MAS Seminar course
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Sustainable Water and Wastewater Management in Urban Growth Centres

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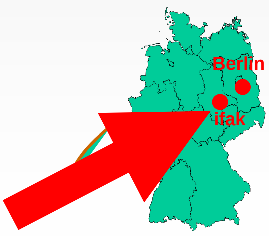
ifak – Institut für Automation und Kommunikation e. V.

- Non-profit institute for applied research, 62 employees
- Affiliated to Otto-von-Guericke-University of Magdeburg
- Publicly-funded research projects (National, EU)
- Contract work (e.g. for water companies)
- Cross-fertilisation between applied research and application
- National and international cooperations and contacts



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Group “Environmental Software and Control“

- Modelling and simulation for design, planning, operation of urban water systems
- Off-line and on-line simulation and control
- Sewer system, WWTP, receiving waters
- Simulator SIMBA for sewer, WWTP, river
- Water in megacities

- Implementations / Customers include:
  - Magdeburg WWTP, Several other large WWTPs
  - Sewer system control: Magdeburg, Emscher pipe
  - Ruhrverband, Wupperverband, Emschergen.schaft
  - Consultancy in these areas

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World population

- 7 billion (estimate for 31 October 2011)
- 5 billion (1987)
- Most people live in cities (many of them: urban growth centres)
- Inequal distribution: the 1000 richest persons have four times more possessions than the poorest 3.5 billion persons of the world (SZ, 29.10.11)

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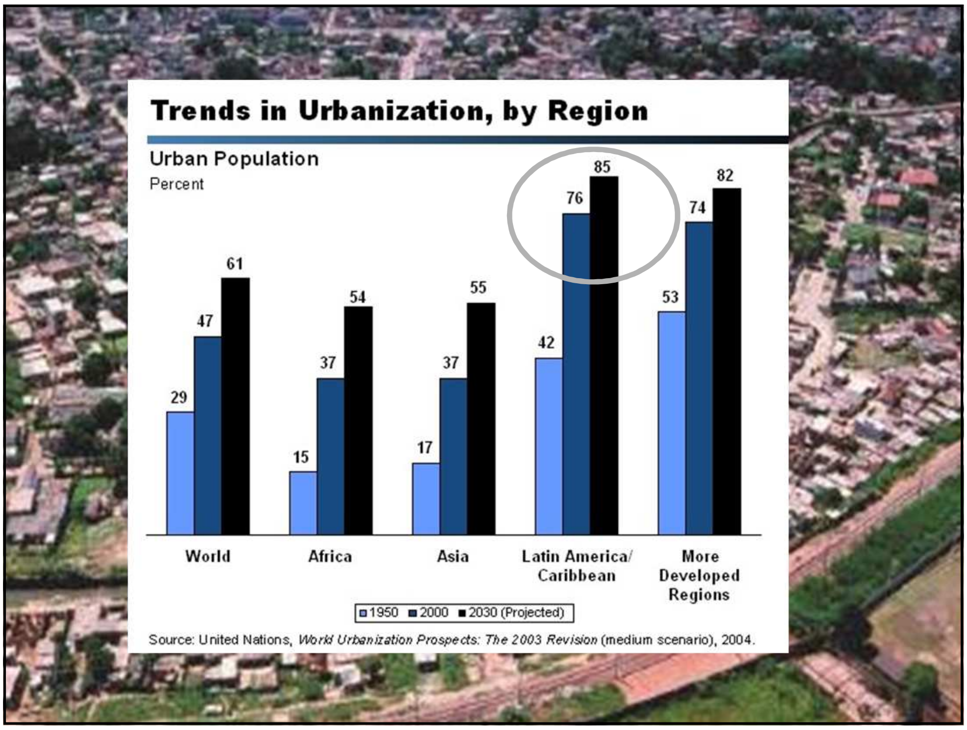

Water in Megacities:

An example:

Lima / Peru

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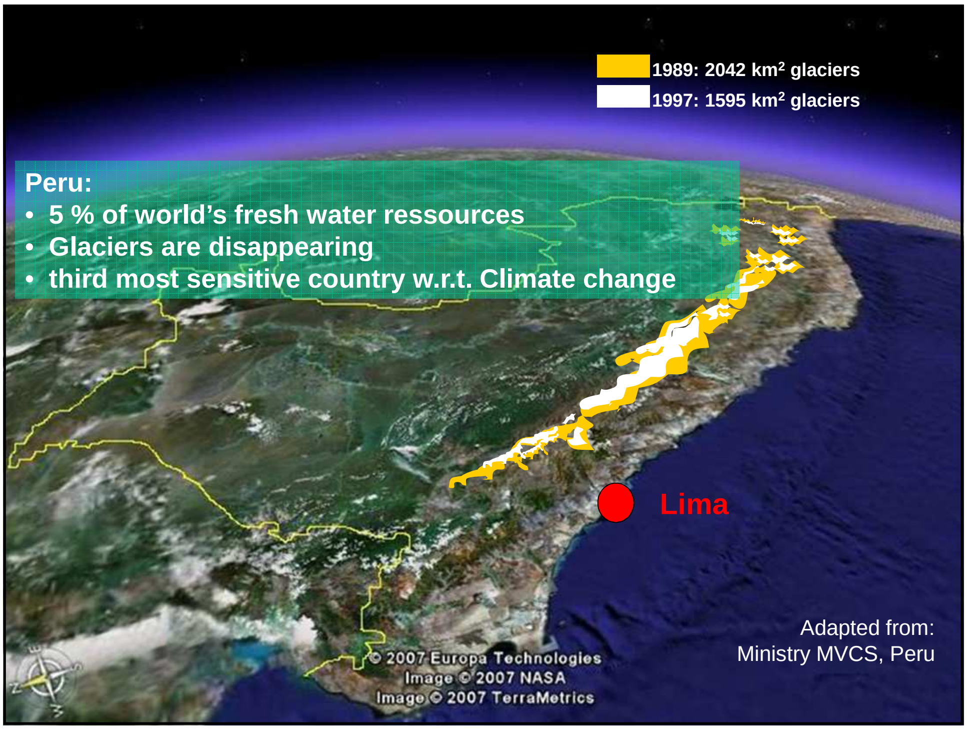

Glacier melting in the Andes:

Source: SEDAPAL (2011)

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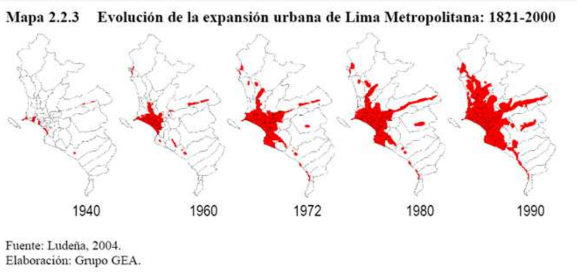
Urban growth centre Lima

The urban growth centre of Metropolitan Lima, Peru:

- > 8 million inhabitants, annual growth rate: around 2 %
- Social diversity
- Second-driest city of the world (9 mm annual rainfall)

Periurban settlement



Urban growth in Lima

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Urban growth centre Lima

Lima in comparison with other Latin American cities

City	Population	production capacity	reserves	reserves per capita	precipitation	NAW
	(Mill. Hab.)	(m3/s)	(Mill. M3)	(M3/hab)	(mm/año)	(%)
Río de Janeiro	9	52	(*)	0	1170	57
Sao Paulo	25	90	2073	83	1500	38
Santiago	5.9	24	900	153	384	29
Bogotá	6.5	25	800	123	800	35
Lima	8.0	20	282	35	9	38

* No tiene problemas de fuente por el gran caudal del río que abastece la ciudad y por el alto nivel de precipitaciones

Fuente: Memorias Anuales Principales Empresas de Saneamiento de Sudamérica

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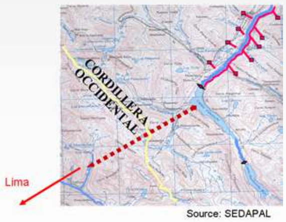
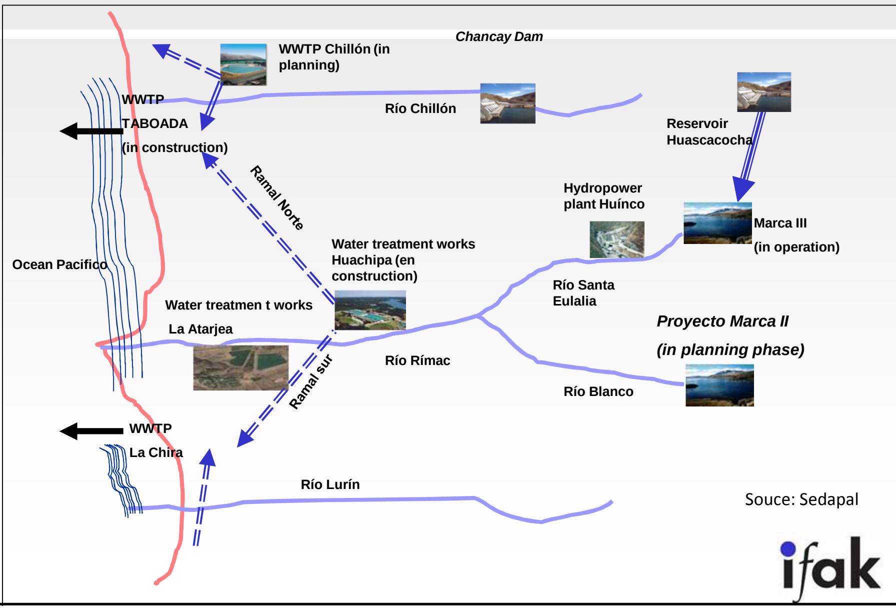
Urban growth centre Lima:
Lifelines

- Water
  - Water scarcity; Trans-Andean tunnels, Amazon region
  - Water supply: River Rímac and increasing groundwater abstraction
  - At present: about 20 % of wastewaters treated; irrigation reuse
  - Conflicting catchment water uses, e.g. supply, hydropower, mining



- Energy
  - Hydropower generation affected by glaciers
  - Operation of water/wastewater infrastructure
- A critical lifeline: water, interacting with energy

The water system of Lima



Impressions of water supply and sanitation in Lima

Rio Rimac after abstraction

Control of supply network

Water lorries for 20 % of population

Projects on Ecological sanitation

Water reuse in some parks

Carapongo WWTP

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Impressions of water supply and sanitation in Lima

Rio Rímac (Huachipa; October)

Rio Chillón (SMP; October)

Huachipa WTP (in construction)

Santa Clara WWTP (in construction)

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Impressions of water supply and sanitation in Lima

PRODUCTO AHORRADOR

Water saving campaigns

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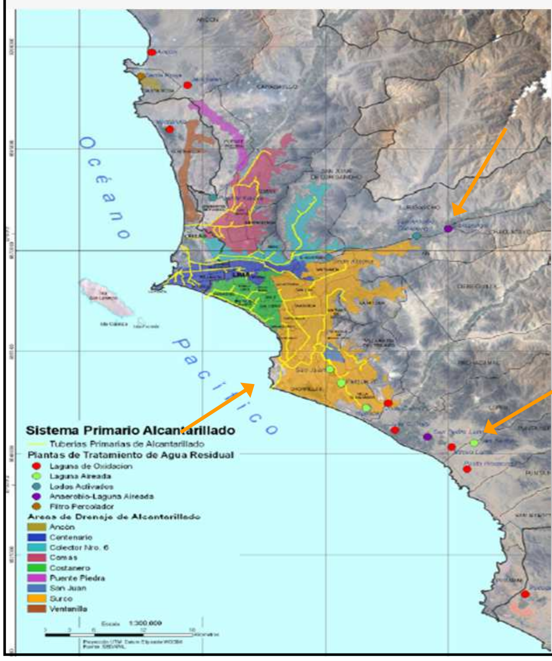
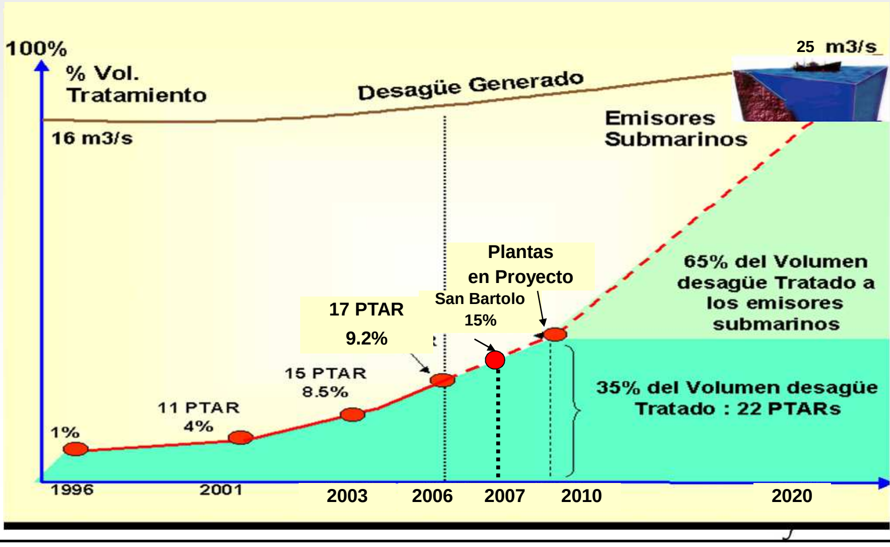


Wastewater treatment in Lima

- 17 wastewater treatments plants
- Anaerobic and aerobic lagoons
- Activated sludge plants
- SBR plants
- More plants in planning and construction

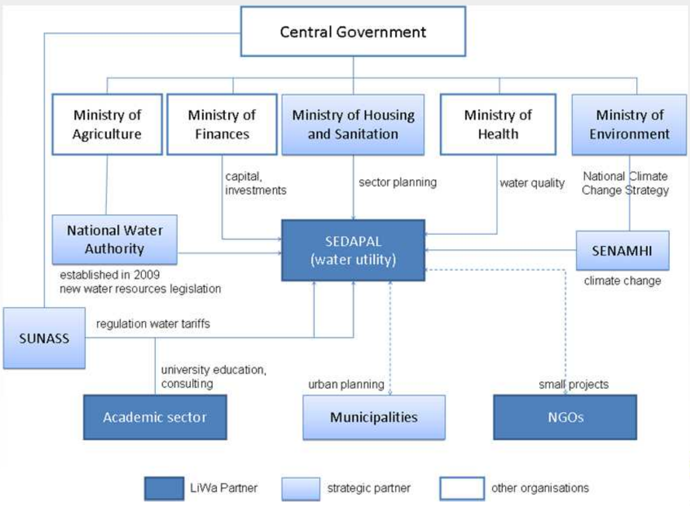
Atlas Ambiental de Lima (2005)

Wastewater treatment in Lima



Institutional setting

❒ Institutional setting in the water sector in Lima



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Water price sitatuation (Networked customers)

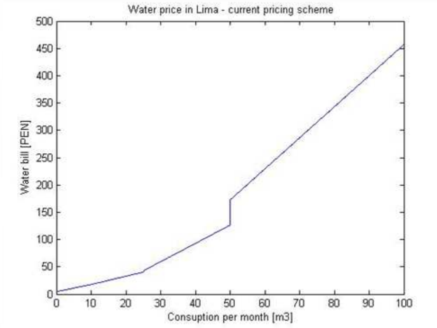
Fixed charge: PEN 4.583/month

Variable charge:

Category	Range m^3/month	Tariff PEN/m^3
Social	> 0	1.306
Domestic	0 - 10	1.306
	10 - 25	1.516
	25 - 50	3.354
	> 50	5.689
Commercial	> 0 / > 1000	5.689 / 6.101
Industrial	> 0 / > 1000	5.689 / 6.101
State	> 0	3.187

non-network consumers supplied by water tankers, PEN 10/m^3

Monthly water bill as function of consumption



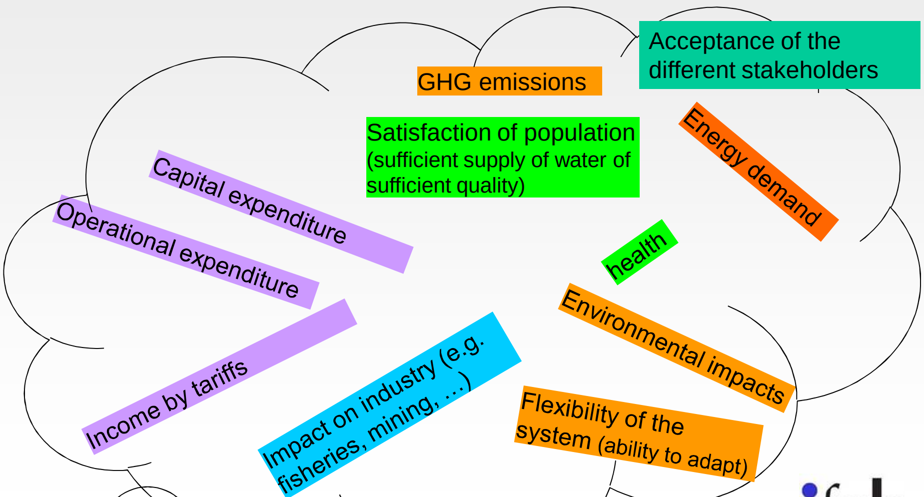
PEN (Nuevo Sol) 1 = CHF 0.32 = EUR 0.25

Current Increasing Block Tariff of Lima

Potential action options:

- Structural measures (large scale), e.g.
  - Additional reservoir lakes (for water supply and energy production)
  - Wastewater reuse plants, Wastewater treatment plants
  - Desalination plants; Fog-catchers
  - Leakage reduction
  - Expansion of existing or construction of new infrastructure (e.g. drinking water networks)
- Structural measures (medium and domestic scale), e.g.
  - Improvement of existing plants (e.g. energy demand, GHG emissions)
  - Water-saving devices (e.g. dual-flush toilets)
  - Stormwater infiltration (in Lima not an issue)
- Non-structural measures, e.g.
  - Real time control (resulting in better, more flexible use of existing infrastructure) of: water supply / pressure management / wastewater system / treatment plants
  - Awareness-raising campaigns; Changes to water tariff structure, metering
  - Capacity building of experts and decision makers
- And many more

Potential criteria for reaching objectives



→ There exists a multitude of relevant criteria

Situation of water and wastewater in Lima - Summary

- Adverse climate conditions (almost no rainfall, climate change?!)
- Dry, hilly, rocky region
- Water: from Andean mountains, groundwater (over-abstraction)
- Still insufficient wastewater treatment
- About 1 million inhabitants not connected to the networks
- Non-ideal water tariffs / ability to pay / willingness to pay
- Social imbalance
- Awareness of water?

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Key challenges and requirements

Challenges

- Complexity of the water system
- Multitude of criteria, actors and stakeholders, conflicting interests
- Multitude of adaptation measures
- Existing boundary conditions (e.g. hydrologic, topographic, geographic)

How to cope with future developments?

Require

- **Informed discussions**
- **Participation of stakeholders**
- **Balanced, system-wide approach**; Social, economic, environmental
- **Knowledgeable people**
- **Innovative methodologies and approaches**

A Peruvian – German project

The German-Peruvian project „LiWa“

Sustainable Water and Wastewater Management
in Urban Growth Centres Coping with Climate Change -
Concepts for Lima Metropolitana (Perú) -

„Lima Water“ (LiWa)

Duration: (2005 -) 2008 - 2013

Future Megacities
Megastädte von morgen

SPONSORED BY THE
Federal Ministry
of Education
and Research

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„Future megacities“ programme of BMBF (German Ministry of Education and Research)

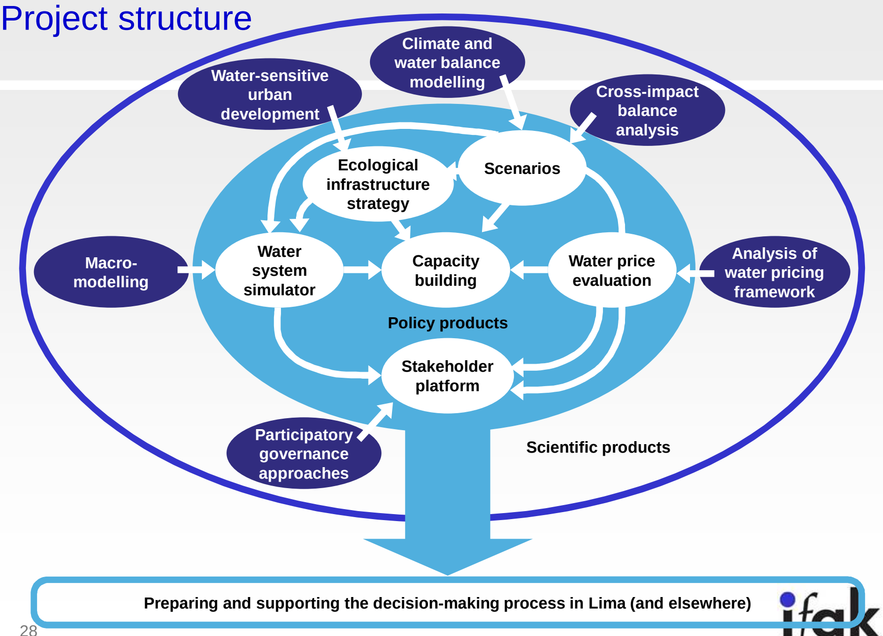
Project team

LiWa

- Peru
  - SEDAPAL – National Water company of Lima
  - National University of Engineering, Lima
  - Foro Ciudades para la Vida (NGO, municip
  - FOVIDA (NGO)
- Germany
  - ifak e. V. Magdeburg (Coordinator)
  - ZIRN, University of Stuttgart
  - IWS, University of Stuttgart
  - Ostfalia University, Suderburg
  - ILPE, University of Stuttgart
  - UFZ, Nat. Centre Environment, Leipzig
  - Dr. Scholz & Dalchow

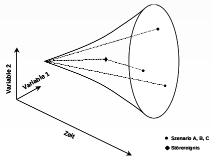
www.lima-water.de

Project structure



Scenarios “Lima 2040”

- Need for several **alternative scenarios** (not predictions) due to **uncertainty** of climate change impacts and socio-political development
- Scenarios are constructed to **integrate** various dimensions (climate change, technology, economy, society and politics)
- Several **stakeholder-workshops** took place in Lima
- Definition of **12 factors** (descriptors) influencing the water situation in Lima
- **Cross-Impact-Balance Analysis** is used as a method to generate **consistent** scenarios (“Scenario Wizard”-tool)
- **6 final Scenarios for Lima 2040** illustrate the complexity of water system and interactions between ecological, economic , social and political factors



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Scenarios „Lima 2040“

Variables describing the water sector in Lima (“descriptors”)

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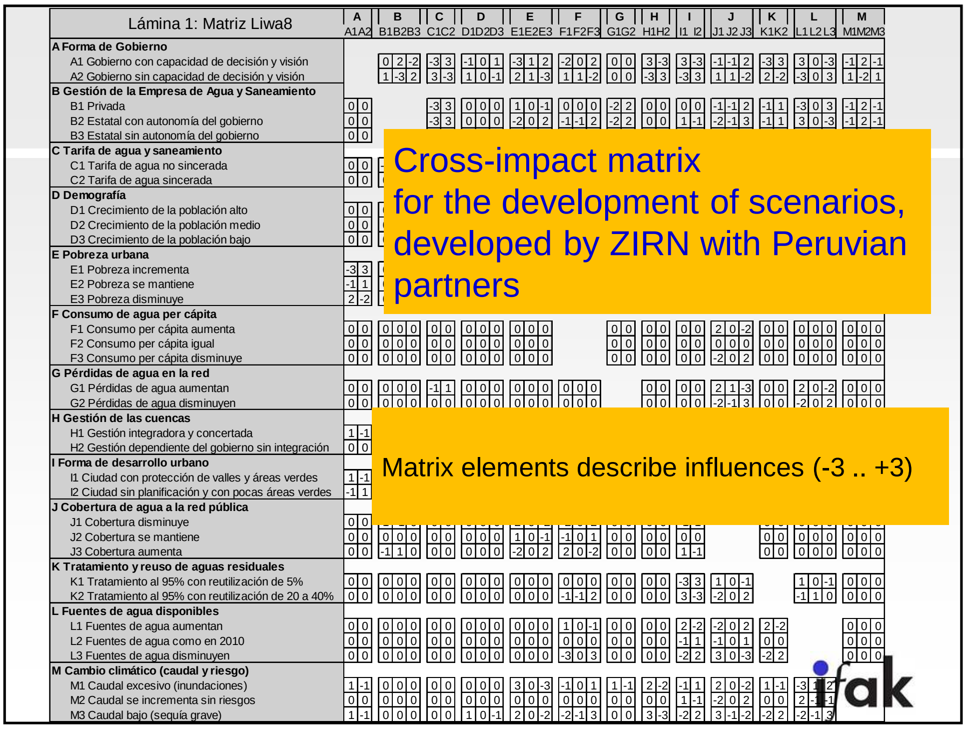
Lámina 1: Matriz Liwa8
A Forma de Gobierno
A1 Gobierno con capacidad de decisión y visión
A2 Gobierno sin capacidad de decisión y visión
B Gestión de la Empresa de Agua y Saneamiento
B1 Privada
B2 Estatal con autonomía del gobierno
B3 Estatal sin autonomía del gobierno
C Tarifa de agua y saneamiento
C1 Tarifa de agua no sincerada
C2 Tarifa de agua sincerada
D Demografía
D1 Crecimiento de la población alto
D2 Crecimiento de la población medio
D3 Crecimiento de la población bajo
E Pobreza urbana
E1 Pobreza incrementa
E2 Pobreza se mantiene
E3 Pobreza disminuye
F Consumo de agua per cápita
F1 Consumo per cápita aumenta
F2 Consumo per cápita igual
F3 Consumo per cápita disminuye
G Pérdidas de agua en la red
G1 Pérdidas de agua aumentan
G2 Pérdidas de agua disminuyen
H Gestión de las cuencas
H1 Gestión integradora y concertada
H2 Gestión dependiente del gobierno sin integración
I Forma de desarrollo urbano
I1 Ciudad con protección de valles y áreas verdes
I2 Ciudad sin planificación y con pocas áreas verdes
J Cobertura de agua a la red pública
J1 Cobertura disminuye
J2 Cobertura se mantiene
J3 Cobertura aumenta
K Tratamiento y reuso de aguas residuales
K1 Tratamiento al 95% con reutilización de 5%
K2 Tratamiento al 95% con reutilización de 20 a 40%
L Fuentes de agua disponibles
L1 Fuentes de agua aumentan
L2 Fuentes de agua como en 2010
L3 Fuentes de agua disminuyen
M Cambio climático (caudal y riesgo)
M1 Caudal excesivo (inundaciones)
M2 Caudal se incrementa sin riesgos
M3 Caudal bajo (sequía grave)
Cross-impact matrix for the development of scenarios, developed by ZIRN with Peruvian partners
Matrix elements describe influences (-3 .. +3)
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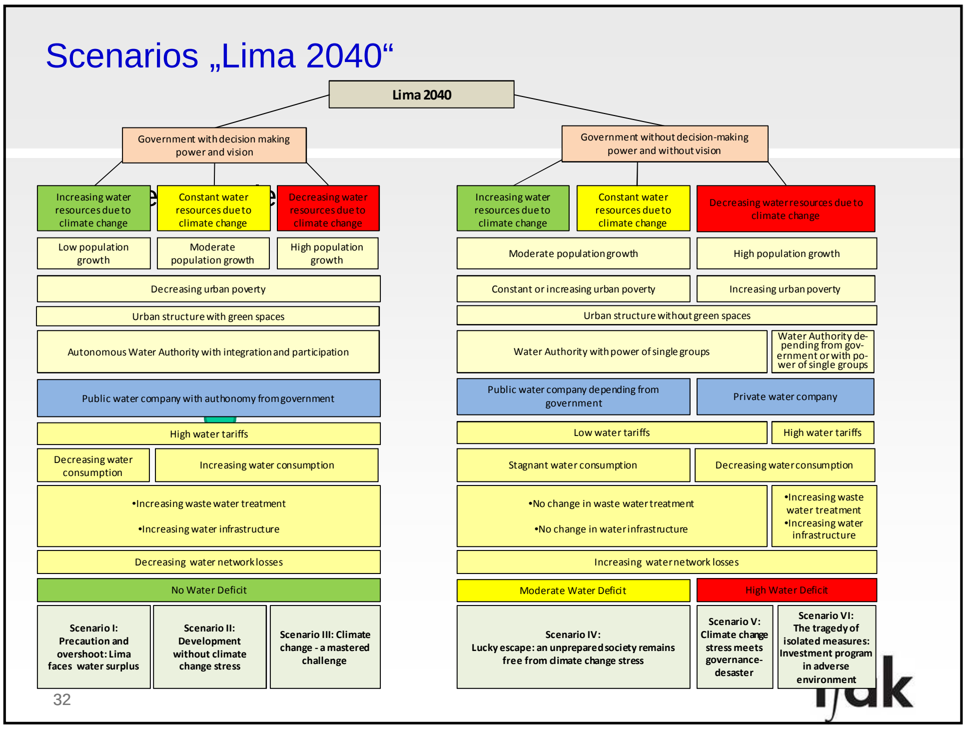
Scenarios „Lima 2040"
Lima 2040
Government with decision making power and vision
Government without decision-making power and without vision
Increasing water resources due to climate change
Constant water resources due to climate change
Decreasing water resources due to climate change
Low population growth
Moderate population growth
High population growth
Decreasing urban poverty
Constant or increasing urban poverty
Increasing urban poverty
Urban structure with green spaces
Urban structure without green spaces
Autonomous Water Authority with integration and participation
Water Authority with power of single groups
Water Authority depending from government or with power of single groups
Public water company with authonomy from government
Public water company depending from government
Private water company
High water tariffs
Low water tariffs
Decreasing water consumption
Increasing water consumption
Stagnant water consumption
•Increasing waste water treatment
•Increasing water infrastructure
•No change in waste water treatment
•No change in water infrastructure
Decreasing water network losses
Increasing water network losses
No Water Deficit
Moderate Water Deficit
High Water Deficit
Scenario I: Precaution and overshoot: Lima faces water surplus
Scenario II: Development without climate change stress
Scenario III: Climate change - a mastered challenge
Scenario IV: Lucky escape: an unprepared society remains free from climate change stress
Scenario V: Climate change stress meets governance-desaster
Scenario VI: The tragedy of isolated measures: Investment program in adverse environment
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Scenarios „Lima 2040“

- Some examples:

III: Climate change - a mastered challenge

An alarmed and capable society takes determined measures (organisational, infrastructure, savings) to respond to the challenge of a severe climate change stress (water resource decrease, rural exodus) and narrowly succeeds (although a failure was not impossible).

Water deficit: 🙂

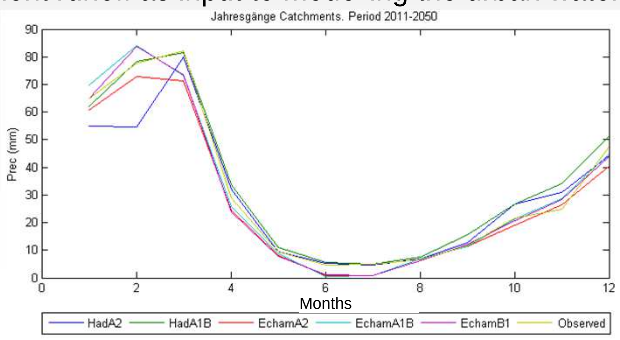
V: Climate stress meets governance-disaster

An inactive society with unprepared water governance faces the cruelty of a severe climate change. Decreasing water resources, rural exodus and a neglected infrastructure combine to a desperate situation. This scenario marks the worst case of the LiWa scenario set. No final judgement was made so far whether it should be considered also as the non-suprise/trend scenario.

Water deficit: ☹

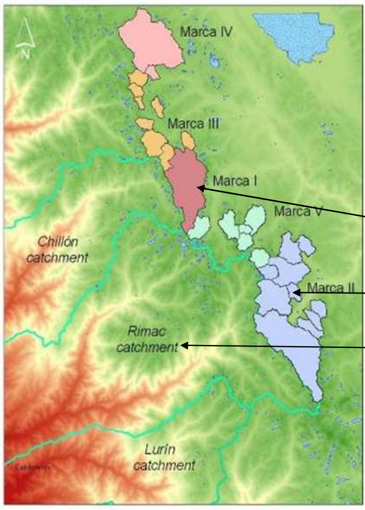
Climate and water balance modelling

- Climate data regionalisation; Water balance in river catchments
- Uncertainty about future climate patterns, but range could be determined – „worst case“: increasing water scarcity in Lima
- Catchment runoff as input to modelling the urban water system

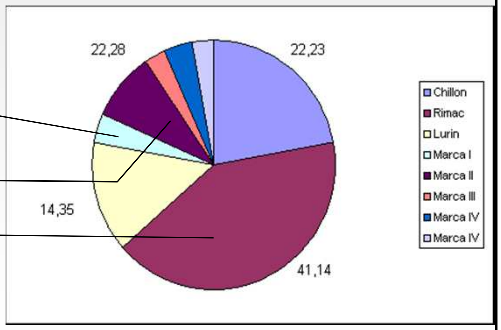


Annual precipitation pattern (downscaling)

Climate and water balance modelling



Rainfall distribution in the river catchments



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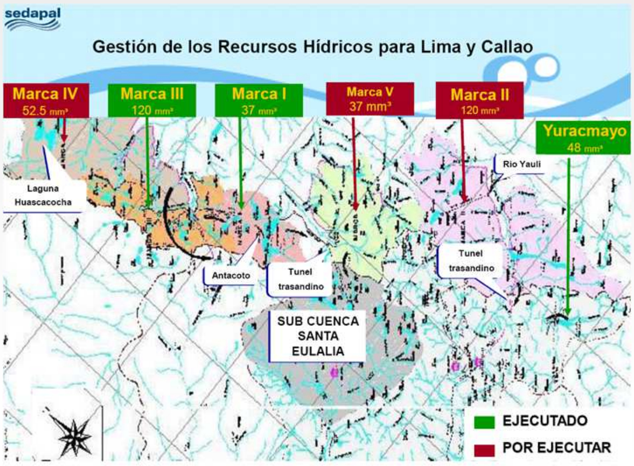
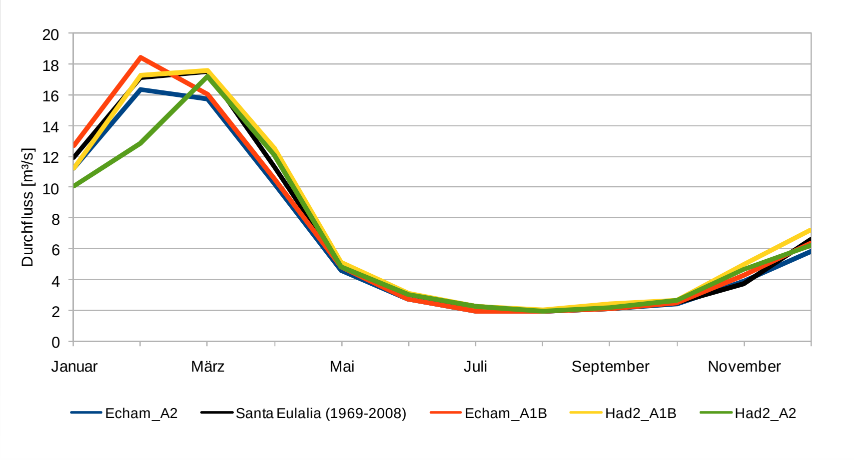
Climate and water balance modelling

Andean reservoirs in operation (green) and in planning/construction (red)



Source: SEDAPAL (2011)

Climate and water balance modelling: Application of GCM to Santa Eulalia river



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Climate and water balance modelling

- Prediction, climate change: Temperature and precipitation
  - Analysis de Global Circulation Models
  - Downscaling
- Rainfall-runoff models
  - Empirical models
  - Conceptual model (HBV)
- Prediction: Flows

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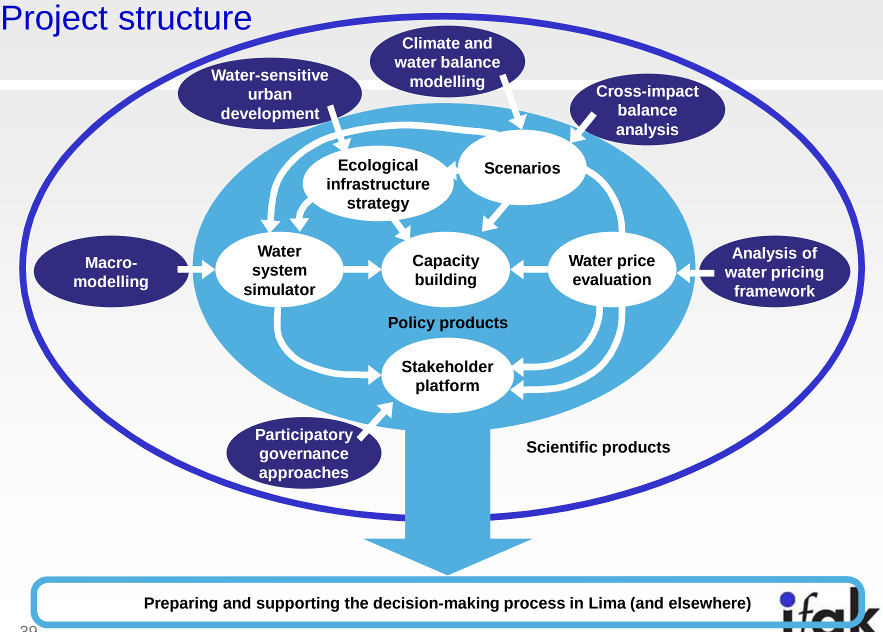
Project structure



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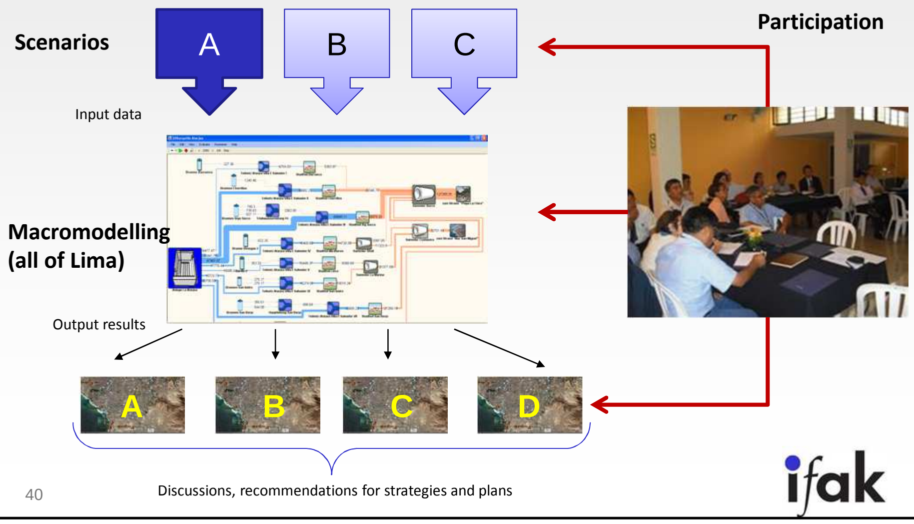
Simulation, evaluation and discussion of scenarios



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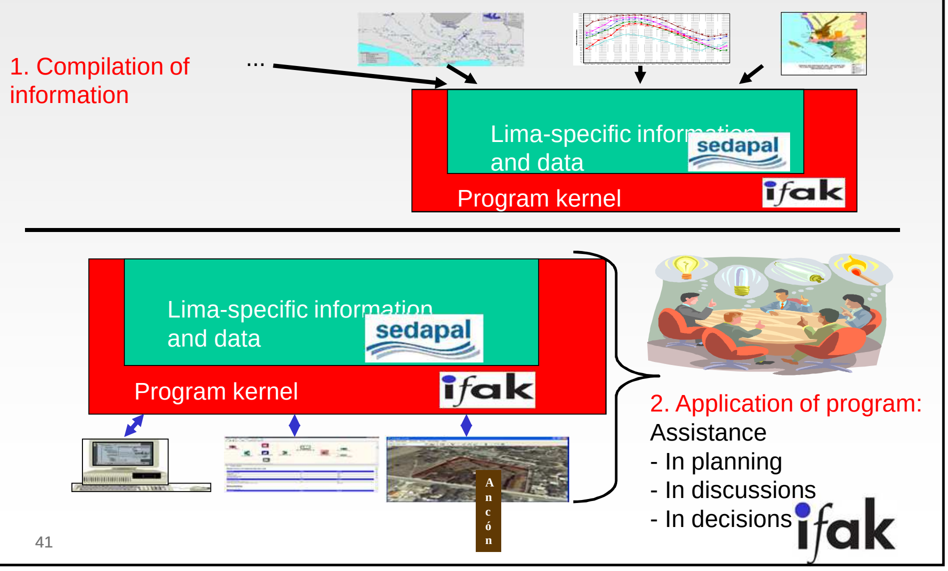
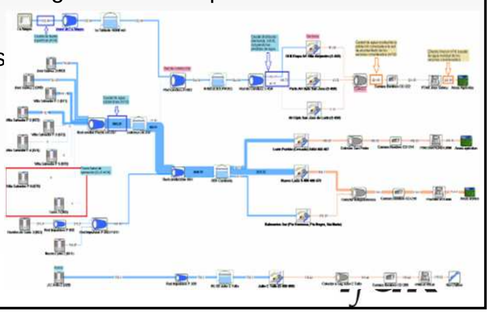
Macromodelling and water-system simulator
Development in close cooperation with the water company

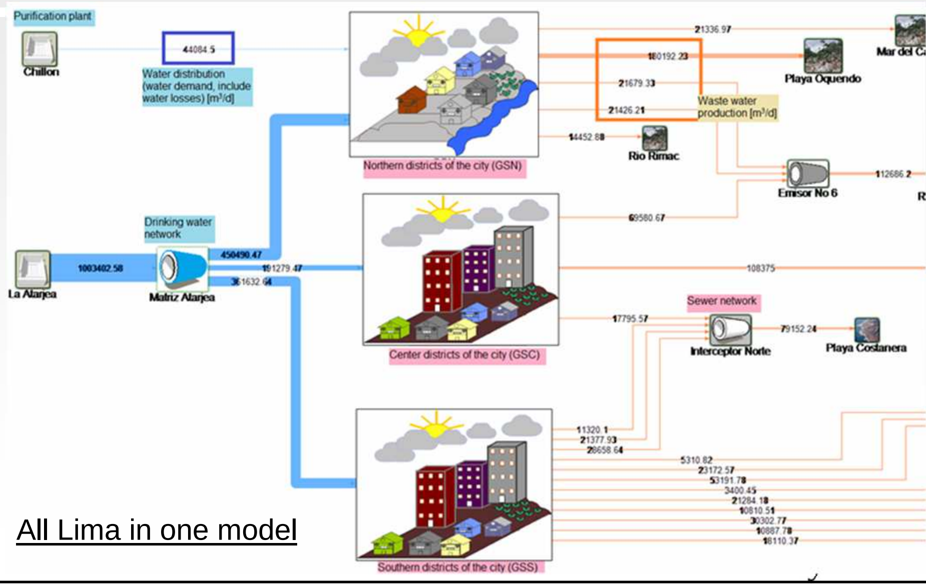


Macromodelling and water-system simulator

- Water system simulator („LiWatool“): Representing the entire water and wastewater system of Lima in one single model
- Ressource fluxes: water, quality; Energy, expenditure, revenue
- Providing a platform for:
  - Participative discussion and decision making
  - Supporting strategic planning and management of complex urban water systems in an integrated form
  - Evaluation of scenarios and options
- High degree of flexibility
- Micromodelling initiated

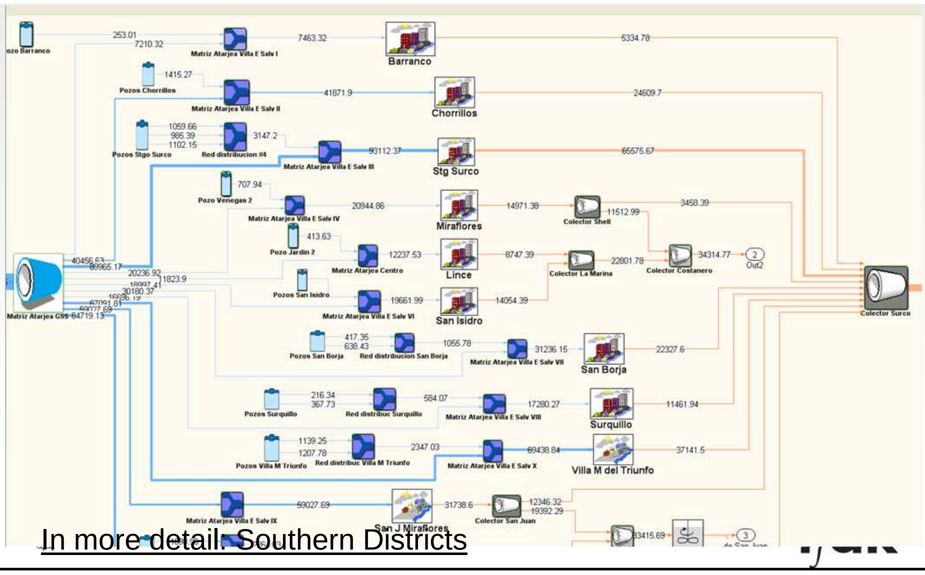


Macromodelling and water-system simulator



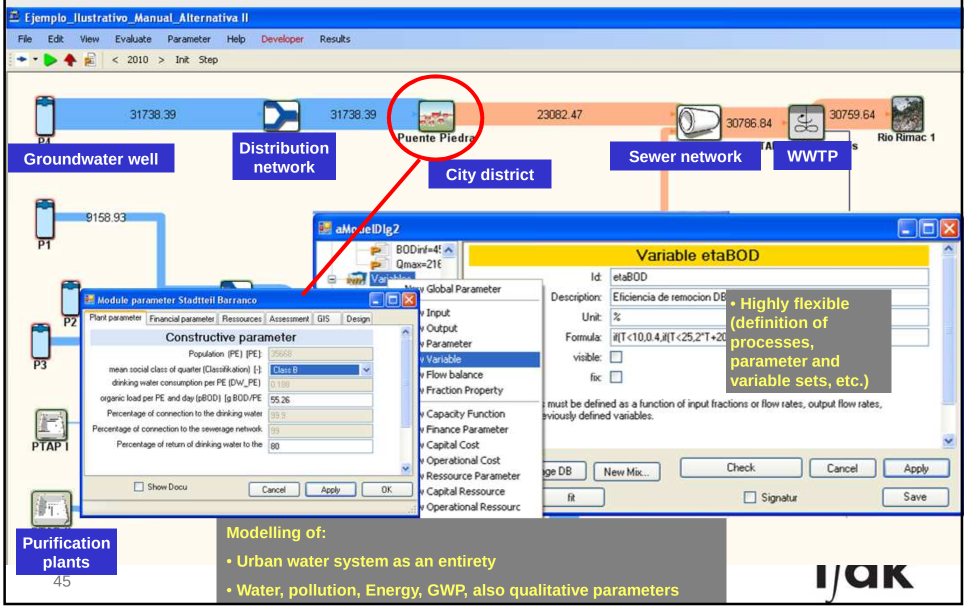
All Lima in one model

Macromodelling and water-system simulator



In more detail: Southern Districts

Macromodelling and water-system simulator



Modelling of:

- Urban water system as an entirety
- Water, pollution, Energy, GWP, also qualitative parameters

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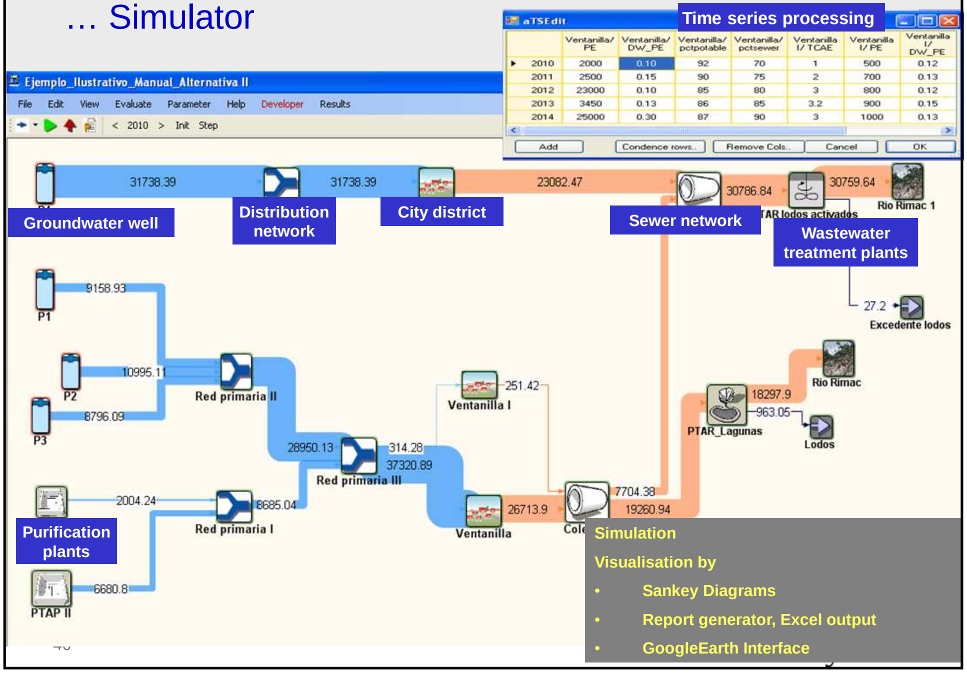
… Simulator

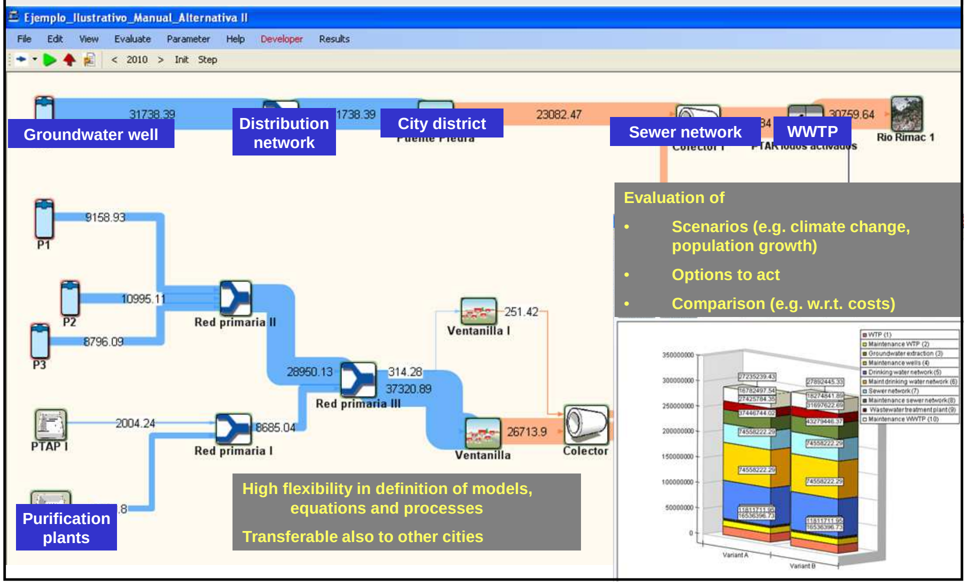


Simulation

Visualisation by

- Sankey Diagrams
- Report generator, Excel output
- GoogleEarth Interface

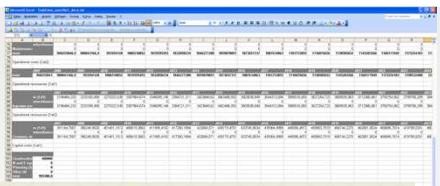
Macromodelling and water-system simulator

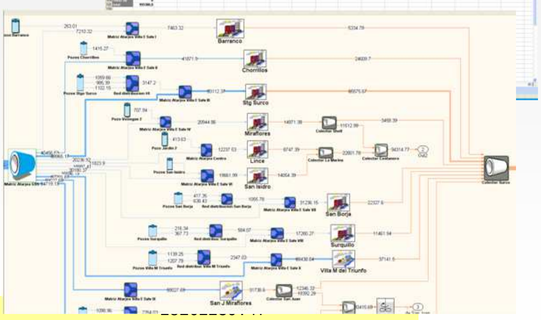


Macromodelling and water-system simulator

Representation of results:

- Excel
- Calculation of criteria values
- Sankey diagrams
- Interactive maps (GoogleEarth)
- Link to GIS envisaged





```
Revenue from tariffs [PEN]:
Energy consumption [kWh]:                         6055758.61
Wastewater [m3]:                                 14896515.28
BOD discharges into the ocean [kg BOD]:           5275836.44
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Macromodelling and water-system simulator

- Future population and water management data:
- Here: Percentage of poorer levels of society in 2030

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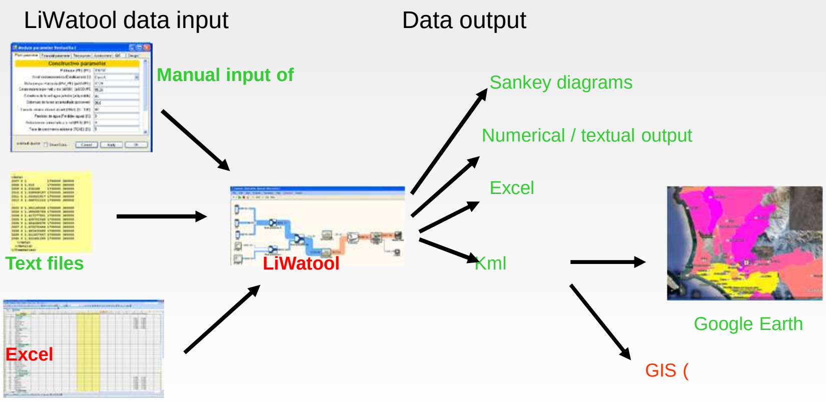
LiWatool – Data input/output



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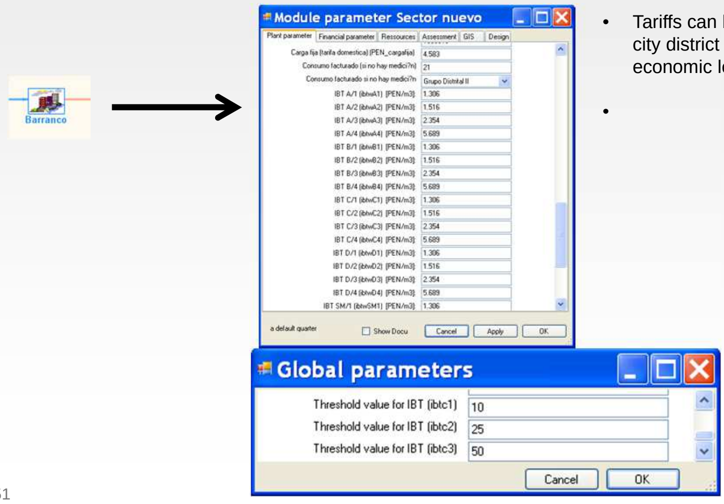
Water tariffs in LiWatool



- Tariffs can be defined for each city district and for each socio-economic level
-

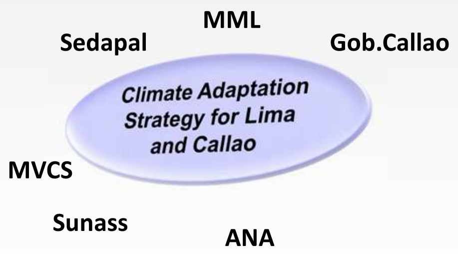
Water price evaluation

- Tariff structure looks good, but some problems:
- Subsidizing affluent single persons
- Non-networked water: expensive
- Lacking perception of water scarcity and value

- Alternative tariff designs
- Effects are being simulated

Participation approach

- First Round Table 06 October 2011



Stakeholder meeting
Comunidad Andina de Naciones, March 2010

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Water sensitive land-use management:
LEIS - Lima ecological infrastructure strategy

Objective: Developing planning and design tools leading to **water sensitive land use management**, considering urban growth and **limited water resources** in Lima metropolitan area

Outcomes:

- **Guidelines:** principles of the **water sensitive urban development** through the ecological infrastructure strategy of Lima
- **Tool: GIS-based planning and design tool** that has data interface to “LiWatool” macromodelling simulator
- **Manual: Design book** that presents **technical solutions** for the implementation of water sensitive urban design

Shangai Houtan Park constructed wetland
Integrated to human and urban development

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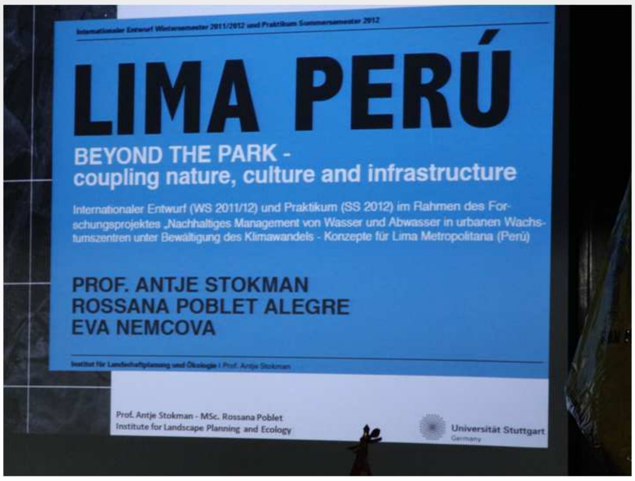
Water sensitive land-use management:
LEIS - Lima ecological infrastructure strategy



Ánnouncement of student project at Stuttgart University (ILPOE)

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Capacity building

- ❒ Modules for **master courses** in Peru and in Germany
- ❒ Moodle E-learning system (**https://liwa.ostfalia.de**)
- ❒ Research on **specific water technologies** by PhD projects
- ❒ **Professional training course**
- ❒ **Interdisciplinary student exchange**
- ❒ **Specific capacitation activities** (modelling, tariffs, …)

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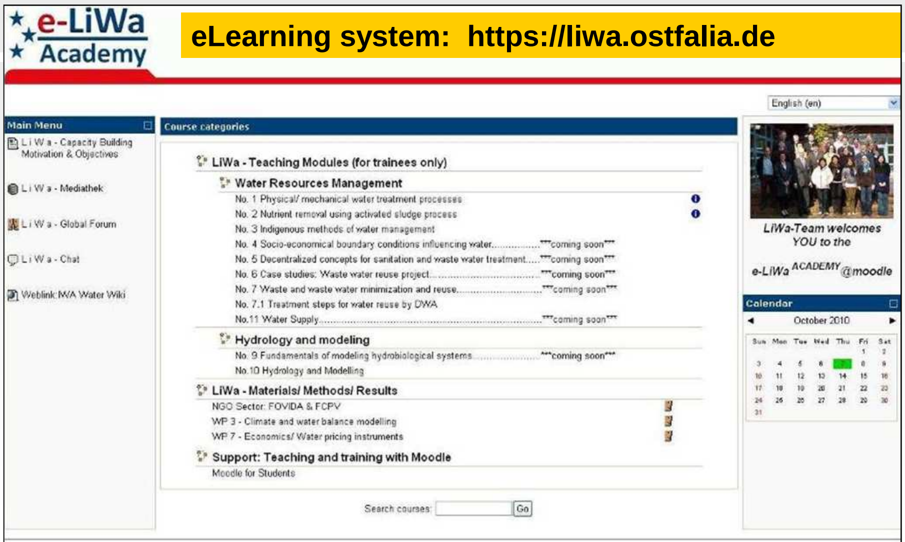
Capacity building

eLearning system: https://liwa.ostfalia.de



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Summary

- Water management in cities is a complex task
- It has to be supported by
  - Consideration of future developments
  - Informed discussions, stakeholder participation
  - Modelling, for enhancing understanding of the system
- Numerous insitutions in Lima (and internationally) involved

- Developments are ongoing in Lima:
  - Baby has been born; now it has started to walk!

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Group A: Action options

- ❒ Which options to improve water and wastewater management in urban agglomerations do exist?
- ❒ How can they be motivated / implemented in practice?

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Group A: Action options
Some potential action options:

- Structural measures (large scale), e.g.
  - Additional reservoir lakes (for water supply and energy production)
  - Wastewater reuse plants, Wastewater treatment plants
  - Desalination plants; Fog-catchers
  - Leakage reduction
  - Expansion of existing or construction of new infrastructure (e.g. drinking water networks)
- Structural measures (medium and domestic scale), e.g.
  - Improvement of existing plants (e.g. energy demand, GHG emissions)
  - Water-saving devices (e.g. dual-flush toilets)
  - Stormwater infiltration (in Lima not an issue)
- Non-structural measures, e.g.
  - Real time control (resulting in better, more flexible use of existing infrastructure) of: water supply / pressure management / wastewater system / treatment plants
  - Awareness-raising campaigns; Changes to water tariff structure, metering
  - Capacity building of experts and decision makers
- And many more

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Group B: Criteria

- „Sustainable water and wastewater management“ – what does this mean? How will you assess the benefit of some measures/action taken? Put yourself in different roles (e.g. water company, population, industry, agriculture, fishermen, national government, …)

- Try to summarise your findings in a list of criteria

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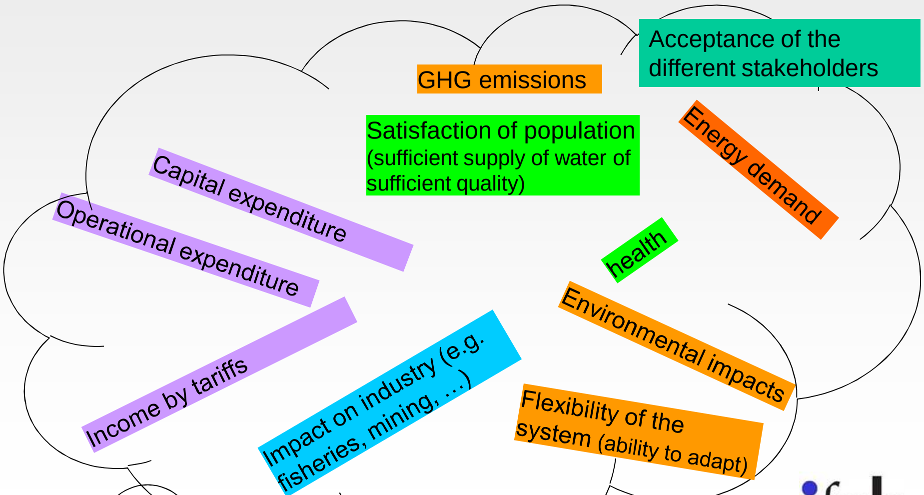
Group B: Criteria
Some potential criteria:



→ There exists a multitude of relevant criteria