



# EXTENDED DOCUMENTATION

Meta HiLight Technology

Term Project – 722A48

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## **1. Preface**

The following document consists of potential jobs where the innovative technique of Meta HiLight could be applicable. The more promising ideas includes more extensive research while other ideas are done with less investigation. The three most promising ideas have been consulted through guidance and opinions from professionals within each field for a more comprehensive view. Additionally, this also showcased the professional's initial opinion of our ideas and if it would be possible or reasonable to further pursue the idea. The group aimed to generate both novel ideas where there were current solutions did not exist but also to improve existing jobs for better efficiency or performance. Additional information about the research and the topic can be found at the end of each chapter.

The promising technology of Meta HiLight and its versatile functions has made it applicable to various industries. From the rapid advancement and increasing interest of stakeholders in this technology, it is undoubtedly true that it will be able the future with a variety of sophisticated products and their application in all major sectors. We commenced our research with identifying major industries and professions where our technology may have a potential scope and applications. We aimed to identify in greater detail what jobs the technology could perform effectively and efficiently in the different industries. Through analysing multiple jobs, we began narrowing down the jobs to be done and categorize them from most to least prominent. We researched how existing technologies are solving the problems and performing. Through thorough research, detailed discussions, and expertise from Meta HiLight professionals, we managed to find potential applications of our technology in the medical and farming sectors. The idea was that we can improve the performance of existing technologies as well as finding a breakthrough application for each prospective industry. Furthermore, we expanded our research further and asked ourselves: what are the strengths and weaknesses of the existing technologies? How is our technology better than the existing ones? Are there any non-consumables and workarounds?

Through interactions with potential stakeholders in multiple fields, it became more evident how the technology of Meta HiLight can potentially resolve issues they encountered. However, there were also cases where the metamaterial would not enrich the industry and thus, excluded that market.

## **2. Most promising idea: Cow Chip for Small Farms in Sweden**

### **2.1 Insights**

Problem: From livestock farmers' point of view, the health of their animals is the most important aspect since it influences the overall ability to get milk or sell the meat of the cows and ultimately, the monetary success for the farmers. By walking around the barn every day, the farmers identify potential signs of sick cows. This takes time every day and is based on the subjective assessment of the farmer. Further monitoring is done by evaluating the feeding behaviour of the animals.

Need: To avoid inefficient time usage and identify symptoms early to avoid costly treatments, one need is to reduce the monitoring done by the farmer only. A solution with high precision is needed, at the same time it has to be worth it in terms of costs. Farmers we talked to confirm this need and were interested in a technology that helps them to monitor the health status of their cows – especially the mother cows since they are the most valuable animals for them.

Idea: A chip using Meta HiLight technology (more specifically the biosensing ability of it) would be implanted into the cow. The chip would then be connected to a technology (e.g., by Wi-Fi) that allows the farmers to quickly access the health data of the cows. Data to be measured could be heart rate, temperature, movement for instance. In general, this would allow farmers to use their time more efficiently and identify sick cows at very early stages which positively affects the process for the veterinarian as well.

### **2.2 How the Technology could work**

*Design:*

- A self-powered microchip that can be implanted internally
- The data result can be transcended via Wi-Fi to a phone app

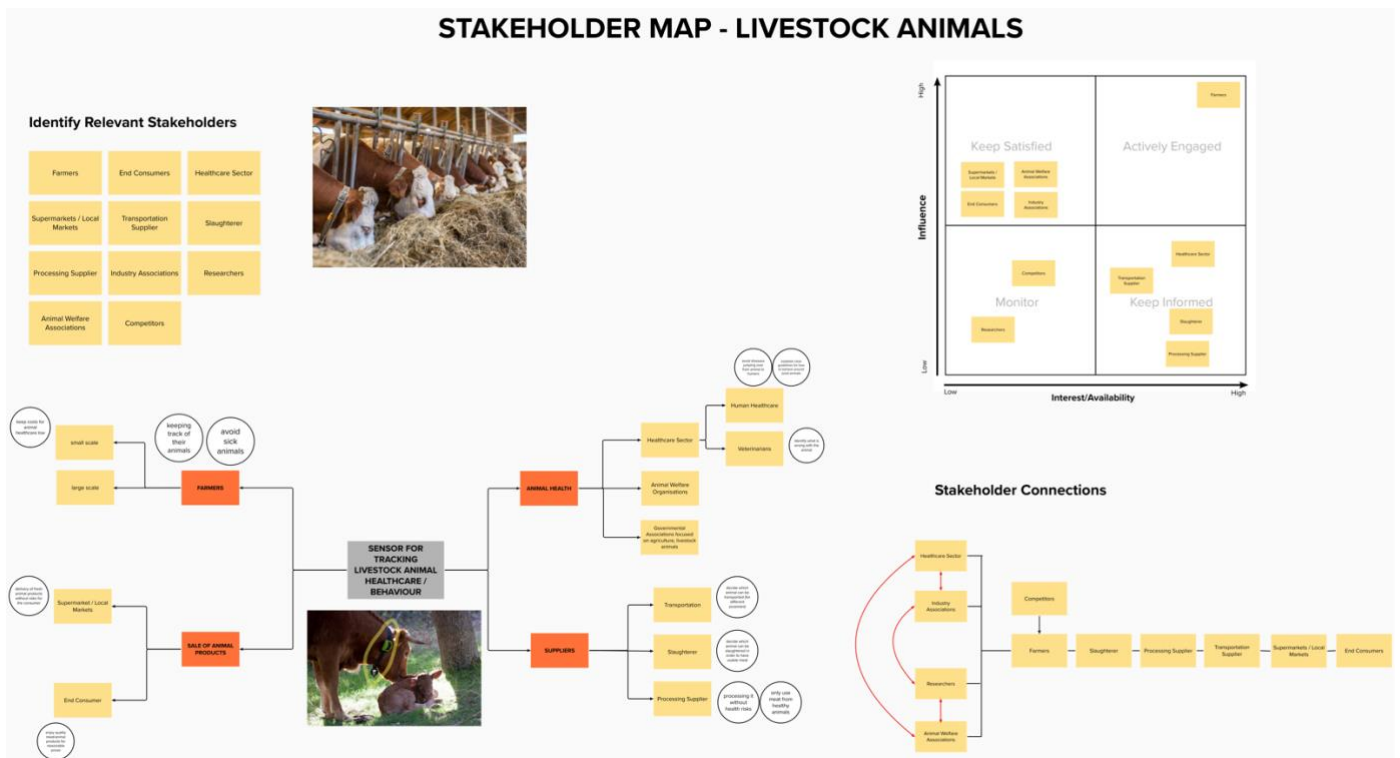
*Criteria:*

- Combination of these two bio sensor technologies
- General biosensor → Detect more simple things such as temperature, heart rate, activities (movements),
- Cell-based biosensor → Detect more detailed things such as cells and tissues.

*Data result readings:*

- The data result should be saved as a track record to display cows' health history
- The data result should also be able to read and interpret the cows' activity (movements) or in other words map cows body language in order to translate what the cow is feeling (Reflect the cows behaviour which help farmers understand the cows mental health)

## 2.3 Stakeholder Map



- Farmers
  - typically must observe the animals every day, by own judgement and based on experience
  - could reduce the necessity of complicated measures, e.g. action plan for reducing the use of antibiotics (or other measures in place to fight the symptoms of incomplete animal health monitoring) (<https://www.landwirtschaftskammer.de/landwirtschaft/tiergesundheit/aktuell/antibiotikamonitoring.htm>)
  - less costs for vaccines, treatments → maybe ask an animal doctor?
  - no specification on the sensors but a similar idea is used in this project: <https://www.thuenen.de/de/at/projekte/digitalisierung-und-automatisierung/digischwein/> → tracking the health of pigs in order to avoid subjective assessment of the farmer
    - checking deviation from the normal behaviour & detecting diseases early
    - measuring water removal, estimated weight by 3D camera, temperature by infrared camera
    - sensor at the ceiling of the barn in combination with ear marks on all pigs (<https://www.youtube.com/watch?v=fyeInE19m7Y>)
  - project to track behaviour (standing, walking, digesting, etc.) of cows with a sensor (<https://www.alpine-space.org/projects/sesam/en/home>) / reached out to get more information regarding the sensor used
- Private Users
  - For example, horse, dog etc. -owners
- End Customers

- Consequences of current factory farming for humans:
  - Antibiotics / leftovers of antibiotics in meat leading to a diminishment of antibiotic effects for humans (<https://www.careelite.de/en/factory-farming/>)
- Healthcare sector
  - veterinarians
  - more general: epidemics (or even pandemics) could be avoided by early detection
- Retailers / Supermarkets / or local markets depending on the area
  - quality of meat could be improved
  - tracking of how the animal you're eating felt during its life
- Transportation/logistics or any other supply chain stakeholders
  - decision process if animals can be transported to the slaughterer → e.g. when cows lose their ear tag, they might have to be killed because it cannot be tracked where they come from
  - (<https://www.landwirtschaftskammer.de/landwirtschaft/tiergesundheit/pdf/leitfaden-rindertransport.pdf>)
  - also benefits the improvement of the transportation process → very stressful for the animals
- Slaughterer
  - being less exposed to sick animals
- Processing plants
- Animal welfare associations
  - refers to how animal welfare of livestock animals can be improved in general (<https://www.thuenen.de/en/cross-institutional-projects/national-animal-welfare-monitoring/>)
- Governmental associations with focus on agriculture, animal welfare, animal health, disease control
- Researchers (who focus on animals and their behaviour)
- Industry Associations: highly criticised recently (e.g. Tönnies in Germany)
- Competitors
  - Smaxtec (for Cows) (<https://smaxtec.com/de/ueber-uns/presse/>)
  - CowManager (for Cows) ([https://www.cowmanager.com/de-de/referenzen/rustholstein](https://www.cowmanager.com/de/de/referenzen/rustholstein))
  - SmartBow (<https://www.smartbow.com/de/Home.aspx>)

## 2.4 Persona

### *User*

Farmers → Cows

- Young adults
- Adults
- Corporations

### *Need*

- Disease protection

- Emotional understanding
- Comprehensive monitoring

*Insight* – what our persona aims for

- Disease protection
  - Cows are especially interesting because mother cows are kept and not slaughtered, so it is very interesting to keep “good” cows healthy as long as possible
  - Subjective detection
- Emotional understanding [Tracking behaviour, mental state]
  - Animals don’t show emotions as humans → requires tracking in different ways than just observing the animals
  - Transparency: Mainly covers information about the origin and the processing of the meat but not the health of the animal
  - Cost
- Monitoring issues:
  - Parasites: cannot be noticed before they show symptoms, then a lot of animals are already infected
  - Difficulty to monitor animals in a big pasture / dangerous plants also cannot be monitored then
  - He said that on his farm they don't use technologies to monitor health. If the farmer detects suspicious behaviours of an animal he contacts a doctor, which investigates the individual animal
- Cost:
  - Private/agricultural use: animals might have to quarantine or be separated from other animals
    - this might be difficult with a lack of resources (money, space)
  - Cost factors are crucial as the costs are paid in the end by the consumer

### 1. *What is the story of our persona?*

Our persona is called John, a farmer in his forties who has worked on his family farm ever since he was young. John's main source of income is the dairy from mother cows and selling the meat and breeding the bulls. The cows are the number one priority for John since smaller animals, like chickens, are more costly to monitor individually rather than in bulk. Having a good reputation on his farm is very important to John because it displays that he is conducting ethically and his cows are happy which results in good quality products, and keeps the local communities and media pleased. The farm currently has 50 cows.

### 2. *What is their journey through the problem space?*

Despite the solid knowledge and experience that he has gained over the years, he still comes across issues in disease outbreaks, emotional understanding, monitoring, and tracking. Thereby, he is in need of a tool that would help him monitor his cattles when he is not around and to get further information on how his cows are doing (Behaviourally, mentally, and physically). This is because in terms of disease protection, the mother cows are especially valuable, and keeping them healthy and alive is crucial for their business. He also found that understanding the emotions of the animals is difficult. It's important to understand their emotions to get a deeper understanding of their mental state and behaviour (their diet)



because the farming industry suffers from transparency issues; the industry is more known for showing origin and process but not animals' health. His monitoring issues stem from the fact that he lacks comprehensive technology to monitor the cow's health and instead detects suspicious behaviours of an animal himself and then contacts a doctor, which investigates the individual animal. Lack of comprehensive monitoring is also bad because it is difficult to monitor animals in big pastures if they consume dangerous plants, or if they catch parasites that cannot be noticed before they show symptoms thus a lot of cows will already be infected (this applies to other diseases too). The lack of early detection is very cost inefficient because John has to go through a cost dilemma of what health stage is treatable while remaining profitable and cost factors are crucial as the costs are paid in the end by the consumer. John got some insider knowledge that installing a comprehensive monitoring system will detect sick cows earlier, which leads to better treatment, less loss of milk, and fewer costs for medication, and hence, higher quality of the product. Other benefits are doctors can see/observe the development of the cow over a longer time. It also supports sophisticated and data-based decision making, higher ease of use, and more efficiency in terms of using time and allows it to have more animals with less effort.



NAME

John, Small Farmer

### Demographic

Male 47 years  
Växjö, Småland

+ ADD FIELD

### Skills

Tech-savvy

Low type Medium type High

Physical labour

Low type Medium type High

+ ADD SKILL

### Technology



### Background

This is John, a farmer who has worked on his family farm ever since he was young. John's primary source of income is the dairy from mother cows and selling the meat from young neutered males. The cows are the number one priority for John, and it is thereby essential that his farm has a good reputation. Thus, John displays that he treats his cattle as ethically humane as possible to keep them healthy and strong. This eventually results in better quality products where the local communities and media are pleased. The farm currently has 100 cows that need daily monitoring. He monitors his cattle's with a daily routine of viewing the cows for the best end quality. Despite the solid knowledge and experience that he has gained over the years, he still comes across issues in disease outbreaks, emotional understanding, monitoring, and tracking. He foremost sells his cows to local markets where the quality of the cows are essential.

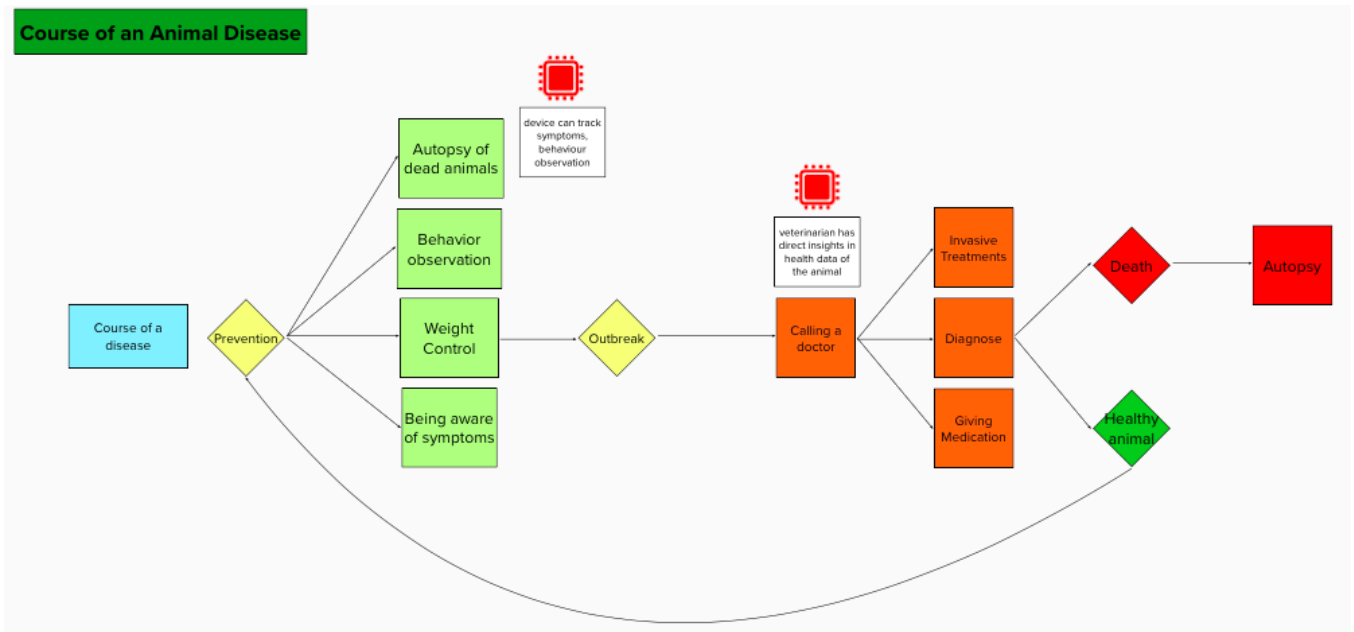
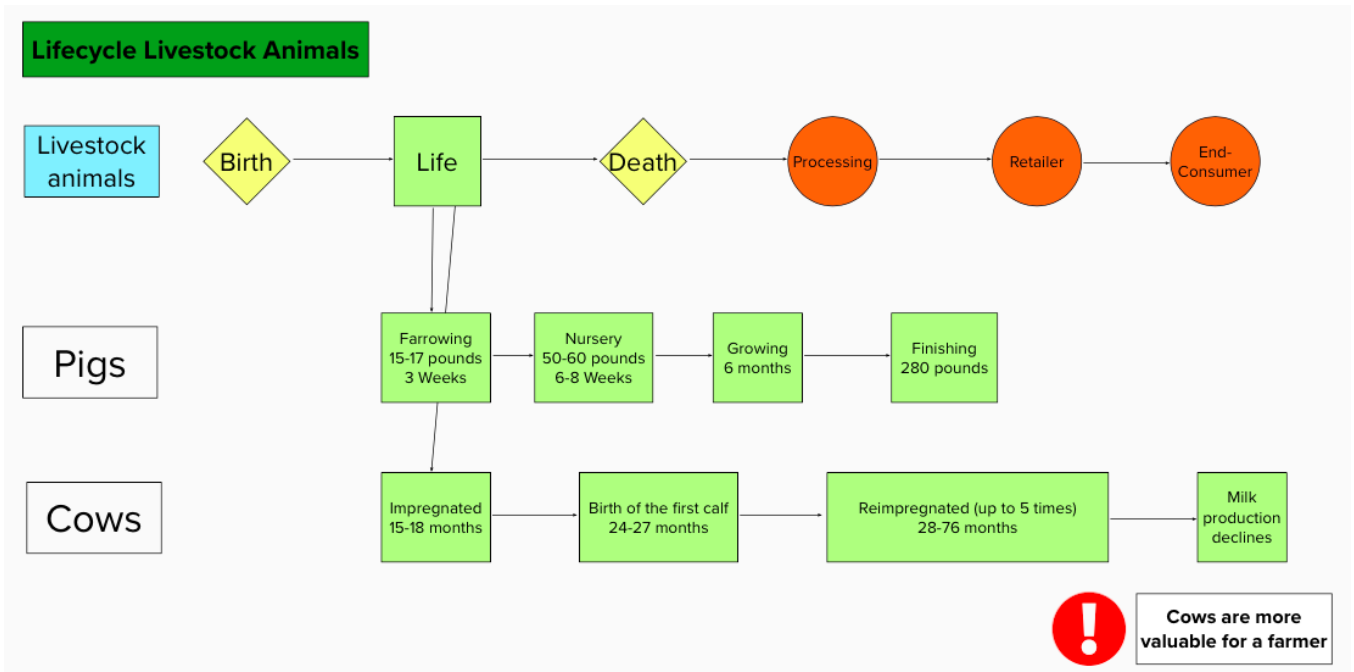
### Motivations

- Raise his cattle and protect them from diseases
- A continued steady income
- Reduce the time and costs surrounding the animal treatment
- Get a better understanding of the cows well being through a more efficient analysis
- Reduce his stress by lowering his working hours
- Optimise time for the most beneficial outcome

### Problems

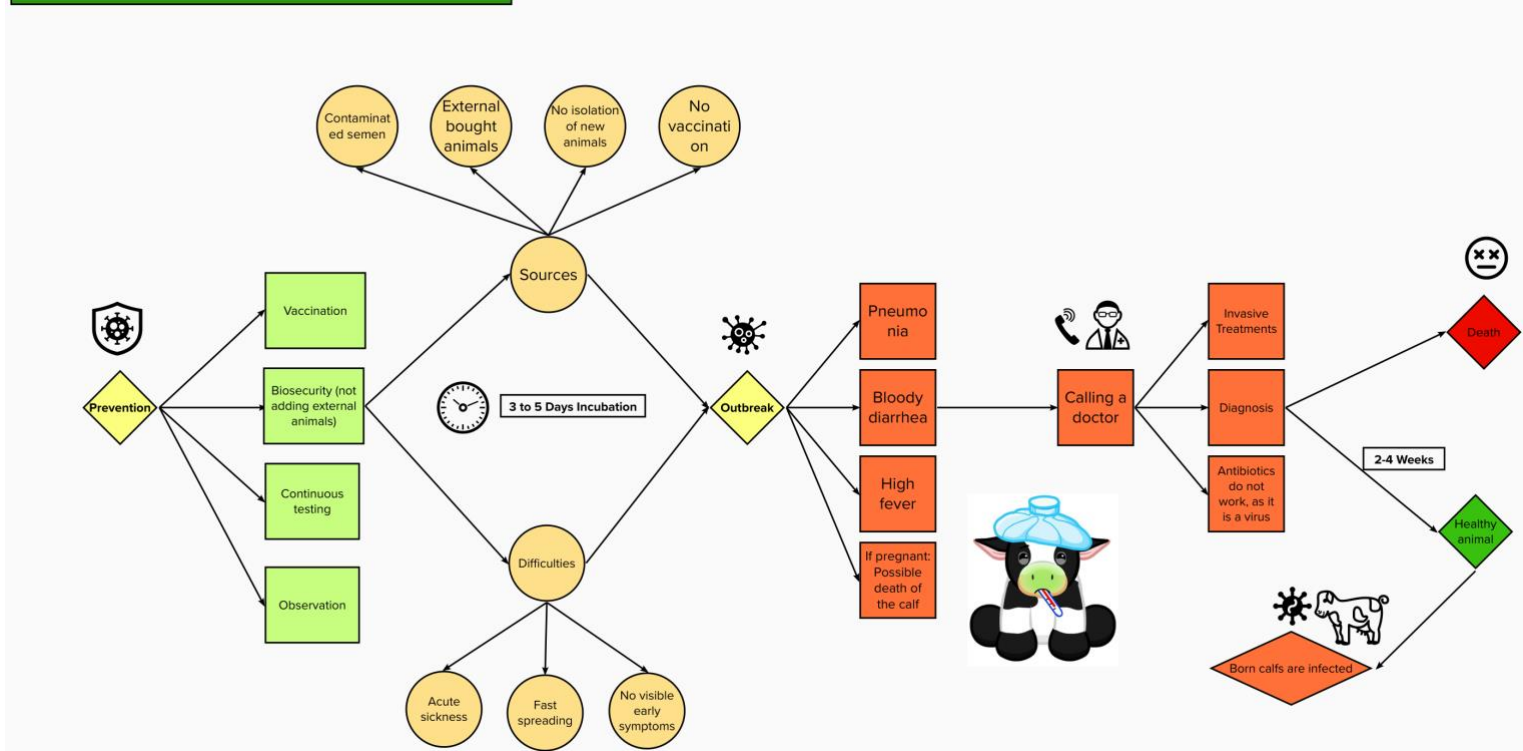
- He has problem keeping track of his cattle (difficult to see who's healthy or sick)
- Issues with disease outbreaks
- Lacks comprehensive technology that can provide a full-scale view of the cow
- - Parasites and dangerous plants are difficult to detect
- The dilemma of what diseases are worth saving
- Difficult to showcase the cows wellbeing
  - Are often environmentally focused rather than individual.

## 2.5 Journey Map



## Exemplary disease of cows:

### Course of Bovine Viral Diarrhea (BVD)



## Cows:

- Female cows are kept for reproduction
- Male cows are slaughtered
- Tails get removed (forbidden in certain regions)
  - Prevention that animals bite each other in the tail
- (<https://thehumaneleague.org/article/what-is-factory-farming>)
- Why cows are more valuable?
- Cows are very special in terms of diseases
- Pigs or animals that provide meat have to fulfil a certain picture, so the focus is laying more on food and weight
  - Health is not important, they only have to fulfil the picture
- The focus at cows is laying on the amount of milk they give and not about the quality
- Pregnancy of the cows is important to the amount of milk
- Goats are also a coming market as they give milk too, but it is small at the moment
- Censoring for meat is also something that is coming
- Consumers do not care about the quality of the meat, even if they say something different, in the end they buy the cheapest one
- Biggest part of the produced fresh milk and meat is used as ingredients for other products, in which no one cares where they come from
- Farmers only care about value for money, so they only invest in items that are \*worth it\*

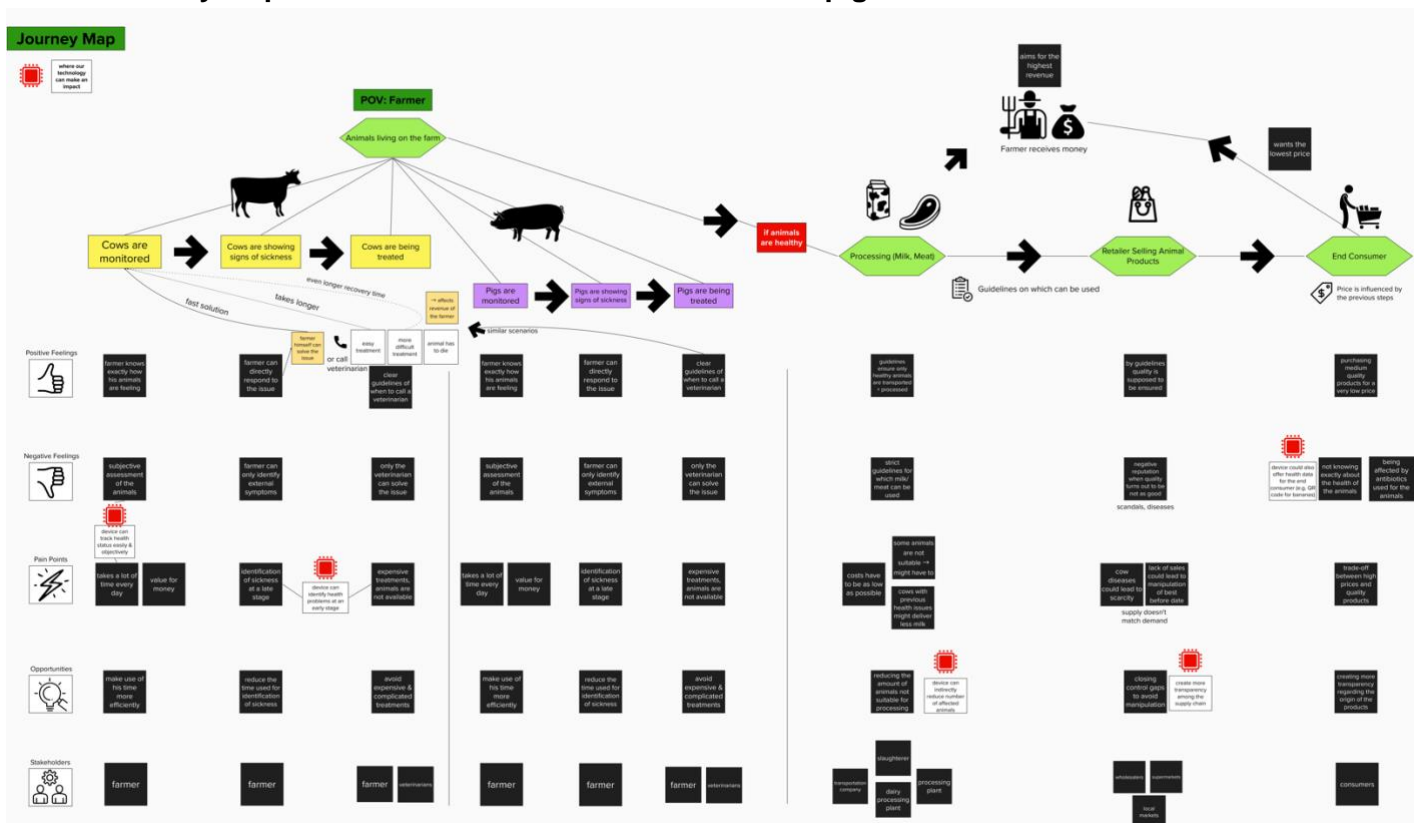
## Chickens:

- Boredom leads to chickens attacking each other with their beaks (can lead to cannibalism or even death), as they have in certain settings no freedom for exploration
  - Therefore, some farmers cut the beaks to prevent that (<https://thehumaneleague.org/article/what-is-factory-farming>)

Pigs:

- Tails get removed (forbidden in certain regions)
  - Prevention that animals bite each other in the tail
  - For pigs it is a way to make them more sensitive in that area and make them intrinsically avoiding to be bitten
- (<https://thehumaneleague.org/article/what-is-factory-farming>)

Journey Map of a small-scale farmer with cows and pigs:



2.6 Research / Information

1+2. How is the job currently done and how are other products trying to solve that problem?

- Using vaccinations to minimize the risk of outbreaks and increase the resistance of the animals against these diseases
- Observation of the animal behaviour by the farmer
- Digital solutions in the stomach or the earmarks but only available for cows
  - Identification of movement routines, body temperature, detection of stress, saliva or other body fluids etc.
- Recognizing the group as a whole recording sneezing and coughing sounds of chickens for example that allows to identify certain diseases

- RFID Chips to identify animals

*3. How has the technology of these jobs evolved?*

- Rapid increase of industrialized animal farming is exacerbating the problem of disease outbreaks
- Weighing costs of vaccination against the possible profits, to reduce the risk of mass outbreaks (Animal vaccination is a mass market)

*4. What are available solutions on the market?*

- Farmers that are not able to spend the money for vaccines or where they are not available have to rely on the natural behaviour of the animals to determine if they are sick or not
- Digital solutions available mostly for cows using an earmark or sensors in the stomach
- Emerging market
- Currently there are some companies that are testing sensors used for human medicine with animals

*5. What are their strengths and weaknesses?*

- Strengths:
- Weaknesses:
  - High costs
  - Requirement of invasive treatments, which is difficult to handle on a regular base
  - Missing or very limited methods or opportunities for diagnostics
  - Basically, no overview
  - Human errors
  - Difficulty to apply technologies for smaller animals as it is difficult to identify the individual animal, which means that they are treated and considered as an entity

*6. How do they compare to our companies?*

Currently existing solutions are mainly available for cows and/or have very limited use. Considering the pandemic situations and the risks emerging through factory farming the further monitoring of animal health gets more and more important, which is also reflected in the fact that there is an emerging market in that area and diverse solutions are currently in a testing stage.

*Do we see any nonconsumption?*

- Reduction of factory farming in the future as it is also not considered as very sustainable and desirable in terms of animal treatment
- Shift of consumers towards buying more ethical and sustainable farming methods

*What workarounds have people invented?*

- Human observation of the behaviour of the animals

*What surprising uses have users invented for existing products?*

- none

*Interview with Salesperson from CowManager:*

CowManager / <https://www.cowmanager.com/en-us/>

- Salesmen: Jan-H. Thye-Lokenberg (tel:+491607278591)
  - Why only cows?
    - Cows are very special in terms of diseases
    - Pigs or animals that provide meat have to fulfil a certain picture, so the focus is laying more on food and weight
      - Health is not important, they only have to fulfil the picture
    - The focus at cows is laying on the amount of milk they give and not about the quality
    - Pregnancy of the cows is important to the amount of milk
    - Goats are also a coming market as they give milk too, but it is small at the moment
    - Censoring for meat is also something that is coming
    - Consumers do not care about the quality of the meat, even if they say something different, in the end they buy the cheapest one
    - Biggest part of the produced fresh milk and meat is used as ingredients for other products, in which no one cares where they come from
    - Farmers only care about value for money, so they only invest in items that are \*worth it\*
  - Why is the company not expanding towards other animals?
  - Which problems do you solve for the farmers?
    - Earlier detection of problems (1-4 days)
    - Possible to identify the level of stress, for example by shifting the cow towards a new group, e.g., hierarchy fights
  - Costs?
    - Company sees themselves as software company
    - Price Hardware + Software is around 25€ per cow a year
    - Minimum 2 antennas necessary (1.300 € each)
    - Sensors 30€ each
    - Customers receive a lifelong guarantee on the function
    - Sensors can be reused
  - Components of the system?
  - Thoughts about switching to B2C?
  - Horses?
    - Future market
    - Security might be an aspect
    - Tracking location of the animals to prevent theft
  - How does it work?

#### *CowManager References*

- Environmental Influences can be shown
- Sick animals can be found earlier, which leads to:
  - Better treatment
  - Less loss of milk
  - Less costs for medication and hence, higher quality of the product
- Doctors can see/observe the development of the cow over a longer time

- Supports sophisticated and data-based decision making
- Higher ease of use and more efficiency in terms using time
- Allows it to have more animals with less effort

#### *“Life Cycle”*

- Maintaining value

#### *Possible Users:*

- Zoos
- Breeders
- Private customers
- Horse (maybe also B2B)
- Check differences in terms of the animals and things in common

#### *Questions for Veterinarians*

- Which diseases are worth tracking? Where would it make a difference to have a device to constantly monitor the health of the cow?
- When can you prevent and when can you heal?
  - Costs per stage
- Options that farmers have to treat the animals / Lifecycle
  - In which cases does a veterinarian have to come? When can the farmer solve it himself? / Regulations regarding this?
  - Veterinarian: Treating causes
  - Veterinarian: Treating symptoms
- Diseases get more resistant to antibiotics, so it gets more and more difficult to treat the sick animals

#### *Interview with a small farmer from Germany:*

*Is there a fundamental interest in constantly monitoring the animals, e.g., to detect abnormalities?*

- It might make sense, but for him the monetary aspects have to be considered in depth

*What would a solution need to make it interesting for you?*

- Continuous monitoring that covers as much aspects as possible

*Are there animals that would require it more or less?*

- Individual monitoring of chickens makes no sense
  - Measurement of their health is also based on the number of eggs they produce per day
  - The take 10 random animals each day and measure their weight
  - In big barns they have automatic scale
- Cows makes sense
- Female pigs that are relevant for reproduction

*How high should the maximum costs be to make it reasonable?*



- Per cow maximum 50€ per years is a price that would be reasonable for him

*Which processes and routines do you currently have? (How is the job currently done?)*

- Daily monitoring of the performance and visual control through observation

*What type of data would you want to have?*

- Temperature
- Inflammation levels
- Birth status or signals

*Which animals do you have?*

- 1000 chickens (600 for eggs, 400 for meat)
- 100 cows (30 mother cows / focus on meat production)

*What is the process of a disease?*

- Prevention
  - Weight is controlled
  - Observation of clinical symptoms, e.g.,
    - Animals is a part of the herd
    - Not eating anymore
    - Is not walking or standing
- Outbreak
  - Calling the veterinarian
  - Diagnosis
  - Providing medication
- Death
  - Autopsy to analyse the cause of death, if it could also affect other animals
- Restoring the health of the animal

*Which importance has the quality of your products for you, in terms of showing the health of your animals?*

- He is rather a small farmer that directly sells to his customers
- Quality of his products has a high value as they are sold directly, and the quality decides which prices people accept to pay

*How is the selling and buying of animals done nowadays (analogy of car service)?*

- A history of an animal's life would be good in terms of selling and buying for both sides as the price can be set more accurate
- Nowadays the only ways of considering the health of an animal is to consider the individual and observe the circumstances in which the animal lived before

*Interview with an animal biology student:*

- parasites → cannot be noticed before they show symptoms, then a lot of animals are already infected
- difficulty to monitor animals in a big pasture / dangerous plants also cannot be monitored then

- animals don't show emotions as humans → requires tracking in different ways than just observing the animals
- private/agricultural use: animals might have to quarantine or be separated from other animals
  - this might be difficult with lack of resources (money, space)

Useful articles found on the topic:

Why is it so hard to prevent disease outbreaks in factory farms (<https://sentientmedia.org/why-its-so-hard-to-prevent-disease-outbreaks-on-factory-farms/>)

Existing Solutions for Cows: <https://www.smartbow.com/en-gb/home.aspx> + <https://smaxtec.com/de/module/gesundheit/>

Dawkins (2021), Does Smart Farming Improve or Damage Animal Welfare? Technology and What Animals Want, <https://doi.org/10.3389/fanim.2021.736536>

*Best article to explain the topic:* Neethirajan, S. (2017). Recent advances in wearable sensors for animal health management. *Sensing Bio-sens. Res.* 12, 16–29. doi: 10.1016/j.sbsr.2016.11.004

### **3. Chip for Livestock Animals on Large Farms**

#### **3.1 Insights**

Problem: From livestock farmers' point of view, the health of their animals is the most important aspect since it influences the overall ability to get milk or sell the meat of the cows and ultimately, the monetary success for the farmers. Instead of walking around the barn every day, big farms can already rely on specific technology to monitor their animals. Nonetheless, the existing solutions are expensive and lack accuracy.

Need: To identify symptoms early to avoid costly treatments, one need is to improve the monitoring of the animals. A solution with high precision is needed to especially track the mother cows since they are the most valuable animals for them.

Idea: A chip using Meta HiLight technology (more specifically the biosensing ability of it) would be implanted into the cow. The chip would then be connected to a technology (e.g., by Wi-Fi) that allows the farmers to quickly access the health data of the cows. Data to be measured could be heart rate, temperature, movement for instance. In general, this would improve the current systems used and identify sick cows at very early stages which positively affects the process for the veterinarian as well.

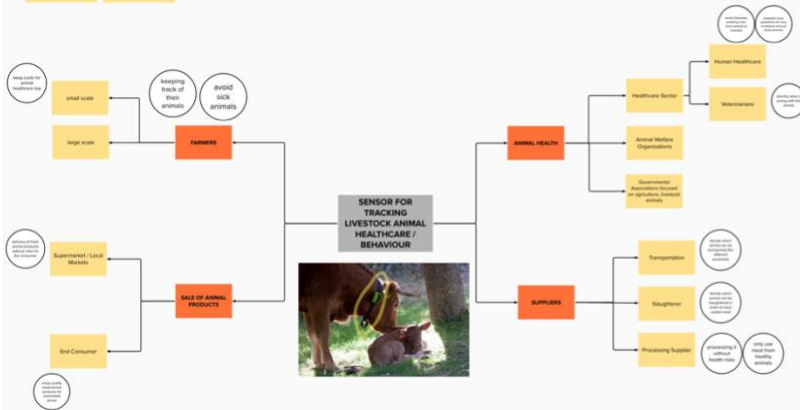
Reason for no further development: Since larger farms have more (personal and financial) resources available than small farms, the need for our product could have been identified stronger for smaller farms. For larger farms, the number of animals also plays a role in how valuable our product would be. The more animals a farm has, the less value has one specific cow in case it has to be slaughtered. This does not mean, they do not want to avoid it, but therefore, the value of healthy animals is more significantly for smaller farms. Ultimately, this market has been skipped to deliver a more precise solution.

### 3.2 Stakeholder Map

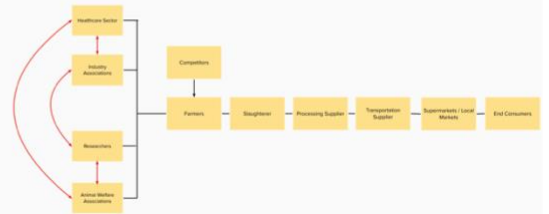
#### STAKEHOLDER MAP - LIVESTOCK ANIMALS

##### Identify Relevant Stakeholders

Farmers	End Consumers	Healthcare Sector
Supermarkets / Local Markets	Transportation Supplier	Slaughterer
Processing Supplier	Industry Associations	Researchers
Animal Welfare Associations	Competitors	



##### Stakeholder Connections



### 3.3 Persona

NAME

⌵ Kerstin, Large Farm 🔄 ✎



#### ⌵ Background

Kerstin is a 39-year-old cow breeder who owns a farm with around 500 cows. She has been in charge of the farm for six years and works long hours with her 12 employees. Similar to smaller cattle farmers, she focuses on the dairy for the mother cows and selling the meat of the bulls and calves. The beef is primarily sold to Westfleisch, a German meat distributor who later sells the meat to supermarkets. Naturally, the quality of the food has to reach certain demands, such as health of the cattle and a sizes of the cows. However, it is generally more critical with quantity rather than the quality of the meat since she is a mass producer.

She currently has a monitoring system that has worked quite well for them initially, but as the years pass, she has noticed various issues emerging and noticed that her monitoring system is quite flawed. This has affected her cost management because she has to pay and compensate for ongoing problems with longer working hours for her employees, and it is challenging to keep track of the sick cows.

#### ⌵ Demographic

♀ Female ⚙️ 39 📉 years

📍 Linsburg, Germany

+ ADD FIELD

#### ⌵ Motivations

- Becoming the market leader in mass-producing by holding the most shares in the market.
- Develop a positive image to increase reputation in media and local communities' eyes.
- Being a good leader and role model to her employees and providing them with benefits.
- An adequate system to reduce working hours and hard physical labour.
- The bigger farm has the potential to obtain large market share and be one of the most prominent players
- The increased reputation of having an excellent monitoring system which leads to better cow treatment
- Becoming a good leader and role model to her employees
- Working less for more results
- Great employees whom she wants to keep

#### ⌵ Skills

Tech-Savvy



Physical labour



+ ADD SKILL

#### ⌵ Frustrations

- A flawed system results in the health of her cows being jeopardised
- Disease outbreak has transmitted to other cows
- Late disease detection has resulted in severe disease stages that are costly to treat or unprofitable
- Fatalities due to not detected diseases in time
- Unhealthy cows produce worse quality products where batches can become unusable
- Working long hours for ineffective results

The issues mentioned can be related to why Kerstin has poor cost management, which has made the farm lose income. The continuation of this will naturally lead to lower income.

#### ⌵ Technology





## **4. Chip for Pets, more specifically Horses**

### **4.1 Insights**

Problem: Horses are animals that depending on the owner are used for horse riding, jumping – either professionally or just for fun. They are very expensive animals and once they suffer from a disease, the horse owners are not only emotionally affected by it but do everything in their power to make the horse healthy again. Treatments are often very costly and therefore, want to be avoided. Some owners also cannot visit their horse every day, e.g., when the stable is not as close to their home.

Need: This dilemma creates a need for checking on the horse regularly and identifying diseases early in order to avoid costly treatments.

Idea: A chip for pets – more specifically horses – could solve the issue of monitoring the horse regularly. This way, symptoms could be identified much earlier and similar to the livestock animals, costs could be avoided. A chip, connected to an app the animal owner has access to, could track heart rate, temperature, and other health statuses.

Reason for no further development: Since the emotional value of pets like horses is difficult to measure, it was a bit unclear for us how much value a chip to monitor the health status would bring for the owners. Since the industry behind livestock animals was more graspable and clearer needs could have been identified, we decided to go with livestock animals instead of horses.

### **4.2 Stakeholder Map**

- Families
  - Personal owning: These are owners who purposely own horses just for the sake of keeping them within the farm with no additional intentions than just owning them. It's still important to monitor the health of the horses for maintaining their lives and prevent disease outbreak
  - Horse riding: Some families own horses for the purpose of competitive horse riding. Therefore, it's crucial to check and monitor the health state of the horse and make sure it's at an optimal and suitable level for the competitions.
- Medical
  - Veterinarians are interested in horses due to either curing them for families or businesses, or for personal studies and research.
  - Health insurance, because horses are expensive to buy and maintain, getting insurance may be a necessity for owners.
- Media
  - News: Few news mediums may be interested in promoting or displaying results of horse competitions, betting or just any potential disease outbreaks to aware citizens with interest.

- Journalists: Journalists with interest in animals, particularly horses, may want to write a paper or potentially expose any horse mistreatments of farms or businesses.
- Local communities
  - Whistle blowers: If there's any animal mistreatments, whistle blowers would want to expose these matters for justice and improve unethical behaviors. This would also be a specific interesting input for journalists and local communities in particular but also all of the stakeholders.
  - Avid horse betters: Individuals who are actively involved and interested in horse betting may be interested in general knowledge of horses.
- Business
- Horse betting
  - Horse clubs
  - Competitors: Within horse betting, competitors in various clubs are desperate in obtaining the healthiest and most competent horses to get advantage over their other competitors.
  - Horse riders: The individuals who ride the horses for the betting, are also interested in getting the best ones. Both for winning the rounds and getting paid more for it but also for personal intrinsic reward of accomplishment.
  - Club managers: Club managers in charge of managing and trading the horses are also interested in getting the most suitable and best current horse on the market for recruiting new potential horse "winners".
- Government

When owning horses not only for personal use, sports but especially for business purposes, governmental officials will put laws and regulations on the usage, betting and trading of the horses. This is to ensure the economical state of trading but also minimize unethical practices and mistreatments.

#### *Connection between stakeholders*

1. Businesses can be hindered and affected through two major stakeholders. News and journalists' output can have a big effect on the media which results in either positive or negative reputation of the business/farm. Additionally, any rules or regulations set by the government can also limit activities that the businesses conduct.
2. Horse betting and horse trading has an intercorrelated relationship, trading horses is a part of the process of recruiting the most optimal and strong horse/breed that's suitable for the competition. It's important for the horse betting clubs to win since it affects the horse betters and their money. Horse trading also has connections with personal investors who aren't directly connected to horse betting but just want to invest in valuable horses. In continuation zoos are also involved in horse trading, trading the best-looking horse for the zoos.
3. Show jumping connects with both sports and families since individuals in a family who owns horses are usually involved in show jumping sports which is a competition.

### **4.3 Persona**

#### *User*

Horse owners with farms



- Business (Sports) → Adults, corporations
- Hobbies (Horse riding, Horse farms) → Teens, young adults, Adults

### *Needs*

#### Comprehensive monitoring

- Disease detection
- Cost management

### *Insights*

#### Comprehensive monitoring

- Cost vs treatment
  - Diseases if not detected early can be very expensive to treat
- Colic diseases → Issue
  - High maintenance
  - High purchasing power
  - Personal connection
- Valuable investment → Willingness


### *What is the story of our persona?*

This story is about Michaela, she has three horses that need daily care, especially during winters when she has to take them in during the nights and free them during the mornings. Furthermore, she has to ride the horse as well as feed and shovel the horse's feces. This already takes a lot of her spare time, but she still feels that she should spend even more time in the stable for her to see that the horses are doing well, and she feels like there's always something she should do. Every time when she's not in the stable, she always has an anxious feeling about the horses' well-being, and she wished that there was a tool where she could see her horses. Even though she has some other riders in the stable that can help her with some of the daily duties, she feels like they do not know her horse as well as she does. Simultaneously, she wants to keep track of the horses, both during the nights and while the horses are in the paddock to make sure that everything is running smoothly.

### *What is their journey through the problem space?*

One very common disease amongst horses is a colic disease. It often happens during the night and the horse experiences pain which could result in intestinal diorsiton and veterinarians would have to get there to inspect. The problems are relatively easy to detect and could be prevented or ease the disease by walking the horse for 20 minutes, rest 10, and continuing in the same pattern. However, other diseases that are less easy to cure may emerge thereby it is important to have a comprehensive monitoring system to detect diseases. This is because once a horse has caught a disease, we may not know what stage the horse is in, nor if other horses have caught it too. This is affecting her cost management and she needs to be sounder in her expenditures. Therefore, the dilemma of whether it's worth treating her horses (depending on what sickness stage it's in) due to the cost vs the risk of actually being able to cure them. This means she needs a good monitoring system to avoid such issues. Michaela is willing to pay large amounts for a good monitoring system because she has personal connections to them, horses need high maintenance and it's a valuable investment.

## :: Michaela, Aspiring Show Jumper



### :: Background

This story is about Michaela; she is an aspiring showjumper with two horses that need daily care, especially during winters when she has to take them in during the night and free them during the mornings. Moreover, she has to ride the horse and feed and shovel the horse's faeces. This already takes a lot of her spare time, but she still feels that she should spend even more time in the stable to see that the horses are doing well and feels like there's always something she should do. Whenever she's not in the stable, she always has an anxious feeling about the horses' well-being and wishes there was a tool where she could see her horses. Even though she has some other riders in the stable that can help her with some of the daily duties, she feels like they do not know her horse as well as she does. Simultaneously, she wants to keep track of the horses, both during the night and while the horses are in the paddock, to ensure that everything runs smoothly.

### :: Demographic

Female 26 years  
Kassel, Germany  
Sales Representative & Aspiring horse. who

+ ADD FIELD

### :: Goals

- She wishes to have a better balance in her life between her ambitions with her attempt to become a professional showjumper and her job.
- The horses *take up a lot of her spare time, but she still feels that she should spend even more time in the stable to see how the horses are doing.*
- *Whenever she's not in the stable, she always has an anxious feeling about the horses' well-being and wishes that there was a tool where she could see her horses.*
- *Even though she has some other riders in the stable that can help her with some of the daily duties, she feels like they do not know her horse as well as she does.*

### :: Skills

Tech-Savvy: 0 to 100 (slider at ~60)

Physical Labour: 0 to 100 (slider at ~40)

+ ADD SKILL

### :: Motivations

The following motivations for the monitoring device for Michaela:

- See how the horses are doing when she's not there
- Better evaluation of the horses well being
- An early indication of any diseases
- A more scientific view of the horse's physical status

### :: Frustrations

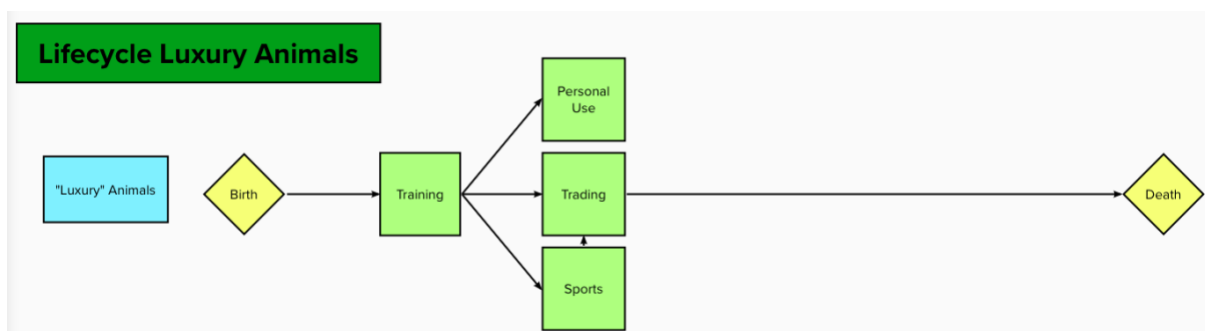
She wishes to have a better balance in her life between her ambitions to become a professional showjumper and her job.

*She wants to know how the horses are doing when she's not there*

*Even though other riders in the stable can help her with some of the daily duties, she feels like they do not know her horse as well as she does.*

*She needs to be aware of the horse's daily physical status.*

## 4.4 Journey Map





could be prevented or ease the disease by walking the horse 20 minutes, rest 10 and continue in the same pattern.

Further on, she mentioned that there are multiple ways to detect colic, for instance:

- The movement of the horse
- The stomach is quiet (Usually very loud)
- Fever
- Kicks a lot
- The pulse increases
- Fever
- Lays down on its stomach

The expenses, if not detected early, can become extremely high. She mentioned that one of her horses got colic and had to be transferred for a 2,5h trip for a three-day surveillance with veterinarians, which obviously became very costly.

Malone (2021) mentions that “You should call a veterinarian if:

- You haven’t observed the horse in several hours and you notice signs of colic
- You don’t know the length of time the horse has been showing signs of colic
- The colic is severe and doesn’t improve with walking
- The horse’s vital signs are not normal, you can review normal vitals for horses in “Basic first aid for your horse.””

Malone, E. (2021). Colic in your house. *University of Minnesota Extension*. Available at: <https://extension.umn.edu/horse-health/colic-your-horse>

#### Different Diseases:

One usual disease among horses is colic. It is very common and one of the deadliest diseases for both cows and horses. The causes can vary but it is usually abdominal pain caused by over digestion of grain, eating sand or the water itself. The symptoms can be shown in multiple ways, for instance:

- The horse is laying down
- Losing its appetite
- Walking in circles
- Diarrhea
- Sweating

#### Prevention:

Colic is not preventable usually but by taking certain measurements the chances of getting colic can be mitigated. These include:

- Turn your horse out as much as practical
- Have a clean water source
- Don’t feed hay on sandy ground
- Don’t feed grain unless the animal needs the extra energy
- Change your horse’s diet gradually

- Have a good insect control program

It is usually treatable, especially if you notice it at an early stage. Otherwise, it can become costly for the horse owner.

#### *Strangles:*

- Most frequently diagnosed infectious disease in horses, cattle, buffaloes, sheep, and goats
- Highly contagious
- Easily transmitted between animals
- Infects horse's throat and caused by a bacterial infection called Streptococcus Equi
- Lymph nodes swell and eventually burst thus discharging puss that then runs out of the jaws and nose of the animal.
- Rarely fatal but if not treated then death of the animal can occur

#### *Symptoms:*

- Fever, mucous discharge, laziness, decreased appetite, and difficulty in swallowing.
- Symptoms typically last for at least 3 weeks.
- Mortality rate is 8.1%.

#### *Prevention:*

- Vaccines - Most have adverse side effects.
- Quarantine the infected horse.
- Clean and wash everything the horse contacted (Barn, equipment, clothes)
- Existing Treatment:
- Getting puss out with a scope.
- A course of Antibiotics
- Anti-inflammatory medication

#### *Costs:*

Minor costs for initial testing such as:

- For initial examination of the animal the total costs will be  $550+475+110=1135$
- For a recheck the total costs will be  $425+475=900$
- For issues related to horse's back:
  - Cost for the examination of the spine:  $550+475 = \$ 1025$
- In case of foot pain:
  - Initial examination, X-rays (lateral, frontal, and skyline) and Ultrasonography of tendons:  $550+475 + 6 \times 55 = \$ 1355$

In case of an outbreak the additional costs could be significantly higher such as:

- Diagnosis Tests- blood tests, guttural pouch endoscopy, swabs, and vet visit costs.
- Treatment and Monitoring- medication, first aid equipment, thermometers, gloves.
- Set up of Isolation areas, fencing, signs, new equipment, disinfectant, sanitizer, buckets, sprayer.
- Protective Equipment- coveralls, gloves, shoe covers.
- Additional forage, bedding, feed costs due to containment and stripping stables.
- Additional staffing costs to cover extra hours required for containment, procedures and health checks.

- Replacement of potentially contaminated equipment- hay nets, lead ropes, headcollars, rugs.
- Removal from the yard of potentially contaminated bedding and waste.
- Loss of income from facility hire or events.
- Loss of income from inability to introduce new clients.
- Loss of competition entry fees

## **5. Health Care: Implanting a Meta HiLight Stereocilia**

### **5.1 Insights**

Problem: Sensorineural hearing loss that is related to the damage of hair cells (stereocilia) is an irreversible medical issue once the hair cells are dead. It is caused by various things such as illnesses, drugs, loud noises, etc. Therefore, patients will have to live with damaged/no hearing for the rest of their lives. The problem is relatively stable, once you've damaged the vital part it stays damaged. However, the urgency lies within patients who have limited time against them to fix their hearing loss issue before its permanent. Nevertheless, the technology would focus more on patients with already permanent damage.

Need: Existing hearing aids only improve sound but come with limitations such as emphasis of unneeded background sound, bulky/heavy, visible, etc. Nevertheless, these technologies improve rather than recover permanent hearing loss. Thereby a need for technology that can effectively restore or potentially replace dead stereocilia would majorly revolutionize the medical industry.

Idea: Create artificial stereocilia compatible with human hair cells by implanting and replacing the biological human hair cells with these artificial hair cells. It's done by mimicking a similar process as *biomimetic flow sensor which attempts to replicate the function of the hair bundles of hair cells within fish neuromasts*. If we could mimic this process to be more applicable to the human hair cells, it may be a replacement technology for dead human hair cells. Thus, restoring dead stereocilia and recovering permanent hearing loss.

Reason for no further development: We planned on further improve the research article "*Biomimetic flow sensor which attempts to replicate the function of the hair bundles of hair cells within fish neuromasts*" written by Asadnia et al. (2016) with meta material technology. However, the ideas we had on improving that concept were closely discussed in the research article "*Development of Ultrasensitive Biomimetic Auditory Hair Cells Based on Piezoresistive Hydrogel Nanocomposites*" by Ahmadi et al. (2021). Thus, due to limited knowledge in-depth technical understandings of the technology we were not able to detect a loophole which would distinguish our ideas from what Ahmadi et al., 2021 had mentioned. However, with knowledge of professional engineers from Sintef, this research may be possible to further advance upon if desired to.

### **5.2 Stakeholder Map**

The stakeholders can be divided into 4 different categories: medical, internal, external and financial stakeholders.

#### Medical

Within medical, the following stakeholders are identified:

- Doctors
  - This refers to the professionals that will apply the product to their services. This stakeholder is vital since they will adopt the product and perform the surgeries. Thus, they have to be informed of this new technique and continuously involved in the

creation of the product as well, since they have the skills and knowledge of what is possible during medical procedures

- Customers
  - The users are the hospitals and other institutions that purchase the innovative technology and the product. This stakeholder will play a major role for many reasons. First of all, they are the ones that generate an economic stream for Meta HiLight. While the professionals will have explicit knowledge of the product, the customers will have a general knowledge of their experience with the product and the services included. Thus, it will be vital to gain their experience of the general view of Meta.
- End users
  - Similarly, these stakeholders are essential for the progress. Our product can cure, or at least reduce their hearing disabilities. These stakeholders are the essence of the progress, and it is important to understand their experiences with the artificial stereocilia. Hence, it is important to engage the end customers for the progress of the product and to produce an optimal ending result, for both the users and our innovation.
- Health insurance
  - Health insurance will especially become important in countries where the medical procedures are financed through the health insurance. Hence, it is important to proclaim the importance of these procedures, so they are included in the health care package.

#### Internal Stakeholders

The following internal stakeholders will be important to consider:

- Employees
  - The employees are the ones that move the project forward and It will be important for them to have the proper understanding of what has to be done. Hence, it will be important to keep them engaged and attract the right personnel with suitable knowledge for the different tasks. Generally, the employees could be included within all the four different categories since they should be informed, engaged, monitored and satisfied.
- Managers
  - The managers are the ones that should align the employees and make sure that everyone is following the correct direction of the firm and everything that surrounds it. Their main responsibility is to manage the stakeholders and keep them satisfied, informed, monitored and engaged.
- Mediators
  - Altercations and compromising may be a part of the process since the research and development requires many aspects and judgements along the journey, therefore having mediators to affirm and resolve any potential obstacle may be important to provide unbiased and smooth results.

#### External stakeholders

- Government
  - Government may intervene in terms of law and regulations on how and what extent the company can operate on.
- External research professional



- Specific research professionals may be needed in any specific niche field (if required, e.g biomedical field) to give an in-depth judgement or contribution to the project.
- Distributors
- Some materials involved may be sensitive and need additional temperature or physical protection in order to stay active or workable.
- Suppliers
- Since the technology involves intricate materials and methods it's important for suitable and knowledgeable suppliers to be involved. Creating good relationships and loyalty between them can lead to better service (in terms of availability in providing) as well as price reductions.
- Competitors
- The approach and materials used for this idea has similar feel with existing research competitors, thereby staying on par with them by finding loopholes on how to create a competitive edge when compared will be vital in establishing a competitive advantage of being either a first mover or better option.
- Community
- New procedures that involve noble inventions/technology can remain sceptical within communities due to the fear of various risks. Being able to create credibility and trust is very important to the public eye.
- Media
- Medias are the ones painting the company's image, knowing the right ways to portray the technology will be important to create credibility and good portrayal in medias.

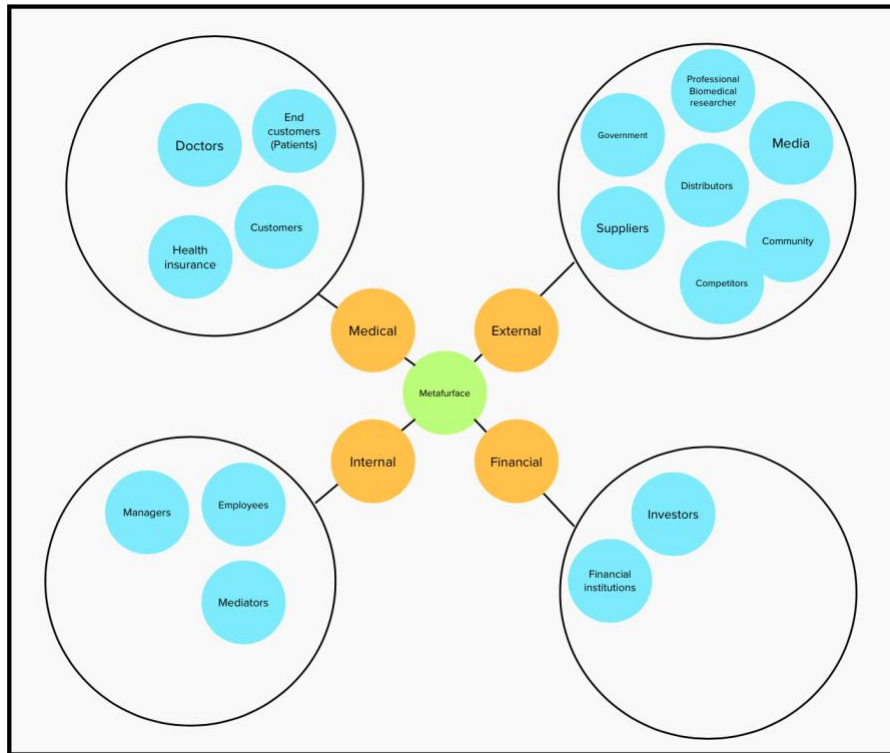
### Financial

#### *Investors*

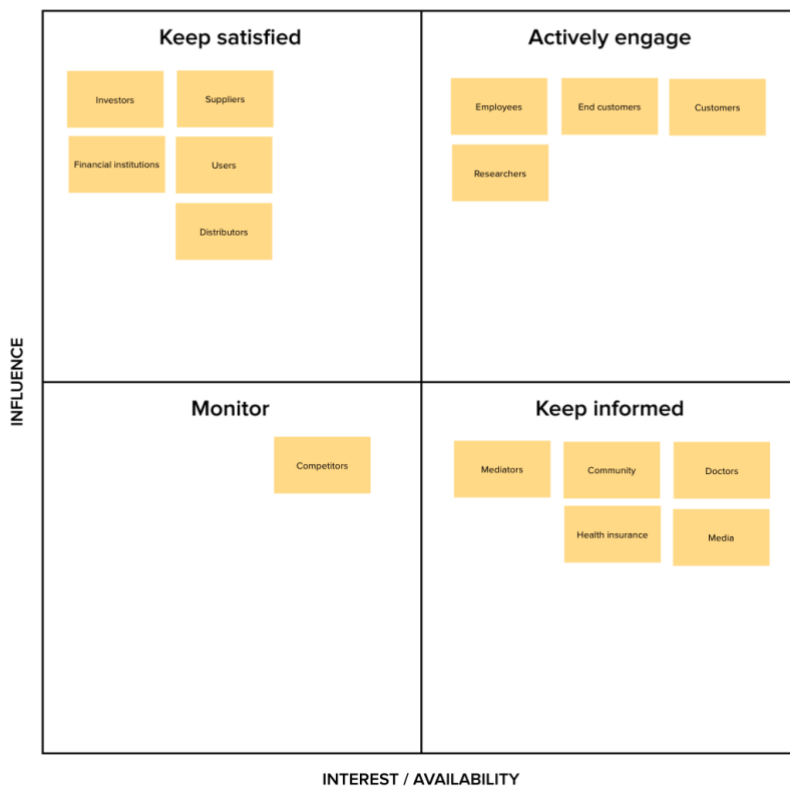
- When raising capital to fund the project, having a good overview of the plan but more so focusing on the purpose, success rate, end/long term result (potential future development) will be important to create enough trust for investors to risk their money in and ensure this money has constant growth and investing value (The technology can be used for other purposes, which creates growth and coverage in various areas)

#### *Financial institutions*

- Similar concept applies to financial institutions, if the company decides on taking loans. more focus will be on the entire plan/process from start to end. Involving materials, methods, "doability", success rate, and ability to pay back any loans taken.



Managing Stakeholder Expectation



### 5.3 How the Technology could work

What we know from initial research of the existing biomimetic technology:

- Combining biomimetic technology with nanofabrication technologies will advance the ability to sense which exceeds the standard sensors and match the increased sensitivity of biological counterparts.

*Technology and Process: \*Quoted and summarized from the article\**

1. The creation of pillars in rows with graded heights - The artificial ciliary bundle can be created through **building polydimethylsiloxane (PDMS)** micro-pillars with graded heights
2. Creation of electro spun PVDF nanofiber links - Electrospinning polyvinylidene fluoride **(PVDF) piezoelectric nanofiber tip links**. [The stereocilia sensors uses piezoelectric nanofibers as sensing elements which makes them self-powered thus no external power usage. The sensors are made from all-polymer materials which makes them flexible as well as biocompatible Which paves the way for numerous applications in biomedical and microfluidic devices.]
3. **Development of a HA-MA hydrogel cupula** - A HA hydrogel cupula which is created to be a dome shap encapsulates the artificial hair cell bundle. It is created by precisely drop-casting and using processes such as swelling. The drag and collision of fluid forces stimulate the hydrogel cupula and deflects the micro-pillar bundle, which causes the nanofibers to stretch and create electric charges.

*The things that meta could improve upon:*

- “Future work should involve further improvements to mimic the sensing principle and morphology of the biological hair cells to enhance flow sensitivity.”
- “Improvement of the biomimetic sensors will involve research in multidisciplinary fields, including fluid mechanics, neurophysiology, nanofabrication, and soft polymer materials. For example, sensitivity can be improved by optimization of the flexibility of the PVDF (special plastic) tip. Another way is to include arrays of varying size artificial hair bundles encapsulated by hydrogel cupule of different sizes. These types of morphological variations have been shown to result in 30-fold range in sensitivity.”
- “Designs featuring pillar bundles that laterally stick together and pivot at the base, as is the case in their biological counterparts, could further improve the sensitivity and the velocity threshold limit of the sensors.”
- “Include several artificial bundles per cupula similar to the structure of a neuromast. Simulated coupling of hair cells has been shown to reduce noise and enhance amplification of sinusoidal stimuli leading to increased sensitivity.”

Source: <https://www.nature.com/articles/srep32955>

## 5.4 Research / Information

*How are the jobs from week one being currently done?*

- In hearing devices
- Cochlear or brainstem implant

*How have other existing products tried to solve the problem that you have identified?*

- In-the-ear devices such as ICC, CIC, ITC
- Behind-the-ear such as RITE, BTE with earmold
- Implant of small cochlear electronic device that stimulates nerve hearing

- All of these technologies and procedures have been done to improve problems of hearing, less bulkier products, more so improvements.

*How has the technology of these jobs evolved?*

- More compact
- From analogue to digital hearing aid
- Cancel background noise more
- Increase speech understanding

*What are available solutions on the market?*

- See Q2.

*What are their strengths and weaknesses?*

- Strengths:
  - Accessibility
  - Affordable alternatives
- Weaknesses:
  - Don't restore a normal level of hearing
  - Some hearing aids emphasize unwanted background noises
  - Initially, using hearing aids may be uncomfortable because the noises may be too loud.

*How do they compare to our companies?*

- Our technology is more advanced
- If our invention becomes a success, it will be more effective due to better sound vibration thus, bettering the hearing abilities, increasing the success of reversing hearing loss, and potentially achieve a normal level of hearing.
- Our company's design is more compact and thinner (Nanotechnology)
- Our company is more multi-functional which means we could potentially tackle multiple problems in one device, compromising less factors. Ex: Increases sound vibration while being compact

*Do we see any nonconsumption?*

- Patients may not want to wear a hearing device, but they have to in order to hear, some may skip wearing them in general due to reasons stated below.
  - Bulky
  - Insecure
  - Non-fashionable
  - Inconvenient & inefficient
  - Heavy

*What workarounds have people invented?*

- Google AI lip reading
- Augmented lip reading → Identity faces and pick up conversations (Sony)

*What surprising uses have users invented for existing products*

- Connecting the hearing device to other devices such as iPhones, iPads, computers etc

*Where are these new technologies necessary or more impactful?*

- Medical industry

In 2016, an article was published explaining a project/research on *Biological Cilia to Artificial Flow Sensors: Biomimetic Soft Polymer Nanosensors with High Sensing Performance*. Thus,

meaning that a similar concept to our job exists. However, this can potentially further be enhanced to develop artificial stereocilia applicable/replaceable to human biological hair cells.

Sources:

[https://en.wikipedia.org/wiki/Stereocilia\\_\(inner\\_ear\)](https://en.wikipedia.org/wiki/Stereocilia_(inner_ear))

<https://www.cse-lab.ethz.ch/wp-content/papercite-data/pdf/noca2000c.pdf>

Asadnia et al. (2016): <https://www.nature.com/articles/srep32955>

Ahmadi et al. (2021): <https://pubs.acs.org/doi/10.1021/acsami.1c12515>

### Interview with a General Doctor

Input:

- Not specialist in ear
- Not denying, but not confirming
- Potential to perform surgery within the cort area due to the ability of other surgeries to perform in that area
- Difficulty in terms of seeing the small stereocilia → Microscopic surgeries?
- Difficulty of performing intricate surgeries in one small part of the cochlea
- Uncertainty of removing dead stereocilia which is a part of the hair cell organism, don't know if removing them to replace them with the artificial stereocilia will damage/kill the entire hair cell.
- Might be more efficient to create an entire artificial cochlea and perform procedures with the same vibes as the cochlea implant.

### Competitors

Initial findings on competitors:

- In-the-ear devices such as ICC, CIC, ITC
- Behind-the-ear such as RITE, BTE with earmold
- Implant of small cochlear electronic device that stimulates nerve hearing
- Atoh1 → Gene therapy

### Recent findings on competitors:

Source: Ahmad et al., 2021

- Development of Ultrasensitive Biomimetic Auditory Hair Cells Based on Piezoresistive Hydrogel Nanocomposites
- “Although the sensor demonstrated good sensitivity and a wide bandwidth comparable to the mammalian cochlea, it is important to note that sensor output in the artificial experimental environment will likely be considerably different to that when the sensor is implanted in the mammalian cochlea. This is because the sensor output is influenced by several factors, such as hydrodynamics and cochlear mechanics, which are the largest at low frequencies. This is expected to provide an additional gain “boost” to the sensor at low frequencies and an overall increase to the sensitivity and tuning of the device in vivo.”
- “However, transferring the VGN from its metallic substrate without imposing any significant change in its fragile structure remains a challenge”

### Technology Approach & Development

Initial approach:

[Based on research finding] Imitation of hair cells in fish neuromasts than mimic similar structure and functions as human ear hair cells.

[Idea] This is done by creating artificial stereocilia that can replace dead ones to improve hearing or potentially cure hearing loss to a normal state of hearing.

[Metas application] Develop the idea by creating PVDF tips with meta materials = More flexibility (Increased sensitivity) + could generate better self-powering technology. Meta materials in terms of nano technology could potentially make the stereocilias pillars smaller to create more bundles and coupling of hair cells = Increased sensitivity

## **6. Energy**

### **6.1 Insights**

Problem: Solar panels are becoming more accessible and cheaper nowadays. Still, it is a technology that requires many installation costs when private house-owners want to use it for their houses. In general, the energy sector has to become more sustainable in order to fight against the climate change happening. Therefore, any improvement for harvesting energy is helpful.

Need: Solar panels have to become cheaper to make them even more accessible. This requires a cheaper technology and cheaper installation costs.

Idea: Metasurfaces could potentially create cheaper solar panels. They could also store the energy better (e.g., as a substitute material for glass windows). This could be applied to greenhouses as well – and improve the energy consumption and usage of these greenhouses.

Reason for no further development: Since the solar panel market is already quite sophisticated and it was not so easy to understand how Meta HiLight can improve the existing technology. The idea was rather abstract and was therefore dismissed due to the time frame of the project.

### **6.2 How the Technology could work**

Using metamaterial to improve the performance of solar cells could make them more effective in storing energy. This could support the overall efficiency as well as create a cheaper price if they can be produced in mass.

Furthermore, applying Meta HiLight to glass windows could also turn basic windows into an energy storage – ultimately improving the energy usage of a house.

Meta HiLight could also affect how energy can be captured in multiple ways. An example could be the movement of kinetic energy.

### **6.3 Research / Information**

*Job: Collecting and storing energy for a more efficient use*

- Use more renewable energy sources
- Multi-usage (Use windows as solar panels)
- “Angle itself”
- Using existing ones for more efficient use

The demand for energy is increasing, for instance the need for electricity will rise by more than 50% by 2040 (Belkhir & Elmeligi, 2017). Simultaneously, studies have shown the importance of reducing co2 emissions and a road map for future electricity was developed. It stated that the 143 included countries need to switch to 100% clean and renewable power no later than 2050, and at least 80% by 2030. Hence, the need for more sustainable solutions will be crucial (Jacobson et al., 2021). Today, there are multiple solutions with renewable energy, for instance, solar panels, which converts the sun's energy into electricity.

Solar power already plays a vital role regarding energy and can be applied in multiple situations, from small households to larger facilities and projects (Green Match, 2022). Today, most of the electricity generated in the USA comes from fossil fuels, such as: natural gas, petroleum and coal. Solar power only accounts for 0.9% (Clearway Community Solar, 2018). There are today multiple different locations and situations where solar power can be utilized through two main categories of panel options:

- **Monocrystalline solar panels**- known to deliver the highest efficiency through the pure silicon which are further cut into wafers.
- **Polycrystalline solar panels**- not grown as a single cell but as a block of crystals which are further cut to individual cells. Not as efficient as monocrystalline but less expensive (Green Match, 2022).

Today, the solar industry is the number one source of employment for the “United States Electric Power Generations sector’s workforce” (Clearway Community Solar, 2018).

#### *The evolution of Solar Power*

From the 60s and 70s contributions towards solar powers decreased the prices per watt from \$100 to \$20. However, it was for a long while considered to be better suitable for space operations (Skylab who orbited the world during the 70s were equipped with solar panels), because of the high costs (Kamak, 2019). Furthermore, the advancements in photovoltaic and concentrated solar power have helped lowering the costs. Hence, making it accessible to a larger market. Currently, there have been efforts to make solar power yet more affordable and efficient with the so-called perovskite solar cell. The crystalline material could possibly replace the silicon in solar panels by its simpler production, and thereby reduced costs.

#### *High Initial Prices*

#### *Large Area*

However, there are multiple problems surrounding today's solar energy usage. First of all, the installation areas are required to be quite large for them to operate efficiently. For instance, In Spain the largest solar field covers 173 acres (which cannot be used for anything else) and only provides power to 12,000 households. This means around 144 m<sup>2</sup> per household.

#### *Location dependent/ not always sunny*

#### *Inefficiency*

A study made by North-western University showcases the inefficiency of solar panels on households only converting 14% of their available energy into power. The market leaders and most efficient solar panels can only convert 22% of the available energy (Sawrey, 2016). Furthermore, even though the solar panels efficiency is around 15-20%, solar cell efficiency can reach up to 42% (during laboratory conditions).

#### *Our Solution*

- Metasurface absorbers that collects the light better
- Collecting lights from more angles
- Better durability



We think that through utilizing the technique of metasurfaces and the optical technology that it provides, we believe we can make solar power more efficient and thereby not require the large scales that they do right now. It is stated that “MSs can improve light trapping in solar cells and extend the absorption of a photon with an energy below the bandgap of a semiconductor by injecting hot electrons generated by nonradiative processes. Another approach for solar-power harvesting, which can benefit from MS technology, is by means of solar thermophotovoltaics, an approach that converts the absorbed broadband energy to a narrowband emission corresponding to the bandgap of a PV cell” (Scheuer, 2020, pp. 1334). It is further stated that MS could be an important technology in making them more economically efficient to (Scheuer, 2020).

Lastly, viewing the WEFs top 10 emerging technologies during 2019, utility-scale storage of renewable energy is among them. With innovation emerging within this technology field, the combination of improved solar power through metasurfaces and better storage could potentially advance the energy consumption towards less co2 emissions.

#### *Already competitors*

However, there are already competitors working with metasurfaces within the solar power industry, but many of them are in the early stage and it could potentially generate a large ROI.

1. Do we see any nonconsumption?
2. What workarounds have people invented?
3. What surprising uses have users invented for existing products?

Nonconsumption, referring to people who are not buying into the product can be equally important for a company. In the case of energy, there are still multiple alternatives that are more used. Some of the reasons are:

- Accessibility
- Initial prices
- Reliability
- High initial prices

Viewing workarounds, as the name refers to where people or companies have had to work around a problem. This could be a potential market since there is usually dissatisfaction with the current products. This is something that the company can utilize. This could for instance be seen in Sweden during the winter where the electric bills increased immensely and Another issue is for countries becoming dependent on other countries. For instance, Germany is now quite dependent on Russian gas.

Question: How will it interact with heat?

#### **Alternative Application in Greenhouses:**

*Job: Creating optimal conditional environments for agricultural growth*

*1+2. How is the job currently done and how are other products trying to solve that problem?  
Greenhouses and foils*

- Most common build out of Polyethylene (very energy efficient) or glass
- Sensors that can identify the needs of the plants and adapt the settings regarding air humidity, temperature, CO2-content in the air and water automatically
- Double glass constructions allow to store more heat and lets more light through
- LED Lights that imitate the sunlight, when the sun is not shining, or it is night

- Partially animals like bees are held in the houses or close by
- Energy shields consisting out of plant based or synthetic materials that reduce the loss of energy and spend shadow for the plants
- Reducing the impact / dependence of external and uncontrollable factors
- Solution made with Plexiglas lenses that allow more sustainable farming in greenhouses

### 3. How has the technology of these jobs evolved?

- Very basic settings in the past, as they were already used by ancient civilizations. Nowadays they are highly technologized, as humans are able control and adapt very precisely the different aspects that are relevant for certain plants to maximize their growth

### 4. What are available solutions on the market?

- Usage foils, plastic glazing, single and double glazing
- Still requires a lot of human work, which is planned to be replaced by robots in the future if possible that also might be able to detect diseases and remove sick plants preactive, by using cameras and deep learning techniques, but it is still only based on visible aspects or characteristics

### 5. What are their strengths and weaknesses?

- Strengths:
  - High success-rate in comparison to usual agricultural methods like open fields (e.g., Tomato's 10 times more tomatoes on the same number of square-meters)
- Weaknesses:
  - High energy consumption (depending on the growing plants) in months where the sun is not really shining or during the winter to keep the temperature on a stable level (→ not very sustainable)
  - No automatized disease detection, which can lead to a loss of the whole farm
  - Insulation problems to reduce heat loss in greenhouses

### 6. How do they compare to our companies?

Current solutions are often connected to high costs in terms of energy and are not really sustainable. Therefore, the usage of metasurfaces or better to say the lenses technology to maximize the usage of the incoming sunlight and create a more sustainable solution in the long-term.

### *Do we see any nonconsumption and what work arounds have people invented?*

- Conventional farming on fields
- Using foils as coverage for plants on the fields

### *What surprising uses have users invented for existing products?*

- Car dealerships
- Schools

### Useful articles found on the topic:

Belkhir, L. et al., 2017. Assessing ICT global emissions footprint: Trends to 2040 & recommendations. *Journal of Cleaner Production*, September, pp. 448-463.

Forum, W. E., 2019. Top 10 Emerging Technologies 2019.

Jacobson, M. Z., Cameron, M. & Hennessy, E., 2018. 100% clean and renewable Wind, Water, and Sunlight (WWS) all-sector energy roadmaps for 53 towns and cities in North America. *Sustainable Cities and Society*, January, pp. 22-37.

Green Match., 2022. *Green Match*. [Online]

Available at: <https://www.greenmatch.co.uk/blog/2014/11/how-efficient-are-solar-panels>  
[Accessed 13 April 2022].

Sawrey, G., 2016. *Ecavo*. [Online] Available at: <https://ecavo.com/solar-energy-disadvantages/> [Accessed 13 April 2022].

Scheuer, J., 2020. Optical Metasurfaces Are Coming of Age: Short- and Long-Term Opportunities for Commercial Applications. *ACS Photonics*, p. 1323–1354.

## **7. Health Care: Create less Harmful Treatments**

### **7.1 Insights**

Problem: Examination and treatments for cancer, especially breast cancer, involve sometimes hurtful mammography the patients have to go through in order to identify dangerous cancer cells. This also means that some patients skip the regular examination and potentially dangerous cells cannot be identified at an early stage – this can also affect the overall course of the cancer. Alternatives as ultrasound might lack the accuracy of mammography.

Need: Patients aim for a treatment without harm which can still identify dangerous cancer cells accurately.

Idea: The biosensing character of metasurfaces could improve the examination of breasts in a way the patient does not have to experience discomfort any longer. Simultaneously, the accuracy would not suffer from it.

Reason for no further development: Although some patients might skip the mammography, it did not seem like a severe problem compared to other needs. Furthermore, it was similar to the already existing application Meta HiLight was supposed to be for. Therefore, we decided to not proceed with this idea of creating less harmful treatments on the example of mammography.

### **7.2 How the Technology could work**

Based on biosensing tissue/cells with the help of metasurfaces, a device could be developed that harmlessly analyses the patient and screens the body for dangerous cells. This type of screening would be more effective since it not only focuses on the surface but can reach deeper dimensions without having to use X-rays or invasive diagnostic methods.

- Improving cancer treatments: sense first where exactly the cancer cells are
- Treatments (either chemotherapy or radiation) could be less harmful for the rest of the body, the healthy part
- Metasurfaces could be used for mammography → instead a much more comfortable treatment (<https://investingnews.com/daily/life-science-investing/medical-device-investing/metamaterials-medical-diagnostic-device-mri/>)

### **7.3 Research / Information**

*Job: optimizing existing procedures towards a less harmful experience on the example mammography*

*How are the jobs from week one being currently done?*

- One example: Mammography is currently used e.g. to identify cancer cells in female breast. X-ray pictures are done of the breasts where the patient feels pressure because a plate is pressed on the breast in order to take the x-ray picture. This can be harmful since the breast is a very sensitive body part. Even if it is not

painful, it usually feels uncomfortable for most women.  
([https://www.cdc.gov/cancer/breast/basic\\_info/mammograms.htm](https://www.cdc.gov/cancer/breast/basic_info/mammograms.htm))

*How have other existing products tried to solve the problem that you have identified?*

- Ultrasound treatments to identify harmful cancer cells (e.g. in the breast) → hand-held devices or a machine to scan the entire body
  - more useful if women have dense breast tissue
  - less painful than mammography
- MRT: not suitable for breast cancer, but can be used for other detection of problems
- Non-radioactive photoacoustic imaging (computed tomography) which only takes 15 seconds to produce pictures of the breast (<https://www.nibib.nih.gov/news-events/newsroom/light-based-15-second-scan-aims-replace-painful-mammograms>)

*How has the technology of these jobs evolved?*

- Instead of the typical x-ray pictures, digital 3D x-ray pictures are now possible. The pictures are better, but the procedure is the same and the exposure to radiation is still given.
- Alternatives without using radiation have been further developed, e.g. ultrasound.

*What are available solutions on the market?*

- SoftVue machine where the patient can lay down and is being scanned with ultrasound

*What are their strengths and weaknesses?*

- Mammography:
  - radiation is a sophisticated technology +
  - prone to false negatives -
  - being exposed to radiation -
  - can be more difficult if you have dense breast tissue -  
(<https://www.healthline.com/health/womens-health/mammogram-alternatives#d-mammogram>)
- Ultrasound:
  - not so harmful, only cold gel can be uncomfortable +
  - even more prone to false negatives -
- MRT:
  - doesn't rely on radiation +
  - doesn't work for every type of cancer and every type of tissue to be analysed

*How do they compare to our companies?*

- Bioimaging and biosensing is more accurate than ultrasound. This leads also to more accurate diagnoses (Meglinksy & Da Silva, n.a.). With the help of metasurfaces, the tissue could be analysed

*Do we see any nonconsumption?*

- Women sometimes don't go to an important, possibly life-saving mammography.
- The same goes for any kind of screening which is difficult to access because of annoying procedures or lack of specialized doctors.

*What workarounds have people invented?*

- Because of the radiation, the mammography cannot be done so often. With less harmful procedures, the period between two procedures can be decreased and cancer cells might even be detected earlier. This might also increase the acceptance of the procedure.

*Question:* Could a laser also kill dangerous cancer cells without interfering with the body too much? Detecting cells and then eliminating them directly?

*Where are these new technologies necessary or more impactful?*

- to detect deadly diseases, dangerous cells → healthcare sector to improve people's quality of life and detect those earlier and more easily

*Can we see new markets for this technology?*

- It could be implemented in individual healthcare devices as well in order to relieve the doctors and create opportunities to detect dangerous cells at home. In case, the technology identifies something unusual, the doctor can be informed, and further procedures can be done.
- This could not only be done for screening breast for cancer, but also screening birthmarks

*Are there jobs that can be performed that are not done today with the existing technology?*

- With developing the technology further, the scanning could be outsourced to the individual person (or at least during the procedures at the doctor) to be able to detect these cells early and therefore, make treatments more successful.

## **8. Health Care: Analysing Human Cells and DNA**

### **8.1 Insights**

Problem: To identify cells and tissue of the human body, the biosensing technology used at the moment is restricted to typically one type of cell that can be examined. Furthermore, it usually requires taking a sample which can lead to an uncomfortable biopsy for the patient.

Need: A method to analyse DNA without the need for taking actual samples from the patient.

Idea: Metasurfaces could increase the accuracy of analysing DNA or in general human cells when examining them without taking a sample. This way, Meta HiLight could improve the biosensing technology that exists currently.

Reason for no further development: Since the improvement seemed only minor from the status of our research, we decided not to proceed with this idea. Furthermore, the problem and need were not as clear compared to the other problems we have identified, especially within the healthcare industry.

### **8.2 How the Technology could work**

Since metasurfaces can improve the overall technology of biosensing by screening deeper human tissue/cells/DNA, it can achieve more accuracy than the current methods which are focused on either only the upper layers (of the skin) or only one specific component they are constructed for.

Potentially, it could also replicate stem cells or develop a better method for genetic engineering. This technology is not as developed but Meta HiLight could make this entire process cheaper and more accessible all over the world.

### **8.3 Research / Information**

*Job: achieve more accuracy by biosensing microorganisms/cells/DNA*

*How are the jobs from week one being currently done?*

- Biopsy to extract cells/tissue to analyze it further (under a microscope) (<https://www.webmd.com/cancer/what-is-a-biopsy>).
  - For cytological analysis, cells/tissue is extracted by using fluid or scratching off tissue (e.g. in the mouth). Then it is further examined to identify infectious diseases (<https://my.clevelandclinic.org/health/diagnostics/21714-cytology>).
  - Needle or surgical biopsies are invasive, while other biopsies (explained above) can be harmful.
- DNA can be extracted by applying a buccal swab (cotton swab in your mouth) or using hair (<https://whatisbiotechnology.org/index.php/science/summary/extraction/dna-extraction-isolates-dna-from-biological-material>).

- Biosensing (analyzing cells/DNA in living organisms) is currently used with optical, magnetic or electronic identification of signals (<https://www.youtube.com/watch?v=9lVmGDgVFdQ>).

*How have other existing products tried to solve the problem that you have identified?*

- Detailed instructions about how to use DNA tests and improve processes in order to eliminate most possible sources for mistakes.

*How has the technology of these jobs evolved?*

- DNA tests can be done much faster nowadays, even the possibility at home.
- Many cell tests are not harmful anymore, still invasive (by using a swab) but at least not necessary to cut out a specific part of the skin (?).

*What are their strengths and weaknesses?*

- DNA tests can be manipulated (or less accurate) if a person smoked, drank or ate before the test. - (<https://dnatesting.com/5-surprising-ways-paternity-test-samples-get-contaminated/>).
- Requires a lot of steps where mistakes can happen (medical personnel can drop the swab or the envelope gets wet etc.) - (<https://whatisbiotechnology.org/index.php/science/summary/extraction/dna-extraction-isolates-dna-from-biological-material> / <https://www.edvotek.com/dna-extraction-human-pcr-troubleshooting-guide>).

  - Those issues are likely to be detected only in the lab (when the patient is not present) which can lead to a retake of the sample → increases time to analyze the DNA/cells.

- Relatively easy to do it, people can even take the DNA/cell test at home nowadays +
- Genetic screening is prone to false results, as it only “screens” the body and is not as accurate right away. It is used as a first step to find out if a diagnostic test (with biopsy) is needed. (<https://medlineplus.gov/genetics/understanding/testing/differenttests/>).

*How do they compare to our companies?*

- The devices would be used by medical personnel, in a further development it could be adapted for home-use as well (with smaller devices or implemented in smart watches etc.).

*Do we see any nonconsumption?*

- Do people avoid testing, even if it's only with a swab?

*What workarounds have people invented?*

- People might make use of the possibility to manipulate cells/DNA, e.g. some people drank Coke before a Covid-19 test since the test was not as accurate and responded to the substance of Coke.

*What surprising uses have users invented for existing products?*



- To find out ancestors/possible partners → however, this is not as accurate and reliable as the original tests used for DNA/cell detection
- Biosensors have been used to analyze food nowadays as well.
- Biosensing in soil as well.

## **9. Transportation**

### **9.1 Insights**

Problem: Repackaging costs incurred because of dented, crushed, and ripped packaging. Users refuse to buy faulty, damaged, broken, and unsuitable products. The damage is usually caused while loading, unloading and during transporting goods from one place to another. Transportation of processed and perishable foods at larger distances is a challenge because the food might get rotten or spoiled during transition.

Need: Protecting goods from being damaged while transporting them.

Idea: Our idea is to minimise risks while transporting dangerous goods such as explosives, gases, and flammable liquids. Goods can be prevented from being damaged or exploded as direct solar radiations heat the metal body of the shipping containers or trucks. Fragile goods can be protected from being damaged due to the vibrations produced by the engine and other mechanical parts. Gel packs, heat packs and ice packs are used in industries such as medical, food and flower. Perishable foods such as meat, fish, poultry, and dairy can be protected from decaying due to excessive heat and cold.

Reason for no further development: Although we have found that our technology can have a potential to mitigate transportation issues but alternatively, we did not find the problems crucial to be solved and also cost efficient and therefore decided not to further proceed with it.

### **9.2 How the Technology could work**

The packaging itself could be build out of metasurfaces. This would create an unbreakable and create protection for the good.

This is applicable especially for transportation of products that need to be stored in a specific way.

- e.g., vaccines within a few hours, have to be stored cold
- transportation of compostable gas (the containers) → that could be harmful in an accident

→ minimize repackaging costs by mishandling sensitive packages

### **9.3 Research / Information**

*Job: creating more efficient and safe logistics solutions*

- avoid excessive heat/cold

*How are the jobs from week one being currently done?*

- Protective packaging
- Frozen gel packs (keep cold food cold)
- Cooler Contents (keeping beverages and perishable food in different coolers)
- Cardboard boxes
- Plastic barrels
- Bubble wrap
- Kraft paper

- Foam padding
- Dunnage air bag
- Pallet wrap

*How have other existing products tried to solve the problem that you have identified?*

- To minimize risks while transporting dangerous goods such as explosives, gases and flammable liquids. Goods can be prevented from being damaged or exploded as direct solar radiations heat the metal body of the shipping containers or trucks.
- Fragile goods can be protected from being damaged due to the vibrations produced by the engine and other mechanical parts.
- Gel packs, heat packs and ice packs are used in industries such as medical, food and flower.
- Perishable foods such as meat, fish, poultry, and dairy can be protected from decaying due to excessive heat and cold.

*What are available solutions on the market?*

*What are their strengths and weaknesses?*

Strengths:

- Easily Accessible
- Affordable alternatives
- Durability
- Wooden frames could easily be removed and stored.
- cant time and resources can be saved for plastic disassembling.

Weaknesses:

- Take More time and energy for manual disassembling
- Do not restore the packaging

*How do they compare to our company?*

- Cost effective. Minimize repackaging costs incurred as a result of dented, crushed and ripped packaging.
- Thermal metamaterials for advanced packaging. Metamaterials have the ability to act as thermal conductor and thermal insulator thus absorbing solar radiations to keep warm food warm and reflecting radiations to keep goods cold.
- Gel packs usually last 3 to 4 hours thus making it challenging to transport them at long distances.

*Do we see any nonconsumption?*

Users refuse to buy faulty, damaged, broken and unsuitable products. The damage is usually caused while loading, unloading and during transporting goods from one place to another. Transportation of processed and perishable foods at larger distances is a challenge because the food might get rotten or spoiled during transition.

*What workarounds have people invented?*

Different small packaging companies accept the new technology which is bubble wrap. Basically, bubble wrap was a valuable thing to protect the goods. Previously the best way to secure an item during transportation was to surround it with a balled-up newsprint. It was messy since ink from the old newspaper often rubbed off on the product and those handling it. Basically, it really didn't offer that much protection.

Useful information:

<https://www.smithsonianmag.com/innovation/accidental-invention-bubble-wrap-180971325/>

## **10. Communication**

### **10.1 Insights**

Problem: Assembly of high towers is very troublesome. The gain effect is also limited by assembly and placement. If placed incorrectly then the effect will be significantly reduced. The costs for placing tower stations are considerably high. To catch low frequency signals large antennas must be used. Also due to low frequency signals, long delays can occur in communication and therefore creating bottlenecks. Moreover, many frequencies are incapable of passing through atmospheric noise. Existing technology also requires more power to send and receive signals effectively. Furthermore, unidirectional signals might be blocked by pollutants in the atmosphere and buildings in dense urban areas, additionally strong winds can significantly affect the quality of sound and thereby make it difficult to hear. Satellite signals are also badly impacted by the rain drops because raindrops can scatter or absorb the wave energy thus mitigating the quality of communication. The existing technology is available only in specific locations thus restricting coverage.

Need: Reduced network lagging and elimination of blind spots in the dense urban area. To achieve Sustainability by consuming less energy and reducing the consumption of copper, silver, and aluminium. Metamaterials can enhance the performance of the existing conventional antennas by improving gain and bandwidth. They can also shrink the size of the antennas without compromising the performance of the communication and thereby making them a more sustainable option. Transparent antennas can considerably alleviate the expenses incurred on setting up tower stations. A wave has two main parts: phase and amplitude. Metamaterials can manipulate both components thus allowing waves to travel in multiple directions.

Idea: Our idea is to improve the connection through better quality. Since the waves can penetrate windows and omnidirectional thereby Improving network lagging.

Reason for no further development: After carefully researching and analysing the existing solutions and technologies, we have realized that there are contemporary and more sophisticated solutions to the problems that we have identified. For instance, optical fibre and 5G.

### **10.2 How the Technology could work**

Telecommunications could improve the connectivity through better quality in rural areas since most waves are currently blocked. Using Meta HiLight can enhance that through manipulating the waves.

- Improve Wi-Fi and blind spot (signals cannot reach) and waves can penetrate windows
- Improve network lagging and blind spot
- Improve connection in cars without blocking the vision because they can be invisible
- Remove network lagging

### 10.3 Research / Information

*Job: Reduce network lagging and blind spot*

- Reduce network lagging and blind spot
- High speed signals (Dense urban areas)
- Sustainability (Greener Broadband → Consume less energy, reduces the consumption of copper, silver, and aluminium)
- Enhance quality of communication (Materials that reflects/redirect light/signals more effectively)
- Decreasing the size of e.g., modems (could be implemented in the buildings) → more fashionable (No ugly modems laying around, Less clutter)

*How are the jobs from week one being currently done?*

- Telecom towers:

These towers are usually used for cellular communication and equipped with antennas, transmitters, and receivers.

- 5G:

A wireless communication system that uses higher radio frequencies to carry information at a faster rate through the air.

- Optical fibre:

Optical fibres are carefully designed long and extremely thin strands to transmit telephone, internet and television signals.

*How have other existing products tried to solve the problem that you have identified?*

- Radio Frequencies:

These frequencies can cover obstacles in their path and have the ability to reach at far away destinations due to the large wavelength of the signals.

- Physical Antennas
- Modems and routers

*How has the technology of these jobs evolved?*

Early Era:

- Cave Paintings
- Symbols
- Talking drums
- Smoke signals
- Carrier pigeons
- Postal System

1792 - Visual telegraphy or semaphore

1837 - Electric telephone

1966 - Optical fiber

1876 – Telephone

1890 - Radio or wireless telegraph

1927 - Electronic television

1983 – Internet

1991 - 2019 (2G, 3G, 4G LTE, 5G)

*What are available solutions on the market?*

- **IoT (Internet of Things):**  
IoT technology enables telecommunication companies to improve their performance by automation and digital transformation. The technology helps to alleviate network latency.
- Antenna\Dish
- Satellite communication
- Radar
- Global positioning system
- WLAN (wi-fi)
- Infrared

*What are their strengths and weaknesses?*

Weaknesses:

- **High antennas:**  
Assembly of high towers is very troublesome. The gain effect is also limited by assembly and placement. If placed incorrectly then the effect will be significantly reduced.
- **Low frequency of signals:**  
To catch LF signals large antennas must be used. Moreover, many frequencies are incapable of passing through atmospheric noise.
- **Transmitter Power:**  
Existing technology requires more power to send and receive signals effectively.
- **Restricted directional characteristics:**  
Unidirectional signals might be blocked by pollutants in the atmosphere and buildings in dense urban areas.
- **Highly affected by weather conditions:**  
Strong winds can significantly affect the quality of sound and thereby make it difficult to hear. Satellite signals are also badly impacted by the rain drops because raindrops can scatter or absorb the wave energy thus mitigating the quality of communication.
- **Limited global coverage:**  
The existing technology is available only in specific locations thus restricting coverage.
- **Costly:**  
The costs for placing tower stations are considerably high.
- **High Latency:**  
Due to low frequency signals, long delays can occur in communication and therefore creating bottlenecks.

Strengths:

- **Transmission speed:**  
Existing 5G technology has the ability to transfer data at a better rate due to more bandwidth.

*How do they compare to our companies?*

- **Cost effective:**  
Transparent antennas can considerably alleviate the expenses incurred on setting up tower stations.

- **High frequency signals:**  
MMs have the ability to transmit signals over far away distances without disrupting the performance of the communication.
- **Greatly reduce network latency:**  
MMs can significantly improve network lagging by eliminating blind spots. They are highly effective in densely populated areas where waves are usually blocked, absorbed or scattered by the buildings and pollutants.
- **Reflect and redirect signal passively:**  
A wave has two main parts; phase and amplitude. MMs have the ability to manipulate both components thus allowing waves to travel in multiple directions.
- **More sustainable:**  
Metamaterials can enhance the performance of the existing conventional antennas by improving gain and bandwidth. They can also shrink the size of the antennas without compromising the performance of the communication and thereby making them a more sustainable option.
- **Eliminate blind spots:**  
Unlike telecom towers the new technology is not limited by location and space. The invisible metasurfaces can be installed on the windows of areas such as basements and large apartments where signals are unreachable. For instance, signals can easily penetrate through the windows and windshields of cars thus improving communication.
- High speed signals
- Do not require connection to power supply
- Effective in dense urban areas
- Easily penetrate through exterior windows
- Highly conductive
- Highly transparent
- Compact

*Do we see any nonconsumption?*

- Customers may avoid using the services of a telecommunication company that has poor coverage. Meta HiLight can sell such companies its technology to improve the performance of their services and increase the number of consumers.
- Consumers are also reluctant to use modems and routers because of their low data processing speed. This may eventually cause frustration and anxiety among consumers. Meta HiLight can observe the behaviour of the customers to increase satisfaction with the technology and products.

*What workarounds have people invented?*

- Buy a Wi-Fi extender
- Placing the router to a better place
- Buying a powerful networking adapter
- Installing extra wiring



## **11. Security**

### **11.1 Insights**

Problem: Security solutions for houses (for governmental as well as private homes) are physical products which can be destroyed by burglars easily before they then enter the house.

Need: House-owners would like to have a solution that is more difficult to destroy and does not interfere with the appearance of the house.

Idea: Using Meta HiLight, a sphere around the house could be developed which enables an alarm once a burglar goes through. The sphere could be disabled once the house-owner comes back home, similar to an alarm they enable before leaving.

Reason for no further development: Meta HiLight could support the sphere. However, it is unclear how burglars could be prevented from getting into the house, if only an alarm goes off. Furthermore, it might be a more expensive product compared to the existing ones without increasing security much more. Therefore, this idea was not pursued further.

### **11.2 How the Technology could work**

- Hidden → Security in the sense that you can create spheres over houses that can sensor when something enters the diameter of the sphere → Trigger alarm
- Create sphere around a house invisibility (depending on the light) presidential house
  - Key buildings
  - Important facilities such as
- These spheres could also be created around cars (e.g., of politicians who require special protection)
- Detecting heat waves and sound waves
  - Measure the speed
  - More comprehensive
  - More of improved existing

### **11.3 Research / Information**

*Job: Protection & minimizing the impact*

- Protection & minimizing the impact = (Invisibility, protect, prevention, reassurance)  
Sphere = Detection (sensor the dangerous)
- Privacy / Invisibility (Block/jamming signals)
- Natural disaster management (Identity tsunami (Speed of wave), Protecting buildings from earthquakes due to the ability of vibration, Control weather)
- Disaster management → Meta materials to absorb energy impact (Combustible transportation, gas pumps)

*How are the jobs from week one being currently done?*

Currently, alarm systems consist of combinations of multiple physical devices based on technologies, like

- Infra-red,

- Motion-sensors
- Cameras
- Noise sensors
- Warning signs
- Physical guards

*How have other existing products tried to solve the problem that you have identified?*

- with physical technology, e.g., magnets
- tangible products
- combination of products/technologies
- detecting movements (with sensors or infra-red), noises (with sensors for decibels)

*How has the technology of these jobs evolved?*

- From physical guards to more technological advanced products. By combining physical guards and
- from warning signs to very basic technologies (magnets) to combination of different technologies (infra-red) and more sophisticated ones (noise sensors)

*What are available solutions on the market?*

*What are their strengths and weaknesses?*

- Strengths
  - Can be implemented everywhere
  - Accessible
- Weaknesses
  - Can be bypassed/destroyed
  - Visible and bulky

*How do they compare to our companies?*

- Less advanced [More tangible rather intangible]
- Bulkier [Uncompact]
- Inefficient [Consume more energy → Ours is more sustainable]
- Limitations [Our company is more multi-use]

## **12. Fun Ideas**

### **12.1 Augmented NFTs**

#### **12.1.1 Insights**

Problem: Non-fungible tokens (NFTs) are at the beginning of their development and likely to get more popular over time. With the current, they can – with effort – be replicated.

Need: Trading NFTs and the increase of the industry requires cryptographic tokens that cannot be replicated.

Idea: With using programmable metasurfaces, NFTs could be created in a safer way for end consumer. This technology would allow NFTs that are impossible to replicate.

Reason for no further development: Within the crypto development, the value creation is connected to high volatility which makes the outcome extremely uncertain. This is the reason why this idea was not pursued further.

#### **12.1.2 How the Technology could work**

*Job: Create and enhance an environment for an investment market with holographic images/videos*

- Create augmented values for investment → Holographic images created by codes that could be invested in (own the codes of holographic images/statues) → Intangible currencies.
- Example: Think of Pokémon go, the figures displayed augmented e.g., Pikachu could be a piece or image that people invest in [selling the codes that created the image].
- It is distinguished from companies such as Snapchat where the augmentation uses, or features is a part of another program. People aren't investing in a company; they are investing in the augmented figure.

### **12.2 Revival of Non-Functioning Body Parts**

#### **12.2.1 Insights**

Problem: Due to accidents or operations, certain body parts might lack a neural connection to the brain which can result in partially paraplegic parts as well. With the available technology, it is difficult to strengthen this connection again to re-activate these body parts.

Need: Patients suffer from non-functioning body parts, and it influences their overall quality of life.

Idea: With using Virtual Reality (VR) connected to neural stimulation of inactive body parts with the help of Meta HiLight, the chances of re-activating these body parts could be increased.

Reason for no further development: The idea might be possible. However, it requires extensive further research with an unclear outcome on how it can create value for patients. Therefore, the idea was not further pursued by our group.

### **12.2.2 How the Technology could work**

*Job: Enhance VR technology through creating neural connections to stimulate activity in inactivate body parts*

- Revival of some non-functional parts of human
- Example: Patients in Duke University's Walk Again Project are using brain-machine interfaces that incorporate a virtual reality (VR) system that uses their brain activity to control their legs.
- Use Meta HiLight/material technology to stimulate connection between body parts through generating relative electrical activities.
- Further developing this idea by using more advanced technology may improve this field and further cure in-active body parts aside from just legs. Example: Diagnosed with brain-dead and minimal % of survival → enhance remaining neural activity = enhanced brain activities = Potential surviving)

### **12.2.3 Research / Information**

Article about existing project where VR helps patients to walk again:  
<https://www.neuro.duke.edu/research/research-news/how-vr-helping-paraplegics-walk-again>