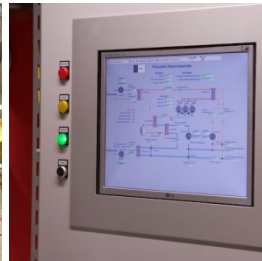


## Fraunhofer UMSICHT

Building integrated food  
production - inFARMING®

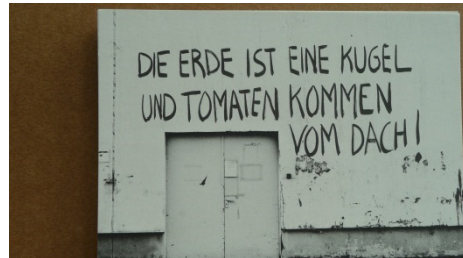
**inFARMING®** | Indoor horticultural  
systems of the future

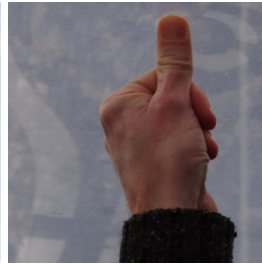


REFAB – Revolution in **Food and  
Biomass Production**  
Cologne, 1-2 October 2018

**Volkmar Keuter**  
Head of Department  
Photonics and Environment

**02/10/2018**

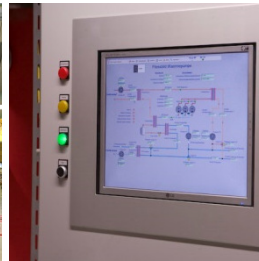
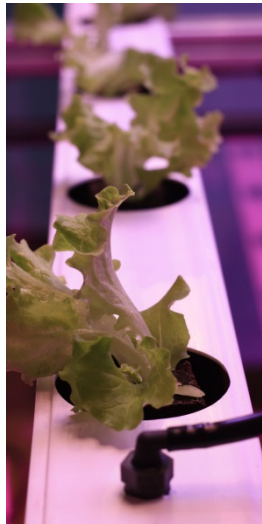




## Fraunhofer UMSICHT

Building integrated food  
production - inFARMING®

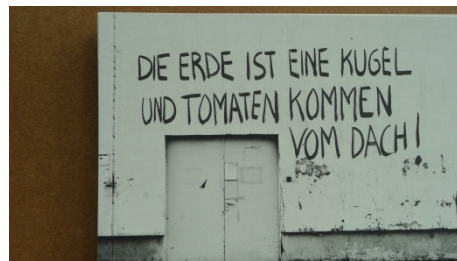
inFARMING® | Indoor horticultural  
systems of the future ~~tomorrow~~



REFAB – Revolution in **Food and  
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Cologne, 1-2 October 2018

**Volkmar Keuter**  
Head of Department  
Photonics and Environment

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# The Fraunhofer-Gesellschaft

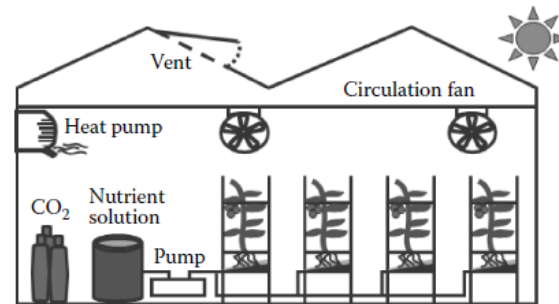
- 69 institutes and independent research facilities
- More than € 2 bn research funds
  - € 2.1 bn contract research
- About 24 500 employees (m/f)
- 40 facilities in Germany
- 13 institutes in North Rhine-Westphalia
- 4 institutes in the Ruhr area



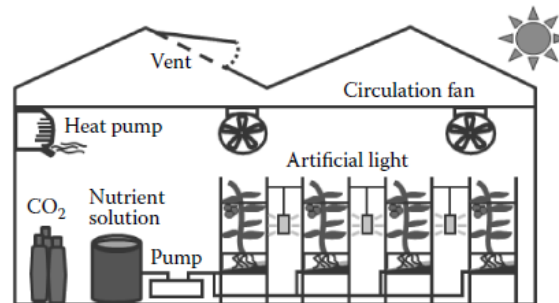




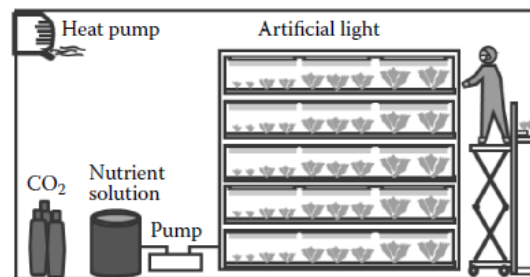
## Types of indoor horticultural systems



1. plant factories with sunlight, the typical Dutch-type greenhouse



2. plant factories with sunlight and supplemental light

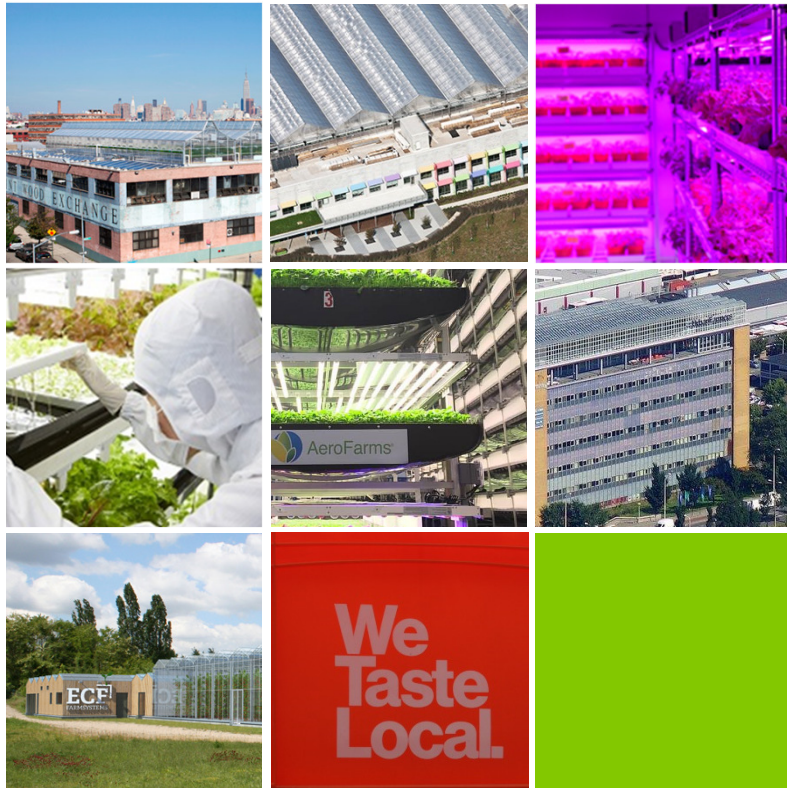


3. plant factories with artificial lighting.

Source: PESSARAKLI, Mohammad (Hg.). *Handbook of photosynthesis*. CRC Press, 2016.



## Approaches in the US, Asia and Europe



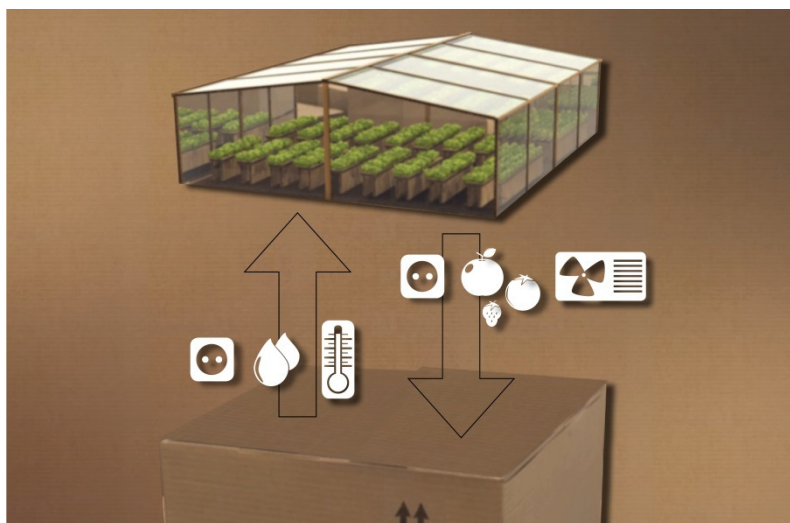
- Rooftop Farming
- Indoor Farming
- Aquaponics
- New business models: Start UPs

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© BrightFarms  
© Toshiba Corporation  
© AeroFarms  
© Urban Farmers  
© ECF



## inFARMING® - Motivation of building integrated food production

Local conditions for the cultivation of fresh horticultural products are basically tied up to the availability of **light, water, heat** and **nutrients**. These requirements can be provided efficiently within the urban space.

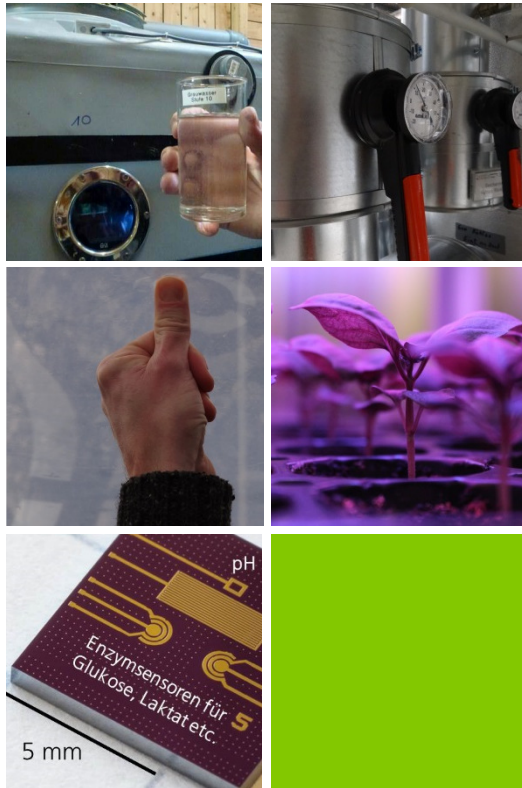


The systems approach **inFARMING®** is

- local,
- sustainable,
- close to the consumer,
- economically feasible
- by an efficient production and
- closed loops to the greatest possible extent.



## Technical approaches for indoor cultivation



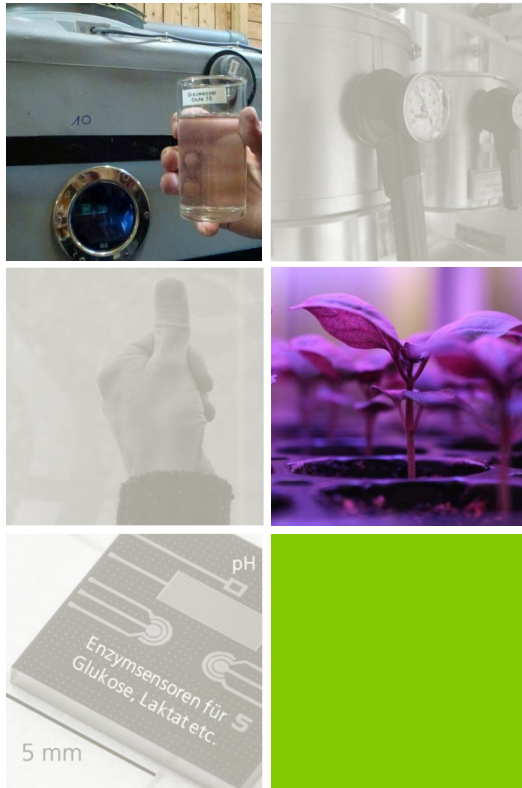
### inFARMING® applies to:

- Fertilizer production from indoor waste streams
- Energy recovery
- Material development
- Artificial light management
- Sensor development and application

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## Technical approaches for indoor cultivation



### inFARMING® applies to:

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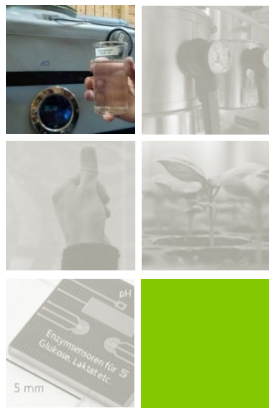




## Technical approaches for indoor cultivation – fertilizer production

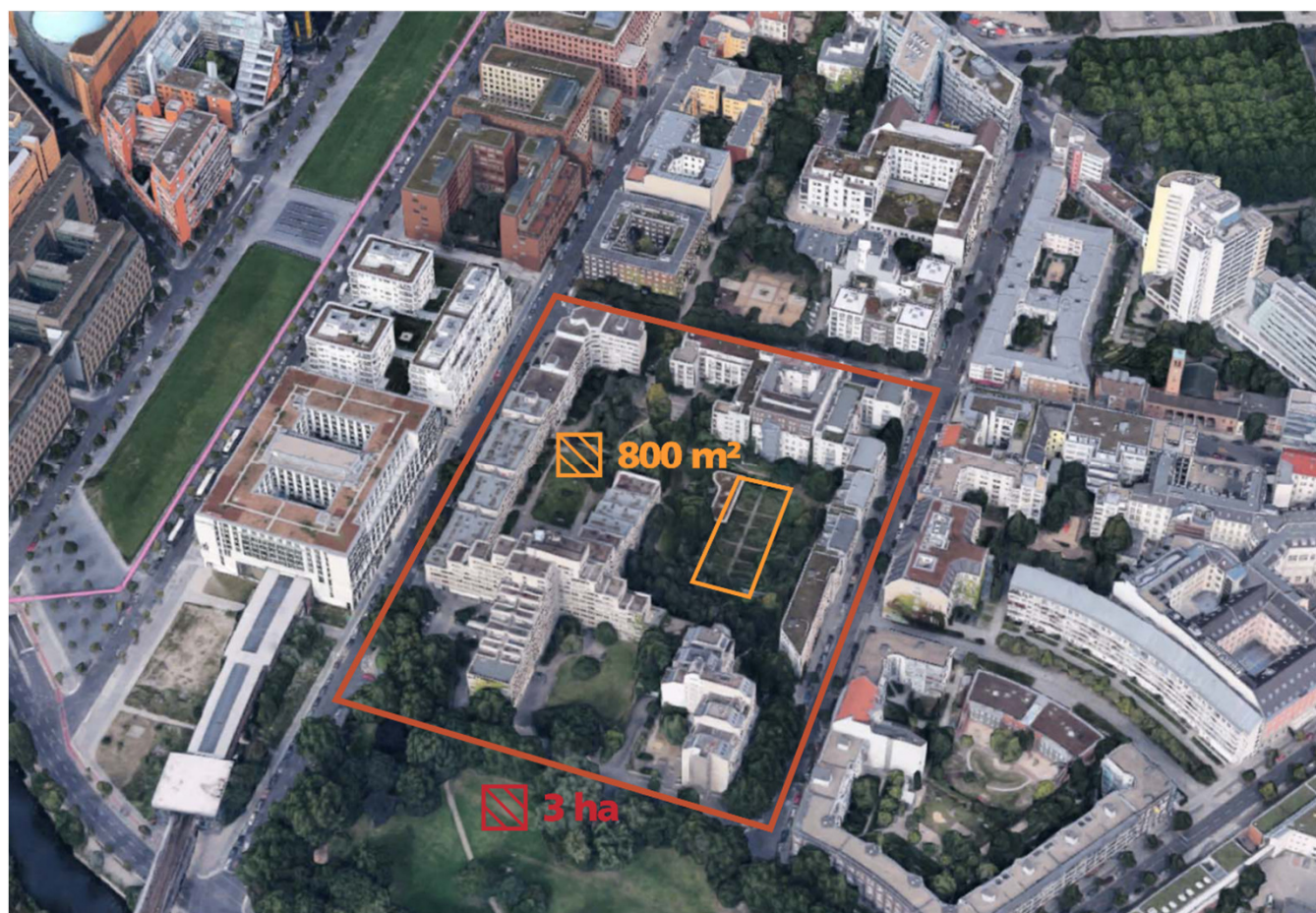
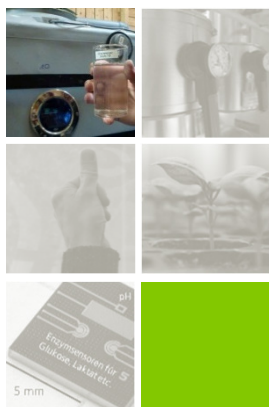
### Motivation:

- Worldwide use of NPK fertilizers: 104 Mio. t N, 46 Mio. t  $P_2O_5$  and 33 Mio. t  $K_2O$
- High energy demand for Haber-Bosch Synthesis and uncertain P-resources
- Growing number of attempts to recycle or convert fertilizers from wastewater and animal excrements e.g. manure.
- Aquaponic systems are based on the same idea.
- No technical processes for safe and efficient urban integrated recovery.





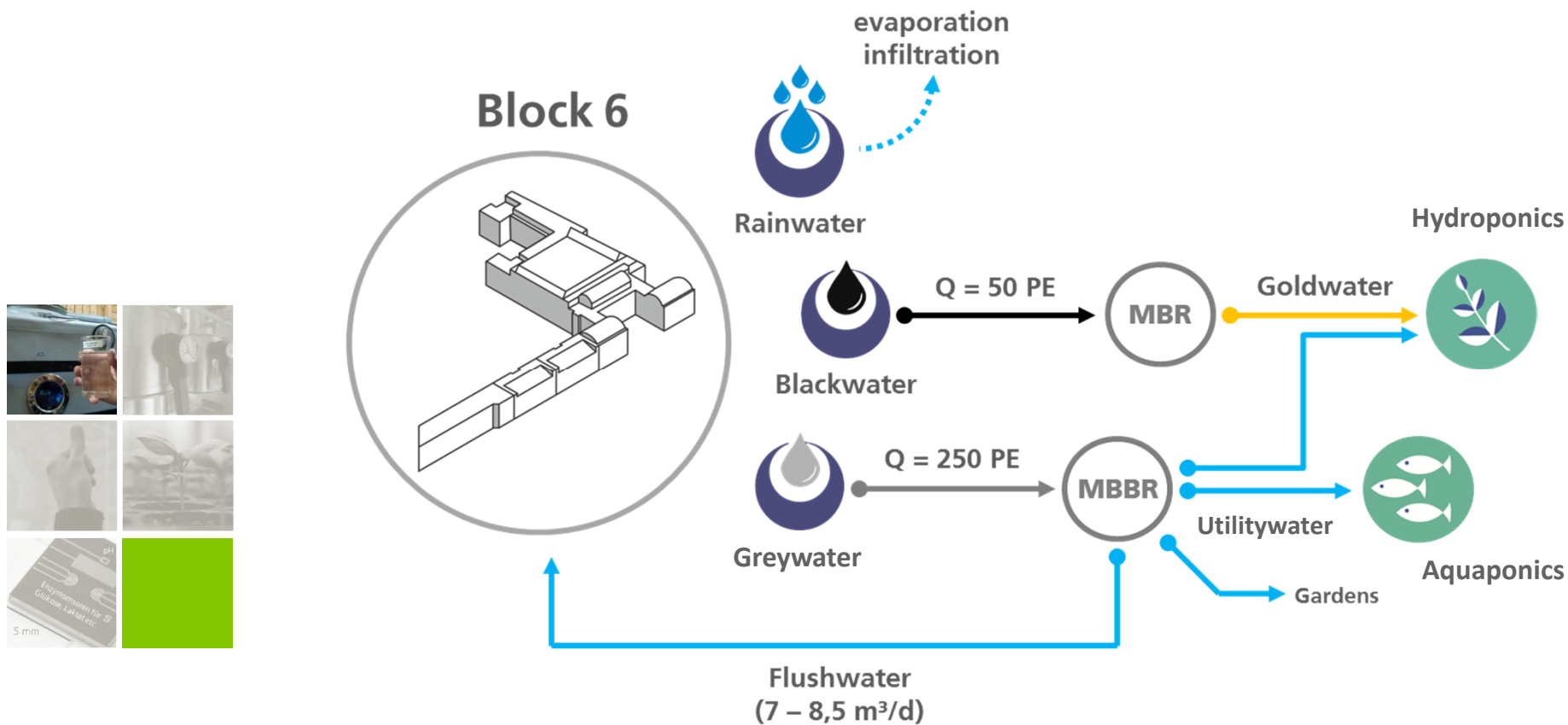
## Technical approaches for indoor cultivation – fertilizer production



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## Technical approaches for indoor cultivation – fertilizer production







## Technical approaches for indoor cultivation – fertilizer production – experimental setup

### Lettuce

19.04 — 23.05

03 Goldwater batches



100 plants

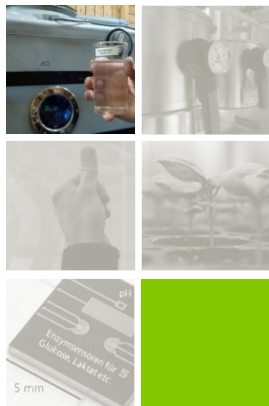
### Cucumber

08.06 — 05.09

06 Goldwater batches



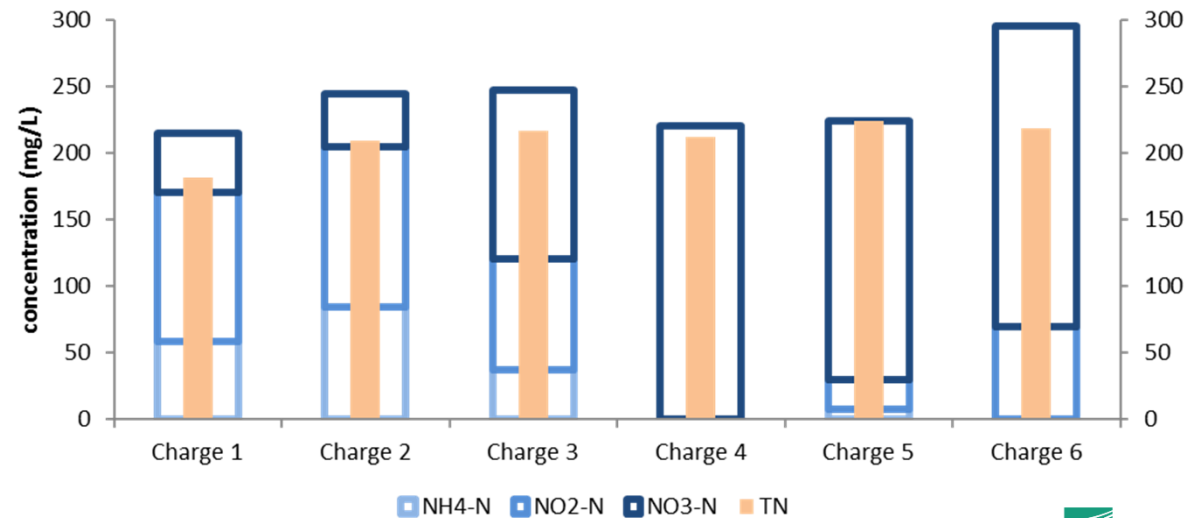
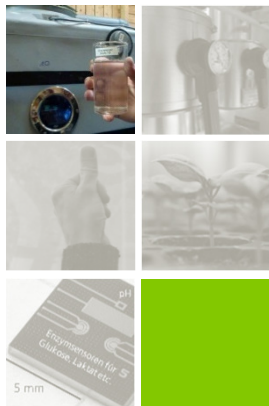
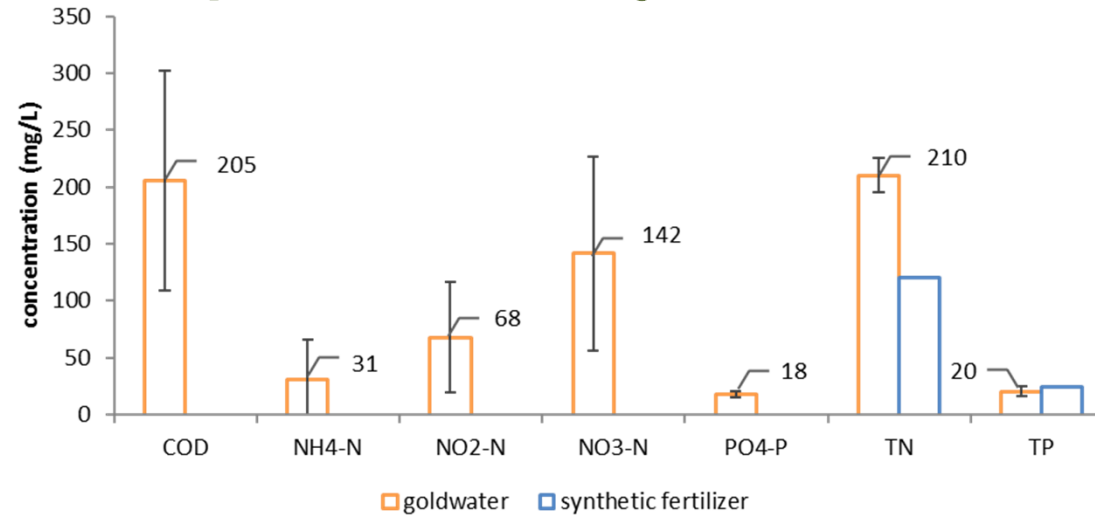
33 plants







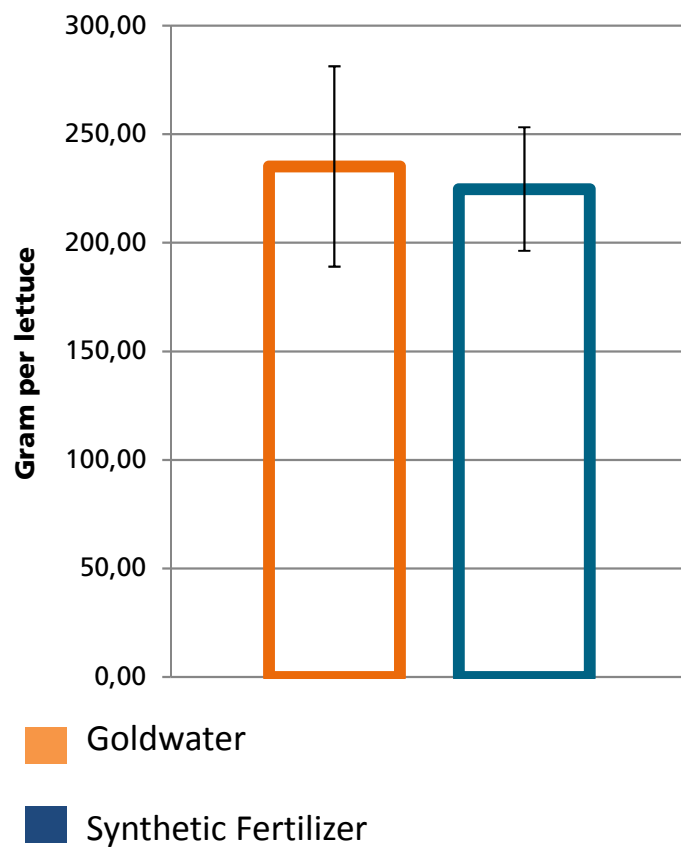
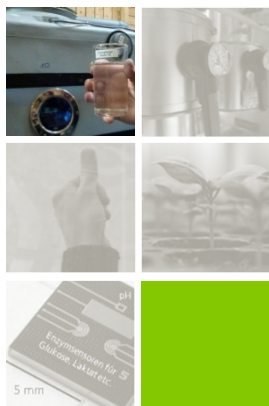
## Technical approaches for indoor cultivation – fertilizer production - analytics



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## Technical approaches for indoor cultivation – fertilizer production - yield

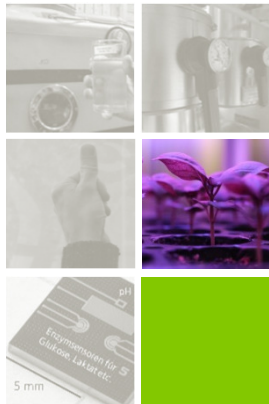




## Technical approaches for indoor cultivation – plant lighting

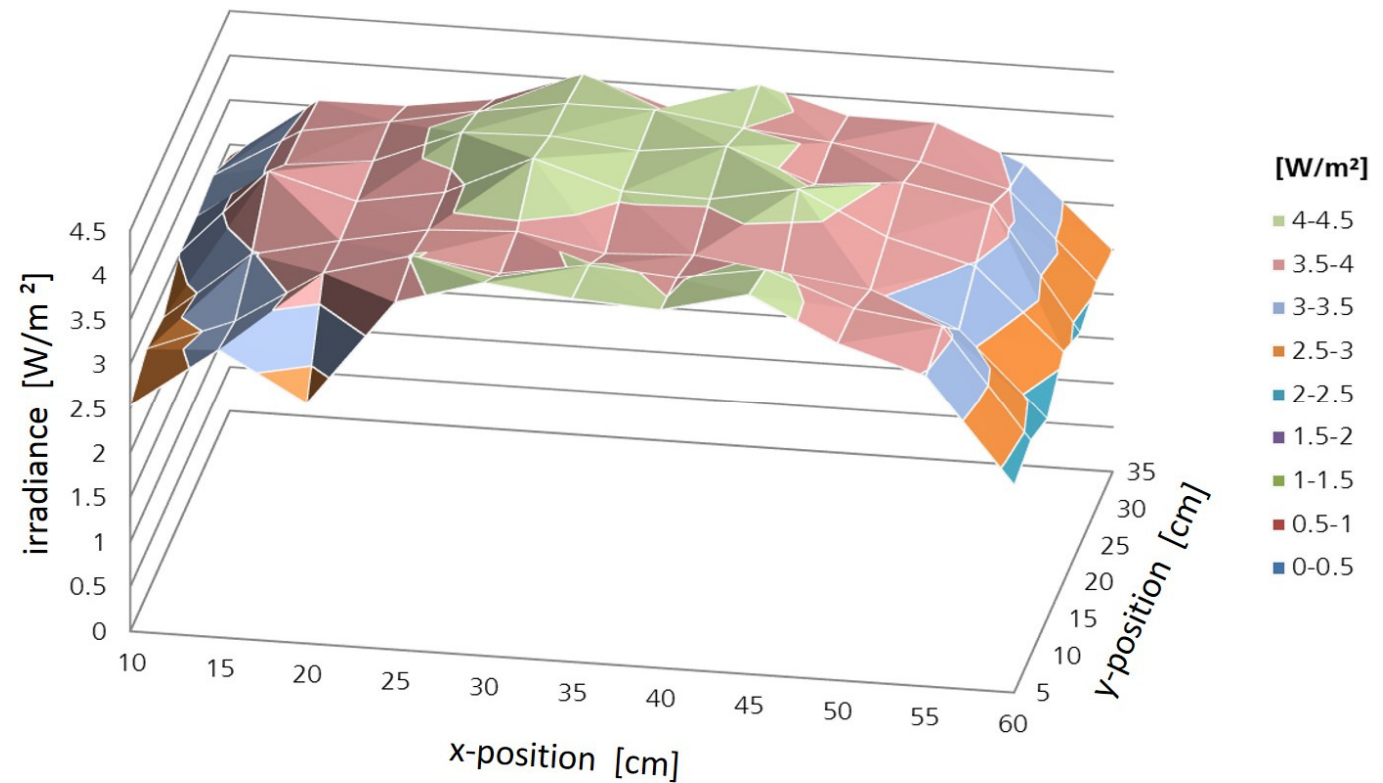
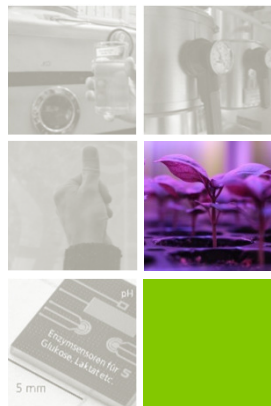
### Plant photoreceptors

- **phytochrome** (660 respectively 730 nm)
  - control of growth processes
  - control of shade protection, flowering induction
- **cryptochrome** (340 respectively 520 nm)
  - continuity of the circadian rhythmic
  - control of photomorphogenesis
- **phototropin** (340 to 520 nm)
  - efficient light use
- **UV-B-photoreceptor** (280 to 350 nm)
  - protective function





## Technical approaches for indoor cultivation – characterization of grow chambers







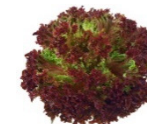
## Technical approaches for indoor cultivation – State of scientific knowledge - phytochemicals



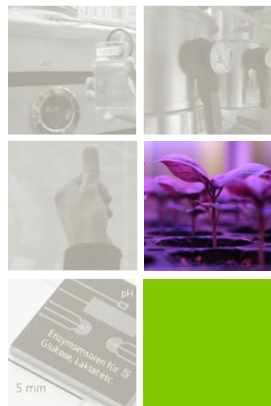
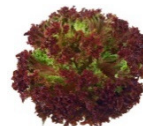
Carotonoids



Phenols



Anthocyanins

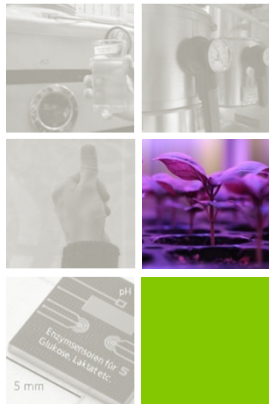




## Technical approaches for indoor cultivation – measurement of phytochemicals

### Analysis of phytochemicals

- HPLC – High performance liquid chromatography; identifying single substances according to standards; destructive.
- Optical measurement; identifying contents of flavonoids and anthocyanins; non destructive method.



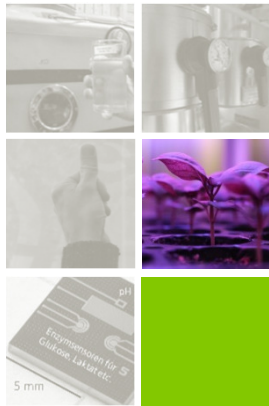
### Requirements for dynamic plant light systems:

Fast measurement, non destructive, applicable to different plants at different stadiums, connectable to automation systems.



## Conclusion

- Horticultural cultivation in Vertical or Indoor Farms is going to enter the market.
- Market prediction for LED growing lights is very positive.
- By today business models for growers are focused on biomass.
- Quality inline monitoring by means of non destructive methods is needed and part of developments by inFARMING®.

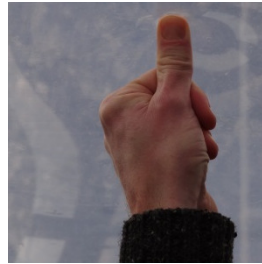




## Outlook spring 2019: Start of operation of the »Altmarktgarten«







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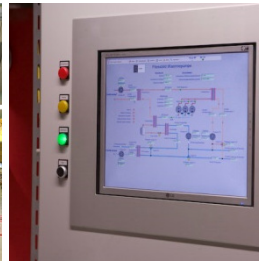
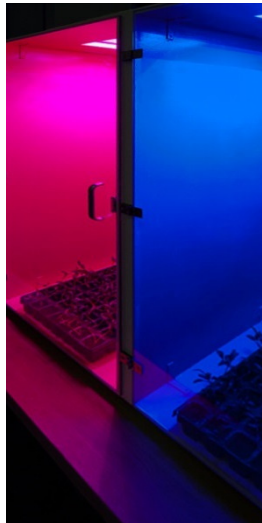
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