1st Symposium on Green Infrastructure for Future City &
4th International Symposium ZEBISTIS
Zero Emission Buildings Integrating Sustainable Technologies and Infrastructure Systems
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Bundang, Republic of Korea

Building integrated food production

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ZERO EMISSION BUILDING Integrating Sustainable Technologies and Infrastructure Systems

Zurich University of Applied Sciences (ZHAW)

- A multidisciplinary university of applied sciences
- 8’000 students
- 1’500 employees
- 3 Locations: **Waedenswil**, Winterthur, Zurich
- Institutes in Waedenswil: Biotechnology, Chemistry, Food and Beverage, **Natural Resource Sciences**, Facility Management

Institute of Natural Resource Sciences

Focal points

- Ecotechnologies, Renewable energy and resources
- Urban Greening
- Nature management and conservation
- Environmental education & ecological tourism

Overview

- Why Urban agriculture? Why integrate food production into buildings?
- Defining the Building-integrated agriculture
- Categorisation
- Some best known BIA projects & case studies
- Energy benefits of BIA – insulation, heating and cooling
- Trends in significance of Building Integrated Agriculture according to internet evaluation

- Comparison with green roofs – energy saving, costs and retrofitting potential

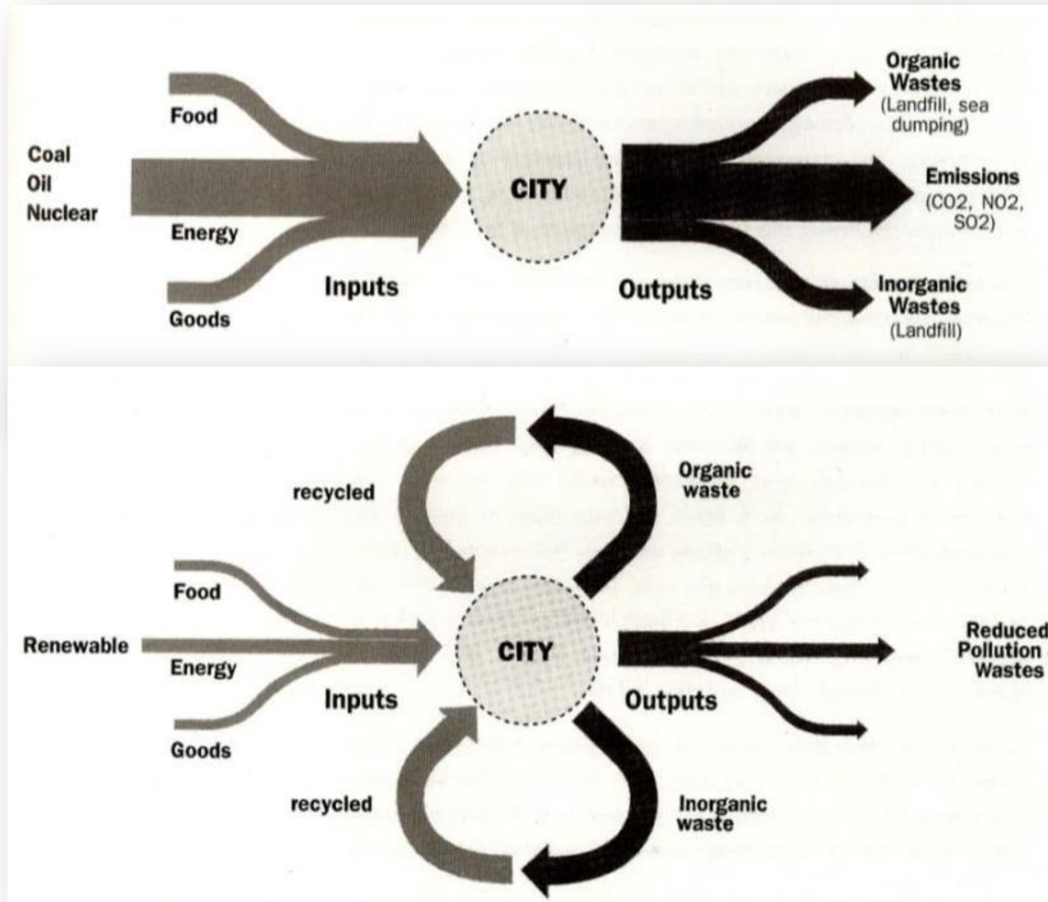
Why Urban Agriculture ?

- **Population development**
  9bn people by 2050 - 100% more food than today – 2/3 will live in cities
- **Global climate change** is predicted to lead to widespread regional shortages of food, water, and arable land by 2050
- **Environment**
  Agriculture is the largest consumer of natural resources. Less land = more intensive farming = more destructive
- **Oceans over-fished**
  Aquacultures already provide >50% of global fish supply
- **Public Health**
  Rising health care costs are directly linked to nutrition (obesity, diabetes, heart disease)

Urban Agriculture will be part of urban culture
in the 21st century.

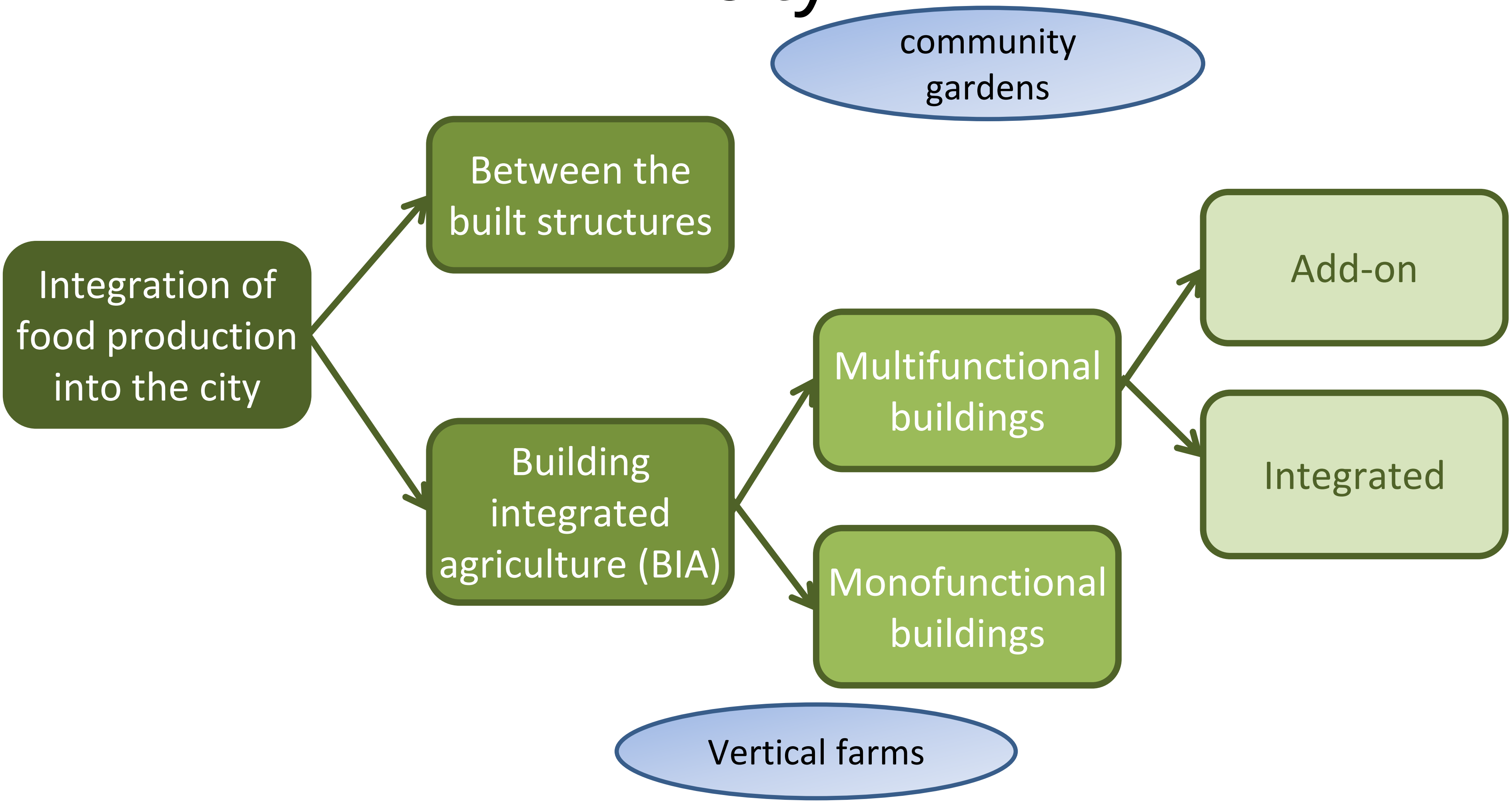
City metabolism: linear vs. circular ...

(Re-)integration of food production into the city is a necessary element to achieve the circular metabolism.



Rogers, R. (1997)
Cities for a small planet

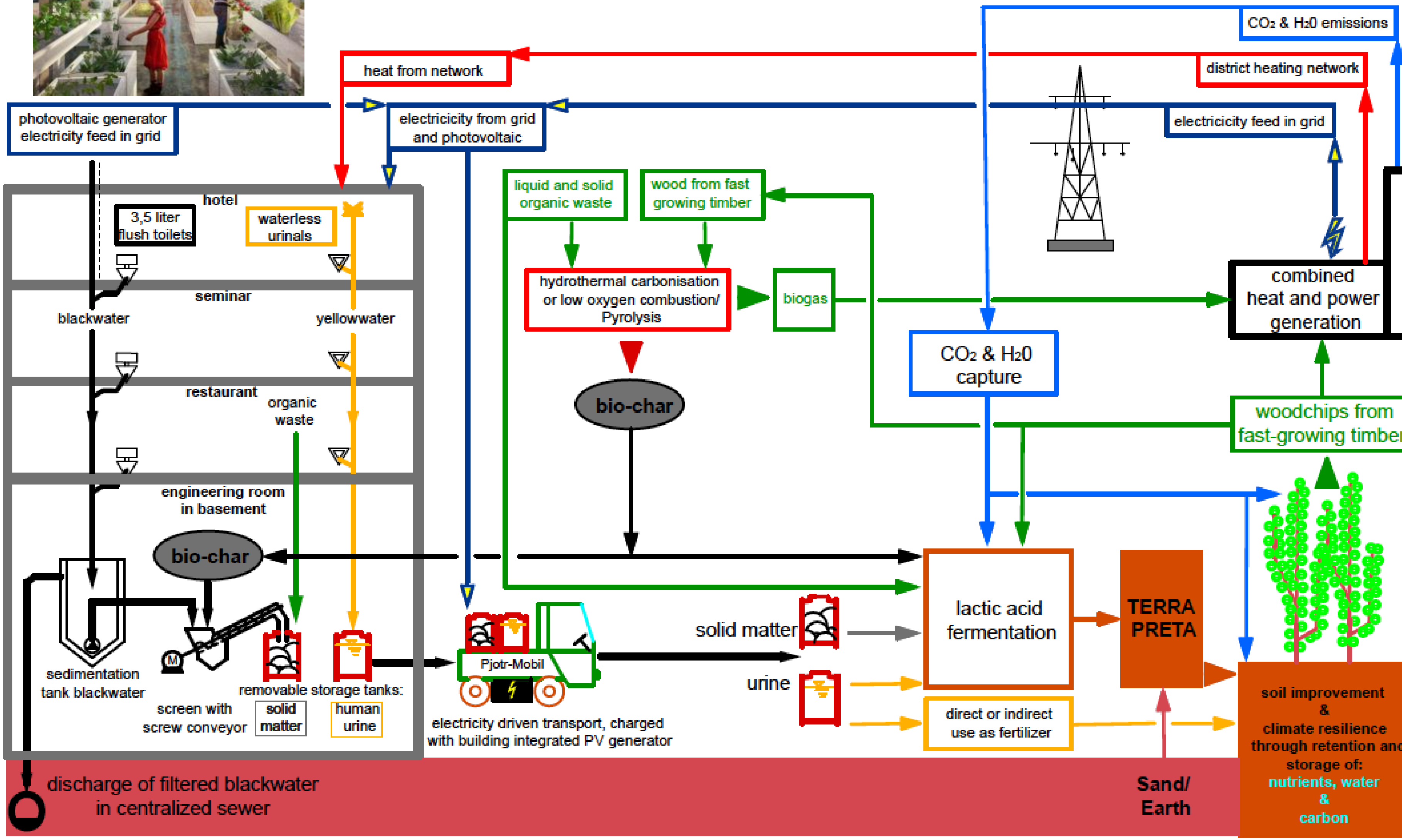
Integration of food production into the city



Building-integrated agriculture (BIA)

= the practice of locating high performance hydroponic greenhouse farming systems on and in mixed use buildings to exploit synergies between the built environment and agriculture.

Caplow, T. (2010) Building Integrated Agriculture: Philosophy and Practice. In: Heinrich-Böll-Stiftung (eds) (2010) Urban Futures 2030. Urban Development and Urban Lifestyles of the Future. Volume 5 (English Edition) in the publication series on ecology. Pp.54-58.



(Schuetze & Zeisel, 2010)

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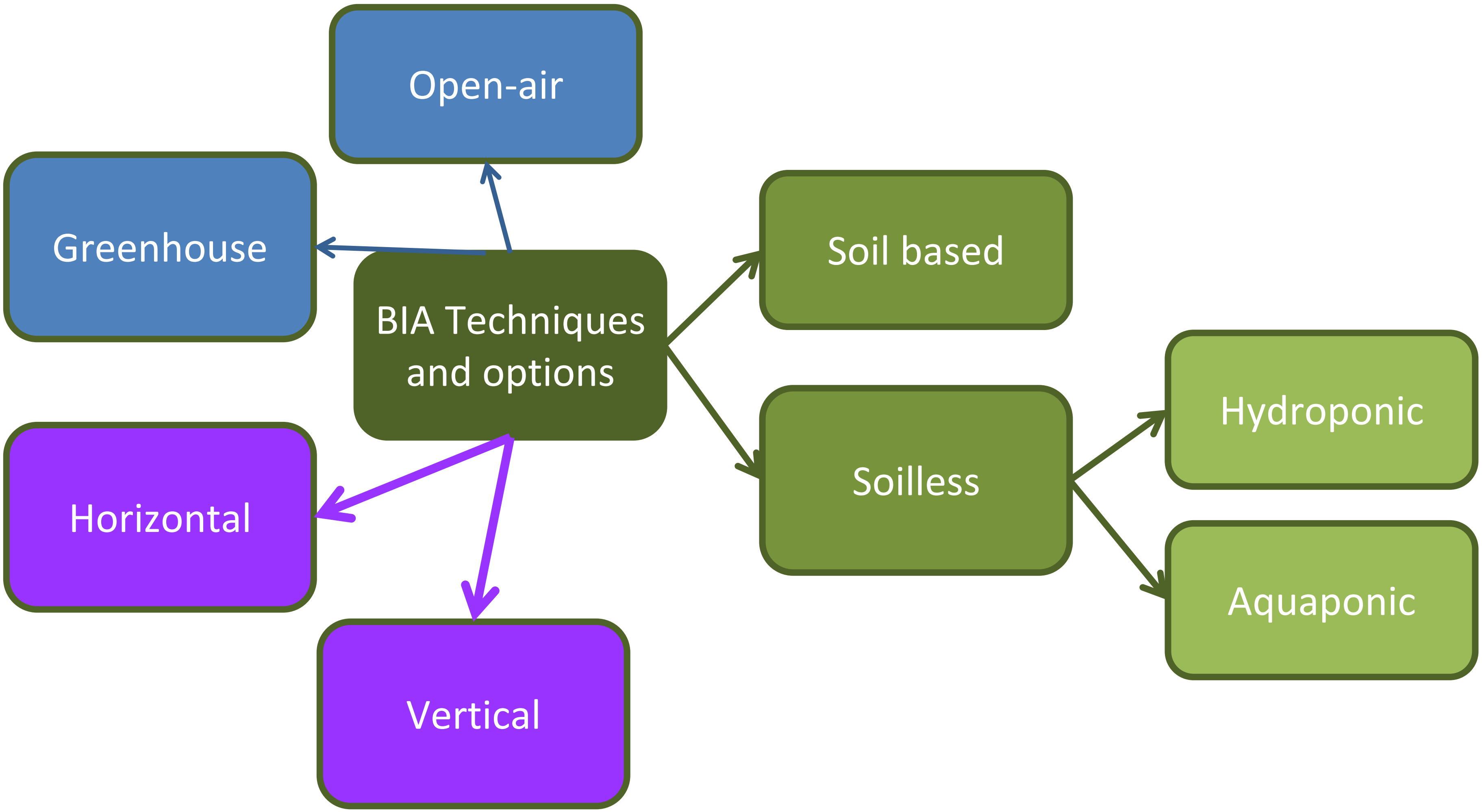
Characteristics of BIA installations

- recirculating hydroponics with/without aquaculture
- waste heat captured from a building's heating-ventilation-air condition system
- renewable energy supply
- rainwater harvesting & treatment for a subsequent use (hydroponics)
- evaporative cooling

BIA Techniques and options



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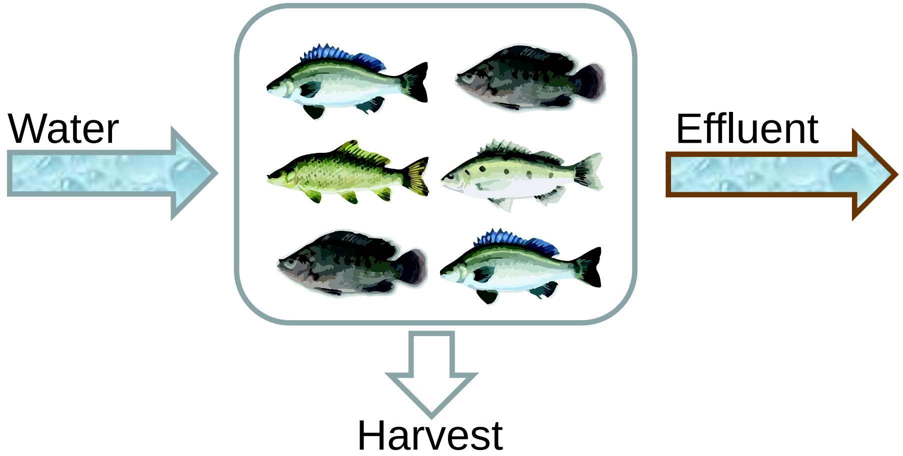
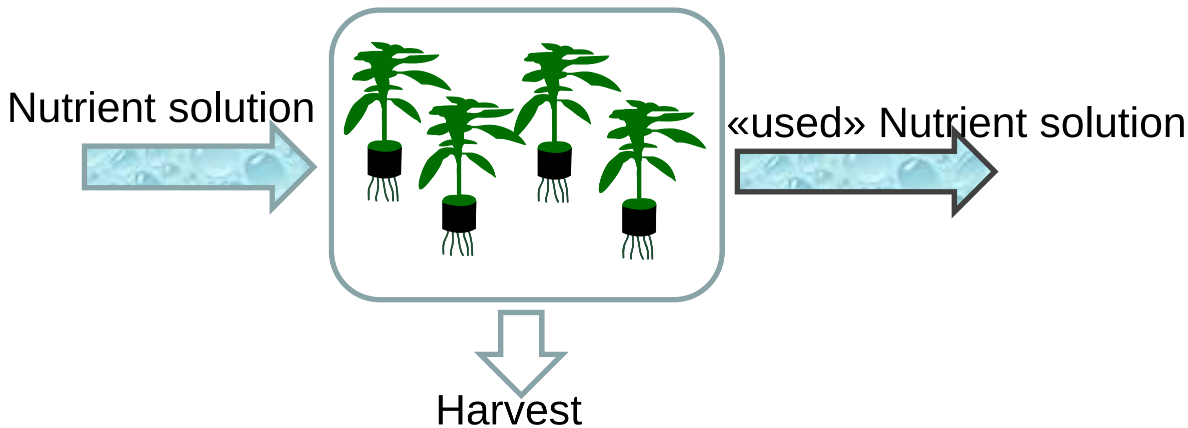
Horizontal & vertical

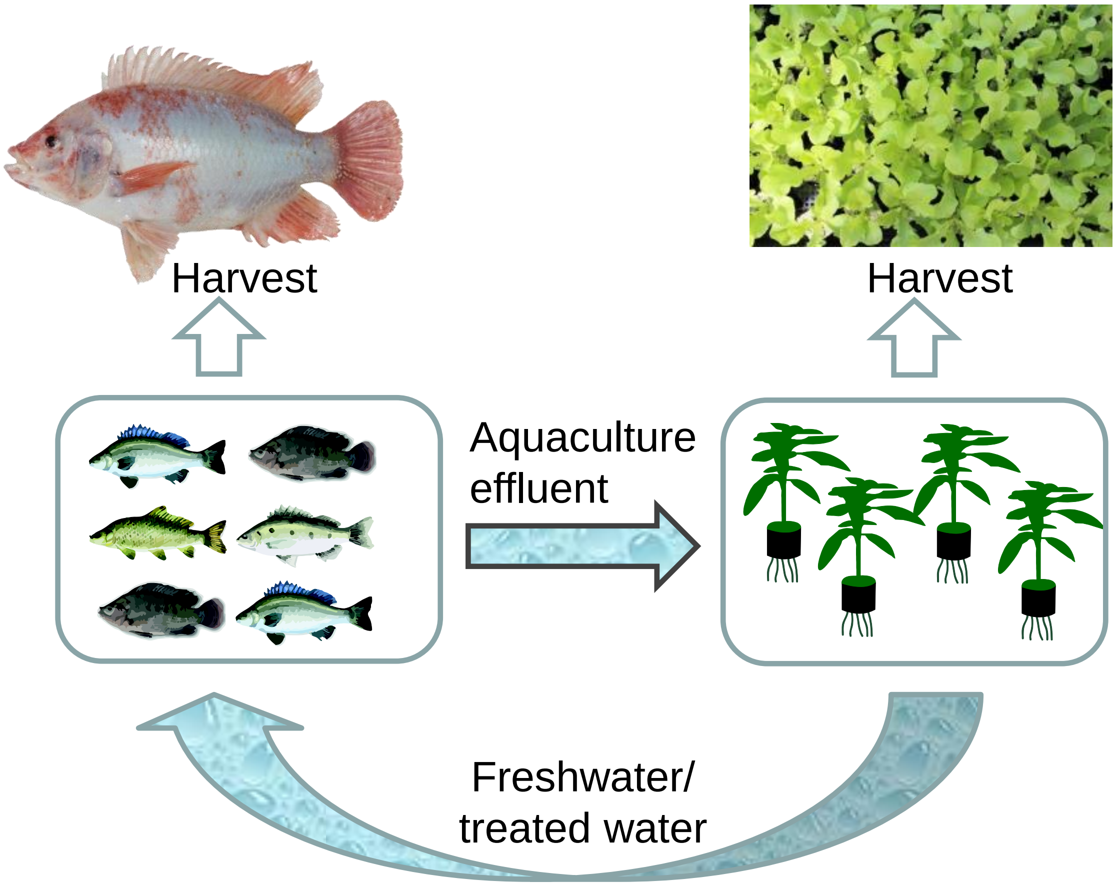
Both examples by Kiss & Cathcart Architects, NY

Aquaculture and hydroponics



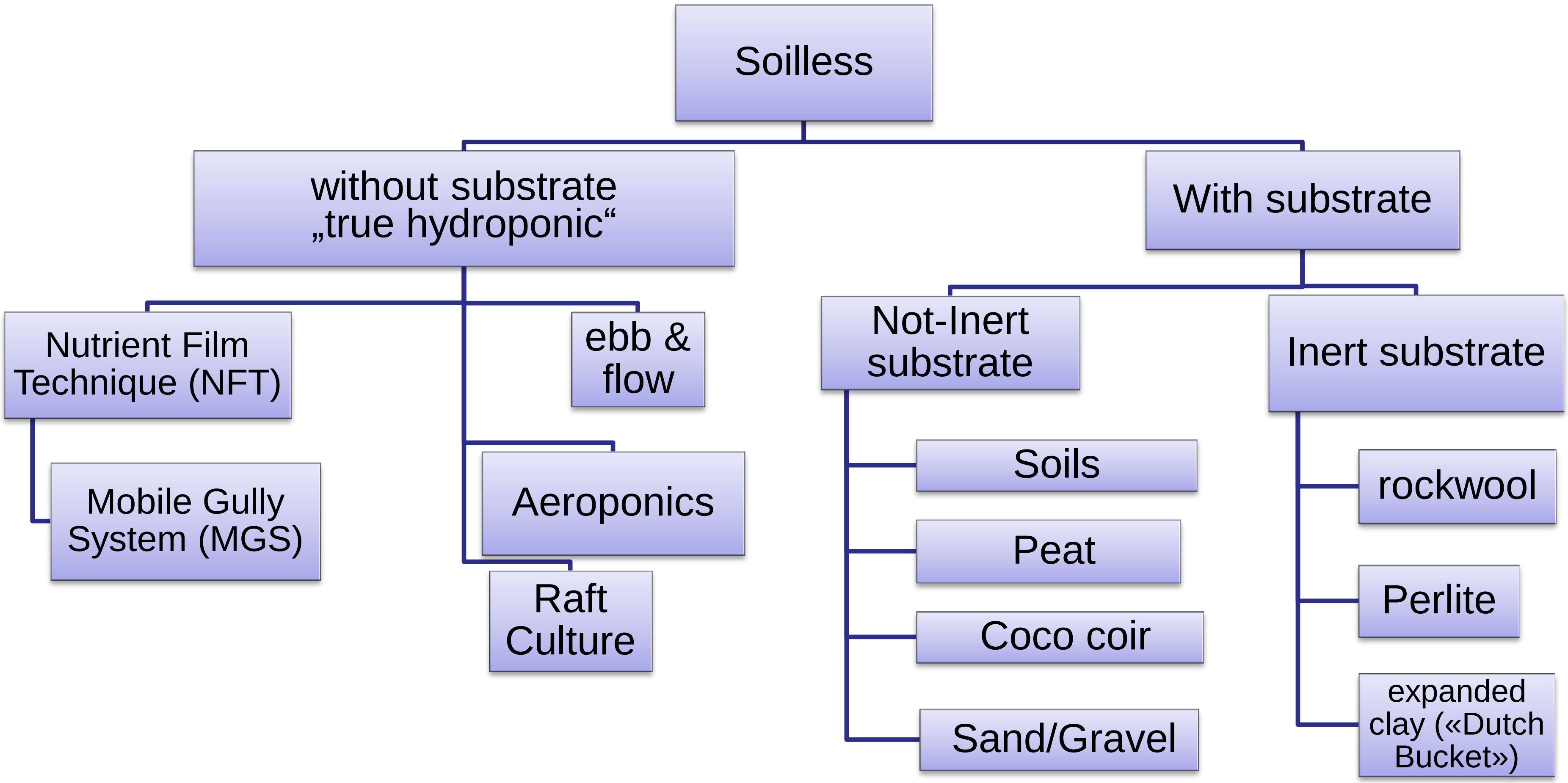


Aquaponics



Harvest
Harvest
Aquaculture effluent
Freshwater/
treated water

Soilless cultures



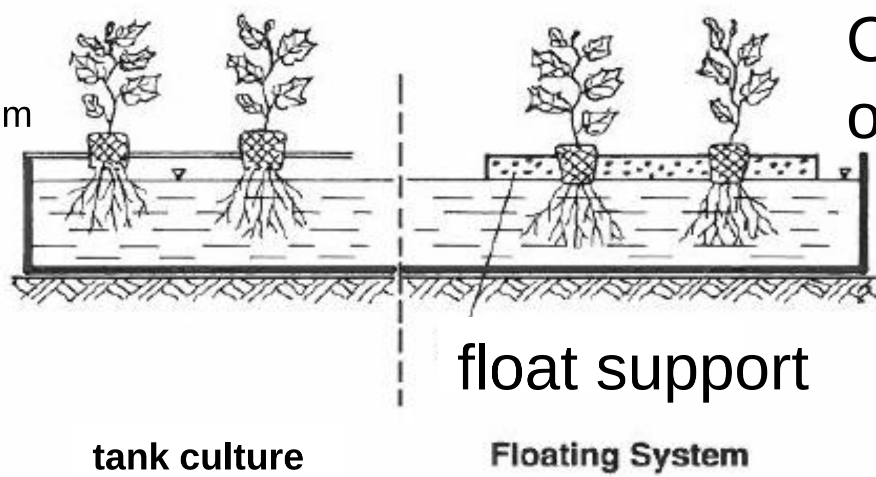
D. Bachmann, A. Mathis

Hydroponic systems 1

Floating system / raft system / deep water flow DWF

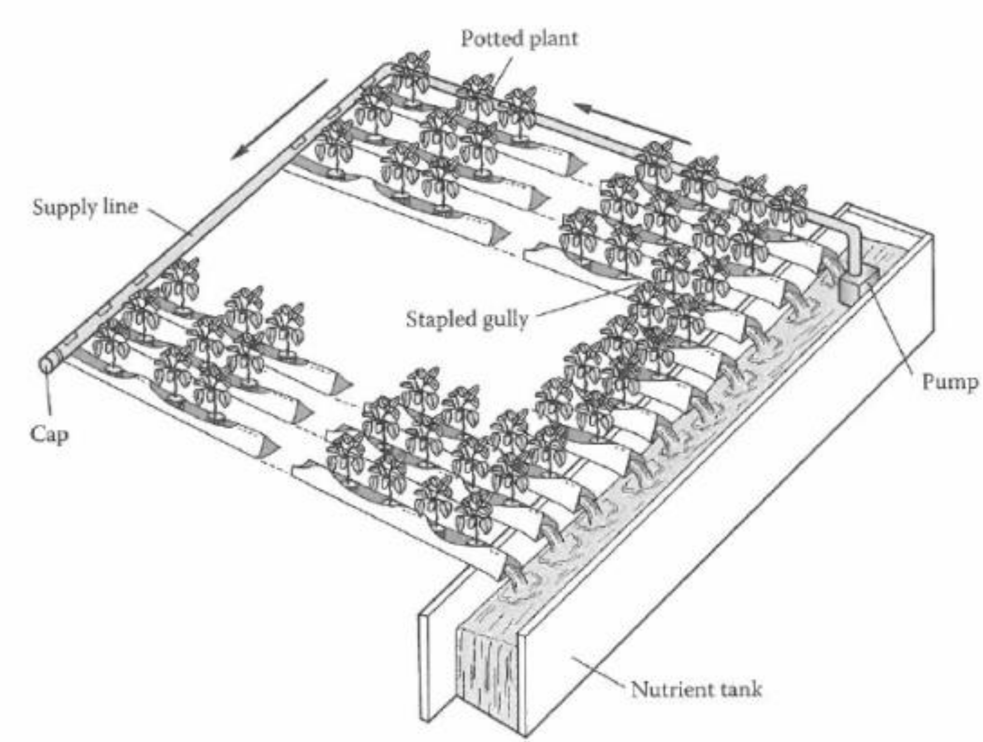
Pak choi in rafts
http://theolleys.wordpress.com

Oak leaf salad on rafts zhaw

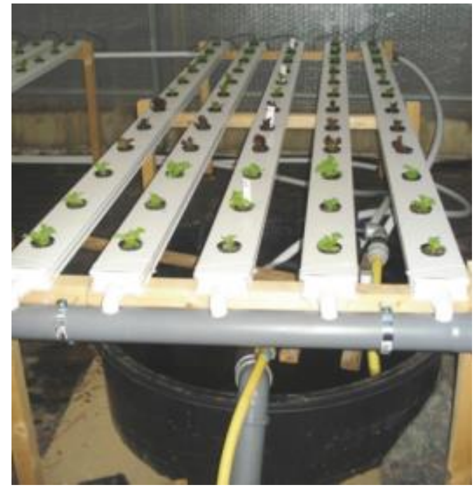


Hydroponic systems 2

NFT – Systems



NFT gullies and nutrient tank
Resh, M. (2013): Hydroponic Food production. CRC Press. 7th edition.



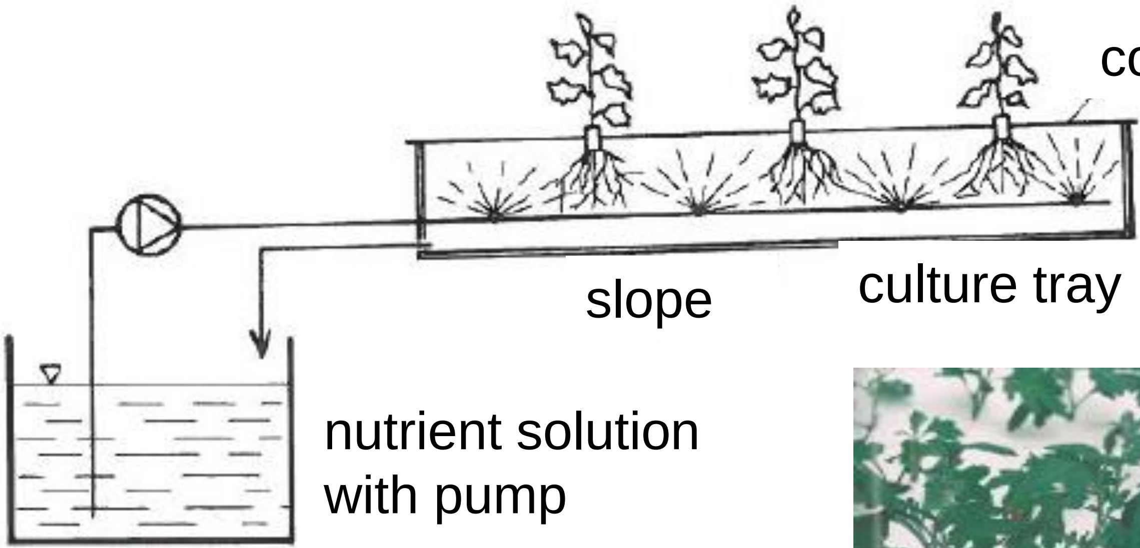
NFT system
zhaw

NFT system
zhaw

→ Slope minimum 2%
→ Water passage about 2 l per min and gully

Hydroponic systems 3

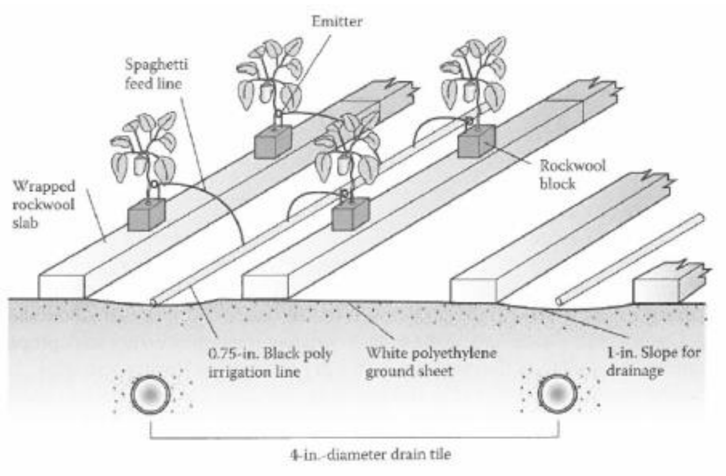
Aeroponic



Göhler, F., Molitor, H-D (2002): Erdlose Kulturverfahren im Gartenbau. Ulmer. Stuttgart.

Hydroponic systems 4

Bag system



Grodan culture

Resh, M. (2013): Hydroponic Food production. CRC Press. 7th edition.

Grodan or Coco coir culture

zhaw

Grodan culture, control unit

zhaw

zebistis
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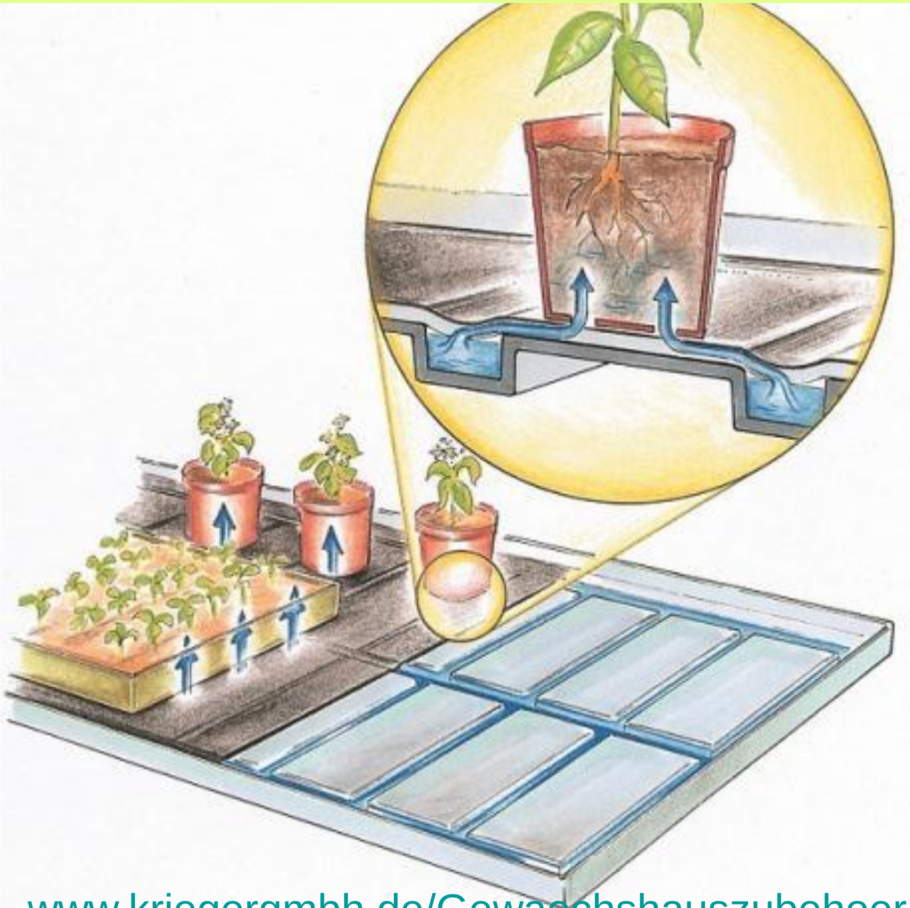
Hydroponic systems 5

Ebb & flow system



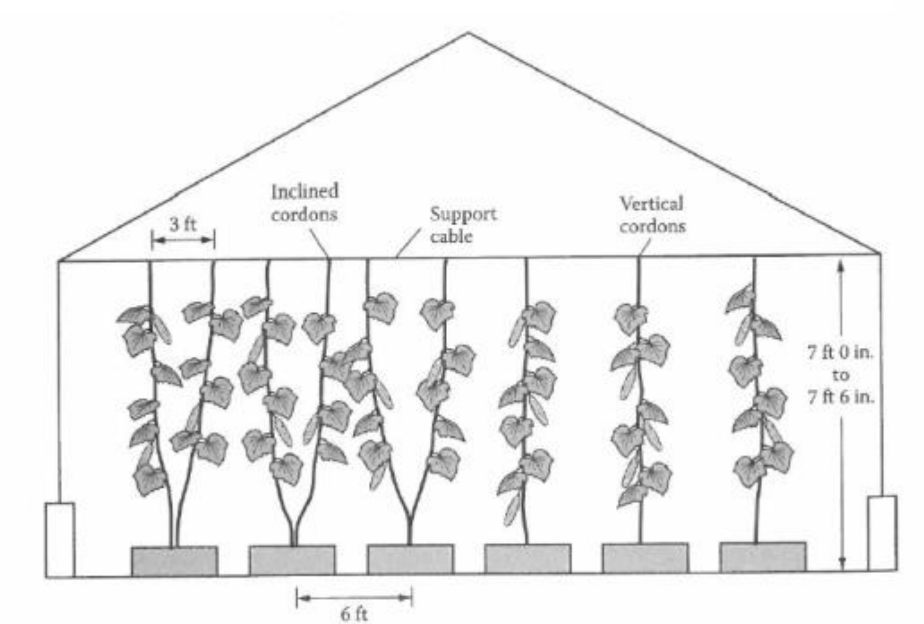
www.kriegergmbh.de/Gewaechshauszubehoer/Bewaesserungswanne-1

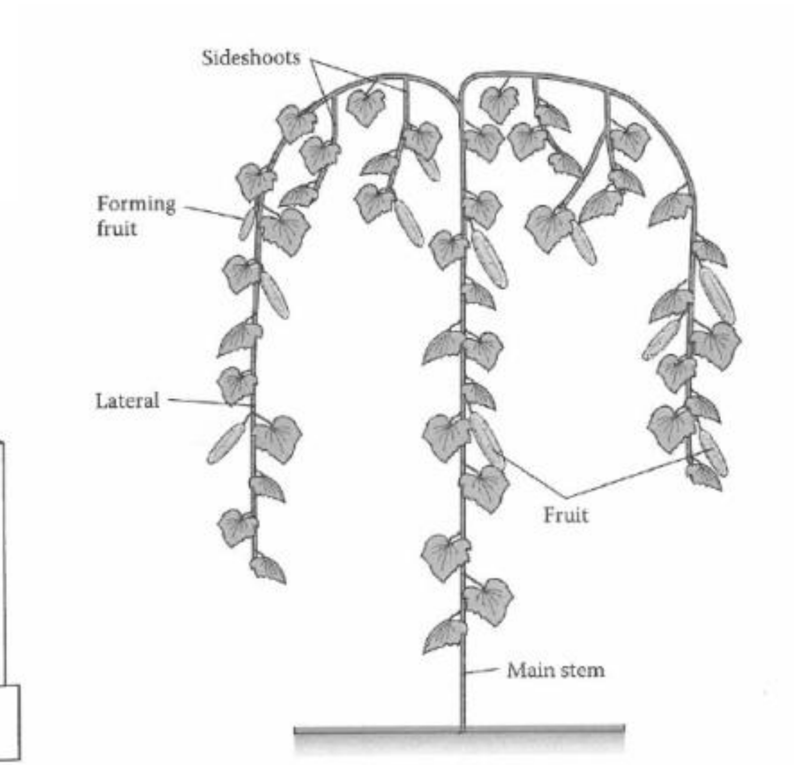
Ebb flow system
zhaw

Special Hydroponic Systems: Vertical Farming

Cucumbers or tomatoes are already vertical crops. They utilise the existing vertical space in a greenhouse.

But what about salads?

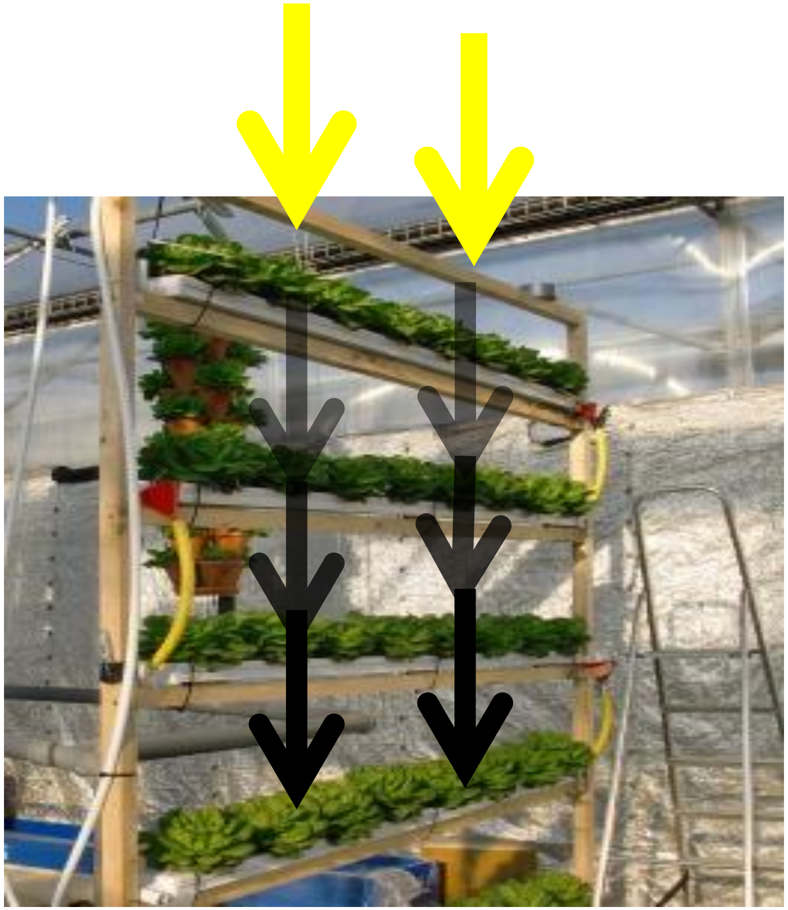




Vertical Low-Tech System 1

Self-constructed vertical plant towers during the winter season at ZHAW 2012/13.

Vertical systems: Main problem light



Problem shading effect

Lichtempfehlung Obst & Gemüse

Pflanzensorte		Empfohlener PPFD-Wert in µmol m⁻²s⁻¹	Lampentyp	Belichtungsperiode	Belichtungsdauer pro Tag	Ziel und Methode
Auberginen	Keim pflanzen	80 - 160	TL/HPI	das ganze Jahr hindurch	16-18 Stunden (ohne Tageslicht)	Produktion von Keimpflanzen in Treibhäusern.
	Jung pflanzen	40 - 50	HID	Winter	14-16 Stunden	Förderung des vegetativen Wachstums, frühere Ernte.
Brechbohnen	Jung pflanzen	55	HID	Okt.-Feb.	16 Stunden	Förderung des vegetativen Wachstums, frühere Ernte, größere Ausbeute.
Rüben (diverse)	Keim pflanzen und Jungpflanzen	65 -100	HID	Sept.-April	16 Stunden	Förderung des vegetativen Wachstums, kürzerer Zuchtzyklus.
Gurken	Keim pflanzen und Jung pflanzen	25 - 40	HID	Okt.- März	16 Stunden	Förderung des vegetativen Wachstums, kürzerer Zuchtzyklus.
Salat	Saat produktion	280 - 300	HID	Winter	16 Stunden	Verkürzung der Anbauzeit, 4 bis 5 Mal.
	Keim pflanzen und Jung pflanzen	150	HID/TL	Winter	16 Stunden (Treibhäuser)	Förderung des vegetativen Wachstums, kürzerer Zuchtzyklus.
	Kopfsalat-Produktion	45 - 60	HID	Winter	16 Stunden (Gewächshäuser)	Förderung des vegetativen Wachstums, kürzerer Zuchtzyklus.
Erdbeeren	Frucht ansatz	1,5 - 2	einschl.	Jan.-Feb.	15 Min. pro Stunde 2 µmol m⁻²s⁻¹ oder 8 pro Nacht durchgehend 1,5 µmol m⁻²s⁻¹	Frühere Blüte, größere und bessere Fruchtproduktion.
Tomaten	Jung pflanzen	45 - 55	HID	Okt.-Feb.	14-16 Stunden	Förderung des vegetativen Wachstums, Verkürzung der Anbauzeit (2 Wochen), höherer und besserer Fruchertrag.
	Frucht-produktion	150	HID	Winter	14-16 Stunden	
Tomaten	Keim pflanzen und Jung pflanzen	300 - 380	TL/HPI	Winter	16 Stunden (ohne Tageslicht)	Produktion in Treibhäusern

Light requirements. Source: Philips (www.lighting.philips.de/application_areas)

Climate control: Example Tomatoes

- **Additional heating** (Daily mean temperature should reach a value between 17° C (winter) - 20° C (spring/summer) depending on daily sunlight
- **Aeration temperature:** 0.5-2° C above Heating temperature, depending on sunlight
- **Humidity:** 60 – 85% relative humidity.
- **CO_2:** 800 – 1200 ppm (double to triple ambient concentration!)
- **Light**: Additional light if daily sunlight in winter is < 25 klux
- **Shading:** activate shades if sunlight > 400 W/m2 depending on plant growth or air temperature > 25° C

Climate control

Food Quality and Safety Standards as required by EU Law and the Private Industry require a high technology in cultivation and equipment:

Heating and CO2 supply

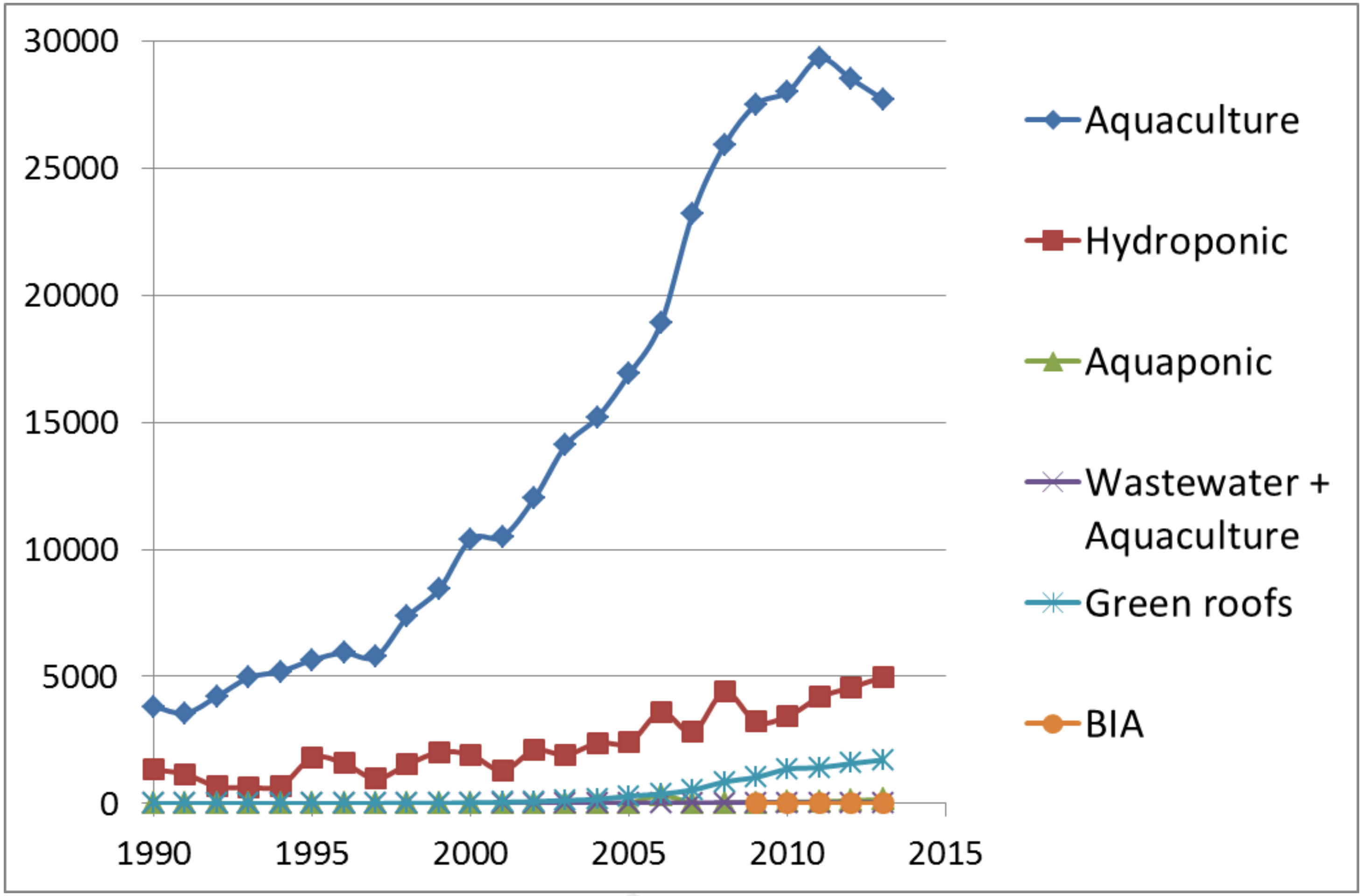
Heating and Aeration on the bottom

High constructed greenhouses with few shading structures

Aquaponics: challenges

- **Energy**
  - supply from photovoltaic
  - reduction of energy demand through heat balance and greenhouse optimizations
  - Lighting (LED? Induction?)
- **Climate control** (humidity, temperature)
- **Water**
  - Rainwater harvesting and pretreatment
  - Optimal nutrient & pH levels for plants (additives)
- **Organic matter / Organisms**
  - Optimal nutrition for Fish (=System Input!)
  - Composting of the fish sludge and plant waste
  - New varieties of vegetables and fish
  - Pest control (Beneficial bacteria…)
- **System building system integration**: interfaces of roof farm with existing roof surfaces

Annual papers published



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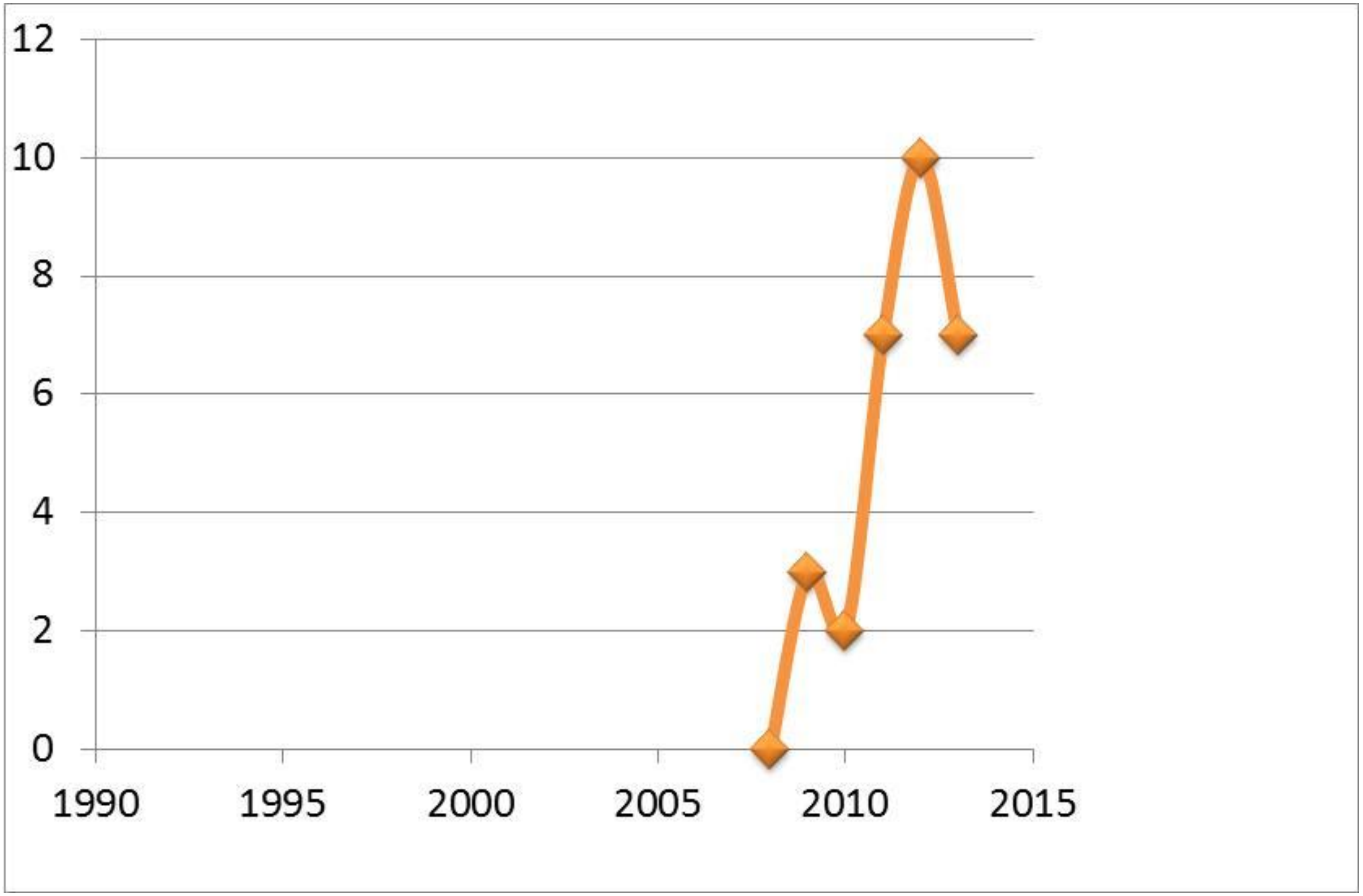
BIA papers published



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What is «hot» is not necessary well researched!!

Keyword	Google	Google Scholar	Ratio
"membrane reactor technology"	368000	28900	13
photovoltaic	8270000	626123	13
Aquaculture	9880000	666000	15
Hydroponic	3740000	67300	56
"Wastewater-fed aquaculture"	21000	335	63
"Green roofs"	1500000	12200	123
"building integrated agriculture"	30400	32	950
Aquaponics	1900000	1330	1429

Realised projects extremely rare

Farm Operators	Location	Realised examples Information	Type	Size (m2)	Produce (tons/annum)
Eli Zabar's Vinegar Factory	New York City	Eli Zabar's Garten	soil	ca. 2000	no data
Sky Vegetables	New York City	Farm Bronx	hydro	743	no data
Gotham Greens,	New York City	Greenpoint Brooklyn	hydro	1394	100
Top Sprouts	Boston, MA	no object declared last BLOG 2009	hydro	-	-
Cityscape Farms	San Francisco	no object declared website abandoned	aqua	-	-
AeroFarms	New York City	no object declared	hydro	-	-
Lufa Farms	Montreal	1 Rooftop-Farm	hydro	2322	75
BrightFarm Systems	New York City	last news 2013, planning	hydro	-	-
Big Box Farms	New York City	no object declared last news 2011	hydro	-	-
Plantagon	Sweden	planning in Lingkoping	hydro	-	-
SweetWaterOrganics	Milwaukee	closed operation as commercial; object used for education	aqua	not clear	no data
PodPonics	Atlanta	Launch 2010 Cargo Containers no object declared	hydro	-	-
Met Farm	Rotterdam	Launch 2012 indoor, LED lighting, indoor + vertical	hydro		
UrbanFarmers	Zürich	UF001, Basel	aqua	260	3 t vegetables 600 kg Fish

Environmental advantages: many claims but few numbers

BIA is claimed to be an environmentally sustainable strategy for urban food production that reduces environmental footprint through:

- reduction of transportation costs (food miles)
- water conservation
- improved food security & safety
- waste reduction
- cooling / warming of buildings

Wilson, Alex. "Growing Food Locally: Integrating Agriculture Into the Built Environment." Environmental Building News. 1 February 2009

BUT!!! This is only possible if the system is operated optimally.

R & D projects at ZHAW 1997-2012

We developed our approach to Aquaponic during 15 years of continuous R & D in more than 20 projects.

Some eminent projects:

- 1996-2000: Aquaculture plant Otelfingen
  for treatment of biogas-effluent
- 1999-2001: Ecological Improvement of Greenhouse Cultivation by Integration of Aquaculture: Tropenhaus Ruswil
- 2004-2007: Aquaponic as new source of income for swiss farmers

We studied different fish species (Tilapia, Trout, Perch) and a broad array of vegetables and ornamentals under temperate, alpine, and tropical conditions.

In addition we developed and are still developing educational modules for schools and professionals.

Closing water, nutrient and energy cycles within cities by aquaponic farms for fish and vegetable production

Aquaponic technology, as developed by ZHAW and marketed by it's Spin-Off UrbanFarmers offers following Unique Selling Points (USP's) in regard to sustainability:

- Approx. 90% reduction in water consumption compared to traditional agriculture
- Nearly closed nutrient cycles based on the natural processes
- 100% organic culture, without fertilizers, pesticides and antibiotics
- Increased efficiency due to vertical mounting options
- Simplified supply chain
- Reduced CO_2 – footprint (zero food miles)

UF001 LokDepot: the world’s fist Aquaponic rooftop farm with commercial purpose

Zürcher Hochschule für Angewandte Wissenschaften
zhaw Life Sciences und Facility Management
IUNR Institut für Umwelt und Natürliche Ressourcen

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Kommission für Technologie und Innovation KTI

christoph merian stiftung basel

GYSI BERGLAS AG

zühlke empowering ideas

NATIONAL INSTRUMENTS

Key figures:

- 260 m^2 of production space, Construction budget CHF 800k
- Construction finished Oct 2012, Start of operations: 01.12.2012
- Capacity of producing annually 5’000 kg vegetables & 800 kg fish

UrbanFarmers

Rooftop Farming Potential: Example Basel, Switzerland

- Total available vacant rooftop area in the city of Basel: **2‘000‘000 m²**
- Key decision criteria for UF:
  - a) FAR (floor-to-area ratio)
  - b) Commercial & Industrial Zoning
  - c) Weight constraint and
  - d) Size (>500 m²)

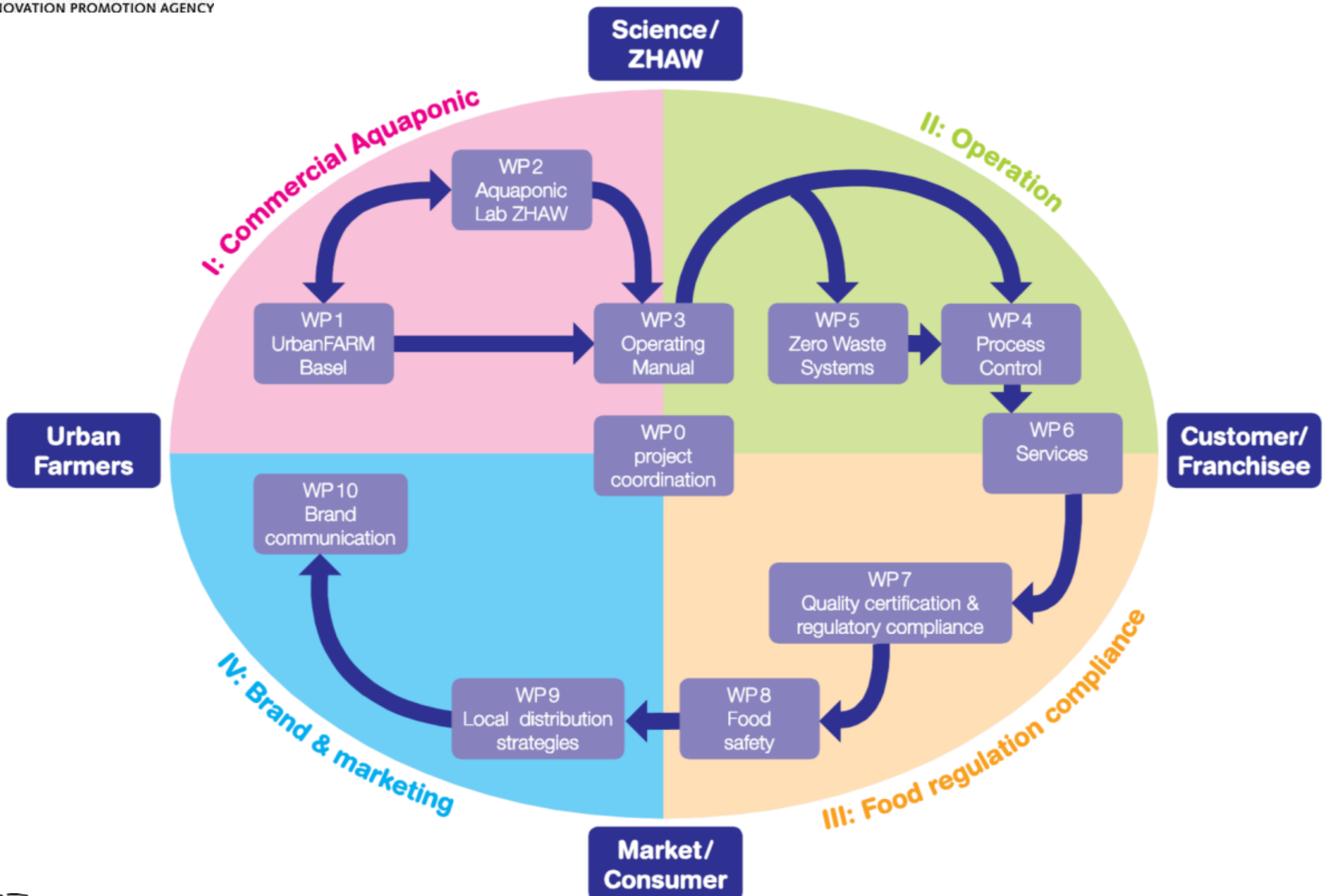
- Estimated Potential: **5%** used for rooftop farms = 100,000 m²

!

340 t fish = consumed by 34‘000 people p.a.
2‘020 t of vegetables = consumed by 14‘000 people p.a.

The city of Basel has 170‘000 inhabitants, UrbanFarmers could contribute **8-20%** to the fresh fish and vegetable consumption in Basel.

Project structure



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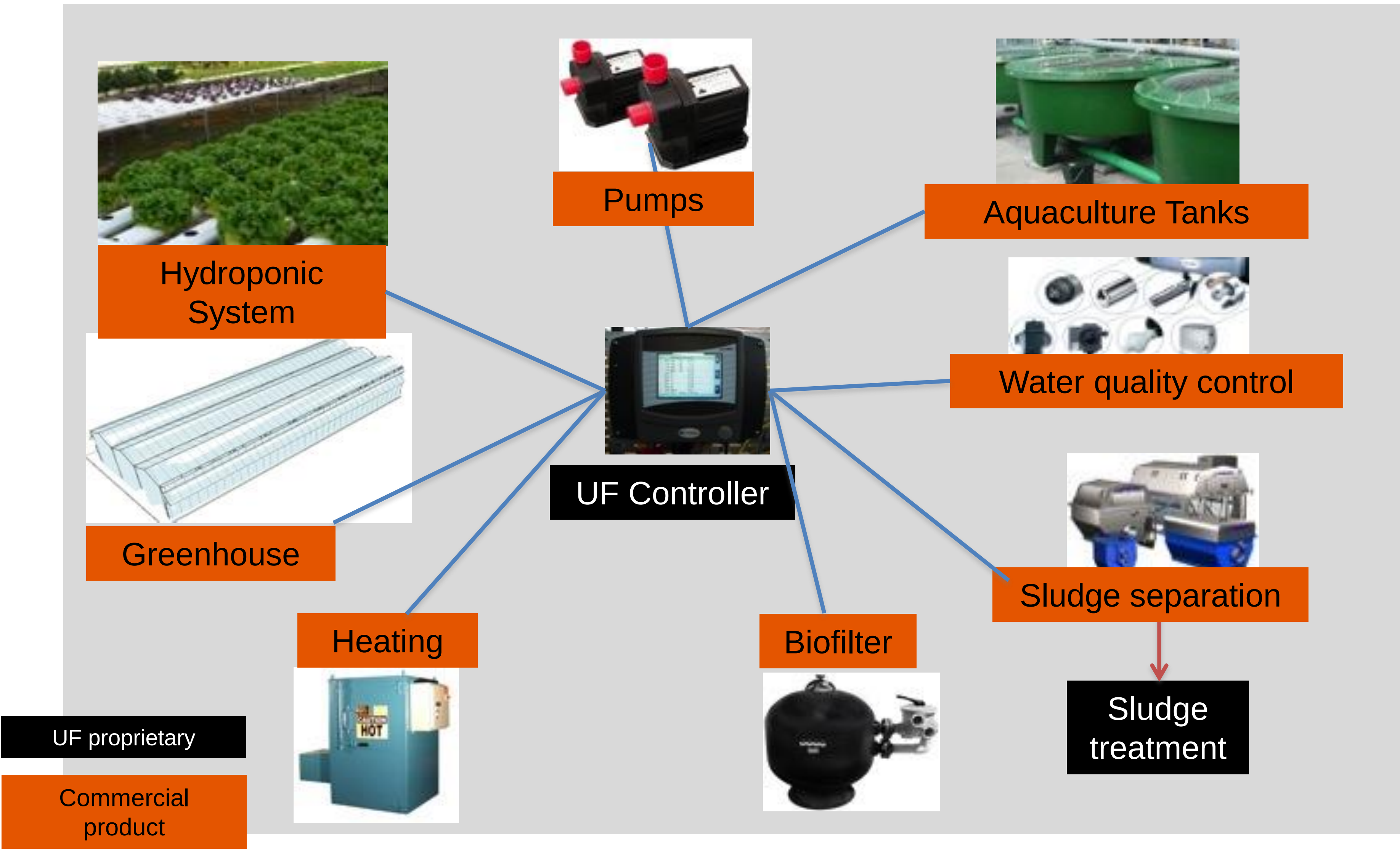
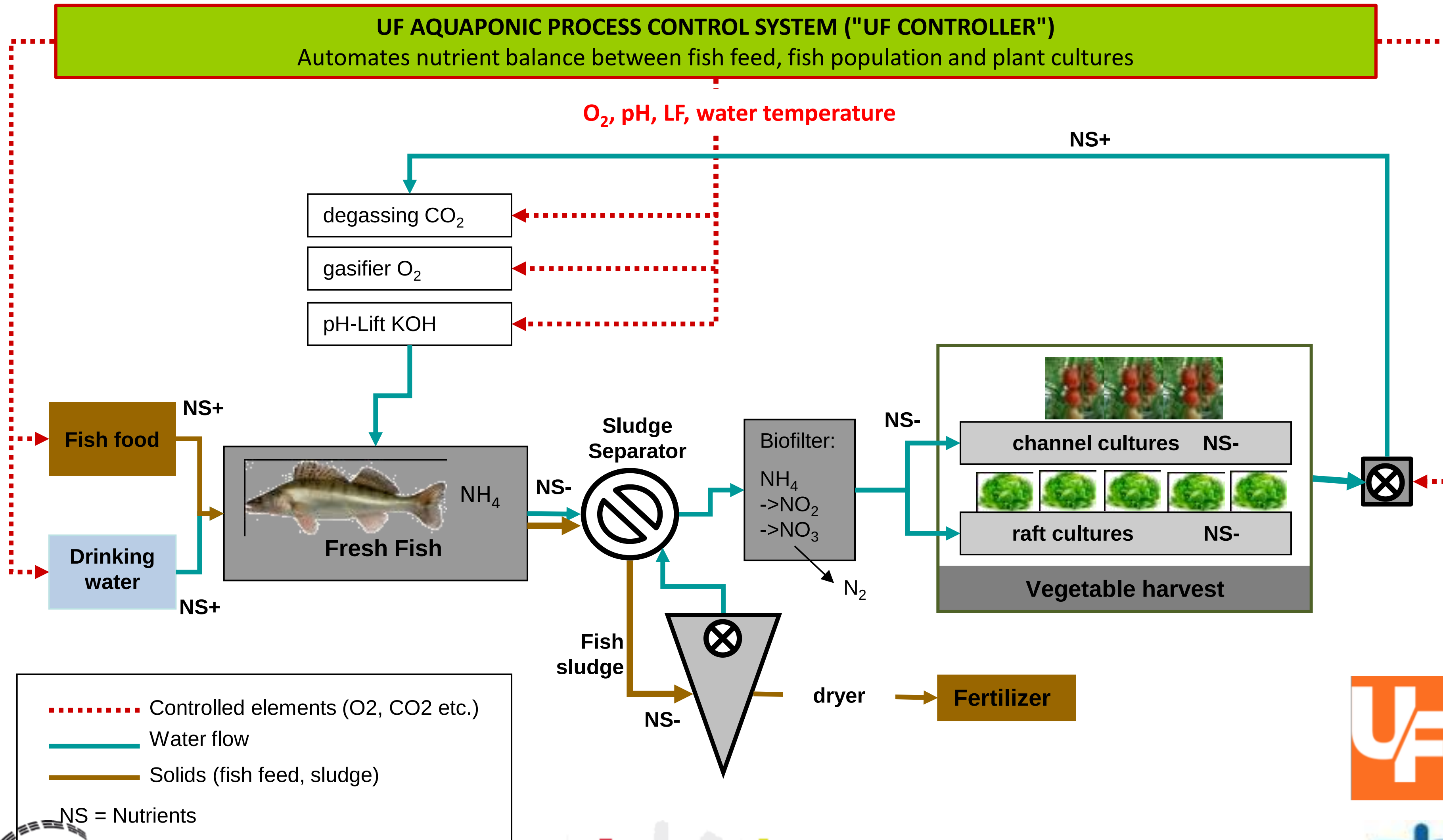
UF System Integration



UF Controller: Process control ensures productivity, safety & efficiency



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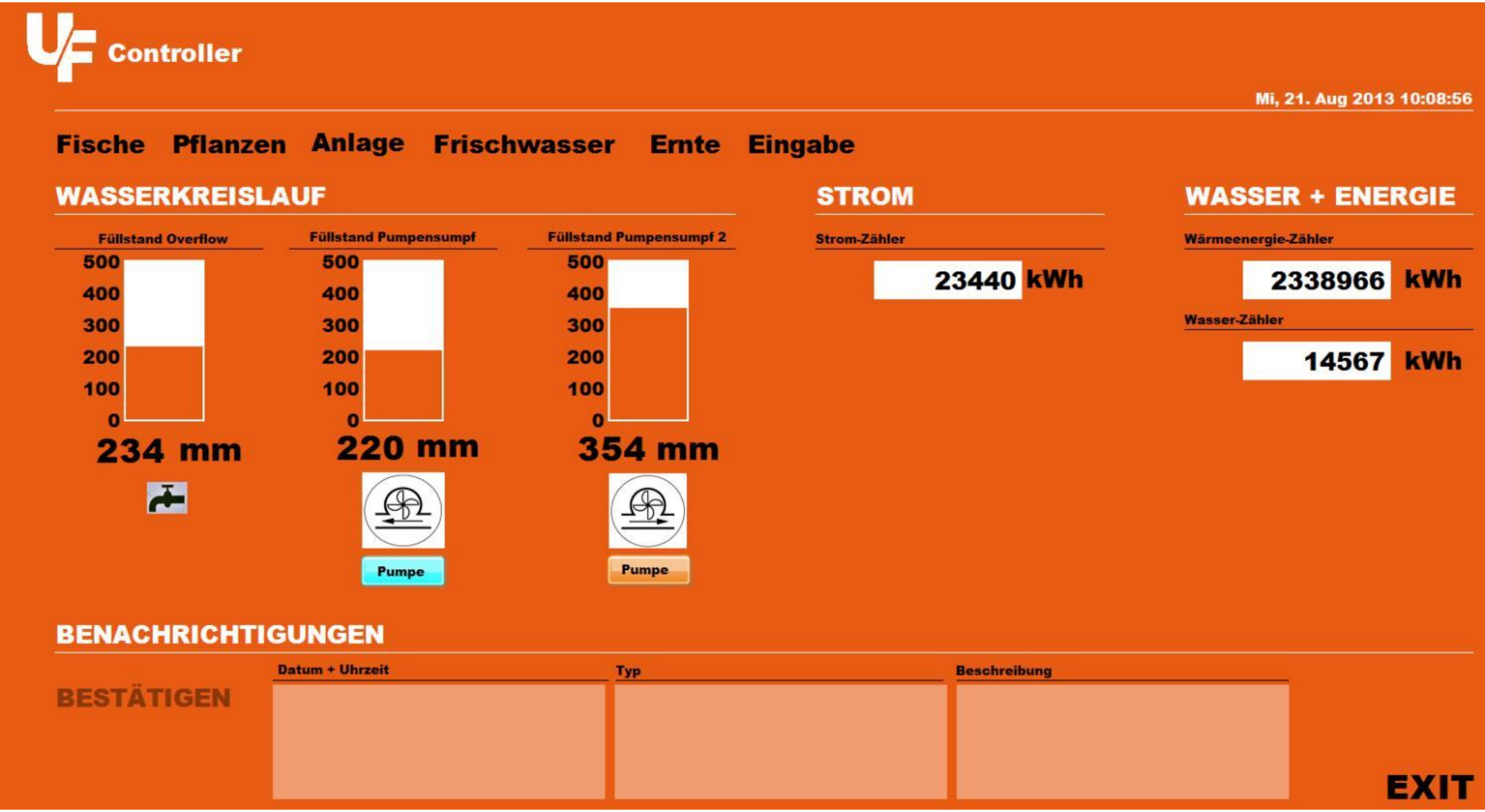
UF Controller Interface




Thank you very much
for your attention!