a Jumbo can carry 200 000 litres of fuel
- the range is 13 500 kilometres  (= 1/3 of the Earth's circumference).
- so the fuel consumption is 15 litres per kilometre
- a Jumbo can carry **500** passengers
- then the consumption is **300 watt-hours** per passenger per kilometre
- about half of the take-off weight of a Jumbo is due to the carried fuel  (on a long distance flight).
- the empty weight is 181 tonnes, the fuel weight of 200 000 litres kerosene is 160 tonnes.
- the cruising speed at a height of 10 kilometres is 900 kilometres per hour

# Electric car



**An electric car from 1916**

Already 5000 electric cars had been manufactured in America by Baker Electric between 1899 and 1915. The top speed was 23 kilometres per hour, with an range of 80 kilometres. Another well-known brand in the initial phase was Detroit Electric. This company produced electric cars that reached a top speed of 32 kilometres per hour, at a 130 kilometres range.

**Nowadays electric cars can cover reasonable distances**
That is due to:

- a better kind of battery (nickel-metal hydride or lithium-ion instead of lead batteries)
- the higher efficiency of the electric motor (90%) compared with a petrol engine (25%)
- a lower speed (the air resistance is proportional to the 2$^{nd}$ power of the speed)
- a low rolling resistance, low weight and a streamline
- regenerating of energy during braking, speed reduction and descending a slope

**Some characteristics of the electric car**

- the electric car is virtually silent
- the electric car produces no exhaust gases (but the power plant does all the more)
- the electric motor can deliver maximum torque at all speeds, this enables a quick acceleration
- the electric motor is never running idle
- there is no need for a gearbox
- the range is (very) limited
- the battery is heavy, very expensive and takes a lot of space
- charging the battery lasts very long (minimum 4 hours)
- heating an electric car comes at the expense of the range

**The Tesla model S**

In 2013 a 5-seater electric car was introduced in Europe, the Tesla model S
Some data:

- the car accelerates in 5,6 seconds from 0 to 100 kilometres per hour
- its top speed is 200 kilometres per hour
- the energy content of the lithium-ion battery is **85** kilowatt-hours
- its range is **480** kilometres (at a constant speed of 88 kilometres per hour)
- the weight of the battery is 700 kilograms
- the weight of the car is 2100 kilograms
- with a **supercharger** the battery can be charged to 80% in 40 minutes.

# Solar powered car

**The Light-year One**

This is a 4-seater electric car, which can drive 400 to 800 kilometres on 1 battery charge. The required energy is (largely) generated by solar cells on the roof of the car. The name “Light-year” is inspired by the fact, that each year the distance of all cars in the world amount to the equal of one light year (approximately). That are 9460 billion kilometres

At the moment these kilometres are still covered with fossil fuels. In total there are about 1 billion cars on earth, travelling 9460 kilometres per year on average.

# Hybrid car

**The Prius**

In 1997 Toyota has launched the "Prius". This is a hybrid car. In 2004 an improved version was launched. IN 2013 there were more than 3 million cars of this type woeldwide. It is a car which is propelled by an electric motor (60 kilowatts), a petrol engine (73 kilo-watts) or a combination of both, depending on the situation. Its goal is to achieve as much (vehicle) efficiency as possible.

- the efficiency of the Atkinson petrol engine is high, but strongly dependend on the load and the speed
- the electric motor always has a high efficiency
- the electric motor cooperates when the efficiency of the petrol engine is low
- the energy for the electric motor is supplied by a rechargeable nickel-metal hydride battery
- at (regenerative) braking and speed reduction the electric motor will work as a dynamo and qill deliver energy back to the battery
- in addition, the battery is recharged by a generator, which is linked to the petrol engine
- the petrol engine, generator and electric motor are linked together by means of a mechanical energy distributor
- this energy distributor also functions as a continuously variable automatic transmission
- the air conditioning is powered electrically and therefore it also works when the petrol engine is not in operation

The highest effect of the hybrid system is being achieved In braking-stopping-acceleration situations.

For instance in traffic jams and in cities with many traffic lights. Over long distances and at high speed the hybrid system is not working. Then only the economical Atkinson petrol engine works.

The Prius is equipped with an "energy monitor" on the dashboard. It invites you to practise an economical driving style. Then the consumption appears to be **1 litre per 21 km**.

# Plug-in hybrid car

In 2012 **Toyota** launched the **plug-in** Prius. This plug-in hybrid car has a relatively large battery that can be charged from the mains. The energy content of the battery will be sufficient to drive electrically for 50 kilometres..

# Fuel cell car

Some characteristics:

- hydrogen is the energy source for a fuel cell car
- in a fuel cell the hydrogen is “burned”, as a result electricity is generated
- at the combustion of hydrogen no harmful gases arise, just water
- the generated electricity is fed through a battery to an electric motor which propels the car
- while braking and during speed reduction energy is returned to the battery

The question remains: **"where does the hydrogen come from"**
Hydrogen can be obtained by electrolysis (decomposition) of water. The electric energy needed for the decomposition of water must be generated through combustion of fossil fuels (which causes harmful gases), nuclear energy, wind energy or other forms of "green" energy.

**Will there ever be a fuel cell car on the road?**
It is not very likely that the fuel cell car ever will appear (large-scale) on the road. It is more obvious, that in future cars will drive on synthetic petrol, synthetic diesel oil or electricity.

# Hydrogen Economy

The energy scenario of the future, when the fossil fuels will be exhausted, may be (partially) based on the so-called Hydrogen Economy. It is assumed that an endless amount of "green" energy will be available around 2050. Also it might be possible to generate energy by means of Nuclear Fusion.

**Energy can be stored in Hydrogen**

- solar energy (from the Sahara) and wind energy (submitted by wind farms in sea) are not constant available (the Sun does not shine at night and the wind is not always blowing)
- so there is a storage problem for the electricity generated by these "green" energy sources
- it is possible to use electricity for the production of hydrogen by electrolysis (decomposition) of water.
- unlike electricity, hydrogen can be stored under high pressure, both in unlimited quantities and during long periods of time.
- the hydrogen can deliver electricity back via fuel cells (or gas turbines), where the only "combustion" product is water.

**Hydrogen is therefore not an inexhaustible source of energy, as some people think.**

# Nuclear fusion

There are 2 types of nuclear reactions, suitable for generation of energy

- fission of uranium nuclei. This is called nuclear energy
- fusion of hydrogen nuclei. This is called nuclear fusion

In both processes Mass loss will happen
The "lost" mass is converted into energy according to the formula of Einstein

Below is a brief summary of **"Nuclear fusion, a Sun on Earth"**
Author: Dr. Ir. M.T. Westra FOM-Institute for plasma physics "Rijnhuizen".

The energy that the Sun radiates comes from nuclear fusion of hydrogen atoms. This nuclear fusion is formed at an extremely high pressure and a temperature of 15 million degrees celsius. In nuclear fusion on Earth the pressure is negligible in comparison with the Sun and therefore the temperature here should be very much higher, around 150 million degrees celsius.

The fusion reaction which can best be established on Earth is the merging of the hydrogen isotopes Deuterium and Tritium. This produces Helium atoms, neutrons and very much energy.

The main problem with fusion is the extremely high temperature, needed in the plasma. No material is resistant to this extreme temperature. In a so-called "Tokamak" the hot plasma is trapped in a strong magnetic field and there is no contact with the wall. A Tokamak is a ring-shaped reactor where the plasma is heated up to the temperature at which fusion occurs.

To deliver more energy than necessary for the merging process a Tokamak must have a minimum size.
This will be realized for the first time in **ITER** (**I**nternational **T**hermonuclear **E**xperimental **R**eactor),
the first (experimental) fusion power plant. ITER must demonstrate the possibility of long-term energy generation with nuclear fusion.

After ITER a larger power plant DEMO will be built. That should demonstrate the technical feasibility, reliability and economic attractiveness of fusion energy. Around **2050** the first prototype of a commercial fusion reactor PROTO should be ready. Nuclear fusion is inherently safe. There is no chain reaction.
If something goes wrong, the reaction will stop. In nuclear fusion there is little radioactive waste. This waste has a short half-life time.

# Nuclear energy

**In 2013 the electricity consumption in the Netherlands was 115 billion kilowatt-hours**
This would require: (rounded)

| | | |
|---|---|---|
| either | 300 tonnes | enriched Uranium |
| or | 36 000 000 tonnes | coal |

Imagine a train with 50 tonnes goods wagons and a length of 10 metres each, then the following image will appear:

| | | |
|---|---|---|
| • for the carriage of enriched Uranium | 6 goods wagons | = 60 metres |
| • for the carriage of coal | 720 000 goods wagons | = 7200 **kilo**metres |

**Some people will think:**

- **“someone” will solve this problem**
  (they simply fill the Sahara with solar panels)
- **it will outlast my time**
  (this remains to be seen and what about the offspring?)
- **in the long term all energy will be generated sustainable**
  (all the energy needed for heating, food production, industry, aircraft, trains and **1 billion** cars?)

In 2009 the nuclear energy's share of electricity generation was

| | | | | | |
|---|---|---|---|---|---|
| France | 77% | Germany | 23% | England | 14% |
| Belgium | 54% | Switzerland | 41% | Sweden | 43% |

**Whether or not nuclear energy?**
Each solution has its advantages and disadvantages. The question is: which is preferable?
**fossil energy sources**

- irreversible climate change (greenhouse effect)
- thereby sea level rising and flooding of the land
- continued increase in air pollution (CO2)
- exhaustion of all fossil fuels
- wars to secure the supply of oil or natural gas
- earthquakes and subsidence by oil and gas extraction

**or nuclear energy**

- no CO2 emissions
- a limited (radioactive) waste problem, which can be solved in principle
- nuclear accidents

**It is curious that one is excited about nuclear energy and not about nuclear weapons**

**Dutch Teletext 3 July 2017**
Russia and the US will decrease their stock of nuclear weapons. Yet the US will invest up to 400 billion in modernization by 2026. There are nine countries with nuclear weapons. Together they have **14 935** nuclear warheads.

**Thorium?**
Thorium is an interesting fuel, because the Thorium inventory on Earth is sufficient for some **thousands** years. A Thorium power plant produces 10 to 100 times **less** radioactive waste than a normal nuclear power plant and this waste has a relatively short half time (300 years)

**Nuclear fusion?**
The clean nuclear fusion does take a long time. The most optimistic estimate is that in **2050** the first commercially operated nuclear fusion plant will be operational.

## The mass-energy equivalent

According to Einstein's formula, mass can be converted into energy $E = mc^2$

**1 kilogram mass is equivalent to 25 billion kilowatt-hours**

## Mass and weight

- **Mass** is the amount of matter.
- **Weight** is the force with which matter is attracted by the gravity of the Earth.
- On the Earth gravity is not uniform and therefore also weight is not.
- **The mass however is the same everywhere**.
- The unit of mass is the kilogram

## Fuels and CO2

The CO2 emissions per kilowatt-hour produced by a petrol engine are the same as produced by a coal-fired power station. Coal-fired power stations are "not allowed", but the car is a "must".

**It is amazing that environmentalists protest against coal-fired power plants, while they are using cars like anyone else** (environmental pastors)

## The greenhouse effect

The greenhouse effect is probably caused by the carbon dioxide (CO2), that is released in the burning of fossil fuels. This greenhouse gas let by solar energy towards the Earth virtually unhindered, while the radiation of heat from the Earth is largely stopped.
As more greenhouse gas is present in the atmosphere Earth cools down less. However it is questionable whether the effect of carbon dioxide (CO2) in this process will be as large as has been assumed up to now. That point has not been settled yet. Future will tell. It is clear however that the climate is changing in recent years.
Think of the melting of the ice at the North Pole and the disappearance of the "eternal" snow in the Alps.
For the past few years (in Europe) winters have been remarkably warm. In addition one has to do more often with extreme weather, such as hurricanes and floods.

## Light sources

**Comparison of various light sources**

| | light efficiency |
|---|---|
| **incandescent lamp** | 5% |
| **energy saving lamp** | 29% |
| **fluorescent tube** | 41% |
| **Led lamp** | 44% |

**Led lamps** (led = **l**ight **e**mitting **d**iode)

- the benefits of the Led lamp are its dimensions, its resilience and longevity. In addition,
- in comparison to small light bulbs, such as in flashlights and in rear light of a bicycle, the light efficiency of Led's is very high

# The combined gas and steam power plant

- in a combined gas and steam power plant electricity is generated using 2 turbines.
- the first turbine is a gas turbine, the second turbine is a steam turbine.
- the steam turbine is powered by steam, produced by the heat of the exhaust gases of the gas turbine.
- the gas and steam turbine often drive the same axis, so together they drive the same generator.
- the efficiency of a combined gas and steam power plant is up to 58%

The ratio between the inlet temperature of the gas turbine and the outlet temperature of the steam turbine in a combined gas and steam power plant is much larger than that of a single process.
The total efficiency is therefore also larger..

# Comparison of power plants required for the Netherlands

The electricity consumption in the Netherlands = **115 000 000** megawatt-hours per year (2013)

| type of plant | amount |
|---|---|
| **gas-fired power plant** 600 megawatts | **28** |
| **nuclear plant** Borssele | **31** |
| **wind farm** Borssele 1&2 | **36** |
| **tidal power plant** Bretagne | **213** |
| **solar trough power plant** Andalusia | **232** |
| **sun-voltaic power plant** Waldpolenz | **2212** |
| **largest wind mill in the world** | **5476** |

A **600 megawatts power plant**

- at a production factor of 80% the annual yield will be 600 megawatts × 0,80 x 24 hours x 365 days = **4 200 000** megawatt-hours = **4,2** billion kilowatt-hours

**The Waldpolenz Solar Park**

- to fulfil the need for electricity in the Netherlands **2212** of these power plants will be needed
- that amounts to **1,2 billion** panels, an area of more than 50 x 50 kilometres.

**Solar-energy**, a realistic perspective?

# CO2 emissions of different types of cars

(at **the same** amount of propulsion energy of **150 watt-hours per kilometre**
and everything "well-to-wheel")

| | **electric car** | **hybrid car** | **petrol car** | **fuel cell car** |
|---|---|---|---|---|
| **CO2-emissions** (per km) | 123 grams by the power plant | 150 grams by the car | 204 grams by the car | 295 grams by the power plant |
| **energy in litres petrol-equivalent** | 1 litre per 18,7 km | 1 litre per 20,6 km | 1 litre per 15,2 km | 1 litre per 7,7 km |

**electric car**

- the electric motor never needs to warm up
- there is no gearbox and so there are no transmission losses
- during braking and speed reduction energy is returned to the battery
- on site the car causes no CO2 emission, but on the other hand the power plant does

**hybrid car**

- the cold petrol engine must be warmed up, that takes a lot of energy
- the continuously variable gear works with a very high efficiency
- during braking and speed reduction energy is returned to the battery.
- the petrol engine is always running under circumstances when the efficiency is high
- the petrol engine is never running idle

**petrol car**

- the cold engine must be warmed up, that takes a lot of energy
- there are relatively large energy losses in the gearbox
- regenerating of energy is not possible
- in a petrol engine the efficiency strongly depends on the speed and torque
- the petrol engine is often running idle

**fuel cell car**

- this is an electric car in which the energy is supplied by a fuel cell
- the 4-fold energy conversions cause a bad total efficiency
- the indirect CO2 emissions will be 2 times as much as at an electric car

**the number of energy conversions of different types of cars**

- **petrol car 1x**
  primary energy in petrol > mechanical energy
- **electric car 2x**
  primary energy in natural gas > electricity > mechanical energy
- **fuel cell car 4x**
  primary energy in natural gas > electricity > hydrogen > electricity > mechanical energy

# Comparison means of transport

**A** = maximum number of passengers per means of transport
**B** = primary energy per passenger per kilometre (watt-hours)

| means of transport | A | B |
|---|---|---|
| **aircraft** Boeing 747 Jumbo | **500** | **300** |
| **fuel cell car** | **4** | **288** |
| **electric train** Thalys | **377** | **151** |
| **petrol car** | **4** | **150** |
| **electric car** | **4** | **121** |
| **hybrid car** Prius | **4** | **108** |
| **electric train** Double-decker | **372** | **48** |
| **electric bicycle** | **1** | **17** |

If there is one person in a petrol car (and that is usually the case), then that person consumes **twice as much** of primary energy per kilometre as one person in a full occupied Jumbo

# The World Solar Challenge

In 2017, the Nuon Solar Team has won (for the 7th time) the World Solar Challenge. This is a 2 yearly contest for vehicles exclusively driven by solar energy. The Nuon Solar Team has been formed by a number of students of the Technical University of Delft,
Under the guidance of ex-astronaut Wubbo Ockels, they have designed or improved the **"solar car"**.
The distance across Australia from North to South is 3021 kilometres. The average speed is about 100 kilometres per hour.

# Shell eco-marathon

The Shell eco-marathon is an annual efficiency contest, sponsored by Shell.
The goal is to trudge as many kilometres as possible with a vehicle on 1 litre of regular petrol.
There are 2 classes: the "prototype" and the "urban-concept"

**1.** In the **"prototype"** class any form of the vehicle is allowed.
Usually it resembles a motorized recumbent

**2.** In the **"urban-concept"** class, the vehicle must resemble a car.
The driver has to sit upright and the vehicle must have four wheels.

**Important factors at the record attempts are:**

- a low air resistance, so a small frontal area and a good flow line
- a low weight
- a low speed (the air resistance is proportional to the 2nd power of the speed)
- the efficiency of the (small) engine must be as high as possible

**In 2014 the following records have been achieved at the consumption of 1 litre of petrol:**

- in the class "prototype" **3315** kilometres
- in the class "urban-concept" **469** kilometres

# A few more things worth knowing

**The Nor Ned cable**
In order to enable the exchange of large quantities of electrical energy, a submarine high-voltage cable, the Nor Ned cable, has been installed between Norway and the Netherlands.
The transport of the electricity is in the form of direct current..
The length of the cable is 580 kilometres

**Hot-air Engine (Stirling engine)**

- a hot-air engine is heated from the outside and contains no valves.
- therefore the reliability will be very good, while the engine will be very quiet.
- virtually all energy sources are suitable to heat the engine, including solar energy or natural gas

**Does a bicycle with a suspension front fork ride heavier than a regular bicycle?**
A suspension fork becomes a little warm while driving on a bumpy road. This heat (= thermal energy) has to be applied **additional** by the cyclist. A bicycle with a suspension fork therefore runs heavier than a regular bicycle.

**Energy losses in the food cycle**

- if a man eats grain, 10% will be converted into muscle proteins
- if a pig eats grain, 10% will be converted into pork
- if a man eats pork, 10% of it will be converted into muscle proteins, so that is only 1% of the grain eaten by the pig.

From the point of view of energy efficiency, eating of meat is very inefficient.

**Electric shaving in comparison to shaving with a razorblade**

- shaving with a razorblade**:** warming up 200 centilitres of water with 50 degrees costs 10 kilocalories = **11,6 watt-hours**
- electric shaving**:** 2,8 watt-hours for 7 times of shaving, = **0,4 watt-hours** at a time
- so shaving with a razorblade costs **29 times** as much energy as electric shaving.

**Comparison of cooking on gas with electric cooking**

At first glance cooking on gas seems to be much more efficient than cooking on electricity, but on closer inspection one has to nuance this somewhat

**cooking on gas:**

- much heat losses, because a lot of heat flows along the pan
- combustion products (carbon monoxide and carbon dioxide) in the kitchen
- danger of gas leaks, which may cause life-threatening explosions
- as a result in many buildings (Tower flats) cooking on gas is prohibited
- energy supply is (very) bad adjustable

**electric cooking:**

- no combustion products in the kitchen.
- the efficiency of the heat transfer between hob and pan approaches the 100%
- the energy supply is excellent adjustable
- the energy supply can be automated, for instance setting the desired temperature and stops heating when the water boils
- a time switch can easily be applied (useful in elderly homes)

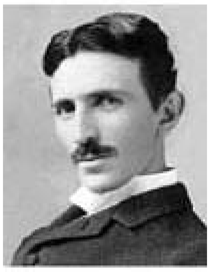
**Reliability of the supply of electricity**

It is commonly expected that the supply of electricity is guaranteed for at least 99,99% of the time. Fortunately, in practise this is considerably better. With a reliability of only 99,99% on average we would sit in the dark during 53 minutes per year

**Energy consumption of lighting**

The energy consumption of Led lighting is approximately **1,6%** of the total electricity consumption of a household. If one really wants to save energy, it is better to set the heating somewhat lower and to abolish the car, than switching off the lighting in the kitchen every now and then.
Small bits only help a bit.
**If everyone does a little, we'll achieve only a little**
Also it will have little effect to reduce the lighting of highways (to save energy) while the car traffic is unaffected.

# Free energy



**Nikola Tesla**

There is no scientific basis for the existence of "free energy" However, one can have vague doubts, because **Tesla** would have invented this in 1889.
Tesla (1856-1943) was one of the greatest inventors of all time. Among other things he designed the infrastructure of electricity networks as we are currently using everywhere. This is energy transport by means of alternating current transported through high tension power lines and transformers. He also was the inventor of the alternating current induction motor, the fluorescent tube, the radio and the remote control. In 1943, shortly after his death, the American Supreme Court officially established that Tesla was the inventor of the radio and therefore not Marconi.
His greatest invention however would be the global energy supply by "free energy", drained from the "ether". However, experiments with this have never taken place because his lenders left failed. They saw nothing in free energy

The **Warden Clyff Tower**
With 5 of these towers Tesla would make a worldwide, wireless energy supply possible

Tesla was able to transport energy wireless over great distances. It was stated that he left lamps burning wireless at a distance of several hundred metres. He also would have converted an electric car, that could drive for a week without charging the battery. This would also be made possible by the wireless transfer of energy.

The wireless transmission of energy in itself is nothing special. Virtually all the energy we use on Earth is transferred wirelessly from the Sun to the Earth. It is much stranger actually that large amounts of electrical energy can be transported through a few copper wires. For example, from a power plant to a big city

# Storage of Energy

**Some examples;**

1. **Electrical energy** in super capacitors
2. **Chemical energy** in batteries and hydrogen
3. **Thermal energy** in materials with a large heat capacity
4. **Kinetic energy** in flywheels
5. **Potential energy** by moving mass against gravity to a higher level or by compressing air

# Energy saving

**Insulation of the house**
Annually an average of 2150 cubic metres of natural gas will be required to heat a poorly insulated house.
A good insulated house does not need more than 700 cubic metres. So insulation really helps a lot.
The ideal house is energy neutral

**Hot water**
Much saving in energy can be achieved by placing the water boiler as close as possible near the tap, as well in the kitchen as in the shower. In many homes a combo boiler is in the attic.
That is the **worst place imaginable**. When hot water is needed, the long branch to the kitchen or bathroom must be warmed up before the water on the consumable place gets the desired temperature. After closing the tap the water cools in the water pipe again, what means pure energy losses. It also costs a lot of extra water.

**Car**
One can achieve a considerable saving in fuel by driving a hybrid car. This can save up to 25%. Of course the only real saving is the abolition of the car. Unfortunately, public transport is of such poor quality, that this is a difficult step to take. Only an extreme increase in the petrol price, for example up to € 5,- per litre, will have any effect on the long term, but most people are addicted to their car.

**Lighting**
Although lighting consumes very little energy, one can save a bit by the consistent use of energy saving lamps. In the near future also Led lamps will play a role in energy savings

# The energy-neutral home

- during a year the amount of energy generated must be equal to the amount of energy consumed
- usually the electricity is generated with solar panels
- water is heated by solar collectors
- as long as there is nothing conceived better, the grid functions as a buffer for the (temporarily) excess of electrical energy
- in summer the surplus electricity is fed to the grid and in winter the shortage of energy is absorbed from the grid
- the most important conditions for an energy neutral home are: good insulation of the roof, walls, windows, doors and floors
- large windows facing South, for maximum irradiation of solar thermal energy during winter
- above the windows there must be a canopy which prevents irradiation of heat when the sun is higher
- 3 layer glass  (but that does not stop the **heat radiation** of the sun)
- hanks to the good heat insulation of 3 layer glass, little or no cooling is necessary in summer, while in winter heat losses are limited
- energy efficient appliances and lighting
- heat recovery at ventilation and when using hot water
- floor heating with a heat pump or with water from solar water heaters
  (at low temperatures, the heat losses are small)
- the relative heat losses decrease as a house is larger
- the heat losses are the smallest with a spherical shape (in practice a cube). Projections in the form of attached garages, greenhouses and dormers cause extra heat losses
- one must be able to verify if the energy generation is in balance with the consumption
- everything stands or falls with the motivation to save energy

# Heat transfer
Heat always (automatically) goes from a high temperature level to a lower temperature level.
A (energy-consuming) heat pump is required for transport in the opposite direction.
Heat can be transported in 3 ways:

**1. by conduction**
In stationary matter, such as a wall, heat is transported by conduction. At a normal cavity wall the space between the 2 walls is filled with air. Then that air can circulate freely between the 2 walls and then heat is transferred by flow. When the gap is filled with, for example, glass wool, the heat insulation is very good, because glass wool contains a lot of stagnant air.

**Stagnant air is a very poor heat conductor.**

Even with 2 or 3-layer glass, there is still air between the glass plates. The distance between the glass plates is so small (about 0,5 centimetres) that virtually no flow of the air can take place. As a result, this type of glass is a poor heat conductor. Also think about clothing. A few layers on top of each other, with stagnant air in between, insulates the heat much better than 1 thick layer.

**2. by flow**
Heat can be transported by a flowing medium, such as water, air or oil. At the central heating, heat is transported by the water that flows from the boiler to the radiators. Warm air flows in or out through an open window. If it is warmer outside then inside, you have to keep the windows **closed**, at least if you want to keep it cool inside.

**3. by radiation**
Solar radiation passes almost unhindered through glass and air. So 2 or 3 layer glass does not help against this. Only glass with a special coating can block the sun's rays. If you want to keep heat **outside**, sun protection must be installed on the **outside** of the window. If you want to keep the heat **inside** in winter, heat insulation must be placed on the **inside** of the window, for example in the form of curtains

# What will the future look like?
**Oil**
The easily extractable oil is running out. Therefore in Canada and Venezuela the difficult recoverable oil from tar sands will be exploited. Also one starts drilling for oil at the North Pole and to a depth of 5 kilometres in the Gulf of Mexico. In America, Western Europe and Russia great stocks of shale oil and gas are found. Winning of this is accompanied by a major pollution of the environment. But no one objects, because "the car must be driven".

**Gas**
There is still sufficient gas, and that will last probably for the next 60 years. The top of gas production will be reached in about 20 years. Then the price will rise strongly. West Europe will be particularly dependent on Russia, Norway, North Africa and the Middle East.

**Coal**
Worldwide coal is available for at least 200 years. Coal is good for everything. It can be used to make City gas, hydrogen, synthetic petrol and diesel oil. In addition very much CO2 is released. But no objections will be raised if there is shortage of energy. The technique for the production of synthetic petrol from coal has been known since 1923. It was applied by Germany on a large scale during the 2nd World War. (Fischer-Tropsch synthesis)

**Hydropower**
Although the most profitable projects have been realized already, there are still great opportunities in Africa and South America. Hydroelectric power plants cause a lot of damage to the environment.

**Green Energy**
Green energy obtained from wind, solar, biomass etc. will be of little meaning provisionally. It is believed this will be up to 14% (in the Netherlands) of (only) the electricity in 2020. Wind energy is still in an initial state in some countries. Solar energy is still negligible. One should think of no more than a few hundreds of the total electricity generation.

**Bio Fuel**
Large-scale production of bio diesel etc. comes at the expense of the long-term food production. In addition, it will cost much fossil fuel. This is not a real option. The conversion of solar energy into bio fuel is accompanied with an extremely low efficiency, in the order of **1%**

**Nuclear Energy**
Nuclear energy at the current consumption rate can last for the next 75 years. If the Uranium has run out, probably one can continue with **Thorium**. Thorium can be "burned" completely in simple reactors This is in contrast to Uranium, of which only 0,7% can be used. (the isotope U235). The amount of Thorium on earth is sufficient for several thousand years

**Nuclear Fusion**
We may expect the first practical results of nuclear fusion around **2050**. Then mankind can have an infinite amount of "clean" energy. The total development time then has seized about 100 years. One might wonder whether one will ever succeed in generating very large quantities of energy by means of controlled nuclear fusion.

**Hydrogen**
The necessary electricity for the electrolysis of water must be generated by nuclear fusion, or by "green" energy. But there is still a long way to go.
Hydrogen is not an energy **source**, but an energy **carrier**.
Producing hydrogen by electrolysis of water costs **1,5 times** more energy than it delivers.
**So hydrogen is not a solution to the energy problem**

There is a mismatch to occur between the production and consumption of energy. There would hardly be a problem, if there were a few billion people less walking around (driving around) on Earth.
Reality is that a few billion people more are to come before the year 2050.
That will be an **increase** of **1 million people per week** on average.

The only solution seems to be**: a strong cut down** on energy consumption and **far less** people
Cutting down on energy consumption, while at the same time the number of earthlings increases, provides nothing per balance. That is emptying the ocean with a thimble.

Many people think: “Crises are of all times and humanity has always found a solution, so now that will happen again”

- for the first time in World history, humanity is threatened by an extreme overpopulation
- **over the last 6 years the world’s population has increased with half a billion**
- sooner or later we will run out of all energy resources
- the amount of $CO_2$ in the atmosphere is growing all the time
- this situation has never occurred before

**These are going to be interesting times**

# Energy and work

- **Energy** can be converted into work Example**:** electricity can make a motor run
- **Work** can be converted into energy Example**:** a dynamo can generate electricity

Suppose we make a trip by car and we return on the point of departure. The car then has consumed a number of litres of petrol. The petrol contains **energy**.
The efficiency of a petrol engine is about 25% That means that 25% of the energy in the petrol is converted into useful mechanical **work**. This propels the car during the trip. Through the cooling of the engine and the hot exhaust gases 75% of the energy disappears in the form of useless heat. After the trip has been finished the useful mechanical work is also fully converted into heat. That heat arises from overcoming the air resistance, the friction in the tires, the gearbox, the bearings, etc. After ending the trip all energy has be "bygone" in the form of heat in space. The mechanical work was an intermediate form.

# A book about energy

**"Sustainable Energy without the hot air"** (2008) **http://www.withouthotair.com/**

This book gives a complete overview of the (imp)possibilities of sustainable energy
Author: David MacKay, professor at the University of Cambridge. Read especially chapter 19: **"Every BIG helps"**

Some quotes from the book:

- if everyone does a little, we'll achieve only a little
- is the population of the Earth 6 times too big? (now 8 times)
- any sane discussion of sustainable energy requires numbers