Short summary “Energy facts” (August 2023)

The full story can be found at www.energiefeiten.nl

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In this story, all kinds of energy sources are always compared to a medium-sized electric power plant with a **power** of **600 megawatt**
The amount of **energy** that such a plant supplies 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 shows what (maximum) is **possible**
- a commonly used unit for **power** is **kilowatt** or **megawatt**

for example
The **power** of a power plant = **600 megawatt** (also if the power plant 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, movement, light, heat, sound, radio waves, etc.
- a commonly used unit for **energy** is **kilowatt hour** or **megawatt hour**

for example
The **energy** produced by a 600 megawatt power plant 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 **kilowatt**
- 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
- so, the **power** 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 deliver per second**
- the **power** determines **how fast the car can accelerate**

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 does not 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 does not change

Energy and Mass are therefore never "consumed"
In normal language people usually talk about "consumed".
For example, if you drive a car until the tank is empty, the petrol is consumed
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

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

Efficiency

efficiency = useful energy / energy supplied

Example: a petrol engine
- suppose, the **useful** mechanical **energy** of a petrol engine is **50** kilowatt hours
- suppose, the **energy supplied** is **200** kilowatt hours (= 22 litres of petrol)
- the **efficiency** is then (50 / 200) × 100% = 25%
- so, 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 / theoretical annual yield

Example: wind energy
- suppose, the power of a windmill is 3 megawatt
- the **theoretical annual yield** is then 3 megawatt 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

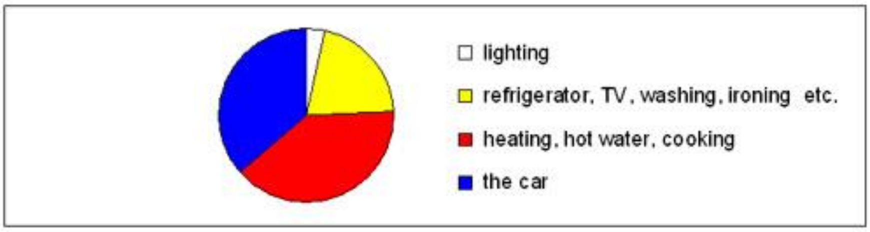
- the **efficiency** is a property of, for example, a solar panel or a wind mill
- the **production factor** is determined by the location of the solar panel or the wind mill

The production factor of wind energy at sea and on land
- the wind blows more often and harder at sea than on land
- as a result, 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 one and a half times as much as on **land**

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 (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

The energy consumption of a household (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 point of view, 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 get 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 consumption of the heating.
Many people think: “every little bit helps". The "little bits" only help a (very little) bit and give the misleading feeling, that one is doing a lot for the environment and that one can therefore continu as usual. (with the heating and with the car)
If everyone does a little, we will only achieve a little.
As soon as comfort is at stake, one is no longer "at home".

Green energy

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

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

The energy consumption of the Netherlands

The **total primary energy consumption** of the Netherlands is 900 000 000 megawatt hours per year.
This is necessary for the generation of electricity, heating, industry, cars, trains, aeroplanes, etc.
This energy is still largely generated by burning fossil fuels such as natural gas, coal, and petrol

.

The Netherlands must get rid of natural gas

- the natural gas will then be replaced by electricity
- that (**extra**) electricity will then be generated with **gas-fired** power plants (?)
- green energy will not be able to supply the entire Netherlands with energy
- that is possible with nuclear energy (see France)
- or with nuclear fusion, but that will take at least another 50 years

Solar energy

Almost all energy on earth comes from the Sun

- almost all energy sources on earth (natural gas, coal, petroleum, biomass, wind and hydropower) have their origins in solar energy.
- exceptions are: geothermal energy, nuclear energy and 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 we will need a large part of it in the distant future
- the energy that the Sun radiates is generated by nuclear fusion
- the amount of solar energy, radiated onto Earth is **7000 times** as much as the world"s energy consumption

Some people draw the conclusion that there is no energy problem.
One should bear in mind:

- 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 the clouds
- the efficiency of the conversion of solar energy into electricity is low
- gigantic areas are needed for the production of electricity with solar energy

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 %

In the winter months, the amount of irradiated solar energy is very little.
That's why it's winter. Especially when you need a lot of solar energy, there is little available

Some options for using 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 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 with 550 000 solar panels
- the land area needed is 1.2 square kilometers
- a 600 megawatt power plant produces **80 times** as much energy per year

2. Concentrated solar radiation
The solar radiation is concentrated on a small surface by means of mirrors. The heat generated in this process is used to generate electricity. The advantage of "concentrated solar radiation" is that part of the collected 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 applied 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, the cross-section of which has the shape of a parabola
- the longitudinal-axis is in North-South direction and the solar trough rotates around that axis with the position of the Sun, so from East to West every day
- there is a tube in the focal line through which oil flows
- the concentrated solar radiation heats the oil
- in a heat exchanger this heats water into hot steam
- the hot steam generates electricity
- the land area needed is 6 square kilometers
- a 600 megawatt power plant produces almost **9 times** as much energy per year

3. Heating water (solar boiler)
Usually this is 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. The 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 (2015)
- the axis height is 135 meters
- the blade diameter is 126 meters
- the highest point reached by the blades is 198 meters
- the windmill`s power is 7.5 megawatt
- the annual production is 21 000 megawatt hours (on land)
- a 600 megawatt power plant produces **200 times** as much energy per year

The Gemini wind farm (85 kilometers from the coast near Groningen)
- the windfarm comprises 150 wind turbines of 4 megawatt = 600 megawatt
- the area is 68 square kilometers
- a 600 megawatt power plant produces **1.6 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 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**
  .With electricity you can pump water to a higher reservoir. In the event of a shortage of electricity, that water can then supply electricity via a hydroelectric power station.
- **Storage in Hydrogen**
  Water can be decomposed into oxygen and hydrogen using electricity. The hydrogen can later generate electricity in a fuel cell or via a gas turbine
- **Storage in the mains**
  For the time being, we can use the mains 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 significance as energy consumption has increased sharply in recent years
- in Switzerland **40%** of electrical energy is generated by nuclear power stations
- only in Norway almost all electrical energy is generated by hydropower
- worldwide **16%** of all electrical energy is generated by hydropower (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 is **3%** of China”s electricity consumption
- that is equal to the annual yield of **20** power plants of 600 megawatt

Geothermal energy

Geothermal energy is extracted from the heat in the Earth
- from the Earth's surface, the temperature rises with increasing depth by roughly 30 degrees Celsius per 1000 meters
- at a depth of 5000 meters the average temperature is 150 degrees Celsius

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

A tidal power plant uses the difference in water height between ebb and flow. The energy is generated 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 located in France, in Brittany
- the difference between high tide and low tide is very large there, a maximum of 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

- with biofuels, for example wood, the solar energy has been converted into chemical energy.
- the efficiency of this conversion is at most **1%**.
- the idea when using biofuel is that as it grows, oxygen is produced and carbon dioxide (CO_2) is absorbed from the atmosphere.
- during 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 all biofuel consisted of wood. For a "CO_2-neutral" use of this amount of wood, an area of **50 x 50** kilometers of trees must be cut down and replanted every year. 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 area of the Netherlands.

Combined Heat and Power

- when producing electricity in a power plant, the efficiency is approximately 40%
- 60% of the energy supplied is then lost in the form of heat via the cooling water.
- at 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 obviously results in a lot of losses.
- nevertheless, this significally increases the overall efficiency of the power plant.

With Combined Heat and Power. the generation of heat and electricity (power) is directly linked to each other. Heat and electricity are then generated at the consumer. Heat production is the main focus, while electricity is now a by-product. The total efficiency is very high, because virtually no heat is lost and all electricity is put to good use.

Combined Heat and Power is used in greenhouse horticulture, hospitals, factories and swimming pools. In greenhouse horticulture the CO2 released is very welcome, because it promotes the growth of the plants (carbon dioxide assimilation).
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 of the gas turbine still contain a lot of heat
- this heat is used to produce steam for the steam turbine
- often the gas and steam turbine are on the same shaft and they then drive a generator together
- 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 is at some depth about 12 degrees all year round. The heat is sometimes also extracted from the air.
- the heat pump works on the same principle as a refrigerator, but the purpose is different.
- in a refrigerator the interior space is cooled and the heat taken outside is of no importance
- with a heat pump it is precisely that heat that matters. This can heat a room.
- the useful heat that is generated is equal to the heat that is extracted from the ground or 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 capacity has decreased to 70% of the new value

Walking and cycling

For a 75 kilogram person, the resting metabolism is approximately 300 kilojoules per hour. This is continuously used for heart rate, breathing, maintaining a constant body temperature, digestion etc.
The international unit of energy is the **Joule** (3600 kilojoules = 1 kilowatt hour)

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

Walking therefore requires **5 times** as much energy as cycling over the same **distance**

Now the calculation for walking and cycling during the same time:
- 1 hour of walking = 4 kilometers = 4 × 300 = 1200 kilojoules
- 1 hour of cycling = 20 kilometers = 20 × 60 = 1200 kilojoules

Walking therefore requires **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.
This example assumes windless weather and a cyclist sitting upright
The above numbers indicate how much energy is consumed in the form of food

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

Cycling:
- a cyclist sits fixed on the saddle and his centre of gravity therefore always remains at the same height. When one leg goes down, the other goes up
- at a constant speed on a flat road, only energy is used to overcome air resistance and rolling friction. The mass of the cyclist + bicycle is not important (Newton's 1st Law)
- acceleration and driving up a slope does require extra energy. The energy required for this is proportional to the mass (weight) of the cyclist + bicycle

You can cycle 100 kilometers on the energy content of 2 liters of whole milk
- so you will not lose weight by 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 degree of support is automatically controlled by a pedal sensor
- the pedal sensor measures the force with which the cyclist steps on the 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, i.e. by the chosen 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 highly dependent on the wind, whether with or against it
- 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 have appeared 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, the support is switched on (usually abruptly) as soon as the pedals are rotated.
Even if little or no force is exerted, the motor is switched on and supplies virtually all the energy required for propulsion. If you want to cycle faster, you have to press disproportionately harder on the pedals, because the cyclist then has to generate the extra energy entirely himself. In practice, people 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 that is at the expense of the range. When 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.
These problems are completely absent with a pedal sensor.

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
4. an electric bicycle does not smell, does not make noise and does not leak oil
5. you can also simply cycle with an electric bicycle

Electric trains

Double Decker

The Double Decker is the most modern and most 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 is 4 wagons 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 normal train
- the train runs on 25 000 volts AC
- the maximum speed is 300 kilometers per hour
- the Thalys has a fixed composition of 8 wagons with **355** seats
- the energy consumption is **161 watt hours** per passenger per kilometer

Aeroplane

Boeing 747 “Jumbo"

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

The energy consumption (and therefore the CO2 emissions) **per passenger per kilometer** is the same for a full Jumbo and a car with 2 people. But an aeroplane covers a long distance in a short time. For example: a return Amsterdam - New York = **12 000** kilometers.
That is a distance you travel with a car in a year
The CO2 problem is therefore not due **to the plane**, but to making **long journeys**

The Electric car

An electric car from 1916

Already 5000 electric cars were manufactured in America by Baker Electric in the years 1899 - 1915. 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 travel reasonable distances these days
That is due to:
- a better type of battery
- the high efficiency of the electric motor
- low speed (the air resistance is proportional to the 2nd power of the speed)
- low rolling resistance
- low air resistance (so a good aerodynamics)
- return of energy during braking, descending a slope and when decelarating

Some features of the electric car
- the electric car is virtually silent
- the electric car does not produces exhaust gases (but the power plant does all the more)
- the electric motor can deliver maximum torque at all speeds, which makes a fast acceleration possible
- the electric motor never idles
- no gearbox is needed
- 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 comes at the expense of the range

Tesla model S

In 2013 a fully electric 5-seater car was launched 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

Solar powered electric car

Lightyear One

This is a 4-seater electric car that can drive 700 kilometers on 1 battery charge.
The energy required for this is (largely) generated by solar cells on the roof of the car.
The name “Lightyear” is derived from the fact that all cars in the world together cover a total distance every year that is approximately equal to 1 light year (= 9460 billion kilometers).
Those kilometers are.still covered with fossil fuel.

The hybrid car

Toyota Prius

In 1997 Toyota introduced the "Prius". This is a hybrid car which, depending on the situation, is propelled by an electric motor, a petrol engine or a combination of both.
The aim 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 cooperates if 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 speed reduction 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 linked to the petrol engine
- the petrol engine, generator and electric motor are linked to a mechanical energy distributor
- this energy distributor also functions as a continuously variable automatic gearbox
- the air conditioning is electrically driven and therefore also works when the petrol engine is not in operatoin

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, you can drive another 1000 kilometers on the petrol engine with a full petrol tank

The hydrogen car

Toyota Mirai

A few features:
- in a fuel cell, electricity is generated by means of hydrogen
- this process does not produce harmful gases, only water
- the electricity generated is supplied, via a battery, to the electric motor which propels the car
- when braking and during speed reduction energy is returned to the battery

The only question remains: **"where does one 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 do produce harmful gases), nuclear energy, solar energy, wind energy or other forms of "green" energy.

Will the hydrogen car ever appear on the road?
As things stand now, It is not very likely that the hydrogen car will ever appear on the road (large-scale). It is more likely, that cars in the future will run on synthetic petrol, or electricity.

The Hydrogen Economy

The energy scenario of the future, when the fossil fuels run out, may be (partly) based on the so-called Hydrogen Economy. It is assumed that by that time (around 2050) an endless amount of "green" energy will be available. This green energy is then generated by wind turbines and solar panels. It is very unlikely that the share of green energy will ever come close to global energy needs.
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 procuces 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 CO2 that is created in this process is stored in empty gas fields. Next generations will just 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)

Mass loss occurs In both processes
The "disappeared" mass is converted into energy according to Einstein's formula

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 takes place at an extremely high pressure and a temperature of 15 million degrees Celsius. With 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 most easily accomplished on Earth is the fusion of the hydrogen isotopes Deuterium and Tritium. This creates Helium atoms, neutrons and a lot of energy.

The main problem with nuclear fusion is the extremely high temperature required to complete 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.
A Tokamak is an annular reactor in which the plasma is heated to the temperature at which nuclear fusion occurs.

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%		

Some people think about the impending energy shortage:

- **"they" will find something to it**
  (you just fill the Sahara with solar panels)
- **it will take my time**
  (that is still the question and what about posterity?)
- **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 or not?
Each solution has advantages and disadvantages. The question is what you prefer.
fossil energy sources

- irreversible climate change (greenhouse effect)
- resulting in sea level rise and flooding
- continued increase in air pollution (CO_2)
- 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 CO_2 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 stockpile of nuclear weapons.
Yet the US is investing at least 400 billion in modernization until 2026.
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 the force of gravity is not the same everywhere and so weight is not either
- 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 high for a petrol engine as for a coal-fired power plant. Coal-fired power plants are "not allowed", but the car "must".

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

The greenhouse effect

The greenhouse effect is probably caused by the carbon dioxide (CO2), which is released when fossil fuels are burned. This greenhouse gas allows the solar energy to pass through almost unimpeded on its way to earth, while blocking the emission of heat from the earth.
The earth cools down less as 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. The winters have also been remarkably warm in recent years (in Europe).
In addition, people are more often 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, required for the electricity supply of the Netherlands

kind of plant	A
coal or gas power plant 600 megawatt	**28**
nuclear power plant Borssele	**31**
wind farm Gemini	**44**
tidal power plant Brittany	**213**
solar trough power plant Andasol	**232**
sun-voltanic power plant Waldpolenz	**2212**

The Waldpolenz Solar Park
- **2212** of these plants would be needed for the entire electricity supply of the Netherlands
- that are **1.2 billion** panels on a field of more than 50 x 50 kilometers

Solar-energy, a realistic perspective?

Comparison of different types of cars

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

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

electric car (**17** kilometers per literof petrol-equivalent)
- there is no gearbox and therefore no transmission losses
- energy is returned to the battery during braking and apeed reduction
- the car does not produce any CO_2 emissions, but the electric power station does so

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

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 CO_2 emissions are almost twice as much 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
aeroplane 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**

Primary energy

Primary energy is the energy content of fuels, in their naturel form, before any conversion has taken place

Examples are: coal, oil, natural gas and solar energy.
Suppose, a power plant runs on natural gas and the efficiency of the power plant = 40%
The amount of electrical energy produced is then 40% of the primary energy

A few things worth knowing

The increase in the world population = 200 000 people per day
No environmental measure will help against that

In 2022 the 8 billionth inhabitant of the earth was born

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

The Nor Ned cable
To enable the exchange of large amounts of electrical energy, a submarine high-voltage cable, the Nor Ned cable, has been laid between Norway and the Netherlands.
Electricity is transported in the form of direct current..
The cable has a length of 580 kilometers

Does a bicycle with a suspension fork ride heavier than a regular bicycle?
A suspension fork gets a little warm while driving on a bumpy road.
This heat (= thermal energy) must be generated **additionally** by the cyclist.
A bicycle with a suspension fork therefore rides heavier than a regular bicycle.

Energy loss in the food cycle

- if a person eats grain, 10% of it is used for the growth of his body
- if a pig eats grain, 10% of it is converted into pork
- if a person 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

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

Comparison of cooking with gas and electric cooking
At first glance cooking with gas seems much more efficient than cooking with electricity, but on closer inspection this should be nuanced somewhat

cooking on 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
- danger of gas leaks, which can cause explosions
- that is why there are many buildings (Tower Blocks) where cooking on gas is prohibited
- energy supply is (very) poorly adjustable

electric cooking:

- no combustion products in the kitchen.
- the efficiency of the heat transfer between hob and pan is approaching 100%
- the energy supply is highly adjustable
- the energy supply can be automated, such as setting it to a certain temperature and stop heating when the water boils
- a timer can also be used (useful in old people’s homes)

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

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 and get rid of the car, instead of turning off the light in the kitchen every now and then.
Little bits only help a (very little) bit.
If everyone does a little, we’ll achieve only a little

Free energy

Nikola Tesla

There is no scientific basis for the existence of "free energy" Yet one can have vague doubts about this, because **Tesla** would have invented this in 1889.
Tesla (1856-1943) was one of the greatest inventors of all time. Among other things he devised 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 and 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.
They saw absolutely nothing in free energy

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

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

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

Storage of Energy

Some examples:
1. Electrical energy in super capacitors
2. Chemical energy in batteries and hydrogen
3. Thermal energy in substances with a large heat capacity
4. Kinetic energy in flywheels
5. Potential energy due to the displacement of mass against gravity or compressing gases

Energy saving

Insulation of the home
Heating a poorly insulated home requires an average of 2100 cubic meters of natural gas 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
A heat pump is **2 times more efficient** than a gas-fired central heating boiler

Hot water
A lot of savings can be achieved by mounting the hot water boiler close to the tap, both in the kitchen and in the bathroom. In many houses a combi boiler is located in the attic.
That is the **worst place imaginable**. If hot water is required, the long pipe to the kitchen or bathroom must be heated before the water at the point of use has reached 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 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 abolition of the car. Unfortunately, public (regional) transport is of such a poor quality, that it will be difficult to take this step. Only an extreme increase in the price of petrol will have any effect in the long term, but most people cannot be knocked out of their cars.

Lighting
Although lighting consumes relatively little energy, it is still possible to cut costs by consistently using low-energy light bulbs and LED lamps

The energy-neutral house

- viewed over a whole year the amount of energy generated must be equal to the amount of consumed energy
- the electricity is usually generated with solar panels
- water is heated by solar collectors
- as long as nothing better has been devised, the mains will function as a buffer for the (temporarily) excess of electrical energy
- in summer the surplus of electricity is supplied to the grid and in winter the shortage of energy is absorbed from the grid
- the most important condition for an energy neutral home is good insulation of the roof, the walls, windows, doors and floors
- large windows on the South, for maximum solar radiation in the winter
- an awning above the windows so that in the summer, when the sun is higher, little solar heat radiates inwards
- 3 layer glass (but that does not stop the sun's **rays**)
- due to the good thermal insulation of 3 layer glass, little or no cooling is required in summer, while in winter the heat losses are limited
- energy efficient appliances and lighting
- for ventilation and the use of hot water, recovery of heat through heat exchangers
- uderfloor heating with a heat pump or with water from solar boilers (at low temperatures, the heat losses are small)
- the relative heat losses decrease as a house gets bigger
- the heat losses are smallest with a spherical shape (in practice a cube). Protrusions in the form of attached garages, greenhouses and dormers cause additional heat losses
- it must be possible to check with measuring equipment whether the energy generation is in balance with the consumption
- everything stands or falls with the motivation to save energy

Heat transfer

Heat always (automatically) moves 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.
With a normal cavity wall the space between the 2 walls is filled with air. That air can then circulate freely between the 2 walls and then heat is transferred by flow. If the interspace 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 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 virtually no air flow can take place. As a result, this type of glass is a poor conductor of heat. Also think about clothes. A few layers on top of each other, with stagnant air in between, insulate 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. With 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, then the windows should be **closed**, at least if you want to keep it cool inside.

3. through radiation

Solar radiation passes through glass and air almost unimpeded. 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 **out in the summer**, 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 starting to run out. That is why Canada and Venezuela are going to extract the difficult to extract oil from tar sands. They will also dril for 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 about 20 years. After that, the price will rise sharply. West Europe is mainly dependent on Russia, Norway, North Africa and the Middle East.

Coal
There is a lot of coal worldwide. Sufficient for at least 200 years. Coal is good for everything. It can be used to produce town gas, hydrogen, synthetic petrol and diesel oil. The technique for the production of synthetic petrol from coal has been known since 1923.and was used by Germany during the 2nd World War. (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 this (in the Netherlands) will be able to generate a maximum of 14% of (only) electricity in 2020. Wind energy is coming off 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 electricity consumption of the resident, but in winter solar energy yields virtually nothing.

Bio Fuel
Large-scale production of biodiesel etc. is at the expense of food production and it also costs a lot of ordinary fuel. So that is 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 another 75 years at rhe current consumption. When the Uranium is gone, one can probably continue with **Thorium**.
The amount of Thorium on Earth is sufficient for several thousand years

Nuclear Fusion
Around **2050** we can expect the first practical results of nuclear fusion. Then humanity can have an infinite amount of "clean" energy. The total development time then took about 100 years.
One might wonder whether it will ever be possible to generate very large amounts of energy by means of 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 for that. Hydrogen is not an energy **source**, but an energy **carrier**. Producing hydrogen by electrolysis of water costs **1.5 times** more energy than it supplies. Hydrogen is therefore not a solution to the energy problem

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

The only solution seems to be (significant) energy **savings** and (much) **fewer** people
Cutting back on energy consumption, while at the same time increasing the number of people on earth, does not yield anything on balance. That's "mopping with the tap open".

Many people think: “Crises are of all times and people have always found a solution, 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 resources we will run out sooner or later
- the amount of CO_2 in the atmosphere is constantly increasing
- this situation has never happened before

It’s going to be interesting times

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