FIPSE-04 „FUTURE INNOVATIONS FOR PROCESS SYSTEMS ENGINEERING“

Water Challenges

Future Directions for the PSE-Community

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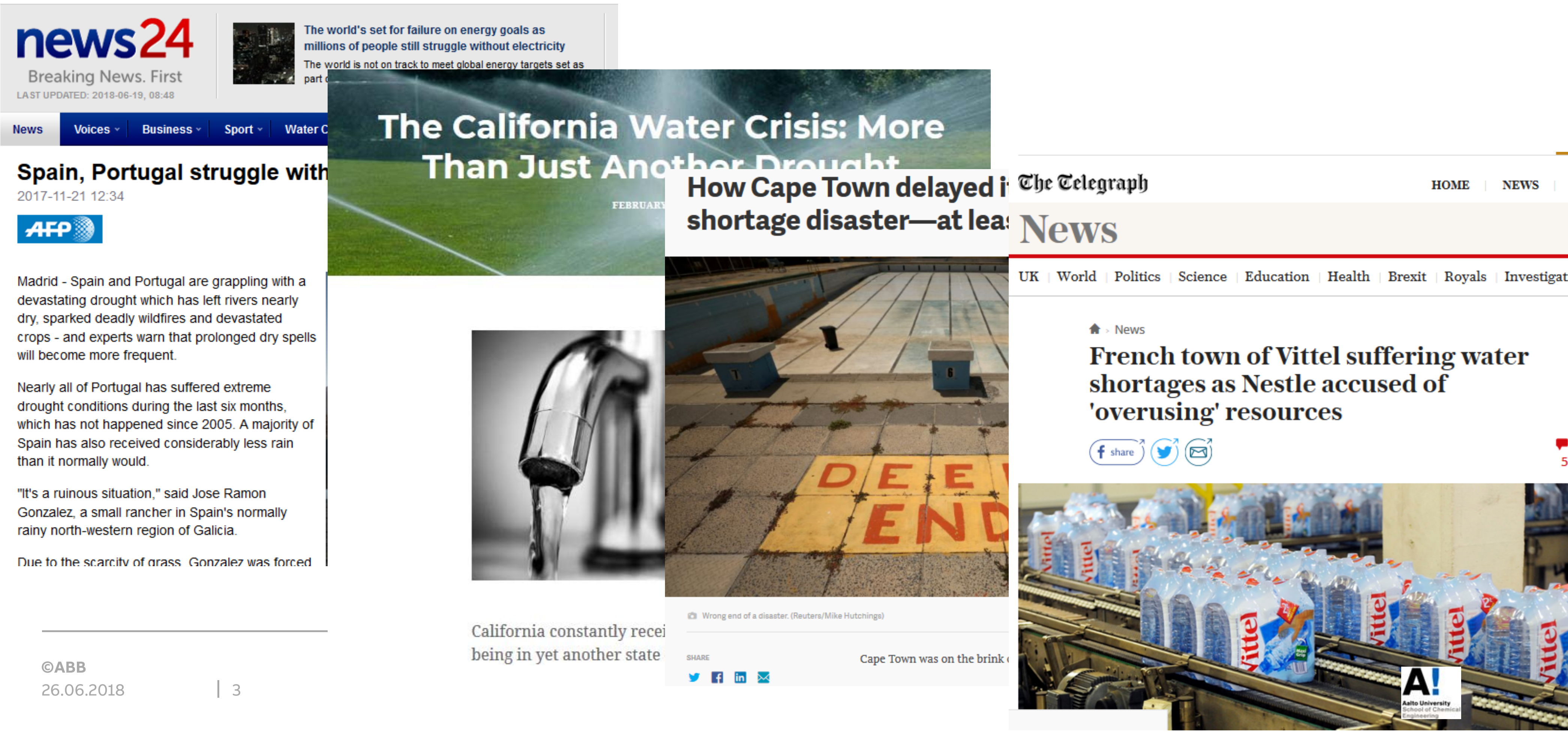
Water – a challenge?

Most of us are lucky not to be facing the water „problem“, the most visible sign of that something is going on is

Water in the News



news24
Breaking News. First
LAST UPDATED: 2018-06-19, 08:48

The world's set for failure on energy goals as millions of people still struggle without electricity

The world is not on track to meet global energy targets set as part

News | Voices | Business | Sport | Water C

Spain, Portugal struggle with

2017-11-21 12:34

AFP

Madrid - Spain and Portugal are grappling with a devastating drought which has left rivers nearly dry, sparked deadly wildfires and devastated crops - and experts warn that prolonged dry spells will become more frequent.

Nearly all of Portugal has suffered extreme drought conditions during the last six months, which has not happened since 2005. A majority of Spain has also received considerably less rain than it normally would.

"It's a ruinous situation," said Jose Ramon Gonzalez, a small rancher in Spain's normally rainy north-western region of Galicia.

Due to the scarcity of grass, Gonzalez was forced

The California Water Crisis: More Than Just Another Drought

FEBRUARY

California constantly recei being in yet another state

How Cape Town delayed i shortage disaster—at lea

Wrong end of a disaster. (Reuters/Mike Hutchings)

SHARE

Cape Town was on the brink

The Telegraph

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News

French town of Vittel suffering water shortages as Nestle accused of 'overusing' resources

share

5

MegaTrends in Water

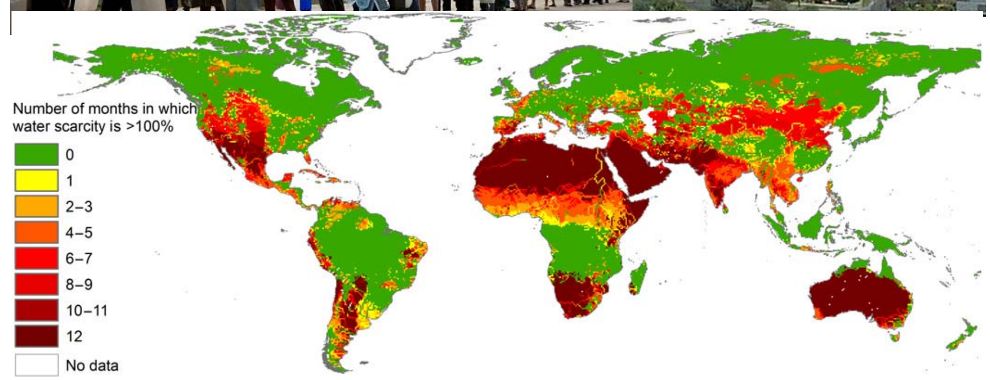
Scarcity & Leakage

Currently some 2.5–3.0 billion people do not have access to clean water

- To ensure all these people and an additional 2.3 billion people expected by 2050 have access to adequate quantity and quality of water will be a very challenging task

Leakage in current water systems is significant

- UK Water Customers are being asked to save water, but more than 20% of water is lost before it reaches homes and leakage levels are not declining
- US loses 1.7 TRILLION gallons of water a year due to broken pipes, that’s $2.6B worth of water. The American Society of Civil Engineers estimates total losses of $147B to the US economy from water infrastructure failures between 2013 and 2020!



Source: https://natgeoeducationblog.files.wordpress.com/2016/02/water-scarcity-map.jpg

MegaTrends in Water

Politics & Climate Change

Earlier no political importance

- During the 1950-1970s, main focus all over the world was on economic development to the extent that environmental conditions were compromised - “the price of progress” (by 1970, there was not a single Environment Ministry)

Water Pollution

- Growing population, urbanization and industrialization have resulted in heavy water pollution!

Growing Urban Clusters

- More and more people live in urban areas increasing the demand for water and risk of water pollution

Price of Water

- Water Tariffs too low to finance investments needed and motivate Water Saving!

Insufficient Water Governance missing in many regions

- Sustainable Water Management and effective control

Source: Whygreeneconomy.org

Water Facts & Predictions (UN)

Politics & Climate Change

Global water use has increased by a factor of six over the past 100 year and continues to grow steadily at a rate of about 1% per year

- At about 4,600 km3 per year (~Lake Michigan), current global withdrawals are already near maximum sustainable levels!

World population is expected to increase from 7.7 billion in 2017 to between 9.4–10.2 billion by 2050, around two thirds living in cities

Global demand for agricultural and energy production (mainly food and electricity), both of which are water-intensive, expected to increase by roughly 60% and 80% respectively by 2025

- Agriculture accounts for about 70% of global water withdrawals, the vast majority of which are used for irrigation
- Industry accounts for roughly 20% of global withdrawals (75% energy production, 25% industrial water for manufacturing)
- Domestic water use roughly accounts for the remaining 10%

Water demand for manufacturing is projected to increase by 400% over the period 2000–2050

CHINA'S 'SPONGE CITY' CONCEPT

Photo: © Syrnx/Shutterstock.com

Source: The United Nations World Water Development Report 2018

What can PSE Community Do?

Food-Energy-Water Nexus → Systems Engineering!

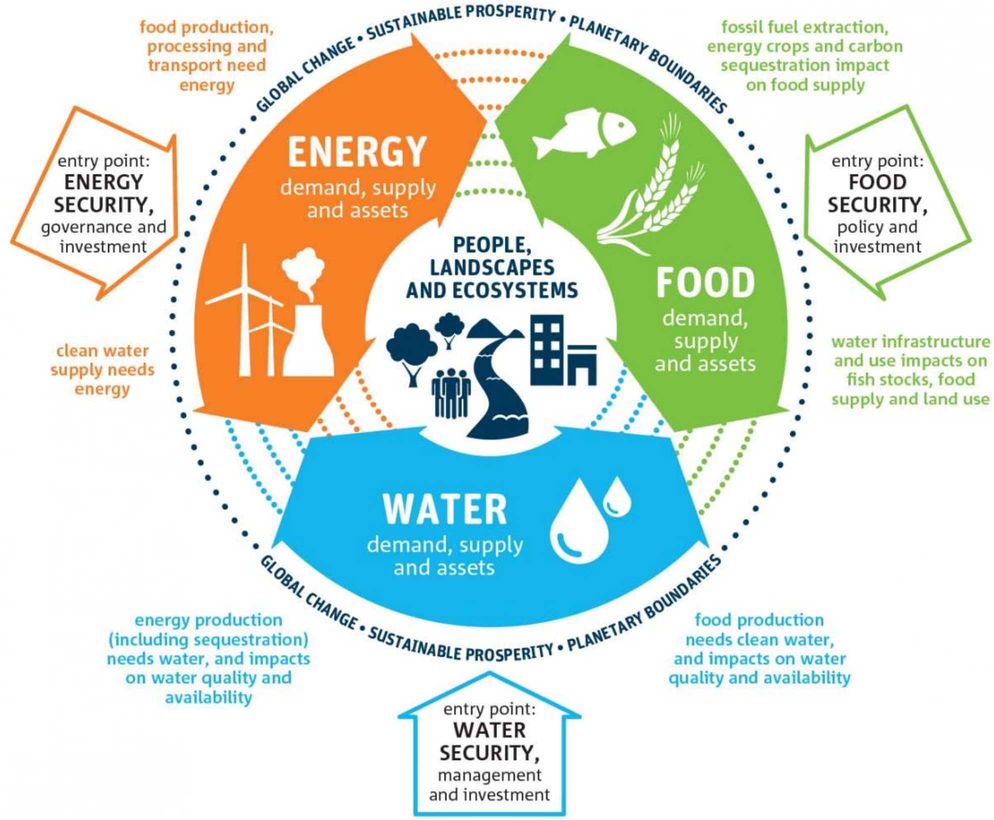
The FEW-Nexus = Conceptual framework to describe complex interrelationships associated with coupled human-natural systems at local, regional, and global scales

Inter-linkages between water, energy, and food → changes in one system can have far-reaching impacts in other systems (ecological, economic, social, and political)

- Analytical "tool" to understand the interplay between natural systems and their human dimensions
- Interconnections in decision-making that span particular objectives, production and consumption pathways, and regulatory modes

Represent systems as holistic entities → more integrative problem-solving and decision-making that accounts for and balances trade-offs and synergies within and across systems

Education component so far underemphasized, despite very real and pressing global challenges in the FEW-Nexus



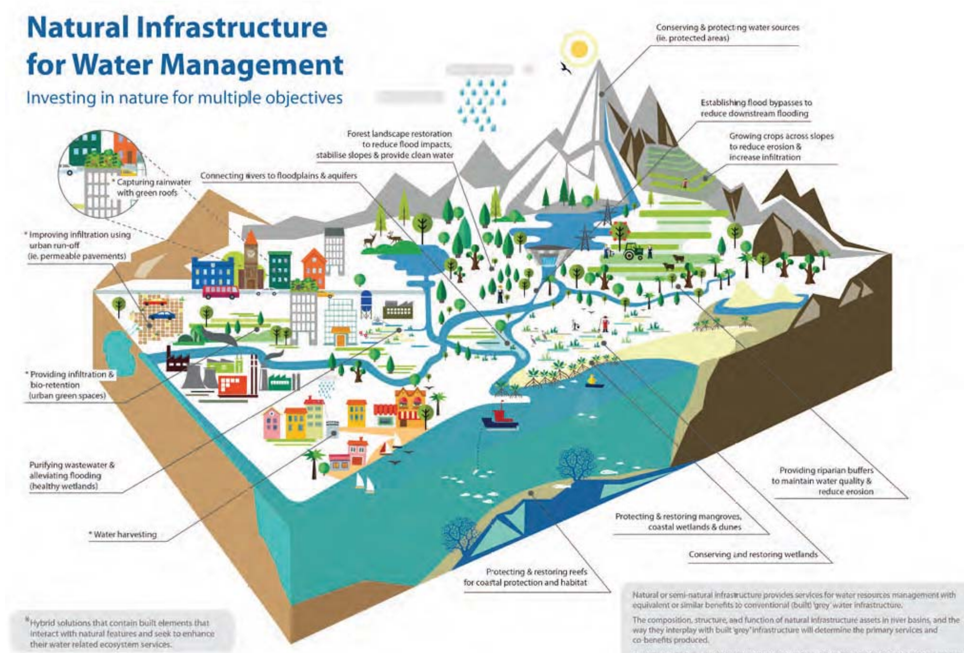
What can PSE Community Do?

Nature-based solutions (NBS)

NBS focus: Managing systems, including integrated green– grey infrastructure approaches maximizing system-wide benefits

The 'water–energy–food nexus' dialogue: Ecosystems need to be more explicitly integrated ('water–ecosystem– energy–food nexus'), because many of the key interlinkages between water, energy and food (reconcile potentially competing interests)

- Improve water quality by reducing pollution, eliminating dumping, minimizing release of hazardous chemicals and substantially increasing recycling and safe reuse globally
- Substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply
- Implement integrated water resources management at all levels
- Expand international cooperation in e.g. water harvesting, desalination, water efficiency, wastewater treatment, recycling
- Upgrade infrastructure and retrofit industries to make them sustainable, with increased resource use efficiency and clean and environmentally sound technologies and industrial processes



Source: The United Nations World Water Development Report 2018

Energy and the Fourth Industrial Revolution

Perfect time to merge & expand research focus!

The Energy Revolution

The Fourth Industrial Revolution

Utilities | **Industry** | **Transport & Infrastructure**

ABB

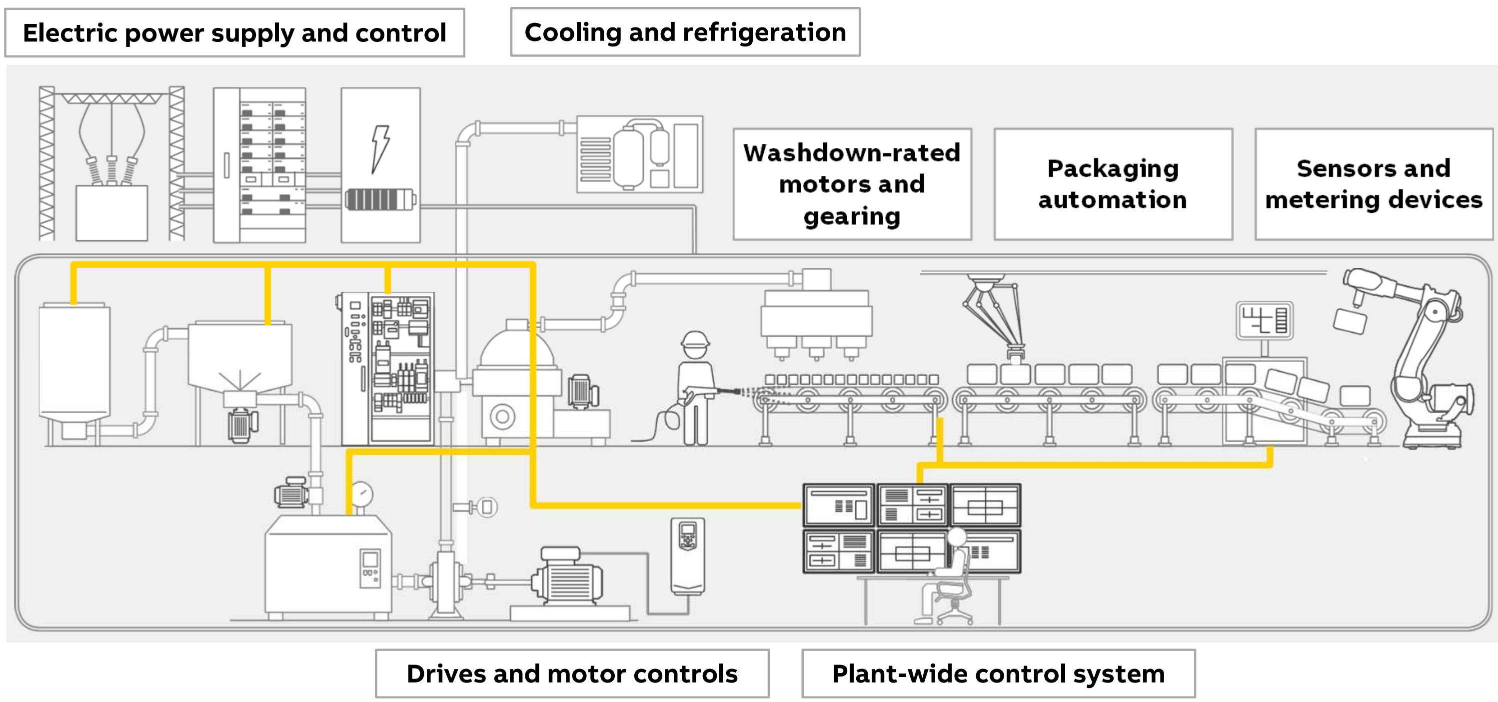
Example: Water in Food & Beverages (10% of global GDP)

Very resource intensive (water and electric energy): Reuse and reduce

	Food	Alcoholic beverages	Dairy	Soft drinks & Juices	Meat, Poultry & Seafood
Segment					
Applications	Flour & Grain Sugar Edible oil & Mustard Confectionary	Brewing Energy balancing Alcohol production	Reception, separation & standardization Whey, cream & yoghurt Cheese yield & ripening Dairy disposal	Filling & dosing of drinks Fruit juice production Energy monitoring	Animal feed production & disposal
Water & Energy usage	Water reuse is necessary to meet sustainability goals & reduce consumption/ discharge, thereby reducing operating costs	Water reuse is an attractive option to minimize use of additional potable water and discharge of wastewater	High organic loads in the effluent stream need to be treated prior to discharge into municipal sewage systems or receiving bodies of water	Reducing overall water consumption while optimizing available floor space is a continuous challenge	Water discharge limits pose a challenge for meat process plants due to high organics, COD and BOD in waste streams

Many inter-related systems and processes

There are benefits to an integrated approach

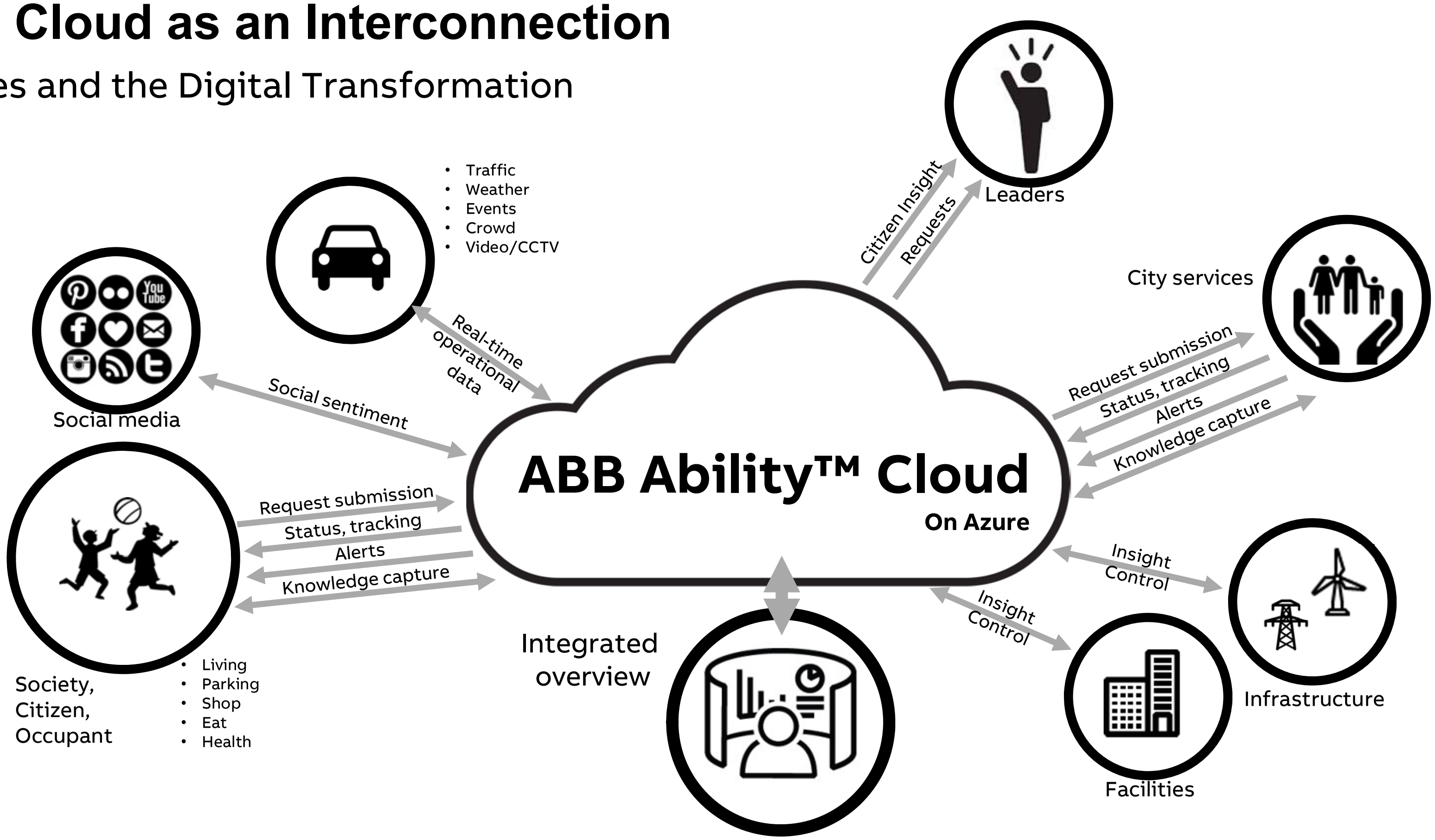


Smart instruments for asset utilization and optimization
Optimize energy and water usage, while reducing downtime

- Smart instruments remove the complexity of devices and helps manufacturers reduce downtime, manage energy and water use, and improve operational efficiency
- Real time and historical trending data allows facility managers to easily manage and monitor both their energy and water use anytime and anywhere
- Integrating smart instruments with automation control offers simple, intuitive information to facility managers enabling smarter decisions for energy management

Using the Cloud as an Interconnection

Water Utilities and the Digital Transformation

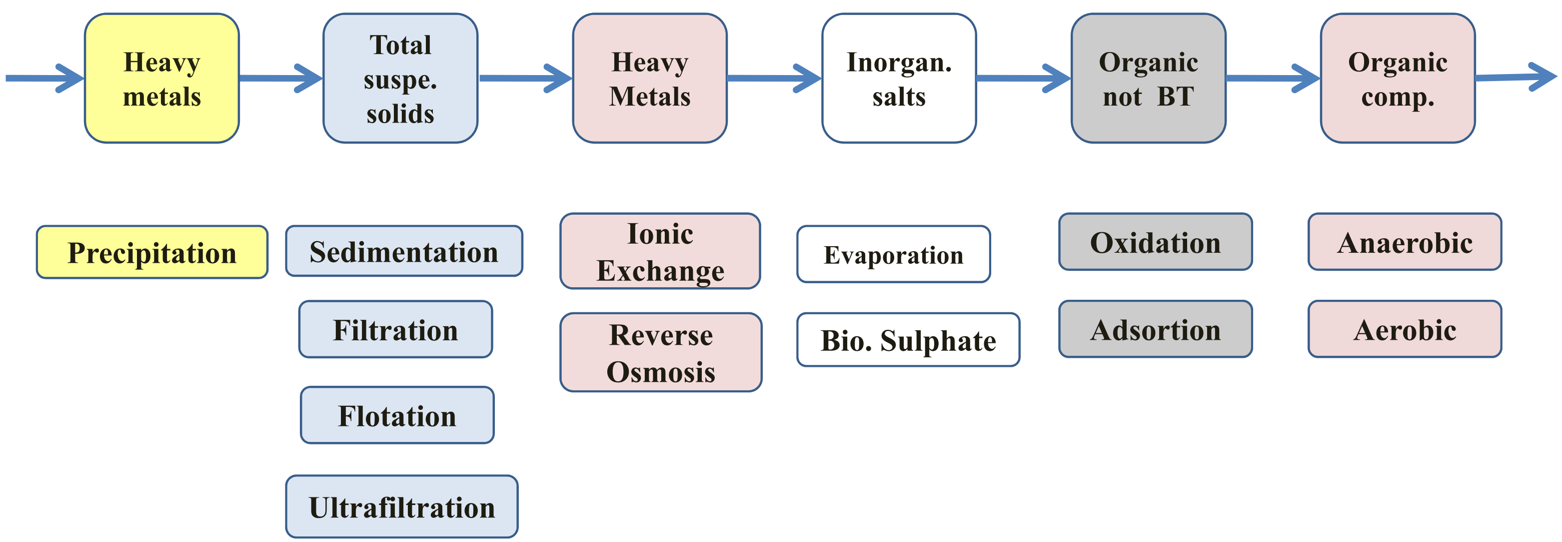


Note on Treatment Units

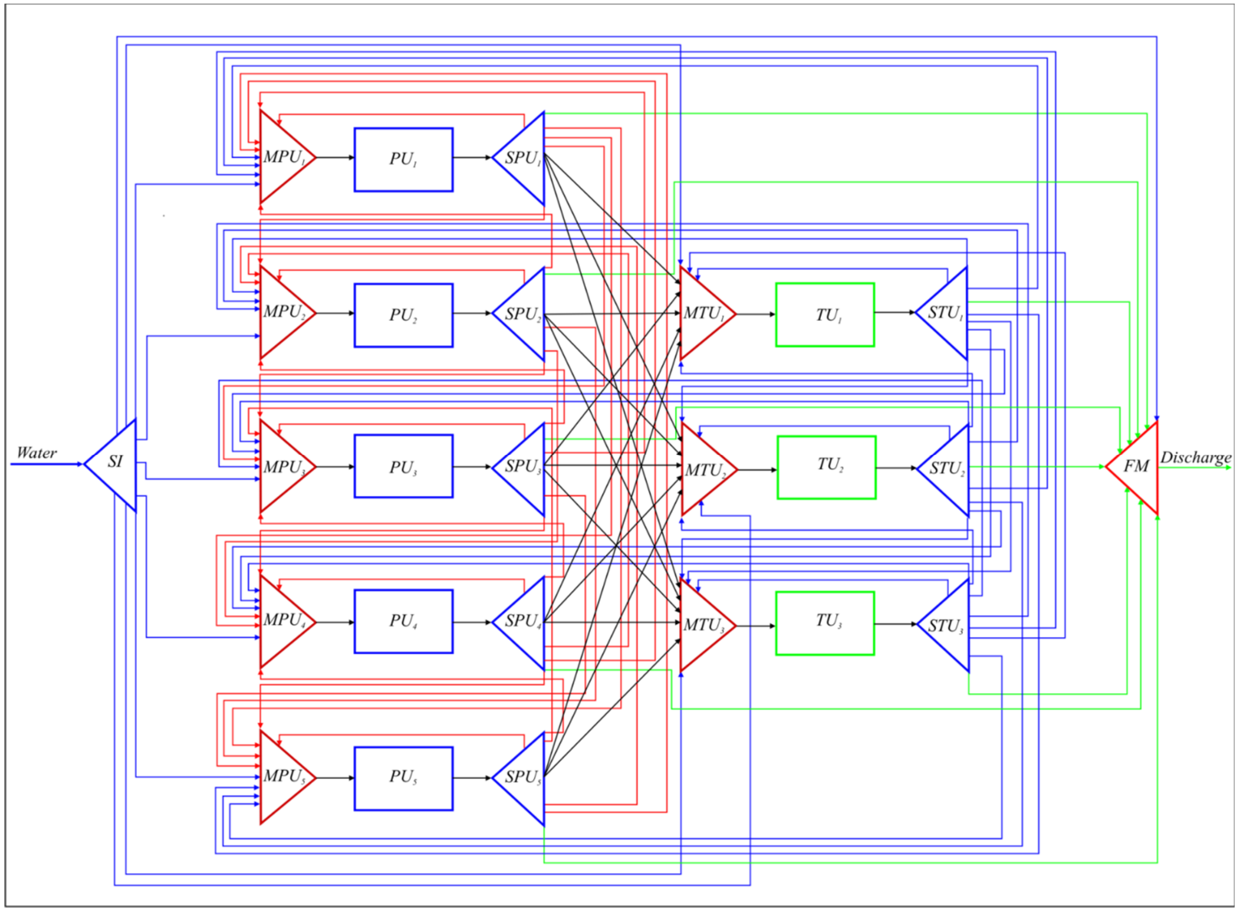
Galan, Grossmann (2011)

Industrial wastewater requires complex treatment networks

Sequential treatment chosen with 2-4 Best Available Technologies for the removal of each type of pollutant



Superstructure of the integrated water network

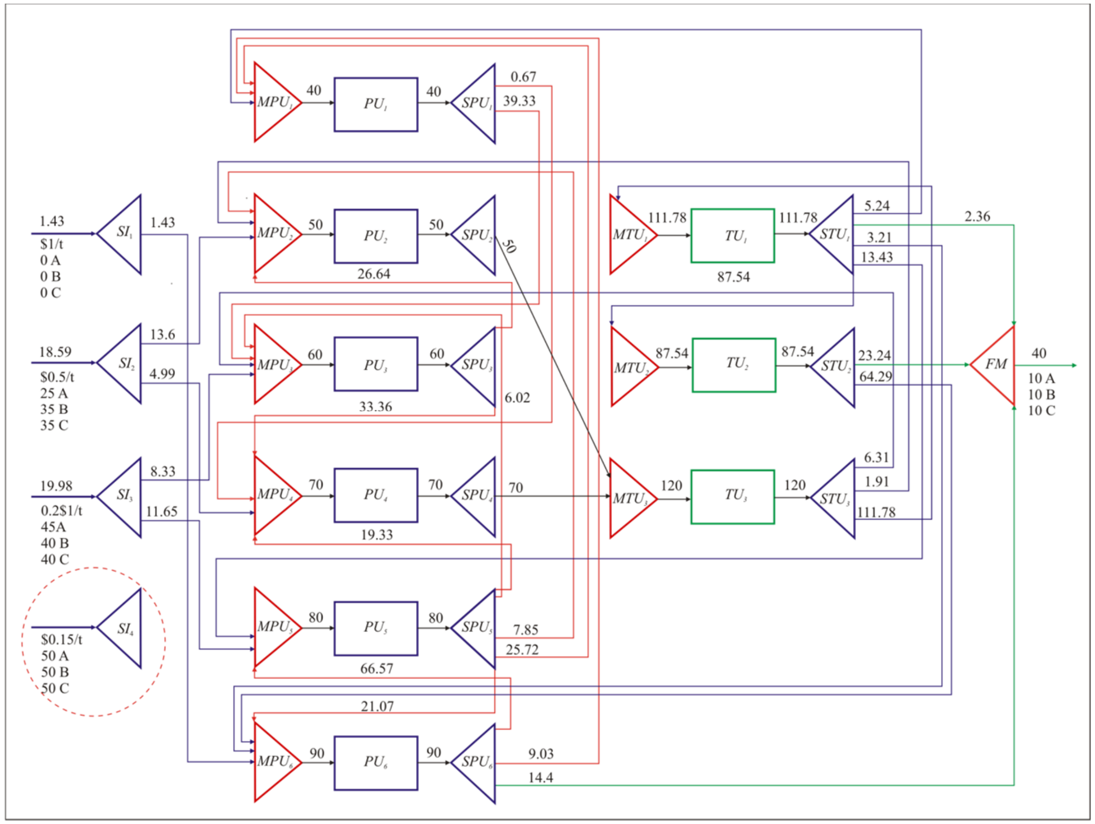


MINLP: 72 0-1 vars, 233 cont var, 251 constr
optcr=0.01 197.5 CPUsec

Large scale water network problem

4 feeds, 6 process units, 4 treatment units, 3 contaminants

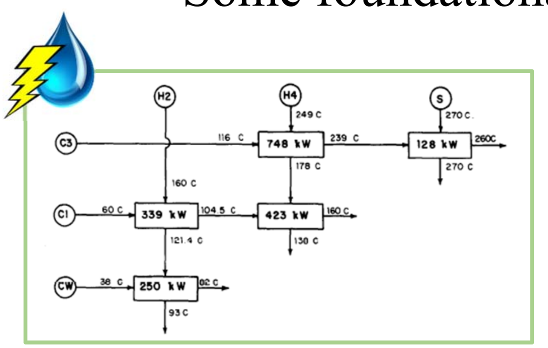
Optimal Freshwater Consumption
40 t/h
vs
390 t/h
conventional



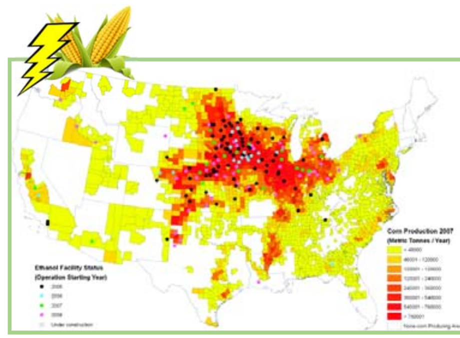
NLP: 232 variables, 121 constraints BARON: 2 secs

The FEWN and Systems Engineering

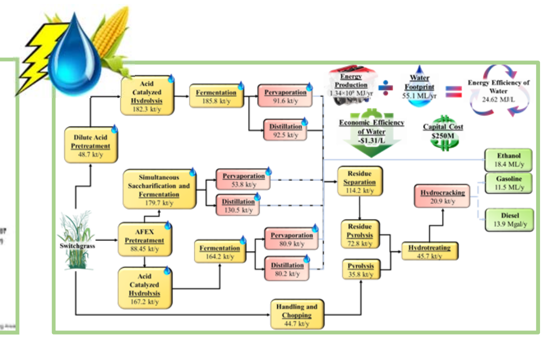
- The FEWN is fundamentally an interconnected network of processes and systems that must be **engineered** for sustainability
  - Systems Engineering is thus well-suited to model, analyze, and optimize the EWFN – almost by definition!
- Some foundational research:



Heat exchange networks



Biofuel supply chain



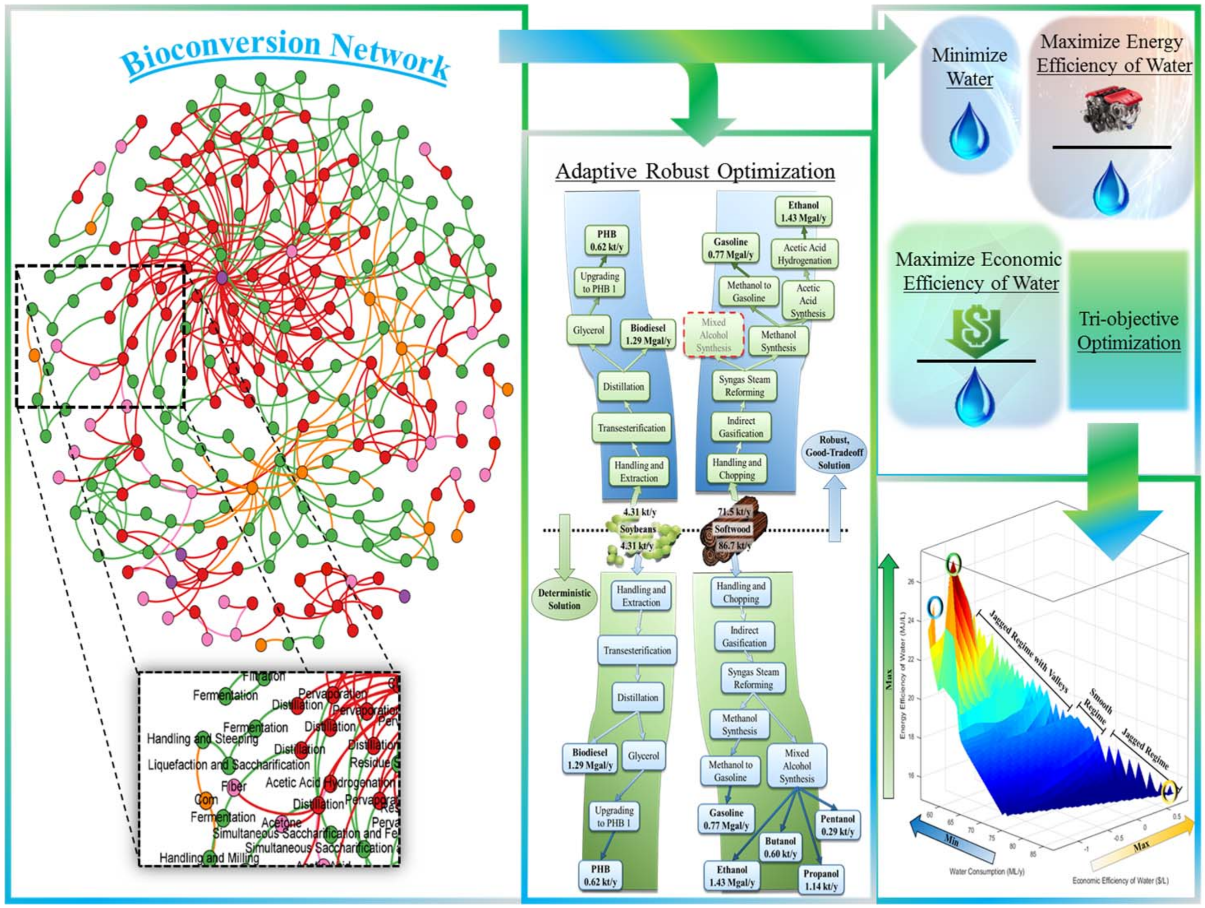
Water minimization for biofuels production

Papoulias, S. A. & Grossmann, I. E. (1983) Computers & Chemical Engineering, 7, (6), 707-721.
You, F. & Wang, B. (2011) Industrial & Engineering Chemistry Research, 50, 10102-10127.
Garcia, D. J. & You, F. (2015) Processes, 3, 514-539.

Four Examples

- **Shale gas water management**
  - **Water for Energy**
- **Energy optimization of water supply network**
  - **Energy for Water**
- **Water and energy efficiency analysis of biomass conversion network**
  - **Food, energy, water**
- **Recover energy and nutrient from food waste**
  - **Food, energy, water**

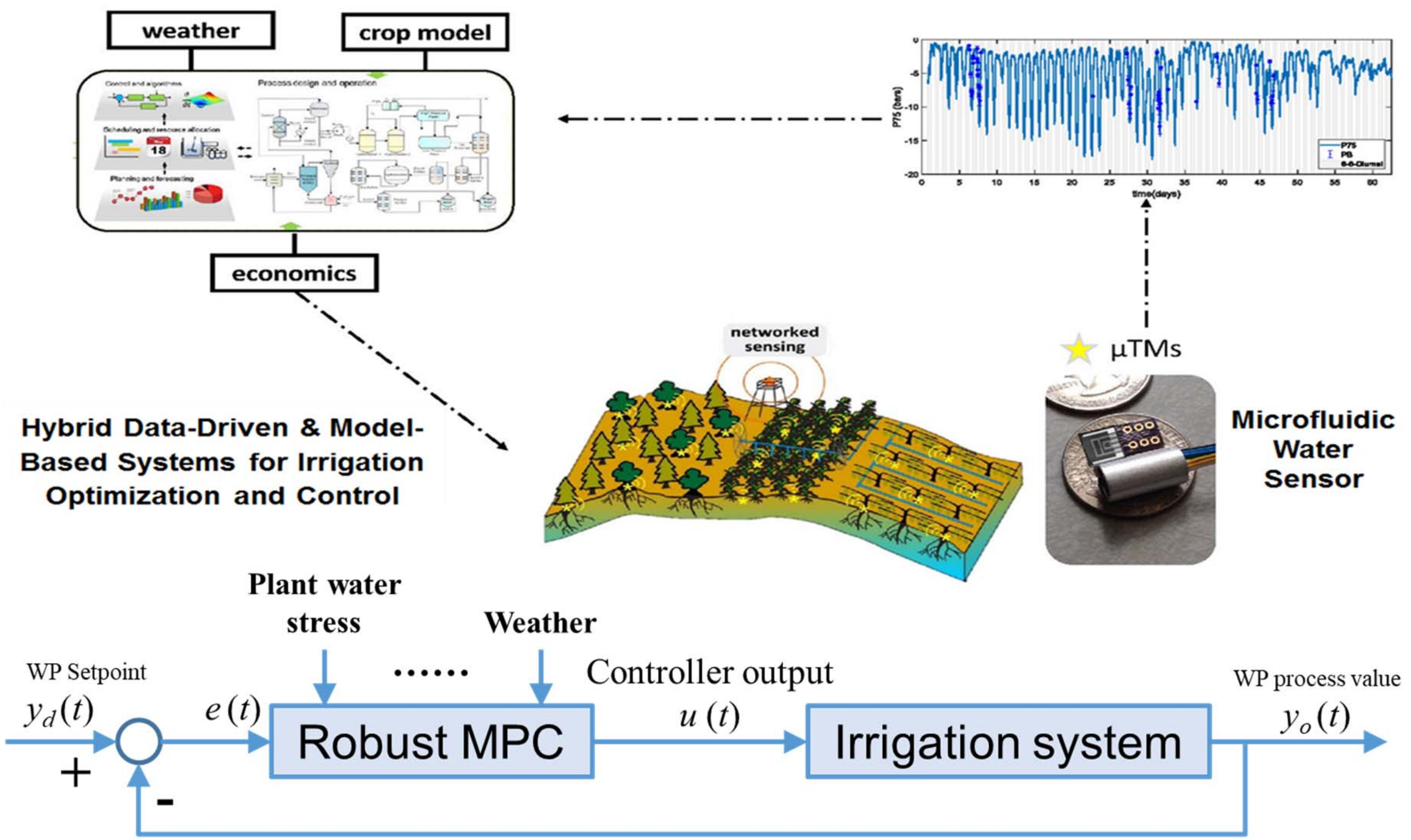
Network Analysis and Optimization for FEWN



Gong et al. (2016). *ACS Sustainable Chem. Eng.*, 4, 3160–3173.
Garcia & You (2015). *Processes*, 3, 514-539.
Garcia & You (2015). *AIChE J.*, 61, 530-554.

Smart Irrigation Scheduling and Process Control

Guo, Lakso, Stroock & You (2018)



Conclusions: All areas of PSE Needed!

Target: Sustainable resource utilization + minimizing operating costs + emissions reduction

Extrapolating the current development → CATASTROPHY!

Paradigm shift necessary: New knowledge, concepts, and solution methods required, e.g. for solving the overall synthesis problem, including large-scale and industrial examples

- Simultaneous optimization of the process flowsheet, water and heat integration

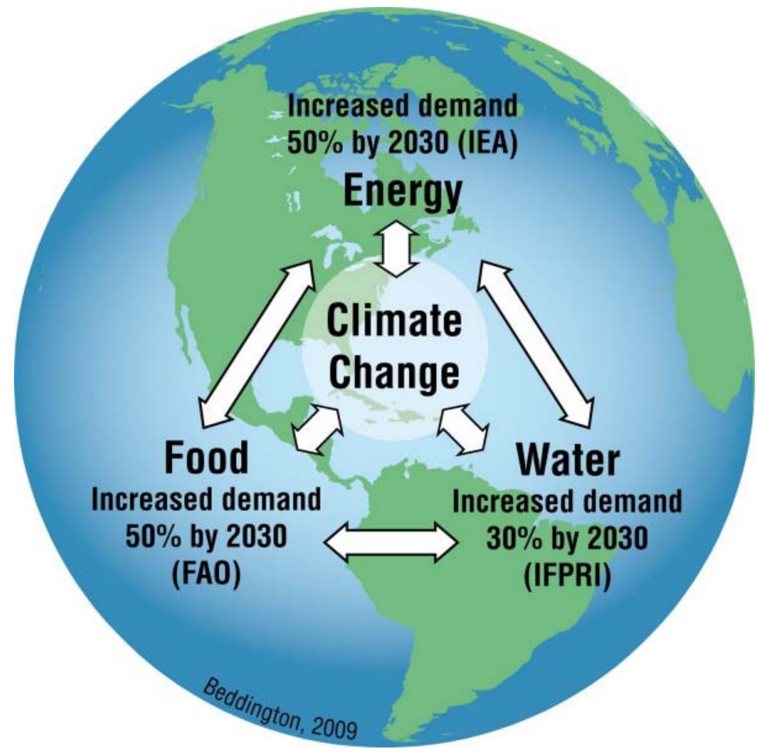
New solution strategies and tools are also required for solution of large-scale operations and networks within the Food-Energy-Water Nexus

- Digitalization an enabler, collaboration with biosciences on micro- and macroscale necessary

Obtain the improved energy and water efficiency through sustainable, and profitable solutions.

- Understand and combine: Process systems, Power systems, Water systems and Ecosystems

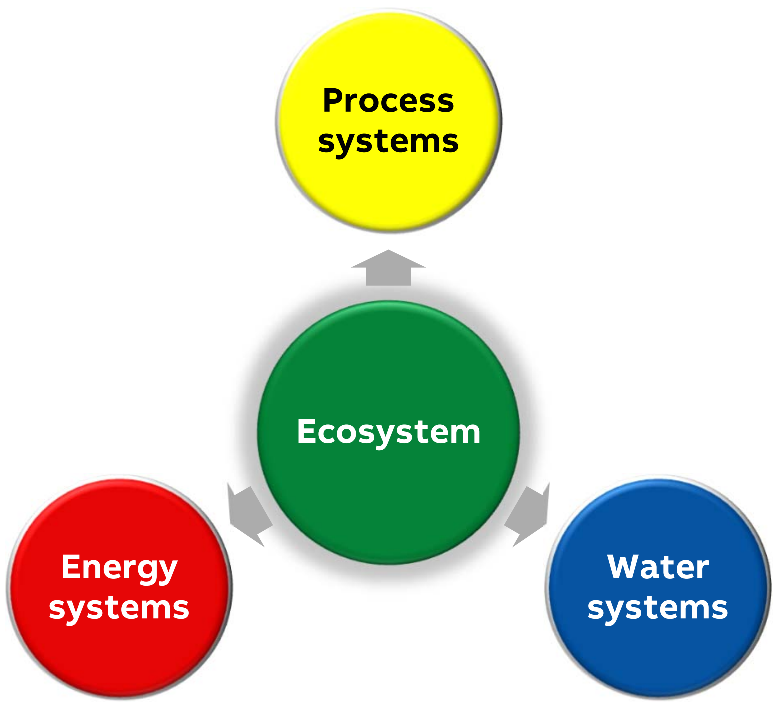
Driving forces: Circular economy, Bioeconomy, Digitalization



Source: a.o. E. Ahmetovic et al. / Computers and Chemical Engineering 82 (2015) 144–171

Cross-Collaboration between Disciplines Necessary

PSE is an excellent „glue“ between areas and „catalyst“ for optimal solutions



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