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A comparative overview of *ENERGY*

“Big numbers tell nothing, ratios do”

Content **page**

Some facts, calculations, and things worth knowing

Preface

The most effective environmental measure
The energy consumption and the associated environmental pollution is proportional to the number of people on Earth. The most effective environmental measure is therefore: **no further increase of the world population.** That will be achieved (in the long run) if the reproduction rate does not exceed **1.** So no more than **2 children** per couple.

Quote from "The Greens Party" program 2002
The uncontrolled growing population is a violent threat to life on Earth. Yet there is an explosive growth of the world's population. Just like China, India will soon be a country with more than one billion inhabitants. (in 2010, India already had 1,2 billion inhabitants). There is a direct relationship between pollution of the environment and the population rate. More people produce more waste, have more need for food, consume more raw materials, have more hassle, have less living space, get less attention and need more money.
The conclusion is clear: **birth control is a necessity.** If not, we all end up like bacteria on a limited breeding ground. After unbridled growth unprecedented mortality follows.

Overview of the population growth (rounded)

	1960	**2000**	**2050**
the Netherlands	11 million	16 million	17 million
World population	3 billion	6 billion	9 billion

In 2011 the 7 billionth earthling was born

- if we count the number of people on Earth with a speed of 1 per second, then therefore **222 years** will be needed:
- at a distance of 1 metre between 2 people this will be a queue of 7 billion metres
- that is 175 times the earth's circumference
- it takes an airplane, flying with a speed of 900 kilometres per hour, **324 days** to cover this distance
- 7 billion people is a column of 18 people wide and a length equal to the distance Earth – Moon (at a distance of 1 metre between the rows)

(why, overpopulation?)

In the past 6 years the world population has increased by half a billion
No environmental measure helps against this

Some definitions and fundamental laws

Power

Power is a measure of the **speed** at which energy **can** be generated or used

power = energy / time

Units:

1 watt = 1 joule / 1 second (= 1 joule per second)

Example:

the **power** of a power plant is 600 **megawatts** (also if the power plant is not in operation).

Power is a property **Power** shows what is (maximum) **possible**

Energy

Energy **is** generated or used during a certain **time**

energy = power x time

Units

1 joule = 1 watt x 1 second (= 1 watt-second)

Example:

the **energy** that a 600 megawatts power plant generates in 5 hours = 600 megawatts × 5 hours
= 3000 **megawatt-hours** (at full power)

Energy always generates something: electricity, movement, light, heat, sound, radio waves, a chemical reaction etc.

In the shop one pays for the power (what is stated on a vacuum cleaner)
At home one pays for the energy (the energy used by the vacuum cleaner)

In daily life is valid:

- the basic unit for **power** is **watt**
- the basic unit for **energy** is **watt-hour**

Law of conservation of Energy

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

Law of conservation of Mass

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

So Energy and Mass are never "consumed"

In the current language one generally talks about "consumed" anyway. For example, if you drive the tank of a car empty, then the petrol is consumed. But then also the "Law of conservation of Energy" and the "Law of conservation of Mass" apply.

Law of conservation of Energy

During the combustion of petrol in an engine, chemical energy converts into mechanical energy (= work) and thermal energy (= heat). This is linked to:
the chemical energy = the mechanical energy + the thermal energy

Law of conservation of Mass

Petrol is a chemical compound of the elements carbon and hydrogen.
The combustion of petrol with oxygen, results in carbon dioxide and water.
the mass of petrol + oxygen = the mass of carbon dioxide + water

Efficiency

efficiency = useful energy / energy supplied

For example: a petrol engine

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

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

Production factor (the availability)

production factor = actual annual yield / theoretical annual yield

For example: wind energy

- suppose, the power of a windmill is 3 megawatts
- suppose, the **actual annual yield** is 7 884 megawatt-hours
- the **theoretical annual yield** is 3 megawatts x 24 hours x 365 days = 26 280 megawatt-hours
- then the **production factor** is (7 884 / 26 280) x 100% = 30%

Efficiency and production factor are 2 completely different concepts

For example: solar energy

- The efficiency of a solar panel is 15% The production factor of solar energy in the Netherlands is 11,4% At the Equator 31,8%

For example: wind energy

- The efficiency of a wind mill is 50% The production factor of wind energy on land is 30% At sea 45%

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

Comparing energy sources

When comparing energy sources one should not look at the power, but consider the **energy yield**
This is especially true for solar energy, because here the **production factor** and the **efficiency** will be very low

Units and conversion factors for power

1 watt	=	1 joule per second
1 kilowatt	=	1 kilojoule per second

Units and conversion factors for energy

1 watt-second	=	1 joule
1 kilowatt-hour	=	3600 kilojoules

Primary energy

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

Energy content of some fuels

1 kilogram of dry wood	=	5,3 kilowatt-hours
1 kilogram of coal	=	8,1 kilowatt-hours
1 cubic metre of natural gas	=	8,8 kilowatt-hours
1 litre of petrol	=	9,1 kilowatt-hours
1 litre of diesel oil	=	10,0 kilowatt-hours
1 kilogram of hydrogen	=	33,6 kilowatt-hours

Thermal energy in 1 litre of petrol

1 litre of petrol = **7800 kilocalories**

With 7800 kilocalories one can heat 7800 litres of water with 1 degree celsius.

Mechanical energy in 1 litre of petrol

1 litre of petrol = **3 340 000 kilogram-metres**

With 1 litre of petrol one can theoretically lift up a Jumbo of 334 000 kilograms 10 metres. Bringing up such aircraft 10 kilometres, costs (apart from the forward speed, air resistance, efficiency etc.) 1000 litres of fuel

Mechanical equivalent of heat

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

1 kilocalorie is equivalent to 427 kilogram-metres

An example:

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

Efficiencies at the conversion of energy

Conversion of **thermal energy** into **mechanical energy**

The efficiency will be limited according to the **formula of Carnot**
The maximum achievable efficiency is about 50%
For example:
The efficiency of a steam turbine in a power plant is 45%

Conversion of **mechanical energy** into **electricity**

This can theoretically occur with an efficiency of 100%
Example:
The efficiency of a generator in a power plant is 95%

Conversion of **electricity** into **mechanical energy**

This can theoretically occur with an efficiency of 100%
Example:
The efficiency of the electric motor is 95%

The formula of Carnot

With the formula of Carnot, one can calculate the **maximum achievable efficiency** at the conversion of thermal energy (= heat) into mechanical energy (= work)

The thermal energy is proportional to the absolute temperature **T** Kelvin

$$\text{efficiency} = (T_{high} - T_{low}) / T_{high}$$

Example

The inlet temperature of a steam turbine is 527 degrees Celsius and the outlet temperature is 207 degrees Celsius. (0 degrees Celsius = 273 Kelvin)

T_{high} = 527 + 273 = 800 Kelvin

T_{low} = 207 + 273 = 480 Kelvin

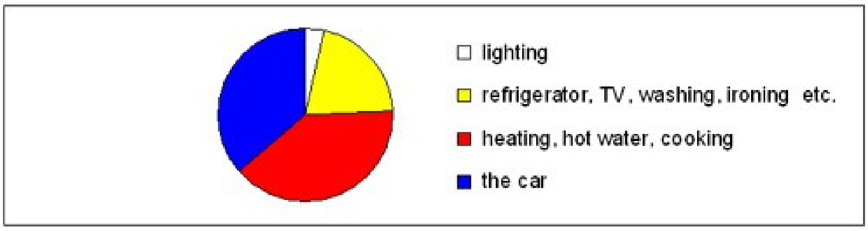
The maximum achievable efficiency will be (800 – 480 / 800 = 0,40 = 40%

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
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 action and reaction forces are equal in magnitude, but opposite in direction

Primary energy consumption of a household

(2008)



Per day a car consumes one and a half times as much primary energy, as an average Dutch household for lighting, refrigerator, TV, washing, ironing, vacuuming etc.

It makes little sense to save on lighting as it is only 4% of the total energy consumption. But it does help lowering the heating.

All energy fed to lighting and devices is fully converted into heat. A living room is not noticeably warmer when the TV or the lights are switched on. Apparently the energy consumption of the lighting and the TV is negligible compared to the energy needed for heating.

Many people think: “all tiny bits will help". The "tiny bits" will contribute very little and give the misleading sense, that one does quite a lot for the environment and that therefore one can further go one's own way. (with the heating and the car)

If everyone does a little, we’ll achieve only a little.

If comfort is at stake, one is no longer "at home".

Green energy

The net energy consumption of 1 household (future scenario)

	kilowatt-hours per year
led lighting	**200**
refrigerator, TV, washing, ironing, etc	**3 000**
heating, hot water, cooking	**7 000**
electric car (40 km per day)	**2 200**
total	**12 400**

How many solar panels are needed for 1 household?
1 solar panel of 1,6 square meters provides 200 kilowatt-hours per year
So for 1 household are needed: 12 400 / 200 = **62** solar panels

How much green energy is produced by 1 wind mill?
1 wind mill of 3 megawatts (on land) produces 7 884 megawatt-hours per year
That is sufficient for 7 884 000 / 12 400 = **636** households

How much is needed for all households in the Netherlands? (without industry, transport etc.)
The Netherlands comprise 7 500 000 households. So:
or 7 500 000 x 62 = **465 000 000** solar panels of 1,6 square meters
or 7 500 000 / 636 = **11 800** wind mills of 3 megawatts

Solar energy

Almost all the energy on Earth comes from the Sun

- in the Netherlands the **irradiation of solar energy** on a horizontal plane = **1000** kilowatt-hours per square meter per year. (seasons, cloudy sky, day and night included)
- the **efficiency** of a solar panel is approximately **15%.**
- the annual yield of a standard solar panel of 1,6 square meters is **200** kilowatt-hours
- to maximise the yield of sunlight in the Netherlands, a fixed solar panel should be mounted under an angle of 36 degrees to the horizontal plane and be directed to the South.
- at the Equator the amount of irradiated solar energy on a horizontal plane is only **3 times** as much as in the Netherlands (during a year and on the same surface)
- the annual amount of solar energy irradiated on the whole Earth is **7000 times** as much as the annual world consumption of primary energy

Some possibilities to use solar energy are:

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

1. Solar panels

1.1. Waldpolenz Solar Park

- the Waldpolenz Solar Park is a large plant with solar panels, located near Leipzig
- the power of this plant is **52** megawatts
- the annual production is **52 000** megawatt-hours
- a 600 megawatts power plant produces **80** times as much energy in 1 year

1.2. Topaz Solar Park

- the Topaz Solar Park in California is the largest solar power plant in the world
- the power of this plant is **550** megawatts
- the annual production is **1 096 000** megawatt-hours
- a 600 megawatts power plant produces **4** times as much energy in 1 year

2. Concentrated solar power (CSP)

At "concentrated solar power" the solar radiation is concentrated on a small surface by means of mirrors. This can be done in different ways**:**

- with **parabolic mirrors**
- with **solar troughs**
- with **heliostats**

Conditions for concentrated solar power

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

2.1. Parabolic mirrors

- a parabolic mirror revolves around 2 perpendicular axes and follows the position of the Sun.
- then there is a temperature of 1000 degrees celsius in the focal point.
- a hot-air engine (Stirling engine) might be posted there, propelling a generator
- the generator generates electricity.

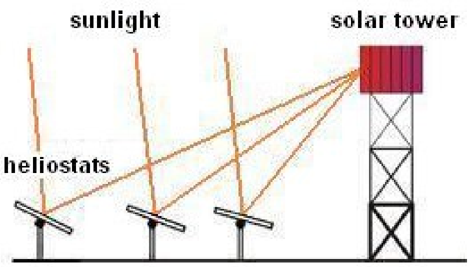
2.2. Solar troughs

- a solar trough is a trough-shaped mirror, with a parabola shaped cross-section.
- the longitudinal-axis is in North-South direction and the solar trough revolves around this axis in the same position as the Sun, so every day from East to West.
- the concentrated solar power heats oil in a tube in the fire line
- in a heat exchanger water is heated to hot steam.
- with the hot steam electricity is generated

Andasol Solar Power Station

- this large plant with solar troughs is located In Andalusia, in Spain
- the power of this plant is **150** megawatts.
- the annual production is **495 000** megawatt-hours
- a 600 megawatts power plant produces **9** times as much energy in 1 year

2.3. Heliostats



- a heliostat is a slightly curved or flat mirror, which turns around 2 mutually perpendicular axes with the position of the sun
- the sunlight reflected by the heliostat is focussed on the top of a "solar tower" which is about 100 metres high
- on the top there is a large barrel filled with water
- this barrel is lightened by a field of hundreds of heliostats and therefore it is the common focal point of a huge surface with a few hundred mirrors.
- all mirrors must be focussed **continuously** and **individually**.
- very high temperatures are reached on the top of the tower, up to 1000 degrees celsius.
- the captured heat is used for the generation of electricity

PS20 Solar Power Plant

- near Seville in Spain there is a large solar power plant with heliostats
- the power of this plant is **20** megawatts
- the sunlight is captured by **1255** heliostats
- the annual production is **48 000** megawatt-hours
- a 600 megawatts power plant produces almost **90** times as much energy in 1 year

Wind energy

The efficiency of a windmill

- the efficiency of a modern windmill is about **50%**
- so the energy yield is about 50% of the energy that passes through the turning circle of the blades
- theoretically the maximum efficiency is 59%

The production factor of a wind mill (globally)

- the production factor increases as the windmill is higher and larger
- the production factor is determined by the place where the windmill is situated
- the production factor of a windmill on **land** is **30%**
- the production factor of a windmill at **sea** is **45%**

The largest wind mill in the world is the Enercon E-126

- the hub height is 135 metres
- the diameter of the blades is 126 metres
- so the highest point that is reached by the blades is 198 metres
- the maximum power is **7,5** megawatts
- that is equal to the power of (only) **100 cars** with a 75 kilowatts engine
- at a production factor of 32% (on land) the annual yield is **21 000** megawatt-hours
- a 600 megawatts power plant produces **200** times as much energy in 1 year

Some Dutch wind farms

	number of windmills	**power per windmill**	**annual yield** (megawatt-hours)
Egmond aan Zee 10 km off the coast	36	3 megawatts	**378 000**
IJmuiden 23 km off the coast	60	2 megawatts	**435 000**
Westereems Eemshaven, on land	52	3 megawatts	**470 000**
Gemini 85 km off the coast	150	4 megawatts	**2 600 000**

The Gemini wind farm

- 150 wind mills with a power of 4 megawatts
- so the total power is **600** megawatts
- the annual yield is **2 600 000** megawatt-hours
- annually a 600 megawatts power plant produces **1,6** times as much energy

TenneT wants to build an energy island in the North Sea

The plan was launched last summer. It now appears that the project, which could be ready by 2050, already is taking shape. TenneT says, this so-called "North Sea Wind Power Hub" will provide a significant contribution to achieving the climate targets of Paris. The islands first function will be the collecting of electricity from dozens, even yet to build wind farms in the Doggers Bank
These farms will have a total capacity of 70 000 to 100 000 megawatts.
Connections from the island to the countries involved should not only collect the generated electricity, but also link the electricity markets to each other in those countries.

Storage of solar and wind energy

Large-scale application of solar and wind energy is only possible, if a solution will be found for storing very large amounts of electrical energy. The problem occurs especially with solar energy, at which the need for energy usually is greatest, when the Sun has gone down behind the horizon already. Solar and wind energy is usually returned to the grid. Then (temporarily) less "grey" energy needs to be generated. This re-delivery can only take place to a limited extent, otherwise the stability of the electricity grid is jeopardized.

Some possibilities for large-scale storage of electrical energy

- With electricity one can pump up water to a higher situated **saving basin**. At a shortage of electricity, that water can supply electricity back through a hydroelectric power station.
- **Production of Hydrogen**. With electricity, water can be decomposed into oxygen and hydrogen. The hydrogen can generate electricity again in a fuel cell or via a gas turbine
- Storage of electricity in the **batteries of electric cars**. If, for example, **1** million electric cars would be driving in the Netherlands, the storage capacity would be equal to the daily production of **2** electric power stations.
- 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, then the mains is almost always used for the temporary storage of the solar energy.

Hydro power

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

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

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

- the capacity of this power plant is **18 000** megawatts
- the energy yield is **85** billion kilowatt-hours per year
- that is 3% of the electricity consumption in China
- that is **20** times as much energy as a 600 megawatts power plant. produces

Geothermal energy

Geothermal energy is extracted from the heat in the Earth.

- from the Earth’s surface the temperature rises with increasing depth with roughly 30 degrees celsius per 1000 metres
- this can vary (strongly) depending on local circumstances
- in volcanic areas temperatures are considerably higher
- at a depth of 5000 metres the average temperature is about 150 degrees celsius

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

Properties of geothermal energy

- clean, durable and inexhaustible
- not depending on weather conditions seasons and time of the day
- there is no CO_2 emission
- the energy is constantly available, so there is no storage problem

Geothermal energy in a few countries
A = comparison with a 600 megawatts power plant

	A
China	3,00
Sweden	2,38
USA	2,07
Iceland	1,57
New Zealand	0,47
Japan	0,34

Tidal energy

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

- there the difference in height between ebb and flood tide is very large, up to 13 metres.
- the capacity of the tidal power plant is **240** megawatts
- the annual energy generated is **540 000** megawatt-hours
- a 600 megawatts power plant produces **8** times as much energy in 1 year

Biomass

Biomass is the collective name for organic materials, which can be used for the generation of "sustainable energy". Examples of such organic materials are**:** fruit vegetable and garden waste, wood and manure. Special "energy crops" can be grown, such as oilseed rape, maize and sugar cane, which may be used as fuel for vehicles, possibly after digestion, fermentation or gasification. In the case of bio fuels, the solar energy is converted into chemical energy. The return on this is at most **1%**

During the growth of trees for example, oxygen is produced and carbon dioxide (CO_2) is absorbed from the atmosphere. When combustion takes place the opposite occurs. Net, this so-called "short cycle" does not pollute the environment (“CO_2 neutral"). The advantage of using biomass**:** there is no storage problem. The biomass can be incorporated in the fuel of coal-fired power plants. (those coal-fired power plants which are so maligned by environmentalists). The extra CO_2 released is "green".

Of course reality is a bit different. Suppose that all biomass currently used by the power stations in the Netherlands would consist of wood.
Than one should think of annually approximately 80 000 goods wagons with 50 tons of wood each. That can only be achieved by massive logging and not by a little pruning wood.

- 80 000 goods wagons with 50 tons of wood = 4 billion kilograms
- that is a train with a length of 800 kilometres
- the amount of electricity that can be generated will be 7,4% of the annual electricity consumption in the Netherlands

Calculation of the land area that will be needed

- the production of wood is about 20 tons per 10 000 square metres of land area per year
- for 4 billion kilograms of wood an area of 45 x 45 kilometres is needed

For a “carbon neutral” use of wood, planting of new trees has to take place at the same rate as the chopping of trees.

Energy storage in the batteries of electric cars

Maybe someday wind energy will play an important role in common electricity generation. Naturally the supply of wind energy is subject to severe and often rapid fluctuations. The production factor is at best (at sea) 45% because the wind is not always blowing (hard). So in 55% of time no or very little wind energy is excited. Therefore the existing infra-structure for electricity generation should be maintained for 100%.
At large-scale production of wind energy, storage of electricity is necessary to compensate for the fluctuations in the supply. Energy storage can be achieved by production of hydrogen via electrolysis of water, a cumbersome method with little (total) efficiency. The use of batteries seems to be a more realistic solution to the storage problem of electrical energy, When electric cars will be widely used, the potential storage capacity for electrical energy will be very large.

If we assume, that there are **1** million electric cars (in the Netherlands there are over 8 million cars) and each battery has a capacity of 30 kilowatt-hours, then **30 million** kilowatt-hours of total storage capacity will be available. That equals the daily production of **2** power stations of 600 megawatts. This form of energy storage requires an intelligent, automated energy management system. (Smart grid)

If you have solar panels on your roof and you store the energy of it in the battery of your electric car, the choice will soon be: "Will I go for a drive or will I do the laundry". Such a choice also makes people more energy-conscious

Smart grid

Smart grid is an energy management system, which controls the distribution between the energy generated by renewable energy sources (wind and solar energy) and conventional power plants.
The aim is**:**

- the flattening of the peaks and off-peaks in the generation of energy. ("peak shaving")
- compensation for the varying energy yield of renewable energy sources

A primitive form of energy management already exists in the system of "off-peak hours", which is often applied by suppliers of electricity. Electric boilers are remotely enabled when the demand for electricity is low. (usually at night and in weekends)
An intelligent energy management system may offer the following options**:**

- thermostats of devices (for example, boilers and air conditioning) can be remotely and automatically disabled or enabled according to the **instantaneous** load of the grid.
- as the wind varies, the energy of wind farms will be proportionally supplemented by energy from (rapid starting) gas-fired power plants.

Combined Heat and Power

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

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

Combined Heat and Power is widely applied in hospitals, swimming pools, factories and horticulture. In horticulture the CO2 released is very welcome, because it stimulates the growth of the plants. (carbon dioxide assimilation).
The total efficiency of Combined Heat and Power is about **90%**

Some properties:

- Combined Heat and Power is at the expense of the efficiency at electricity generation. For a useful amount of heat, the cooling water should not be too cold. Therefore the efficiency of electricity generation goes down.
- Combined Heat and Power is not "green", because it will only work on electricity generated by means of fossil fuels.

Heat pump

A heat pump transfers heat from a low temperature level to a higher level. For example, the lower level is the ground heat which is approximately 12 degrees during the whole year at any depth. The heat pump works according to the same principle as a refrigerator, but the goal is different. In a refrigerator the interior is chilled and the temperature outside is of no importance. In a heat pump, the heat is important. A room can be heated with it.

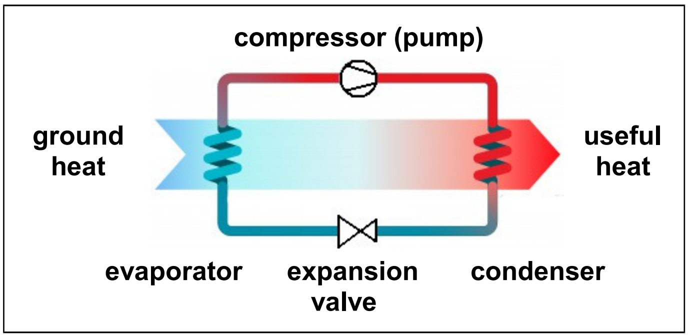
The useful heat that arises is the sum of the heat from the ground and the energy fed to the compressor (pump). Thereby the efficiency seems to be more than 100%.

With a heat pump one uses the concept of COP (= **c**oefficient **o**f **p**erformance).
For example, the COP = 4. Then 3 times as much (free) heat, from the ground is tapped compared with the pump energy. The total amount of heat produced is then 4 times the pump energy. The COP of a heat pump is greater when the temperature difference between inlet and exhaust is smaller. Therefore, a heat pump is often used in combination with floor heating.

Some properties:

- A heat pump is roughly 4 times more efficient than ordinary electric heating.
- The heat generated by the heat pump from the ground or from the air is free and completely CO2-free.
- The electricity that the heat pump runs on is usually generated with a low efficiency and CO2 is generated
- Some heat pumps can work in 2 directions. They therefore can be used for heating or cooling. Also, they can simply be turned off.

The operation of a heat pump



- a heat pump consists of a closed circuit, in which a coolant is circulated
- for evaporation heat is required
- in the evaporator the coolant evaporates at low pressure and thereby heat is extracted from the ground
- the vapour containing the heat is pumped into the condenser by means of the compressor
- in the condenser the vapour condenses at high pressure and the heat which is released is transferred to the environment as useful heat
- in the expansion valve the coolant expands and as a result pressure and temperature drop
- now the cycle starts again

Batteries

Alkaline battery (AA-cell):

- contains 1,5 ampere-hour at 1,5 volt, that is 2,25 watt-hours
- such a battery costs approximately € 0,50
- so 1 kilowatt-hour from an alkaline battery costs **€ 222,00**

Rechargeable nickel-metal hydride battery (AA-cell)

- contains 2,7 ampere-hour at 1,2 volt, that is 3,24 watt-hours
- the use of rechargeable batteries is much cheaper and more environmentally friendly than ordinary batteries.

The vanadium redox battery

- the battery is especially suited for stationary applications and can be used to level off the fluctuating yield of solar panels and windmills
- the energy content is virtually unlimited and is determined by the size of the storage tanks with the electrolytes
- charging may be done (very quickly) by replacing the electrolytes, but the battery can also be recharged by an electric current
- the principle of the redox battery is perhaps interesting for the application in an electric car, because charging can be done very quickly by replacing the electrolytes

Toshiba SCiB
Early 2008 Toshiba launched an improved lithium-ion battery, the **SCiB**
(**S**uper **C**harge **i**on **B**attery)
The main features of a module, which contains 24 cells, are:

- the energy content is 1100 watt-hours
- the energy density is 78 watt-hours per kilogram and that is bad in comparison with an ordinary lithium-ion battery
- the battery is very safe (no explosion or fire hazard)
- the charging time is only a few minutes (in 5 minutes the battery is charged 90%)
- the lifespan is very large, 10 years or 15 000 charging cycles
- the battery can be used within a wide temperature range (-30 to + 45 degrees celsius)

The lifetime of a rechargeable battery

- the lifetime of a rechargeable battery will strongly be influenced by the depth of discharge
- the end of lifetime is reached, when the capacity is only 70% of the replacement value
- the lifetime is expressed in the number of charge cycles consumed
- in case of a lithium-ion battery, aging is also caused by chemical processes that are active in the battery from the moment of production.
- so a lthium0ion battery also wears out when it is not used

For lithium-ion batteries is valid:

depth of discharge	**lifetime** (charge cycles)
100%	500
50%	1500
25%	2500
10%	4700

Fast charging of a battery
At the fast charging of a battery from the mains, one gets to do with massive charge currents.

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

So the refuelling of energy in the form of petrol is much easier and faster than the "refuelling" of electrical energy.

Walking and cycling

For a person of 75 kilograms the basal metabolism will be about 300 kilojoules per hour. That is 2 kilowatt-hours per day. This amount of energy will be needed continuously for heartbeat, breathing, maintaining the constant body temperature (supplementing the heat losses), digestion etc. For example, the energy content of 1 litre of whole milk is 2700 kilojoules and that will be sufficient for 9 hours basal metabolism.

- approximately 300 kilojoules extra will be needed to walk 1 kilometre
- approximately 60 kilojoules extra will be needed to cycle 1 kilometre

So walking costs **5 times** as much energy as cycling over the same **distance**
Now the calculation for walking and cycling during the same time:

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

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

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

A recumbent
The air resistance of a recumbent is about 3 times as small as at a regular bicycle with an upright seated cyclist. Therefore less energy per kilometre will be needed.

Walking:

- the mass of a walker is lifted up and down a few centimetres at every step, that takes a lot of energy
- the energy used is proportional to the mass (weight) of the walker

Cycling:

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

The amount of mechanical energy required for cycling 100 kilometres

- an upright seated cyclist has to produce a power of approximately 75 watts during 5 hours, whilst cycling 20 kilometres per hour and no wind
- so **100 kilometres** of cycling requires a quantity of mechanical energy of 375 watt-hours, this equals 1350 kilojoules.
- the efficiency of the conversion of food into mechanical energy in the muscles is **25%**
- so in the form of food 4 x 1350 = 5400 kilojoules will be required, that equals the energy content of only 2 litres of whole milk.
- one doesn't lose weight by cycling 100 kilometres. As a result of heat losses one does lose weight from swimming (and especially by eating less).

Electric bicycle

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

Ideally, climbing a slope or cycling against wind will be as easy as cycling on a flat road without wind. But of course that will cost a lot of energy. Therefore it is possible at most electric bicycles, to adjust the extent of support more or less progressively by using a switch on the bicycle handlebar. One can 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. The legal maximum power of the motor is 250 watts.

Electric bicycles are so constructed that the electric motor can only be enabled, when one is pedalling. A bicycle with an auxiliary engine in the literal sense of the word.

The energy consumption of an electric bicycle
The energy consumption of an electric bicycle is strongly depending on the circumstances under which the bicycle will be used.
Example:

- 50% support
- an upright seated cyclist
- a speed of 20 kilometres per hour
- a headwind of 4 metres per second
- hard inflated tyres

Under these circumstances, the energy delivered by the battery will be **5 watt-hours per kilometre**

Electric trains

The Double Decker

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

- the basic implementation of the train is 4 wagons with 372 seats.
- the power is **1608** kilowatts.
- the energy use is **18 kilowatt-hours** per kilometre
- that is **48 watt-hours** per passenger per kilometre

The Thalys

The Thalys, which runs on the **H**igh **S**peed **L**ine, consumes much more energy than an ordinary train. The 1500 volt direct current, as applied in the Nether-lands, will no longer be sufficient.
The Thalys on the line Amsterdam-Paris is suitable for 25 000 volts alternating current

- the Thalys has a fixed composition of 8 wagons + 2 motor cars with 377 seats.
- the maximum power is **8850** kilowatts
- the energy use is **57 kilowatt-hours** per kilometre, that is **151 watt-hours** per passenger per kilometre

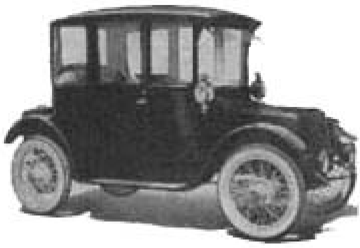
Aircraft

The Boeing 747   "Jumbo"

Some global data and calculations:

- a Jumbo can carry 200 000 litres of fuel
- the range is 13 500 kilometres (= 1/3 of the Earth's circumference).
- so the fuel consumption is 200 000 / 13 500 = 15 litres per kilometre
  = 150 kilowatt-hours per kilometre (1 litre of kerosene = 10 kilowatt-hours)
- a Jumbo can carry 450 passengers
- then the consumption is **333 watt-hours** per passenger per kilometre
- about half of the take-off weight of a Jumbo is due to the carried fuel
  (on a long distance flight).
- the empty weight is 181 tonnes, the fuel weight is 160 tonnes.
- 200 000 litres = 200 cubic metres. That is the equivalent of a "swimming pool"
  of 2 metres deep with a surface of 10 by 10 metres
- the cruising speed at a height of 10 kilometres is 900 kilometres per hour

The electric car



An electric car from 1916

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

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

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

Some characteristics of the electric car

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

For special applications such as courier services, municipal services and commuting there may be a future for electric cars in the offing. It decreases the air pollution in the large cities, however **at the expense of the air pollution at the power plant**

Calculation example of the ideal battery for an electric car

- the range of the car should be at least 500 kilometres
- gross the electric motor consumes 200 watt-hours per kilometre
- so the battery must have an effective energy content of 500 x 200 watt-hours = **100 000** watt-hours
- the battery should take no more space than a regular fuel tank, so a volume of 50 litres
- the battery weight must not exceed a full gas tank, so about **50** kilograms
- then the energy density is 100 000 watt-hours / 50 kilograms = **2 000** watt-hours per kilogram
- the life span should be at least 10 years and the battery should not be too expensive

Summary

- the idea is that the battery has a **large energy content,** sufficient to drive around all day without any limitation
- the battery can be charged during the night with a power, depending on the energy consumed during daytime
- so **no unrealistic fast chargers**, at which one has to wait over half an hour until the battery is full again, after each 200 kilometre ride

energy = power x time
one can choose between:
or a lot of power and little time = fast charger
or little power and a lot of time = charging at night

The General Motors EV1

The General Motors **EV1** (**e**lectric **v**ehicle) has been produced between 1996 and 1999. It was an electric 2-seater car. 1117 pieces have been produced. They were not for sale, as they were meant to be for leasing purposes only. In 2003 all cars were seized and destroyed by General Motors except for a few units, that were donated to museums and schools. At first they were made unusable. This may have happened under pressure of the oil industry.
The first draft was created on the occasion of the "World Solar Challenge" in Australia in 1987. The first type, the "Impact" reached a top speed of 295 kilometres per hour. Everyone was excited, except General Motors. They started developing the EV-1, to show that time was not yet ripe for a successful electric car. However, the developers were so excited, that it was difficult to curb them. The battery of this car could be charged via an induction coil. This was safe during rainy periods. Slow charging via a plug was also possible.

For the user the EV-1 was a great success. For General Motors the profit margin was too low and there was fear that the sale of ordinary cars, which created much profit, would decrease. This happened anyway, because Japan imported many modern cars. The EV-1 was the best electric car ever made. It was far ahead of its time.
Some data:

- low weight because of an aluminium frame and plastic components (1400 kilograms)
- a very low air resistance
- heating by means of a heat pump
- keyless entry and ignition
- the car accelerated in 8 seconds from 0 to 100 kilometres per hour
- its top speed was 130 kilometres per hour
- the range was 200 kilometres

A film has been made about this car in 2006: **"Who killed the electric car?"**

The Tesla model S

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

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

The Opel Ampera-E
Early 2017 Opel launched a fully electric car, the Ampera-E
Some preliminary data:

- the weight of the battery is **430** kilograms
- according to the manufacturer the range will be 500 kilometres
- this has been measured at an average speed of 34 kilometres per hour and an average power of 4 kilowatts

The range has been measured according to the standardised measuring method, the **N**ew **E**uropean **D**riving **C**ycle (**NEDC**)
A practice test shows a more realistic range of 380 kilometres

The hybrid car

The Prius

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

- the efficiency of the Atkinson petrol engine is high, but strongly depending on the load and the speed
- the electric motor always has a high efficiency
- the electric motor is working when the efficiency of the petrol engine is low
- the energy for the electric motor is supplied by a rechargeable nickel-metal hydride battery of 1,3 kilowatt-hours
- at (regenerative) braking and speed reduction the electric motor works as a dynamo and delivers energy back to the battery
- in addition, the battery is recharged by a generator, which is linked to the petrol engine
- the petrol engine, generator and electric motor are linked together by means of a mechanical energy distributor
- this energy distributor also functions as a continuously variable automatic transmission
- the air conditioning is powered electrically and therefore it also works if the petrol engine is not in operation

In braking-stopping-acceleration situations the highest effect of the hybrid system is achieved. For instance in traffic jams and in cities with many traffic lights. Over long distances and at high speed the hybrid system is not working. Then only the economical Atkinson petrol engine works. The Prius is equipped with an "energy monitor" on the dashboard. It invites you to practise an economical driving style. Then the consumption appears to be **1 litre per 21 km**.

The fuel cell car

Some characteristics:

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

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

Efficiencies

- the efficiency of the generation of electricity is **40%**
- the efficiency of electrolysis of water is **70%**
- the efficiency of a fuel cell is **50%**
- the efficiency of an electric motor is **90%**
- the overall efficiency is only 40% × 70% × 50% × 90% = **13%**

Will the fuel cell car ever appear on the road?

It is not very likely that the fuel cell car ever will appear (large-scale) on the road. It is more obvious, that in future cars will drive on synthetic petrol, synthetic diesel oil or electricity. Also **GTL** (**g**as **t**o **l**iquid) has enormous potential, in particular now that world-wide gigantic amounts of shale gas are found.

In 2015 Toyota launched the first fuel cell car

The Mirai

Some preliminary data

- this 4-seater fuel cell car has a range of **500** kilometres
- the hydrogen gas can be tanked in 3 minutes
- the common content of the 2 tanks is 122 litres
- the pressure in the tanks is 700 bar (1 bar is approximately 1 atmosphere)
- per tank turn 5 kilograms of hydrogen is tanked

Large scale application is expected around 2020. Condition for the introduction of the fuel cell car is an infrastructure that makes it possible that in many places (the very explosive and thus dangerous) hydrogen gas can be tanked under high pressure

The Hydrogen Economy

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

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

Some people think hydrogen is an inexhaustible source of energy, but it's not. On the contrary. Producing hydrogen by electrolysis of water will cost 1,5 times more energy than it will deliver

The (ideal) Hydrogen economy provides the following image:
green energy > electrolysis of water > hydrogen > fuel cell > electricity

There are quite a few misunderstandings about water, hydro power, hydrogen and nuclear fusion of hydrogen-isotopes. Therefore the following overview:

Water
Water is the combustion product of hydrogen and oxygen. So it contains **no energy**

Hydro power
When fast running water or water under high pressure drives a turbine, hydro power is released. This happens in a hydroelectric power plant. Hydro power is an **energy source**

Hydrogen
Water can be decomposed into hydrogen and oxygen by electrolysis. The energy in hydrogen is released again at the "burning" in a fuel cell. The energy for the decomposition of water initially has to be provided by fossil fuels, nuclear energy, nuclear fusion, wind energy, hydropower, geothermal energy or solar energy. (so by energy sources).
Therefore hydrogen is **not an energy source** but an **energy carrier**.

Nuclear fusion of hydrogen isotopes
Trough nuclear fusion hydrogen isotopes can fuse into helium. A huge amount of energy is then released. This technique is still in its infancy and it will be at least 50 years before there may be practical applications. (if ever). Nuclear fusion is an **energy source**.

Nuclear fusion

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

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

Mass loss happens in both processes. At nuclear fission, this is about 0,10% and at nuclear fusion (inside the Sun) 0,67%. The "disappeared" mass is converted into energy according to the formula of Einstein

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

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

If matter is very strongly heated, it forms a plasma. In a plasma the atomic nuclei and electrons move separately. Atomic nuclei are positively charged and repel. The repellent force is overcome at 150 million degrees by the speed of the movement of the atomic nuclei. As a result nuclear fusion occurs

The fusion reaction which can best be established on Earth is the merging of the hydrogen isotopes Deuterium and Tritium. This produces Helium atoms, neutrons and very much energy. Fusion of a Deuterium-Tritium mixture with a mass of 250 kilogram generates as much energy as the incineration of 2,7 million tonnes of coal. That is sufficient to keep a power plant of 1000 megawatts running at full power for one year.

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

To deliver more energy than necessary for the merging process a Tokamak must have a minimum size. This will be realized for the first time in **ITER** (**I**nternational **T**hermonuclear **E**xperimental **R**eactor), the first (experimental) fusion power plant. The outer dimensions are**:** 24 metres high and 34 metres in diameter.

ITER is a project, which Reagan and Gorbachev have taken the initiative for at the end of the cold war. ITER must demonstrate the possibility of long-term energy generation with nuclear fusion. It is expected that during 10 minutes 500 megawatts can be generated. This is ten times more than the amount of energy that is used for maintaining the hot fusion plasma. ITER is the biggest international scientific research project since the construction of the **I**nternational **S**pace **S**tation. (ISS)

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

Nuclear energy

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

or	300 tonnes	enriched Uranium
or	36 000 000 tonnes	coal

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

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

From 1973 to 2013 the increase of **world population** has been **84%**
From 1973 to 2013 the increase of **world energy consumption** has been **222%**

Summary

- the world's population and the energy consumption are increasing rapidly
- natural gas and oil resources will be exhausted at the end of this century
- sustainable energy will never meet the requirements of 9 billion earthlings
- nuclear fusion will take 60 to 80 years or maybe it will never come

Conclusion

- coal-fired power plants and nuclear energy are inescapable

Some people think:

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

Anything can be calculated, but that does not mean that it can be achieved in practice, or that it is economically feasible

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

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

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

- irreversible climate change (greenhouse effect)
- thereby sea level rising and flooding of the land
- continued increase in air pollution (CO_2)
- exhaustion of all fossil fuels
- wars to secure the supply of oil or natural gas
- earthquakes and subsidence by oil and gas extraction

or nuclear energy

- a limited (radioactive) waste problem, which can be solved in principle

This dilemma exists, because before the year 2050 it seems to be necessary, that an extra 2 billion people still have to come. On average this means **1 million extra per week**, while already there are **7 billion** earthlings.

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

Dutch Teletext 3 July 2017
Russia and the US will decrease their stock of nuclear weapons. Yet the US will invest up to 20 billion in modernization by 2026. There are nine countries with nuclear weapons. Together they have **14 935** nuclear warheads. That is 460 less than a year ago.

Why no nuclear energy?
Many people oppose against nuclear energy, because they "fear" that their offspring (in thousands of years) will be stuck with the problem of radioactive waste. Nevertheless, these same people are consuming all fossil fuels that are still available in record pace, without putting themselves to any restrictions. The **next** generation should help themselves. Of course these same people will think more carefully balanced about nuclear energy, as it will become clear that their own energy supplies will be in danger.

Quote from Patrick Moore, former Director of Greenpeace International
We made the mistake of lumping nuclear energy with nuclear weapons, as if all things nuclear were evil. I think that’s as big a mistake as if you lumped nuclear medicine with nuclear weapons.

Thorium?
On the internet I found the following message of **ECN** = **E**nergy research **C**entre in the **N**etherlands:
"New nuclear fuel reduces radioactive waste"
“Thorium is an interesting fuel, because the Thorium inventory on Earth is sufficient for some **thousands** years. The radiotoxity of Thorium is a factor 10 to 100 times lower at all stages of the cycle than Uranium".

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

Some facts, calculations, and things worth knowing

Energy consumption in the Netherlands

- **288 billion kilowatt-hours** of primary energy was required for the generation of electricity (2013)
- the total primary energy consumption, needed for heating, industry, cars and the generation of electricity was **900 billion kilowatt-hours**
- that is **3** times more than necessary for the generation of electricity alone

The mass-energy equivalent

1 kilogram mass is equivalent to 25 billion kilowatt-hours

Mass and weight

Mass is a measure of the amount of matter. **Weight** is the force with which matter is attracted by the gravity of the Earth. On the Earth gravity is not uniform and therefore also weight is not. The mass however is the same everywhere. The weight of mass is defined at an acceleration of gravity of 9,81 metres per second squared. The unit of mass is the kilogram

The Sun

Almost all energy on Earth comes from the Sun
Almost all energy resources on Earth (oil, natural gas, coal, biomass, wind and hydro power) find their origin in solar energy. Exceptions are: geothermal energy, nuclear energy and energy from the Moon. (tidal energy).
The most direct source of energy is the light and heat radiation from the Sun. This energy source is clean and inexhaustible and in the distant future we will be largely dependent on it. The energy that is radiated by the Sun is generated by nuclear fusion.
Every second **4,27 billion kilogram mass** in the Sun turns into energy.

In 2013 the electricity consumption in the Netherlands was **115** billion kilowatt-hours. That is equivalent to **4,6** kilogram-mass. The amount of energy the Sun radiates in **1 second** is almost **1 billion** times as much as the total use of electricity in **1 year** in the Netherlands

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

Some people conclude from this that an energy problem doesn't exist.
However, one must bear in mind the following:

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

To replace **one** 600 megawatts power plant by solar panels in the Netherlands an area of **80** square kilometres will be needed

Solar energy near the Equator
Near the Equator the day length is 12 hours throughout the year. In spring and autumn the Sun is perpendicularly above the Equator. The amount of solar energy, that falls on a horizontally placed solar panel at a completely cloudless sky, equals 24 hours / π = 7,6 hours of full sun. In summer and winter, the Sun is perpendicular to a tropic and then the radiation at the Equator is slightly less.
So the production factor during a year will be **31,8%** In the Netherlands this is **11,4%**. So at the Equator the production factor is only **3 times** as much as in the Netherlands.

Solar radiation in the Netherlands in 1999
In this overview our starting point is **1000 kilowatt-hours** per square metre per year.

Wind energy

Everyone is in favour of wind energy, until a windmill will be placed in the neighbourhood. **NIMBY** One experiences or expects the following problems:

- noise
- at a particular position of the Sun the rotating blades can interrupt the sunlight in an annoying way (a few hours per year)
- horizon pollution (endless residential areas on the horizon are no problem)
- birds getting killed against the blades
- large offshore wind farms will cause less rain and wind, while also the height of the waves will be reduced.

Comparison of Solar and Wind energy

some of the features of solar energy

- in winter the yield of solar energy will be little and during the night it will be zero while then the need for energy is greatest
- solar energy can not be realized at sea
- the used land area is not available for other purposes
- fixed solar panels require little maintenance

some of the features of wind energy

- in winter the yield of wind energy will be relatively high while then the need for energy is also high
- wind energy can be realized at sea
- at wind energy on land the area can be used for agriculture or cows can graze there
- wind mills require a lot of maintenance

Some fuels and CO_2

CO_2-emissions from the incineration of single fuels
Through burning of petrol or diesel oil, CO_2 emissions per kilowatt-hour are almost as much as those of the burning of coal. Coal-fired power plants "are not permitted", but the car "is a must".

CO_2 emissions caused by cars in the Netherlands

- in 2008 there were 7 million cars in the Netherlands.
- those 7 million cars consumed 10 billion litres of petrol
- **24 billion kilograms of CO_2** was produced.

CO_2 emissions caused by domestic electricity consumption in the Netherlands

- from only coal-fired power plants **20 billion kilograms of CO_2** would arise
- from only gas-fired power plants **12 billion kilograms of CO_2** would arise

In the Netherlands electricity is generated from both coal-fired and gas-fired power plants. So passenger car traffic causes more CO_2 emissions than the electricity production for all households. So even if one would only apply coal-fired power plants.
It is amazing that environmentalists protest against coal-fired power plants, while they are using cars like anyone else. (environmental pastors)

The greenhouse effect

Many people think that the greenhouse effect is being caused by the energy which is being released in the combustion of fossil fuels. That is not the case, because that amount of energy is negligible compared to the amount of energy of the Sun beaming on the Earth.
The Sun radiates **7000 times** more energy per time unit on Earth, than is generated by human activities.
The greenhouse effect is probably caused by the carbon dioxide (CO_2), that is released in the burning of fossil fuels and also by the vapour in the atmosphere.
These greenhouse gases let by solar energy towards the Earth virtually unhindered, while the radiation of heat from the Earth is largely stopped. As more greenhouse gases are present in the atmosphere Earth cools down less.
However it is questionable whether the effect of carbon dioxide (CO_2) in this process will be as large as has been assumed up to now. That point has not been settled yet. Maybe the "greenhouse effect" should be categorized the same as "acid rain" and "the hole in the ozone layer". The future will tell. It is clear however that the climate is changing in recent years. Think of the melting of the ice at the North Pole and the disappearance of the "eternal" snow in the Alps. For the past few years (in Europe) winters have been remarkably warm. In addition one has to do more often with extreme weather, such as hurricanes and floods.

Light sources

Comparison of various light sources

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

Energy saving lamp
Between 2009 and 2012 the incandescent lamp was gradually withdrawn from the market. This will reduce the CO2 problem a (very small) part, because the energy consumption of lighting is only 4% of total energy consumption. Both energy saving lamps and fluorescent lamps contain harmful substances (e.g. mercury) and must therefore be considered as small chemical waste.
Energy saving lamps, as well as fluorescent tubes and LED lights, cause interference in radio equipment. Incandescent bulbs do not

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

- the benefits of the Led lamp are its dimensions, its resilience and longevity. In addition, light is at full strength immediately after switching it on (as fast as an incandescent lamp).
- in comparison to small light bulbs, such as in flashlights and in rear light of a bicycle, the light efficiency of Led's is very high

Led lamps
At Ikea a 16 watt Led lamp is for sale. The luminous flux is 1600 lumens, which is 100 lumens per watt. The colour temperature is 2700 kelvin. So the light efficiency is 44% and thus higher than at a fluorescent tube. Light is radiated evenly in all directions.
So finally it starts to be something with Led lighting (2018). Most of the supplied energy is dissipated in the heat sink of the Led. The fitting of the lamp becomes so hot, that one can not grasp it long-term

Aircraft

An airplane with a jet engine
Some people think that a jet engine (or a rocket engine) "repels" itself against the air. That is not the case and a rocket engine (which carries its own oxygen) even works better in vacuum. The propeller of an airplane "repels" itself against the surrounding air. A jet engine "repels" itself against the gases that it emits.

- the action of a jet engine (and the rocket engine), is based on the principle **action = reaction** (Newton's 3rd Law)
- in the jet engine kerosene is burned with oxygen from air.
- the thrust is caused by the masses of the combustion products which are emitted at high speed by the jet engine.

Cycling

Power and energy when cycling on a flat road, sitting upright and without wind
A = the power necessary for overcoming the mechanical resistance
B = the power necessary for overcoming the air resistance
C = the total required power
D = the energy per kilometre

speed	A	B	C	D
10 km/hour	8 watts	7 watts	15 watts	1,5 watt-hours
20 km/hour	18 watts	56 watts	74 watts	3,7 watt-hours
30 km/hour	32 watts	189 watts	221 watts	7,4 watt-hours
40 km/hour	52 watts	448 watts	500 watts	12,5 watt-hours

- a well-trained cyclist can provide a continuous power of 130 watts. When there is no wind a speed of 25 kilometres per hour will be reached on a touring bicycle.
- a professional racer can deliver 300 watts continuously. On a race bike that will be sufficient for a speed of 40 kilometres per hour.
- Lance Armstrong ever reached 450 watts Thus he was able to mount the "Alpe d'Huez" in 38 minutes. The height difference is 1061 metres and the distance is 13,8 kilometres. So the average speed was 21,8 kilometres per hour.

Wind during cycling is always detrimental if one returns to the place of departure
calculation example:

- suppose a distance of 30 kilometres there and back.
- **no wind, a cycling speed of 20 kilometres per hour**
  then the cyclist will be cycling for **3** hours.
- **backwind or headwind of 10 kilometres per hour**
  the cyclist experiences the same air resistance when the speed relative to the wind is the same. With backwind the cycling speed will be 30 kilometres per hour and with headwind 10 kilometres per hour. Now the cyclist will be cycling 1+ 3 = **4** hours So the amount of supplied energy will be 4 / 3 = **1,33** times as much as when there is no wind.

Also when there is crosswind a cyclist has to deliver more energy than when there is no wind

Cycling with a constant speed on a flat road
If the roller friction and air resistance are neglected, then cycling with a constant speed on a flat road takes no energy. Then the mass (weight) of the cyclist + bike is not important.
(1^{st} law of Newton).
However in practice cycling with a constant speed is not possible, because the force exerted on the pedals is not constant. For every revolution of the crankshaft, the bike is accelerated a bit twice by the cyclist and slowed down a bit twice by the roller friction and the air resistance.
The ultimate effect of this is that at a “constant speed” yet some energy is needed which is proportional to the mass (weight) of the cyclist + bike

Electric bicycles

- at a speed of 20 kilometres per hour and a headwind of 4 metres per second (wind force 3), an upright seated cyclist must deliver a power of 180 watts
- that corresponds with an amount of energy of 9 watt-hours per kilometre
- for 50% support by an electric bicycle, then 4,5 watt-hours mechanical energy per kilometre is needed.
- the efficiency of the electric motor with associated energy control is approximately 90%
- at 50% support the battery of an electric bicycle has to deliver **5 watt-hours per kilometre**

That is a minimum value, because one uses the support especially at (strong) headwind.
The (average) range of an electric bicycle at 50% support is easy to calculate.

range (kilometres) =
energy-content of the battery (watt-hours) / **5** (watt-hours per kilometre)

There are 3 implementing forms of electric bicycles:

- drive by means of a motor in the **front wheel**
- drive by means of a motor attached to the **bottom bracket**
- drive by means of a motor in the **rear wheel**

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

Does it take more exercise to cycle an electric bicycle without support than a regular bicycle?
It is a widespread misunderstanding, that if support is disabled it will be (a lot) more work on an electric bicycle than on a regular bicycle. Only the rolling resistance of an electric bicycle is a bit more compared to a regular bicycle, due to more weight of the bicycle. The air resistance will be the same of course. On a flat road with constant speed the mass (weight) of the bicycle + rider is (virtually) not an issue. (Newton's 1st Law).
The rolling resistance is negligible compared to the air resistance, especially with moderate or strong headwind. Of course the larger weight will play an important role during acceleration and at a slope. But during a long bicycle ride slopes will not be present very often.
(in the Netherlands)

The range of an electric bicycle is largely determined by the air resistance
Recently I got talking to a couple with an electric bicycle. The man with a large stature said that he realized a much smaller range on his bicycle than his frail wife. He thought that this was caused by the difference in weight. That is not the case, because at a constant speed the weight plays no role. (apart from a negligible difference in rolling friction). The difference in the range is caused by the difference in air resistance.
The air resistance is proportional to the frontal area of the cyclist + bicycle. If the frontal area becomes 50% larger the range will decrease with 25%. One can calculate this easily by means of the data in column B in the table above

The benefits of an electric bicycle are:

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

The combined gas and steam power plant

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

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

Nuclear power plant

The nuclear power plant in Borssele
The nuclear power plant in Borssele has a capacity of **449** megawatts. In the year 2000 the energy yield was **3 700 000** megawatt-hours.

Comparison of the number of power plants needed for the Netherlands

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

	megawatt-hours per year	number of power plants
gas-fired power plant 600 megawatts	**4 200 000**	**28**
nuclear plant Borssele	**3 700 000**	**31**
wind farm Gemini	**2 600 000**	**44**
tidal power plant Bretagne	**540 000**	**213**
solar trough power plant Andalusia	**495 000**	**232**
wind farm IJmuiden (p.12)	**435 000**	**264**
sun-voltaic power plant Waldpolenz	**52 000**	**2212**
heliostats Seville	**48 000**	**2396**
largest wind mill in the world	**21 000**	**5476**

A **600 megawatts power plant**

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

The **Waldpolenz Solar Park**

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

Solar-energy, a realistic perspective?

Electric cars

- in 2014 there were 8 million cars in the Netherlands
- on average the distance travelled by one car was 15 000 kilometres per year
- so the total distance travelled was **120** billion kilometres
- that is 800 times the distance Earth-Sun.
- gross an electric car consumes **200** watt-hours per kilometre
- so in 1 year 8 million electric cars consume 24 billion kilowatt-hours
- for the generation of this amount of energy 6 power plants of 600 megawatts extra would be needed.
- also the capacity of the electricity infrastructure (power lines and power plants) should be increased substantially if everyone is going to drive an electric car

A few electric cars that have appeared on the market recently

	battery (kilowatt-hours	**range** (kilometres)
BMW i3	27	170
Hyundai IONIQ	28	195
Volkswagen e-Golf	32	200
Nissan Leaf	38	240
Renault Zoe R90	39	255
Tesla 3	52	325
Opel Ampera-E	60	375

The range of an electric car
Often, unrealistic values are mentioned, as with the Ampera-E. According to the NEDC standard, this car would have an range of 500 kilometres. The actual range appears to be 375 kilometres.

The problems with the electric car are:

- the small range
- the long charging time of the battery
- the large volume of the battery
- the heavy weight of the battery
- the high price of the battery

As long as these problems are not solved, there can be no question of a large scale use of the electric car. It is significant that Toyota has withdrawn from the electric car market.

How many solar panels are needed for an electric car driving 40 kilometres a day?
People sometimes fantasize, to let their electric car run on the energy that comes from their own solar panels.

- an electric car consumes 150 watt-hours per kilometre
- 40 kilometres per day = 14 600 kilometres per year
- this requires **2 200** kilowatt-hours per year
- in the Netherlands a solar panel of 1,6 square meters delivers 200 kilowatt-hours per year
- therefore at least **11** of those solar panels are needed
- in practice this will not work, because in winter there is not enough solar energy available and in addition the car must be heated
- when the car is on the road, the solar energy from the solar panels on the roof of a house, can not be stored in the battery of the car
- then the mains functions as day and seasonal storage of the solar energy
- without a connection to the mains it is virtually impossible to drive an electric car all year round (in the Netherlands) on solar energy

Electric cars with solar cells

The Light-year
This is a 4-seater electric car, that is capable to drive 400 to 800 kilometres on 1 battery charge. The required energy is (largely) generated by solar cells on the roof of the car.
The name “Light-year” is inspired by the fact, that all cars in the world together, cover a total distance every year, approximately equal to 1 light year. That are 9460 billion kilometres. Those kilometres are now still covered with fossil fuels. There are about 1 billion cars on earth, travelling 9460 kilometres per year on average.

In the Netherlands, according to the designers, the “Light-year” could run 10 000 kilometres per year on solar energy. That is an average of 30 kilometres per day.
calculation example:

- suppose, in the Netherlands the yield of solar cells with a high efficiency is 250 kilowatt-hours per square metre per year
- suppose the consumption of the car is 100 watt-hours per kilometre
- so to drive 10 000 kilometres 1000 kilowatt-hours are needed
- then the required surface of the solar cells will be 4 square metres
- condition is, that the car always must be parked in the open air and that there will never be any shadow on the solar cells
- in winter it will not work to absorb enough solar energy

The question remains of course, whether it is any better to place a large number of solar panels on the roof of your house, and to plug in the energy that is generated, into the battery of a ordinary electric car
Light-year’s answer is: you must do both. So solar cells on the roof of your car, as well as solar cells on the roof of your house, with which the shortage can be supplemented if necessary.

The plug-in hybrid car

In 2012 **Toyota** launched the **plug-in** Prius. This plug-in hybrid car has a relatively large battery that can be charged from the mains. The energy content of the battery will be sufficient to drive electrically for 20 kilometres. That is sufficient for commuting (a single trip) or shopping.
Some data: (borrowed from the journal "My Toyota", spring 2011)

- the range for full electric driving is20 kilometres
- the energy content of the battery is 5,2 kilowatt-hours
- the charging time from an ordinary socket is 90 minutes
- on average the petrol consumption is 2,6 litres per 100 kilometres
- the CO2 emission is 59 grams per kilometre

According to Toyota the car would have a petrol consumption of 2,6 litres per 100 kilo-metres. This only applies, if you always drive 20 kilometres electrically followed by 40 kilometres on petrol. Only then this car has a CO2 emission of 59 grams per kilometre. If the CO2 emission in the generation of electricity is also taken into account, then the plug-in hybrid car produces (indirectly) as much CO2 as a regular hybrid car.
All this does not alter the fact, that it might be fun, (and it is cheap), to put part of the necessary energy into the battery from the socket at home.
Depending on how the car will be used, perhaps one doesn't need to tank petrol anymore or in any case less often. But in winter this will not work. Then the petrol engine has to run almost continuously, in order to heat the car
With this kind of calculations one can "prove" everything but the fact remains, that a "plug-in" hybrid car will be **not** more fuel-efficient than a regular hybrid car and (indirectly) causes comparable CO2 emissions.

CO_2 emissions of different types of cars

(at **the same** amount of propulsion energy and everything “well-to-wheel”)

	electric car	**hybrid car**	**petrol car**	**fuel cell car**
propulsion energy (per km)	150 watt-hours	150 watt-hours	150 watt-hours	150 watt-hours
CO_2-emissions (per km)	123 grams by the power plant	150 grams by the car	204 grams by the car	295 grams by the power plant
energy in litres petrol-equivalent	1 litre per 18,7 km	1 litre per 20,6 km	1 litre per 15,2 km	1 litre per 7,7 km

electric car

- the electric motor never needs to warm up
- there is no gearbox and so there are no transmission losses
- during braking and speed reduction energy is returned to the battery
- on site the car causes no CO_2 emission, but on the other hand the power plant does

hybrid car

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

petrol car

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

fuel cell car

- this is an electric car in which the energy is supplied by a fuel cell
- the 4-fold energy conversions cause a bad total efficiency
- the indirect CO_2 emissions will be 2 times as much as at an electric car

the number of energy conversions of different types of cars

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

Comparison means of transport

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

means of transport	A	B
aircraft Boeing 747 Jumbo	**450**	**333**
fuel cell car	**4**	**288**
electric train Thalys	**377**	**151**
petrol car	**4**	**150**
electric car	**4**	**121**
hybrid car Prius	**4**	**108**
electric train Double-decker	**372**	**48**
electric bicycle	**1**	**17**

If there is one person in a petrol car (and that is usually the case), then that person consumes 600 watts-hour of primary energy per kilometre. That is almost twice as much as one person in a full occupied Jumbo

The World Solar Challenge

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

- length is 5 metres, width is 1,8 metres and height is 80 centimetres
- the total surface of the solar panels 8,4 square metres
- weight 189 kilograms (excluding the driver)
- the capacity of the battery is 5 kilowatt-hours

The Shell eco-marathon

The Shell eco-marathon is an annual efficiency contest, sponsored by Shell. The goal is to trudge as many kilometres as possible with a vehicle on 1 litre of regular petrol.
There are 2 classes: the "prototype" and the "urban-concept"
In the **"prototype"** class any form of the vehicle is allowed. Usually it resembles a motorized recumbent
In the **"urban-concept"** class, the vehicle must resemble a car. The driver has to sit upright and the vehicle must have four wheels.

Important factors at the record attempts are:

- a low air resistance, so a small frontal area and a good flow line
- a low weight
- a low speed (the air resistance is proportional to the 2nd power of the speed)
- the efficiency of the (small) engine must be as high as possible
  (sometimes a Honda 4-stroke moped engine is used)

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

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

Bio fuel

rapeseed oil

the conversion efficiency of solar energy to chemical energy will be **0,20%**

bio-ethanol

the conversion efficiency of solar energy to chemical energy will be **0,60%**

wood

the conversion efficiency of solar energy to chemical energy will be **1,06%**

Comparison of above bio fuels at an irradiation of 1000 kilowatt-hours per square metre per year

A = the energy yield per square metre per year (kilowatt-hours)
B = the production of electricity at an efficiency of 40% (kilowatt-hours)

	A	**B**
rapeseed oil	2,0	0,8
bio-ethanol	6,0	2,4
wood	10,6	**4,2**

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

- with wood **4,2** kilowatt-hours of electricity can be generated, per square metre per year
- in the Netherlands a solar panel generates **150** kilowatt-hours of electricity, per square metre per year
- so solar panels are (at least) **36 times** more efficient than wood

A few more things worth knowing

The NorNed cable
In order to enable the exchange of large quantities of electrical energy, a submarine high-voltage cable, the NorNed cable, has been installed between Norway and the Netherlands. The transport of the electricity is in the form of direct current, because at this large distance the capacitive losses in the cable in the case of alternating current are far too large.
Some data:

- the cable was put into operation in 2008
- the length is 580 kilometres
- it is a 2 wire cable with a maximum power of 700 megawatts, with a DC voltage of 900 kilovolts
- at the beginning and the end of the cable there are converters that convert the alternating current into direct current and on the other hand the direct current into alternating current
- during the day energy generated by hydropower is transported from Norway to the Netherlands
- during the night, cheap Dutch night power can be returned to Norway

Hot-air Engine (Stirling engine)

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

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

Energy losses in the food cycle

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

From the point of view of energy efficiency, eating of meat is very inefficient
There are of course people who think very differently about this.

Electric shaving in comparison to shaving with a razorblade

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

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

cooking on gas:

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

electric cooking:

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

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

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

Some units

Watt peak
Watt peak is the electrical **power** of a solar panel, at an perpendicular irradiation of 1000 watts per square metre and a panel temperature of 25 degrees celsius
Example:

- a solar panel has a surface of 1,6 square metres
- the efficiency is 15% (current state of the art)
- then the electrical power is 1,6 × 1000 × 15% = 240 watt peak.

The energy yield of 1 watt peak is approximately 850 watt-hours a year

- the efficiency of a solar panel depends on the irradiated energy and on the panel temperature (the warmer the worse).
- a solar panel will be subject to aging and pollution.
- a fixed solar panel almost never is mounted under the ideal angle of 36 degrees and is rarely exactly facing South.

The electric power of a standard solar panel = 240 watt peak.
So the annual yield is 240 x 850 watt-hours = **200** kilowatt-hours.

1 household = 10 kilowatt-hours a day = 3650 kilowatt-hours a year
1 household is the average consumption of **electrical** energy per household per year in the Netherlands.
Example:
The wind farm at **IJmuiden** generates 435 000 megawatt-hours per year. So that will be sufficient for 435 000 000 / 3650 = 119 200 households

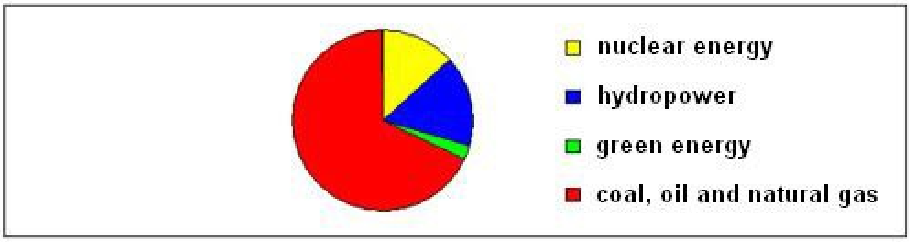
Tables and graphs

Distribution of the World Primary Energy Supply in 2014

oil	31,3%
coal	**28,6**%
natural gas	21,2%
bio fuel and waste	10,3%
nuclear energy	4,8%
hydro power	2,4%
geothermal, wind and Sun	1,4%
total world	100,0%

One may be "against coal" but that does not alter the fact that almost 29% of the total primary energy supply comes from coal

Energy sources for generating electricity worldwide in 2009



green energy = wind energy, solar energy, geothermal and biomass

Alternative energy sources

Anything can be calculated, but that does not mean that it can be achieved in practice, or that it is economically feasible

A good example of this is the "solar Tower". which should have a height of 1 kilometre. The highest building in the world (in Dubai) is 828 metres high. The efficiency of the solar tower is only 1,5%

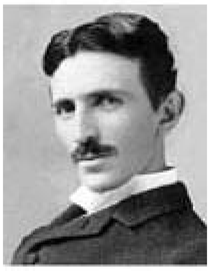
Solar Tower

Solar radiation warms the air located under a low circular, translucent collector. This collector is open at the border. The translucent roof of this collector together with the ground is a storage space for the heated air. A tower is stated in the centre of the round roof. The heated air rises in this tower. As a result new cold air enters on the edge of the storage space. At night also there is a continuous flow of warm air to the tower, because the entire ground surface consists of tubes filled with water. At daytime these tubes are being heated and at night they release their heat again. In the air flow to the tower a number of wind turbines are placed. The associated generators generate electricity. It is possible that such a tower might ever be built in Australia.

Some data

- the temperature of the air under the collector rises 30 degrees
- the speed of the airflow at the foot of the tower is 60 kilometres per hour
- the power is **200** megawatts
- the annual production is **680 000** megawatt-hours
- a 600 megawatts power plant produces **6** times as much energy in 1 year
- the tower is 1 kilometre high and the diameter is 130 metres
- the diameter of the round collector is 5 kilometres
- at the foot of the tower there are 32 turbines of 6,5 megawatts

Free energy



Nikola Tesla

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

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

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

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

Storage of Energy

Some forms of storage of energy

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

Energy saving

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

Heating of the house
The principle of Combined Heat and Power can also be applied in the heating of a dwelling.
A good example of this is the high efficiency electric boiler.
A better solution is the use of a heat pump.

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

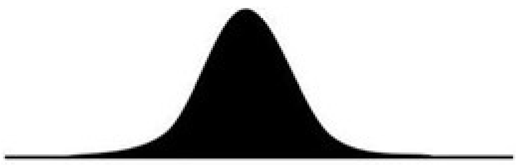
Car
One can achieve a considerable saving in fuel by driving a hybrid car. This can save up to 25%. Of course the only real saving is the abolition of the car. Unfortunately, public transport is of such poor quality, that this is a difficult step to take. Only an extreme increase in the petrol price,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

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

The energy-neutral home

- during a year the amount of energy generated must be equal to the amount of energy consumed
- usually the electricity is generated with solar panels
- water is heated by solar collectors
- as long as there is nothing conceived better, the grid functions as a buffer for the (temporarily) excess of electrical energy
- in summer the surplus electricity is fed to the grid and in winter the shortage of energy is reabsorbed from the grid
- the most important conditions for an energy neutral home are: good insulation of the roof, walls, windows, doors and floors
- large windows facing South, for maximum irradiation of solar thermal energy during winter
- above the windows there must be a canopy which prevents irradiation of heat when the sun is higher
- 3 layer glass
- thanks to the good heat insulation of 3 layer glass, no cooling is necessary in summer, while in winter heat losses are limited
- energy efficient appliances and lighting
- heat recovery at ventilation and when using hot water
- floor heating with a heat pump or with water from solar water heaters
- low temperatures, then the heat losses are small, so the efficiencies are high
- the relative heat losses decrease as a house is larger
- the heat losses are the smallest with a spherical shape (in practice a cube). Projections in the form of attached garages, greenhouses and dormers cause extra heat losses
- one must be able to verify if the energy generation is in balance with the consumption
- everything stands or falls with the motivation to save energy

The collapse of the Oil Economy



Civilization as we know it today will soon come to an end, because we will run out of oil. That is a scientifically based conclusion. The oil will not suddenly be gone, because its production follows a bell-shaped curve. On the ascending side of the curve cheap oil is available in increasing extent. On the descending side there is less oil, which is becoming increasingly more expensive. The top of the production coincides with the point, where half of the oil has been consumed. After the peak, the production takes off and the costs increase because it is harder to win the oil. Moreover scarcity has a very strong effect in rising the price. Yet this year (2007) the world oil consumption will exceed **1000 barrels per second**. (1 barrel = 159 litres)

Meanwhile (2014) the situation on the oil and gas market has changed completely. The oil price drops

- In America large stocks of shale gas and oil are discovered
- In 2005 America imported 60% of its need for oil. Now that has fallen to 30% and in time, America will even export oil
- It appears that also in Russia, Europe and Asia very much shale gas and oil will be found
- the global recession reduces the need for oil

Shale gas and oil
Shale gas and oil is extracted from shale formations Winning is accomplished by a major pollution of the environment. First there is horizontally drilling in slate Under high pressure a mixture of water, sand and chemicals is pumped into the horizontal well. This mixture causes mechanical stress in the rock, causing small cracks. The gas and oil in the rocks will be released trough these cracks

According to **IEA** (**I**nternational **E**nergy **A**gency) the global shale gas reserves are sufficient for **60** years of world consumption. The reserves of shale oil are almost equal to the proven conventional reserves It appears that there is no energy crises anymore, but only a **climate crisis**

How will the future look?

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

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

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

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

Green Energy
Green energy obtained from wind, solar, biomass etc. will be of little meaning provisionally. It is believed this will be up to 14% (in the Netherlands) of (only) the electricity in 2020. Wind energy is still in an initial state in some countries. Solar energy is still negligible. One should think of no more than a few hundreds of the total electricity generation. In 2009, the world production of solar energy was only **0,1%**

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

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

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

Hydrogen
Hydrogen can be produced using nuclear energy via a thermo-chemical process or by electrolysis of water. The necessary electricity for the electrolysis of water must be generated by nuclear fusion, or by "green" energy. But that is still a long way to go. Hydrogen is an "unruly" fuel, for which no infrastructure exists. The fuel cell is still far too expensive and requires much development yet. Hydrogen is **not** an energy source, but an energy carrier. Producing hydrogen by electrolysis of water costs **1,5 times** more energy than it delivers
So hydrogen is not a solution to the energy problem

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

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

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

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

These are going to be interesting times

Water example

To make clear the difference between **power** and **energy**, one often uses the qater example

power

- suppose, the water pipe is capable of supplying (maximum) 10 litres of water per minute through a tap in a bucket.
- then the **"power"** of the water pipe is **10 litres of water per minute**
- this power is also present when the tap is closed.

energy

- as soon as the tap is fully open, every minute 10 litres of water is flowing into the bucket
- for example, after 5 minutes 50 litres of water have flowed from the tap
- then the **"energy"** supplied is **50 litres of water**

The longer the tap is open, the more "energy" is flowing from it. If one closes the tap, the "energy supply" stops but **the power to provide energy remains**.

Energy and labour

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

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

Anecdote
During a birthday party I entered into conversation with a middle-aged lady The conversation soon went to trains and cars. **"Did You come here by train?"** she asked with an expression of disbelief and horror on her face. When I said that in the long term, we will run out of petrol, she suddenly became very aggressive. Her reaction was: "but you cannot suppose that I will stop driving my car?" (so even if the petrol has gone !?)

The most horrible stories about public transport are always told by people who never use it.

A book on energy

"Sustainable Energy without the hot air" (2008)
This book gives a complete overview of the (imp)possibilities of sustainable energy
Author: David MacKay, professor at the University of Cambridge. Read especially chapter 19: **"Every BIG helps"**

Some quotes from the book:

- if everyone does a little, we'll achieve only a little
- is the population of the Earth 6 times too big? (now 7,6 times)
- any sane discussion of sustainable energy requires numbers