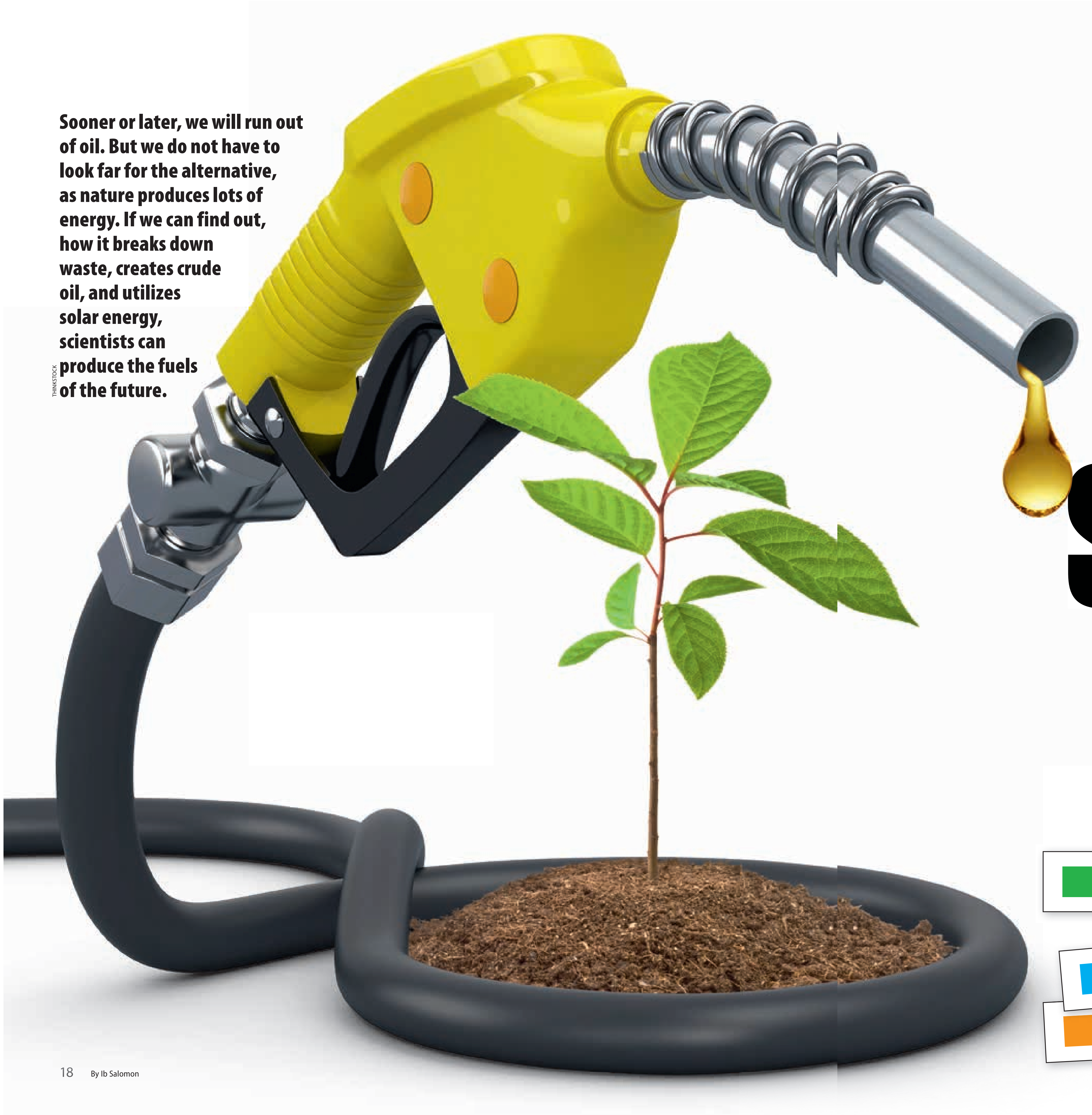
IN 2050 NATURE SUPPLIES OUR OIL

Sooner or later, we will run out of oil. But we do not have to look far for the alternative, as nature produces lots of energy. If we can find out, how it breaks down waste, creates crude oil, and utilizes solar energy, scientists can produce the fuels of the future.



THINKSTOCK

- Enzymes convert waste into oil
- Reactor brews crude oil in 0.5 hour
- Nanoforest turns sunlight into fuel

Enzymes convert waste into oil

Scientists use a wide range of enzymes to convert waste into a brownish liquid.
DONG ENERGY

WASTE IN – FUEL OUT

Pilot plants in Copenhagen convert household waste into an energy-rich liquid by means of enzymes. The principle of the reactor is the same as when waste and plants decay out in the open.

2. The waste is heated
Water is added to the waste, and both are heated to a temperature of up to 50-70 degrees. All paper is converted into a thick mass.

3. Enzymes attack
Enzymes are added to the mass, and the former react with the organic components. In 18-20 hours, the waste is broken down, and 90+ % of the biomass is utilized.

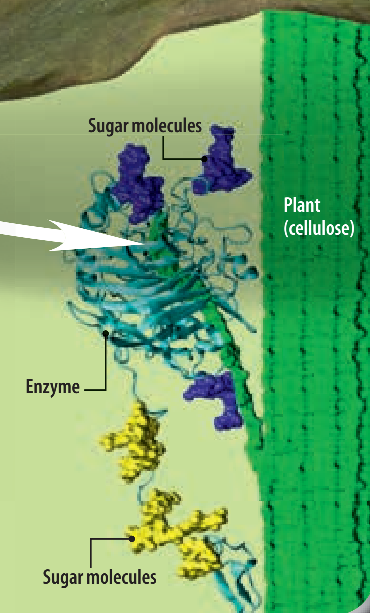
4. Two products come out
The result is an energy-rich liquid, which resembles diesel oil and can be used for biogas extraction or refined. Waste, which cannot be broken down, such as tins and plastic, can be recycled.

1. Waste goes in
A refuse collector unloads household waste into a silo.

CLAUS LUNAU

NATURAL ENGINEERS BREAK DOWN PLANTS

Enzymes are proteins, i.e. long chains of amino acids, which boost chemical reactions in living cells – like when a plant decays or is attacked by a fungus. The enzyme has a chemically active zone, which is customized for one particular plant molecule. When the molecule binds to the enzyme, it is split, and a product such as energy-rich glucose (sugar) is released. The enzymes are not consumed in the reaction and can carry out their tasks over and over again.



The Cel7A fungal enzyme rips the plant's cell membrane.

RENESCIENCE

THE NATURAL WAY

Scientists must resort to natural enzymes to break down green plants, trees, grass, etc.
SHUTTERSTOCK

Autumn holiday. Your family is on a road trip, and after several hours, it is time to refuel. Oil and coal are in short supply, and Asian superpowers are in control of the existing resources. Nevertheless, daddy parks at the pump, opens the fuel tank, and fills it up. The fuel is made from the waste, which your family threw out the other day, and there is lots of it.

The scenario, in which the Earth's fossil resources do not meet the needs of mankind, is only 40 years away, according to some models. But scientists need not look far for a solution. Nature is full of energy, generated by the green machines of our planet. Enzymes convert household waste into energy. Underground heat and pressure produce crude oil. And plant photosynthesis can extract fuels directly from the air. Scientists just need to find out how to do it.

We demand a lot from the successor of oil, as petrol and diesel involve great advantages. The fuels are easy to handle and boast high energy density. Pour 30 litres of petrol into your fuel tank, and they will take you 5-600 km.

But alternatives exist. For years, scientists have known how to produce fuel from for instance wheat, sugar canes, and corn. In Brazil, the government started to develop an alternative fuel infrastructure back in the 1970s. Today, more than 90 % of all new cars are fully or partly fuelled by ethanol made from sugar canes. But for ethical reasons, most scientists would rather not use potential food to produce fuel.

Consequently, they have started to take an interest in another abundant human resource: waste.

Loads of waste

Global agriculture and forestry produce approximately 140 billion tonnes of waste products a year, according to UNEP. Add to this the waste from cities, in which an average citizen produces 1.2 kg of waste a day, according to the World Bank. If treated in the right way, one of our major burdens could be the salvation of motorists. Nature commands an army of enzymes, which are able to consume our waste, be it ears of ▶

Horse dropping enzyme taps oil from trees

Wood is hard to convert into liquid fuel, as it contains a lot of cellulose, which is difficult to break down. But a scientist from the US University of California, Michelle O'Malley, may have found the answer in a horse dropping fungus. The fungus contains an enzyme, which breaks down cellulose into carbohydrates, that can be converted into fuel. Something similar is emerging in Austria, where scientists have modified the genes of a wood decomposing fungus. The enzymes will be able to convert for example sawings into biofuel.

Scientists look for usable enzymes everywhere – for instance in horse droppings.
SHUTTERSTOCK

THE NATURAL WAY

Underground oil was originally an organic material, which was subjected to pressure and heat.

SPL/SCANPIX

▶ corn or empty milk cartons. In the process, energy is generated, and scientists are thus trying to find the enzymes, which can turn our rubbish bins into fuel pumps.

In cooperation with the DONG Energy energy company, Danish scientists have developed a pilot plant, which copies the biological breakdown process, that goes on in nature. When the enzymes attack the waste, the end product is a brownish liquid, which contains so much energy that it can be refined into fuel over time. Since 2009, the test plant has processed one tonne of waste per hour and proved that enzymes can compete with roughnecks and oil fields.

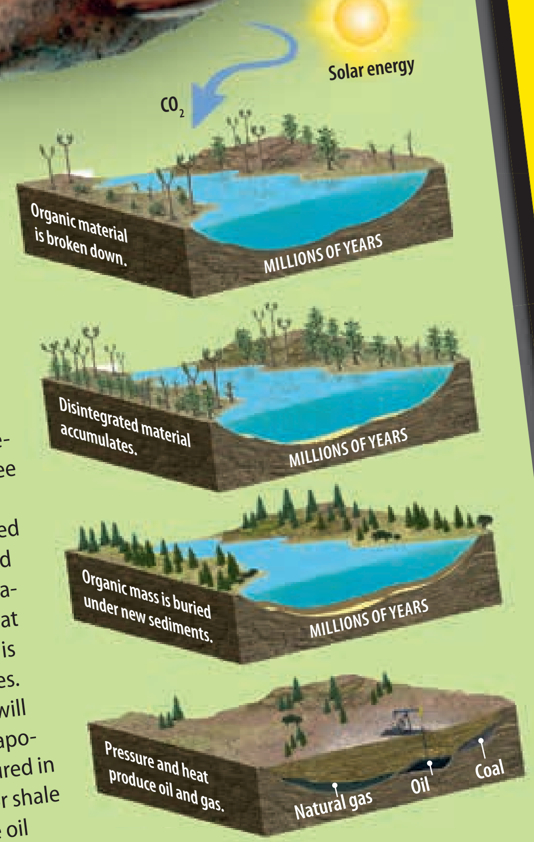
Even plastic can become oil

According to Senior Engineer Michael Skov Johansen, a commercial plant will probably be in operation within three years. The plant will be able to handle all household waste from a big city and convert most of it into fuel.

The input is waste of all sorts, which makes the method simple. Nevertheless, there will be things, which the enzymes cannot handle – typically metals and plastic. But earlier this year, a South African company introduced a technology, which can convert even plastic into crude oil, and the metals are easy to reuse, so 100 % recycling could be within reach.

NATURE USES MILLIONS OF YEARS

Crude oil is produced from organic material deposits such as algae, pollen, dead microorganisms, and plant debris. Over time, the substances become part of a so-called source rock and buried still deeper beneath new sediments. The temperature increases by 1 degree for every 30-40 metres, so the source rock is subjected to increasing pressure and temperatures. The generation of oil and gas starts at approx. 60 degrees, but is fastest at 90-120 degrees. The majority of the oil will move upwards and evaporate. But some is captured in oil traps such as clay or shale layers, which stop the oil from moving to the surface.



CLAUS LUNAU

Reactor brews crude oil in 0.5 hour

FAST OIL MACHINE

A sophisticated pressure cooker copies the natural way of producing oil. In nature, the process takes millions of years – scientists do it in half an hour.

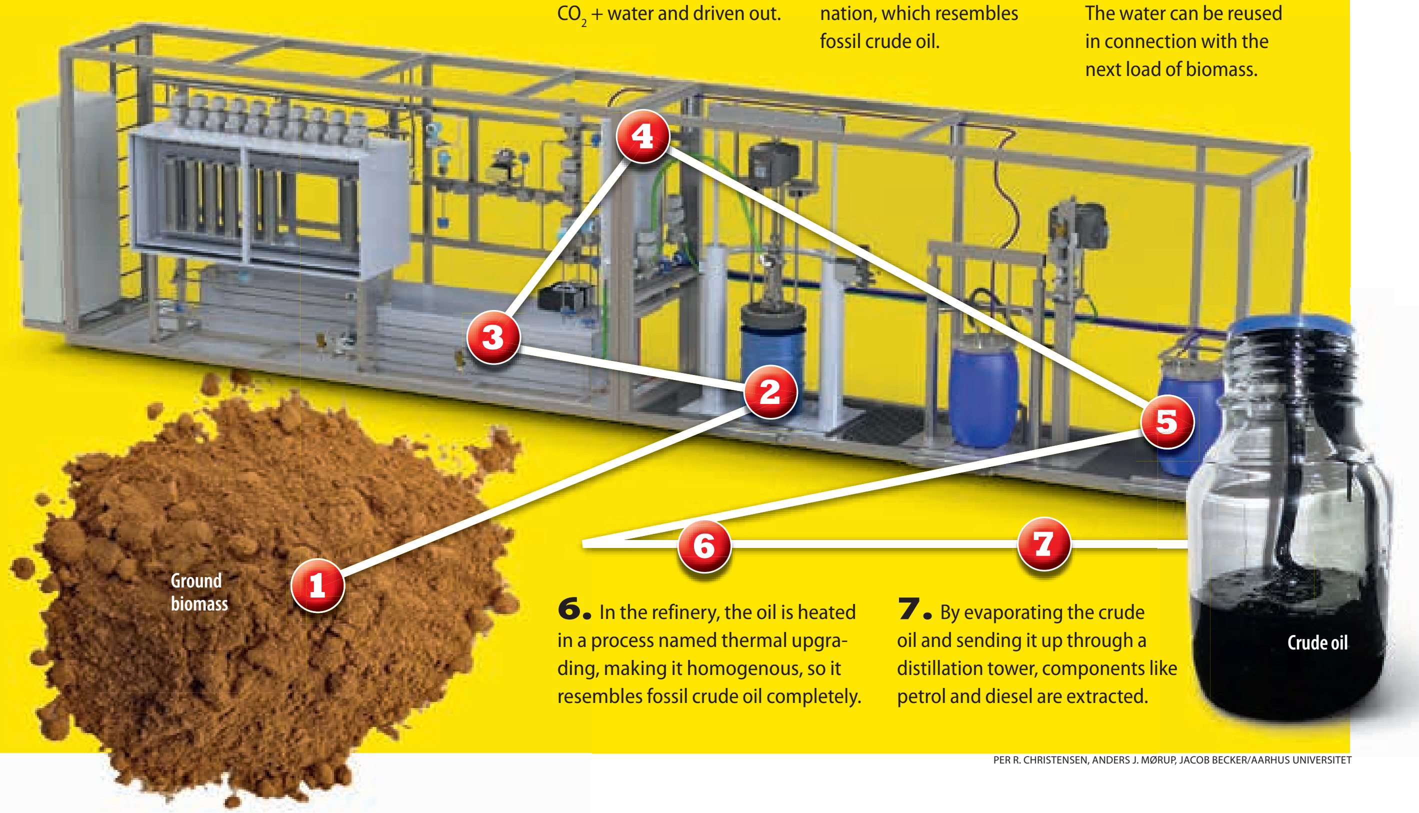
1. Biomass is fine ground. The test plant can handle straw, wood, rice husk, chipped bark, oil seed husk, or the like.

2. In a feed barrel, the ground biomass is mixed with reused water from the previous load, and catalysts such as calcium carbonate are added.

3. The mixture is heated and pressurized, so the water becomes supercritical. The biomass is broken down into small molecules. Oxygen is converted into CO_2 + water and driven out.

4. Hydrogen and carbon molecules remain. In the reactor itself, the small molecules get together, forming long chain hydrocarbon molecules: a combination, which resembles fossil crude oil.

5. A barrel collects oil, process water with water-soluble components, plus solid substances. Outside the plant, bio crude oil and water are separated. The water can be reused in connection with the next load of biomass.



6. In the refinery, the oil is heated in a process named thermal upgrading, making it homogenous, so it resembles fossil crude oil completely.

7. By evaporating the crude oil and sending it up through a distillation tower, components like petrol and diesel are extracted.

STEEPER ENERGY & THOMAS HELMER PEDERSEN/AALBORG UNIVERSITET

PER R. CHRISTENSEN, ANDERS J. MØRUP, JACOB BECKER/AARHUS UNIVERSITET

Production takes millions of years

In nature, where the biological breakdown is not disturbed by engineers and chemists, organic waste such as algae, collapsed trees, and dead animals are left to themselves, and after millions of years, they have turned into oil, gas, and coal captured deep in the ground. The process is a tough one, but nature can convert almost anything into pure energy.

So what if we did not have to wait for millions of years? What if we were able to produce oil from our waste right now? Another Danish team of scientists has managed to do this. In a test plant at the Aalborg University, scientists have copied natural oil production on a small scale. One of the main elements of the so-called HTL (Hydrothermal Liquefaction) process is water, which is otherwise a byproduct of biomass treatment. By heating the water to 400 degrees and increasing the pressure to 250-350 ATM (corresponding to the pressure approx. 3 km below the ocean surface), the liquid enters a supercritical state.

Under such conditions, the water becomes extremely reactive and is converted into a strong dissolving agent. Straw, wood, and rice and oil seed husk, which are otherwise not ▶

▶ dissolved, will be dissolved. The reactor can break down almost any type of biomass. And it does it so efficiently that the mass is split into very small chemical building blocks like carbon and hydrogen. Compared to other types of breakdown, the crude oil becomes homogenous in this case, no matter what type of biomass the reactor is fed, and up to 90 % of the energy is utilized. The bio crude oil can be processed in a refinery, and the end products are for instance petrol and diesel.

So far, scientists have aimed to control the process, so the oil production in the small reactor is modest – 1-2 litres per hour. The head of the plant, Professor Lasse Rosendahl, does however expect that the next step will be a demo plant, which will produce 48,000 litres of crude oil a day.

Extracting fuel from the air

But even waste is a scarce resource, so scientists ultimately dream of producing fuel from the air. It sounds like pure science fiction, but a glance out of the window demonstrates what to do.

Natural photosynthesis produces all the energy, which makes our planet habitable. Plants utilize sunlight to produce oxygen and sugar, and if scientists are able to copy them, we will have cheap energy forever. Scientists can "build" fuel from the chemical compounds of photosynthesis. And the energy will even be environmentally friendly, as artificial photosynthesis will utilize the CO_2, which is already contained in the air, and the only "waste product" will be oxygen.

Still, experts have had to realize that it is very difficult to copy nature. The majority of the processes, which are involved in natural photosynthesis, can be recreated in the lab, but so far, the energy output is very modest.

The scientists, who have achieved the most, are a team from the Lawrence Berkeley National Laboratory in the US. In May, they published their preliminary results. The scientists have built a nano-version of a forest, in which microscopic structures split water into oxygen, hydrogen ions, and electrons, just like in plants. The electrons and the hydrogen subsequently convert the CO_2 into hydrocarbon, which is what scientists are after, as hydrocarbons are so to speak the building blocks of our fuels.

But so far, the outcome has been nothing to write home about, as only 0.12 % of the sunlight is turned into energy. If the same were true for crude oil, we would get 1 litre of fuel per 834 litres of crude oil.

One big challenge consists in finding the right catalysts. Nature uses manganese, but that is not necessarily the most efficient, according to scientists. Even plants do not utilize more than 2-5 % of the solar energy. With the right catalyst, artificial photosynthesis could become much more efficient.

The head of research, Peidong Yang, is sure that the team will soon manage to multiply the production. If so, the perspectives are promising. In just one hour, Earth receives enough energy from the Sun to cover our needs for a whole year.

However, most experts agree that commercial utilization is well into the future. But until then, the more earth-bound alternatives are ready to take over, so the world does not stop, the day the oil supplies run out. □

THE NATURAL WAY

Photosynthesis has existed on Earth for 3.7 billion years. Nevertheless, scientists are struggling to copy it, as plant chemistry is highy sophisticated.

CLAUS LUNAU

NATURE IS A CHEMICAL ENERGY EXPERT

Based on something as easily accessible as sunlight, plants, algae, and blue-green algae produce both glucose and oxygen. Every year, some 200 billion tonnes of organic compounds, which animals and humans feed on, are generated. Photosynthesis consists of a complex series of biochemical processes, which physicists have been struggling to understand for years.

The majority take place in the plants' leaves, or in the chlorophyll of the chloroplasts, which are found in the mesophyll. Through small cracks, the leaf gets CO_2 from the air for use in photosynthesis, in which manganese functions as a catalyst. The plant mostly uses the blue and red parts of the sunlight, wheras the light of the green spectrum passes right through the leaf or is reflected – thus plants are green.

The products of photosynthesis can be converted into fuel, so scientists would really like to copy the process. And improve it. No matter how efficient plants are, they do not utilize more than 2-5 % of the solar energy affecting them: too little to make artificial photosynthesis worthwhile.

Microbe converts CO_2 into fuel

Scientists of the University of Georgia in the US have found a microbe named Pyrococcus furiosus, which lives in the deep sea. It converts carbon dioxide into a chemical, which can easily be used as fuel. By means of gene modification, scientists hope that the microorganism can extract CO_2 from the air and convert it into fuel.

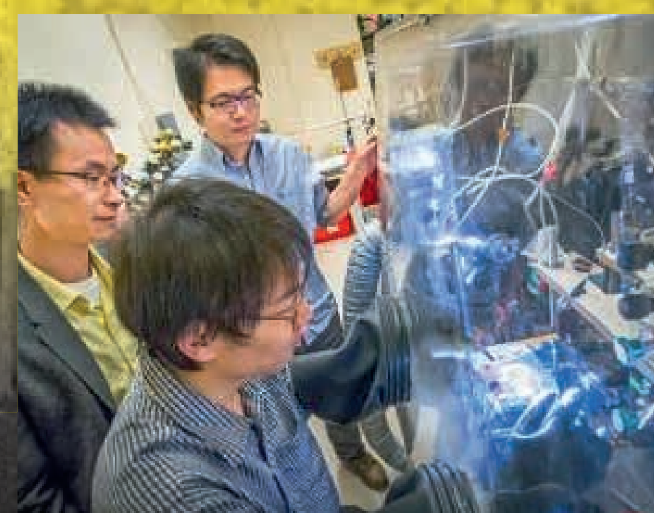
FUJI/VO314

Nanoforest turns sunlight into fuel

SILICON TREES SUNBATHE

American scientist have established an artificial, nanosize forest, in which the leaves absorb sunlight and split water into oxygen, hydrogen ions, and electrons. The end product is hydrocarbon, the cornerstone of our fuels.

PEIDONG YANG/UC BERKELEY



Chong Liu from the US Lawrence Berkeley National Laboratory demonstrates his and his colleagues' artificial photosynthesis.

1 Brushes capture light
The trees have bushy canopies with leaves pointing in all directions. This provides a large surface to capture the light.

2 Dense forest boosts efficiency
Flexible silicon trunks make up a dense latticework of trees and absorb the visible light. The trees are designed to reflect as little sunlight as possible for the sake of efficiency.

3 Petals eat UV rays
When the sun is shining, the leaves absorb the light, and titanium oxide reacts with the UV rays. Along with the trunk, the leaves split water into oxygen, hydrogen ions, and electrons.