Short summary “Energy Facts”
(vertaald door Google Translate)

"Big numbers say nothing, ratios do"

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In this story, various energy sources are repeatedly compared to a medium-sized power plant with a **power** of **600 megawatts**
The amount of **energy** that such a plant produces in 1 year = **4,200,000 megawatt hours**

Some definitions and fundamental laws

Power

power = energy / time

- power is a measure of the **speed** at which energy **can** be supplied or used
- power is a **property**
- power shows what is (maximum) **possible**
- a commonly used unit for power is **kilowatt** or **megawatt**

for example
The **power** of a power station = **600 megawatts** (even when the station is not in operation)

Energy

energy = power x time

- energy **is** supplied or used for a certain **period of time**
- energy **always produces something:** electricity, work, light, heat, sound, radio waves, etc.
- a commonly used unit for energy is **kilowatt hour** or **megawatt hour**

for example
The **energy** that a 600 megawatts power station supplies in 1 year = **4,200,000 megawatt hours**

The difference between power amd energy

An example

- the engine of an electric car has a **power** of 50 **kilowatts**
- the amount of **energy** in the battery is 30 **kilowatt hours** (= 30,000 watt hours)
- suppose the energy consumption of the car is 150 watt hours per kilometer
- the range of the car is then 30,000 / 150 = 200 kilometers
- the **power** therefore has no influence on the range
- while driving, the electrical **energy** from the battery is supplied to the engine
- in the engine the electrical energy is converted into mechanical energy + heat
- the **power** determines how much energy the engine **can supply per second**
- the **power** therefore determines **how quickly the car can accelerate**

Law of conservation of Energy

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

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

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

So Energy and Mass are never “consumed”
In normal language people usually talk about “consumed”.
For example, if you run a car until the tank is empty, the petrol has been used up
But even then the “Law of conservation of Energy” and the “Law of conservation of Mass” apply.

No energy is lost during combustion
The chemical energy in petrol is converted into mechanical energy (= work) and thermal energy (= heat) when burned in a petrol engine
the chemical energy = the mechanical energy + the thermal energy

No mass is lost during combustion
Petrol is a chemical compound of the elements carbon and hydrogen.
When petrol is burned with oxygen, carbon dioxide and water are produced
the mass of petrol + oxygen = the mass of carbon dioxide + water

Energy content of some fuels

	kilowatt hours
1 kilogram of dry wood	5.3
1 kilogram of coal	8.1
1 cubic meter of natural gas	8.8
1 liter of petrol	9.1
1 liter of diesel oil	10.0
1 kilogram of Hydrogen	33.6

(1 kilogram of Hydrogen = 11 cubic meters, at a pressure of 1 bar)

Efficiency

efficiency = useful energy / energy supplied

Example: a petrol engine
- suppose, a petrol engine delivers **50** kilowatt hours of **useful** mechanical **energy**
- suppose, the amount of **energy supplied** is **200** kilowatt hours (= 22 litres of petrol)
- the **efficiency** is then (50 / 200) × 100% = 25%
- 150 kilowatt hours are dissipated 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 / theoretically possible annual yield

Example: wind energy
- suppose, the power of a windmill is 3 megawatts
- the **theoretically possible annual yield =** 3 megawatts x 24 hours x 365 days = **26,280** megawatt hours
- suppose, the **actual annual yield** is **8,000** megawatt hours (the wind does not always blow)
- the **production factor** is then (8,000 / 26,280) x 100% = **30%** (rounded)

Efficiency and production factor are 2 completely different concepts

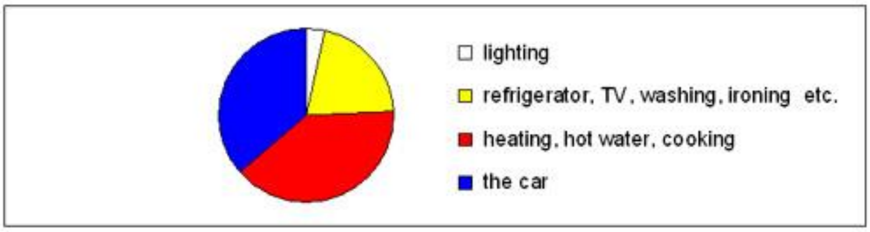
- the **efficiency** is a **property** of, for example, a solar panel or a wind turbine
- the **production factor** is determined by the **location** of the solar panel or wind turbine

The production factor of wind energy at sea and on land
- at sea the wind blows more often and harder than on land
- therefore the production factor of wind energy at sea is greater than on land
- the production factor at sea = **45%** and on land = **30%** (rounded)
- for the same wind turbine, the annual yield at **sea** is therefore one and a half times as much as on **land**

Newton's laws

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 (that is **independent** of the mass of the object)
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

Household energy consumption (2008)



A **car** consumes **one and a half times** as much energy as is needed for lighting, refrigerator, TV, washing, ironing, etc. The total annual energy consumption of a household is equal to the energy content of **4000 liters of petrol**

Saving only on lighting makes little sense from an energy-saving perspective, as it is only 4% of the total energy consumption. It does help to turn the heating down a bit. **All** energy supplied to the lighting and devices is ultimately fully converted into heat. A living room does not become noticeably warmer when the TV or the lights are switched on. Apparently the energy consumption of lighting and the TV is negligible compared to the energy consumption of heating.
Many people think: "every little bit helps". The "little bits" only help a (very small) bit and give the misleading feeling, that one is doing a lot for the environment and that one can therefore continue as usual. (with the heating and with the car)
If everyone does a little, we will achieve just a little.
Once comfort is compromised, one is no longer "at home".

Renewable, green or sustainable energy

This is energy from natural sources that are constantly replenished and do not emit CO2
Some examples are: solar energy, wind energy, hydropower and geothermal energy.

1 solar panel of 1.6 square meters delivers **0.2** megawatt hours per year
1 wind turbine of 3 megawatt (on land) produces **8,000** megawatt hours per year

The **net electricity consumption** of the Netherlands is **120,000,000** megawatt hours per year.(rounded)
This would require:
or 600,000,000 solar panels of 1.6 square meters
or 15,000 wind turbines of 3 megawatts

Primary energy

Primary energy, is the energy content of fuels in their natural form, before any conversion has taken place. Examples are: coal, oil, natural gas and solar energy

The energy consumption of the Netherlands

The **total primary energy consumption** of the Netherlands is 900,000,000 megawatt hours per year. This is needed for the generation of electricity, heating, industry, cars, trains, airplanes, etc. This energy is now largely generated by burning fossil fuels such as gas, coal, oil and gasoline.

The Netherlands must get off gas

- the gas is then be replaced by electricity
- that (**extra**) electricity is then generated with **gas-fired** power stations (?)
- it will not be possible to supply the whole of the Netherlands with green energy
- that is possible with nuclear energy.
- or with nuclear fusion, but that will take at least another 50 years

Solar energy

Nearly all Earth's energy comes from the Sun
- Earth’s energy sources (oil, natural gas, coal, biomass, wind and hydropower) have their origins in solar energy.
- exceptions are: geothermal energy, nuclear energy and energy from tidal power stations
- the most direct source of energy is the light and heat radiation of the Sun. This source of energy is clean and inexhaustible and we will have to rely on it for a large part, in the distant future
- the energy that the Sun radiates is generated by nuclear fusion
- the amount of solar energy, that is radiated onto the Earth is **7000 times** as much as the world”s energy consumption

Some people conclude that there is no energy problem.
The following must be taken into account:
- 71% of the earth's surface consists of water
- the irradiation on the remaining 29% is therefore **2000 times** as much as the world”s energy consumption
- a large part of the solar energy is blocked by cloud cover
- the efficiency of converting solar energy into electricity is low
- gigantic surfaces are required to extract solar energy
- the sun does not shine at night, so there is a (major) storage problem

The 3-monthly solar energy irradiation in the Netherlands (rounded)

February + March + April	= 24 %
May + June + July	= 48 %
August + September + October	= 24 %
November + December + January	= 4 %

During the winter months, the amount of solar energy irradiated is very little.
That’s why it’s winter. Just when a lot of solar energy is needeed, there is little available

Some possibilities to use solar energy are:
1. producing electricity with **solar panels**
2. producing electricity with **concentrated solar radiation**
3. heating water (solar boiler)
4. photosynthesis (biofuels)

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

A solar power plant with solar panels

Waldpolenz Solar Park

- the Waldpolenz Solar Park is a large solar power plant near Leipzig
- the electricity is generated by 550,000 solar panels
- the land area is 1.2 square kilometers
- a 600 megawatt power plant supplies **80 times** as much energy per year

2. Concentrated solar radiation
The solar radiation is concentrated onto a small surface by means of mirrors. The heat that is generated is used to generate electricity. The advantage of "concentrated solar radiation" is that part of the captured heat can be stored temporarily. This can bridge sunless periods

Conditions for concentrated solar radiation
- a sun-tracking system
- only usable in places where the sun shines all day
- concentrated solar radiation does not work when the sky is cloudy
- so it cannot be used in the Netherlands

A solar power plant that works with concentrated solar radiation

solar trough power plant "Andasol"

- this solar trough power plant is located in Andalusia, Spain
- a solar trough is a trough-shaped mirror, where the cross-section has the shape of a parabola
- the longitudinal-axis is set in a North-South direction and the solar trough rotates around that axis with the position of the Sun, so every day from East to West
- in the focal line there is a tube through which oil flows
- the concentrated solar radiation heats the oil
- in a heat exchanger this is used to heat water into hot steam
- electricity is generated with the hot steam
- the ground surface is 6 square kilometers
- a 600 megawatt power station supplies almost **9 times** as much energy per year

3. Heating water (solar boiler)
This is usually done with panels on the roof of a house. They look like solar panels, but they are filled with water. The hot water can be used as preheated water for a washing machine, shower, underfloor heating or as a heat source for a heat pump

4. Photosynthesis (biofuels)
Under the influence of sunlight, biofuels can be grown, such as rapeseed and trees. In this process, solar energy is converted into chemical energy. (photosynthesis). The efficiency of this conversion is at most **1%**

Wind energy

The efficiency of a windmill
- the efficiency of a windmill is approximately **50%**
- the theoretical maximum efficiency is **59%** (Betz's law)

The largest windmill in the world is the Enercon E-126
- the hub height is 135 meters
- the blade length is 63 meters
- the highest point reached by the blades is 198 meters
- the power of the windmill is 7.5 megawatts
- the energy yield is 21,000 megawatt hours per year. (on land, at a production factor of 32%)
- a 600 megawatt power plant supplies **200 times** as much energy per year

The Gemini wind farm (85 kilometers off the coast of Groningen)
- the wind farm comprises 150 wind turbines of 4 megawatts = 600 megawatts
- the surface area is 68 square kilometers
- a 600 megawatt power plant supplies **1.6 times** as much energy per year

(the production factor of a power plant is greater than that of a wind farm)

Storage of solar and wind energy

Large-scale application of solar and wind energy is only possible, if a solution is found for the storage of very large amounts of electrical energy. The problem with solar energy in particular is that the energy requirement is usually greatest when the sun has already disappeared behind the horizon.

Some options for storing electrical energy
- **Storage in a reservoir**
  .Electricity can be used to pump water to a higher reservoir. If there is a shortage of electricity, this water can supply electricity back via a hydroelectric power station.
- **Storage in Hydrogen**
  Electricity can be used to break water down into oxygen and hydrogen. The hydrogen can later be used to generate electricity
- **Storage in the mains grid**
  For the time being, we can use the mains 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, the mains is almost always used for temporary storage of the solar energy

Hydropower

Even in Switzerland, hydropower has become of limited importance, as energy consumption has increased sharply in recent years
- in Switzerland **40%** of electrical energy is generated by nuclear power plants
- only in Norway almost all electrical energy is generated by hydropower
- worldwide **16%** of all electrical energy is generated by hydropower (2009)

China is home to the world's largest hydroelectric power station, the Three Gorges Dam
- the energy yield is **85,000,000** megawatt hours per year
- that is **3%** of China"s electricity consumption
- that is equivalent to the annual yield of **20** power plants of 600 megawatts

Geothermal energy

Geothermal energy is extracted from the Earth's heat

- from the Earth’s surface, the temperature increases by approximately 30 degrees Celsius per 1000 meters
- at a depth of 5000 meters the average temperature is 150 degrees

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

Properties of geothermal energy

- clean, sustainable and inexhaustible
- not dependent on weather conditions, seasons and time of the day
- there are no CO_2 emissions
- the energy is constantly available, so there is no storage problem

Tidal power plant

The energy of a tidal power plant is generated by the difference in water level between low and high tide. This is caused by the rotation of the Earth and the gravitational pull of the Moon and the Sun.
The largest tidal power plant in the world is in France, in Brittany

- the difference between high tide and low tide is very large there, up to 13 meters.
- energy production is **540,000** megawatt hours per year
- a 600 megawatt power plant produces almost **8 times** as much energy per year

Biofuel

- in the case of biofuel, for example wood, the solar energy is converted into chemical energy.
- the efficiency of this conversion is at most **1%**.
- the idea behind using biofuel is that oxygen is produced during its growth and carbon dioxide (CO_2) is absorbed from the atmosphere.
- in combustion, the reverse process takes place. This so-called “short cycle” does not pollute the environment. (CO_2-neutral).

The share of biofuel in electricity production in the Netherlands is 7%. Suppose that biofuel would consisted only of wood. Then an area of **50 x 50** kilometers of trees have to be cut down annually and also replanted annually. That will **never** work.

Teletext 31 March 2021

Research by the World Resources Institute and the University of Maryland shows that **42,000 square kilometers** of primery forest were destroyed worldwide in 2020. That is slightly more than the surface area of the Netherlands.

Combined Heat and Power

- when producing electricity in a power plant, the efficiency is about 40%
- 60% of the supplied energy is lost in the form of heat via the cooling water.
- in many power plants this "waste heat" is now used for district heating and heating of greenhouses.
- the heat often has to be transported and distributed over great distances, which of course results in quite a few losses.
- nevertheless, the overall efficiency of the power plant. is significally increased

In Combined Heat and Power. the generation of heat and electricity (power) is directly coupled.
Heat and electricity are then generated at the consumer. The heat production is the main thing here, while the electricity is now a by-product. The total efficiency is very high, because almost no heat is lost and all electricity is used usefully.

Combined Heat and Power is widely used in greenhouse horticulture, hospitals, factories and swimming pools. The total efficiency of Combined Heat and Power is approximately **90%**

The Gas and Steam power plant

- in a Gas and Steam power plant, electricity is generated using two turbines
- the first turbine is a gas turbine, the second is a steam turbine
- the exhaust gases from the gas turbine still contain a lot of heat
- this heat is used to make steam for the steam turbine
- often the gas and steam turbine are on the same shaft and together they drive a generator
- the efficiency of a Gas and Steam power plant is 58%

Heat pump

- a heat pump pumps heat from a low temperature level to a higher level.
- the low level is for example the ground heat, which at some depth is approximately 12 degrees all year round. The heat is sometimes also taken from the air.
- the heat pump works on the same principle as a refrigerator, but the purpose is different.
- in a refrigerator the interior is cooled and the heat that is generated outside the refrigerator is taken into the bargain
- with a heat pump it is precisely that heat that is important. With that a room can be heated
- the useful heat generated is equal to the heat that is extracted from the ground or from the air, plus the energy supplied 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 lifespan is 1000 charging cycles

The lifespan of a rechargeable battery
- the lifespan of a rechargeable battery is strongly influenced by the depth of the discharge
- the end of life is reached, when the battery capacity has decreased to 70% of the new value

Walking and cycling

For a person weighing 75 kilograms, the resting metabolic rate is approximately 300 kilojoules per hour. This amoumt of energy is continuousely consumed for heartbeat, breathing, maintaining a constant body temperature, digestion etc.
The international unit of energy is the **Joule** (3600 kilojoules = 1 kilowatt hour)

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

So walking takes **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 kilometers = 4 × 300 = 1200 kilojoules
- 1 hour cycling = 20 kilometers = 20 × 60 = 1200 kilojoules

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

The amount of energy required for cycling is highly dependent on the cycling speed and the wind.
In this example. calm weather and an upright cyclist are assumed
The above figures indicate how much energy is used in the form of food

Walking:
- the mass of a walker is moved up and down a few centimeters with each step, which costs a lot of energy
- the energy used is proportional to the mass (weight) of the walker

Cycling:
- a cyclist sits fixedly on the saddle and his centre of gravity therefore always remains at the same height. (if one leg goes down, the other goes up)
- at a constant speed on a flat road, energy is only used to overcome air resistance and rolling friction. The mass of the cyclist + bicycle is not important (Newton’s 1st Law)

You can cycle 100 kilometers on the energy content of 2 liters of whole milk
- you do not lose weight from cycling 100 kilometers
- you do lose weight from swimming, due to heat loss (and especially by eating less)

Electric bicycle
- with an electric bicycle the cyclist is supported by an electric motor
- this motor gets its energy from a rechargeable battery
- the level of support is automatically controlled by a pedal sensor
- the pedal sensor measures the force with which the cyclist pedals
- proportional to that force, the amount of energy supplied to the motor is regulated
- the result of this is that when driving up a slope or in a headwind, the support (automatically) increases

Ideally, when climbing a slope or in a headwind, one would continue to cycle just as easily as on a flat road without wind. But then the battery would have to supply a lot of energy. That is why it is possible with most electric bicycles, to set the level of support using a switch on the handlebar.You can then, for example, 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, so by the selected level of support. The legally permitted power of the motor is 250 watt. The support works up to a speed of 25 kilometers per hour.

The energy consumption of an electric bicycle
- energy consumption is strongly dependent on the wind, with or against
- the average energy consumption from the battery = **5 watt hours** per kilometer
- with a battery of, for example 400 watt hours, the range is then 80 kilometers

Pedal sensor or rotation sensor?
Recently more and more electric bicycles are appearing on the market, which are equipped with a rotation sensor instead of a pedal sensor. The avantage of the rotation sensor is its lower price and simple construction. The disadvantage is the smaller range and the unsavety.
When using a rotation sensor, support is switched on (usually abruptly) as soon as the pedals are turned..
Even if little or no force is exerted, the motor is switched on and supplies almost all the energy required for propulsion. If you want to cycle faster, you have to padel disproportionately harder, because the rider then has to generate the extra energy entirely himself. In practice, people therefore usually continue cycling at the speed at which the support is maximum. An excellent solution for people who do not want to exert themselves, but this does come at the expense of the range.
If you stop pedaling, the support usually continues for a while. That is why these bicycles are often equipped with a switch at the brake lever. When you brake, the circuit to the motor is immediately broken. Electric bicycles with a rotation sensor are potentially dangerous in traffic, especially for older cyclists. But you get used to everything.
With a a pedal sensor. the problems mentioned are completely absent

The advantages 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 for a distance of 80 kilometers costs 400 watt hours
3. an electric bicycle is much sportier and healthier than a moped, because one always pedals along
4. an electric bicycle does not stink, makes no noise and does not leak oil
5. you can also just cycle with an electric bicycle

Electric trains

Double Decker

The Double Decker is the most modern and economical train of the Dutch Railways
- the train runs on 1500 volts DC
- the maximum speed is 140 kilometers per hour
- the basic version of the train consists of 4 carriages with **372** seats.
- the energy consumption is **48 watt hours** per passenger per kilometer

Thalys

The Thalys, which runs on the **H**igh **S**peed **L**ine, uses much more energy than a regular train
- the train runs on 25 000 volts AC
- the maximum speed is 300 kilometers per hour (only in France)
- the Thalys has a fixed composition of 8 wagons with **355** seats
- the energy consumption is **161 watt hours** per passenger per kilometer

Airplane

Boeing 747 "Jumbo"

Some facts:
- a Jumbo cosumes 15 liters of kerosene per kilometer
- it can carry **500** passengers, the energy consumption is then **300 watt hours** per passenger per kilometer
- a car with 2 occupants also uses **300 watt hours** per passenger per kilometer

The energy consumption (and therefore the CO_2 emissions) **per passenger per kilometer** is for a full Jumbo and a car with 2 people, the same. But an airplane covers a large distance in a short time. For example: a return Amsterdam - New York = **12 000** kilometers.
That is the distance you travel with a car in a year
So the CO_2 problem is not due **to the airplane**, but to making **long journeys**

The Electric car

An electric car from 1916

As early as 1899 – 1915 more then 5000 electric cars were manufactured in America by Baker Electric.The top speed was 23 kilometers per hour, with an range of 80 kilometers. Another well-known brand from those early days was Detroit Electric. This company produced electric cars that reached a top speed of 32 kilometers per hour, with a range of 130 kilometers.

Electric cars can now cover reasonable distances
That is due to:
- a better type of battery
- the high efficiency of the electric motor
- a low speed (air resistance is proportional to the 2nd power of the speed)
- low rolling resistance
- low air resistance (so a good streanlining)
- energy return during braking, descending a slope and when reducing speed

Some features of the electric car
- the electric car is virtually silent
- the electric car does not produce exhaust gases (but the power plant does)
- the electric motor can deliver maximum torque at all speeds, which makes fast acceleration possible
- the electric motor never idles
- no gearbox is required
- the range is (very) limited
- the battery is heavy, very expensive and takes up a lot of space
- charging the battery takes a long time
- heating an electric car reduces the range

Tesla model S

In 2013 a fully electric 5-seater car came onto the market in Europe, the Tesla model S
Some data:
- the car accelerates from 0 to 100 kilometers per hour in 6 seconds
- its top speed is 200 kilometers per hour
- the energy content of the largest possible battery is **85** kilowatt hours
- the range is then **480** kilometers (at a constant speed of 88 kilometers 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

The hybrid car

Toyota Prius

Toyota introduced the "Prius" in 1997 This is a hybrid car that, depending on the situation, is propelled by a petrol engine, an electric motor or a combination of both.
The aim here is to achieve the highest possible efficiency.

- the efficiency of the Atkinson petrol engine is high, but strongly depends on the load and the speed
- the efficiency of the electric motor is always high
- the electric motor helps when the efficiency of the petrol engine is low
- the energy for the electric motor is supplied by a rechargeable nickel-metal hydride battery
- when braking and reducing speed the electric motor works as a dynamo and then supplies energy back to the battery
- in addition, the battery is charged by a generator, which is coupled to the petrol engine
- the petrol engine, generator and electric motor are coupled to a mechanical energy distributor
- this energy distributor also functions as a continuously variable automatic gearbox
- the air conditioning is electrically powered and therefore also works when the petrol engine is not running

The plug-in hybrid car

In 2012 **Toyota** launched the **plug-in** Prius. This car has a relatively large battery, which can be charged from the mains. With the latest type, you can drive 50 kilometers ectrically.
It is actually an electric car with a limited range, but without “charging station stress”. If the battery is empty, one can drive another 1000 kilometers on a full tank of petrol

The hydrogen car

Toyota Mirai

Some features:
- in a fuel cell the hydrogen “burns”, generating electricity
- this process does not produce any harmful gases, only water
- the generated electricity is supplied via a battery to the electric motor which moves the car
- when braking and reducing speed, energy is returned to the battery

The only question remains: **"where do we get the hydrogen from?"**
Hydrogen can be obtained by electrolysis (decomposition) of water. The electricity required for this must be generated by burning fossil fuels (which does produce harmful gases), nuclear energy, solar energy, wind energy or other forms of "green" energy.

Will the hydrogen car ever hit the road?
Given the poor (total) efficiency, it is very unlikely that the hydrogen car will ever appear on the road (on a large-scale). Moreover there is no infrastructure yet to be able to refuel hydrogen..
There are already reports circulating that Toyota is discontinuing the Mirai. With the arrival of the solid state battery, the electric car will probably become a better solution.

The Hydrogen Economy

The energy scenario of the future, when fossil fuels are depleted, may be (partly) based on the so-called Hydrogen Economy. This assumes that by that time (around 2050) an endless amount of "green" energy will be available. This can then be used to produce hydrogen. The green energy is then generated by windmills and solar panels. **It is very unlikely that the share of green energy will ever come close to global energy demand.**
Nuclear fusion is potentially a possibility for generating enormous amounts of energy

- Hydrogen is not freely available in nature
- it has to be made and that takes a lot of energy
- the most commonly used method is electrolyses (= decomposition) of water
- producing hydrogen costs **1.5** times as much energy as what it yields later
- Hydrogen is therefore **not** an inexhaustible **source** of energy, but an energy **carrier**

“green” hydrogen
Green hydrogen is produced with green energy, such as solar or wind energy. The potential of green hydrogen is therefore very limited.

“blue” hydrogen
Blue hydrogen is produced with fossil fuels. The CO_2 that is created in this process is stored in empty gas fields. Future generations will have to see what they do with it

Nuclear fusion

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

- fission of uranium nuclei. (this is called nuclear energy)
- fusion of hydrogen nuclei. (this is called nuclear fusion)

In both processes mass loss occurs
According to Einstein's formula, the "lost" mass is converted into energy

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 occurs at an extremely high pressure and a temperature of 15 million degrees Celsius. In nuclear fusion on Earth, the pressure is negligible compared to the Sun and therefore the temperature here must be very much higher, about 150 million degrees Celsius.

The fusion reaction that can most easily be achieved on Earth is the fusion of the hydrogen isotopes Deuterium and Tritium. This produces Helium atoms, neutrons and a lot of energy.

The biggest problem with nuclear fusion is the extremely high temperature required to achieve the fusion process. No material can withstand that temperature. In a so-called "Tokamak" the hot plasma is confined in a strong magnetic field and therefore does not come into contact with the wall.

Nuclear energy

In 2009 the share of nuclear energy in electricity generation was

France	77%	Sweden	43%	Germany	23%	The Netherlands	4%
Belgium	54%	Switzerland	41%	England	14%		

When faced with the threat of energy shortages, some people think:

- **"they" will find something for it**
  (you just fill the Sahara with solar panels)
- **it will take my time**
  (that remains the question and what about the offsprmg?)
- **in the long term all energy will be generated sustainable**
  (so all the energy needed for food production, heating, industry, aircraft, trains and **1 billion** cars?)

Nuclear energy: yes or no?
Every solution has pros and cons. The question is what do you prefer.
fossil fuels

- irreversible climate change (greenhouse effect)
- resulting in rising sea level and flooding
- further increase in air pollution (CO2)
- depletion of all fossil fuels
- wars to secure the supply of oil or natural gas
- earthquakes and subsidence due to oil and gas extraction

or nuclear energy

- no CO2 emissions
- a limited (radioactive) waste problem, that can in principle be solved
- a very small chance of accidents with nuclear power plants (see France)

It is strange that people are concerned about nuclear energy and not about nuclear weapons

Teletext 3 July 2017
Russia and the US are reducing their stockpiles of nuclear weapons.
Yet the US is investing at least 400 billion by 2026 in modernization..
There are nine countries with nuclear weapons. Together they have **14 935** nuclear warheads.

The mass - energy equivalent

According to Einstein's formula, mass can be converted into energy **$E = mc^2$**
E = energy **m** = mass **c** = the speed of light (= 300,000 kilometers per second)

1 kilogram of mass is equivalent to 25 billion kilowatt hours

Mass and weight

- **Mass** is the amount of matter.
- **Weight** is the force with which mass is attracted by the Earth's gravity.
- on Earth gravity is not the same everywhere and therefore neither is weight
- M**ass is the same everywhere**.
- the unit of mass is the kilogram

Fuels and CO2

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

It is strange that environmental activists protest against coal-fired power plants, while they themselves, like everyone else, drive around in a car (environmental pastors)

The greenhouse effect

The greenhouse effect is probably caused by the carbon dioxide (CO2), which is released during the combustion of fossil fuels. This greenhouse gas allows the solar energy to pass through almost unhindered on its way to earth, while it blocks the radiation of heat coming from the earth.
The earth cools less when there is more greenhouse gas in the atmosphere.
However, the question is whether the effect of carbon dioxide (CO2) in this process is as great as has been assumed up to now. The future will tell. What is clear is that, in any case, the climate has been changing significantly in recent years.
Consider the melting of the ice at the North Pole, in Greenland and the disappearance of the "eternal" snow in the Alps. Winters have also been remarkably warm in recent years (in Europe).
In addition, people are increasingly confronted with extreme weather, such as heat waves, long periods of drought or heavy rainfall, hurricanes and associated flooding.

Light sources

Comparison of various light sources

	luminous efficiency
light bulb	5%
energy saving lamp	29%
fluorescent tube	41%
Led lamp	44%

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

Comparison of different types of power plants

A = the number of power plants, that would be needed for the Netherlands

type of plant	A
coal or gas power plant 600 megawatts	**28**
Borssele **nuclear power plant**	**31**
Gemini **wind farm**	**44**
Andasol **solar trough power plant**	**232**
Waldpolenz **sun-voltanic power plant**	**2,212**

The Waldpolenz Solar Park
- **2,212** of these power stations would be needed to supply the entire electricity of the Netherlands
- that are **1.2 billion** panels on a field of 52 x 52 kilometers

Solar-energy, a realistic prospect?

Comparison of different types of cars

(with the same propulsive energy of 150 watt hours per kilometer)

hybrid car (**21** kilometers per liter of petrol)
- the continuously variable transmission works with a very high efficiency
- during braking and deceleration, energy is returned to the battery.
- the petrol engine always runs under conditions where efficiency is maximum
- the petrol engine never idles

electric car (**17** kilometers per literof petrol-equivalent)
- the car has no gearbox and therefore no transmission losses
- during braking and deceleration energy is returned to the battery
- the car does not cause CO2 emissions, but the power station does

petrol car (**15** kilometers per liter of petrol)
- there are relatively large losses in the gearbox
- no energy return is possible
- with a petrol engine the efficiency is strongly dependent on the speed and torque
- the engine often idles

hydrogen car (**8** kilometers per liter of petrol-equivalent)
- this is an electric car where the energy is supplied by hydrogen
- in a fuel cell the energy in the hydrogen is converted into electricity
- due to the 4-fold energy conversion, the total efficiency is poor
- the indirect CO2 emissions are almost twice as high as with a petrol car

the number of energy conversions in different types of cars

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

Comparison of means of transport

A = number of passengers per vehicle
B = **primary energy** per passenger per kilometer (watt hours)

means of transport	A	B
airplane Boeing 747 Jumbo	**500**	**300**
hydrogen car	**4**	**288**
electric train Thalys	**355**	**161**
petrol car	**4**	**150**
electric car	**4**	**121**
hybrid car Prius	**4**	**108**
electric train Double-decker	**372**	**48**
electric bicycle	**1**	**17**

A few facts

World population growth = 200,000 people per day
No environmental measure will help against this

In 2022 the 8 billionth inhabitant of the earth was born

- with a distance of 1 meter between 2 people, that is a line of 8 billion meters, that is **200 times** the circumference of the earth
- an airplane travelling at a speed of 900 kilometers per hour takes **370 days,** to cover this distance

Is a bicycle with a suspension fork heavier to ride than a regular bicycle?
A suspension fork gets a little warm while riding on a bumpy road.
This heat (= thermal energy) has to be generated **extra** by the cyclist.
A bicycle with a suspension fork therefore rides heavier than a regular bicycle.

Energy loss in the food cycle

- when a human eats grain, 10% of it is used for the growth of its body
- when a pig eats grain, 10% of it is converted into pork
- when a human eats pork, 10% of it is used for the growth of his body, that is only 1% of the grain that was eaten by the pig

So from an energy point of view, eating meat is very inefficient.

Comparison of gas cooking with electric cooking
At first glance cooking with gas seems much more efficient than cooking with electricity, but on closer inspection this needs to be qualified somewhat

cooking with gas:

- a lot of heat loss, because a lot of heat flows around the pan
- combustion products (carbon monoxide and carbon dioxide) are created in the kitchen
- risk of gas leaks which can cause explosions

electric cooking:

- no combustion products in the kitchen.
- the efficiency of the heat transfer between the hob and the pan approaches 100%
- the energy supply is excellently adjustable

Reliability of the supply of electricity
Everyone expects that the supply of electricity is guaranteed for at least 99.99% of the time.
Fortunately, in practice this is considerably better.
At 99.99% reliability, people would spend an average of 53 minutes per year in the dark.

The energy consumption of the lighting
The energy consumption of Led lighting is approximately **1.6%** of the total electricity consumption of a household. If you want to be serious about saving energy, it is better to turn down the heating a bit and do away with the car, instead of turning off the light in the kitchen every now and then.
After all small amounts only help a very small amount.
If everyone does a little, we'll achieve only a little

Free energy

Nikola Tesla

There is no scientific evidence for the existence of "free energy" However one can have vague doubts about this, because **Tesla** is said to have invented it in 1889.
Tesla (1856-1943) was one of the greatest inventors of all time. Among other things he invented the infrastructure of the electricity grids as we use them everywhere today. So energy transport by means of alternating current via high-voltage lines and transformers.
He was also the inventor of the alternating current induction motor, the fluorescent tube, the radio and the remote control. In 1943, shortly after his death, the US Supreme Court officially established that Tesla was the inventor of the radio, not Marconi.
His greatest invention would be the global energy supply by "free energy", tapped from the "ether" However, experiments with this never took place, because his backers failed to respond.
They saw no point in free energy at all.

The **Warden Clyff Tower**
With 5 of these towers Tesla wanted to enable
a global, wireless energy supply

Tesla was able to wirelessly transmit energy over great distances. It is said that he wirelessly lit lamps at a distance of several hundred meters. He is also said to have converted an electric car, which could then drive around for a week without the battery being charged from the mains.
This too is said to have been made possible by wirelessly transmission of energy.

In itself, wireless transfer of energy is nothing special. Almost all the energy we use on Earth is transferred wirelessly from the Sun to the Earth.
It is actually much stranger one can transport amounts of electrical energy via a few copper wires. For example, from an electric power plant to a large city

Energy Storage

Some forms of energy storage
1. Electrical energy in supercapacitors
2. Chemical energy in batteries and hydrogen
3. Thermal energy in substances with a high heat capacity
4. Kinetic energy in flywheels
5. Potential energy by moving mass against gravity or the compression of gases

Energy saving

Insulation of the home
For heating a poorly insulated house, an average of 2100 cubic meters of natural gas is needed per year. For a well-insulated house this is only 700 cubic meters. Insulation really helps a lot. The ideal house is of course energy neutral

Heat pump
Heating with a heat pump is twice as efficient as heating with natural gas.
(including the efficiency of the electricity generation for the heat pump)

Hot water
Much savings can be achieved by mounting the hot water boiler close to the tap, both in the kitchen and in the shower. In many houses there is a combi boiler in the attic.
That is the **worst possible place**. If you need hot water, the long pipe to the kitchen or bathroom must first be heated before the water at the point of use has the desired temperature. After turning off the tap, the water in the pipe cools down again, which means pure energy loss. Moreover, this also costs a lot of extra water.

Car
A considerable saving in fuel can be achieved with hybrid cars. One should think of maximum 25%.
The only real saving is of course the abolishting of the car. Unfortunately, public (regional) transport is of such a poor quality, that this step will be difficult to take. Only an extreme increase in the price of petrol will have some effect in the long term, but most people cannot be driven out of their car.

Lighting
Although lighting uses relatively little energy, it is still possible to save some energy by consistently using energy-saving lamps and LED lamps

The energy-neutral house

- over a whole year, the amount of energy generated must be equal to the amount of energy consumed
- the electricity is usually generated with solar panels
- in summer the surplus electricity is returned to the grid and in winter the shortage of energy is taken back from the grid
- the most important condition for an energy neutral house is good insulation of the roof, the walls, windows, doors and floors
- large south-facing windows for maximum solar heat in winter
- an awning above the windows so that in the summer, when the sun is higher, little solar heat radiates inward
- energy efficient appliances and lighting
- for ventilation and the use of hot water, heat recovery through heat exchangers
- uderfloor heating with a heat pump or with water from solar boilers
- **everything depends on the motivation to save energy**

Heat transport

Heat always moves (automatically) from a high temperature level to a lower temperature level.
For transport in the opposite direction a (energy-consuming) heat pump is required.
Transport of heat can take place in 3 ways:

1. by conduction
In stationary matter, such as a wall, heat is transported by conduction.
In a normal cavity wall the space between the 2 walls is filled with air. This air can then circulate freely between the 2 walls and heat is transferred by flow. If the space between is filled with glass wool, the heat insulation is very good, because glass wool contains a lot of still air. **Still air is a very poor conductor of heat**

Even with 2 or 3-layer glass, there is still air between the glass plates. The distance between the glass plates is so small (approximately 0.5 centimeters) that there is virtually no air flow. This makes this type of glass a poor heat conductor. Also think of clothing. A few layers on top of each other, with still 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. In central heating, heat is transported by water flowing from the boiler to the radiators. An open window lets warm air flow in or out. If it is warmer outside than inside, then you should keep the windows closed, at least if you want to keep it cool inside.

3. through radiation
Solar radiation passes through glass and air virtually unimpeded. So 2 or 3 layers of glass do not help against this. Only glass with a special coating can block the sun's rays. If you want to keep heat **out in the summer**, you need to install sun protection on the **outside** of the window. If you want to keep the heat **in in the winter**, you need to install thermal insulation on the **inside**, for example in the form of curtains

What will happen next with energy?

Oil
The easily extractable oil is running out. That's why Canada and Venezuela are going to extract the hard to extract oil from tar sands. They will also going to dril oil at the North Pole and at a depth of 5 kilometers in the Gulf of Mexico. Large reserves of shale gas and oil have been found.In America, Western Europe and Russia.
The extraction of this is accompanied by a major pollution of the environment. But of course nobody cares, "As long as the car drives".

Gas
There is still enough gas for the time being, probably for the next 60 years. The peak of natural gas production will be reached in 20 years. After that, the price will rise sharply. Western Europe is mainly dependent on Russia, Norway, North Africa and the Middle East.

Coal
There is a lot of coal in the world. Enough for at least 200 years. Coal is good for everything. It can be used to produce gas, hydrogen, synthetic petrol and diesel oil. The technique for the producing synthetic petrol from coal has been known since 1923.and was used by Germany during World War.2 (Fischer-Tropsch synthesis)

Hydropower
Although the most profitable projects have already been realized, 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, sun, biomass etc. is of little significance for the time being. It is thought that with this (in the Netherlands) a maximum of 14% of (only) electricity in 2020 can be generated.. Wind energy is emerging from the "starting blocks" in some countries, as is solar energy.
Solar panels on the roof of a house are often sufficient for a large part of the resident's electricity consumption, but in winter solar energy yields virtually nothing.

Bio Fuel
Large-scale production of biodiesel etc. is at the expense of food production and also costs a lot of regukar fuel. That is therefore not a realistic option. The conversion of solar energy to bio fuel is accompanied by an extremely low efficiency, in the order of **1%**

Nuclear Energy
Nuclear energy with Uranium is possible for another 75 years at rhe current consumption. When the Uranium is used up, one can probably continue with **Thorium**.
The amount of Thorium on Earth is sufficient for several thousand years

Nuclear Fusion
Around **2050** we may expect the first practical results of nuclear fusion. Then humanity will have an infinite amount of "clean" energy at its disposal. The total development time will then have taken about 100 years.
One may wonder whether it will ever be possible to generate very large amounts of energy through controlled nuclear fusion.

Hydrogen
The electricity required for the electrolysis of water will have to be suipplied 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 yields.
Hydrogen is therefore not a solution to the energy problem

What will happen now to the world population?

There is a threat of a disproportion between the production and consumption of energy. There would be virtually no problems, if there were a few billion fewer people (driving around) on earth
The reality is that there will a few billion more people before the year 2050.
That's an **increase** of **1 million more per week**.

The only solution seems to be (strongly) **cut back** on energy and (much) **fewer** people
Cutting back on energy consumption, while at the same time the number of people on earth increases does not yield anything in the end. That's "mopping with the tap open".
The solution is of course: "**close the tap**"

Many people think: "Crises have always existed and a solution has always been found, so that will happen again now"

- humanity is. for the first time in World history, threatened by an extreme overpopulation
- **in the last 6 years the world's population has increased by half a billion**
- all energy supplies such as oil, natural gas and coal will run out sooner or later
- the amount of CO_2 in the atmosphere is constantly increasing
- this situation has never happened before

Interesting times ahead

A book about energy

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

This book gives a complete overview of the (im)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