BRINGING IN THE CHEMICAL HARVEST

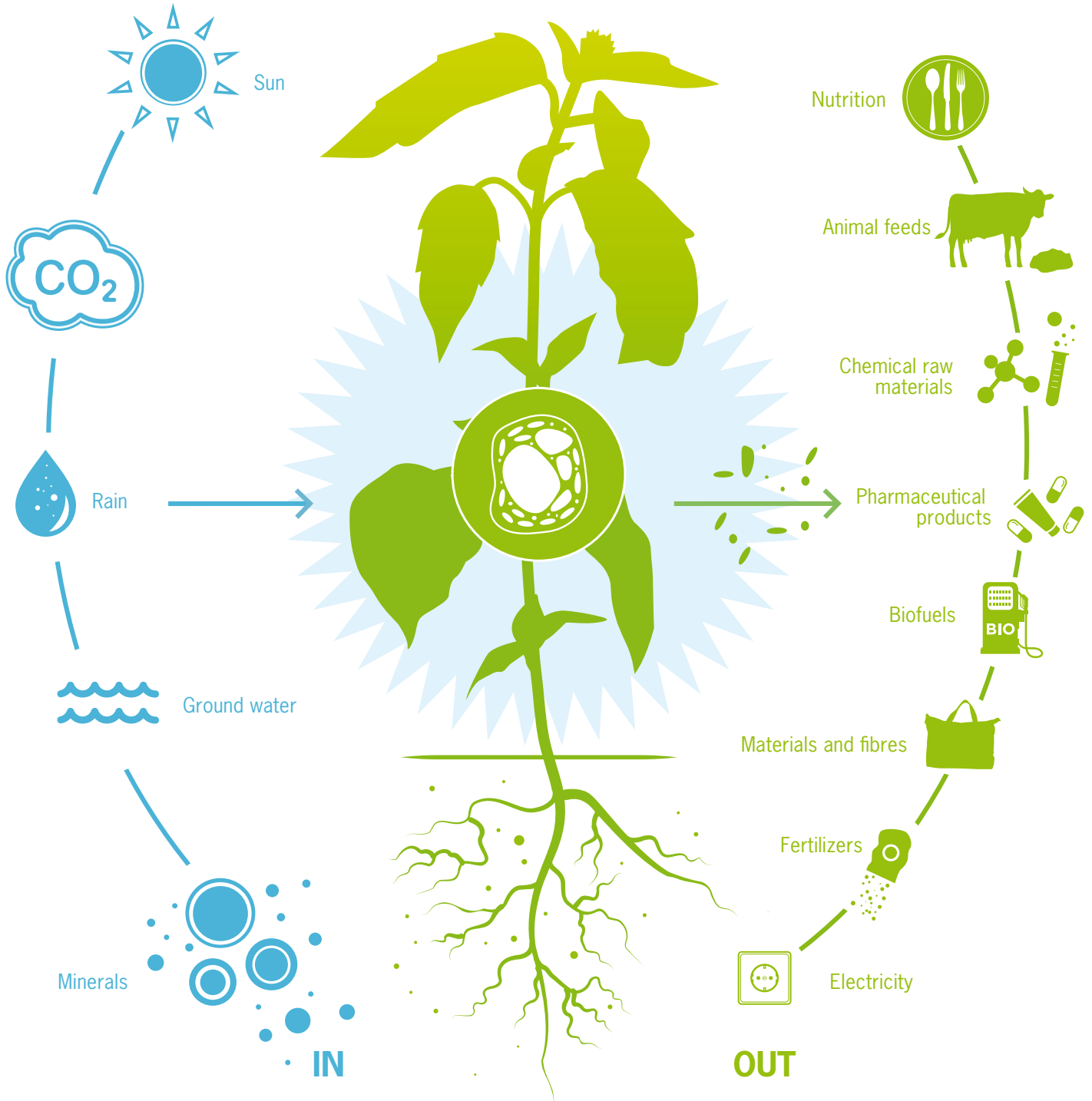
The green factory

Plants seem to be well suited to the production of a large variety of raw materials for industrial use and for medical drugs. Wageningen researchers are working on several fronts to perfect the processes that make this possible. It may lead to the production of a cancer drug from potato leaves. **TEXT** RENÉ DIDDE **PHOTOGRAPHY** GUY ACKERMANS **ILLUSTRATIONS** KAY COENEN

Agricultural crops are not just a source of food but can also constitute a factory for the production of green raw materials. Along with the climate crisis, rising prices of conventional raw materials are stimulating the rise of the 'biobased economy'. Researcher Andries Koops of Plant Research International, part of Wageningen UR, puts it like this: 'A sugar beet plant, for example, is really a highly efficient factory. One hectare of sugar beets has the same production capacity as a 100 litre industrial fermenter, which requires pumps, cooling, thousands of kilos of stainless steel and loads of energy. A sugar beet is a self-contained factory based on sunlight; 60 percent of the factory is underground and 40 percent of it is located in the leaves. Which we don't do anything with; we just throw them away.' In the Radix building nearby on the Wageningen campus, Luisa Trindade, Biobased Economy research group leader at Plant Research International, tells a similar story. She is trying to link up the agricultural sector with the chemical industry, with the potato as the go-between. 'Of course we are all familiar with the potato from our mash or our French fries', says the Portuguese researcher. 'It is also well known that tens of thousands of hectares of potatoes are grown for starch for the food industry, but quite a lot of the starch also goes into the chemical industry for use in products such as glue, plastic and paper.' But the possibilities do not end there. 'Potato leaves, which go entirely unused to date, contain substances that can slow the growth of cancer, or perhaps even prevent it. And parts of the potato waste can be used to generate energy.'

OIL-DEPENDENT

The key motive for developing these new uses for plants is to create an economy which is no longer dependent on the oil >


Sun
CO_2
Rain
Ground water
Minerals
IN
Nutrition
Animal feeds
Chemical raw materials
Pharmaceutical products
Biofuels
BIO
Materials and fibres
Fertilizers
Electricity
OUT

ANDRIES KOOPS,
manager of the Bioscience business unit at Plant Research International, part of Wageningen UR

'We are not talking peanuts but massive amounts of raw materials, all currently sourced from oil'

industry, but runs instead on renewable resources and fuels. Green raw materials are badly needed if ambitious sustainability goals are to be reached. The chemical industry, for example, aims to get half of its raw materials from renewable sources by 2030. At the moment the figure is one percent. Not long ago, the Dutch government was aiming at reducing CO_2 emissions by 30 percent by 2020, but it has recently shifted the goal to 14 percent. And the Platform for Biobased Raw Materials has set its sights on the Netherlands obtaining 30 percent of its energy from non-fossil fuels by 2030. At present barely 6 percent of the country's energy comes from renewable sources, and that is chiefly in the form of heating generated by burning waste.

Yet these ambitions are not just empty promises and hot air. The green future is closer than we think. Mice exposed to substances in potatoes isolated by Luisa Trindade develop fewer cancers. Andries Koops has successfully made the potato produce 15 times more lysine than it usually does. Lysine is an essential amino acid for humans and other animals, but it is also a suitable basis for caprolactam, which in turn forms the basis for nylon production. 'Globally, we now produce 2.5 million tons of this stuff from crude oil, using a great deal of energy', says Koops.

The ultimate goal for the Wageningen duo is to get plants to produce the desired 'chemical' substances directly, making it possible to harvest pure chemicals and intermediate products more or less directly from the land. Trindade explains that potato starch

manufacturer Avebe has to use substantial quantities of chemicals in order to adapt the starch for industrial uses. 'That takes amounts of energy equivalent to the annual consumption of a city like Amsterdam', says Trindade. This would no longer be necessary if the plant was able to synthesize the right kinds of starch itself.

THE POTATO AS MODEL CROP

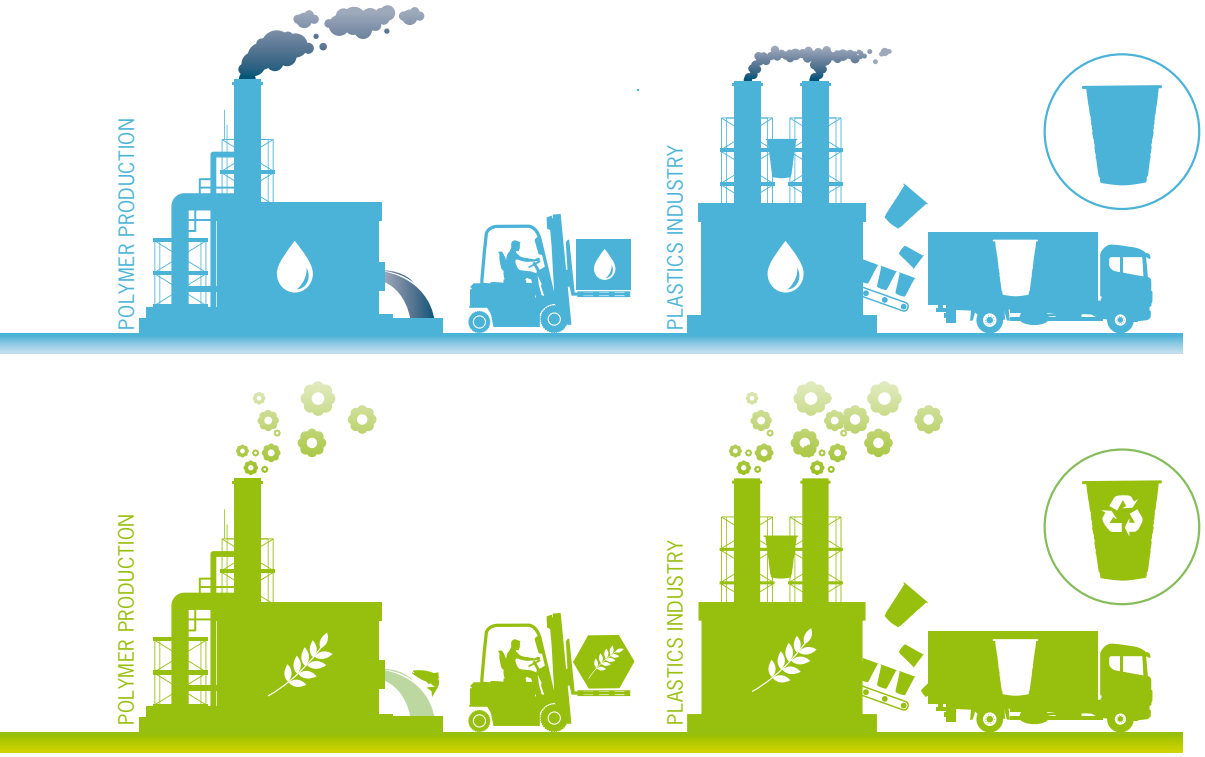
But the plant will not do that of its own accord or for no good reason. 'We have to give the crops a helping hand and also to accept that the production of directly usable green raw materials happens to some extent at the expense of the production of – for example – sugar from sugar beets' says Koops. But that is the least of their concerns. 'Lysine is already worth four times as much as sugar, so it more than compensates for the lower sugar harvest.'

Giving the plant 'a helping hand' is easier said than done, though. It is done by cross-breeding plant species and using genetic modification. Koops is now conducting his research on the model crop, the potato. 'If it works well in the potato, it will be a smaller step to do it with the sugar beet', he explains. In the case of lysine production, he exchanges a base pair in the gene for an enzyme that usually limits lysine production once enough has been produced for the potato's metabolism.

Koop's team is now working on a second change. 'We hope to use this to increase lysine production by five times. After that it will take us another four years to build the mechanism into the beet, hopefully >

LUISA TRINDADE,
lecturer and Biobased Economy research group leader at Plant Research International, part of Wageningen UR

'If only because of the bio-energy, the 'plant as factory' is viable in the short term'



resulting in a beet that produces 500 to 1,000 kilograms of lysine per hectare. Our business case study suggests that at that production rate it is commercially viable' says Koops. 'Some Dutch companies are sure to be interested', he expects. It is up to society to decide whether we are going for a biobased economy, thinks Koops, but in his view there is not much choice. 'You cannot get chemical resources such as lysine from a wind turbine or a solar panel. When the oil runs out, plants will be the only way of securing the raw materials for the chemical industry. It is the job of scientists to show that it is possible to contribute in this way to solving global problems such as climate change and sourcing raw materials. And then it is up to society to decide.'

ABSORBENT DIAPERS

Another promising substance for production in plants is itaconic acid, a product which can be derived from the metabolism of the citric acid cycle in the plant. 'Itaconic acid is still made my means of a micro-organism, but we think plants would be cheaper', says Koops. The acid is used in the plastics industry for manufacturing polymers, but if the production price went down, it could also be used to produce polyacrylates, used for their super-absorbent properties in diapers. Koops: 'Please note, globally we are not talking peanuts, but massive quantities of raw materials, all currently sourced from oil.' In a comparable way, Trindade is working on changing potatoes. 'With the help of chemicals we are inducing a mutation in the genetic coding of an enzyme. We do this with the aim of stimulating the potato to produce starch that contains a lot of phosphate, opening up various potential applications', explains Trindade. 'If we do the opposite, we get the opposite effect: starch that is very well suited to processing in 'light' products.'

BIOBASED RESEARCH AT WAGENINGEN UR

Production of chemicals from green resources

e.g.: producing isosorbide from starch sourced from grain, maize or potatoes. Isosorbide can be used to make a new kind of phthalate-free plasticizer.

Manufacturing materials from green resources

e.g.: poducing polylactide (PLA) packaging from sugary waste matter.

Research on the adaptation of crops

For use in a biobased economy. Example: a cross between Miscanthus and sugar cane.

Biorefinery

Producing food, energy and chemicals, all from the same crop. Example: making crop waste products suitable for fermentation into biofuels. But biorefinery also includes such processes as the extraction of amino acids from grass, and this entails research on the logistical chain and production process as well.

Social and economic aspects of biomass use

Examples: studies on sustainability or how to optimize the production chain, and life cycle analyses. There is also important research going on into potential land use changes resulting from competition between biofuels and food.
Info: Erik van Seventer, Wageningen UR Food & Biobased Research

There are potential applications not only in the food industry but also in pharmaceutical and medical products, reckons Trindade. Genetic modification, or the creation of mutations in genetic material using chemical substances, happens in a far more controlled manner than do natural genetic changes, whether in nature or in classical breeding methods, she points out. 'You know exactly which characteristics you are introducing into a plant. With classical breeding it is more a case of waiting to see how it turns out.'

BREAKING DOWN LIGNIN

Luisa Trindade is also working on ways of making the woody parts of a plant, such as the stalks of Miscanthus and maize, more suitable for fermentation. This would make it possible for yeast cells to use far larger quantities of biomass for manufacturing ethanol. Miscanthus is one of the best crops for this form of biofuel production. Trindade sums up why: 'Its production costs are low and so is its nutrient consumption, while its net energy yield is very high. What is more, this plant can fix nitrogen from the air.' One of the focal topics of the research is lignin, a substance which forms a protective coating on digestible cellulose and hemicellulose and up to now has hindered yeast cells in breaking down matter to produce the biofuels bio-ethanol and biogas. 'We have conducted tests in which we fed Miscanthus to a whole series of fungi. The fungi that can grow on it are the ones we need because they break down lignin. We must make sure we build the proteins that are responsible for this into Miscanthus' says Trindade.

But the researchers' repertoire does include classical plant breeding methods too. 'For example, we want to cross-breed Miscanthus with sugar cane', explains Trindade. 'Sugar cane is highly suited to fermentation for ethanol, but unfortunately it does not grow in Europe. We have already got a long way with this research.' Just like Koops, she expects to see interest from companies wanting to market her new plant varieties.

> 'Potato leaves go entirely unused but contain substances that slow the growth of cancer'

RISING OIL PRICES

It is a promising and sustainable perspective. But the question is: is there a market for these newly bred plants as producers of green raw materials? Sure, there is, say Koops and Trindade unequivocally. 'If only because of the bio-energy, the 'plant as factory' is viable in the short term', Trindade believes. 'Oil prices are rising steadily. In a few years' time, if the market for green raw materials takes off, the cost price will go down and biobased resources will become increasingly valued as part of the economy. We are working out production chains together with plant breeding companies and the processing industry.'

Andries Koops has equal faith in the prospects of a breakthrough of the biobased economy. 'The more oil prices go on rising, the more this alternative has to offer.' He thinks it is important to make sure the biobased economy goes hand in hand with sufficient food production and the conservation of nature areas. Koops: 'For this reason we need in any case to raise the production per hectare, so that we generate a surplus for markets over and above the food and animal feed markets, while simultaneously reducing the need for scarce resources such as water, nitrogen and phosphates.' ■

MINISTER VERHAGEN GIVES 5 MILLION

The Centre for Biobased Economy of Wageningen UR is to receive 5 million euros. This was announced by Maxime Verhagen, Dutch minister of Economic Affairs, Agriculture and Innovation, during a working visit to Wageningen at the end of January. 'Through Wageningen University, the Netherlands is becoming a centre for biobased research', said the minister. 'We can use algae and plants to manufacture valuable green products. Sustainable fuels can help us reduce CO_2 emissions. Like this we will have not just a cleaner economy but also a more innovative one with which we can make money.' Verhagen embroidered on his theme during a guest lecture to students. He does not want to invest more in innovation, but more effectively. 'I would rather invest in a few world-class knowledge and research institutes such as Wageningen UR than in a patchwork of small, isolated institutes.' Collaboration between knowledge institutions, the business world and the government is the key to economic success, said the minister.