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Better sustainability for year-round tomato production with digital tools

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Three tomato growers from Närpes providing data

Luke

Equipment and studied digital tools in the two Test Case (TC) farms

Equipment and studied DATs in the two Test Case farms
(DAT=Digital Agricultural Tool)

Farm 1 without the new DATs (non-DAT farm):

- ✓ 1,287 h round tomatoes (Livento) in rockwool. Cropping period usually 11 months (August-June)
- ✓ Climate program HortiMax
- ✓ Grodan GroSens sensorer for continuous measurement of humidity and EC in rockwool slabs (no coupling with climate program, the grower decides on irrigation intervals and amounts)
- ✓ Heating with solid fuels (wood chips and peat) plus heat from HPS-lamps
- ✓ Drainage 20 %

Farm 2 with new digital tools (DAT-farm):

- ✓ 1,2 ha round tomatoes (Gerdisia) in peat/moss plus 6 rows of cocktail tomatoes (Ardilles)
- ✓ Cropping period usually 11-11,5 months (July-end of May/beginning of June)
- ✓ Climate program Priva Connext
- ✓ Trutina system for irrigation start (weighs plants and substrate slabs), helps to decide on irrigation needs
- ✓ Heating with district heating (heating plant in the same village), propane, light fuel oil, and electricity in the last year via electricity kettles)
- ✓ Drainade 25 %

Luke

Studied DATs or IoTs in TC-DAT (DAT=Digital Agricultural Tool, IoT=Internet of Things)

Farm 1, non-DAT:

- ✓ 2022-24: HPS-lamps above plant tops (light intensity 200-215 µmol/m^2/s) + Philips led-interlights (30-40 µmol/m^2/s)
- ✓ 2024-25 hybrid lighting: Dynamically controlled led lighting with Signify's lamps above corridoors between plant rows and HPS-lights above plant rows. GrowWise for steering light intensity of led-lamps.
- ✓ No water recirculation

Farm 2, DAT:

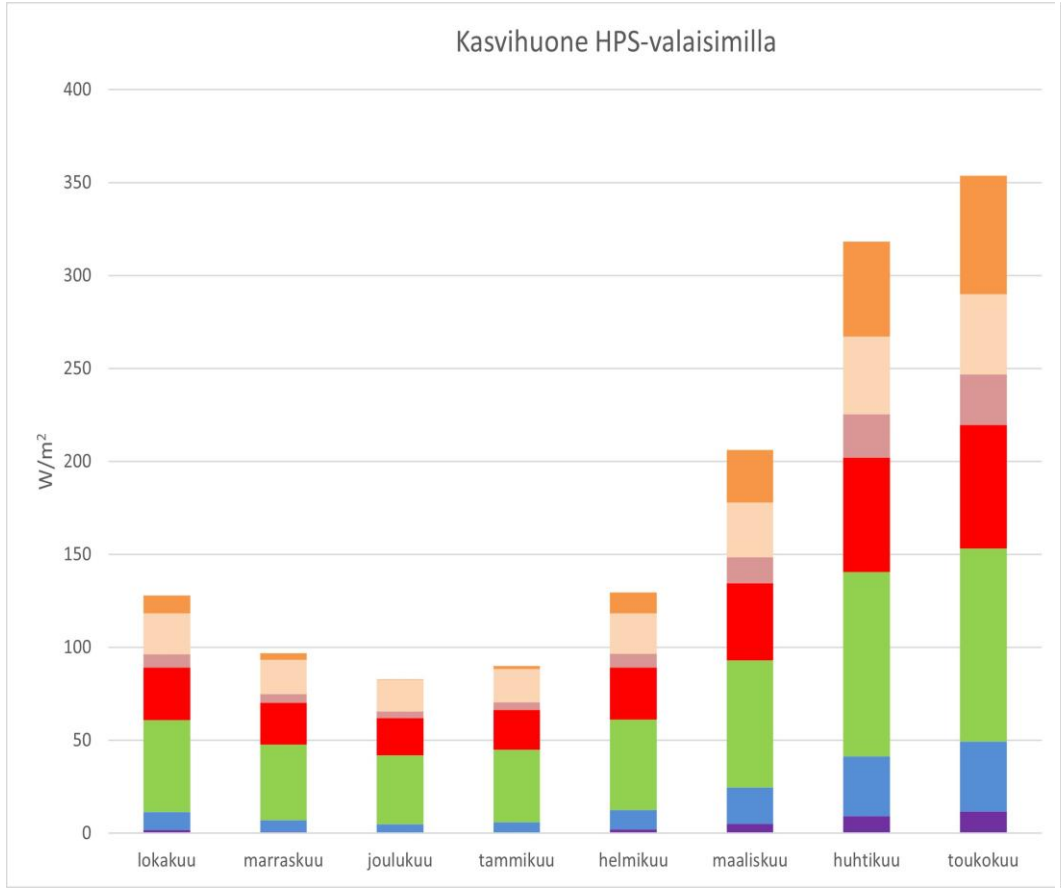
- ✓ Dynamically controlled led lighting (Signify)+ GrowWise integrated with Priva Connext. Dimning of led-lamps steplessly down to 10 % of maximum light intensity.
- ✓ Kathari UF1 ultrafiltration for disinfecting drainage, installed in March 2023

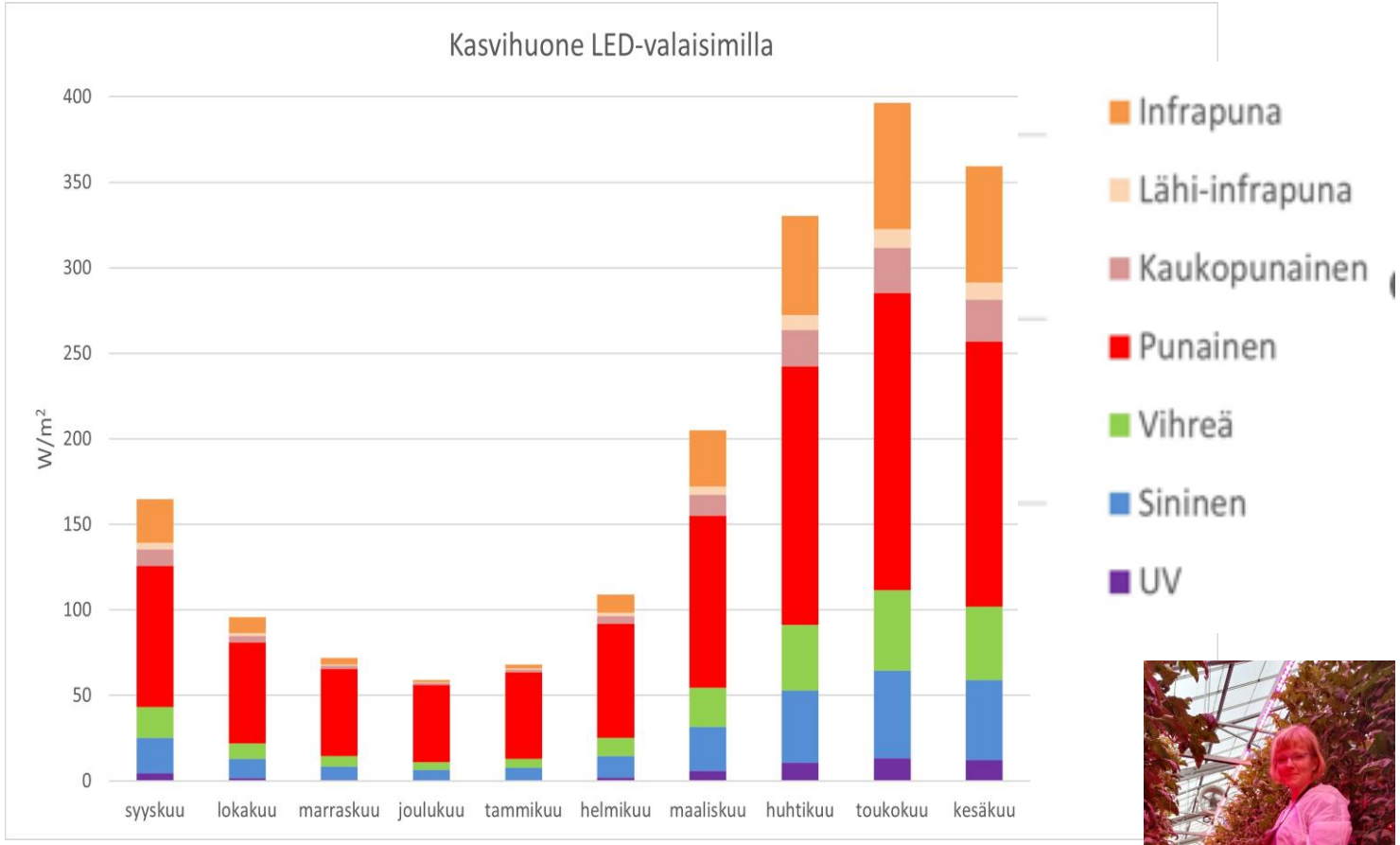
Luke

Både DAT och non-DAT odlare odlade som de själva ville, projektet bestämde ingenting, bara insamlade data regelbundet

Signify dynamically controlled led-lights with red and blue as dominant wavelenghts

Distribution of different wavelengths from HPS and Signify's led-lamps and radiation (W/m^2) over the year

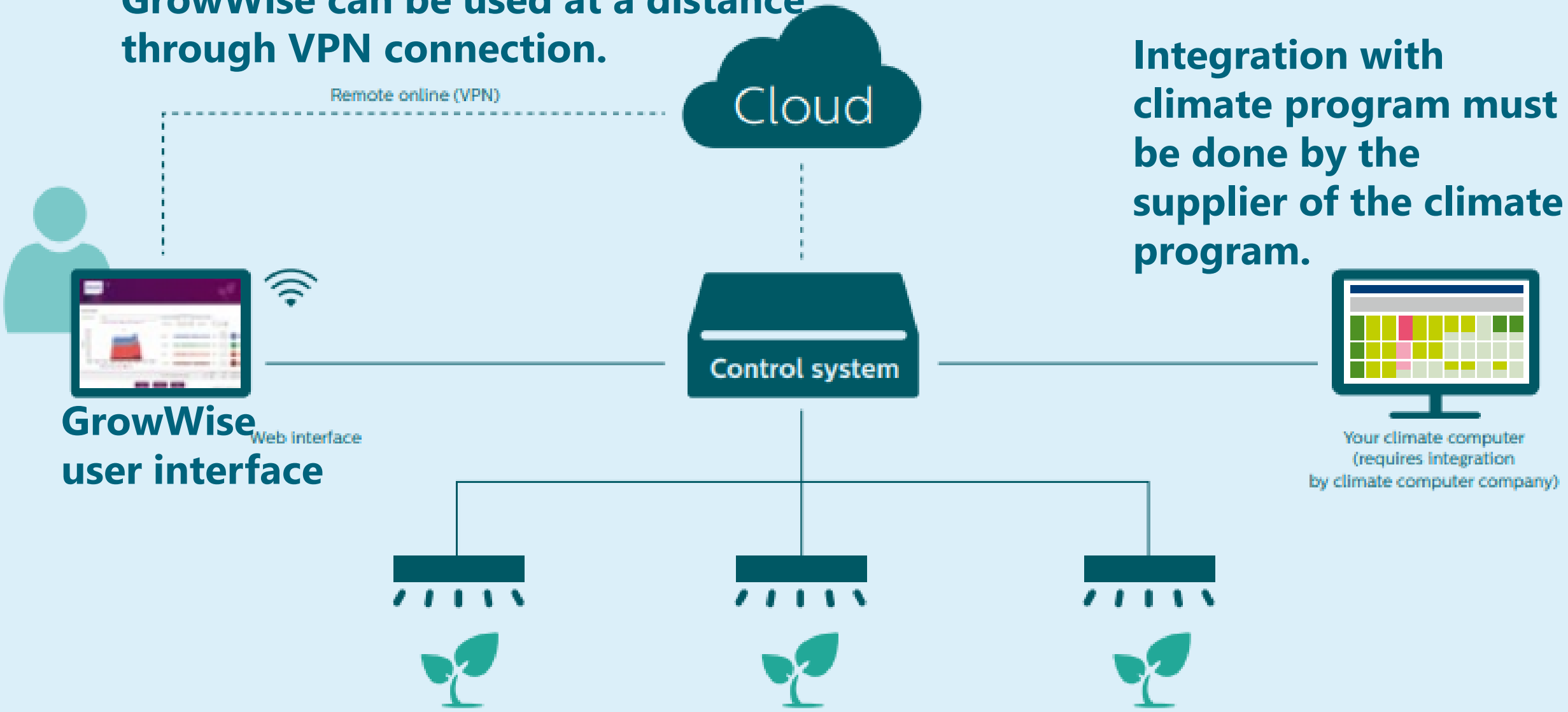




Light measurements by
Titta Kotilainen, Luke

How does the **GrowWise Control System** work?

GrowWise can be used at a distance through VPN connection.



Integration with climate program must be done by the supplier of the climate program.

Kathari UF1, IoT-based ultrafiltration system (apparatus + data) (Van den Ende Group)

Cistern with sockfilter for drainage from greenhouse

Prefiltration before UF-membrane

UF-membrane

Before prefilter flocculation of phosphates, colloidal substances and humus with iron chloride.

Luke

Pre-filtering unit before water goes to the UF-membrane tube

Close-up of the membrane "straws". Prefiltered drainage goes to the straws, particles stay there, and cleaned water enters the tube in the middle and from there onwards. The membrane requires regular **backflushing** to prevent clogging.

Ultrafiltration removes plant viruses, bacteria, unicellular algae, and dissolved substances (+ lets through, - removes)

Filtering technique	Water	Monovalent iones (Na^+, K^+, NO_3^-...)	Polyvalent ions (Mg_2^+, PO_4^{3-} ...)	Viruses	Bakteria, unicellular algae	Dissolved substances
Mikrofiltration 10-0,1 µm	+	+	+	+	-	-
Ultrafiltration 0,1-0,01 µm	+	+	+	-	-	-
Nanofiltration 10-1 nm	+	+	+/-	-	-	-
Reverse osmosis <1 nm	+	-	-	-	-	-

Luke

How were the DAT and non-DAT farms compared?

Three study periods (July - June)

2022-23:

- **Warm autumn, cold December and January.**
- **Exceptional period:** high electricity prices in the autumn and winter months
- **Non-DAT grower had a winter pause of 2,5 months** (middle of Feb – end of April april), **cropping period only 6 months**
- DAT-farm continued throughout the winter
- DAT-farm installed Kathari in March 2024 = covered only 2,5 mo of this cropping period

2023-24:

- **Dec, Jan, Feb colder than on average**
- DAT-farm with normal cropping period of 11 months
- **Non-DAT farm with cropping period of 13 months** to compensate for winter pause in the preceding period

2024-25:

- **Warmer autumn and witner than on averge**
- Normal cropping period lenghts in both farms
- **DAT-farm installed electricity kettle** for heating purposes (storage of hot water during low electricity prices)
- **Non-DAT farm installed hybrid lighting**

Luke

Data collecting: inputs and their costs plus yield.

Note! Only variable costs are included.

DATA:

- Water
- Electricity (for lighting)
- Hearing energy (wood chips, peat for non-DAT; district heating, propane, light fuel oil, electricity in the last year through e-kettles for DAT)
- Fertilizers (mineral and CO_2)
- Work hours
- (plants, growth slabs, pesticides, biocontrol excluded – so small in the big picture)

ANALYSIS:

- **Inputs and costs per kg of yield**
- **Revenues from sold yield**

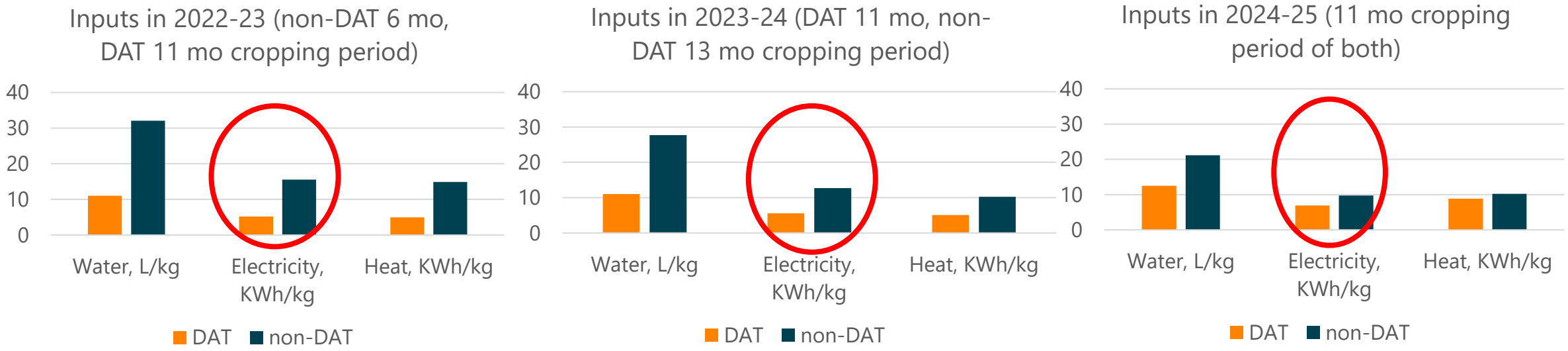
- Ekonomic, social and ecological sustainability – some preliminary results were available

- **Can the effect of the DATs be seen in input amounts, their costs, revenues and sustainability indexes?**

Luke

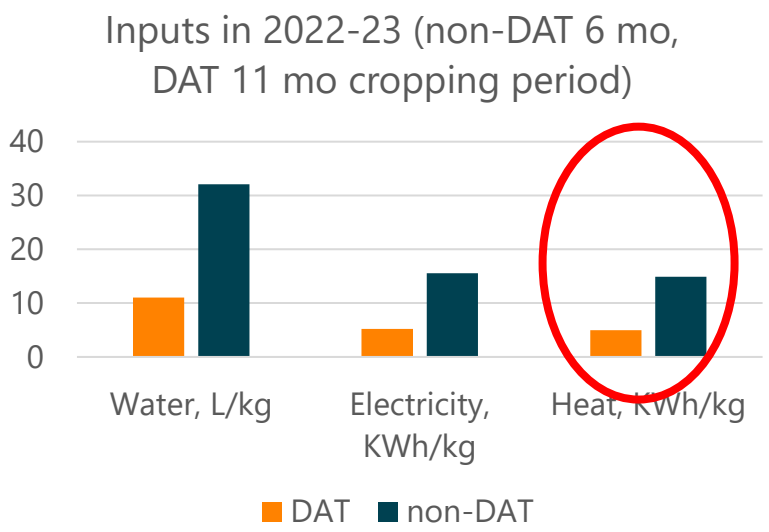
Results

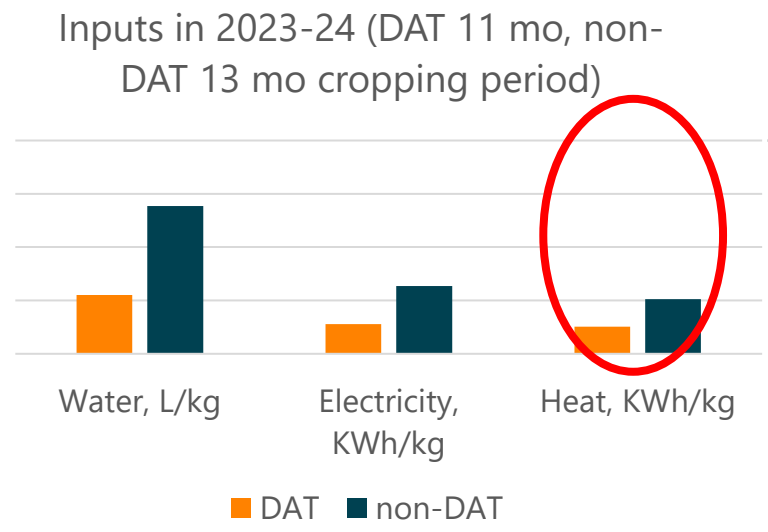
Inputs: electricity, heat and water (key resources) per kg of produced tomatoes

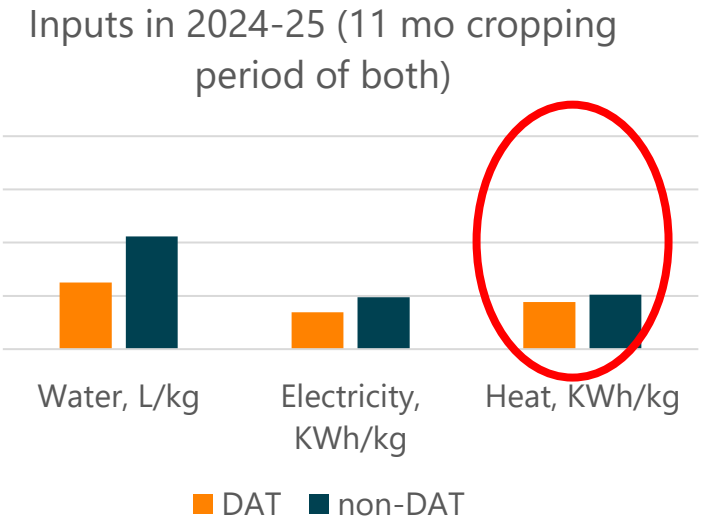


- Electricity consumption for lighting per kg tomatoes was 30-66% lower with dynamic LED lighting.
- LED lamps are more energy efficient: the same amount of energy produces more micromoles, and the number of micromoles affects yield.
- The difference in electricity consumption between the two farms is now smaller after the non-DAT grower installed hybrid lighting for 2024-25

Inputs: electricity, heat and water per kg of tomatoes



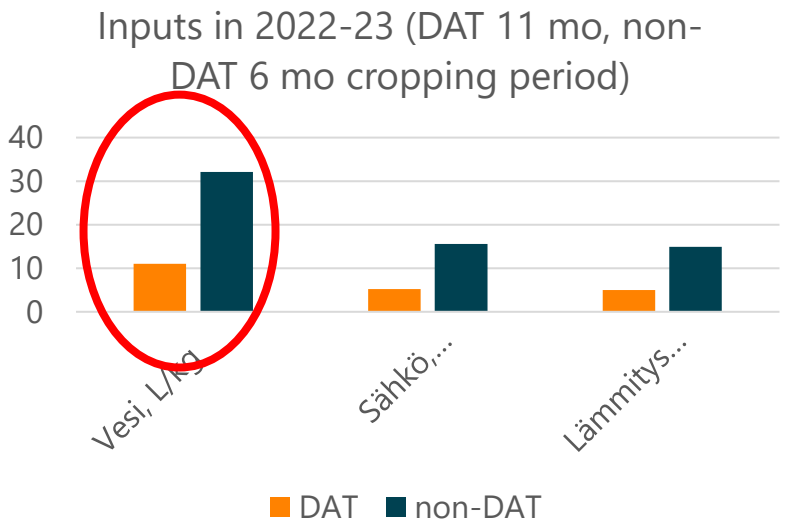


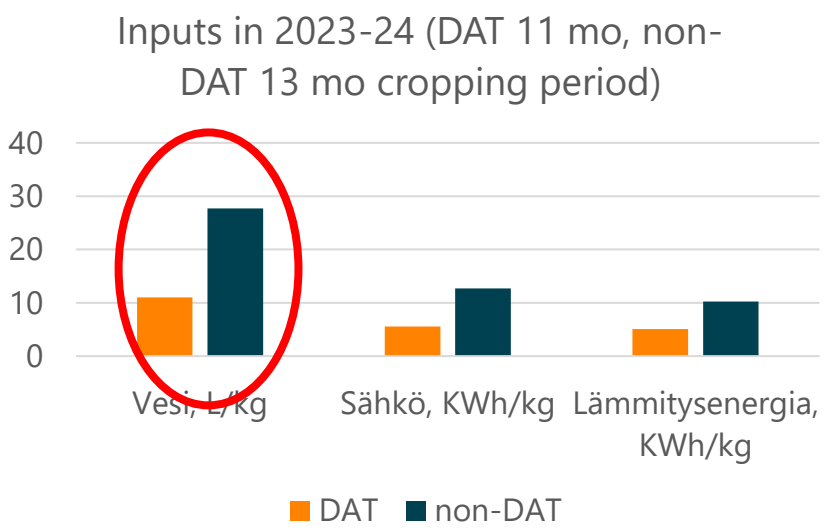


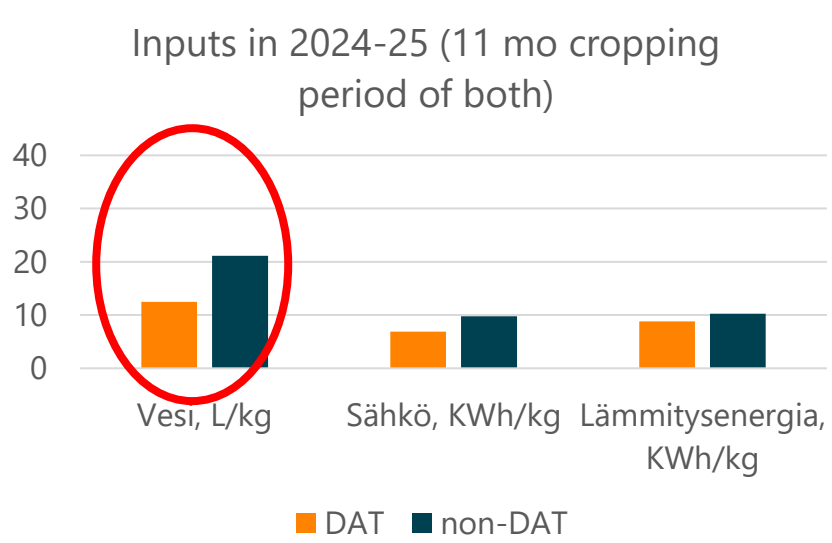
- Heating inputs at the non-DAT grower were higher than at the DAT grower in 2022-24, but…

- …they have converged during the last research period.

Inputs: electricity, heat, and water per kg of tomatoes

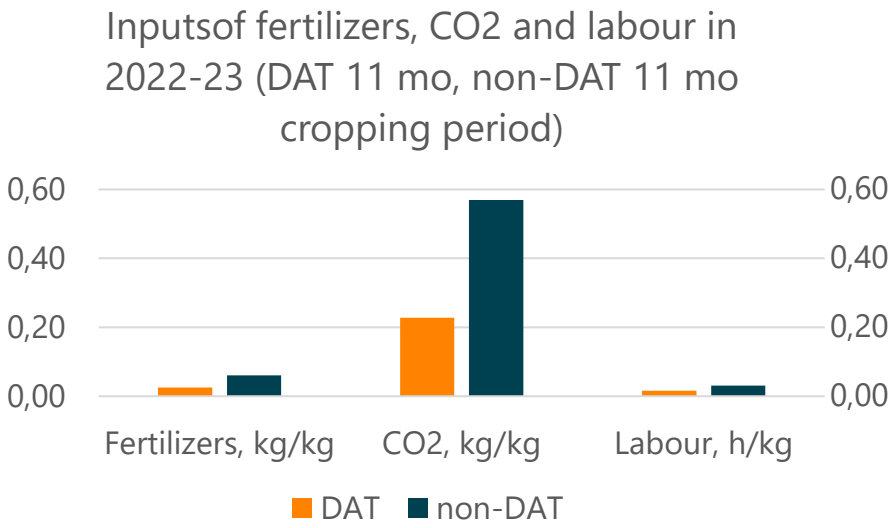


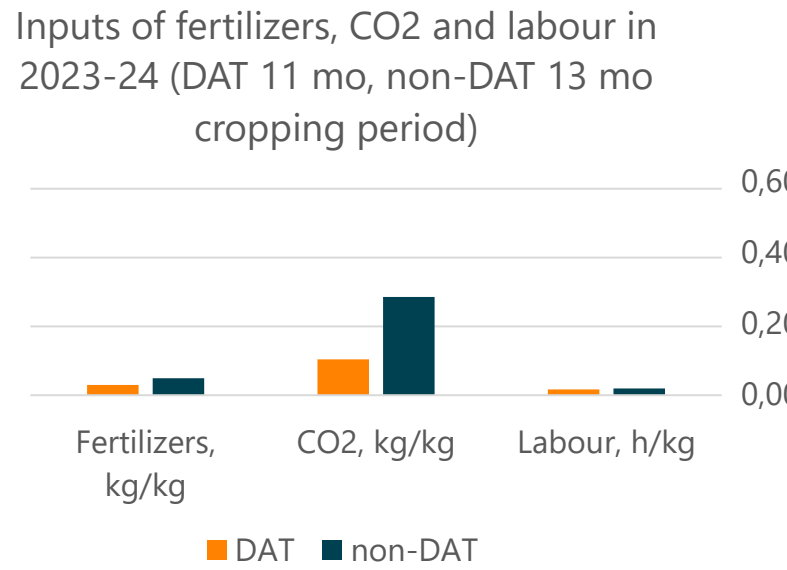


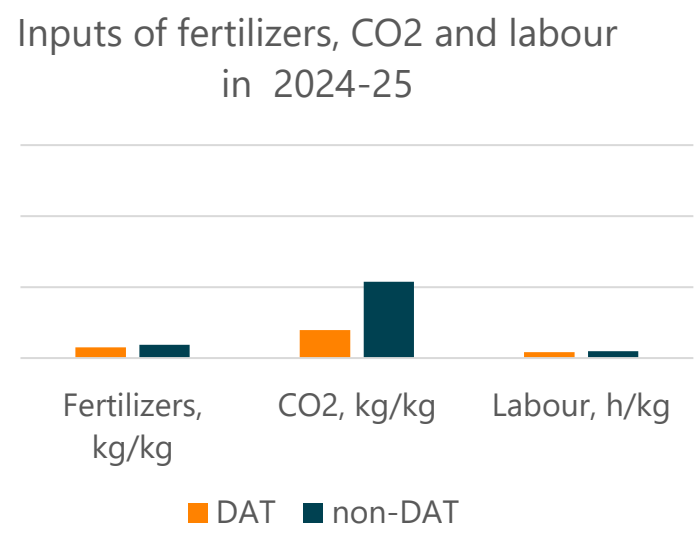


- Water consumption reflects the effects of the lighting method (HPS vs. LED) and somewhat of the growing medium (peat vs. rock wool).
- Water consumption in DAT cultivation is low – among the best levels that can be achieved in high-tech greenhouses.
- **The non-DAT grower's water consumption has been reduced by about 30% owing to hybrid lighting.**

Inputs of fertilizers, CO_2 and labour per kg of tomatoes

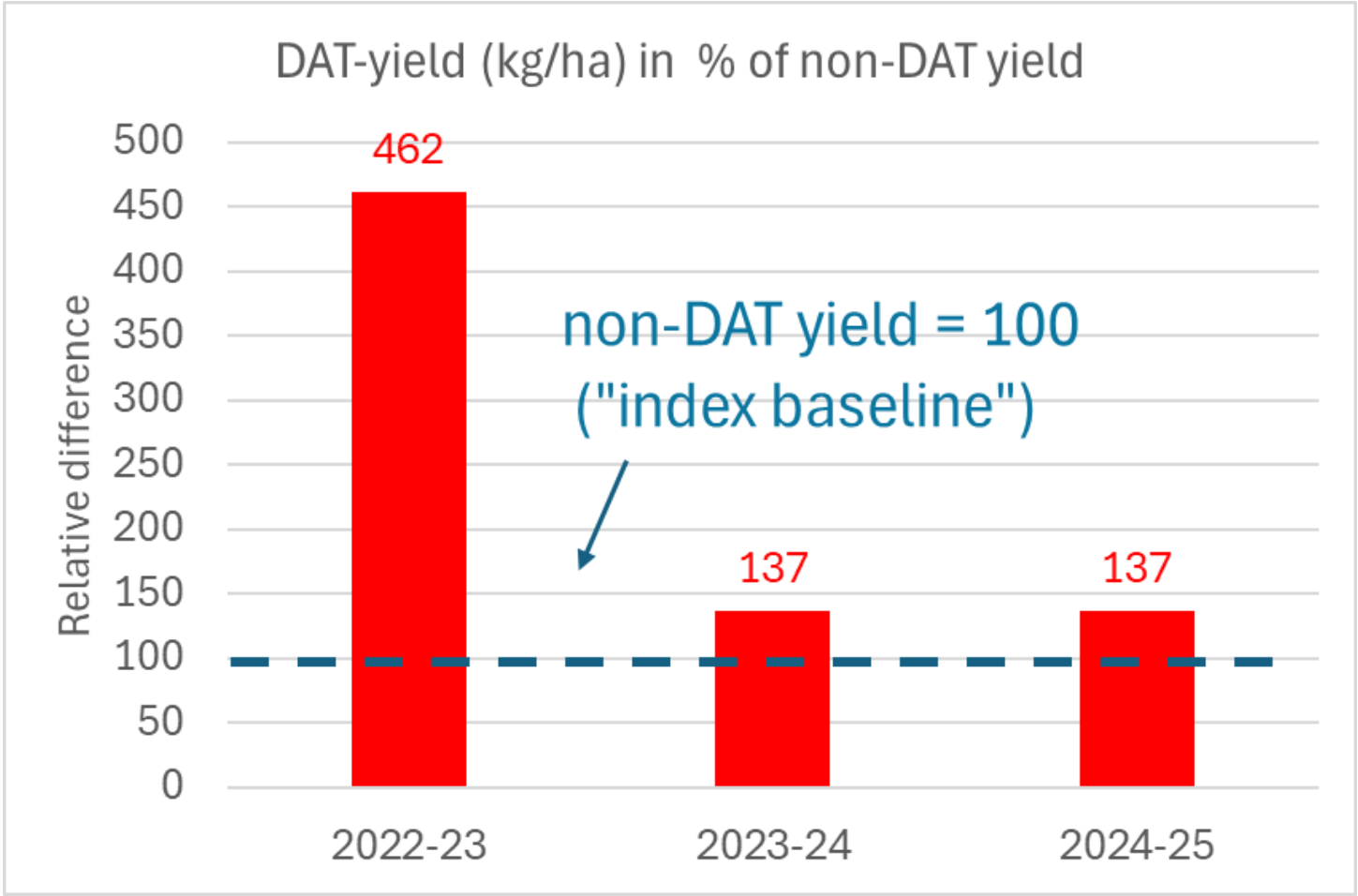






- Per kg of tomatoes, DAT growers used less **fertilisers** than non-DAT grower, but the difference has decreased over three years.
- DAT growers' fertiliser use has been relatively stable. Non-DAT growers' fertiliser consumption is decreasing – he irrigates less after switching to hybrid lighting.
- There are clearer differences in **CO_2** use, indicating different strategies for climate control and yield levels.
- The difference in **labour** input per kg of tomatoes is small, with the exception of the first study period, which was short for the non-DAT grower. (Note: working arrangements differ between the two growers: two pickings per week for the DAT grower and three for the non-DAT grower.)

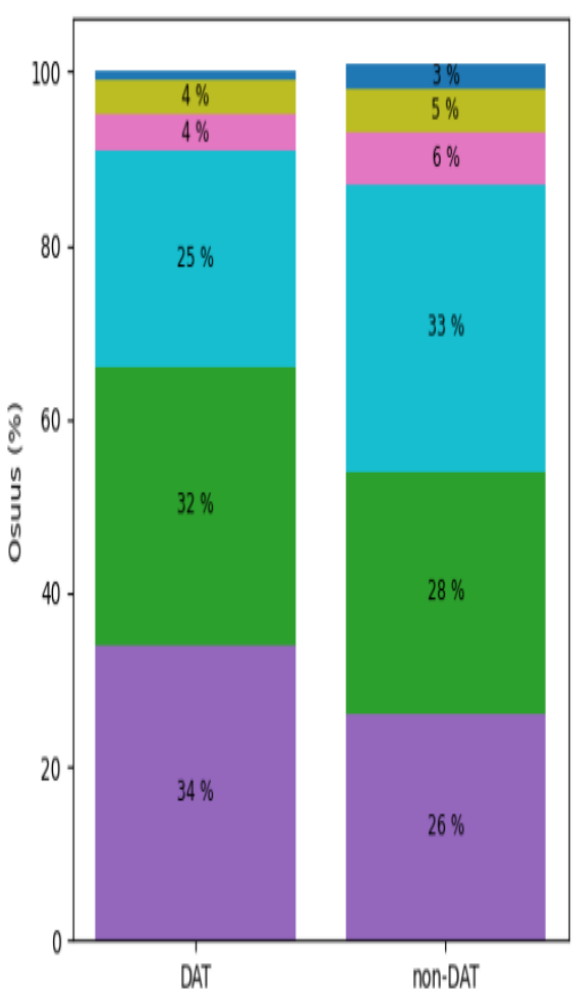
Differences in inputs (among other things), influence yield per hectare



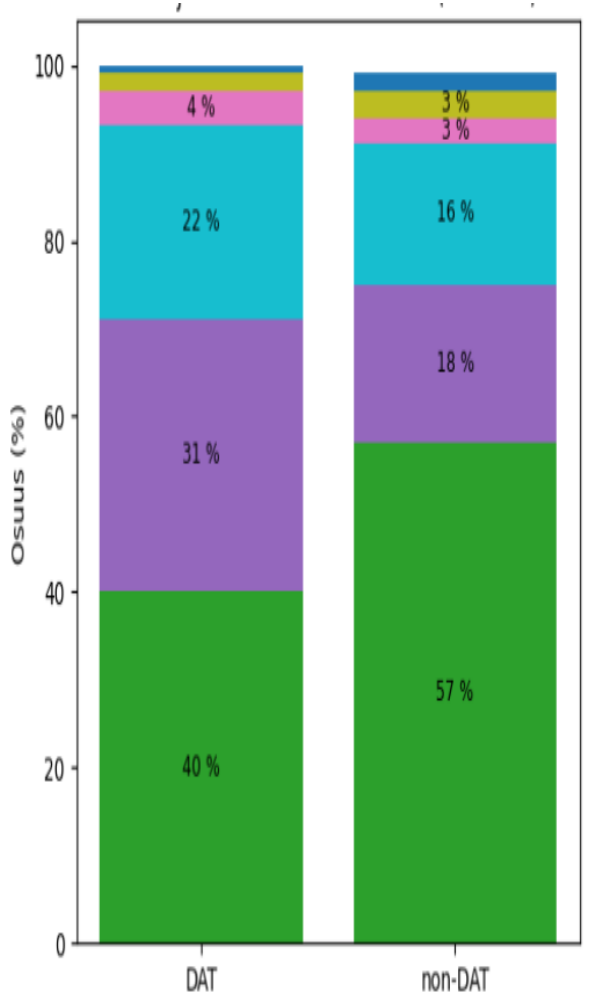
Lenght of cropping period, months:	**Non-DAT 6 DAT 11**	**Non-DAT 13, DAT 11**	**Both about 11**

Electricity, heating and labour account for the largest proportions of variable total costs per kg of tomatoes

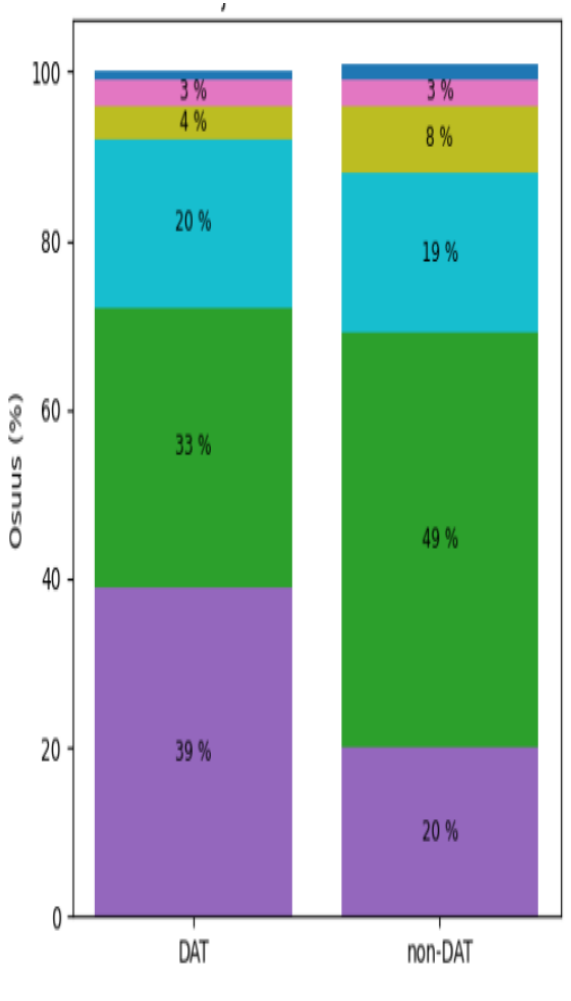
2022-23:

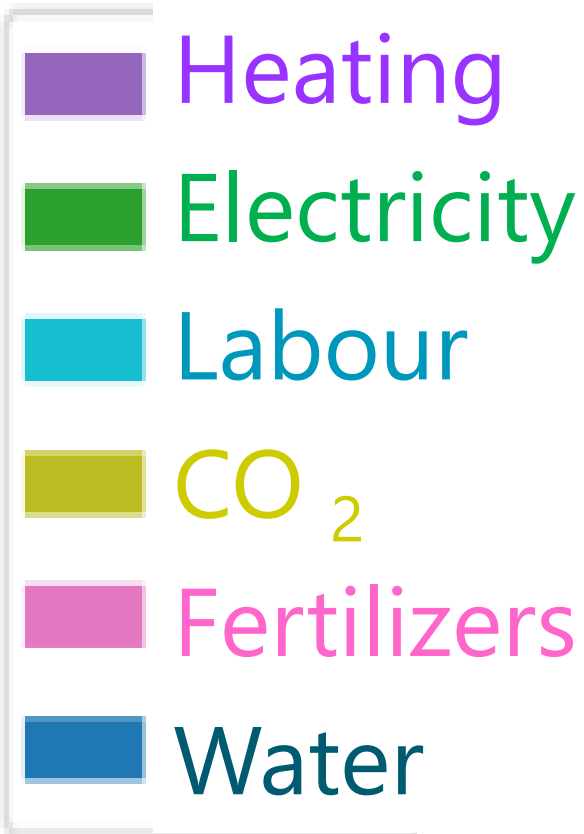


2023-24:



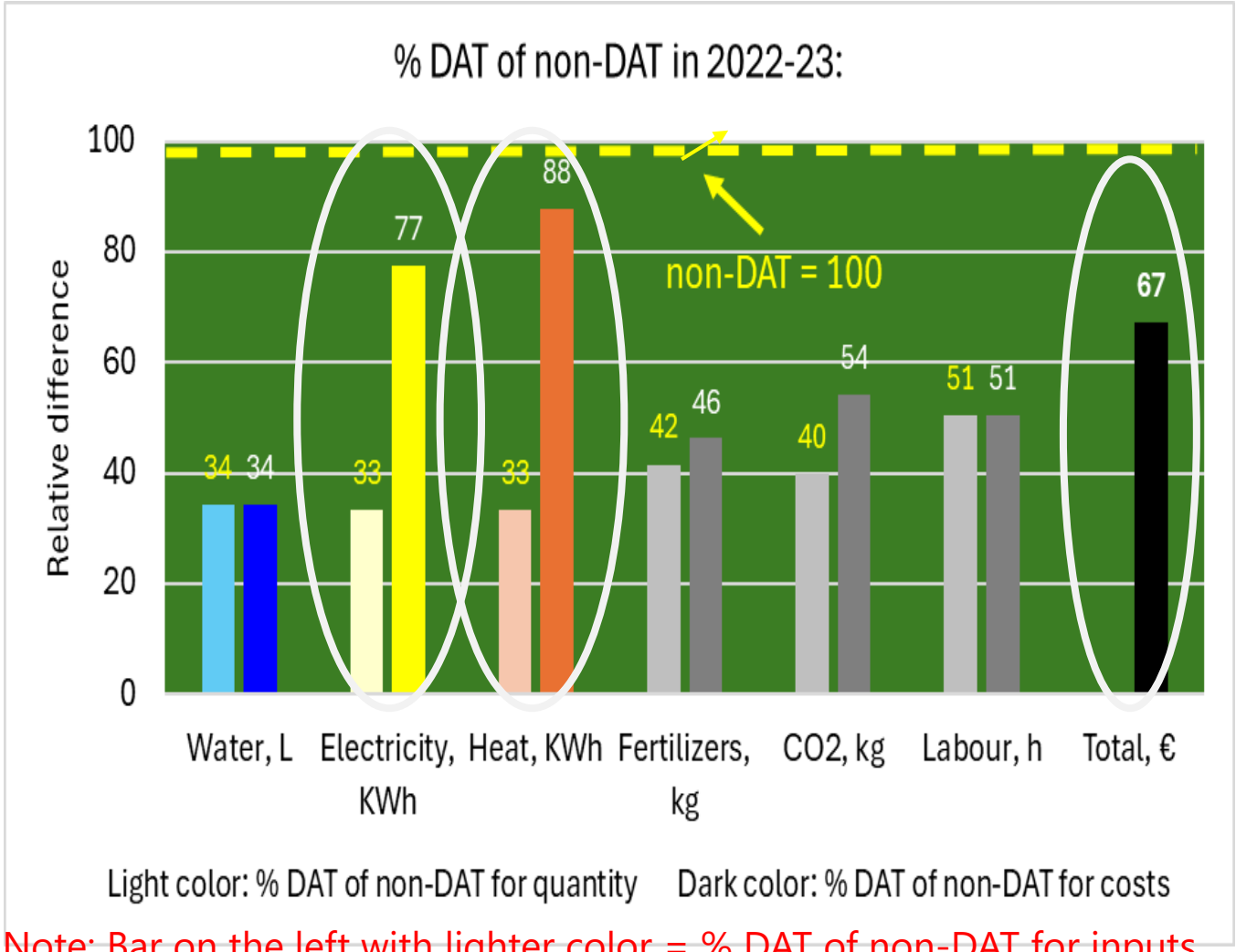
2024-25:





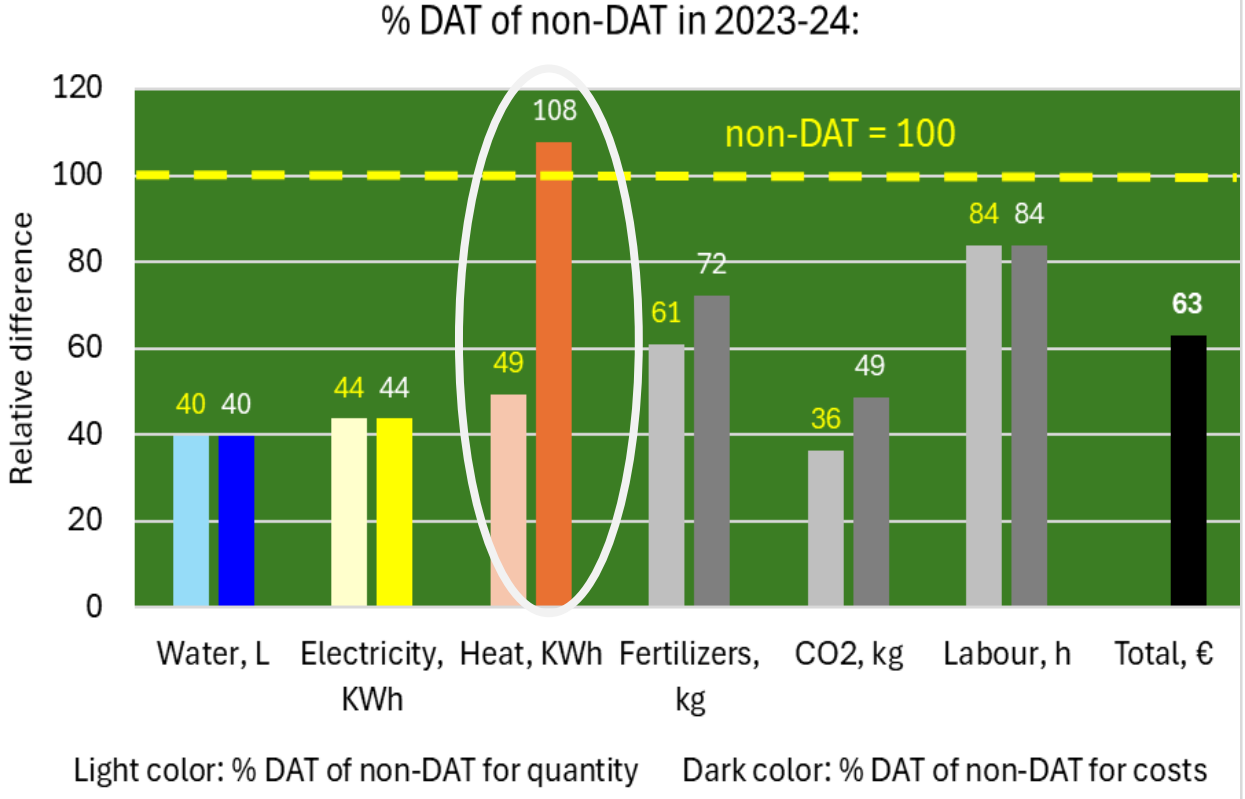
Relative difference in input quantities & costs per kg of tomatoes in 2022-23: high electricity prices & winter break for non-DAT, uncertainties in data

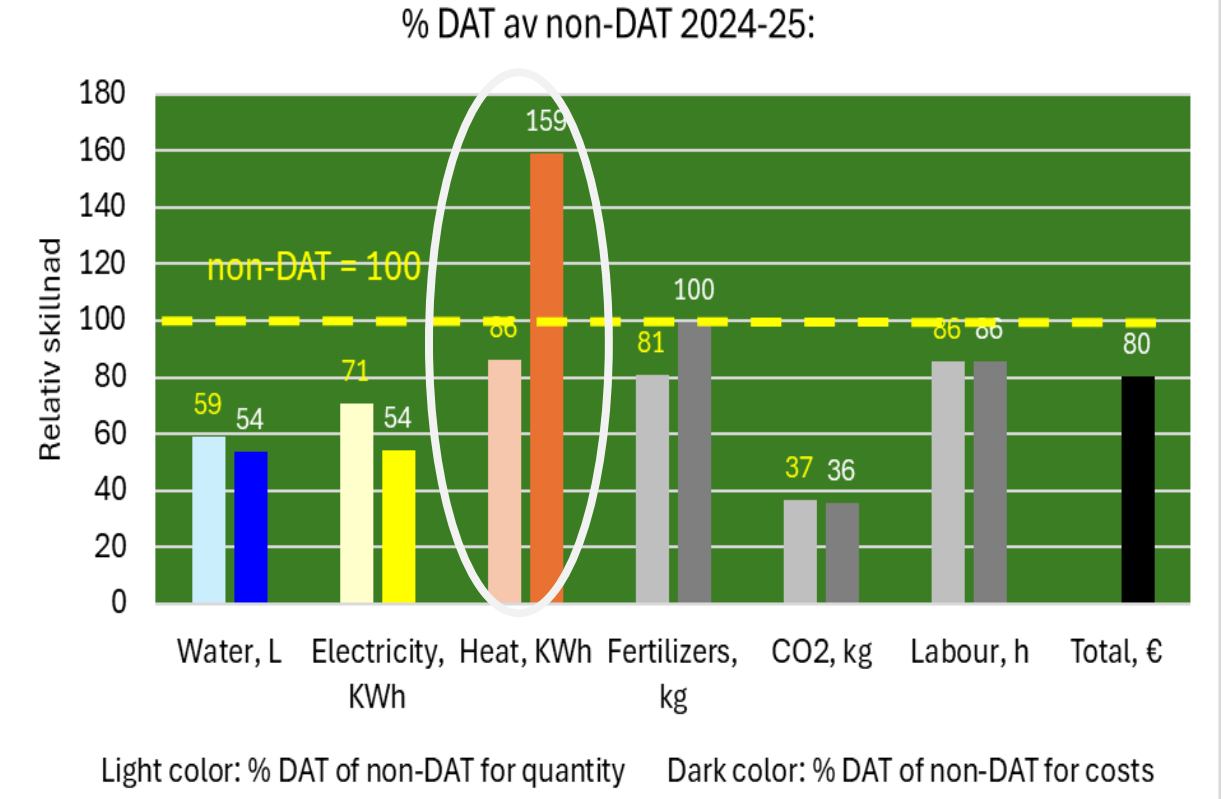
- DAT growers used fewer inputs and had lower costs per kg of tomatoes
- Over 11 months, DAT cultivation used only 34% electricity/kg of tomatoes compared to non-DAT, which cultivated for 6 months → non-DAT's harvest amounted to only 22% of DAT's harvest.
- Difficult to determine electricity costs for non-DAT: his electricity contract was based on purchased electricity, so he could sell back the unused portion → the calculated difference between electricity costs/kg of tomatoes is probably too large for non-DAT's advantage.
- For heating per kg of tomatoes, DAT growers paid almost as much as non-DAT growers, regardless of the larger harvest per ha



Note: Bar on the left with lighter color = % DAT of non-DAT for inputs
Bar on the right with darker color = % DAT of non-DAT for costs

Relative difference in input quantities & costs per kg of tomatoes in 2023-24: heating

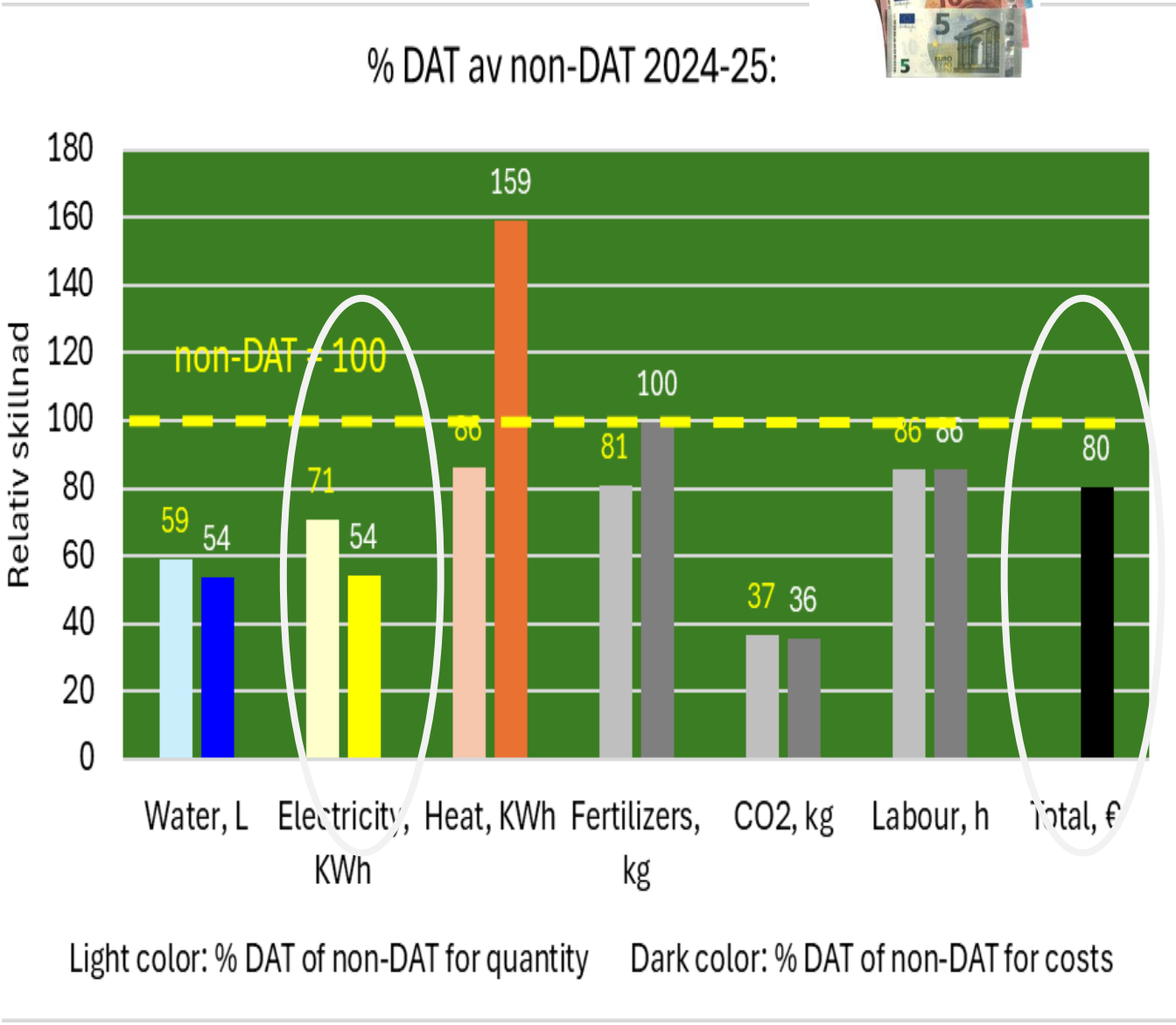




- In terms of costs, DAT growers spent more money on heating in 2023-24 and 2024-25, even though they still used less kWh for heating than non-DAT growers.
- The choice of energy sources for heating greenhouses affected heating costs per kg of tomatoes.

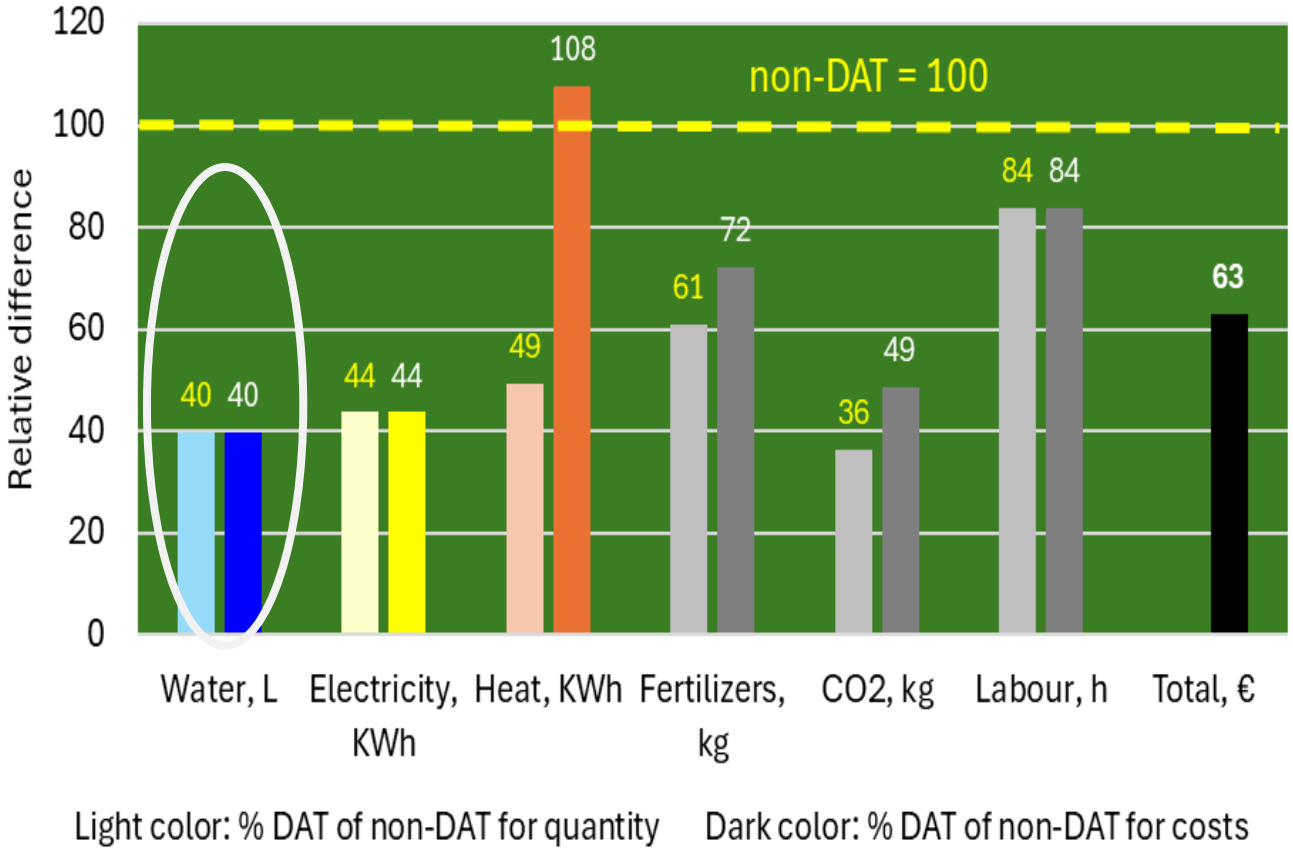
Electricity KWh

- Over the three years, **DAT growers used 22–55% less euros for electricity per kg of tomatoes.** In the last year, they not only used less electricity, but also had cheaper electricity.
- The cost difference for electricity was generally large, even in the last year, when electricity consumption at the two farms converged. The DAT growers have succeeded in finding favourable times for their electricity use.
- The DAT growers' higher level of automation facilitates better control of electricity consumption according to electricity prices – an advantage of digitalisation.
- **Total costs converged between DAT and non-DAT in 2024–25.**



H_2O L/kg

- Water is cheap compared to electricity and heating. In terms of cost only, reducing water consumption is not particularly attractive to growers.
- However, water use is important from an ecological and social perspective: it affects the water footprint and possible nutrient leakage from excess water if water recirculation is not used.
- The water footprint and minimizing nutrient leakage are now also important for the image of production and thus for competitiveness.



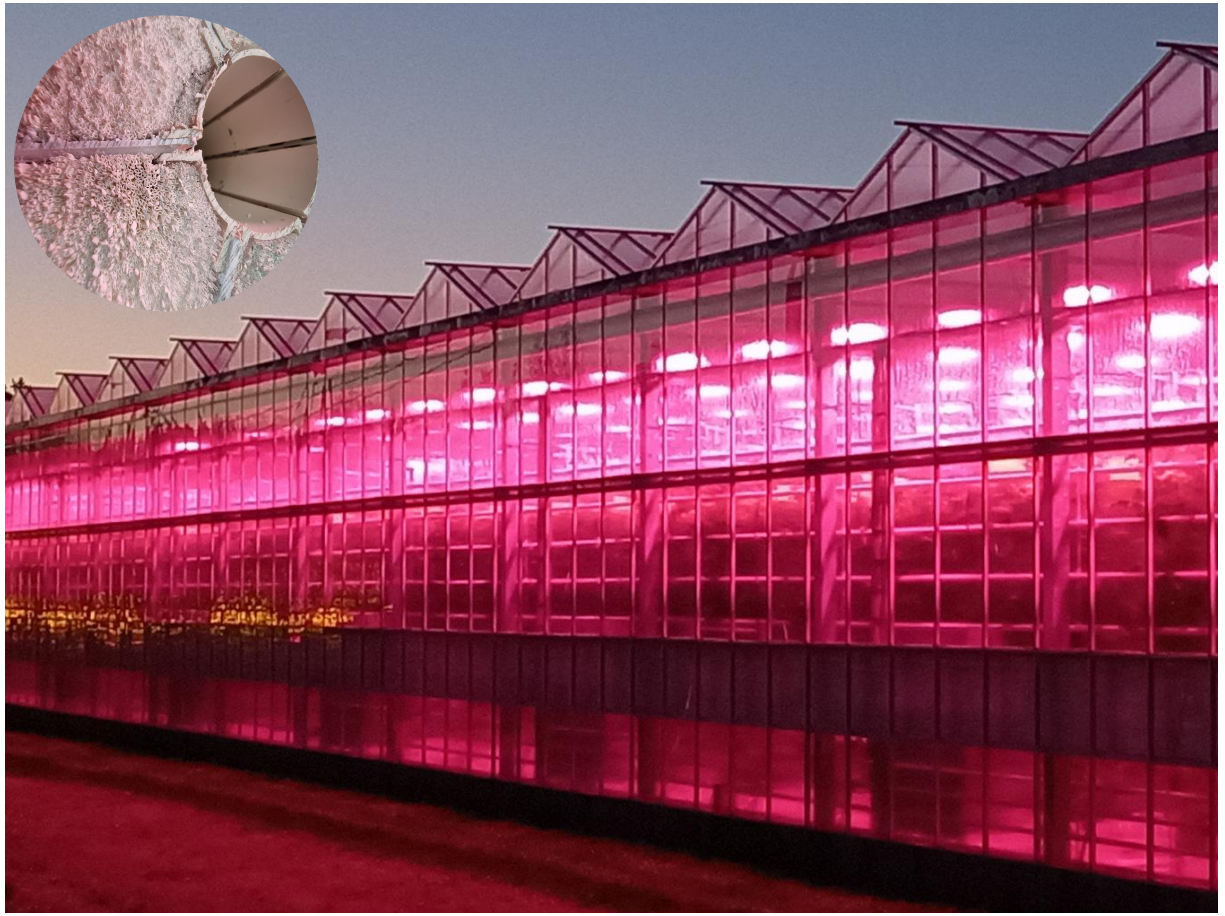
Luke

Results for selected sustainability indicators for 2023-24 (by Politecnico di Milano) support presented conclusions:

Ekonomic effects in €:	Performance of DAT - farm
Water use	-
Electricity consumption	-
Heating energy	+
Fertilizers	-
Yield	+
Netto benefits	+
Some ecological and social sustainability effects:	
N, P, K use	-
N efficiency	+
P efficiency	+
K efficiency	+
Electricity consumption	-
Energy for heating	-
Water consumption	-
Producitivity of irrigation	+
Revenue for yield	+
Social sustainability (continuation of cropping even when key resources such as electricity become more expensive)	+

Summary on the effects of DATs:

- **Dynamic LED lighting reduced electricity consumption at both farms**
- **LED lighting resulted in a 30% reduction in water consumption even without water recirculation → very likely less nutrient leakage.**
- **Water recirculation resulted in less fertiliser use per kg of tomatoes**
- **Lower water consumption and recirculation resulted in better utilisation efficiency of NPK at the DAT farm**



Thank you !

Growers who shared their data for this research
Researchers at the Politecnico di Milano who analysed sustainability aspects
Liisa Pesonen (Luke) for comments
Participants of the seminar

luke.fi

Luke SCADS QuantiFarm