# Autonomous Greenhouse Challenge

Anna Petropoulou, WUR Greenhouse Horticulture

*NVTL Annual Conference*

*24/05/2022*

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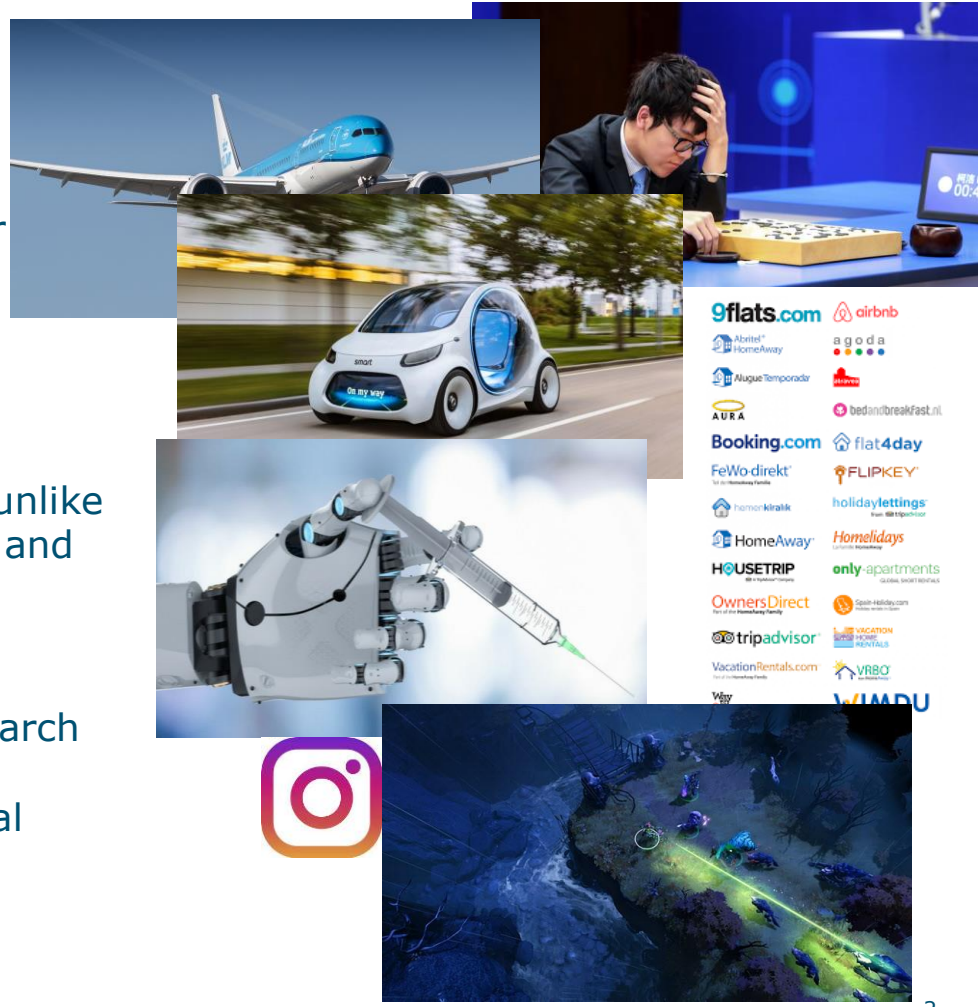
# Artificial Intelligence

- The theory and development of computer systems able to perform tasks normally requiring human intelligence (visual perception, speech recognition, decision-making).
- Intelligence demonstrated by machines, unlike natural intelligence displayed by humans and animals which involve consciousness and emotionality.
- Traditional problems (or goals) of AI research include reasoning, knowledge representation, planning, learning, natural language processing, perception and the ability to move and manipulate objects.

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# Today’s high-tech greenhouses

- Increased food demand
- Larger greenhouse compartments
- Greenhouse crop production a green industrial production process
- Internationally lack of skilled labour
- Grower needs to decide on many aspects
    - Yield
    - Product quality
    - Resource use, sustainability
    - Market

**+35% -51% over 2010-2050**

- Per capita consumption (kcal per capita per day)
- Total food consumption (in $1 \times 10^{15}$ kcal)

https://www.nature.com/articles/s43016-021-00322-9

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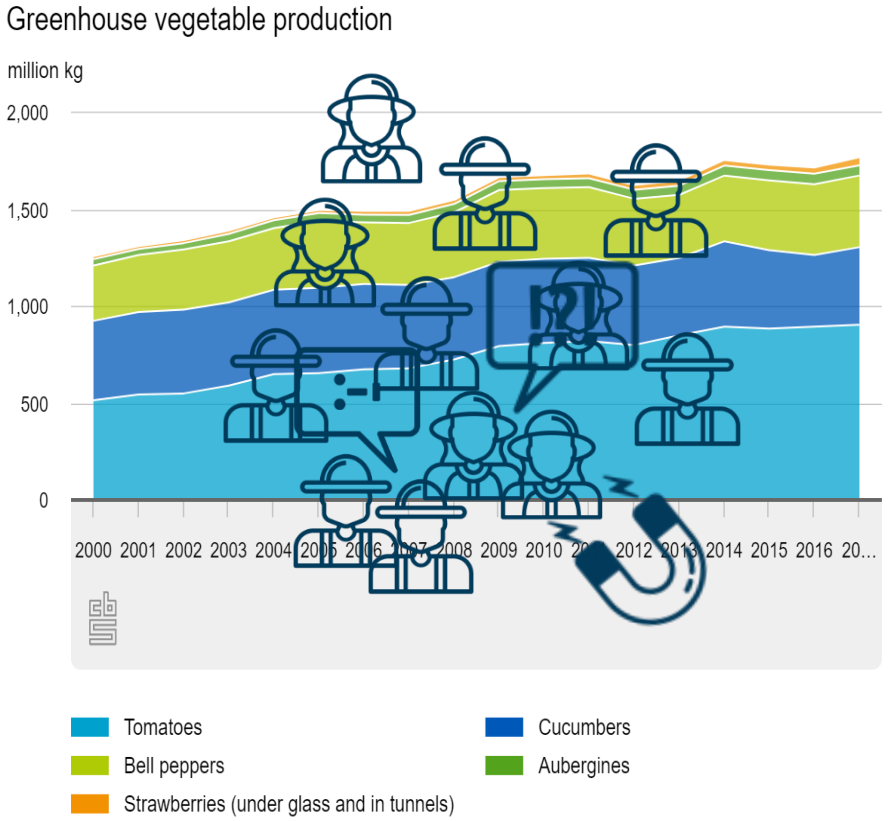


https://www.cbs.nl/en-gb/figures/detail/37738ENG

# Road Map of Autonomous Greenhouses


- Toward an optimal control strategy for sweet pepper cultivation (Buwalda *et al.*, 2006; DOI: 10.17660/ActaHortic.2006.718.42)– *Sweet pepper*
- Multiobjective hierarchical control architecture for greenhouse crop growth (Ramirez-Arias *et al*., 2010;DOI: 10.1016/j.automatica.2012.01.002) - *Tomato*
- **Remote Control of Greenhouse Vegetable Production with Artificial Intelligence—Greenhouse Climate, Irrigation, and Crop Production (Hemming *et al.*, 2019; DOI: /10.3390/s19081807) - *Cucumbers***
- **Cherry Tomato Production in** Intelligent Greenhouses—Sensors and AI for Control of Climate, Irrigation, Crop Yield, and Quality (Hemming *et al.*, 2020; DOI: 10.3390/s20226430) - *Cherry Tomatoes*
- 3rd International Autonomous Greenhouse **Challenge- *Lettuce***

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Tencent 腾讯

*“Explore the potential of Artificial Intelligence for the remote and autonomous monitoring and control of greenhouse climate and crop using sensor data”*

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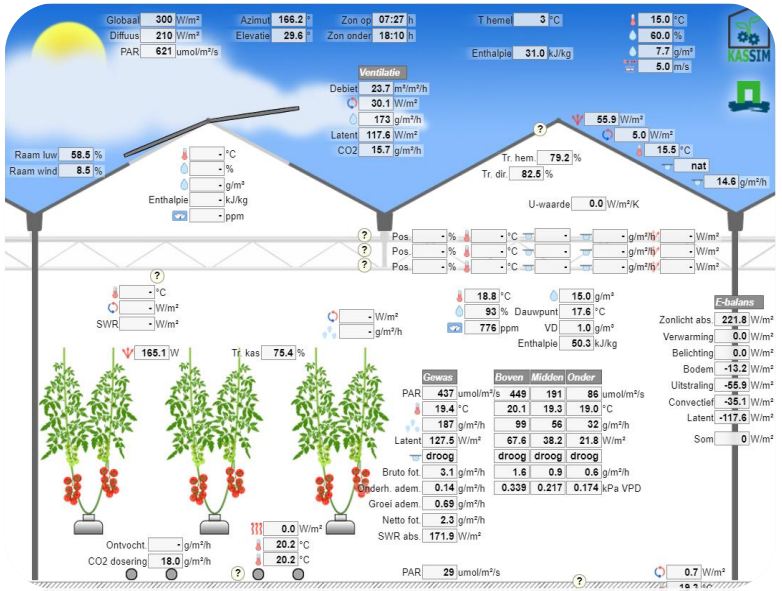
# Autonomous Greenhouse Challenge

- ✓ International competition
- ✓ Multidisciplinary teams
  - IT-domain
  - Horticulture
  - Students
  - Companies, startups, research centers
- ✓ 24h Hackathon
- ✓ Real Challenge- Growing experiment

# Physical models: Kapsro-Intkam

- Translating outside weather conditions and **control actions** into greenhouse climate
- Calculates the impact of control actions on energy (electricity and heat) and $CO_2$ use
- Accounts for limitations that follow from choices made in capacities and equipment.
- Calculates the costs and gains associated within a cultivation cycle




https://www.digigreenhouse.wur.nl/edu/kassimClient2/?token=26dbe18a-cdcb-485d-891c-29a4c4fb4bd8

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# Autonomous Greenhouse Challenge

- ✓ Five compartments
- ✓ Equal size
- ✓ Equal base equipment
  - Heating
  - Fogging
  - $CO_2$ dosing
  - Movable screens
  - Illumination
- ✓ Commercial sensing equipment
- ✓ Interface: data and control
- ✓ Internet connection
- ✓ Reference

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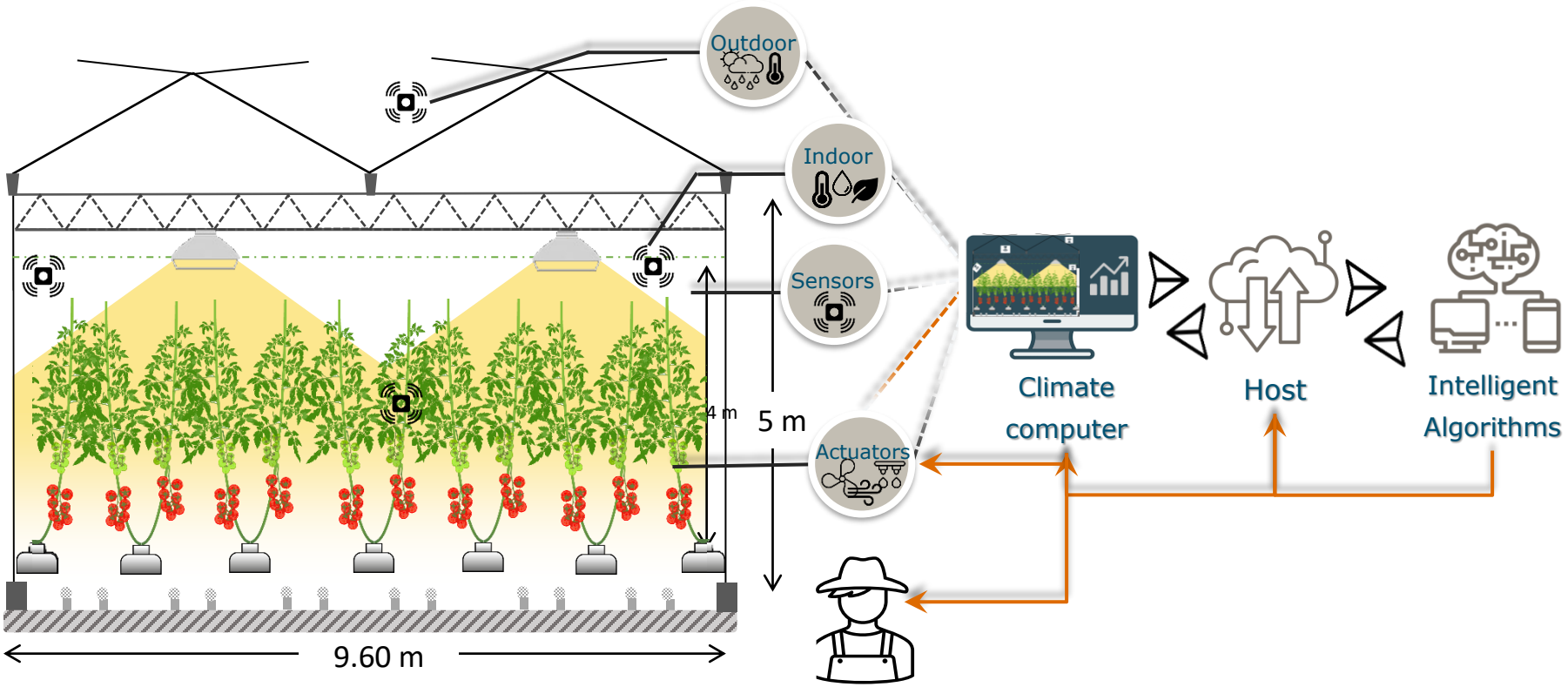
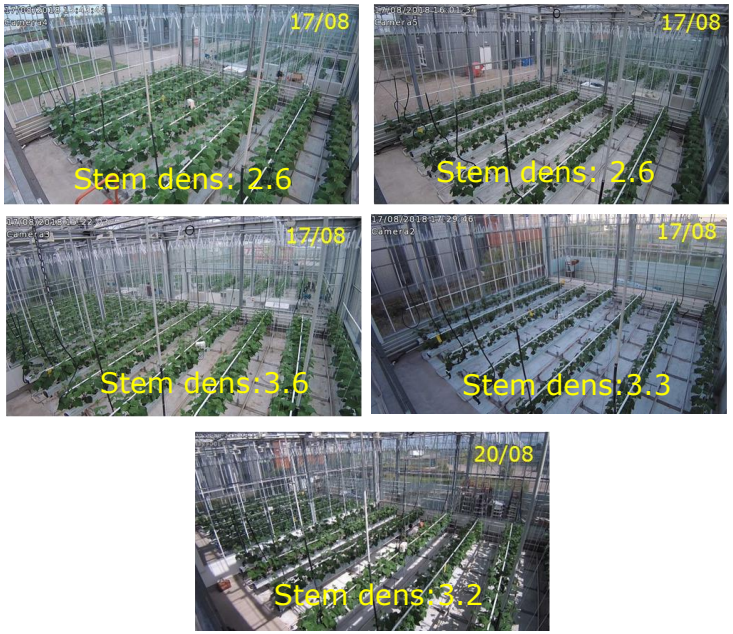
# Remote Control of Greenhouses



# Remote Control cucumber production with AI

# Remote Control of cucumber cultivation




RGB

Thermal cameras

Slab VWC

stem-diameter

net-radiation

weighing gutters

sap-flow

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# Remote Control of cucumber cultivation

- ✓ 5 International teams
  - Sonoma
  - Croperators
  - AICU
  - Igrow
  - DeepGreens

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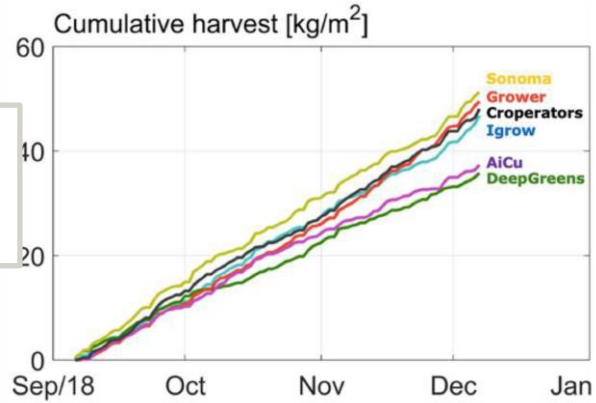
# Final results

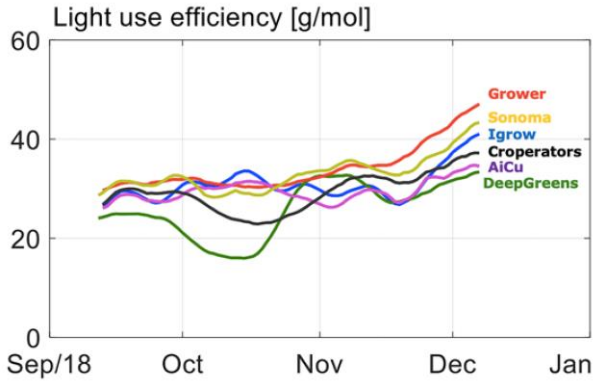
| | Reference | Sonoma | iGrow | Deep_Greens | The Croperators | AiCU |
|---|---|---|---|---|---|---|
| Young plants and substrate slabs | €3.74 | €2.74 | €3.74 | €2.29 | €2.74 | €2.47 |
| Electricity | €8.89 | €10.97 | €8.68 | €9.35 | €10.91 | €7.04 |
| Heating | €0.95 | €0.77 | €0.82 | €2.92 | €1.40 | €0.70 |
| $CO_2$ | €0.59 | €0.62 | €0.55 | €1.00 | €0.85 | €0.59 |
| Water | €0.27 | €0.25 | €0.28 | €0.21 | €0.29 | €0.28 |
| Labour | €8.32 | €9.47 | €8.85 | €8.73 | €9.48 | €10.03 |
| *Costs* | *€22.76* | *€24.82* | *€22.92* | *€24.50* | *€25.67* | *€21.11* |
| *Income* | *€43.94* | *€49.60* | *€42.95* | *€31.88* | *€42.82* | *€36.21* |
| *Net Profit* | *€21.18* | *€24.78* | *€20.03* | *€7.38* | *€17.15* | *€15.10* |

**Net profit 50% of total points**

**AI 30% of total points**

**Sustainability 20% of total points**

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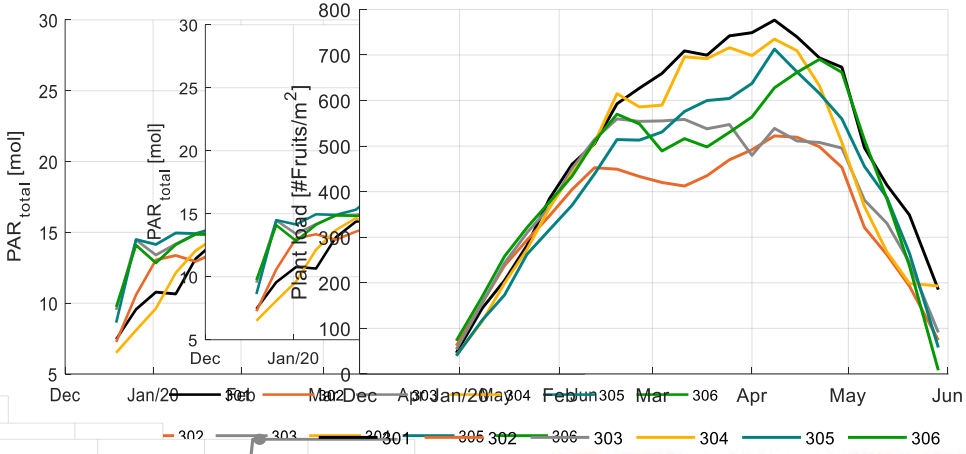
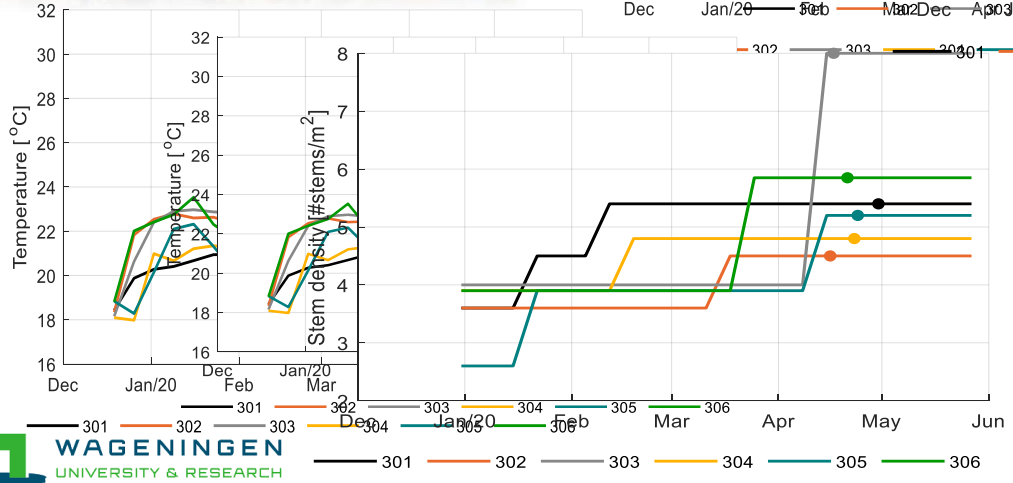
# Cherry Tomato Production in Intelligent Greenhouses

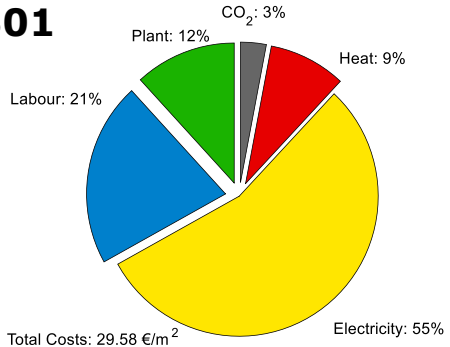
# Challenge set-up



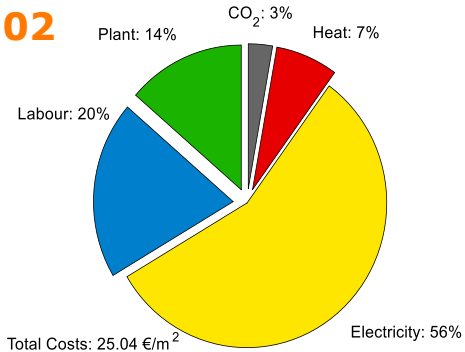

# Cost components

**301**



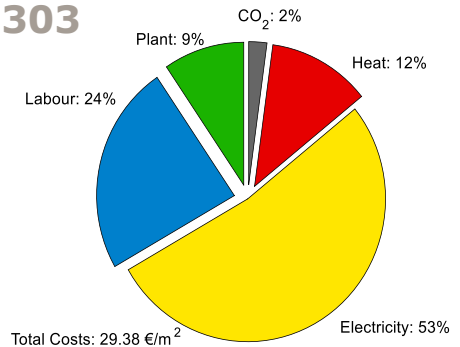

Total Costs: 29.58 €/m$^2$
Income: 36.73 €/m$^2$
Profit: 3.19 €/m$^2$

**302**



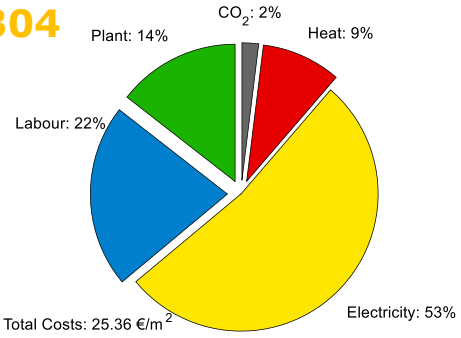

Total Costs: 25.04 €/m$^2$
Income: 35.27 €/m$^2$
Profit: 6.27 €/m$^2$

**303**



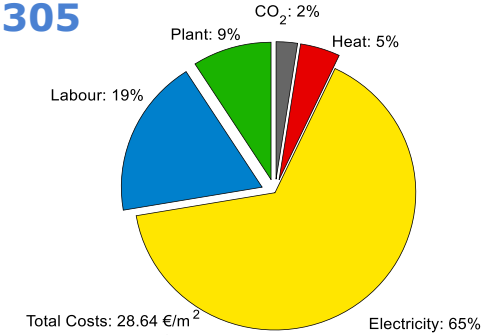

Total Costs: 29.38 €/m$^2$
Income: 35.56 €/m$^2$
Profit: 3.1 €/m$^2$

**304**



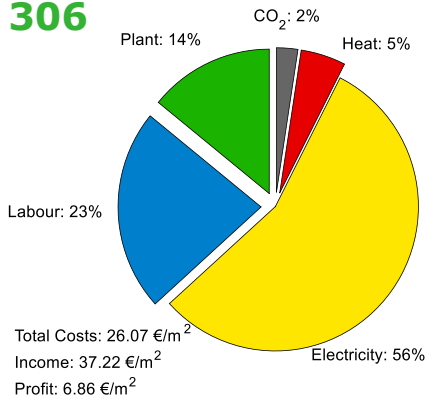

Total Costs: 25.36 €/m$^2$
Income: 33 €/m$^2$
Profit: 3.35 €/m$^2$

**305**




Total Costs: 28.64 €/m$^2$
Income: 35.09 €/m$^2$
Profit: 3.59 €/m$^2$

**306**




Total Costs: 26.07 €/m$^2$
Income: 37.22 €/m$^2$
Profit: 6.86 €/m$^2$

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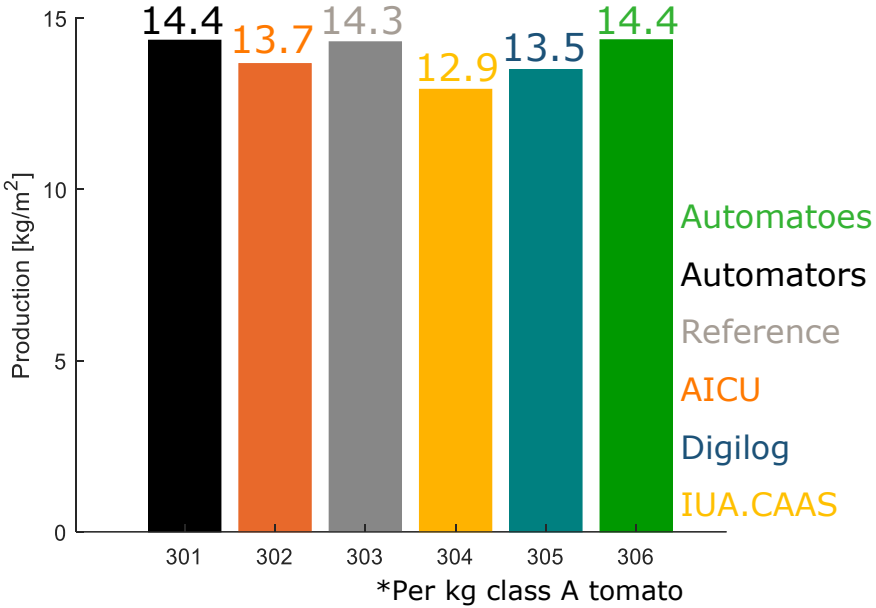
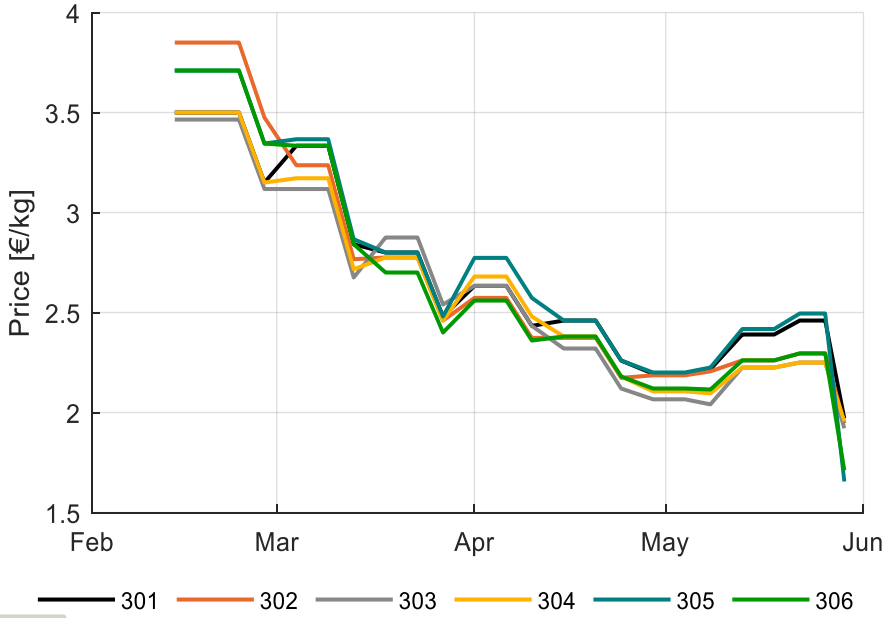
# Production and Quality




**50% of total points**

# Ranking in sustainability & AI

| Heat (MJ) | Electricity (kWh) | $CO_2$ (kg) | Water (l) | Nutrients (g) | AI approach |
|---|---|---|---|---|---|
| 12,9 | 18,7 | 0,63 | 25,0 | 83,0 | Automatoes |
| 18,5 | 17,6 | 0,74 | 25,2 | 81,0 | AICU |
| 25,3 | 19,9 | 0,87 | 25,9 | 78,0 | The Automators |
| 25,9 | 17,7 | 0,56 | 26,9 | 90,0 | IUACAAS |
| 12,8 | 24,0 | 0,72 | 27,9 | 100,0 | Digilog |
| 33,0 | 19,0 | 0,60 | 27,4 | 99,0 | |

*Per kg class A tomato

**20% of total points**

**30% of total points**

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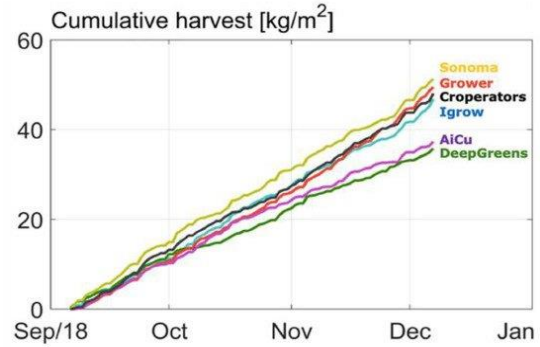
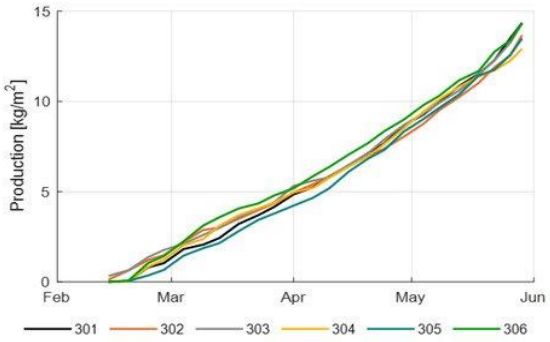
# Earlier editions

| | | | |
|---|---|---|---|
| 1st | 1045 views | 498 downloads | 1 citations |
| 2nd | 2848 views | 1071 downloads | 0 citations |
| 3rd | 492 views | 245 downloads | 0 citations |

https://doi.org/10.3390/s19081807
https://doi.org/10.3390/s20226430

- https://doi.org/10.4121/uuid:e4987a7b-04dd-4c89-9b18-883aad30ba9a
- https://doi.org/10.4121/uuid:88d22c60-21b3-4ea8-90db-20249a5be2a7
- https://doi.org/10.4121/15023088.v1.

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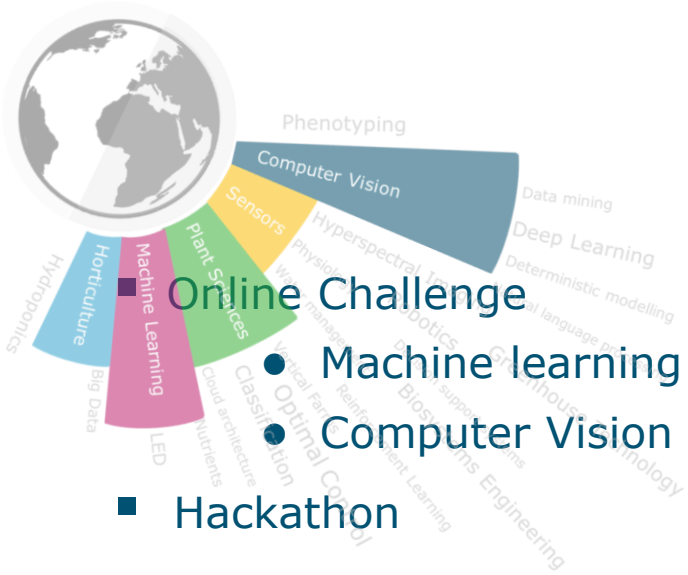
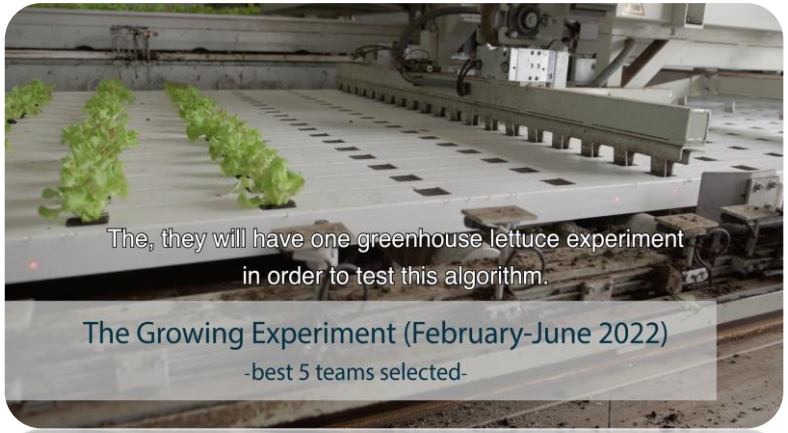
# Hydroponic Lettuce Production in Intelligent Greenhouses

# 3rd Autonomous Greenhouse CHallenge

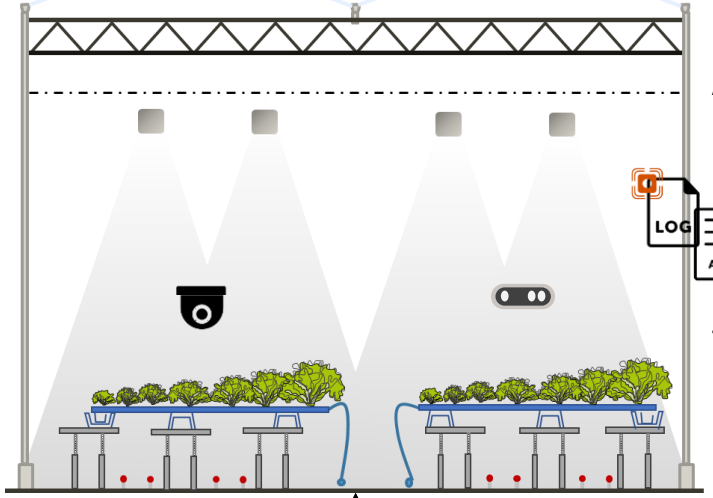



- Online Challenge
  - Machine learning
  - Computer Vision
- Hackathon
- Real Challenge




***Autonomy***

# Communication protocol




Additional team's sensors

Weather forecast
Outdoor, indoor climate,
Default sensors
(Sigrow, Realsense, Ridder)

Virtual Machine

Limited access to VMs upon request to WUR organizers

Climate setpoints
Crop instructions

LetsGrow.com

Climate setpoints

Climate setpoints

Climate computer

Crop spacing/ Day of harvest

Crop Instructions

Teams

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# Real experiments

- 1st February- 15th March
- 3rd May- Ongoing

***Cultivation strategy and spacing to obtain …***

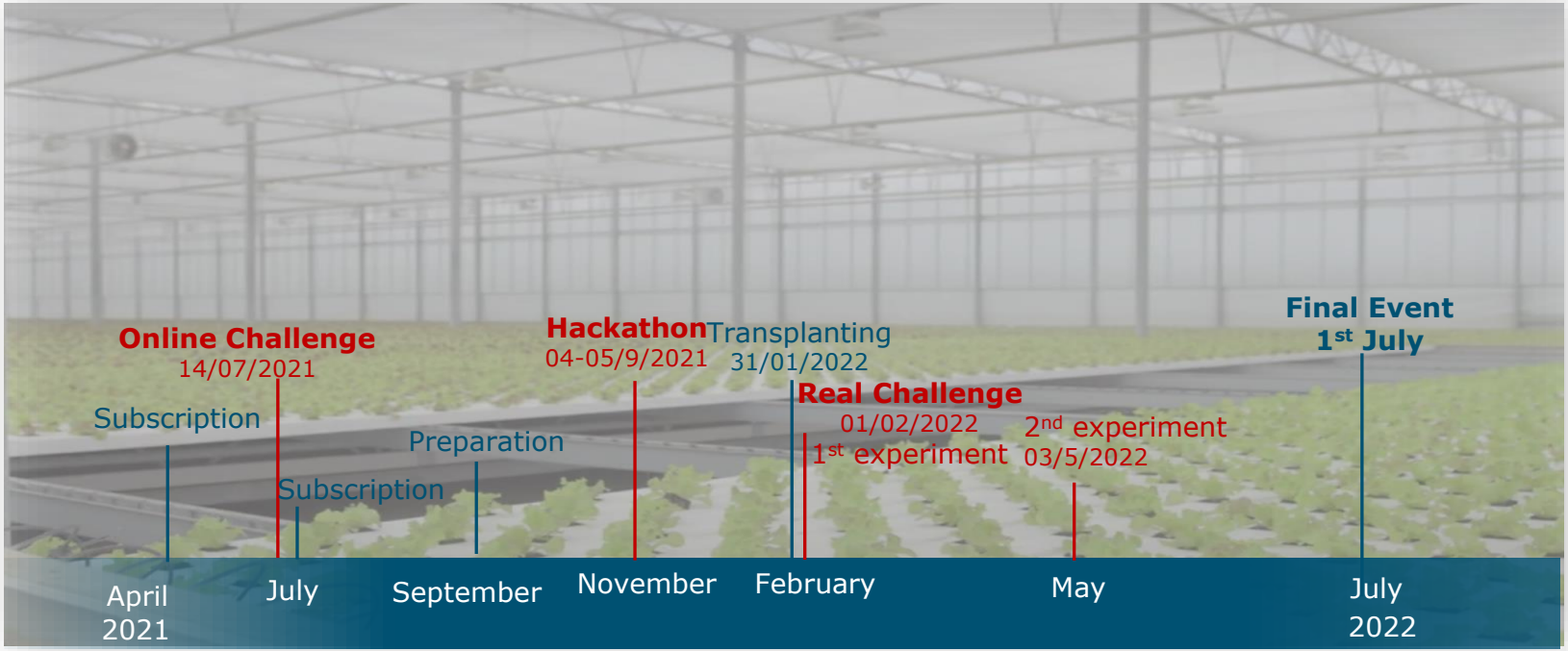
… the optimum number of lettuce heads…

…of the right quality …

… making optimal use of resources…

… to obtain maximum net profit!

# 3rd Autonomous Greenhouse Challenge




https://www.wur.nl/en/show/Register-for-the-International-Autonomous-Greenhouse-Event.htm

# Final Event 3rd Autonomous Greenhouse Challenge


1st July

1st International Autonomous Greenhouse Event

Organized by
Wageningen University & Research
Greenhouse Horticulture

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https://www.wur.nl/en/Research-Results/Research-Institutes/plant-research/greenhouse-horticulture/show-greenhouse/International-Autonomous-Greenhouse-Event.htm

sponsored by Tencent and
David Wallerstein, CXO Tencent

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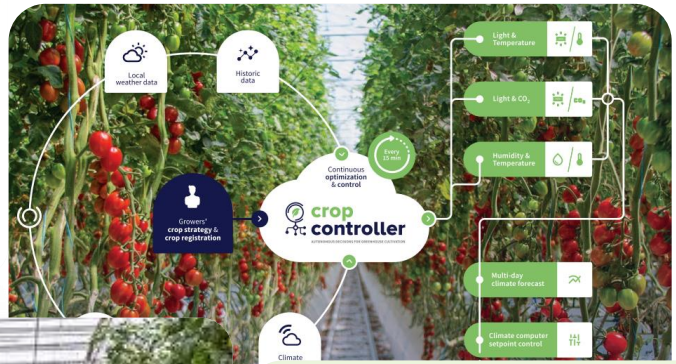


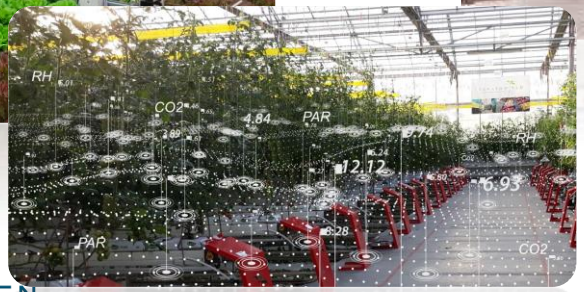



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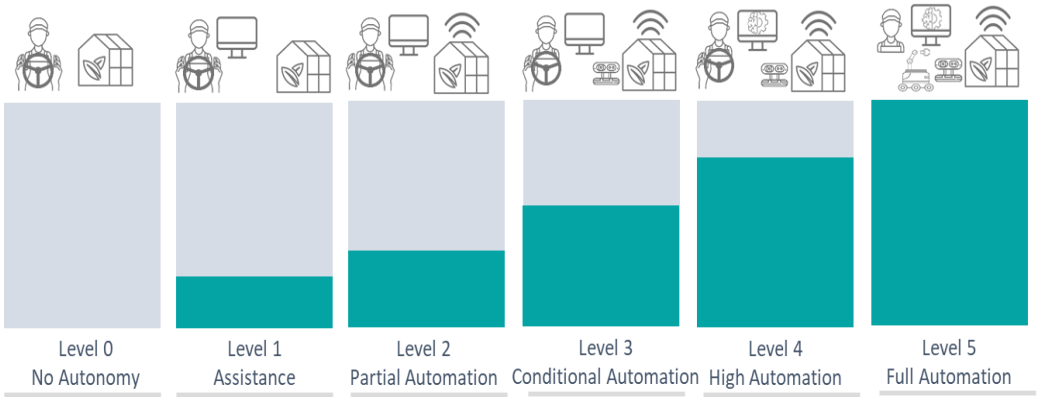
# Levels of Autonomy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# Autonomous Greenhouses

- Autonomous decision support systems (climate, irrigation, crop management)
- Intelligent sensing of cultivation parameters (climate, crop, irrigation, fertigation, pest, diseases)
- Automated handling of activities with robotics (harvesting, spraying)

# Digitalizing Green Fingers

Autonomous growing & levels of autonomy

Key role: Volume & Variety in data

- ❑ High-Tech Research facilities
- ❑ Non-invasive automated sensing
- ❑ FAIR data principles

Integrated approach


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https://www.wur.nl/en/Research-Results/Research-Institutes/plant-research/greenhouse-horticulture/Research-themes.htm

# Conclusions

- AI algorithms can compete & outperform human reference
- Training data is lacking in quality and quantity
- Computer vision towards understanding and measuring plant performance
- Crop registrations need to be digitalized (non invasively, automated)
- Pest and diseases, nutrients
- Digital twins
- Robotics

# 3rd Autonomous Greenhouse Challenge

More information:

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