Established methods for future-oriented technology analysis

water technology as a case

Ahmed Gaber

May 23,2015

Outline

1. Strategic Review of Technology Landscape
2. Technology Roadmap
3. Future-Oriented Technology Analysis (Strategic Foresight)

1. Strategic Review of Technology Landscape

KACST-THOMSON REUTERS wonderful work published 2013, strategic review of scientific papers and patents in 15 technology areas.

The output is valuable and the applied process and tools are as valuable.

CONTENTS

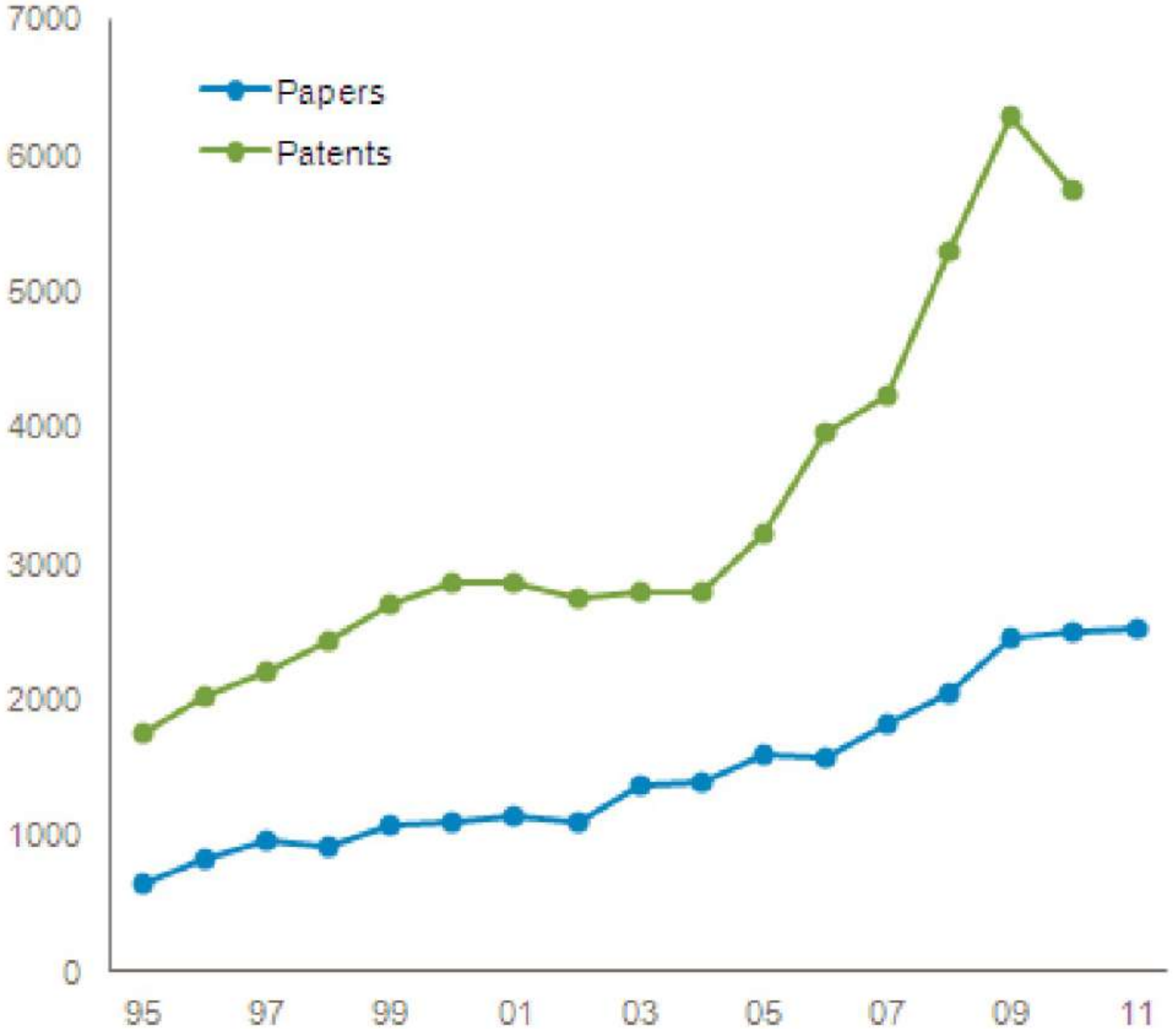


Figure 2 – Timeline[1] of Scientific Paper and Patent Family Activity

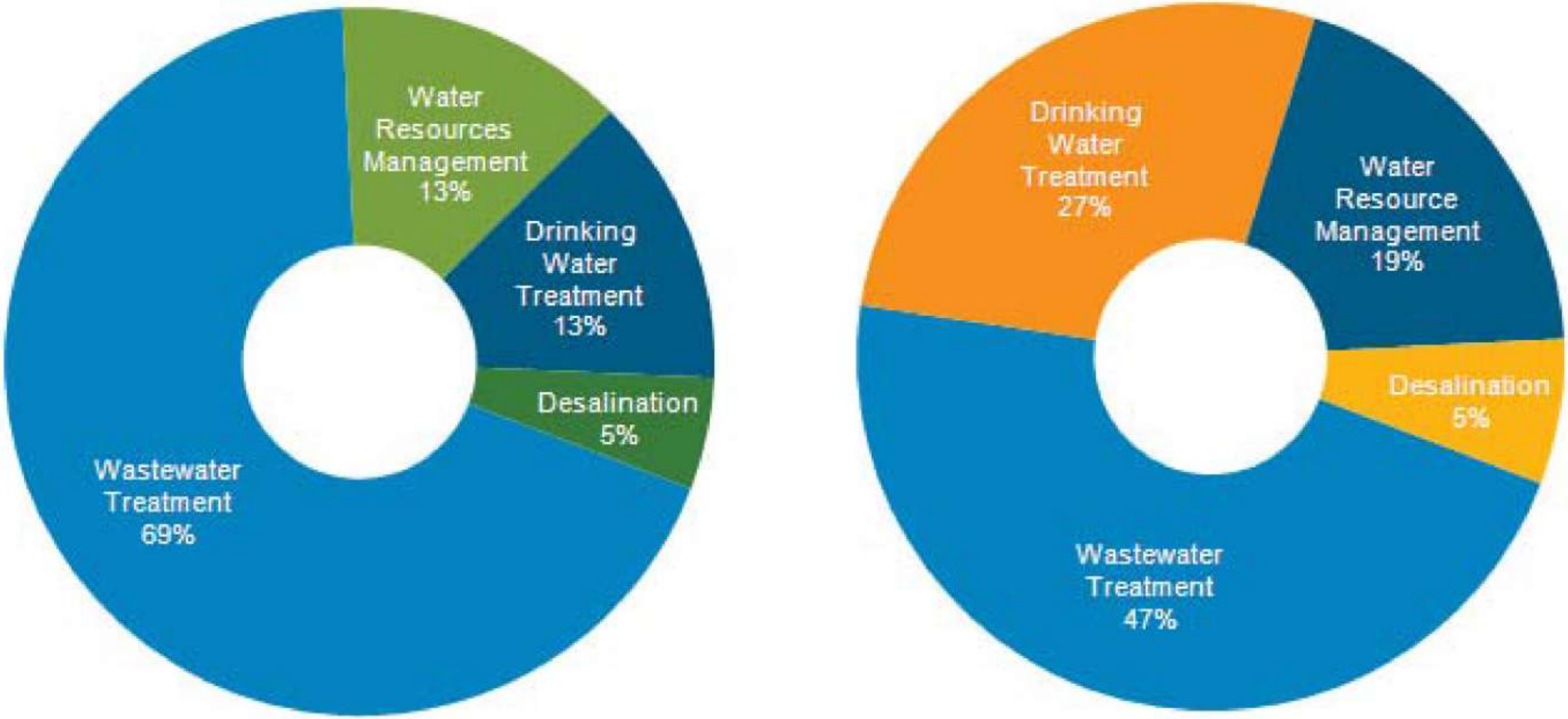


Figure 3 – % of Patent (left) and Scientific Paper (right) collections by Water Topic

Waste water treatment is the single largest topic of scientific research in terms of volume and is growing at a healthy level in patent output, but shows much more modest rises in output amongst scientific papers. This trend would indicate that research in wastewater treatment has become significantly more applied in recent years.

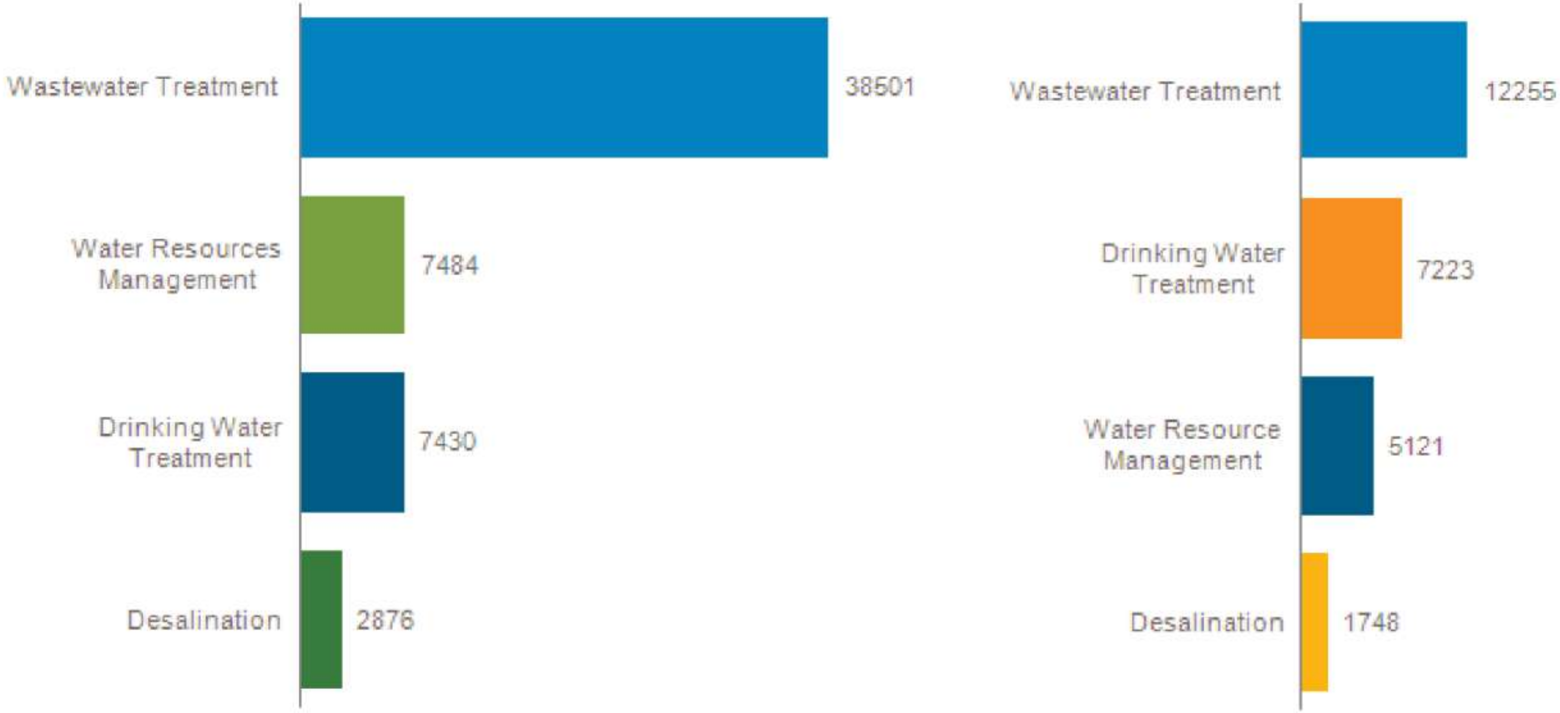
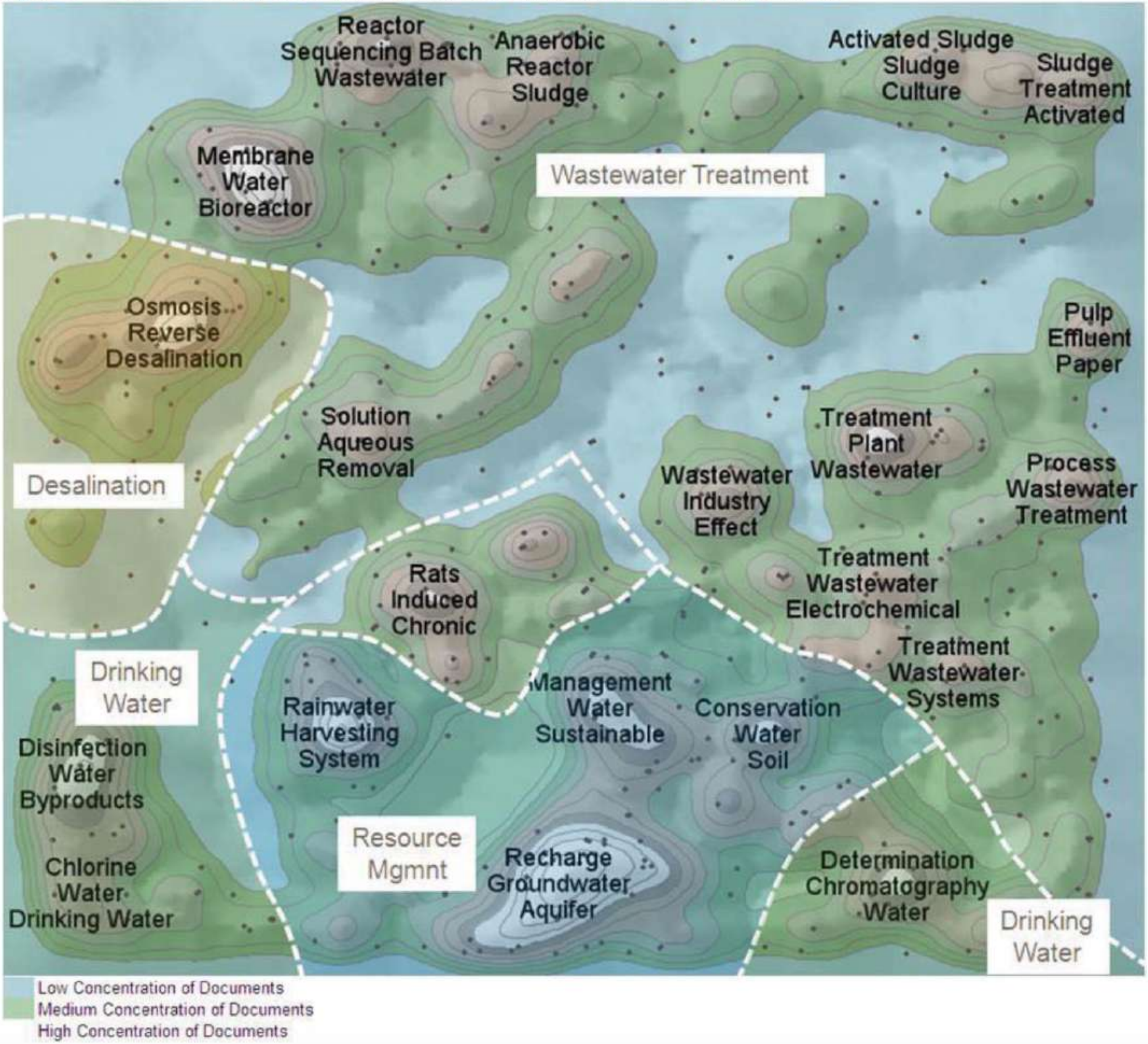


Figure 4 – Number of Patents Families (left) and Scientific Papers (right) per Water Topic

Figure 8 – ThemeScape Map of Scientific Paper Water Collection; Annotated by Major Theme



ThemeScape Map of Scientific paper Water Collection

26,000 papers are shown in Figure 8 as a “ThemeScape map” - a visualization method for understanding the common themes and concepts within thousands of documents. Used for market analysis, government intelligence and primarily technology landscape, the algorithm parses large amounts of text into a topological map of peaks and troughs.

Themes that are commonly shared between documents are represented by mountainous peaks, where as documents that share little commonality are located within the valleys of the map.

The location of an individual document is the vector sum of all the attractions to other documents in the collection based on shared phraseology and the frequency and proximity of these terms.

The map has been annotated by hand to summarize the major technology areas within the project collections. Some technologies will necessarily overlap, and the delineation of one technical area versus another is therefore only approximate. However the map is very useful in describing what topics are features of global water scientific research.

Source: KACST study, page 14

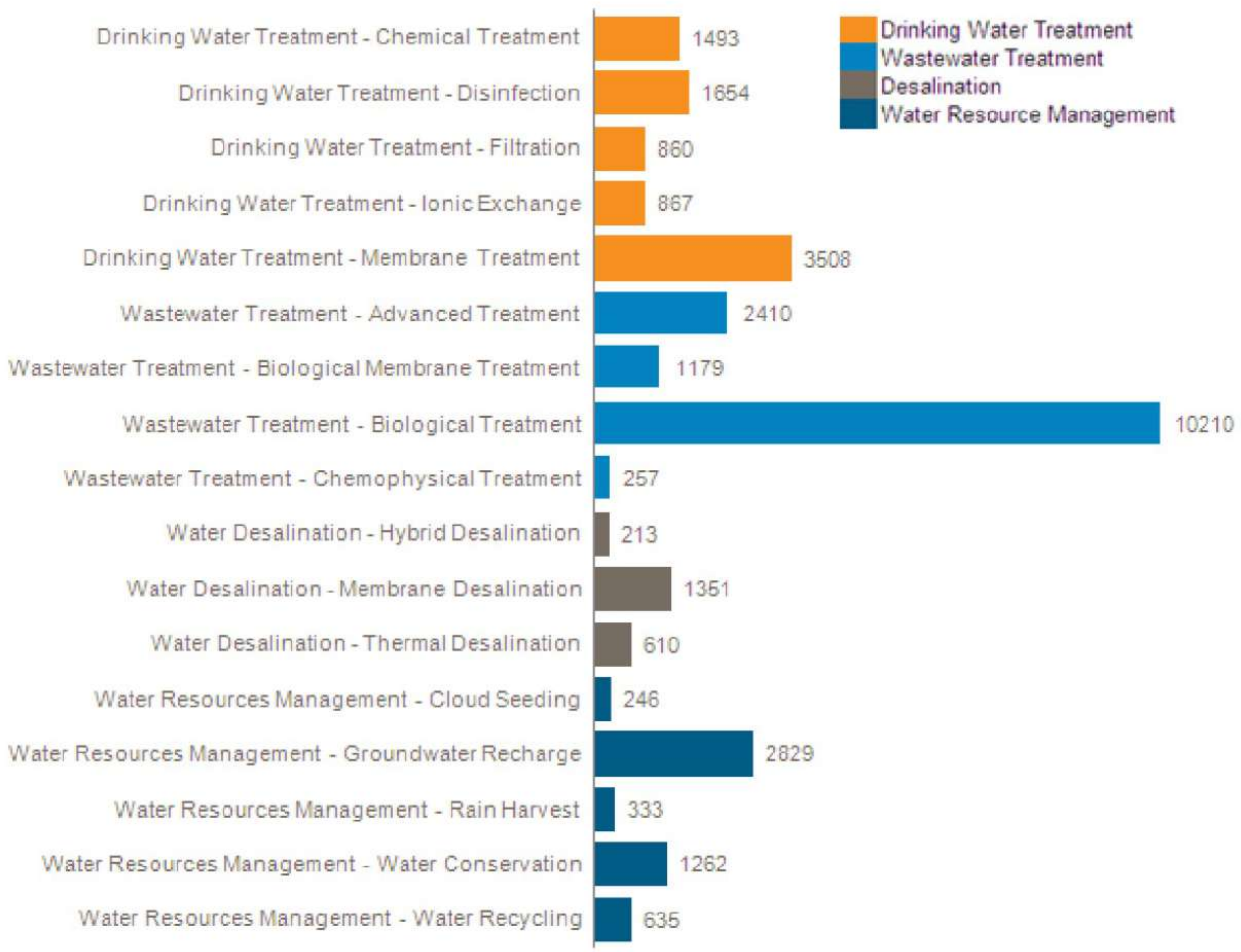


Figure 9 - Number of Scientific Papers per Water Category, 1995 to 2011

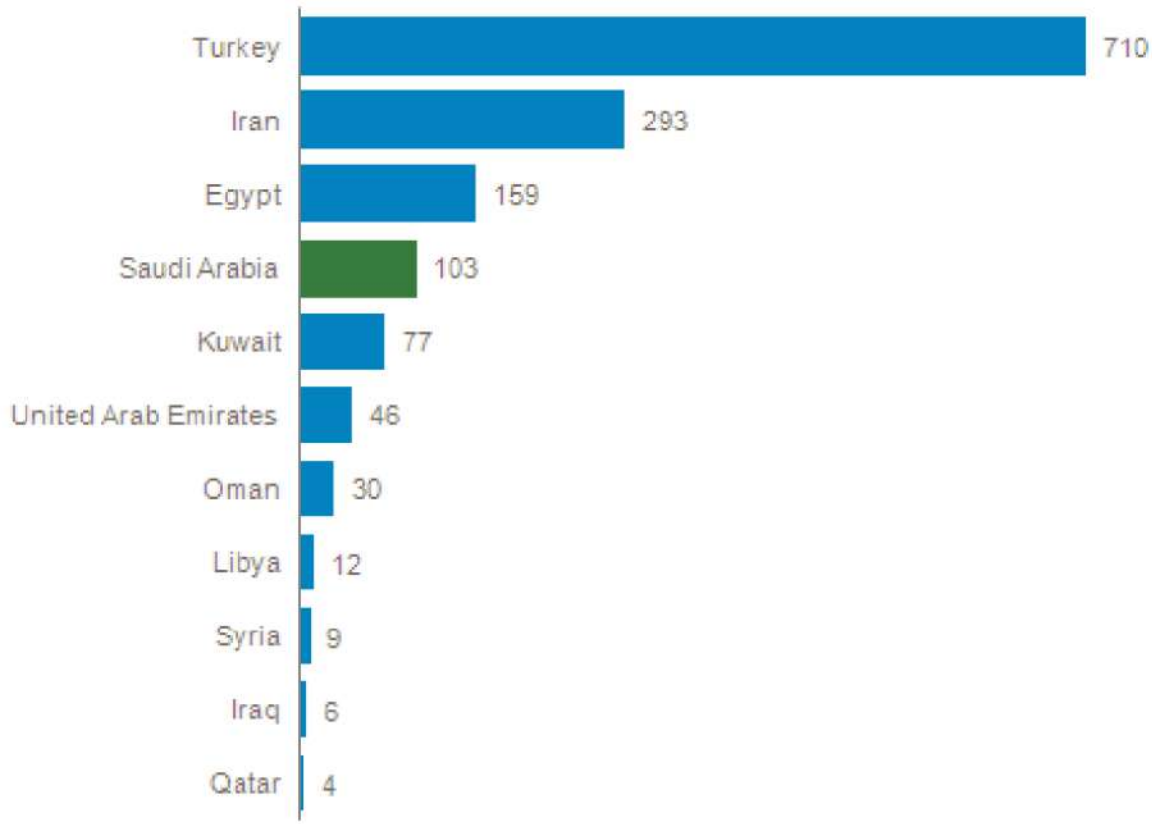


Figure 14 – Number of Scientific Papers per Country; KSA Regional Competitors, 1995 to 2011

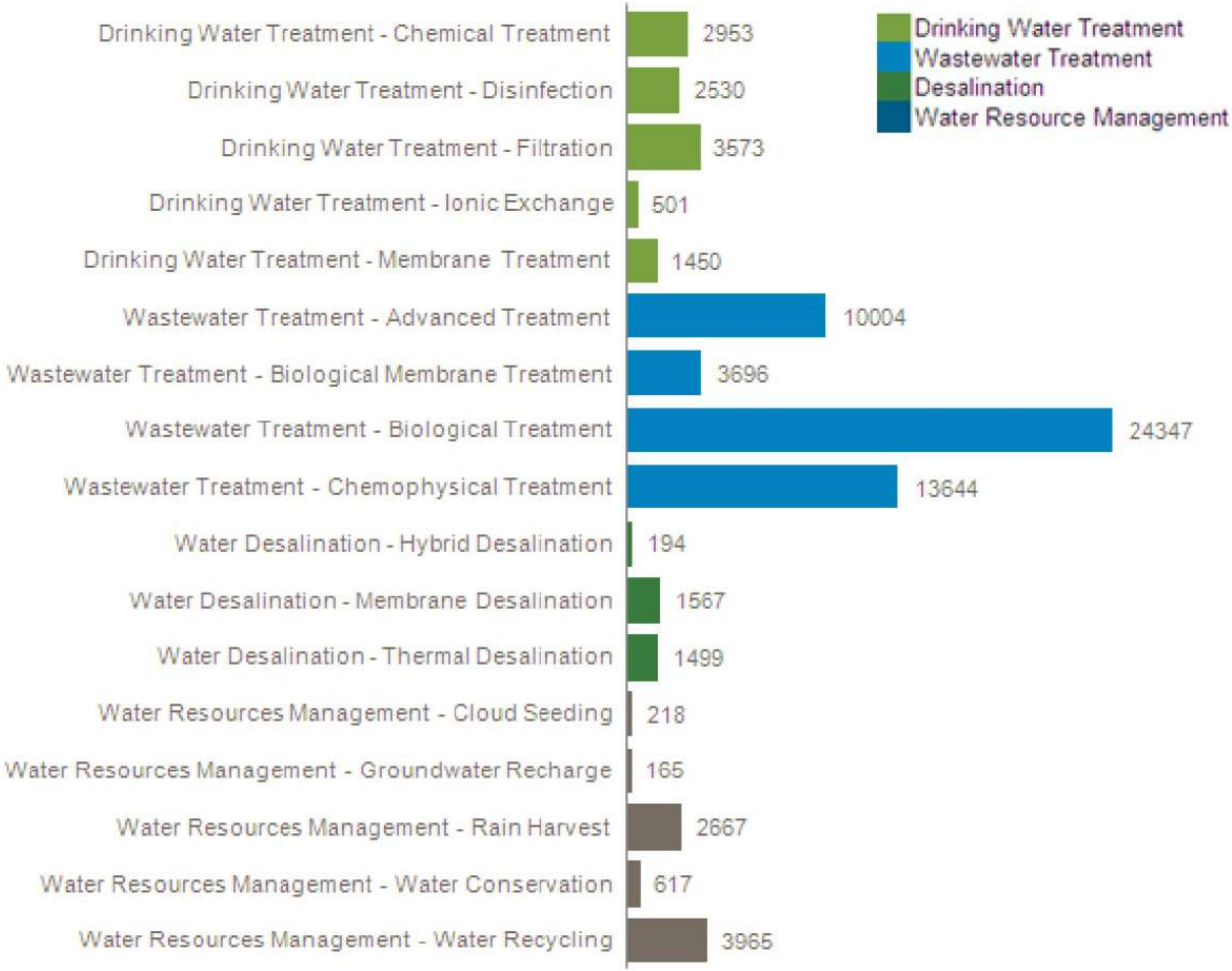


Figure 23 - Number of Patent Families per Technology Field, 1995 to 2010

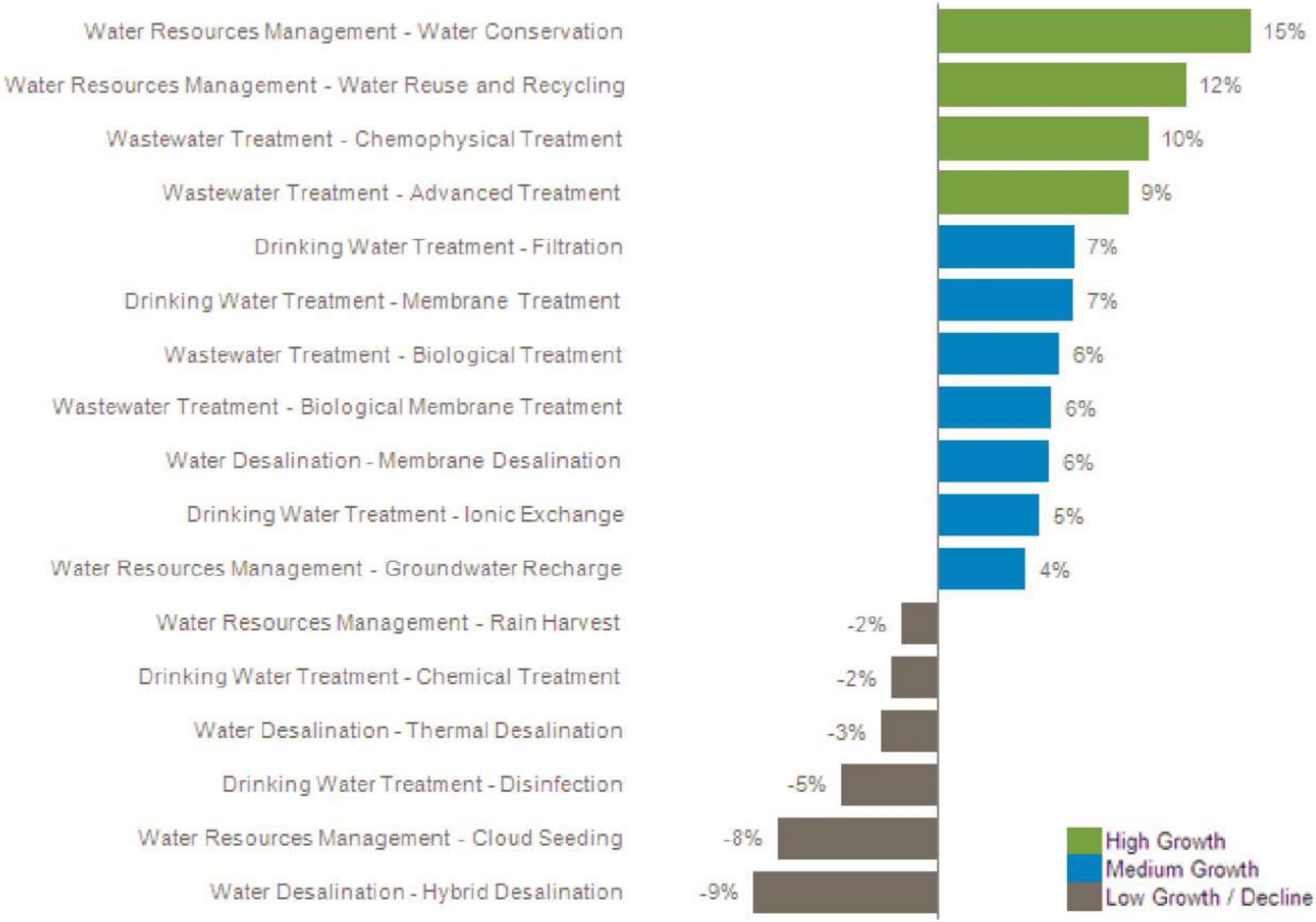
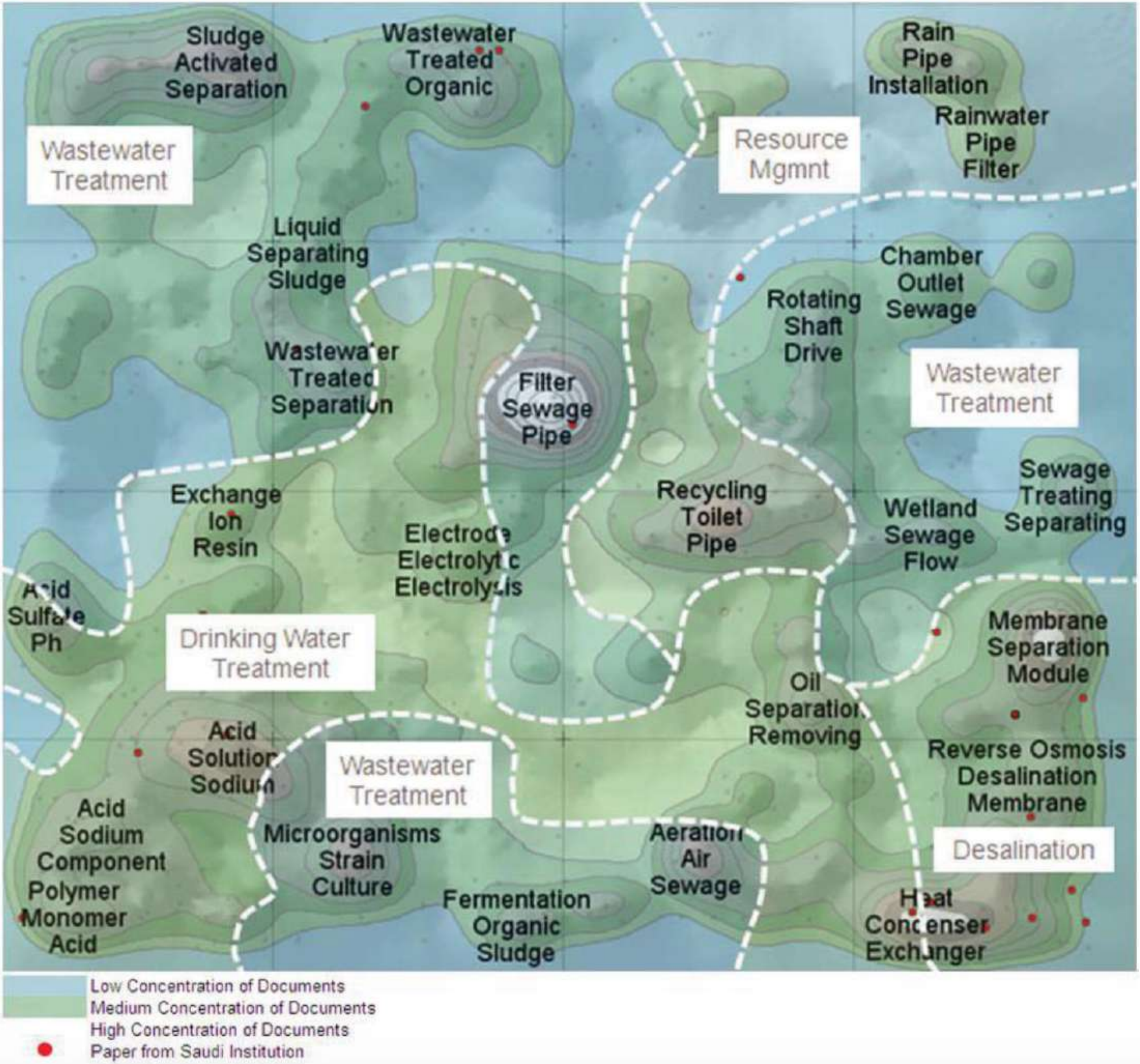


Figure 24 - Average Annual % Growth or Decline in Patent Family output between 2006 and 2011, by Water Category

Figure 32 - ThemeScape Map of Water Patent Collection; Annotated by Major Theme. Saudi Patents Highlighted.



ThemeScape Map of Water Patent Collection

Table 10 – Number of Patent Families per Country, 1995-2011: Wastewater Treatment – Biological Membrane Treatment, Biological Treatment and Chemophysical Treatment

Wastewater Treatment - Biological Membrane Treatment	Total
Saudi Arabia	3
Japan	1516
China	1156
United States	353
South Korea	309
Germany	154
European Patent Office	113
France	62
Canada	32
Australia	27
United Kingdom	26
Netherlands	20
Taiwan	20
Russia	17
Italy	12
Spain	9
Austria	8
South Africa	7
Denmark	6
Singapore	6
Sweden	6
Belgium	5
Israel	4
Brazil	3
Switzerland	3
Czech Republic	2
India	2
Malaysia	2
New Zealand	1
Portugal	1

Wastewater Treatment - Biological Treatment	Total
Saudi Arabia	6
Japan	9216
China	7508
South Korea	2567
United States	1893
Germany	1139
European Patent Office	682
Russia	453
France	305
United Kingdom	187
Canada	145
Australia	140
Spain	91
Netherlands	84
Taiwan	80
Italy	68
Sweden	66
Czech Republic	62
Austria	61
Denmark	53
Brazil	50
Finland	43
Belgium	42
South Africa	37
Israel	31
New Zealand	30
India	25
Mexico	25
Hungary	23
Poland	22
Singapore	20
Switzerland	16
Romania	14
Norway	12
Malaysia	10
Portugal	10
Slovakia	9
Ireland	8
Ukraine	7
Chile	5
Greece	5
Croatia	3
Colombia	2
Costa Rica	2
Hong Kong	2
Cyprus	1
El Salvador	1
Gulf Cooperation Treaty	1
Kazakhstan	1
Luxembourg	1
Macedonia	1
Morocco	1
Slovenia	1
Sri Lanka	1
Turkey	1

Wastewater Treatment - Chemophysical Treatment	Total
Saudi Arabia	4
China	5881
Japan	3747
South Korea	1466
United States	885
Germany	468
Russia	419
European Patent Office	289
France	130
United Kingdom	87
Taiwan	76
Australia	73
Canada	64
Sweden	49
Brazil	45
Italy	38
Spain	35
Austria	33
Czech Republic	31
South Africa	26
Finland	25
Netherlands	21
Denmark	19
Israel	17
Belgium	16
Romania	14
India	12
Mexico	11
Norway	11
Singapore	11
New Zealand	9
Poland	9
Switzerland	7
Slovakia	6
Hungary	5
Malaysia	5
Portugal	4
Colombia	3
Ireland	3
Chile	2
Hong Kong	2
Morocco	2
Ukraine	2
Croatia	1
Cyprus	1
Greece	1
Kenya	1
Mongolia	1
Sri Lanka	1

Example of tables presented to show number of patents per country in different water technologies.

2. Technology Roadmap

Technology Roadmapping

Part A
Principles, process and examples

Dr Rob Phaal

University of Cambridge Centre for Technology Management

Wednesday 21 March 2007, 14:00-15:30

UK

Energy, Water and Waste Roadmaps to 2050: A synthesis of Drivers, Technologies, Targets and Policies

Tim Dixon and Judith Britnell

Retrofit2050

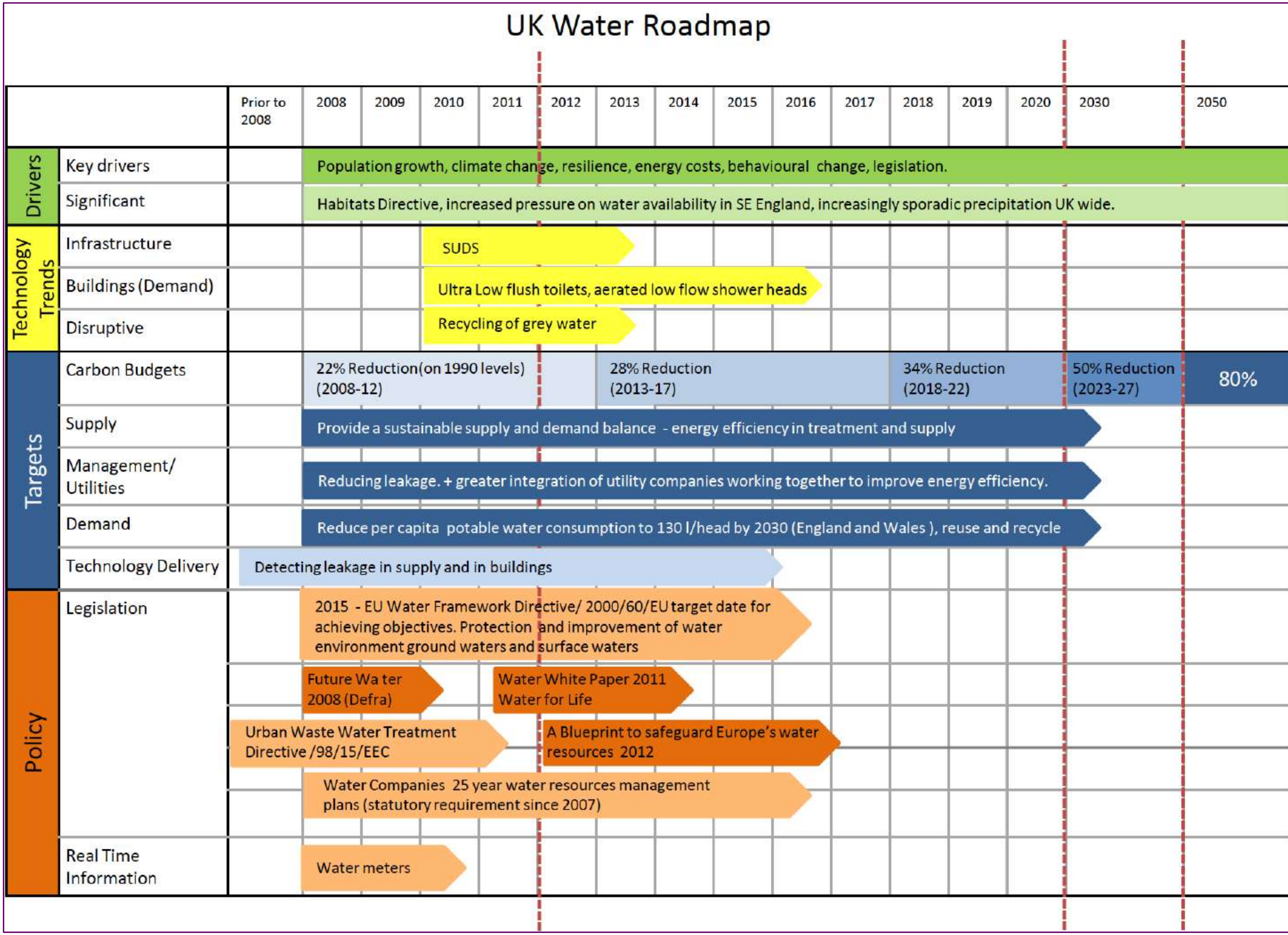
Introduction

Roadmaps can be defined as: *'simple, adaptable 'strategic lenses' through which the evolution of complex systems can be viewed, supporting dialogue and communication'* (Phaal and Robert, 2009), or as *'a sequence of measures designed to bring about a desirable future'* (McDowall and Eames, 2006). Technology roadmaps, which also draw on other foresight approaches such as scenarios, Delphi surveys and forecasts, are useful for framing major socio-technical system changes, or technological transitions. In essence they combine three different ways of understanding the future through 'expectations', 'desires' and 'promises'. They address key questions which include:

• Where do we want to go? Where are we now? How can we get there?

• Why do we need to act? What should we do? How should we do it? By when?

http://www.retrofit2050.org.uk/sites/default/files/resources/EnergyWaterandWasteRoadmaps.pdf


UK Water Roadmap
Prior to 2008
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2030
2050
Drivers
Key drivers
Population growth, climate change, resilience, energy costs, behavioural change, legislation.
Significant
Habitats Directive, increased pressure on water availability in SE England, increasingly sporadic precipitation UK wide.
Technology Trends
Infrastructure
SUDS
Buildings (Demand)
Ultra Low flush toilets, aerated low flow shower heads
Disruptive
Recycling of grey water
Targets
Carbon Budgets
22% Reduction (on 1990 levels) (2008-12)
28% Reduction (2013-17)
34% Reduction (2018-22)
50% Reduction (2023-27)
80%
Supply
Provide a sustainable supply and demand balance - energy efficiency in treatment and supply
Management/ Utilities
Reducing leakage. + greater integration of utility companies working together to improve energy efficiency.
Demand
Reduce per capita potable water consumption to 130 l/head by 2030 (England and Wales), reuse and recycle
Technology Delivery
Detecting leakage in supply and in buildings
Policy
Legislation
2015 - EU Water Framework Directive/ 2000/60/EU target date for achieving objectives. Protection and improvement of water environment ground waters and surface waters
Future Water 2008 (Defra)
Water White Paper 2011 Water for Life
Urban Waste Water Treatment Directive /98/15/EEC
A Blueprint to safeguard Europe's water resources 2012
Water Companies 25 year water resources management plans (statutory requirement since 2007)
Real Time Information
Water meters

Water: key facts

Business as usual?

- England—average person uses 150l/day or a tonne of water per week
- Heating water is a major use of energy in UK homes
- Energy represents 28% of operating costs of water industry
- UK has over £250bn invested in water infrastructure of varying age and condition, with £8bn pa on capital and operating costs

What do we need to do to change?

- Reduce per capita water consumption to 130 l/head by 2030 (England and Wales) Reducing individual consumption by 20 litres a day would mean water companies could reduce GHG emissions by up to 8% (equivalent to annual emissions from 90,000 cars, or from supplying the population of Liverpool with electricity for a year)
- Reduce leakages (England and Wales) Using current technology, it would cost companies about £100 billion to replace existing pipe networks and every customer's supply pipe

Key references:

- Defra (Department for Environment, Food and Rural Affairs)(2011) Water for Life
- Defra (Department for Environment, Food and Rural Affairs)(2008) Future Water: The Government's Water Strategy for England
- Hall, J. W., Henriques, J. J., Hickford, A. J. & Nicholls, R. J., Ed.s (2012). *A Fast Track Analysis of strategies for infrastructure provision in Great Britain*. Environmental Change Institute, University of Oxford, Oxford.
- GOS(2011) Taking Responsibility for Water
- Defra /OFWAT (2011) Innovation Priorities for the Water Sector
- UKWIR (2007) R& D Roadmap
- Retrofit Expert Review 17 and 18
- EKTN (2008) Energy Efficient Water and Waste Water Treatment
- Ofwat (The Water Services Regulation Authority, England and Wales) : 'Waste not, want not' making the best use of our water (2010)

Fraunhofer IGB brief profile

The Fraunhofer IGB develops and optimizes processes and products in the fields of medicine, pharmacy, chemistry, the environment and energy. We combine the highest scientific quality with professional expertise in our fields of competence – Interfacial Engineering and Materials Science, Molecular Biotechnology, Physical Process Technology, Environmental Biotechnology and Bioprocess Engineering, as well as Cell and Tissue Engineering – always with a view to economic efficiency and sustainability. Our strength lies in offering complete solutions from laboratory scale to pilot plant. Customers benefit from the constructive cooperation between various disciplines at our institute, which opens up novel approaches in fields such as medical engineering, nanobiotechnology, industrial biotechnology, and wastewater purification. The Fraunhofer IGB is one of 66 institutes and independent research units of the Fraunhofer-Gesellschaft, Europe's largest organization for application-oriented research.

Fraunhofer Institute for Systems and Innovation Research (ISI)

- Is one of 60 Fraunhofer Institutes located all over Germany
- Employs 130 engineers, social and natural scientists, and economists and 65 other people to handle about 300 research projects every year
- Studies how innovations originate, which actors are to be integrated, who benefits from them and how they can be promoted
- Evaluates economic, social and political potentials and limits of technical innovations
- Performs technology foresight and prepares scenarios and roadmaps of future technological developments
- Investigation of the scientific, economic, ecological, social, organizational, legal and political framework conditions conducive to innovations, and their impacts
- Evaluation of innovations and their potentials in an economic, societal and ecological perspective
- Provides decision support for actors from industry, science and politics
- Is devoted to the study of environmental issues in 3 of its 7 competence centers

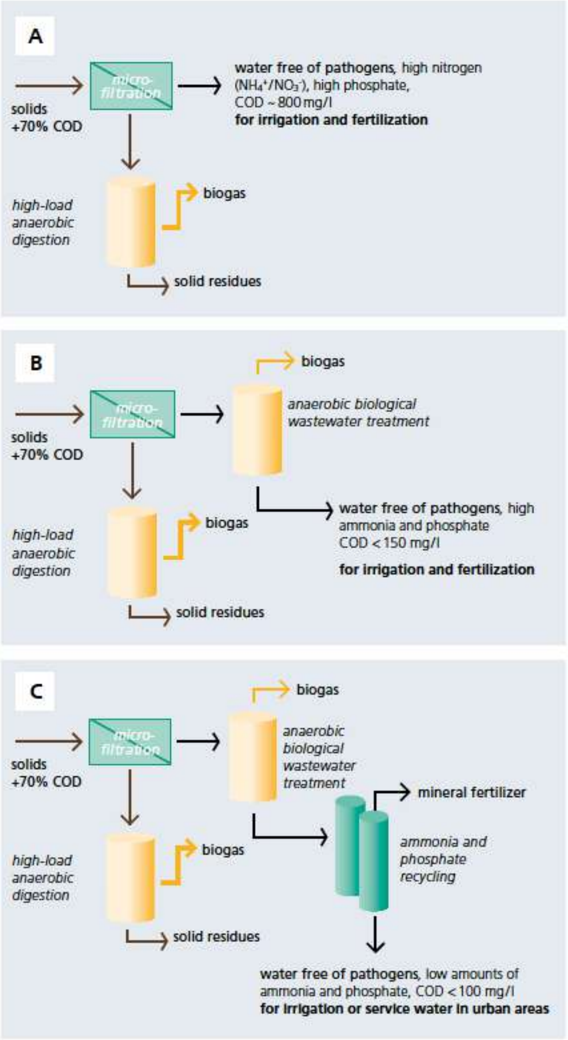
Solutions for arid and semi-arid regions

Obviously, regions with low precipitation characterized by long periods of drought and high insolation need different infrastructure systems for reliable water supplies and waste-water disposal compared to central Europe. The technologies developed at the Fraunhofer IGB are suitable for both arid and semi-arid areas, and can be adapted to the requirements of individual regions.

The rotating disk filter is an innovative microfiltration technology (p. 17) which separates solids from water together with up to 70 percent of the chemical oxygen demand (COD) of the raw effluent. The filtered water no longer contains pathogenic bacteria, but it does contain nitrogen compounds and phosphate, and its COD is below 800 mg/l. The filtered water can be used directly for irrigation and fertilization purposes. The separated solids are anaerobically biodegraded and converted into biogas (Fig. 2 A). Alternatively, once the solids have been removed, the wastewater can be treated in an anaerobic bioreactor where the organic carbon compounds are converted into biogas and the nitrogen compounds into ammonium. This water can then be used for irrigation and fertilization or as process water for low-value industrial purposes (Fig. 2 B).

For higher-quality uses and in urban areas with a greater population density, ammonium and phosphate must be recovered from the water in order to achieve the water quality required for approval by the authorities. They can then be used for the production of mineral fertilizers (Fig. 2 C). The degree of purity and the efforts required to purify wastewater are determined by the subsequent use of the element.

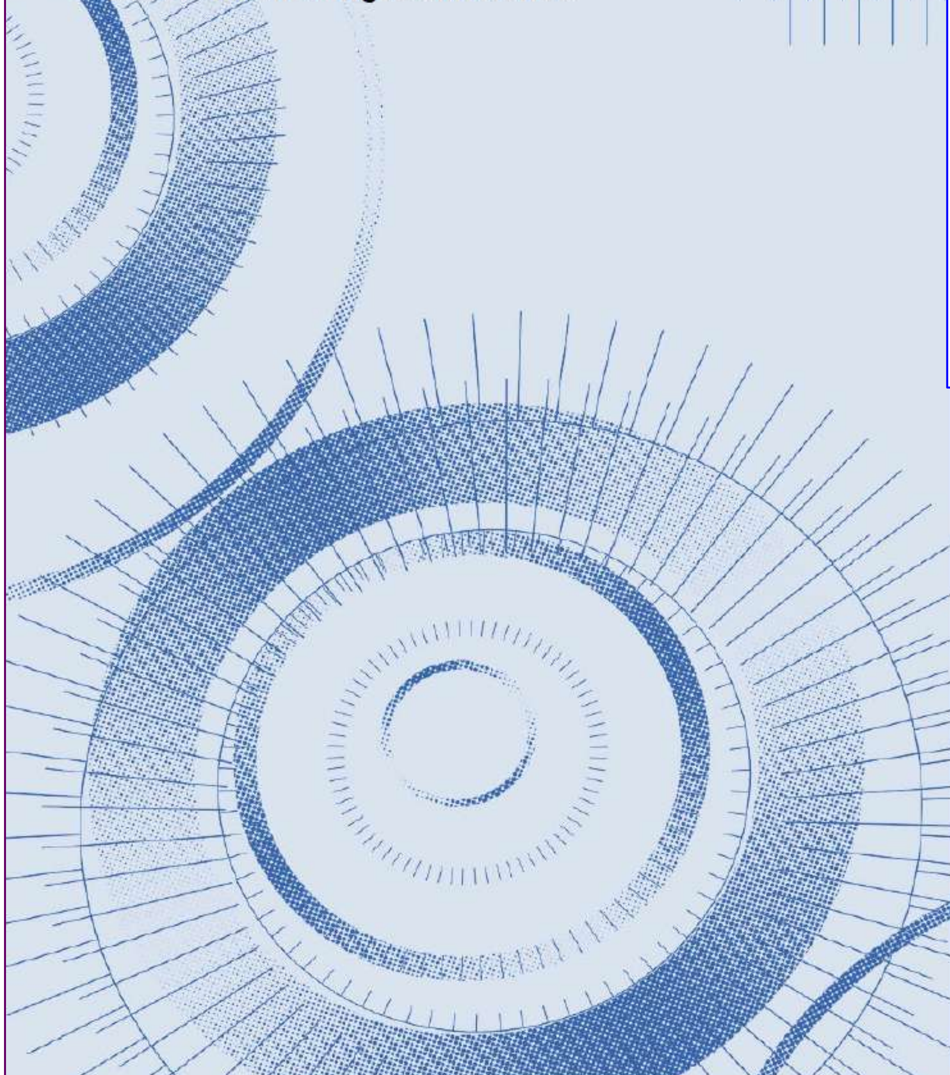
2 Adaptation of various IGB technologies to arid and semi-arid regions



Example of solutions presented in the Fraunhofer report

Integrated Technology Roadmapping

A practical guide to the search for technological answers to social challenges and trends



Integrated Technology Roadmapping

Published by:
ZVEI - Zentralverband Elektrotechnik und Elektronikindustrie e.V.
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60596 Frankfurt am Main
Department: Research, Human Resources Development, Production Engineering
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July 2007

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Federal Ministry of Education and Research

SÖF Social-Ecological Research

The Dutch Roadmap for wastewater treatment.

NEW stands for: Nutrients, Energy and Water

Another Dutch Study

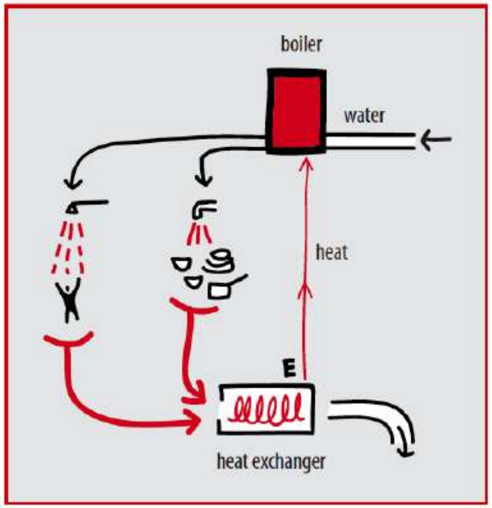
Roadmap
Wastewater management

Vision brochure

Wastewater management roadmap towards 2030

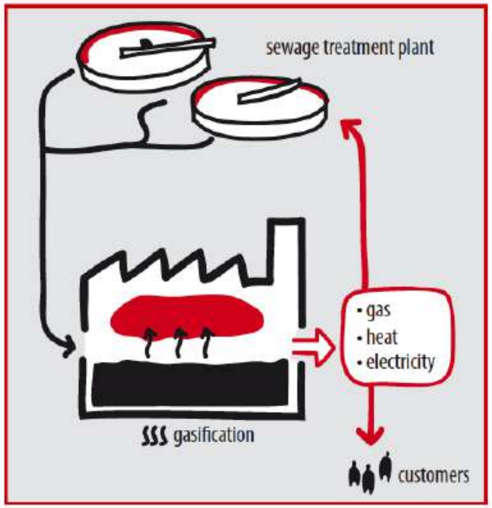
A sustainable approach to the collection and treatment of wastewater in the Netherlands

Opportunities for energy



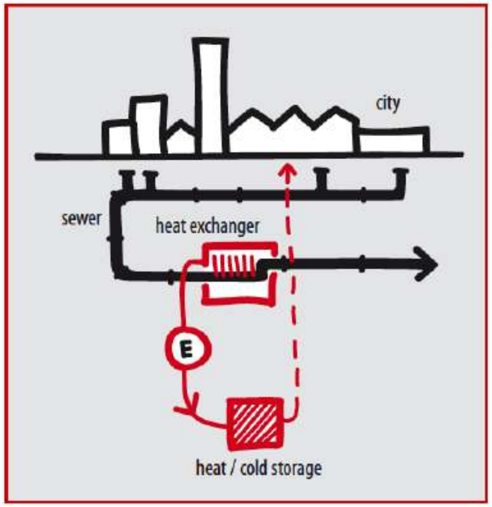
Recovering heat in homes and buildings

Heat exchangers allow residents to reuse the heat from hot tap water in the kitchen and shower. There are two options: preheating of tap and shower water or using a heat pump to generate heat. The heat exchangers are easy to install in new homes and buildings. For larger buildings, a heat exchanger in a well is a good solution.



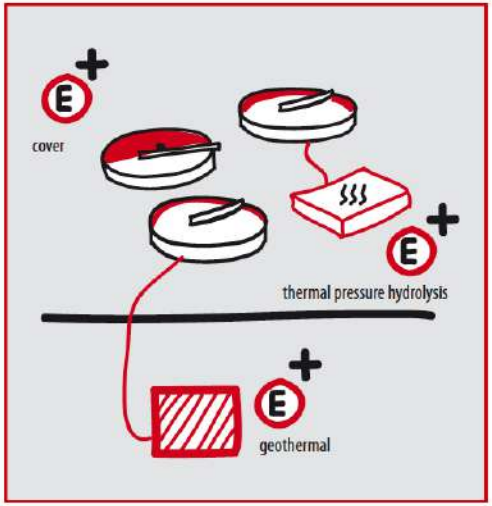
Wastewater treatment plants as energy factories

The wastewater treatment plant converts the chemical energy in wastewater into electricity. The sewage treatment plant uses this electricity to meet its own demand, and also supplies energy to customers. Thanks to supercritical gasification, the sludge no longer requires conventional final processing. In combination with other waste flows, such as manure, the yield is even higher. The sewage treatment plant also reuses the heat from discharged effluent.



Recovering heat from sewage

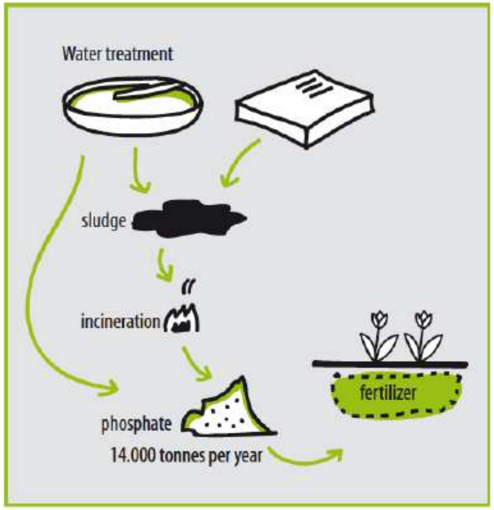
In the summer, a sewage heat exchanger recovers heat from wastewater. This heat is stored in a thermal storage system. In winter, a heat pump delivers this high-quality heat to buildings. Sewage heat also helps prevent ice build-up on roads.



Energy savings at the wastewater treatment plant

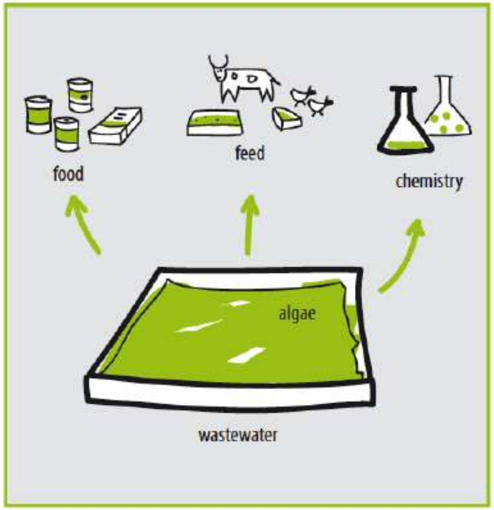
Thanks to improved process operations, the sewage treatment plant also saves on operational energy. Techniques like thermal pressure hydrolysis help improve digestion. Geothermal energy, covering tanks and recovering individual heat for sludge drying are other examples of smarter ways to deal with energy.

Opportunities for raw materials



Phosphate for fertilizer

Phosphate ore is an increasingly scarce and expensive commodity. During treatment, or during final processing, we recover some 14,000 tons of phosphate annually. Phosphate is an important raw material for fertilizer. Biophosphate from wastewater is suitable for use in sustainably produced fertilizers.

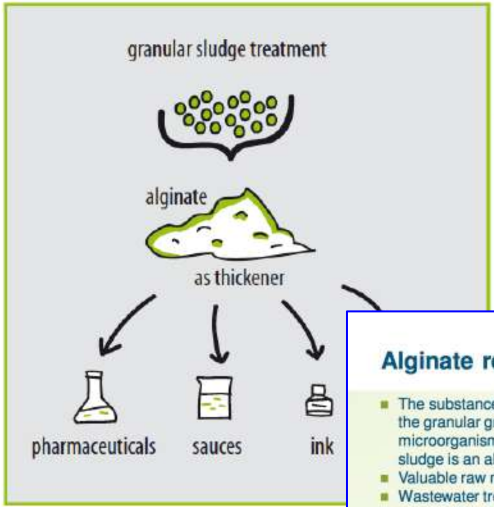


Algae for human consumption, animal feed, chemistry

Algae grow on residuals from wastewater, and they are a raw material for animal feed and fish food. Algae contain raw materials for the production of bioplastics and resins. Specific algae secrete oils used in the pharmaceutical industry. Experiments with algae and other water plants continue.

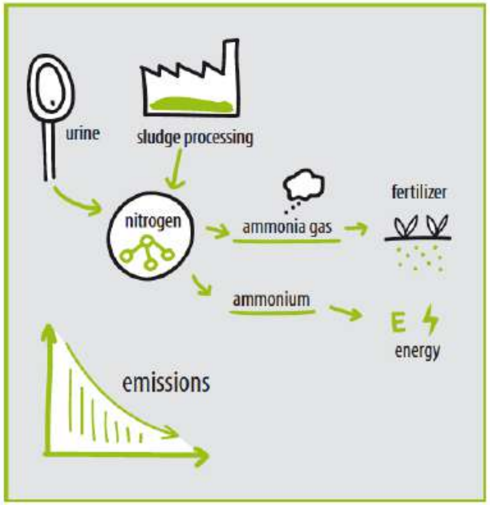
Recycling toilet paper

Cellulose from toilet paper is a raw material for building insulation and road construction. We also use cellulose for chemicals that are refined into bioplastics for furniture, plastic car parts and toy building blocks. Wastewater can provide for 5% of our country's demand for cellulose. The quality and quantity are constant.



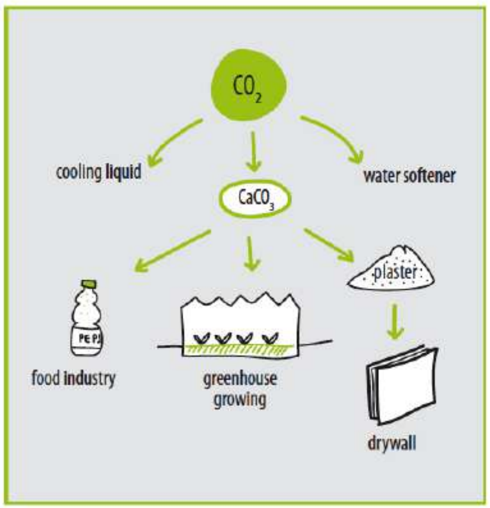
Alginate for stabilising liquids

Alginate is a by-product of the treatment of (granular) sludge. Alginate can be used for emulsifying and stabilizing liquids, i.e. as a thickening agent for ink, sauces, dairy products, pharmaceuticals, paper, etc. Granular sludge is rich in alginate. Alginate represents a somewhat significant financial value.



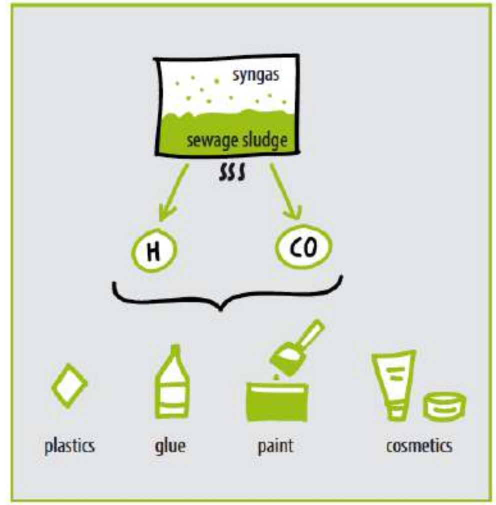
Nitrogen for ammonia compounds

We harvest nitrogen from sewage sludge or urine. With the nitrogen, we make ammonia compounds, which have a variety of uses. Ammonia gas, for example, is needed in the production of fertilizers. In a fuel cell, ammonium can be a source of energy. Harvesting nitrogen is also a way of reducing greenhouse gas emissions. This can be done in locations where there is residual heat available to strip the nitrogen.



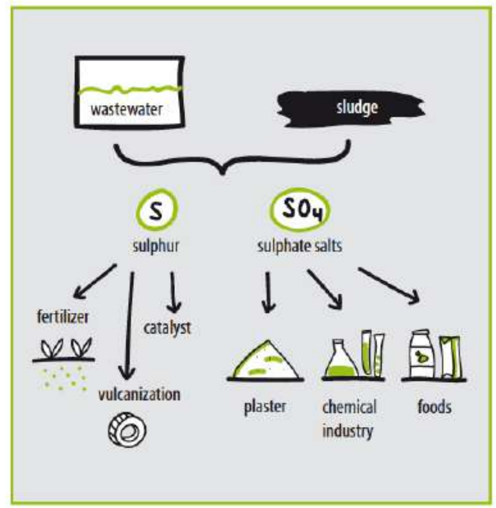
CO_2 as useful product

CO_2 can be used as a liquid coolant, water softener or for the production of calcium carbonate. Calcium carbonate is used as the chalky filler for drywall, for soil enrichment, and as a fertilizer for greenhouse growing. CO_2 is also used in a number of other industries, such as the soft drink industry.



Syngas in bulk chemicals

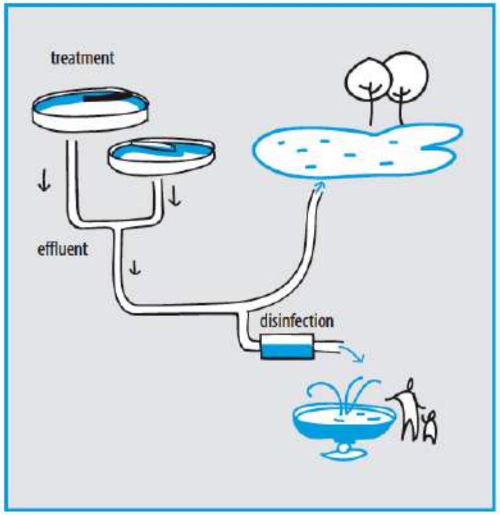
Syngas is composed mainly of hydrogen and carbon monoxide. It is a component used for the production of chemicals like methanol. Syngas can be used in bulk chemicals for plastic, glue, paint and cosmetics. Gasification of sewage sludge is one way to produce syngas.



Sulphur or sulphate for various applications

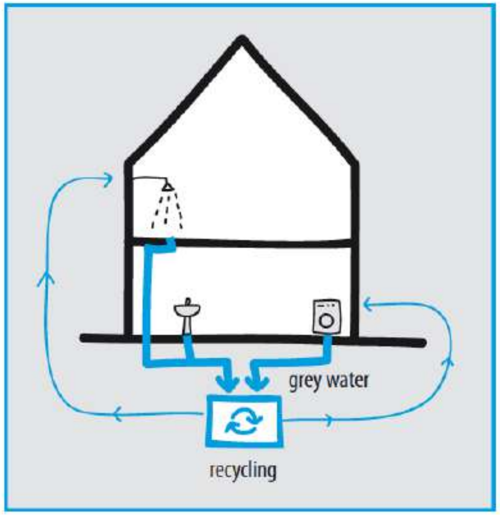
We harvest sulphur or sulphate from wastewater or sludge. Sulphur can be used in the production of fertilizer and for vulcanizing rubber. Sulphur is also used as a catalyst in various industrial processes. Sulphate is a useful component in plaster, as a catalyst in the chemical industry and as a raw material in the food industry.

Opportunities for recycling wastewater



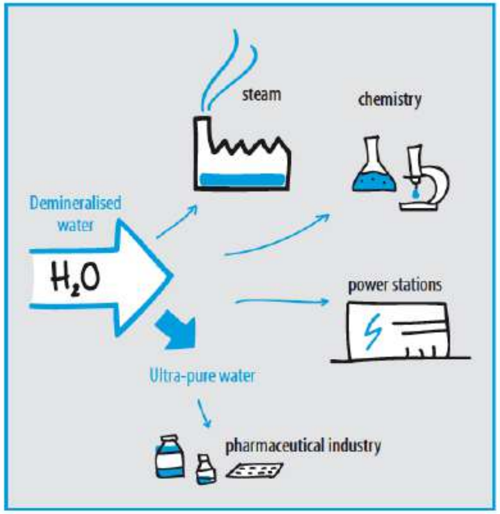
Landscaping or recreational water

In our country, we use effluent as urban, park and recreational water. This takes some of the burden off of groundwater levels. It also means we can irrigate longer in periods of drought. In any situation in which recreational users can come in direct contact with effluent, the effluent is subjected to disinfection processes.



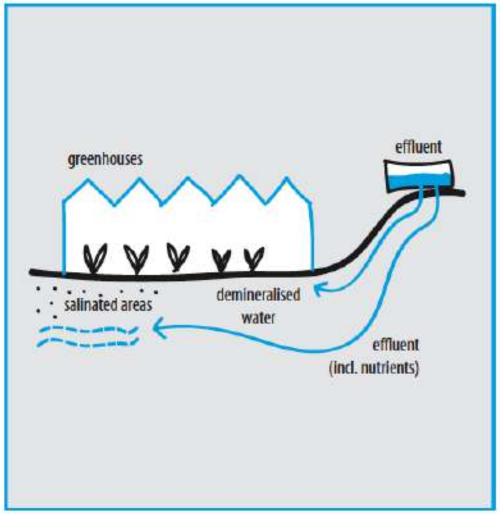
Household water

In 2030, the reuse of water will be much more important than it is now. One example is the domestic use of grey water. It is a trend being driven by the importance of sustainability and self-sufficiency, and the principle of doing locally whatever can be done locally. It also helps reduce consumption of drinking water. Hygiene of the effluent must, however, be guaranteed.



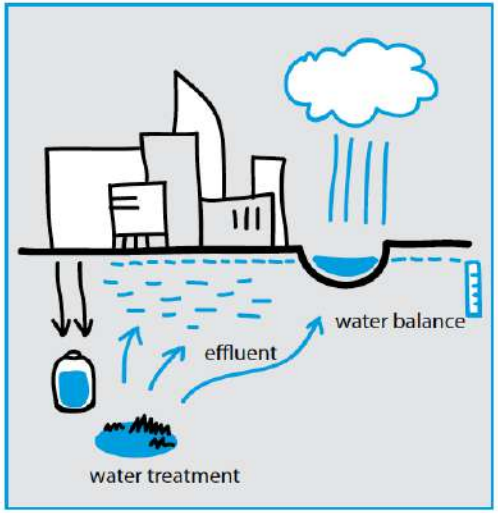
Process or cooling water

From effluent, we create desalinated water with the quality of demineralised water. Desalinated water can be used for the production of steam and processes requiring high-quality water. This level of water quality is in demand among chemical companies, power plants, producers of 'new energy,' and other types of facilities. One special type is ultrapure water, which is used by the pharmaceutical industry.



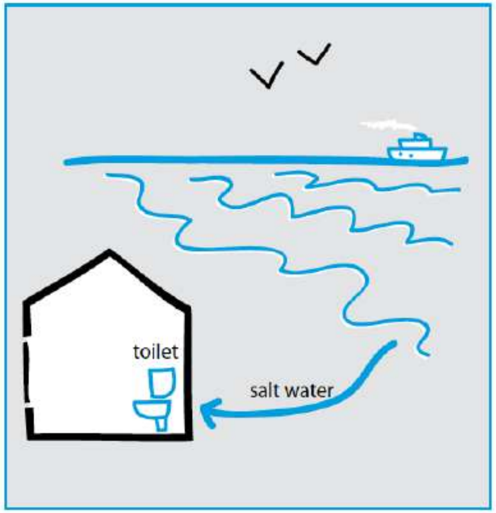
Water for agriculture and greenhouses

We use effluent to maintain the water resources level in agricultural areas through dry periods. It is also used to compensate freshwater shortages in salified areas. Effluent with nutrient content is beneficial to agriculture. In greenhouses, we use demineralised water. Demineralised water is free of bacteria and viruses. Supplying effluent to greenhouses reduces the demand for storage space for water.



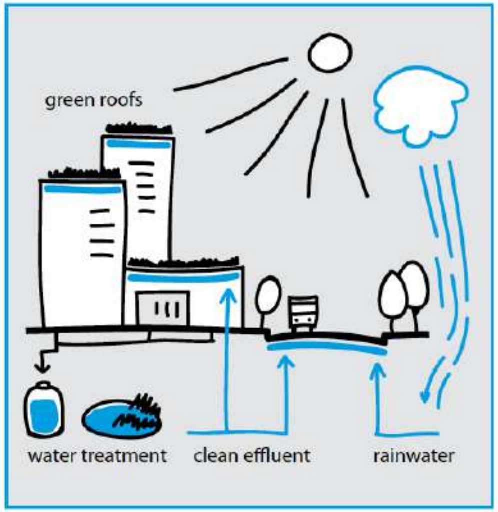
Effluent for water balance

Cities use effluent to maintain water levels. The Dutch city of Leeuwarden, for example, uses effluent to keep up the level of the city canals. As climate change increases the risk of long dry periods, using purified wastewater as a component of maintaining the water balance in urban systems becomes more and more attractive.



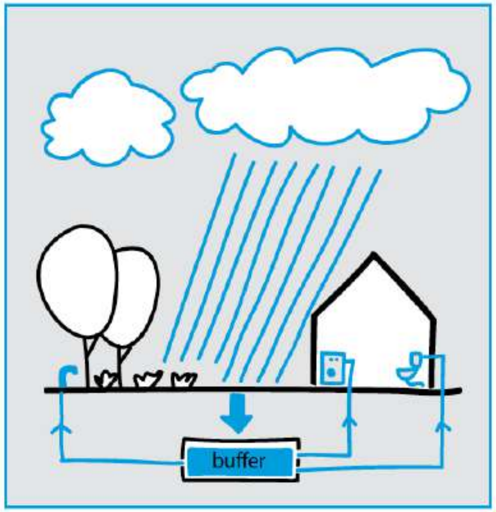
Saltwater for toilet flushing

The city of Hong Kong has been using saltwater for toilet flushing for half a century. The health risks of saltwater are much less than those of grey water. Water for toilet flushing needs no comprehensive pre-treatment. It also requires much less energy than recycled wastewater. In the Netherlands, the coastal areas are densely populated, so there is a lot of potential for the use of saltwater. Whenever there is a connection problem anywhere, the conductive properties of saltwater lead us right to it.



Combating urban heat islands

The densely packed, tall buildings in cities trap a lot of heat in urban areas. This leads to heat stress and urban 'heat islands.' Temperatures can be reduced by using rainwater (for example, under roads and on green rooftops) and clean effluent. Semi-porous pavement can also reduce urban heat stress.



Rainwater for toilet and washing machine

Rainwater storage, for example below the home or above ground in the garden, can help reduce consumption of drinking water. Homes can use rainwater for toilet, washing machine and garden. For gardens, filtration boxes or biosand filters can be useful for buffering and filtering precipitation. This also helps keep rainwater from unnecessarily flowing into the sewers.

The talk about National Critical Technologies…..

Critical technologies: Raw materials

- Slurry filters
- Gasification/supercritical gasification
- Syngas production technologies
- Chemical (hydrolysis, gasification, pyrolysis) and biological (digestion, fermentation) technologies for producing base chemicals
- Fermentation and alternative techniques for processing biomass
- Vacuum sewerage
- Robust stand-alone technology for aerobic/anaerobic treatment and struvite precipitation

Critical technologies: Energy

- Heating and cooling storage from surface water
- Gas water pumps
- Supercritical gasification
- Fuel cell technology
- Sewage heat exchangers
- Heating and cooling storage from surface water
- Use of residual heat for sludge drying
- Use of geothermal energy for drying slides and heating sewage treatment plant processes
- Anaerobic local treatment of wastewater (new sanitation)
- Thermal pressure hydrolysis
- Bubble aeration at sewage treatment plant
- Wind and solar energy on sites

Critical technologies: Water

- High-load systems like AB systems
- Aerobic granular sludge technology
- Cold Anammox
- Membrane filtration and downstream filtration techniques
- Active carbon adsorption
- Floatation and filtering technologies
- Forward and reverse osmosis
- Struvite reactors
- Fermentation technologies
- Fuel cell technology
- Natural postprocessing methods with plants and crops

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Aerobic sludge granulation: A tale of two polysaccharides?

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OR…the talk about innovation-based leapfrogging

Technological Forecasting & Social Change 79 (2012) 155–171

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Conceptualizing leapfrogging with spatially coupled innovation systems: The case of onsite wastewater treatment in China

Christian Binz [a,*], Bernhard Truffer [a], Li Li [b], Yajuan Shi [b], Yonglong Lu [b]

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3. Future-Oriented Technology Analysis (Strategic Foresight)

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Future-oriented technology analysis: Its potential to address disruptive transformations

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A RAND INFRASTRUCTURE, SAFETY, AND ENVIRONMENT PROGRAM

Household level

Ecological sanitation (Separate urine from ww)

MSW in two bags

Solar heaters for hot water

Water-use efficient appliances (80 lcd)

Energy-use efficient appliances

Decentralized WWTP

5000 population max

- Reuse of the urine stream
- Reuse of the treated effluent

Dry fermentation

- Input: organic fraction of MSW
- Sludge from WWTP

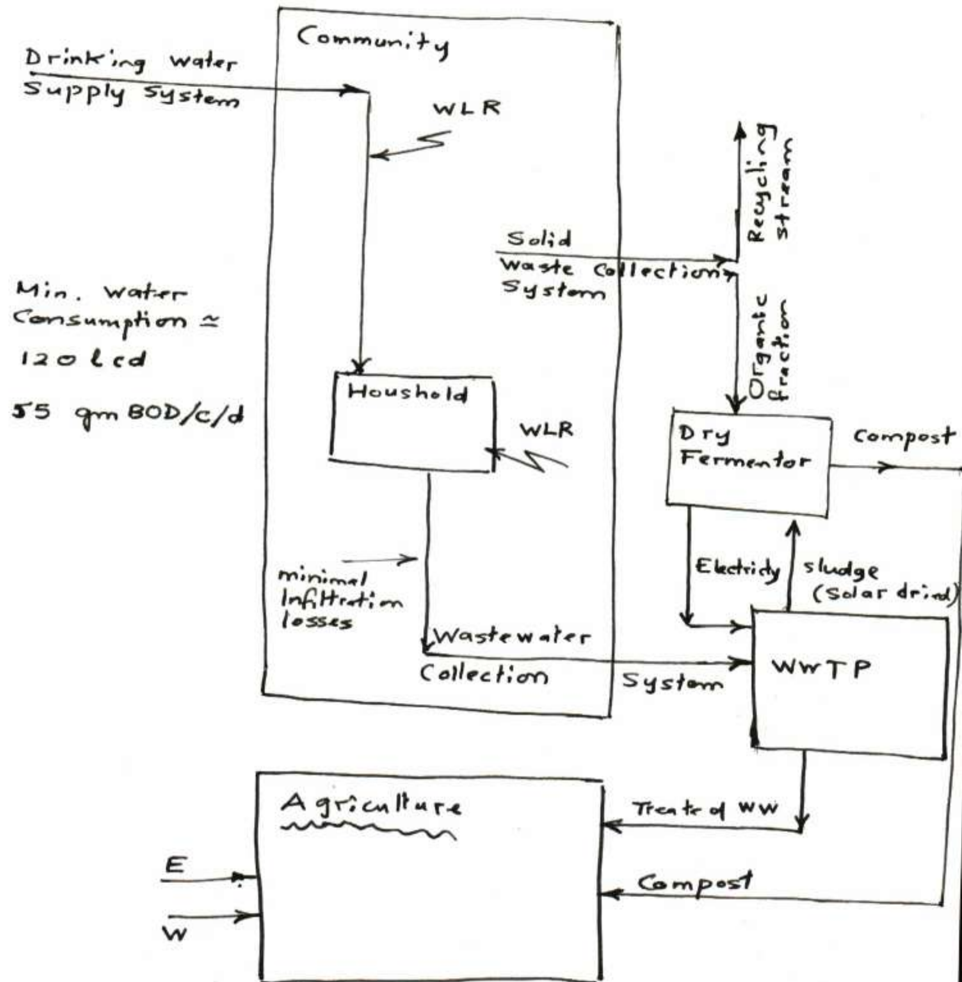
Reuse of the compost product

Sorting and 1st level processing of the recyclables

Export sorted recyclables to a the central recycling park

Minimum losses drinking water networks

Minimum infiltration sewerage network



Ahmed Gaber, May 12, 2015