WOBOT

by

TEAM EKOPAÍS

EXECUTIVE SUMMARY

With the growing population, the demand for food is higher than ever and so is the need for efficient agriculture. The result is a high use of fertilizer. Because of large amounts, but a lack of raw material, the need-based fertilization increases. The remaining problem is the excess of fertilizer from the previous years. Since the industrial production of fertilizer, the distribution increased that much, that the amounts in the environment are reaching critical values.

To reduce that huge amount of nitrate, which has negative impacts on human and environment, the design concept „WOBOT“ is developed. It is a system consisting of autonomous robotic worms that collect excess of fertilizer in the soil. An autonomous field robot is provided for the supply of the worms.
With this system it would be possible, to rid our soils of nitrate.

Whitepaper
by Team Ekopaís
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1

CBI A^3 PROGRAM

What is behind the CBI A3 program?

We as Team Ekopaís are part of the Design Factory „Inno. space“ at the University of Applied Sciences Mannheim. In the last 8 months we have participated in the interdisciplinary program: CBI A³ - Challenge Based Innovation.

This is an initiative of the Design Factory Melbourne for the Design Factory Global Network (DFGN) in conjunction with IdeaSquare Cern. The challenge is to connect CERN technology with societal needs and create a design innovation for the future 2030.
In this year the United Nations Sustainable Development Goal (SDG) 15 „Life on Land“ gave us the framework, within we – 3 multiplinary teams: 2 of Mannheim and 1 of Melbourne – developed and prototyped respectively a design concept for the future.

The goal is to give CERN technology a second life, contributing to a sustainable world and getting us students to think big and be creative and innovative.

Figure 1: SGD 15

The UN‘s SDG 15 aims to protect and restore our terrestrial ecosystems for sustainable conservation and use. This includes combating desertification, halting and reversing land degradation, and reducing biodiversity loss. [1]

2

TEAM EKOPAÍS

We are Team Ekopaís.
An interdisciplinary team out of four students with different study and interest backgrounds.

What does Ekopaís mean?
We wanted to connect the challenge „Life on Land“ with our language interest and the connectedness with everywhere in the world. Eko is a short form for ‚ekologinen‘ the Finnish word for ‚ecological‘ and ‚país‘ is Spanish and stands for ‚land‘.

Naemi Maile
Chemical and process engineering
Think „outside the box“ and try to make the world a little bit better was her motivation to participate in this project. Happy to have been part of the project, she takes away from it that crazy big thinking is sometimes the key to happiness – the key to develop something new and bring change.

Carina Galante
Business engineering
The CBI A3 was a new challenge for her where she saw the opportunity to self-grow and learn new ways of thinking. During the CBI A3 Projekt, it was a lot of fun for her to work in an interdisciplinary team where everyone had different ideas and perspectives. It was very interesting to see how different people look at things.

Christian Müller
Computer science
To improve his prototyping and design thinking skills, he decided to participate in this project. Together with his team, he now wants to contribute to the achievement of SDG 15 – Life on Land. Being a student at inno.space was a unique, hands-on and amazing experience that cannot be compared to any other course.

Matthias Bachstädter
Chemical and process engineering
Joining the project was a spontaneous decision, with the knowledge, to do something for the environment. He aimed for a successful conclusion of the project. For him, it helped, to find such a conclusion, to go to the ideation square of CERN in Geneva.

3

PROBLEM SPACE

„*Nitrogen compounds that threaten our groundwater [and environment] are one of the biggest unsolved environmental problems of our time.*“

[Christian Meyer, Lower Saxony Minister of Agriculture] [2]

Nitrate Contamination of Groundwater
(692 Measuring Stations in Germany) [3]

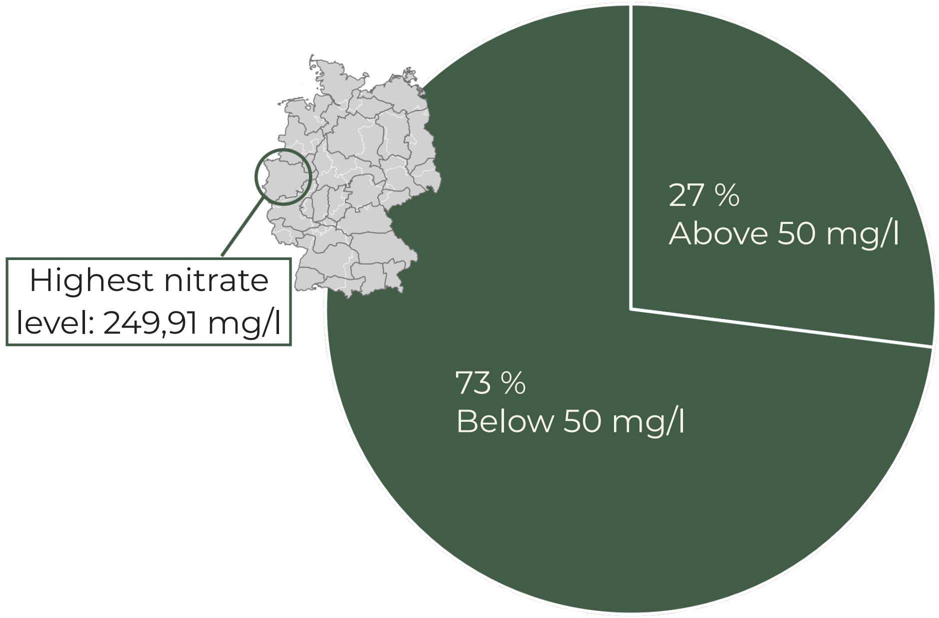


Figure 2: Nitrate Contamination

For many years, nitrate contamination in Germany have exceeded the limit of 50 mg/l groundwater at a quater of all nitrate measuring stations. In addition to impairing the ecosystem, for example through the eutrophication of water bodies, nitrate-contaminated drinking water also harms human health. [4]

The earth's atmosphere consists of 78 % nitrogen. Nitrogen is an indispensable nutrient for all creatures on this earth, including above all for the growth of crops. However, plants cannot simply use the nitrogen of the air, only in chemically converted form like nitrate. For decades, nitrogen compounds have been added to plants in agriculture by soil fertilizers (organic or mineral). With the intention to increase harvests in line with the growing world population that needs to be fed. In the process, the exact amount of fertilizer required was and still is not taken into account in large parts. Particularly as a result of factory farming, excessive amounts of organic fertilizer from animal excrement are often spread on agricultural land. According to studies, only 20 to 30 % of the fertilizer applied in one cycle is consumed by the plants [5]. Currently, there is an annual nitrogen surplus of approximately 80 kg/ha of agricultural land. Nitrate that is not absorbed, the so-called surplus, is washed out by rain due to its easy solubility and ends up in groundwater, surface water or in the air with fatal consequences for the environment and humans. [6]

Indicative of high nitrate levels in the soil, are the nitrate levels in groundwater. Overall, around 27 % of the 692 nitrate measuring points in Germany currently have higher values than the specified limit of 50 mg/l groundwater (see „Figure 2: Nitrate Contamination“).

Why is the limit value 50 mg nitrate/l in groundwater?

Based on the EU Groundwater Directive 2006/118/EC, the threshold value of maximum 50 mg nitrate per liter was set in the Grundwasserverordnung (GrwV). If the value is above this, treatment of drinking water is significantly more expensive and complex. The threshold value was set for reasons of health protection. It was calculated on the basis of acute toxicity for sensitive infants. Nitrate itself is harmless to the human body. It becomes dangerous when the nitrate is converted to nitrite in the body. Infants have a less acidic stomach environment with different bacteria than adults, which can lead to a reduction of ingested nitrate to nitrite. [7]

If the nitrite enters the blood, oxygen uptake is reduced and there is a risk of suffocation (blue infant syndrome) [7]. For the limit calculation, the long-term cancer risk to adults from nitrate exposure was not considered. A study from Aarhus University examined the association of long-term nitrate exposure via drinking water with colorectal cancer risk [8]. This found out that the nitrate limit is significantly overestimated. The known harmful effects of too much nitrate on the environment were also not included in the calculation. This is probably because exact numerical values are not possible, as several influences interact.

Many companies are currently working on solutions for needs-based fertilization, so that there is less nitrogen surplus in the soil. By 2030, the German government wants to reduce the nitrogen surplus to 70 kg/ha*a [9] in soil. However, despite new fertilization regulations to apply less fertilizer, nitrate levels in groundwater continue to be exceeded at present. And especially in the winter months, when fertilizer is not actually applied at all. For infomation - fertilization period is spring/summer.

What is the reason for this?

Nitrate is easily soluble in water. If it rains, the nitrate is washed out and either carried into deeper soil layers or into surface waters. The further path of the nitrate to the groundwater depends on the hydrochemical conditions in the subsurface. It can take up to 20 years for the nitrate to reach the groundwater. Accordingly, the partly elevated measured values today are consequences of earlier times. [10]

„Nitrate that today pollutes the groundwater, was under circumstances already fertilized 20 years ago.“

J. Schulz-Marquant

Dangers for the environment

In addition to the health hazards for humans, there are also negative effects on the environment. Two big effects are eutrophication and soil acidification.

Eutrophication

A nitrate surplus leads to the so-called eutrophication of the surrounding landscape and water bodies. The oversupply of nutrients from agriculture causes increased growth of unicellular algae in water bodies, for example, which in turn displace other plants and thus lead to a decrease in biodiversity. Due to the strong oxygen depletion of the algae, the fauna and fish living on the seabed also die. Worldwide, 43.2 megatons of nitrogen enter our oceans every year, and 80 % of marine ecosystems are affected by eutrophication. [11]

In terrestrial ecosystems, an oversupply of nitrogen can have long-term negative effects on vegetation and species composition. Plants and animals adapted to nutrient-poor living conditions can be displaced by nitrogen-loving species that then spread more widely. As a result, vegetation may become uniform and biodiversity may decline. [11]

Soil acidification

The nitrate excess, which is leached-out into the groundwater, leads to base leaching, thus an altered ion composition in the soil and accelerates soil acidification. At the same time, this is associated with changes in the soil structure and the living conditions for soil microorganisms. As a result, this can have an impact on soil fertility and quality of plant products. [12]

The SDG 15 covers exactly these areas that are affected by high nitrate pollution in the soil. With our project WO-BOT we want to contribute a part to SDG 15 and reduce nitrate pollution.

4

FUTURE SCENARIO

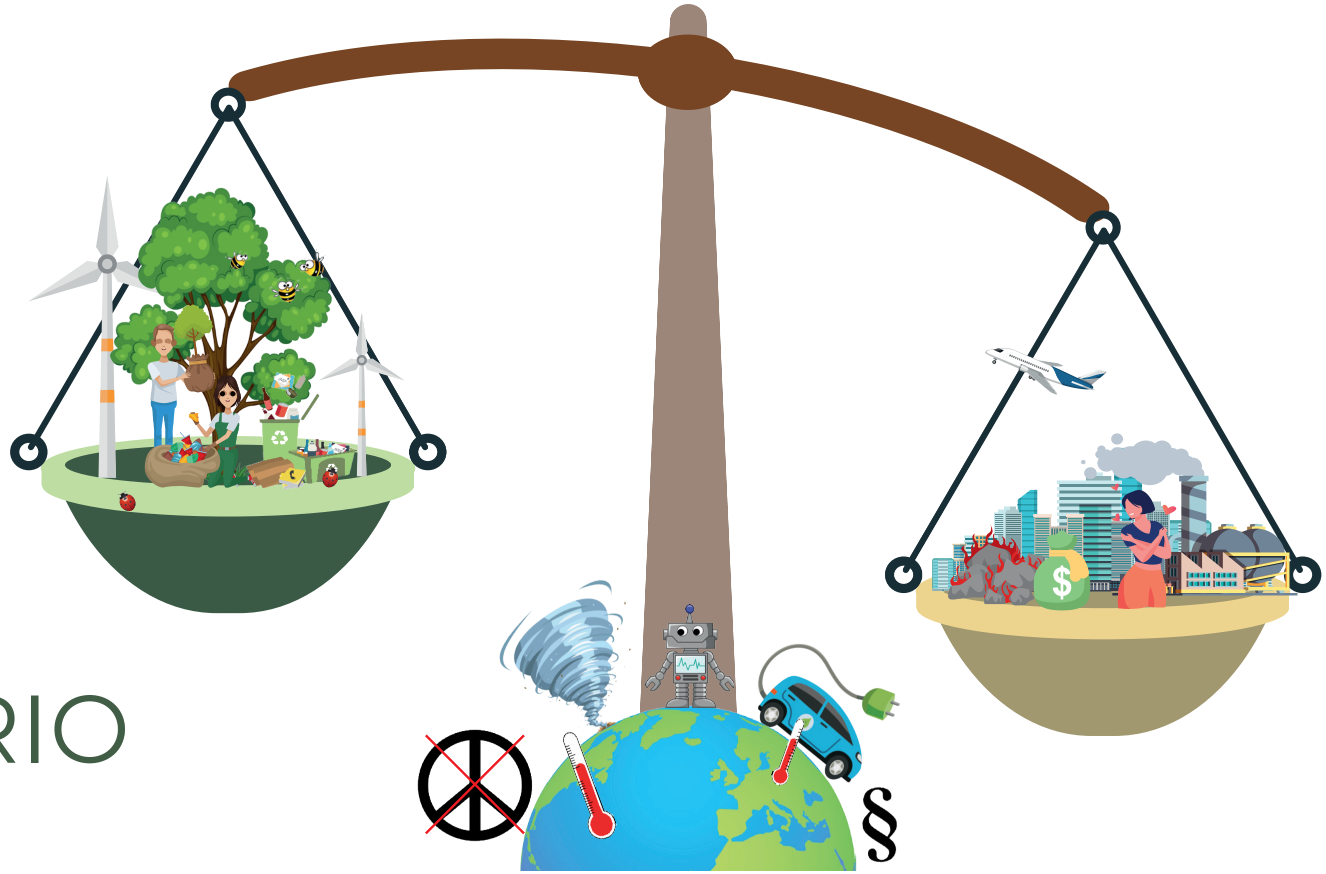


Figure 3: Future scenario 2030

Our design concept is intended for the year 2030, in other words for the future. Until that time our world will still be changing. This means that we cannot base the design of our concept on current conditions, right?

We have to consider what society, politics, technology, etc. will look like in 2030. Since the future is an uncertain component, we can only develop a future scenario that we believe is most likely to occur.

In our future scenario „Green Shade“, society is divided. The minority tries to actively fight climate change. The awareness for the environment and sustainability is strong. In contrast, the majority continues to live as before. This means that they see the responsibility for actively fighting climate change not in themselves, but in politics and business. Therefore, they are not prepared to put their own needs behind climate protection. Here, the human being, the individual, comes first, who lives according to the philosophy:

„After me, the deluge, but please with a good conscience“.

In 2030, however, some political measures will be taken against climate change. People will switch to electric mobility, renewable energies will account for a large part of electricity production, subsidies for sustainability concepts in industry, penalties for companies with a weak eco-balance, etc. Nevertheless, the measures are not sufficient or are implemented too late to achieve the climate goals of the Paris Agreement. For example, coal power plants continue to produce high CO_2 emissions. As a result, weather extremes are becoming more frequent and natural, biodiversity as well as human and animal habitats continue to be endangered. [13] [14] [15] [16]

On the other hand, there are enormous progresses in technology. Everything will become more digital: the workplace, the home and cities. Drones, autonomous vehicles, and robots are part of everyday life. Especially technologies in the field of AI, sensor technology, batteries and renewable energies will develop strongly. [17] [18]

Digitalization is also taking place in agriculture, which means that the professional life of a farmer is changing significantly. A large part of the activities on the field, such as seeding, fertilizing or harvesting, are taken over by autonomous agricultural machinery and drones. The farmers only interact remotely from the office or the edge of the field. Instead, they are increasingly working on office tasks, such as farm management or data analysis. [19]

In addition, there will be more and more bio-farms, as sustainable and environmentally friendly farming is subsidized by the state. But the conversion to sustainable agriculture and the investment in more efficient agricultural machinery is very costly. In addition, the prices of agricultural goods, such as fertilizer and seeds, are increasing. This leads to large farms forcing small farms out of the market. [20] [21]

In view of this future scenario, it is important for us to develop a technology concept that on the one hand makes a positive impact on the environment. On the other hand, it should be accessible to everyone, regardless of whether they are small or large farmers.

How exactly the concept looks like is explained in the following chapters.

5

How might we reduce the excess of nitrate in deeper soil layers?

DESIGN SOLUTION

WOBOT

WOBOT, our design solution, reduces the nitrate level directly in the soil.
Our concept consists of two main components. The WOBOTs - a team of robotic earthworms, collecting excess of nitrogen from the soil.
And the WOBOT Kindergarten which serves as a supply base for the Wobots and is also responsible for the further processing of the collected nitrate.

5.1 USER JOURNEY

As the farmer is our main stakeholder for our concept we first want to guide you through a short user journey to give an overview of the concept.

1. That's John, he is a farmer in Germany. He knows about the huge nitrate problem and his impact in environment. Our WOBOT system will help him to rid his field of excess nitrate.

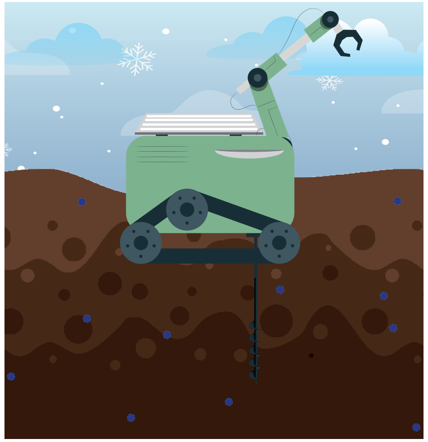
Figure 4: User Journey 1

2. Often farmers do not cultivate their fields with crops in winter. Instead, grass or other small plants are planted solely to maintain soil fertility through the cold season. This is when the WOBOT will come in to filter the nitrate out of the soil without disturbing the crop.

Figure 5: User Journey 2

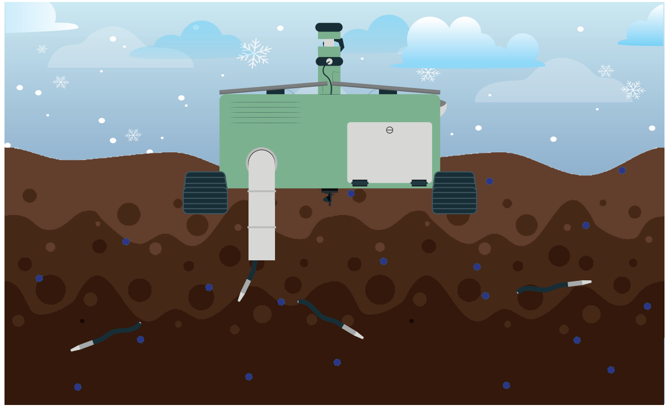
3. The design concept consists of two main components. The WOBOT itself, which filters the nitrate from the soil underground similar to real earthworms, and the WOBOT Kindergarten. The Kindergarten serves as a supply base for the WOBOTs and is also responsible for the further distribution of the collected nitrate. Here, one Kindergarten is responsible for 40 WOBOTs.

Figure 6: User Journey 3



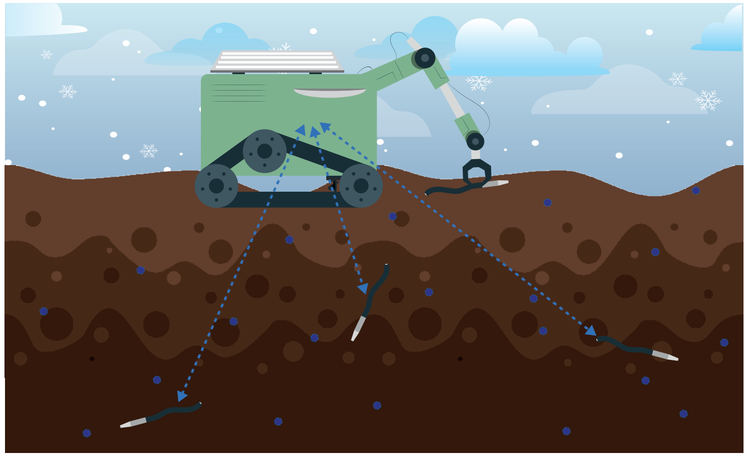
4. First, the autonomous Kindergarten drives onto the field and measures the nitrate content of the soil at regular intervals with the help of a sensor that drills 2 m into the soil. If an excess of nitrate is measured, the WOBOTs are released.

Figure 7: User Journey 4



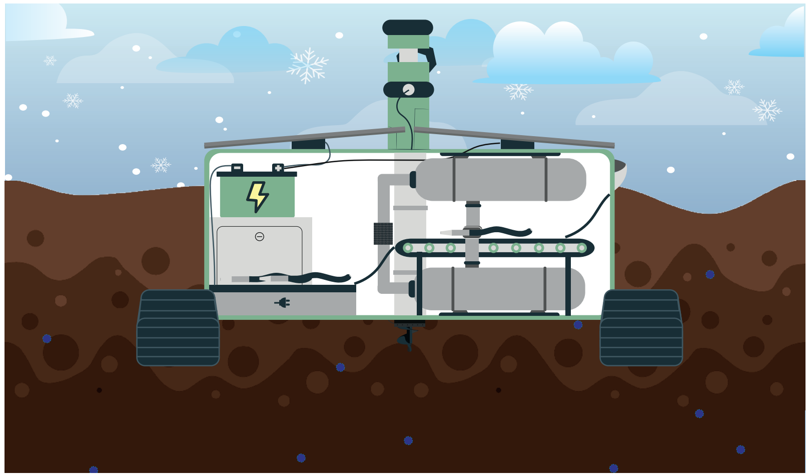
5. For this purpose, the Kindergarten extends a pipe through which the WOBOTs enter the soil. At a working depth of 2-3 m, the WOBOTs filter the nitrate, which is dissolved in water and removed from the soil.

Figure 8: User Journey 5



6. At the same time, the WOBOTs give the Kindergarten permanent feedback about their nitrate level, battery level and current location. If the WOBOT has a full nitrate level or the battery is empty, it returns to the surface and notifies the Kindergarten, which drives to the WOBOT location and picks it up.

Figure 9: User Journey 6



7. The Kindergarten takes the WOBOT in and feeds it. More precisely, the nitrate water is replaced with fresh water and the battery is refilled. After that, the WOBOT can be set free again. The collected nitrate water is filtered again in the Kindergarten using osmosis.

Figure 10: User Journey 7

8. By means of a dashboard, the farmer can monitor the WOBOTs and the Kindergarten with regard to the filling levels of the tanks, battery level and position and, if necessary, intervene remotely in the control.

Figure 11: User Journey 8

9. Once the farmer has collected enough nitrate, he can resell it to the fertilizer manufacturers.

Figure 12: User Journey 9

10. Since the investment costs of agricultural technologies are very high and many farmers cannot afford it, a renting system should be made possible. Here, the farmers can rent the WOBOT from the agricultural machinery manufacturers if needed, instead of buy the technology themselves. This means that small farmers also have access to the WOBOT.

Figure 13: User Journey 10

End.

Let's have a deeper look into the design!

5.2 WOBOT Kindergarten

WOBOT Kindergarten

>***This is me:*** Autonomous driving field robot or better known as supply base for the WOBOTs

> ***My tasks:*** Nitrate measurement, transportation of WOBOTs and separation of nitrate from water

> ***Dimensions:*** 100 cm x 70 cm x 60 cm
(but modular: I am adaptable to field size and crop plants.)

> ***Weight:*** ~ 150 kg

> ***Speed:*** 7 km/h

> ***Working area:*** On the soil surface of fields

> ***Working time:*** Especially in winter

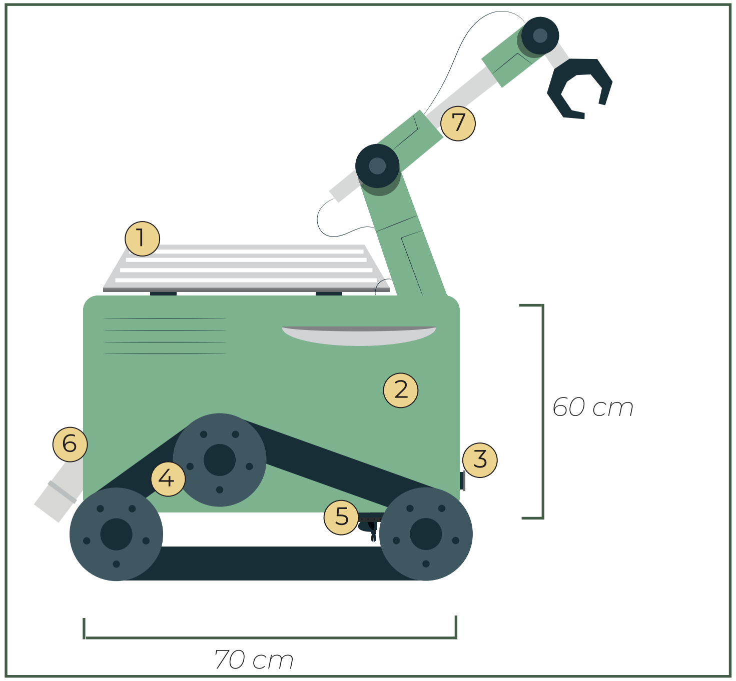


Figure 14: WOBOT Kindergarten

1 Photovoltaic Modules
2 Recycled Aluminum
3 Stereo Camera
4 Caterpillar Tracks
5 Nitrate Sensor
6 Jump Start
7 CERNbot Arm

Following the main components of the WOBOT Kindergarten.

5.2.1 - WOBOT Kindergarten Main components

Material

The main material of the Kindergarten is recycled aluminum, a light metal. Aluminum is one of the few metals that retains its properties after the recycling process. Thanks to its relatively low weight, the soil is under less pressure. Aluminum is also corrosion resistant, which is important when working outdoors. [22]

Another advantage of recycled aluminum is the ecological aspect. The recycling process is much more energy-efficient than producing primary aluminum. Recycling aluminum requires only 5% of the energy used in primary production. [23]

Energy Supply

With photovoltaics, the Kindergarten produces independent and environmentally friendly electricity. The photovoltaic modules (size: 0,7 m², current electricity power: 140 W [24]) are mounted on the roof to ensure maximum solar radiation. Unlike conventional silicon solar cells, solar cells with two absorber materials are used, perovskite and silicon. These cells use almost 30 % of the sun‘s energy. Currently, this is the highest efficiency that has been achieved. In the future, an efficiency of 40 % should be possible with this technology. [25]

For bad weather-days with only few hours of sunshine, the Kindergarten has an additional electricity storage system to store a surplus and make it available again when needed. A zinc-air battery is used as a power storage unit. In contrast to lithium-ion batteries these batteries are less flammable, react less with water and are less likely to short-circuit [26]. In addition, the electrical capacity is significantly higher; about three times as much charging capacity can be stored in the same space.

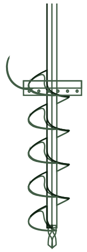
Movement

For movement, the Kindergarten is equipped with caterpillar tracks. With the caterpillar wheels, the Kindergarten is around 7 km/h fast. Five rollers distribute the weight of the Kindergarten evenly on the soil and thus prevent point loads. This minimizes the soil pressure, which largely prevents soil compaction. Likewise, perfect soil adaptation and a large contact area protect the soil. The caterpillar undercarriage enables the Kindergarten to withstand even the toughest conditions, for example it can drive through deep mud. [27]

Locomotion and control

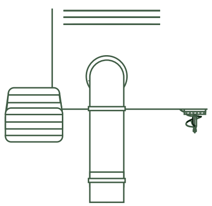
The autonomous control of the WOBOT Kindergarten is based on existing technology of the John Deere autonomous tractor. Six pairs of stereo cameras are used to provide 360-degree obstacle detection and distance measurement. This camera takes continuous images, which are analyzed by an AI and then decides whether the Kindergarten continues to drive or stops depending on whether an obstacle has been detected. [28]

To ensure that the Kindergarten does not drive beyond the field boundaries, its position is continuously checked using geofencing [29] [30]. Geofencing is a kind of geographical fence that defines the area of operation of a mobile object, in this case the Kindergarten. If the Kindergarten leaves or enters the defined area, an action is triggered [31]. The exact position is determined by GPS and mobile communications, which ensures an accuracy of up to 2 cm [29] [30].



Nitrate measurement

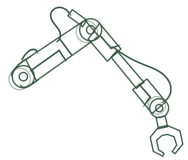
The nitrate measurement takes place before the outlet of the WOBOTs. The WOBOT Kindergarten drives over the field and measures the nitrate content at regular intervals at a depth of 2 meters. Soil solution is collected, sampled directly, and analyzed in real time using one to two suction cups on a soil auger similar to the Archimedes screw, which can extend out of the bottom of the WOBOT Kindergarten into the soil.
Thus, a high temporal resolution of the measurement is possible and the WOBOTs can be released directly into the soil at the measured location if needed. On demand means, when the nitrate content at the site shows comparatively high nitrate values and thus a high excess can be concluded.
The online nitrate measuring method uses the already existing system NITROM, which is protected as a utility model. [32] [33]



Jump Start

The working depth of the WOBOTs is 2-3 m. In order for the WOBOTs to reach the earth, the Kindergarten extends a pipe that bores 2 m into the depth. This means that the WOBOTs do not have to dig themselves into the earth and are positioned correctly. To ensure an easier and faster start for the WOBOTs.

CERN Technology



CERN-Bot Arm

For picking up the WOBOTs of the soil surface and put them through a hatch on his body into himself the Kindergarten uses a robotic arm, based on the official CERN technology CERNbot. The CERNbot is an autonomous robot with arms, built to do tasks in environments, that are hard accessible or even dangerous for humans. His arms are very versatile because they can move in a lot of different directions [34], which is the reason, why we use this technology for the Kindergarten. A versatile arm, that can move in several directions, allows an autonomous and more continuous process.

WHAT HAPPENS INSIDE THE KINDERGARTEN WHEN A WOBOT IS LET IN BY THE CERNBOT ARM VIA THE HATCH?

(5) Charging station and (6) zinc-air battery

At this step, the WOBOT is placed on a surface of a charging station. Here, they are getting recharged through a resonant wireless charging process. The energy for this process comes from the energy supply of the Kindergarten. The solar panels are collecting renewable energy and save it in an zinc-air battery. This battery delivers the energy, the WOBOTs need for their working process. At this part is space for 40 WOBOTs. This is also the place, where the WOBOTs are stored and wait for their next assignment.

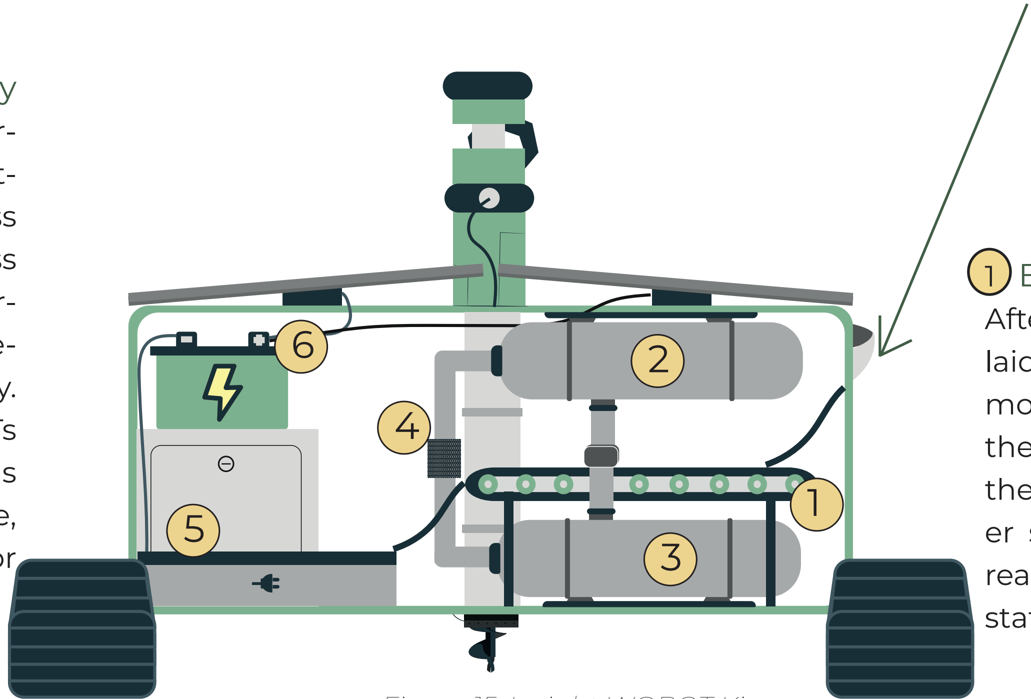


Figure 15: Insight WOBOT Kindergarten

(1) Band conveyer

After entering, the WOBOT is laid on a band conveyer, which moves the WOBOT through the water exchange station in the Kindergarten. The conveyer stops the WOBOT, when it reached the water exchange station for reload.

(4) Osmosis Filter

The filter between the two tanks has the function to perform a reverse osmosis. On this way, the WOBOT Kindergarten can regain fresh water for the WOBOTs, without returning to a refilling station. This enables a more autonomous working process. The required pressure for the reverse osmosis is about 10 – 150 bar [35]. A reverse osmosis can hold back particles with the size of 0,001 µm. With this, more than 98 % of e.g. salts in the water can be filtered [36]. This enables the reliable recovery of fresh water. The reverse osmosis is working independent from the rest of the other processes, inside the WOBOT Kindergarten.

(2) Fresh water tank (3) Nitrate water tank

The exchange of the water inside the WOBOT, happening at this part, is the first important step. Here, the WOBOT receives fresh water from the upper water tank. The water, along with the nitrate (nitrogen water) inside of the WOBOT is emptied into the lower tank. After this step, the water exchange is completed and the conveyor is moving the WOBOT forward, to its next station. The water tanks have both a volume of 55 liter. At the beginning, only the upper water tank is filled with water. During the working process, the lower tank is filled gradually with nitrogen water. If there is enough water in the lower tank, a part is pumped back to the upper tank. During this process, the nitrate water is passing a filter.

5.3 The WOBOT

WOBOT

>***This is me:*** Robotic earthworm eating soil and flush out the nitrate from it

> ***My tasks:*** Digging through the soil and meanwhile collecting nitrate

> ***Length:*** 30 cm

> ***Diameter:*** 2 cm

> ***Speed:*** 1,4 cm/s

> ***Working area:*** Below the root zone (between 1 - 2 m deep in soil). We are let out via the jump start of the Kindergarten at a depth of 2 m. From there we can continue to dig vertically and horizontally. At this depth, the we extract the current year's excess nitrate from the soil. For filtering out surplus from previous years, we can dig deeper.

> ***Working time:*** Especially in winter

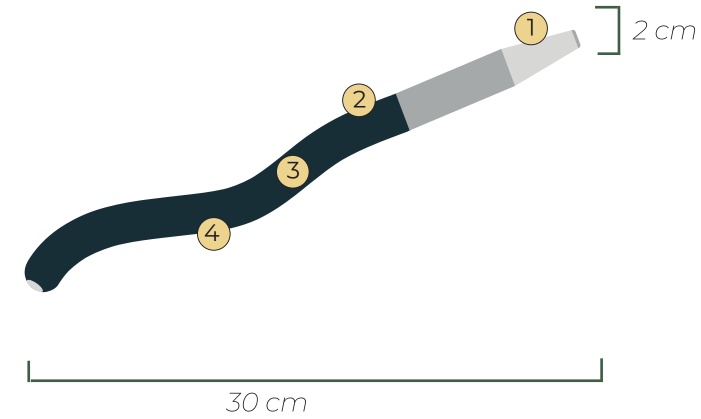


Figure 16: WOBOT

1. Corrosion-Resistant Steel
2. Silicone Rubber (Layer 1)
3. Net Tube (Layer 2)
4. Silicone Rubber (Layer 3)

Following the main components of the WOBOT.

5.3.1 - WOBOT Main components

Material

To achieve the UN's sustainability goals, we need novel materials that conserve resources and enable technological progress. The German Federal Ministry of Education and Research (BMBF) has been continuously promoting material technologies for decades [37]. Therefore, we expect new findings in the next years until 2030, so that, if necessary, even more suitable materials for the WOBOT will be discovered.
The head or front part of the WOBOT is made of corrosion-resistant steel. Ferritic stainless steel, which has magnetic properties, is provided for long life. This is necessary for being rescued by the RESCUEBot (see 5.5 The RESCUEBot)

The rear body of the WOBOT consists of three „skin" layers. The three layers are listed below from the outside in. The thickness of all three layers together is 1 mm.

1. Outer skin made of elastic, flexible material. Durable and ecological silicone rubber is used for this purpose, which has a high load-bearing capacity. An important argument for this choice of material is its biocompatibility and sustainability. Silicone rubber is derived from silicon and is therefore a petroleum- and mineral oil-free material. [38]
Small bristles are provided around the outermost WOBOT skin layer, which act as barbs to provide grip in silty soil like the chitin bristles of real earthworms. A precise elaboration is still necessary.
2. Net tube with NiTi coils. For the peristaltic locomotion of the body the WOBOT is inspired by the hydrostatic skeletal structure of real earthworms. For this purpose, a braided mesh tube with NiTi coils is used.

NiTi is a nickel-titanium alloy and the best-known representative of shape memory alloys, which induce reversible structural transformation by temperature change. This enables peristaltic movement. The energy supply for the temperature changes is provided by an air-zinc battery. At present, high temperatures are still required for this. The phase transition temperature of the NiTi coils is 90 °C so that targeted actuation occurs. We expect further development in this area to occur by 2030. [39]

3. Inner skin also like the outer skin made of silicone rubber. Like the outermost skin layer, the inner one is also made of silicone rubber to keep the water inside the WOBOT's stomach and provide protection for the NiTi wire of the second „skin" layer. [38]

Working range and speed

Speed 1.4 cm/s like real earthworm, so as not to scare other animals in the soil. With this speed, a single WOBOT can dig through about 1 m² in four hours and filter out the excess nitrate. There are 40 WOBOTs in one WOBOT Kindergarten, so together they can dig through 40 m² in 4 hours. If they are on the road all day, then together they can manage 2400 m². On average, the agricultural area per farmer is 63 ha [40].

This means that 40 WOBOTs, with a 10% time premium due to possible delays, would be able to dig through the entire area once in about 288 days. This corresponds to 9.5 months. In addition, with another Kindergarten and thus a total of 80 WOBOTs, the time can be halved, so that an average arable land can be freed from nitrate surplus in a winter period of about 4 months.

5.3.2 - Closer look into the inner life of the WOBOT

HOW DOES THE WOBOT DIG THROUGH THE SOIL?

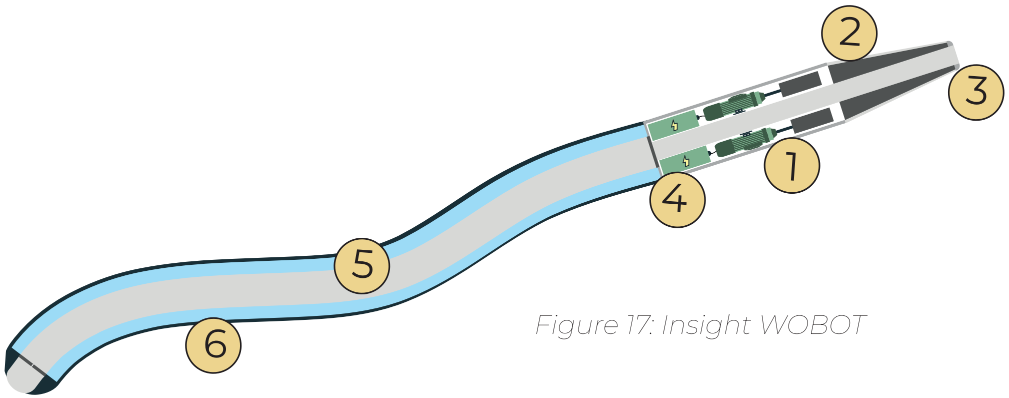


Figure 17: Insight WOBOT

1. Impact Piston
2. Steel Head
3. Localization System
4. Air Zinc Battery
5. Artificial Stomach
6. Water Tank

1 Impact Piston

The locomotion of the WOBOT works via a percussion mechanism. For this purpose, an example was taken from the existing earth rockets or ground displacement hammers.

An electric motor sets an impact piston in the head of the WOBOT in motion. The impact piston hits the steel head, transfers kinetic energy and the WOBOT is pushed forward. During the forward thrust into the soil, the soil is entered into the cavity of the steel head; approximately 1.1 cm^3 is absorbed per impact. With the next impact, the WOBOT is again moved further forward and even more soil is picked up. The soil already in the head is pushed backward toward the WOBOT stomach by the newly added soil.

By creating an antagonistic (opposite) actuation in a tubular soft structure, the rear part of the WOBOT can move along its body from head to tail with the help of a peristaltic travelling wave in addition to the forward movement caused, by the blow.

3 Localization System

At the Karlsruher Institut für Technology, an autonomous localization system was used as part of a PHD, which we would like to use to locate our WOBOTs. This system is largely independent of GPS and is therefore particularly well suited for the underground working area of the WOBOTs. The position of the WOBOTs is only recorded once by GPS before they enter the soil.

Each WOBOT is equipped with inertial sensors that permanently measure acceleration and rotation rate. These values are recorded and processed by an algorithm. This makes localization possible. Since each WOBOT is additionally connected to its associated Kindergarten via Bluetooth, position data is permanently transmitted. In addition to this theoretically already available technology, we are currently researching for a further development, which enables the WOBOTs to avoid obstacles such as larger stones or animals in hibernation. For this purpose, RGBD depth cameras are to be used, which scan the environment via infrared. With the 3D image created in this way, WOBOTs can detect obstacles and dig around them accordingly. [41]

4 Zinc-Air Battery

The WOBOT is powered by efficient air zinc batteries. According to the latest research results, these batteries can now also be recharged, unlike originally. The advantages over lithium-ion batteries are that they are manufactured in a way that conserves resources and can be recycled. They also have a significantly higher energy density (theoretically up to 400 Wh/kg), resulting in up to three times the electrical capacity. Size and weight are also significantly lower than conventional cells. We expect further findings in this area of research by 2030.
The battery should also be flexible. It is envisaged that the battery will be located between the layers of the WOBOT's skin and will be able to flexibly conform to the body's circumference. Flexible batteries already exist and there will certainly be a lot of research on this in the next few years as well. [42] [43]

5.3.3 Nitrate filtration process inside the WOBOT

HOW DOES THE WOBOT FLUSH THE NITRATE OUT OF SOIL?

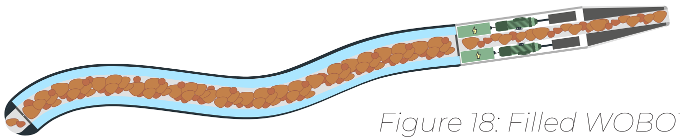
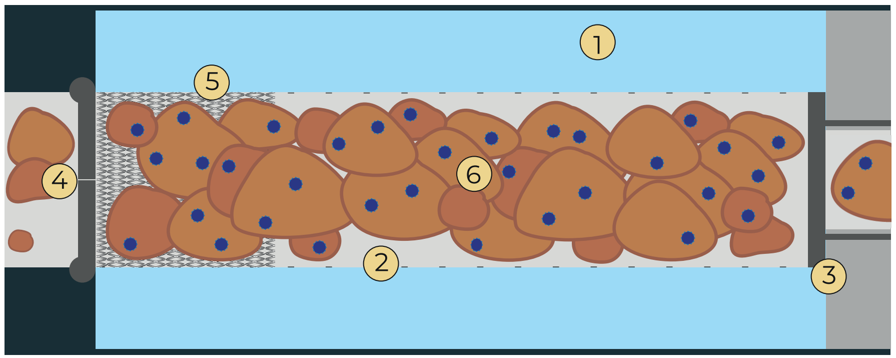


Figure 18: Filled WOBOT

The separation of nitrate and soil takes part in the inside of the WOBOT and takes four steps.

1 First, the WOBOT consumes material during its movement through the underground. This material is primarily soil, but can also be dirt, peat, or gravel. Together, with the soil, the nitrogen compounds are consumed, primarily nitrate. The collected soil is stored in an artificial stomach. This is the first of four steps, to separate the nitrate from the soil.



1 Water Tank
2 Artificial Stomach with Water Hatches
3 Piston
4 Hatch
5 Filtration Membrane
6 Soil with Nitrate

Figure 19: Nitrate Filtration 1

2 After reaching the inside, the stomach is closed waterproof. The water around the stomach is flushed through the water hatches into it, to mix the water with the soil and receive a slurry mass.

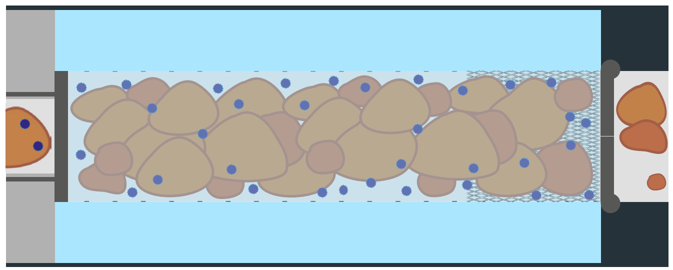


Figure 20: Nitrate Filtration 2

Nitrate has a high solubility in water [44]. During the mixing process the nitrate becomes dissolved, to enable a separation from the soil. When the stomach is filled with water and the soil is completely drenched, the second step is completed and the third step starts.

3 In the third step, the water is pumped back into the water tank body of the WOBOT.

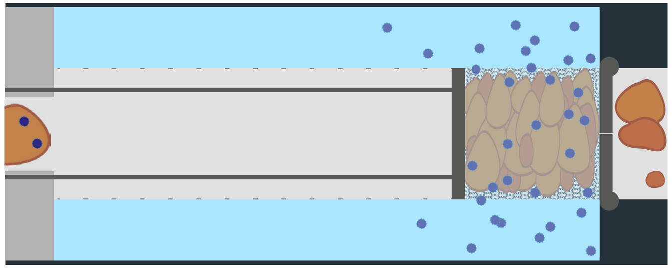


Figure 21: Nitrate Filtration 3

To separate the water from the soil, a small piston is pressing the whole mass against a membrane. This membrane is based on the membrane technology, used in Ultrafiltration.

Membranes, used in this kind of filtration are permeable for particles and materials, smaller than 0,1 µm. This means, beside micro-organisms, like bacteria and algae, also materials like trubs, e.g. small part from soil or plants are impermeable for the membrane. Raw materials, like the soil itself or small rocks are also not able to pass the membrane. The working pressure of the piston lies between 1 and 10 bar. [35]

The third step is aiming for a separation of water and soil. At the end of this step, the water has returned to the tank, along with the nitrate and the soil is released from the water.

4 In the fourth and final step, the soil is released back into the environment.

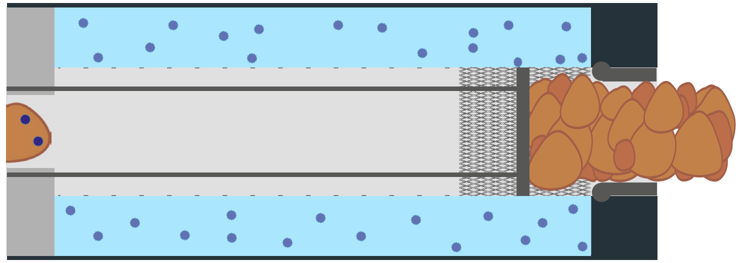


Figure 22: Nitrate Filtration 4

After the separation form the nitrate water and the soil, the WOBOT opens its backside, and the piston is pushing the almost dry soil out of the stomach. At the end of the WOBOT, the material is released into the environment. This step is comparable to excretory process of the real earthworm.

With this, the whole separation is finished, and the stomach is empty for a new load of soil. This is repeatable, as long the concentration of nitrate in water is not too high. If the WOBOT is done with the task, or the concentration of nitrate in water reaches its limit, the WOBOT returns to the surface and calls the WOBOT Kindergarten for picking up.

5.4

Communication and Data management

INTERACTION WOBOT AND KINDERGARTEN

The WOBOTs are permanently connected to their respective Kindergarten via Bluetooth.

Bluetooth connections are already sufficiently strong today to be able to connect a few meters even underground. Thus, indoor ranges of up to 40 meters can be achieved with Bluetooth 5. [45]

Via this Bluetooth connection, the WOBOTs continuously provide information about their battery status, the current calculated position, and the level of fresh water and level nitrate water. The Kindergarten also records position data and battery status. In addition, the level of the water tanks is recorded via sensors. Furthermore, sensor data of the soil measurements are available. All this information and data is then sent from a Kindergarten to the „WOBOT" cloud via the farmer's network or Internet connection. Alternatively, connectivity via the mobile network (4G/5G) is also possible.

Regardless of the transmission technology selected, a VPN connection is established for secure transmission. Mobile WLAN devices today already have Bluetooth modules, which means that the necessary technology can be accommodated in the kindergarten to save space. [46]

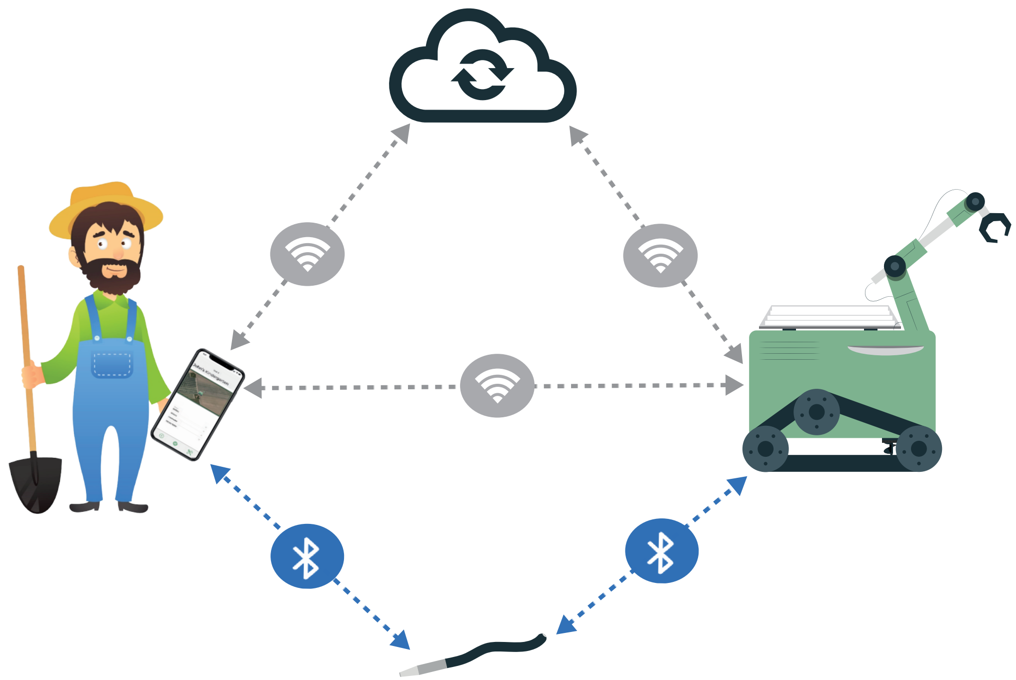


Figure 23: Communication

The data is then processed and made available to farmers via a dashboard. Through this dashboard, farmers can view and monitor the current status of their WOBOTs at any time. In addition to real-time data, we also offer farmers to perform an analysis of the data and make a recommendation for planting and fertilizing the fields based on this analysis.

Alternatively, farmers will also receive information if they are on the same local network as their kindergarten or if there is a Bluetooth connection to the WOBOTs. For research and public relations purposes, the data is made available to the general public in an anonymized form.

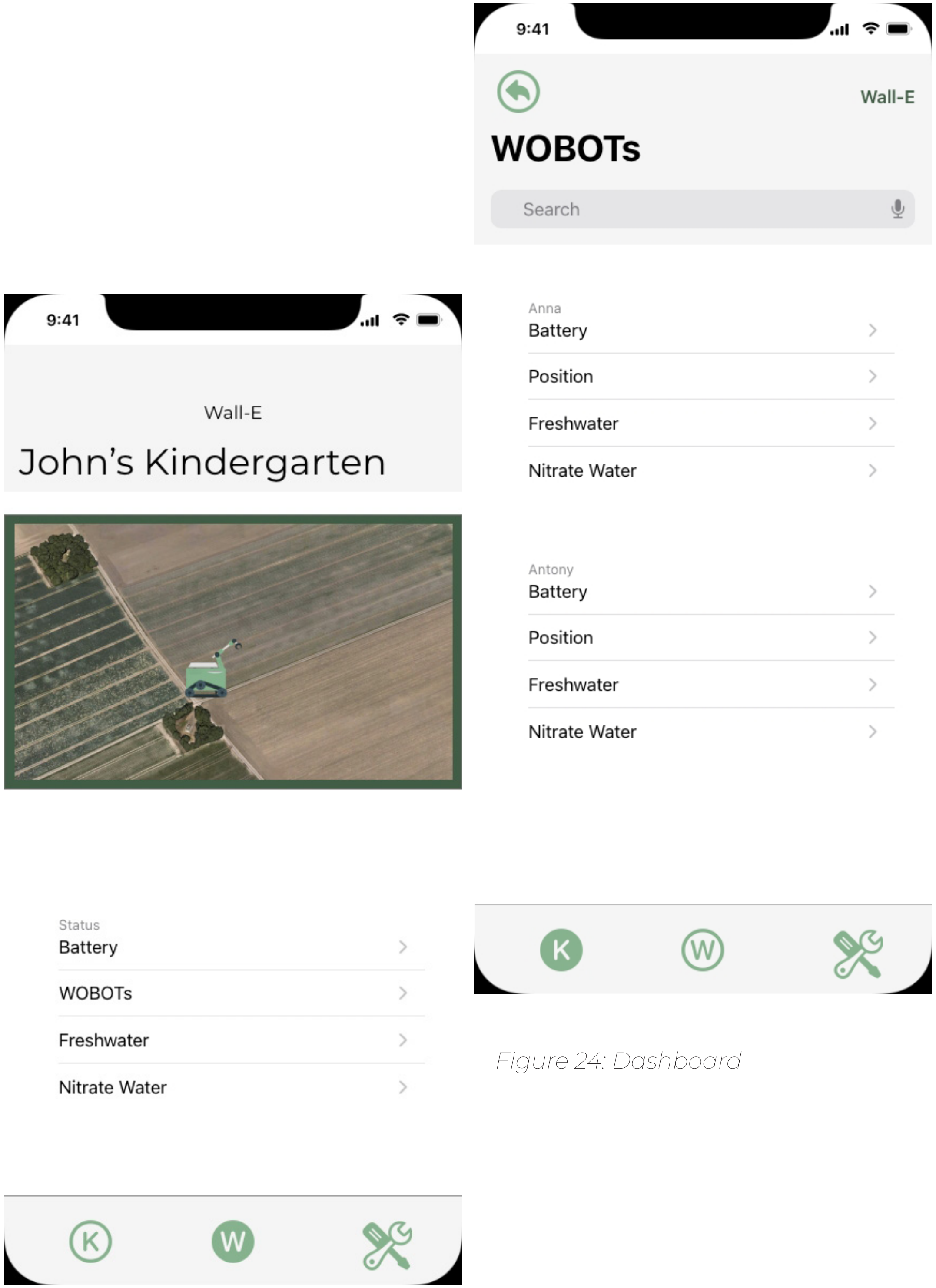


Figure 24: Dashboard

5.5

The RESCUEBot

WHAT HAPPENS IF A WOBOT STUCK IN

One very important aspect is the question, what happens, when a WOBOT is getting lost somewhere in the underground?

For this task, the WOBOT Kindergarten is equipped with the RESCUEbot. These are robotic worms, like the WOBOT. The main difference is that the RESCUEbots are not able to separate nitrate from the soil. Instead, they are only able to move through the soil.

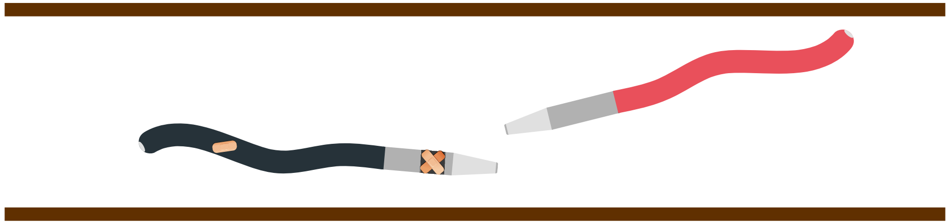


Figure 25: RESCUEbot

If a WOBOT is unable to move or lost, the Kindergarten is locating the last signal of the WOBOT. After the localization, a Rescuebot is sent out. These robots are moving through soil to the place, where a broken WOBOT stuck, to pick them up. Then, they dock through magnetism at the WOBOTs steel head and taking them back to the surface, where the Kindergarten can pick them up again. A broken WOBOT has to repaired external.

Check out our video to see the animated WOBOT Concept process.

Video WOBOT Concept

6

VALUE

Since the WOBOT concept helps to reduce the amount of nitrate in the soil, several benefits results for environment, fauna, farmers, and also consumers. Resulting from the previous information, a lot of valuable benefits can be achieved.

Ecosystems – the regeneration of the ecosystems by reducing the amount of nitrogen is the main target. Keep the ecosystems is one of the central aspects of the SDG 15.

Keep – keeping the groundwater clean, to have clear drinking water. Reducing the amount of nitrate in drinking water make it more healthy and less dangerous, especially for little children.

Organisms – microorganisms will have better conditions to live. Too much nitrate disturbs the balance of nutrients. By reducing nitrate, this danger is reduced.

Plants – more bearable and natural conditions to grow. If there is only the nitrogen, the plants require, their growth is healthier and more natural.

Algae – with less nitrate, the growth of algae and the resulting eutrophication is reduced. Too much algae take oxygen out of the water. With less algae, the other organisms in the water will have enough oxygen to live.

Insects – the survival of insects depends on the diversity of ecosystems. The nitrate concentration determines, which plants can grow in an area. When the correct plants grow in an area, the insects like bees will have food to survive.

Support – help the farmers to reduce their nitrogen impact. They will have better soil conditions which helps, to have better food for consumers. Also, they will have less problems with lawful restrictions.

7

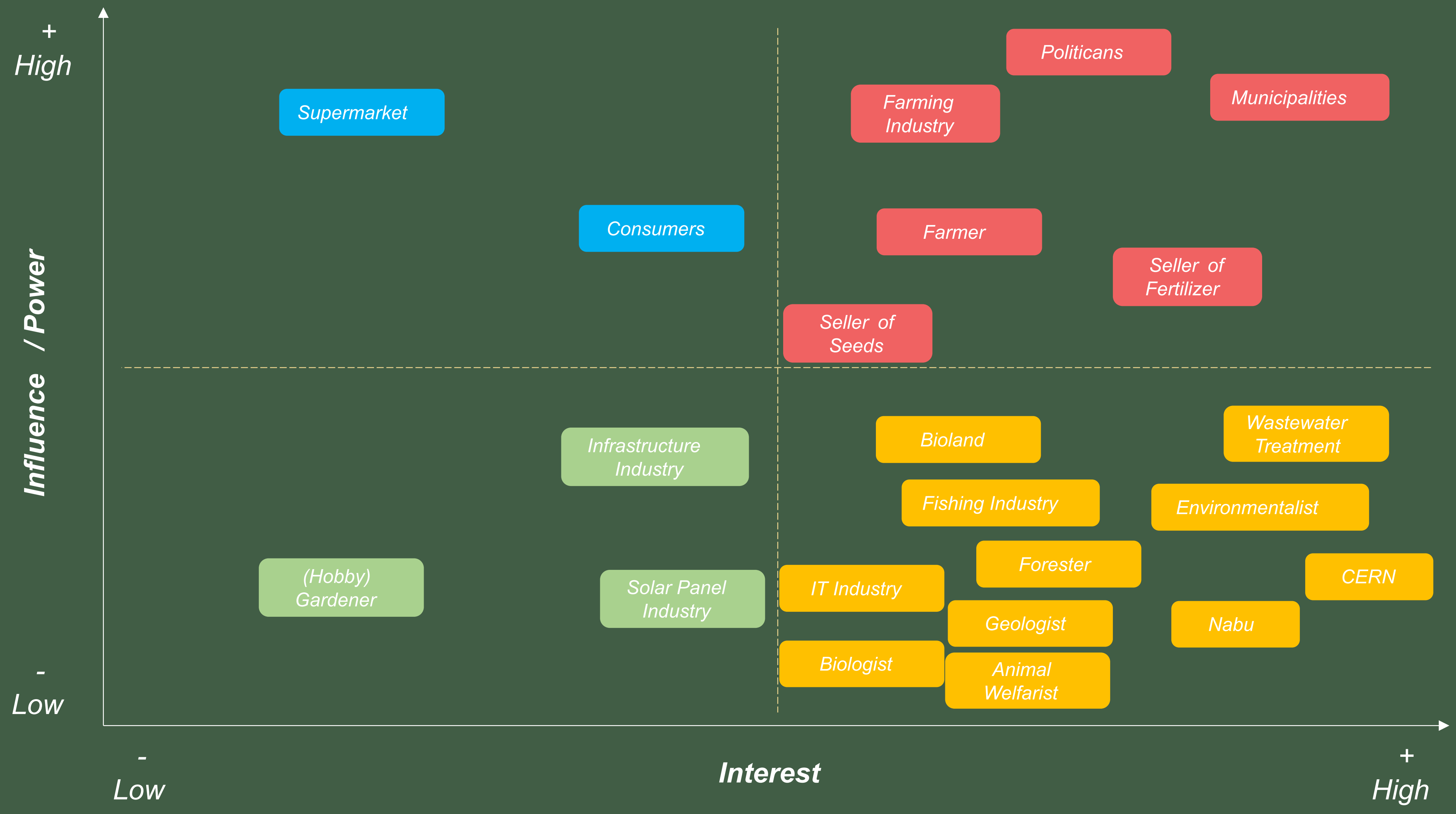
STAKEHOLDER
AND USER TOUCHPOINTS

Who do we address with our concept?
Which stakeholders are affected and involved?

In order to develop a successful and feasible concept, it is important to look at the problems and needs from different perspectives.

For this reason, we did numerous interviews and research to understand the interests of different stakeholders. In the following chapter, we show the most important stakeholders regardign to the development phase who have influence and interest in our concept.

TEAM EKOPAÍS



TEAM EKOPAÍS

Stakeholder	Contributions	Motivations	Enablers	Engagement
K+S (Fertilizer Seller)	- Possibilites for Recycling - Know -how and experience - Money	- Profit - Save ressources - Better image	- Already are active in this sector (know -how available) - Contact with farmers already in place	- Formal meetings - Agricultural fairs
John Deere	- Possibilty to build WOBOT and Kindergarten - Know -how and experience	- Profit - Better Image - Increase product portfolio - Increase customer base	- Already are active in this sector - Contact with farmers already in place	- Formal meetings - Agricultural fairs
Farmer	- Possibilty to recycle nitrate - Work place for WOBOTs - Key customer	- Better image - Healthier crops - Improved soil quality - Profit	- System is rentable - Enable more fair prices for better products	- Formal meetings - Website - Social media
Consumers	- Attention - (indirect) Cashflow	- Healthier vegetables - Improved drink water - Better biodiversity	- Products are identified at the supermarkets - Follow via Website and support with adopting a WOBOT	- Advertisement - Identified products - Website - Social Media
Bioland	- Attention - Marketing	- Profit - Increase product portfolio - Increase customer base	- Certification Experience already availabe - Contact with farmers and supermarkets already in place	- Formal meetings
Wastewater Treatment / Infrastructure Industry	- Business partner for renting system - Data	- Being a business partner - Improvement for own technology & processes	- Job / work opportunities - Extra money to invest	- Formal meetings

For our concept, we especially considered our two main stakeholders: the farmer and the consumer. Let's have a closer look at them.

Description: John is a farmer in Mannheim. Together with his wife Anna, he farms an 8 ha field. Besides keeping a few farm animals, he grows wheat and potatoes. On the weekends, he likes to watch the soccer games of his two sons. Sustainable and environmentally conscious farming is very important to John. However, his good intentions are often held back by financial necessity.

John Jumper

>***This is me:*** Supporter of the WOBOT system

> ***Age:*** 47

> ***Marital status:*** Married, 2 children

> ***Residence:*** Mannheim, Germany

> ***Formation:*** Master in Agriculture sciences

> ***Occupation:*** Farmer

> ***What are my motivation and my goals?***

- Reduce negative nitrogen impact
- Reuse ressources
- Sell ecological products at fair prices

Quote of the day:

On vacation at the North Sea with my family a few years ago, I clearly noticed the effects of eutrophication, the excess of nutrients in the lake. I am very happy that I can contribute with needs-based fertilization and additionally the WOBOT system a part that these effects subside.

Description: Gabriella is married and a happy mother of a four year old daughter. She lives in a small town near Mannheim and loves to spend time with her family outside in nature. After studying communication design, she first worked for some time at an advertising agency. For about 2 years now she has been working independently as an interface designer.

Gabriella Green

>***This is me:*** Supporter of the WOBOT system

> ***Age:*** 32

> ***Marital status:*** Married, 1 child

> ***Residence:*** Frankenthal, Germany

> ***Formation:*** Bachelor of Communication Design

> ***Occupation:*** Interface Designerin

> ***What are my motivation and my goals?***

- Support regional providers
- Healthy food for her family
- A more sustainable, greener future

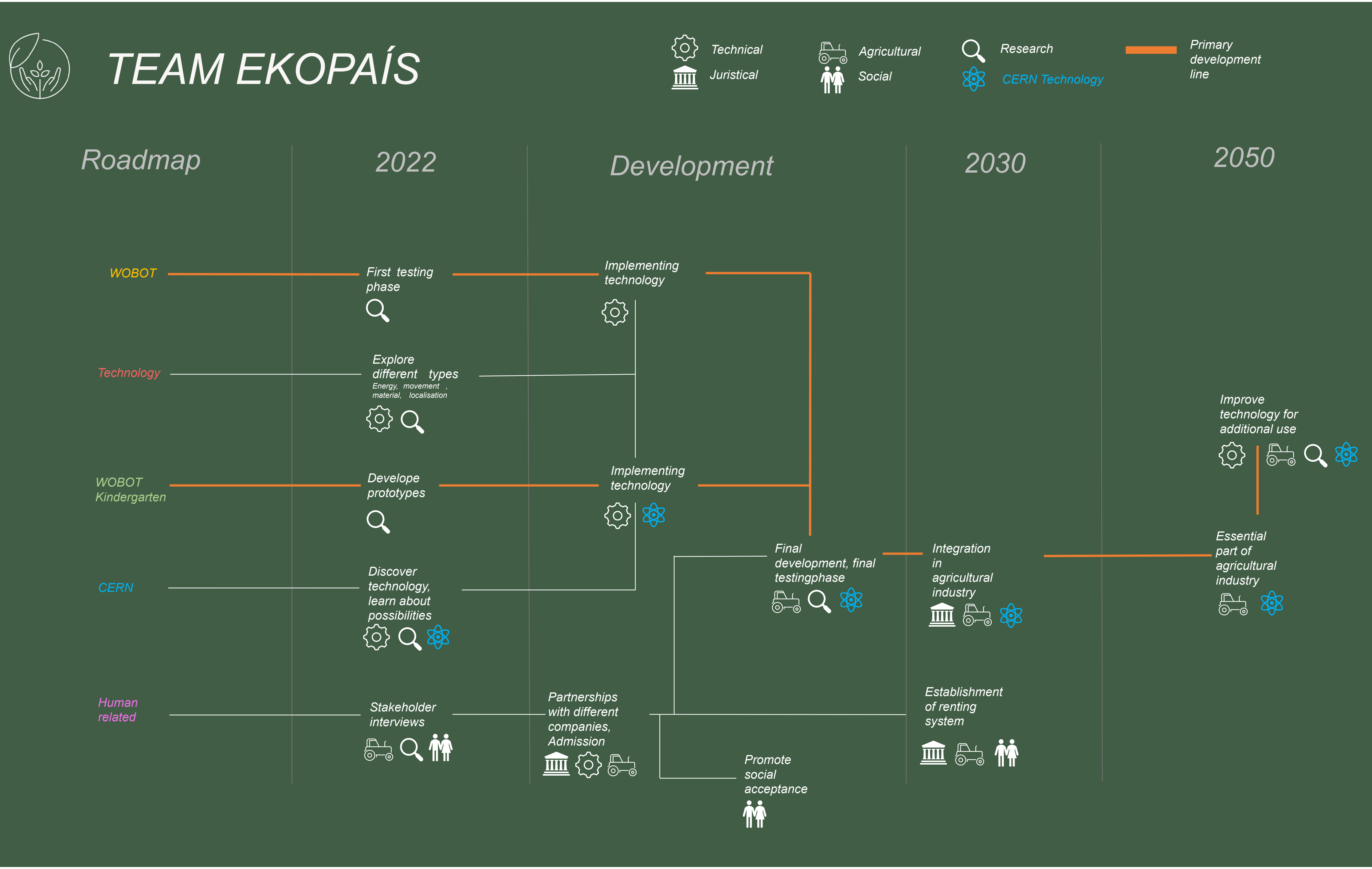
Quote of the day:

I love going to the farmer's market to buy my vegetables. It's great to know where the food comes from and how plants and soil are treated.

8

ROADMAP

Within our roadmap we describe current activities, the necessary development until 2030 to achieve the mission for 2030 as well as the vision of our system for 2050. The roadmap is divided into the categories WOBOT, technology, WOBOT Kindergarten, CERN technology and human-related activities. In addition, we take into account the various influencing factors such as legal and social aspects. The orange path shows the main development path.


TEAM EKOPAÍS
Technical
Juristical
Agricultural
Social
Research
CERN Technology
Primary development line
Roadmap
2022
Development
2030
2050
WOBOT
First testing phase
Implementing technology
Technology
Explore different types
Energy, movement, material, localisation
WOBOT Kindergarten
Develope prototypes
Implementing technology
Improve technology for additional use
CERN
Discover technology, learn about possibilities
Final development, final testingphase
Integration in agricultural industry
Essential part of agricultural industry
Human related
Stakeholder interviews
Partnerships with different companies, Admission
Establishment of renting system
Promote social acceptance

9

REVENUE STREAMS

How is the whole system financially possible?

In order to keep costs as low as possible for farmers, we offer the option of renting a WOBOT system in addition to purchasing one. This means that farmers only pay for the time they actually need the WOBOTs. The rental and necessary repairs are carried out for the farmers by trained, local partners.
To fund the costs of the WOBOTs, we plan to generate various types of income. Our main source of income will be generated through government funding. That this is quite possible is shown, among other things, by the funding from the German Federal Ministry of Food and Agriculture, which will provide climate-friendly farms with 816 million euros for the years 2021 to 2024 [47].

In addition, we would like to establish a certificate, comparable to an organic seal, for farmers who use WOBOTs on their fields and thus have soil that is lower in nitrates. Through these seals, consumers recognize the quality of the product and are therefore probably willing to pay a higher price in the supermarket.

We also plan to sell the extracted nitrate back to fertilizer manufacturers so that they can recycle and offer a discounted fertilizer to farmers.

We would also like to give our supporters the opportunity to sponsor a WOBOT. For a fixed amount, one can „adopt" a WOBOT and in return always contain information about it. With the inclusion of gamification, supporters can see how much nitrate their respective WOBOT has already collected.

10

FURTHER IDEAS

When someday our soil used for agriculture is cleaned of excess nitrate, how can the WOBOT system live on and be used?

In the future, we would like to use WOBOT systems not only in the agricultural sector for nitrate filtration, but also in other areas and for other materials and raw materials. The WOBOTs will then be adapted accordingly for these scenarios, e.g. in the filtering process or the composition. In the field of agriculture, for example, the recycling of phosphorus would initially be an important challenge. In addition, we can also imagine using WOBOTs in forests to collect copper. We also see the possibility of collecting microplastics from the soil or, as a higher-level vision, from the oceans.

10

CONCLUSION

WOBOTs make it possible to reduce the negative nitrate impact of farmers by collecting nitrate from deeper layers of soil before it seeps into groundwater.
In this way, we reduce the risk of excess nitrate to drinking water, especially for younger people, and limit the negative effects on the environment, such as euthrophication and soil acidification.

To make all this possible, we rely on the expertise of farmers and experts. In addition, we use cutting-edge technology such as a GPS-independent tracking system, zinc-air batteries for power, and even the CERNBot arm at our Kindergarten.Through this combination of people and technology, we aim to sustainably improve ecosystems for people, animals and plants, while efficiently recovering nitrate from recycling for farmers.

At the current time, there may be aspects that have not yet been considered. This is due to the relatively short processing time of this project. In comparison - the development of a robot fly took 20 years [48]. One of these aspects describes the economic consideration of the project. It is our conviction that the WOBOTs can save costs and, above all, valuable resources. However, in order to be able to give exact figures on this, further calculations and research will be necessary in the future.

We are convinced that with the WOBOTS we can create a solution that enables sustainable and environmentally friendly agriculture. We do not know how our planet will look in 2030, but we are inspired to think big to change our future - a future that starts today.

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