Section 3 - The Project

1. What is the method/approach you will use? Why did you choose this method/approach? (4000 char.)

Tomato Picking Robot:

In order to make a successful Tomato Picking Robot you need to fulfil following procedures:

1) A mobile unit needs to locate a tomato plant (by laser and vision scanner) and position itself correct in relation to the plant.

2) Then maturity judgement of the tomatoes. The lowest tomatoes are always the most mature as they are the elders. It never occurs that higher hanging tomatoes are mature before the lower ones. This is a fundamental production method in tomato greenhouses.

3) If the lowest tomatoes are not mature – the mobile unit will continue to next tomato plant.

4) If the lowest tomatoes are mature: A TPR needs to hold the plant steady and cut off the tomatoes and place them in the cart without any damage to the tomatoes.

In order to pick the tomatoes you will need a detection of the stem:

- in order to do the cut at the right point

- to hold the stem steady (if not, it is very difficult to do the cut)

Our Method of TPR:

Our philosophy is to detect the tomatoes by following the stem with a mechanical cutter head (see pictures in attachement). We have already developed a prototype of a special cutting- and detection head, which via the stem identifies the location of the tomatoes and perform the cut at the correct place. We have invented this method and we do hold a patent for complete system.

We have chosen this approach after initial test based on a vision system to detect and cut the tomatoes. These tests clearly showed that this approach is too unstable. Both in the detection, robustness and certainly in the estimation of the cutting point, which will result in failures in the cutting procedure. It was clear, from the tests, that the right approach must be some kind of stem detection and stem following method.

The stem following method has been evaluated, and found to be possible and feasible by the largest Danish tomato grower, who is considered as a valid representative for the future TPR costumers. The concept is based on following steps:

Grippers hold stem steady and the cutting head is closed around the stem. Grippers are then retracted and cutting head is following the stem until it detects either a leave or a tomato. Them it perform the cutting procedure using cutting knifes and tactile sensing system.

We have chosen this approach for several reasons, main ones are mentioned below:

a) It is a 100% secure and natural way of locating the tomatoes;

b) THE ONLY STABLE WAY to guarantee the cut of the stem at the correct place;

c) The cutting provides natural back-pressure when performing the cut, because it has the support of the cutter head in 360° around the stem;

d) When performing the cut we know where the tomatoes are (by using sensors) and therefore we can catch and guide them gently and safely to the cart AND

e) While approaching the tomato bunch, we use the cutter head to de-leaf the plants as the leaves are located in the same way as the tomatoes. None of our competitors are offering this function in their prototype-versions.

2. What is the technical challenge of this approach? (4000 char.)

The TPR is defined as the development of an automated solution consisting of the following 3 sub-systems:

<u>1. Upperpart</u>

1.1 The column

Vertical movement and rotations of the entire gripping and cutting system

1.2 The grippers

Telescopic grippers with built in tipping function (upper gripper)

1.3 The cutting head

The cone with cutting knifes and tactile sensing system

2. The mobile unit

2.2 AGV cart adapted to the heating pipes between rows

This is the cart itself where the column is mounted. The cart is basically a type of AGV, but made for movement along the heating pipes which is present in all green houses.

2.3 Row changing functions (extractable side wheels)

This is down foldable wheels enabling side wards motion of the cart.

2.4 Charging system and logistics interface

This is a special charging device for TPR´s with charging and other TPR service functions

2.5 The cart for tomatoes

This is a standard cart – also driving on water pipes – and hooked to the mobile unit. Made easy to change/remove when full.

3. SYSTEM – Stem detecting system and vision system

3.1 The stem detecting system

This system will be based on laser scanners. This is to ensure a robust and fast positioning of the cart within gripping range, which is relatively wide.

3.2 The vision system

The vision system will be used for following tasks:

- “On the fly” general evaluation for grower inspections (screening mode)

- Precise bunch detection

- Maturity evaluation

We do not see any big challenges regarding the mobile unit mentioned in point 2. However, the correct and fast location of the unit in relation to the plant requires some engineering work. However, we not consider this as a crucial risk.

The main challenges we estimate is the Upperpart and the System. We predict 2 main challenges by using our patented method of detection by the stem:

1) Increasing the capacity of the entirely harvesting process to minimum same speed as “one person” doing the job. The entire operation is defined as:

a) Visual detection of mature tomatoes

b) Detection of stem

c) Mechanical hold of the stem by our 2 grippers

d) Stem following procedure

e) cutting the tomato and guidance to the cart.

We strongly believe out stem detection method is the fastest way. Nevertheless, we are still concerned if we can achieve high enough capacity.

A customer can naturally always buy an additional TPR to increase capacity - but that compromises our basic Return-on-Investment calculation.

2) Avoiding to mix leaves with tomatoes. The stem leading to leaves is similar to the stem leading to tomatoes. However a tomato plant is genetic born as 1 stem with tomato – then 2 stems with leaves – then 1 stem with tomatoes etc.

HOWEVER, there can be deviations (less than 1-2%). If leaves ends up together with the tomatoes there is a risk of decay of the tomatoes.

3) Vision based method for maturity of tomatoes. The challenge is to reduce the failure-detection (either picking green non-mature tomatoes OR not picking mature tomatoes) to less than 1%. A higher fail-detection will result in to big economical losses for the tomato producers. Today tomato producers estimate less than 1% fail picked tomatoes/not picked tomatoes by manual harvesting (source: Mads Pedersen, CEO of AFP)

3. What are the risks of this approach? How will you reduce these risks? (4000 char.)

Biggest risk for the project is that one of our competitor (Panasonic or Mitsubishi) will launch a finish go-to-market TPR before us. The first-mover benefit on the market is considered very important. Especially due to the fact that the Breaking News effect will provide a lot of free advertisement/marketing. As earlier mentioned, the videos made public from the 2 makers does not show that they are near a system. It only shows simple movements and not a complete system. Only way to reduce this risk is to speed up the development process. For this a capital injection is needed. Thus this application.

This risk is however not directly connected to the chosen approach.

In our opinion, the largest risks - by using the stem detection approach – is to obtain sufficient speed in the complete harvesting process, as described above. We are not sure that we can get more capacity by using any other way of detection (eg. by vision) – on the contrary. We believe we already have the fastest approach, but it might not be fast enough.

Nevertheless, first indicative test shows that we are able to reach the needed capacity. But in order to make sure that we achieve the needed capacity, we need to redesign and re-develop a new/modified mechanical solution. This is one of the main tasks in this project, which require solid economic support.

Another risk is the fact that we also offer the de-leafing in our TPR. None of the mentioned competitors can offer this function. The de-leaf function is a result of using the stem-detecting approach. However, the same de-leafing function can result in leaves mixing with the tomatoes, which could result in a decay of the tomatoes.

However, it can be solved in many ways. We believe we can use force censors in our cutter head to determinate weather it is a leave or a tomato.

The third risk is to achieve a min. 99% correct maturity detection by our vision system. We will assure that by applying state of the art machine- and deep learning algorithms for the classification of the tomato maturity. We believe that standard colour segmentation and machine vision algorithms will not be able to achieve this high level of correct maturity detection. However, deep learning algorithms requires a big quantity of data material for training the classifier. Furthermore, the annotation task of the data requires a huge work effort, which is a costly process and therefore a part of the reason for seeking the funding.

4. What other methods/solutions are available (both technical and non-technical)? Why is yours better? (4000 char.)

A commercial Tomato Picking Robot does not exist today.

Only solution today for harvesting/picking tomatoes is by manual labour.

However, many Tomato Picking Robots solutions can be imagined:

One could be a gantry ceil mounted industrial robot equipped with vision, gripper and cutting device. A method like this could be developed from standard mechanical components and high specialized vision system. However, the price will not be competitive and therefore not realistic. Also the technical solution will face lots of challenges. Safety of the robot would certainly be one of the issues.

Another solution could be a standard AGV with an industrial robot mounted on top, equipped with cutting device, vision system and grippers, but it will face same problems.

PRIVA from Lithuania presented in 2017 a demo de-leafing tomato robot on GreenTech exhibition in Amsterdam in June 2017. However, they do not include the tomato picking system at all.

We are aware of at least two other companies, which have shown a demo of a Tomato Picking Robot application. That is Panasonic and Mitsubishi. They have already published very early fair demo types. This is already more than 5 years ago. These do not seem to give any answers on navigation and mobility in the greenhouses, cart for collecting the tomatoes, speed of the robot or many other technical issues.

However, it is clear that they will not include the de-leafing function. The de-leafing is an even bigger job for the persons picking the tomatoes. That means that they will still need manual labour to do this work.

It also seems clear that they will use vision for everything. That is locating tomato, judge maturity and find optimal point of cutting. It also seems like they want to have a "hold" of the tomato before cutting. This will dramatically reduce speed/capacity.

We are sure our solution is the best. Due to the fact, that we are including the de-leaf function and secondly because of our patented stem-detection cutter-head. Which means:

- It is a 100% secure and natural way of locating the tomatoes and secure high speed/capacity;

- THE ONLY SECURE WAY to guarantee the cut of the stem at the correct place;

- It provides natural back-pressure when performing the cut, having the support of the cutter head in 360° around the stem;

- When performing the cut we know where the tomatoes are (sensor system) and therefore we can catch and guide them gently and safely to the cart AND

- While approaching the tomato bunch, we use the cutter head to de-leaf the plants as the leaves are located in the same way as the tomatoes. None of our competitors are offering this function in their prototype-versions.

5. Are there any ethical or legal issues linked to this approach?

No. None of this work is illegal. None of this work involves experimentation with people or animals. None of this work constitutes a security risk or affects people's privacy.

Since this project involves robot prototypes, we will be using uncertified equipment, but only under normal (safety) regulations for these experimental machines.

Questions regarding whether automation "steals jobs" are outside the scope of this proposal, but we strongly believe that automation in fact creates jobs. It normally increases productivity at the company and improves product quality, which increases sales. Evidence suggests that the 2-4 jobs lost to the automation are soon

followed by increased employment both at the factory, greenhouse and in downstream jobs in the local horti industry.