Plantenna: met sensoren naar een Internet of Plants

Peter Steeneken *et al.*, TU Delft

AVAG GREENHOUSE TECHNOLOGY CENTER

GreenTech HORTICULTURE'S FOREFRONT

HORTIVATION TECHNICAL GREEN INNOVATION HOLLAND

TNO innovation for life

Plantenna: met sensoren naar een Internet of Plants

Peter Steeneken Faculty 3mE, TU Delft

with Elias Kaiser, Jeremy Harbinson, Leo Marcelis, Tim van Emmerik, Martine van der Ploeg, Remko Uijlenhoet, Vittorio Saggiomo, Aldrik Velders, Sander Bronckers, Bart Smolders, Heinrich Wörtche, Vojdan Vidojkovic, Peter Baltus, Harijot Bindra, Bram Nauta, Tom van den Berg, Jurriaan Schmitz, Cynthia Maan, Marie-Claire ten Veldhuis, Antoon van Hooft, Bas van de Wiel, Qinwen Fan, Kofi Makinwa, Satadal Dutta and Gerard Verbiest

https://www.4tu.nl/plantenna/en/

HORTIVATION
TECHNICAL GREEN INNOVATION HOLLAND

Plantenna

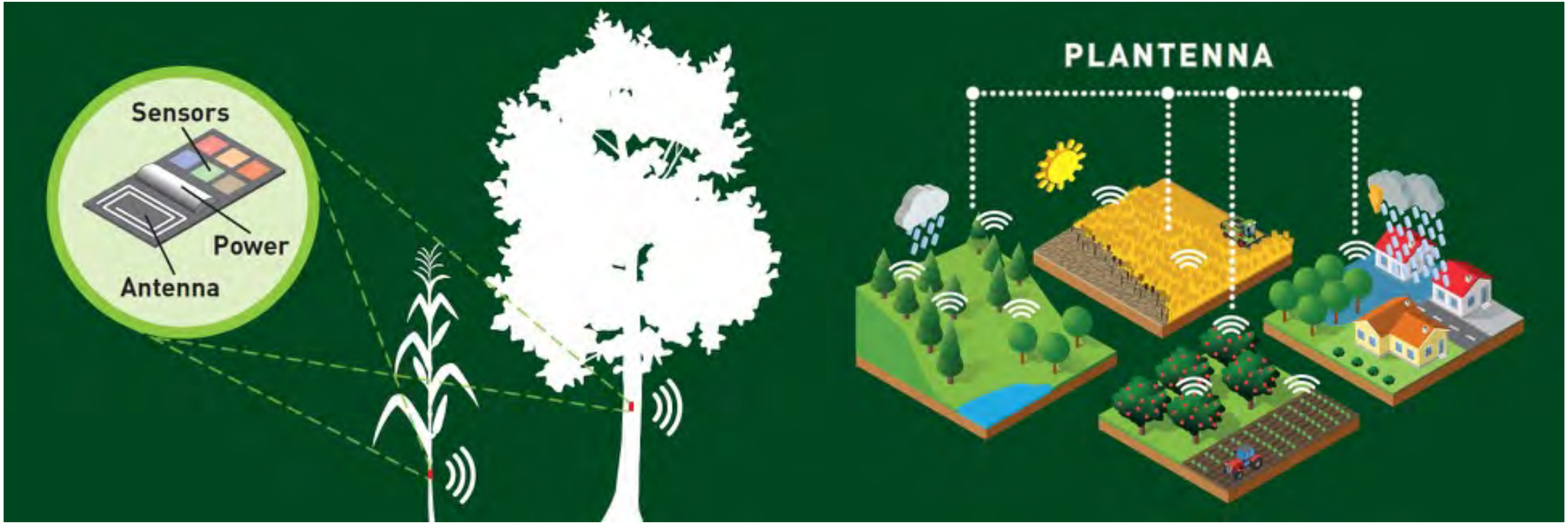
Movie Plantenna project

https://youtu.be/GBTeQOneymc

Plantenna: (2019-2023)

Botanic Sensor Networks, Towards an Internet of Plants

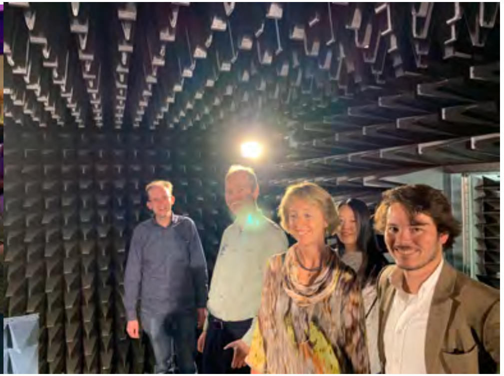
Plantenna



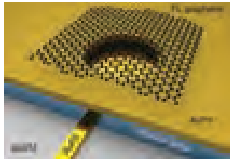
Plantenna team

- 4 TU: Twente, Eindhoven, Wageningen and Delft
- 10 groups: sensors, electronics, plant science, wireless, climate/hydrology
- >25 researchers, of which 8 new assistant professors

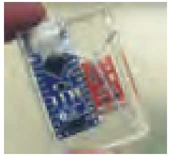




Plantenna activities

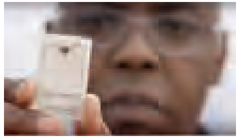


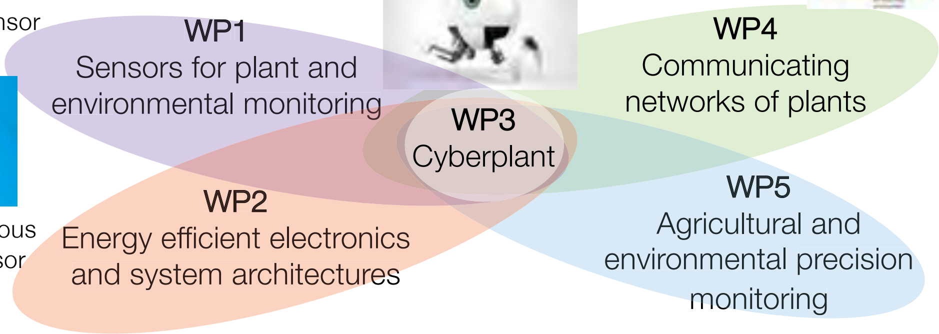
Pressure sensor TUD

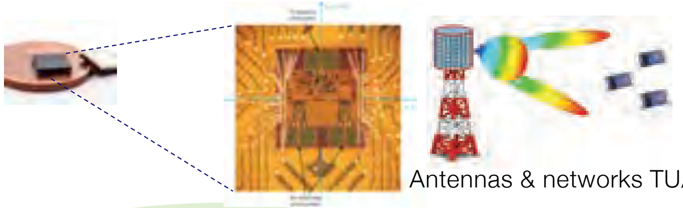


Crop quality sensor WUR

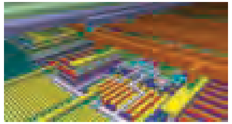
Weather station TUD



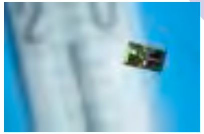




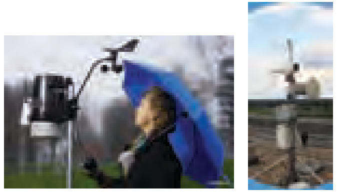
Antennas & networks TU/e



3D nm-scale chip-design UT



Wireless autonomous temperature sensor TU/e



Agricultural and environmental monitoring TUD & WUR

https://www.4tu.nl/plantenna/en/about_us/

TU/e Technische Universiteit Eindhoven University of Technology

WAGENINGEN UNIVERSITY & RESEARCH

TU Delft

UNIVERSITY OF TWENTE.

Main project goals

1. Smaller and cheaper sensors (<5 euro per sensor)
2. Wireless readout and autonomous power
3. New sensor concepts
4. Implementation of sensors

Current sensor systems: Often large and expensive

Tule

Sensing

+ digital processing

+ wireless transmission

1500$/sensor/year

Application:

Soil moisture, temperature, humidity

Feature:

- Solar energy + cellular connection

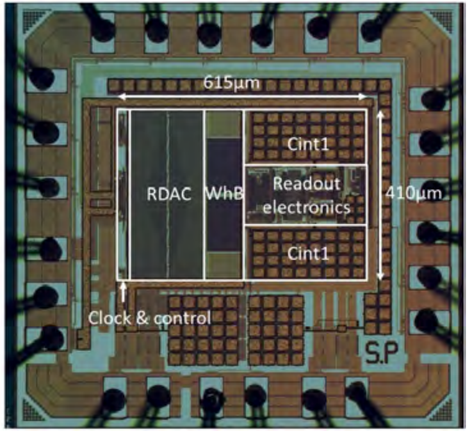
Low cost sensors

Temperature Sensor TU Delft

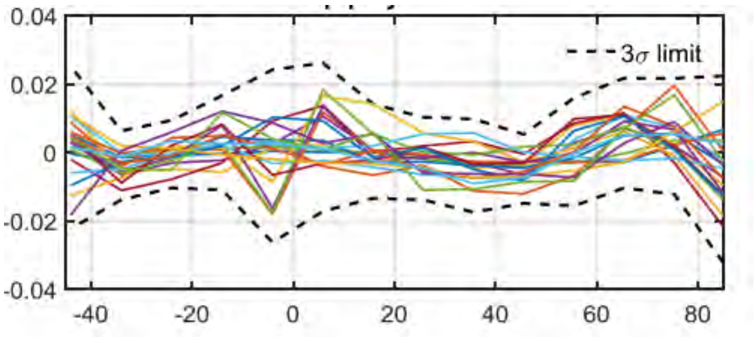
Most energy efficient, high resolution high accuracy temp. sensor

Feature:

- Peak power consumption 160 µW
- Typ. Accuracy < 0.02 °C (-40°C-85°C)
- Resolution 0.4 mK
- Area 0.25mm^2



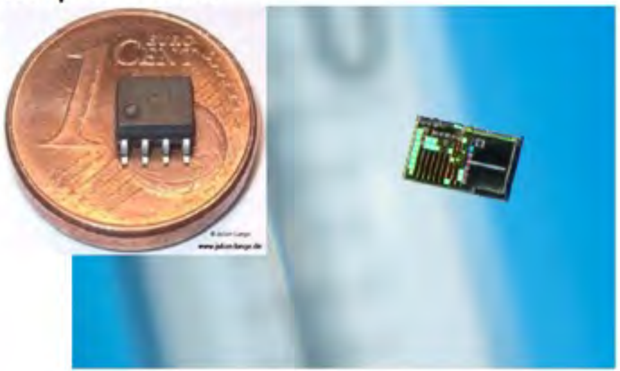
0.25 mm^2



by Qinwen Fan, Kofi Makinwa

Ultra small temperature sensor (< 2 mm^2)

Micro-temperature sensor



The world's tiniest temperature sensor is powered by radio waves

by Eindhoven University of Technology

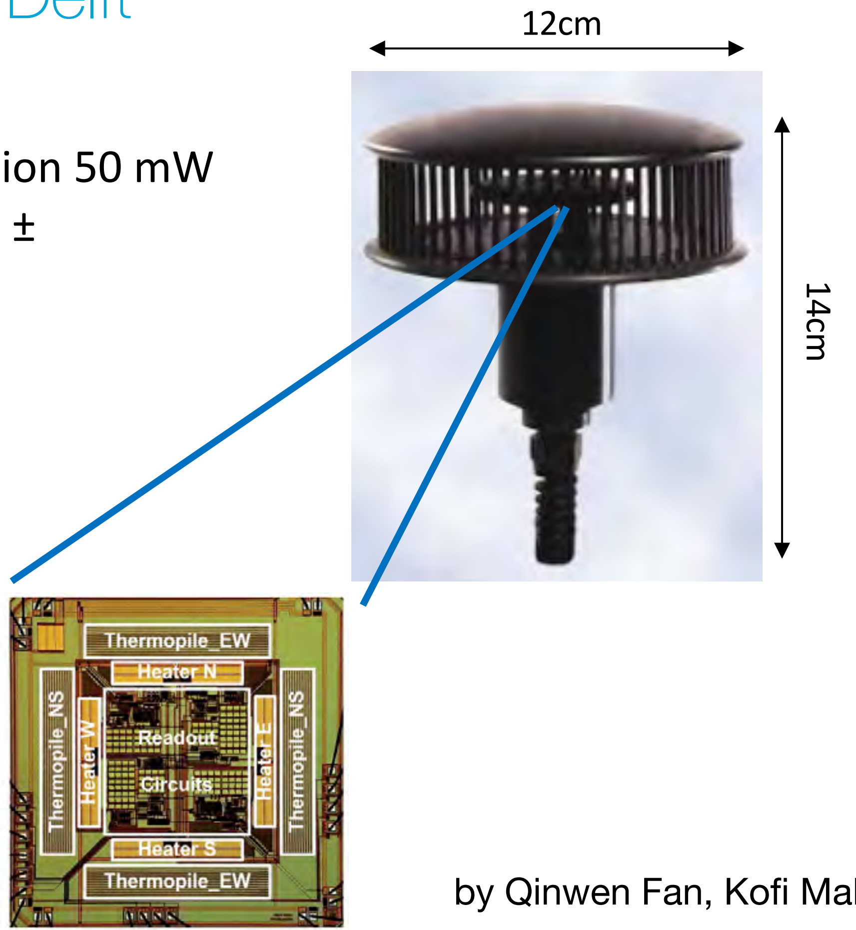
The tiny sensor on the finger of PhD-student Hao Gao. Credit: Bart van Overbeeke

by Peter Baltus TU/e

Wind Sensor TU Delft

Feature:

- Peak power consumption 50 mW
- Accuracy: ± 4% speed; ± 2°direction error



by Qinwen Fan, Kofi Makinwa

Rain Sensor TU Delft

Feature:

- Peak power consumption 50 mW
- Resolution: 0.1 mm*
- Measurement range: 0.1 mm ~ 6.4 mm

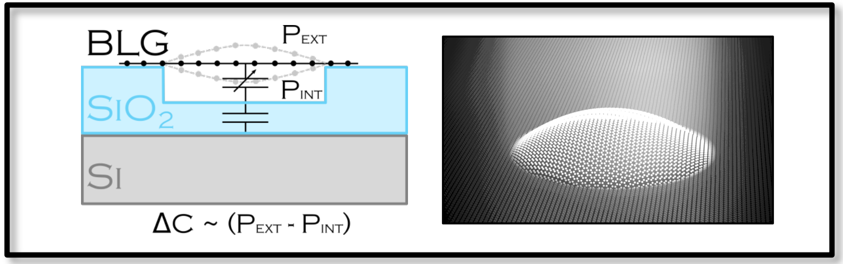
* Diameter of the rain drop in mm

TUDelft

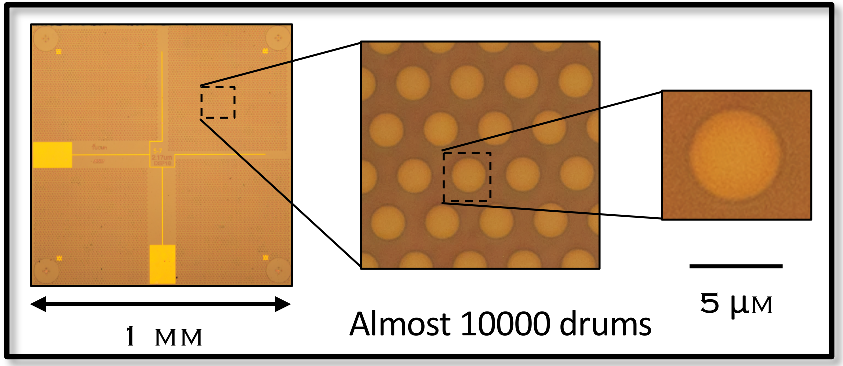
by Qinwen Fan, Kofi Makinwa

Graphene air pressure sensor

Working principle



Devices



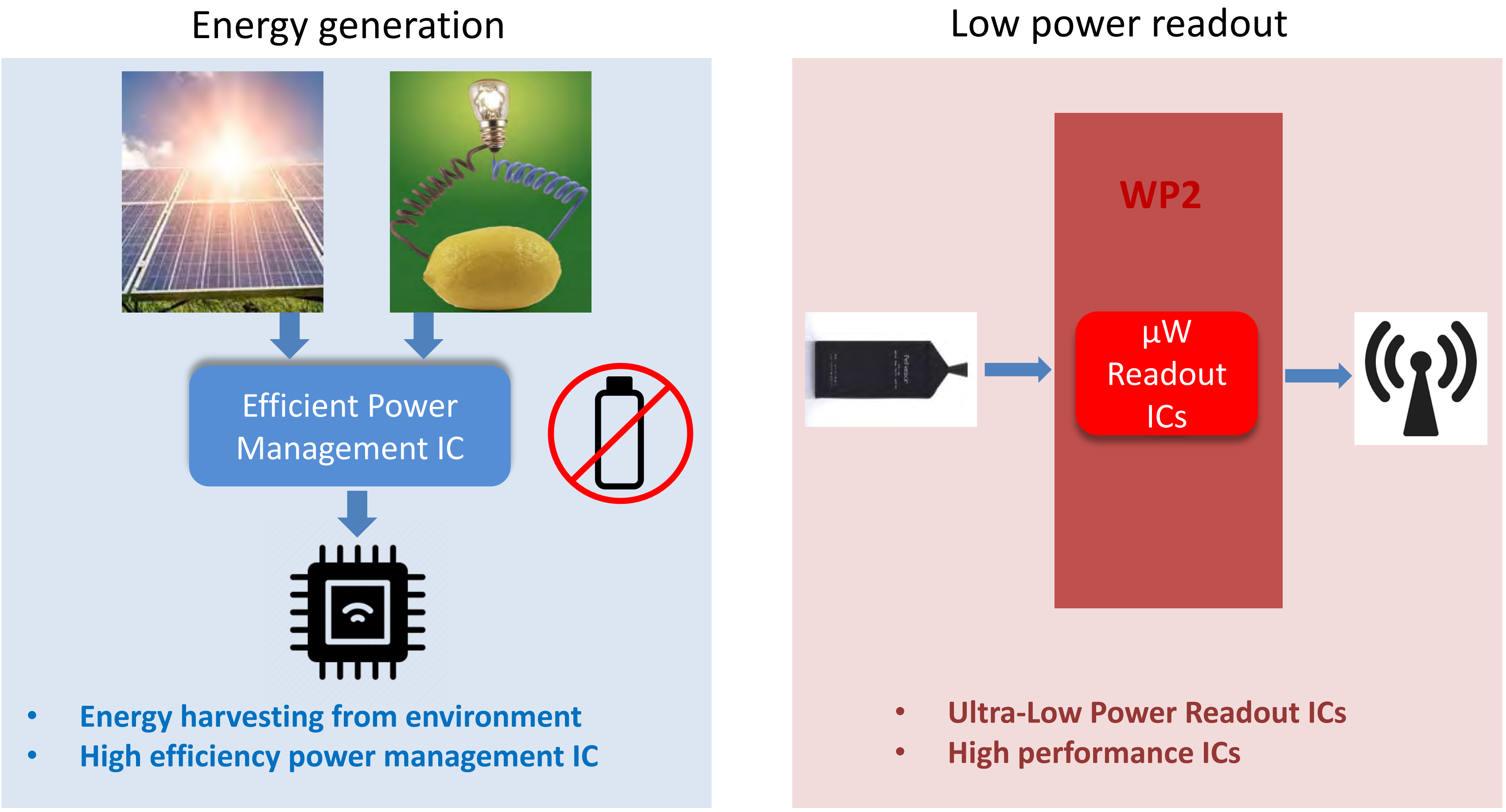
More sensitive and smaller than existing sensors

Membrane only 2 atoms thick

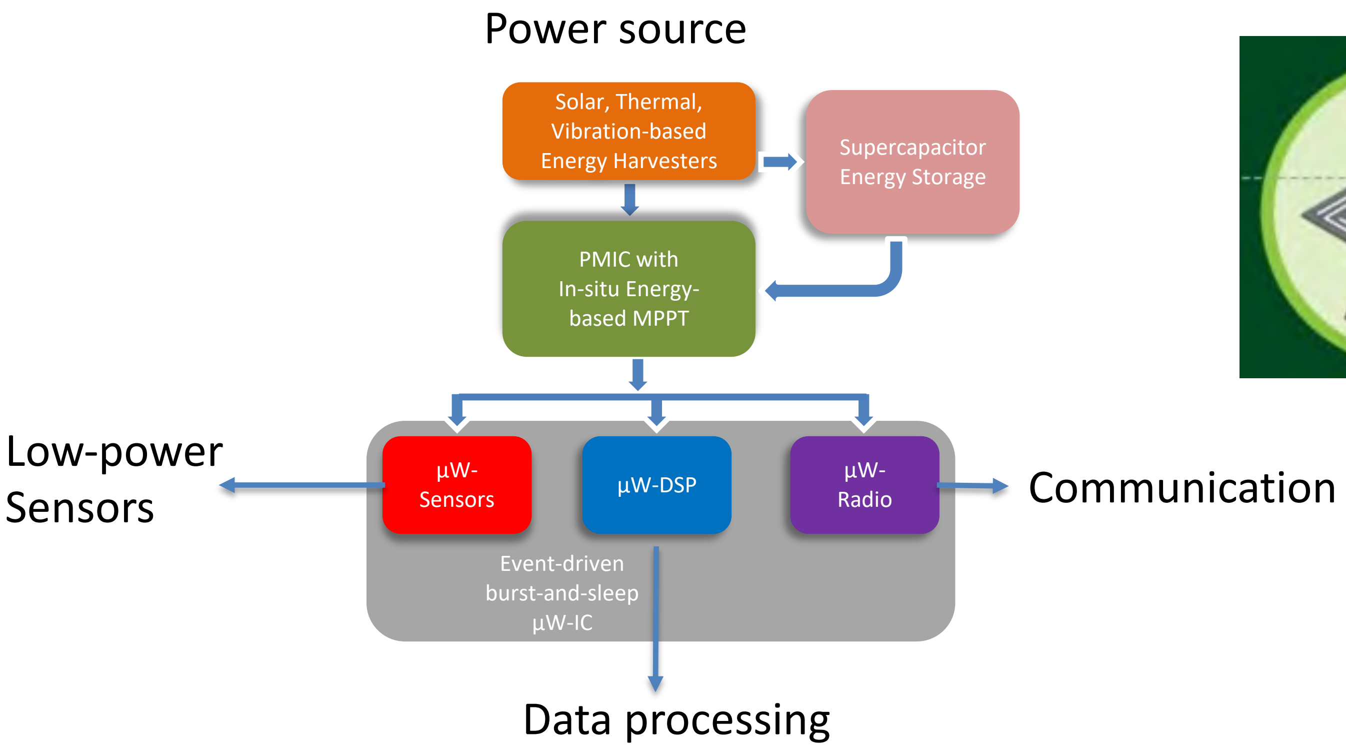
GRAPHENE FLAGSHIP

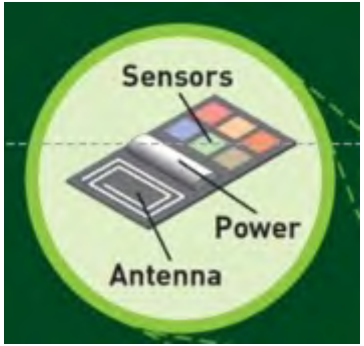
ANL Applied Nanolayers

Low power and autonomous sensors


Energy generation
Efficient Power Management IC
Energy harvesting from environment
High efficiency power management IC
Low power readout
WP2
µW Readout ICs
Ultra-Low Power Readout ICs
High performance ICs

Autonomous Wireless Sensor Node





TUDelft

15 euro: ST NFC Sensor Smartag sensor module 4x4 cm^2

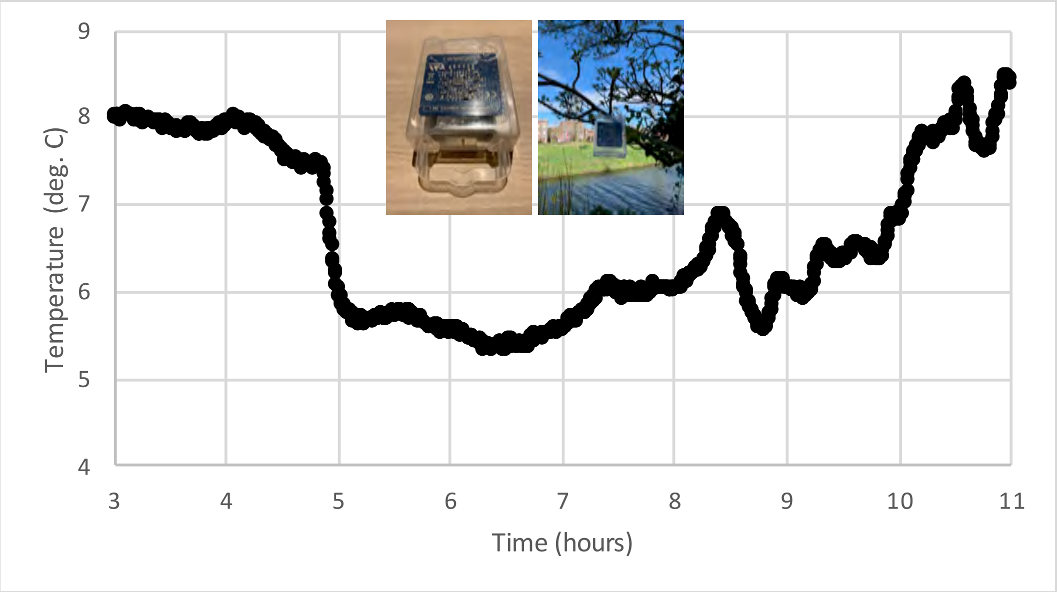
Product summary table

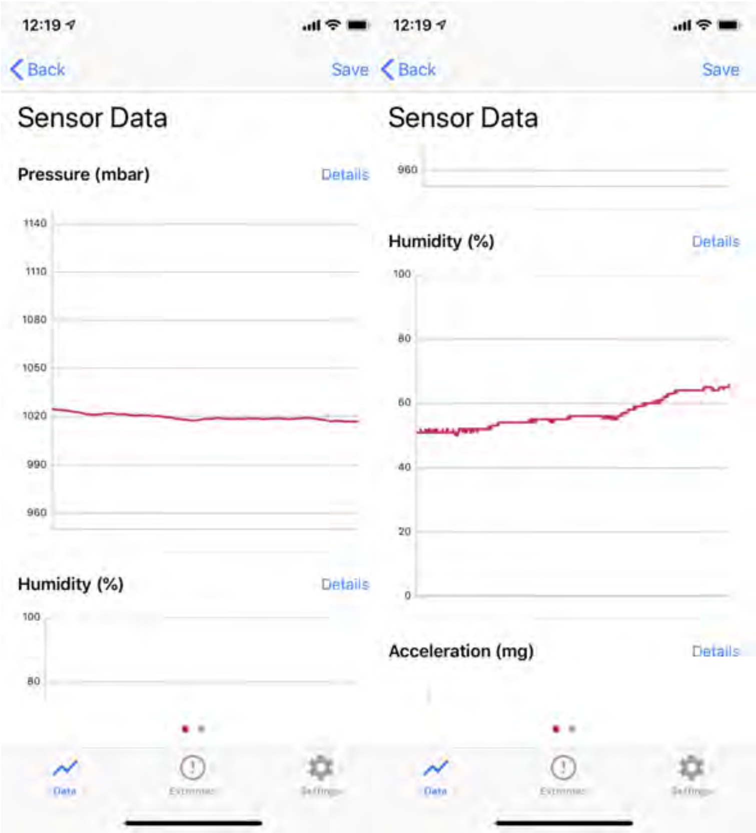
Features

- Temperature
- Humidity
- Pressure
- Acceleration
- NFC readout
- Integrated memory
- Integrated microprocessor
- Power by battery or NFC field

Measurement: temperature, pressure, humidity, acceleration

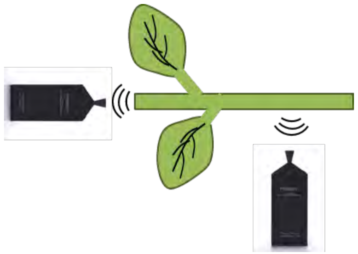
Sensor tag stores datapoint every 30 seconds in memory.
Dataset is read out using NFC on phone in the morning.
Temperature resolution 0.02 K

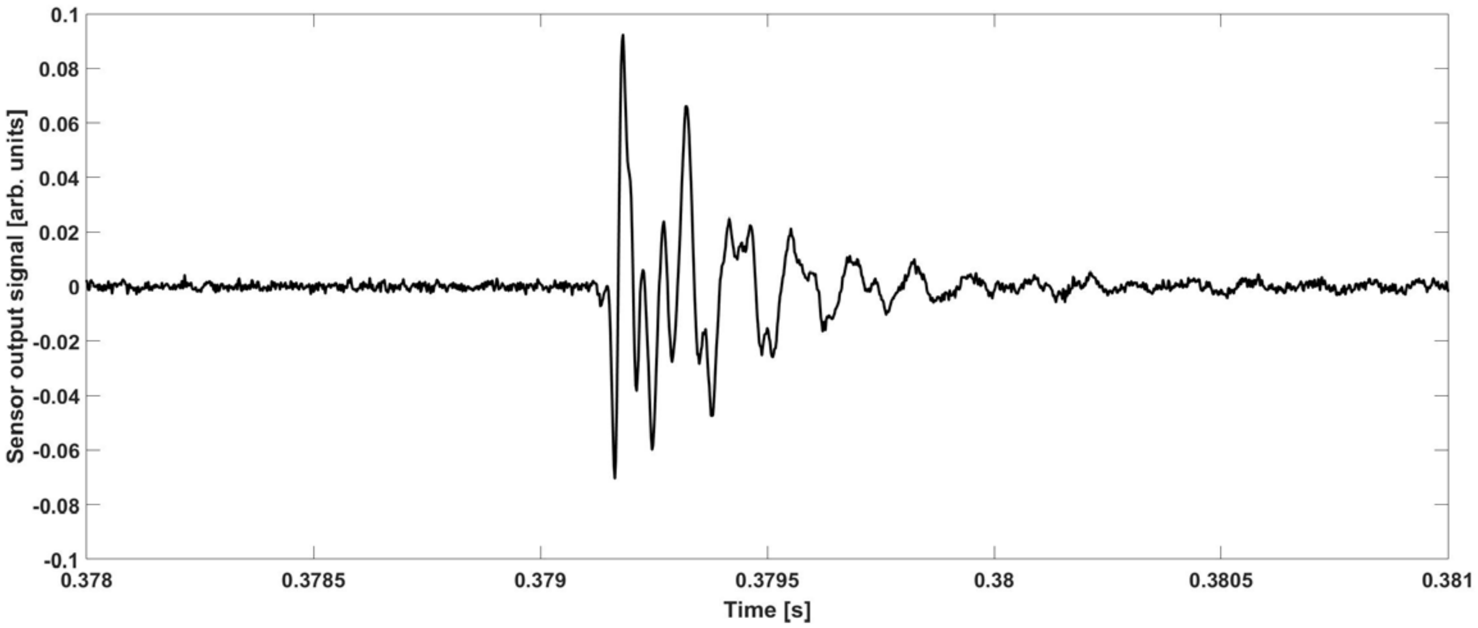




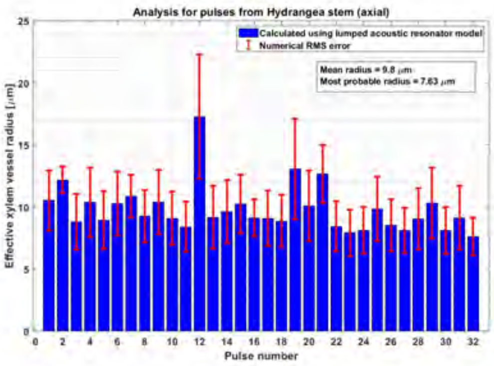
New sensors

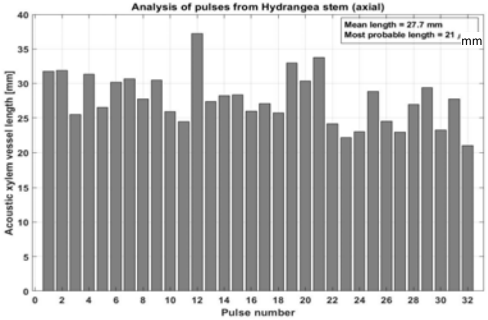
Ultrasound of a plant under drought stress



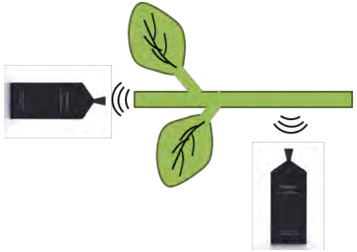


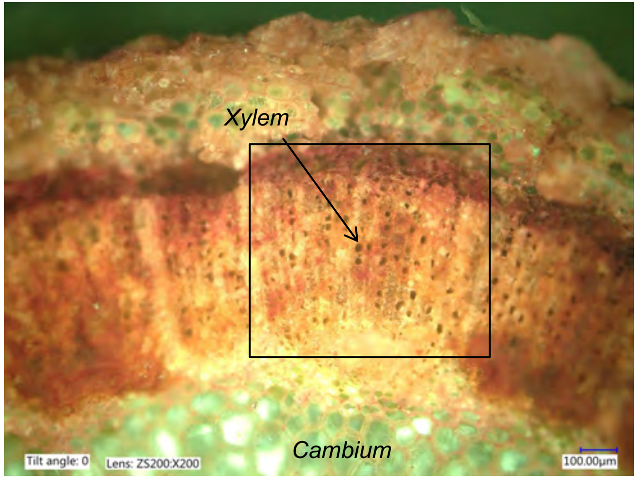
Measuring xylem vessels using ultrasound





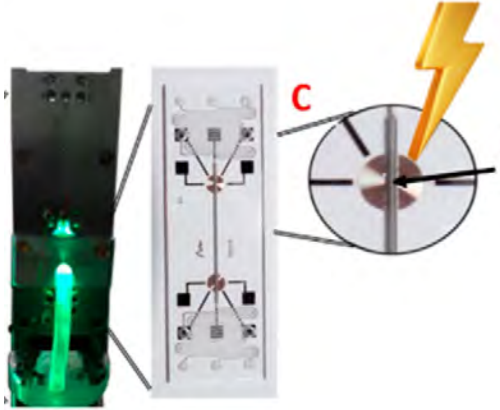
Ultrasound radius
7-13 μm





Xylem radius 8-15 μm

Nanoliter realtime NMR spectroscopy



Detection volume

25 nanoliter

Detecting less than picomole

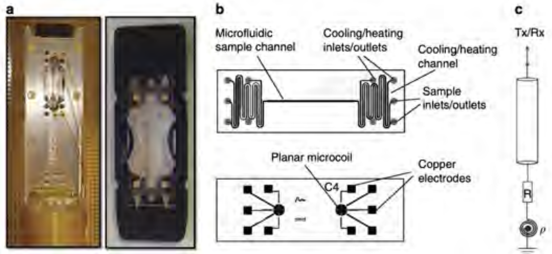
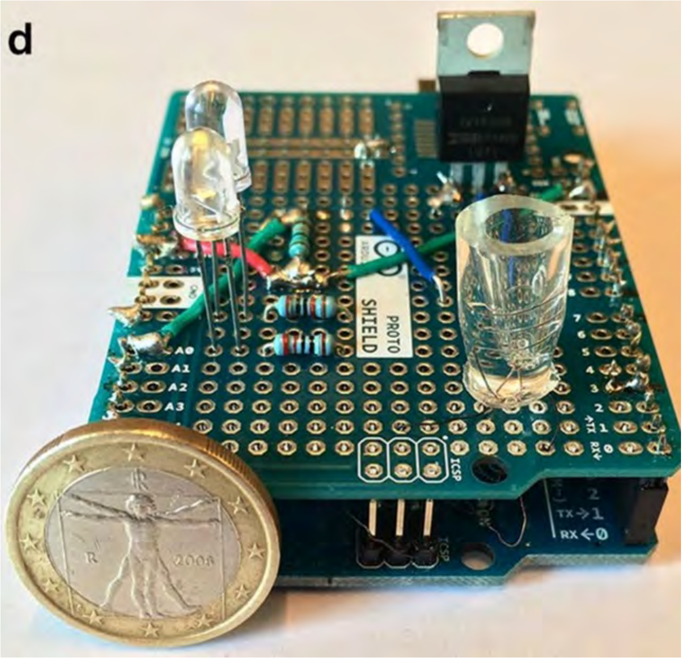


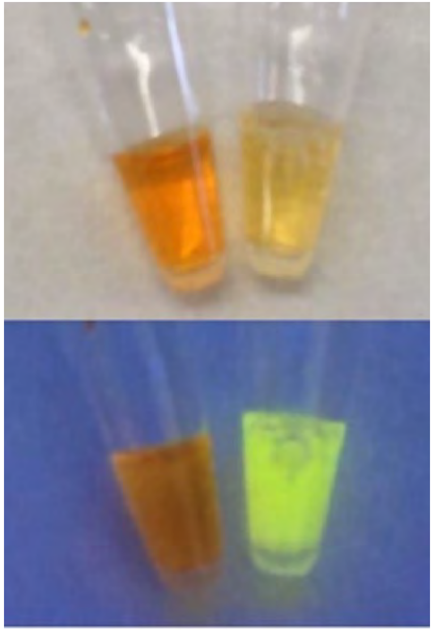
Figure 1 | Multipurpose NMR chip with two detection areas. (**a**) photograph of the NMR probe set-up (left) and microfluidic 1.5 × 4.5 cm NMR chip (BBC) inside slider (right). (**b**) Schematics of the chip with top-side-view (centre), front-view with fluidic channels (top) and back-view with copper electrodes and coil (bottom). (**c**) RF circuit of the BBC: a microcoil having a DC resistance ρ in series with an optional variable resistor (R). See Supplementary Information for further details of the chip and coil properties. Tx, transmitter. Rx, receiver.

Velders et al., Nature Comms. 2014, 2018 and Analytical Chem. 2018

Low cost DNA detection

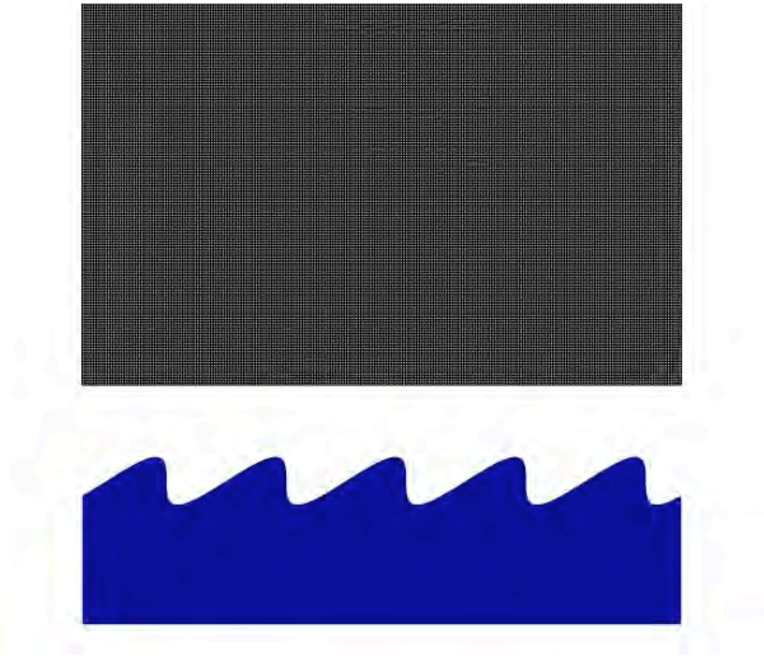


Color change indicates DNA match



Velders et al., BMC Research Notes 11, 93 (2018)

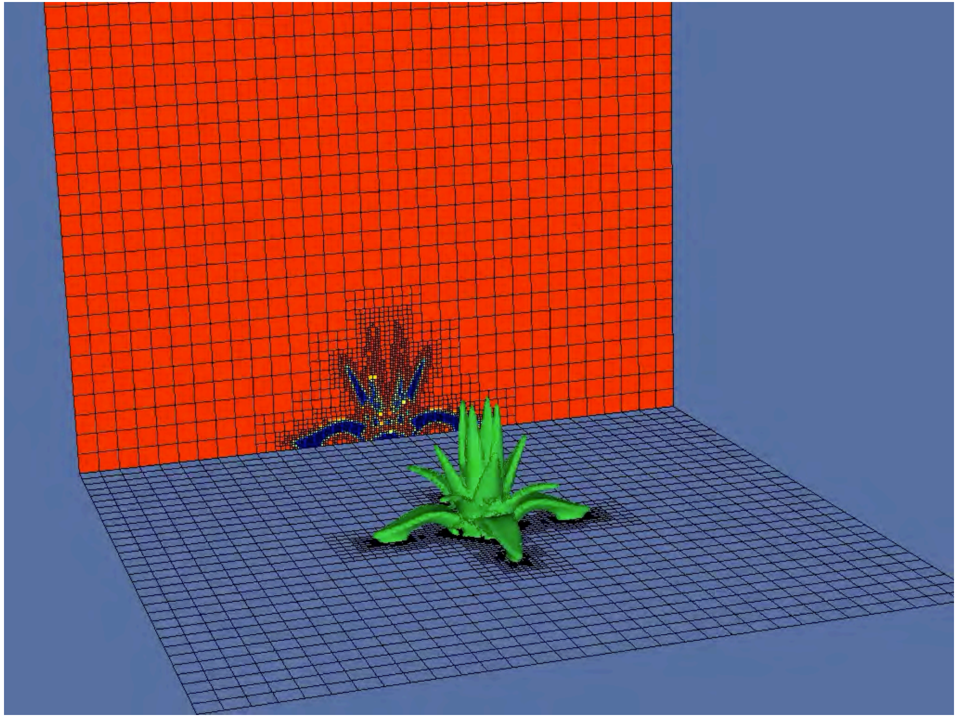
Modeling of temperature in a greenhouse

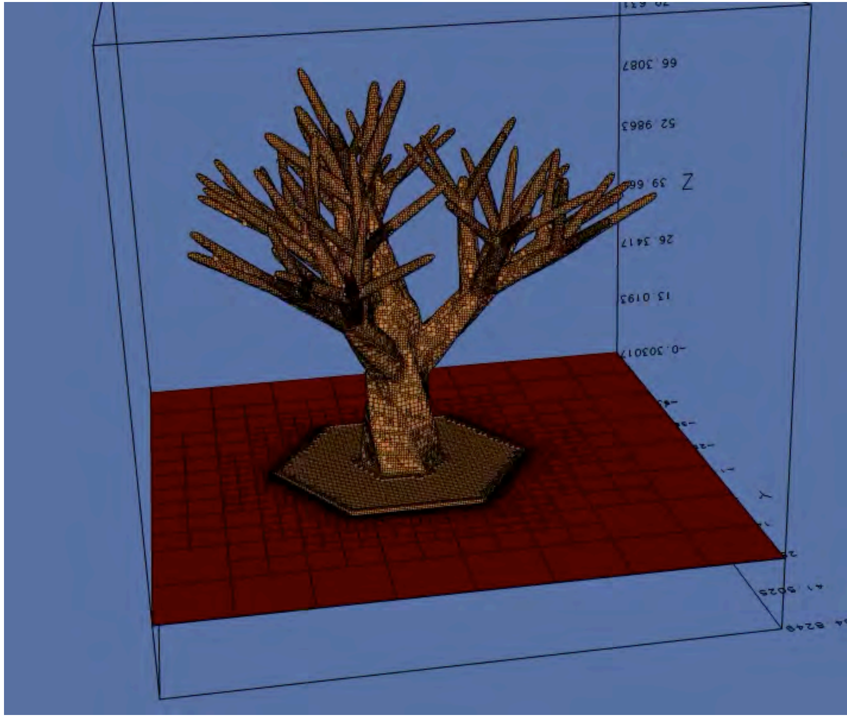


Temperature range 25℃

by Antoon van Hooft, Bas van de Wiel

Modeling of temperature around a plant





'Bubbles' are turbulent volumes, colors indicate flow velocity

by Antoon van Hooft, Bas van de Wiel

3-D distributed sensor networks
Example: fruit frost damage mitigation

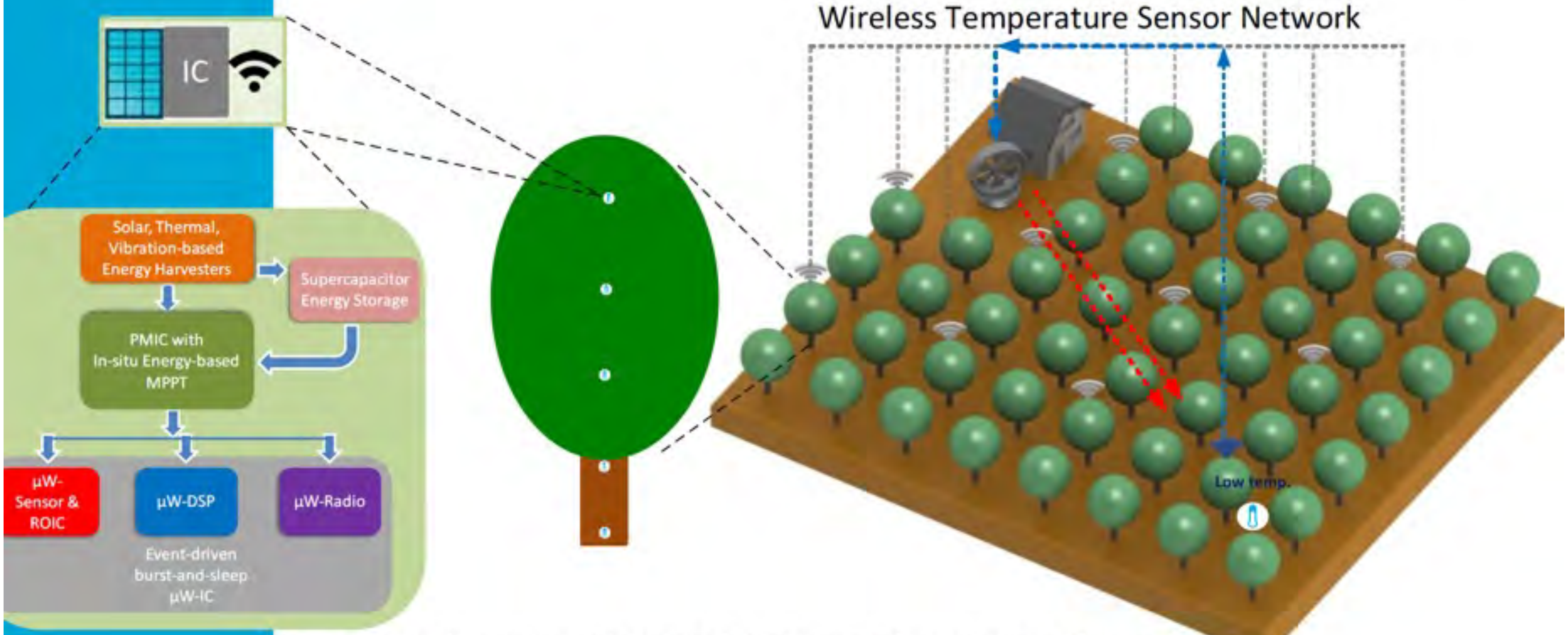
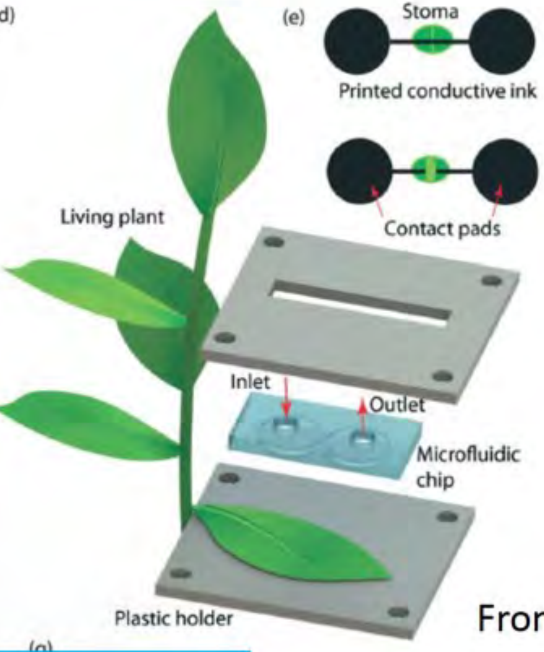


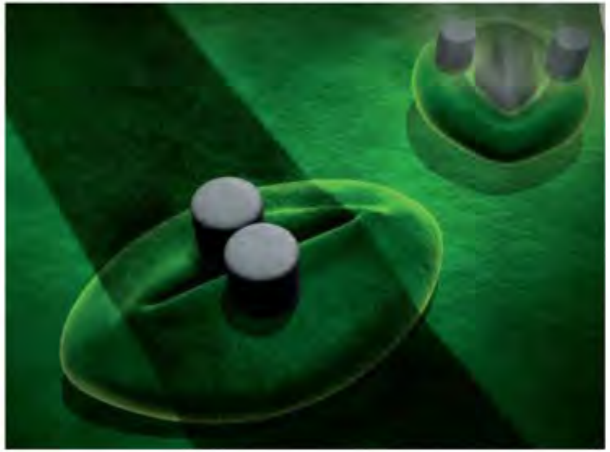
Figure 1: Autonomous Wireless 3D Temperature Sensor Network

by Marie-Claire ten Veldhuis, Qinwen Fan, Bas van de Wiel

Lab-on-a-Chip:

Measuring stomata opening and closing on the leaf





From: Koman et al. (2017)

by Tom van den Berg, Jurriaan Schmitz, UTwente

Unifarm WUR for testing

Conclusions

- Goals: Increase yield and quality of agricultural products
- Solutions needed for low-cost monitoring of crops during growth
  - Greenhouses and fields
- Plantenna aims for:
  - Low cost sensor modules
  - Novel sensing concepts
  - Autonomous operation and wireless communication (Internet of Plants)
  - Implementation methods of sensors modules for improved yield

Delft AgTech Institute

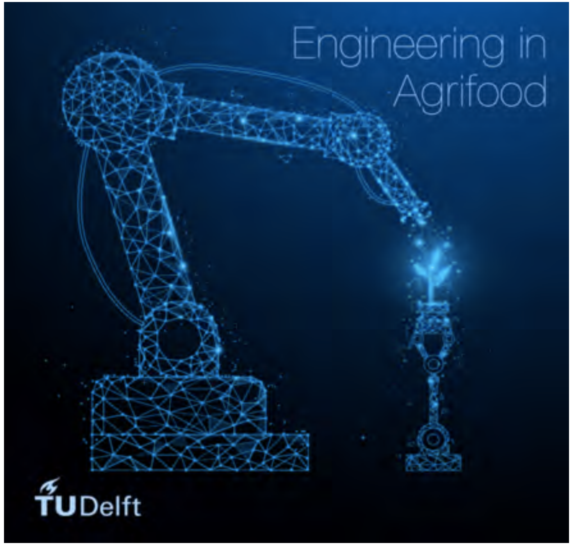
Wetenschappelijk Directeur

Roeland van Ham

(Prof. Plant Computational Biology)

Business Developer

Liselotte de Vries

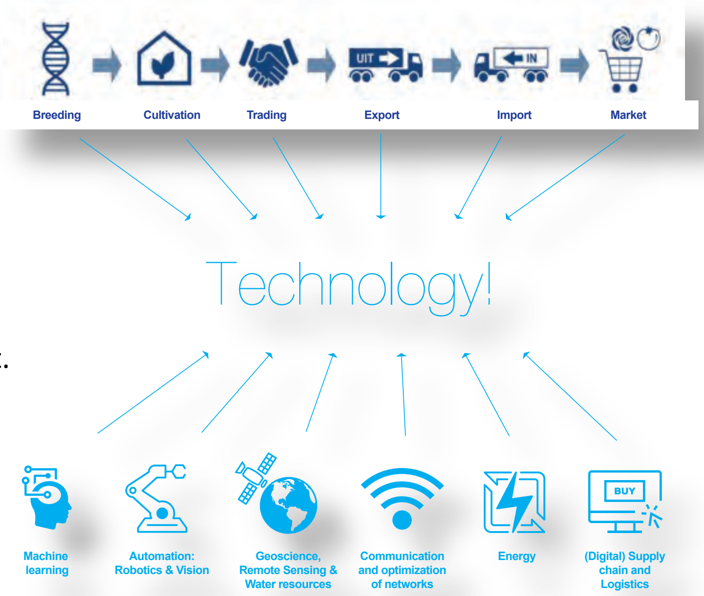


Stakeholder netwerk

- **Private sector**
  - 45 grotere bedrijven
  - 15 (TU Delft) startups

- **Publiek sector**
  - Topsector Horticultuur & Uitgangsmaterialen
  - Topsector Agrifood
  - PZH, Innovation Quarter
  - Gemeente Delft, Westland, Lansingerland & Barendrecht.
  - 4TU Ht2FtW, LDE Greenport Hub
  - LTO

- **TU Delft**
  - 5 faculteiten (EWI, CiTG, AE, 3ME en TBM)
  - 16 afdelingen
  - 56 onderzoekers



TU Delft

Uitnodiging

Eind Q1 2020

Lancering Delft AgTech institute + partner event!

Meld je aan via Liselotte.deVries@tudelft.nl

T +31 6 41 63 45 27

Stellingen

1. Opbrengsten kunnen verhoogd worden met nieuwe types sensoren nodig die parameters kunnen meten die niet door de teler met het oog te zien zijn (stress, ziekte)

Stellingen

1.
2. Opbrengsten kunnen verhoogd worden met meer goedkope sensoren per kas, om sneller en preciezer te kunnen regelen

Stellingen

1.
2.
3. Sensoren zijn alleen nuttig als ze weinig onderhoud vragen en aangesloten zijn op een geautomatiseerd regelsysteem

Implementatie

- Hoe kan deze kennis toepasbaar gemaakt worden?
  - Relevante cases van bedrijven!
  - Sensoren kleiner, goedkoper en autonoom maken: grotere aantallen sensoren.
  - Computer analyse van sensor data
  - Data combineren met fysische modellen
  - Ontwikkeling nieuwe types sensoren nieuwe parameters te meten
  - Productontwikkeling

Implementatie

- Hoe kan je als tuinbouw toeleverancier hierbij aanhaken?
  – In de studiefase kunnen toeleveranciers aanhaken door inbrengen van hun wensen, cases, discussies, mailing list, en eventueel gezamenlijke studieprojecten op te zetten met de partners in het Plantenna project.
  – p.g.steeneken@tudelft.nl