This presentation premiered at WaterSmart Innovations

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Integration of participatory and technical approaches for urban water management in scarcity conditions

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The research team

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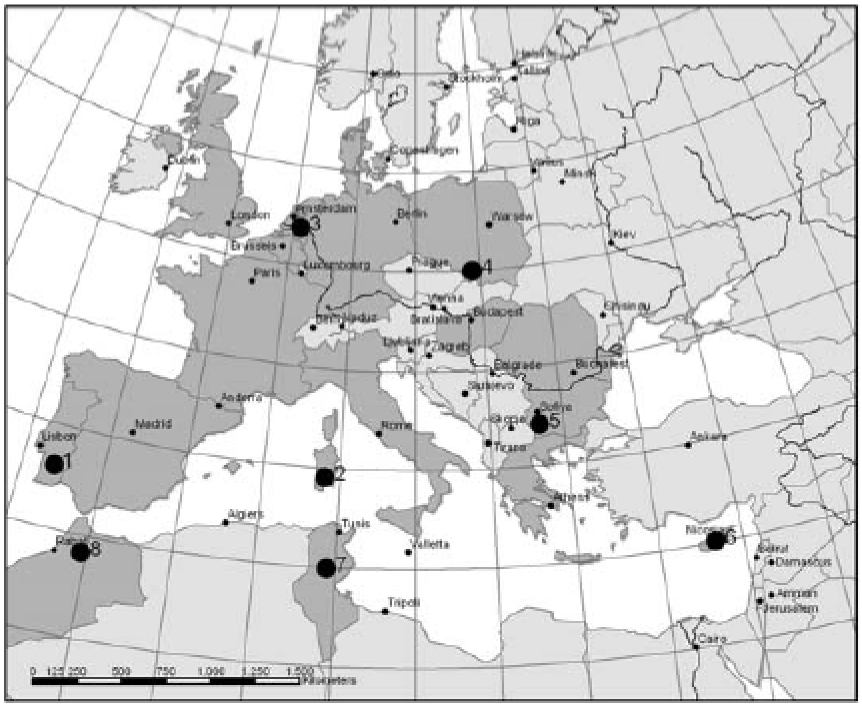
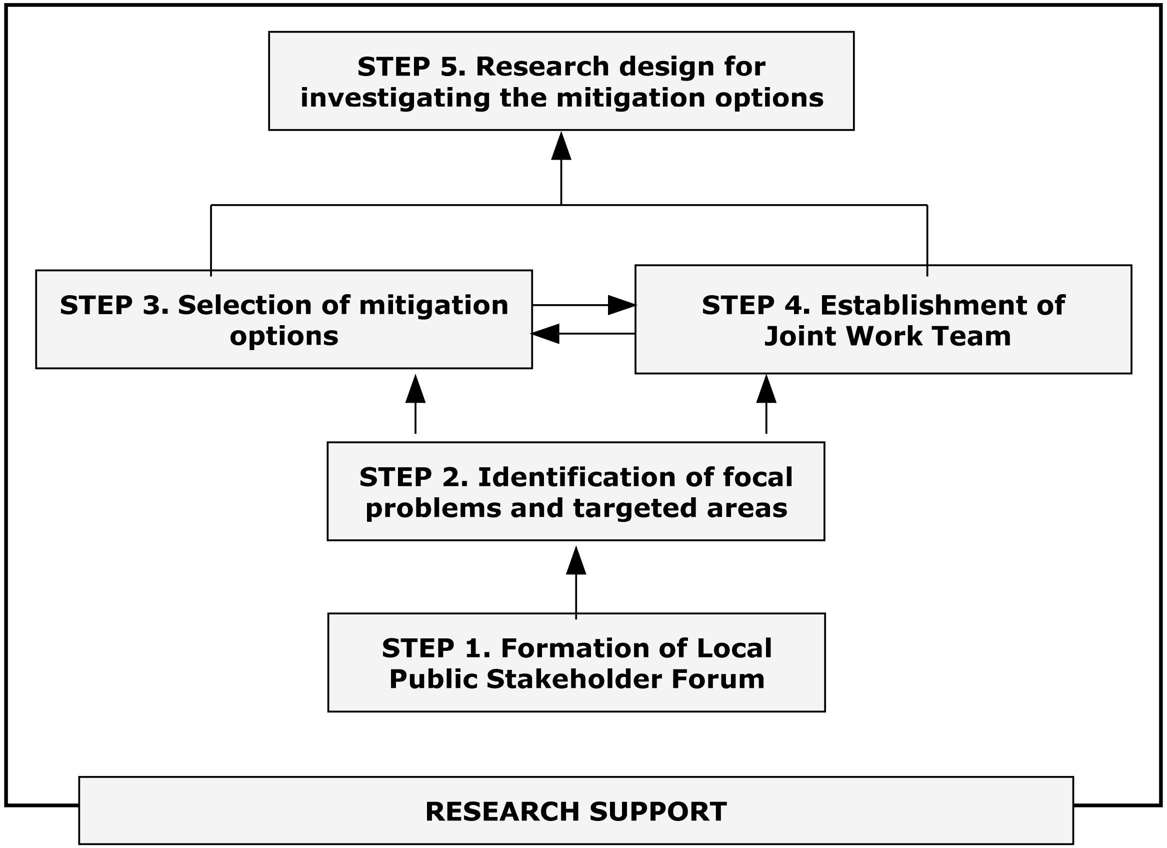
- Rheinisch-Westfaelische Technische Hochschule Aachen (RWTH), Germany
- University of Exeter, UK
- Cranfield University, UK

Aquastress project

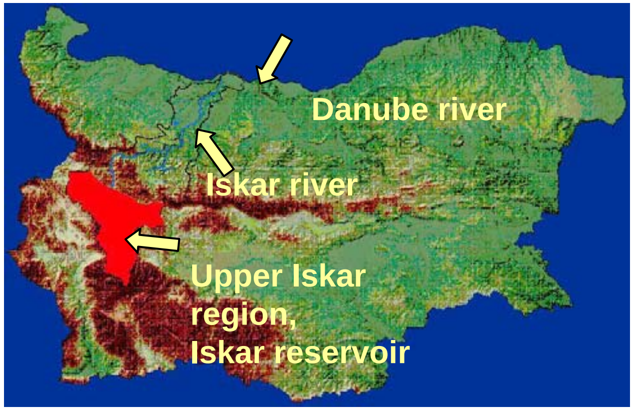


- Financed by the EU Commission, 2005-2009;
- Around 14 million Euro;
- 36 partners;
- 8 test sites – EU and Africa

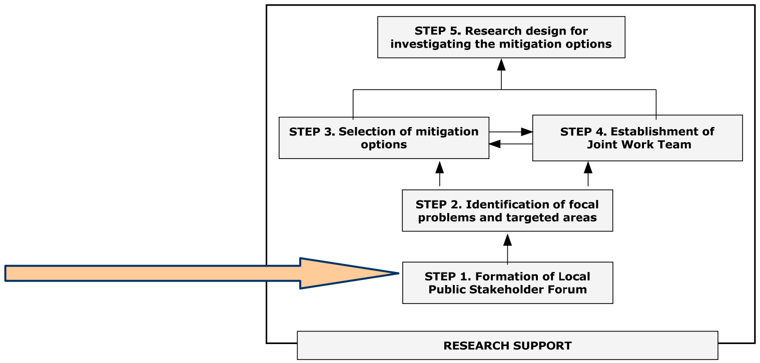
The test sites approach



Iskar test site, Bulgaria



Step 1 - LPSF

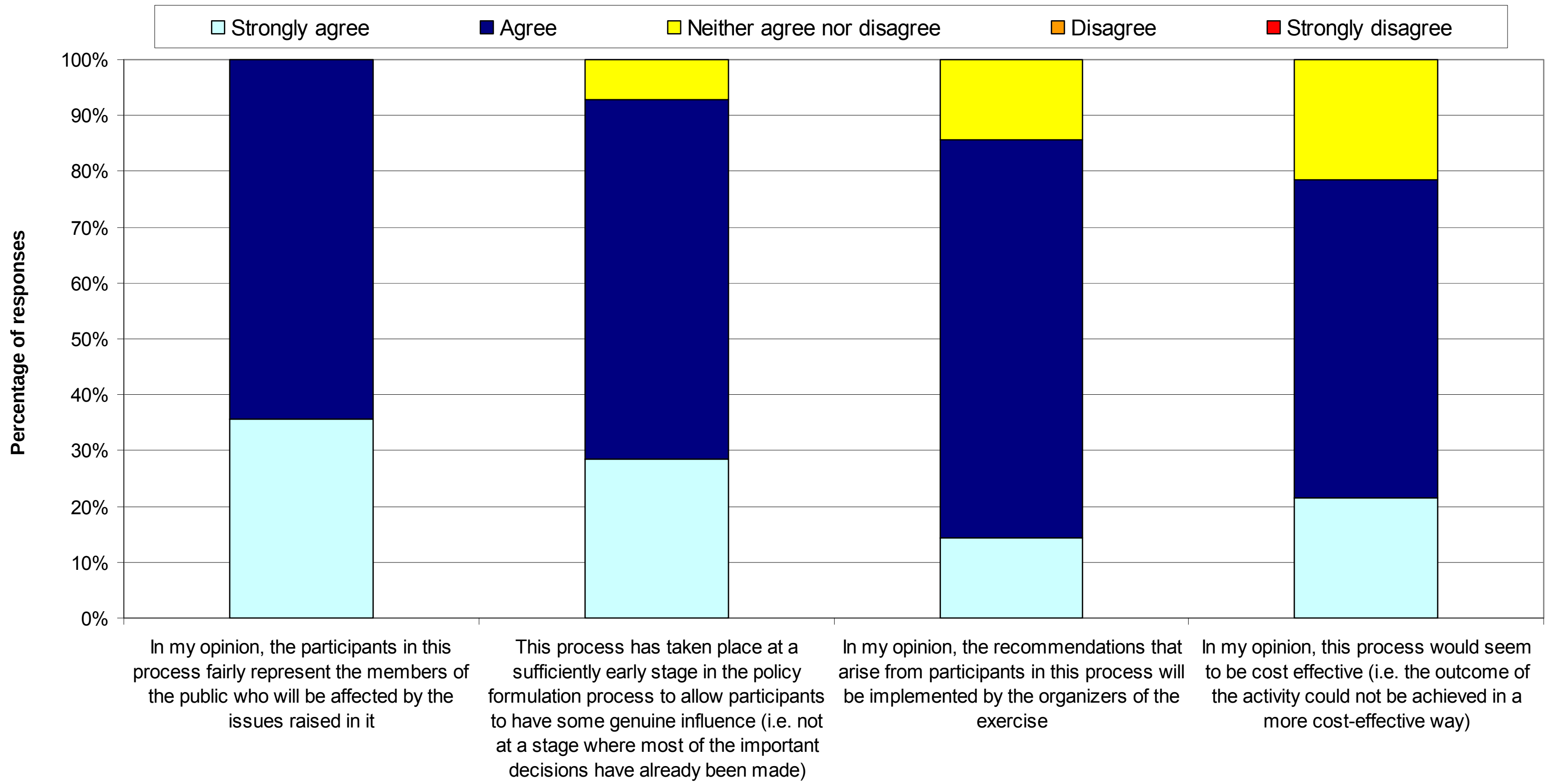


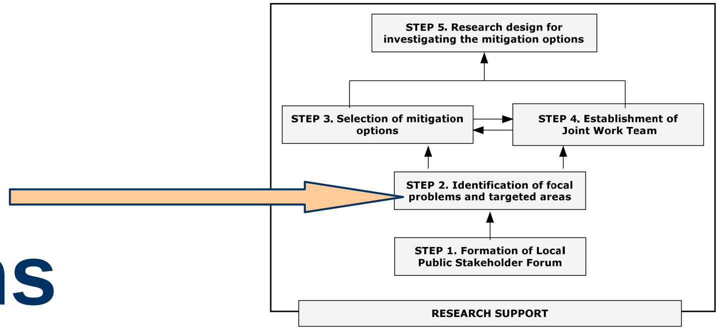
- LPSF – Local public stakeholder forum;
- Identification (mapping) of the stakeholders;
- Assessment of stakeholder interests and agendas;
- Investigation of patterns of interaction and dependence.

Members of Iskar LPSF

Participant	Type	Role
Ministry of Environment and Waters	*Institution*	Determines the water policy in Bulgaria
Danube Basin Directorate	*Institution*	Controls execution of the water law in the Iskar catchment
Municipality of Samokov	*Institution*	Administrates the first large town upstream of Sofia
Department of Dams and Cascades from the National Energy Company	*Public Utilities*	Operates the Iskar reservoir
Sofiyska Voda Ltd	*Related Services*	Responsible for the provision of the water, sewerage and wastewater treatment services to the city of Sofia
Raikomers	*Related Services*	The biggest company in Sofia building new pipelines and repairing old ones
Institute of Irrigation and Mechanization, Sofia	*Main water consumer*	Determines the irrigation policy in the Sofia region
Heating installations	*Main water consumer*	Supplies Sofia with heating services, operates the installations
Kremikovtzi, Ltd	*Main water consumer*	The biggest metallurgy plant in Bulgaria, significant polluter of the Iskar river
Bulgarian Water Association on Water Supply and Sewerage	*NGO*	Open to all individuals who are interested in water problems
Association of Lawyers	*NGO*	Provides knowledge on the legislative aspects
Forum of Bulgarian Women	*NGO*	Examines gender issues
Global Water Partnership, Bulgaria	*NGO*	Participates with experts to examine the interrelations between water and vegetation
Local expert	*Individual*	Provides expertise for Iskar reservoir management, developer of the software SOPER
Chairmen of a building council	*Individual*	Represents the citizens' opinion

Evaluation of the participatory process by the participants





Step 2 – Focal problems

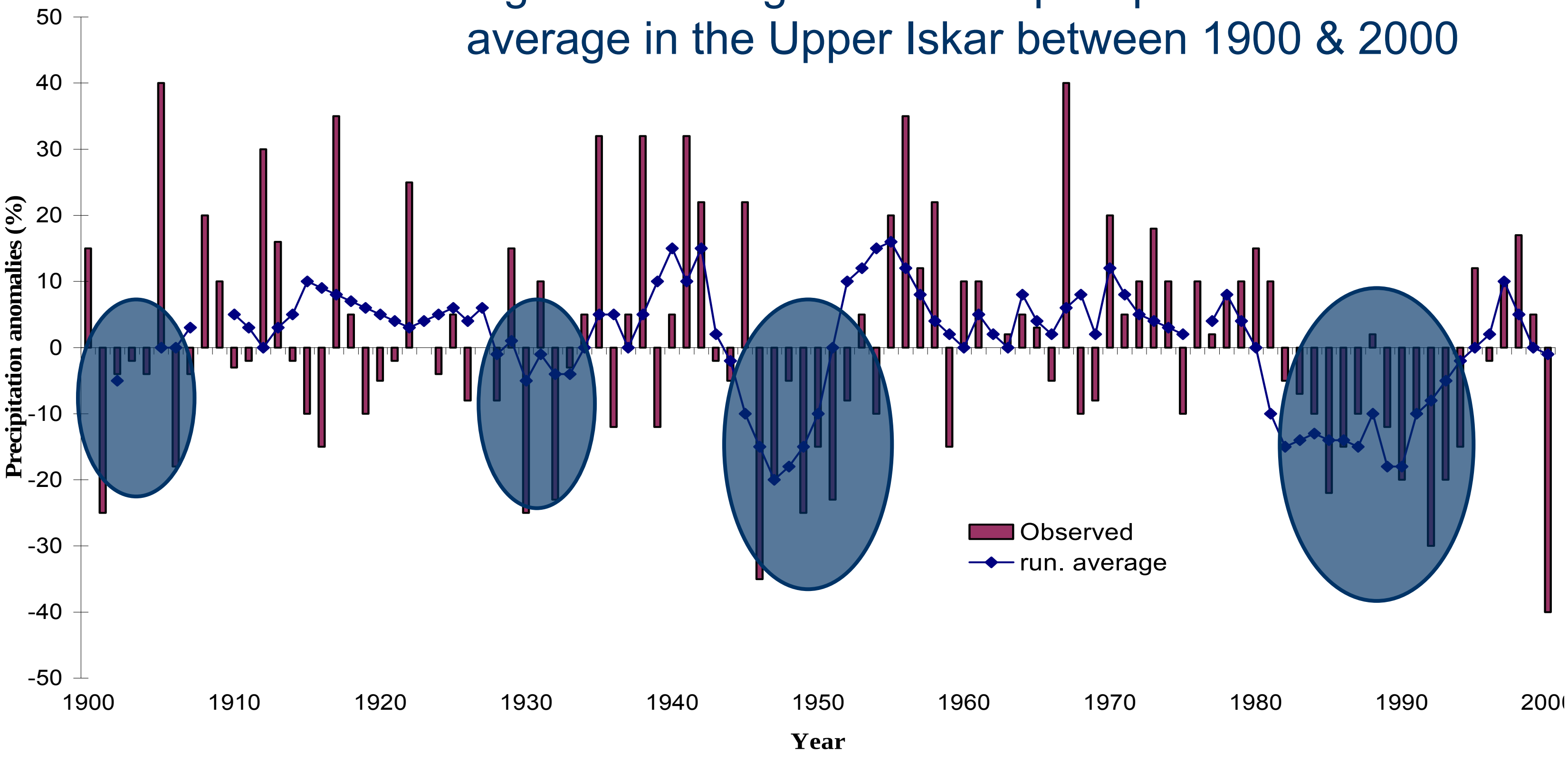
Water Exploitation Index (WEI)

- The European Environment Agency (EEA) uses the Water Exploitation Index to indicate water stress.
- $$WEI = \frac{Total\ consumption\ (annual)}{Total\ available\ water\ resources\ (annual)}$$
- WEI >0.4 = water stress,
- WEI >0.6 = severe water stress.
- The existing total consumption for the Iskar reservoir is 323 Mm^3/year, and the existing total available water resources are 554 Mm^3/year so:

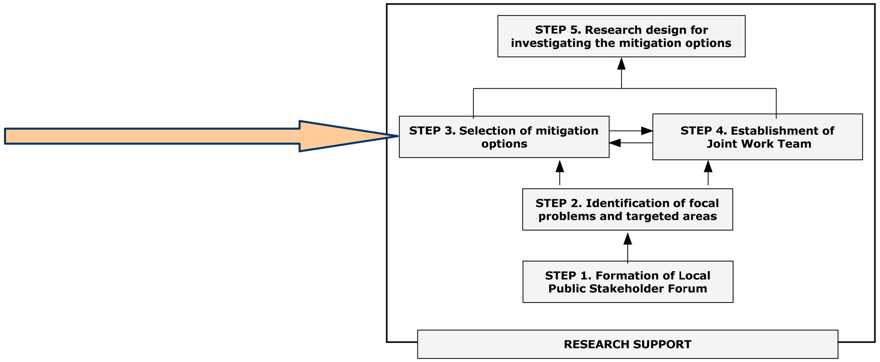
The current WEI in the Upper Iskar is 323/554 = <u>0.58</u>

Risk of water shortages in the Upper Iskar

Histogram showing variation in precipitation from the average in the Upper Iskar between 1900 & 2000

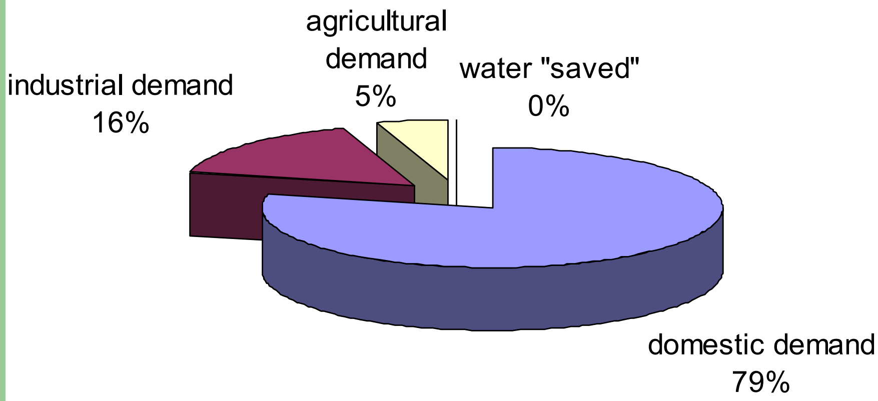


Step 3 – Selection of mitigation options



Water abstraction from Iskar reservoir by sector

2004

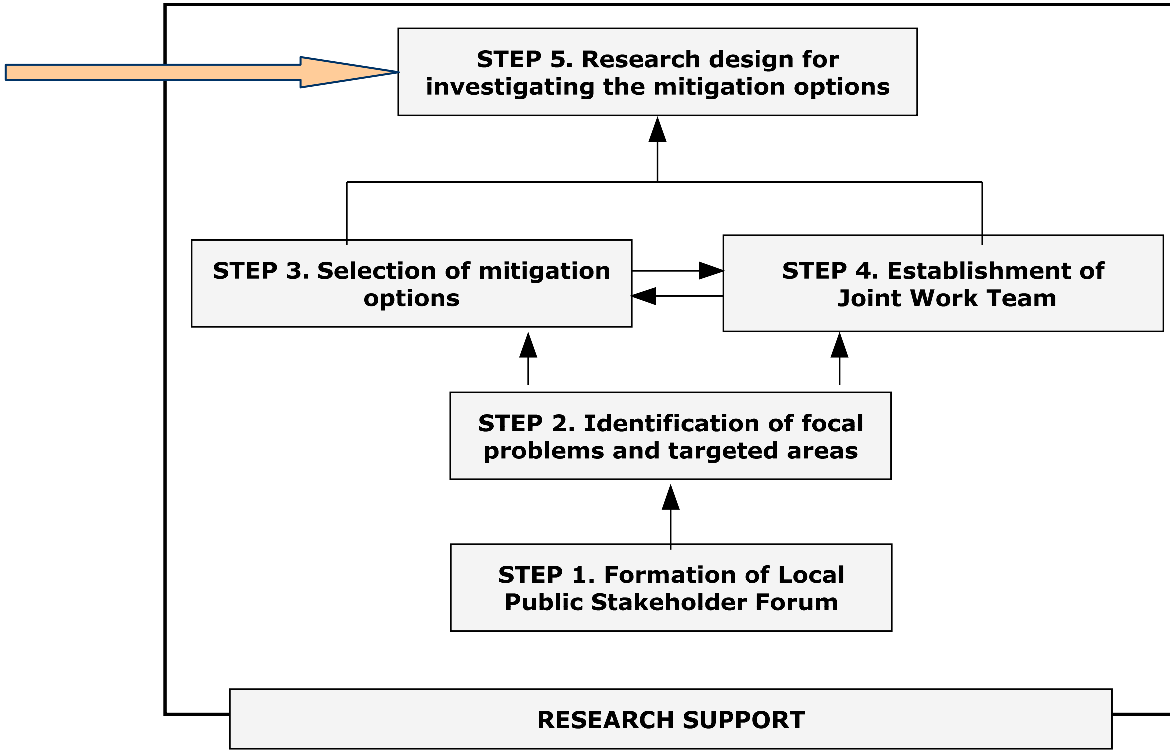


Mitigation options

Option 1. Saving water in industry

Option 2. Saving water in households

Step 5. Research design for investigating of mitigation options



Mitigation Option 1. Exploring the water saving potential in industry

1. 1. Metallurgical plant Kremikovtzi
1. 2. Aim
1. 3. Methods – water balancing and system dynamic modeling
1. 4. Results

1.1. Metallurgical plant Kremikovtzi

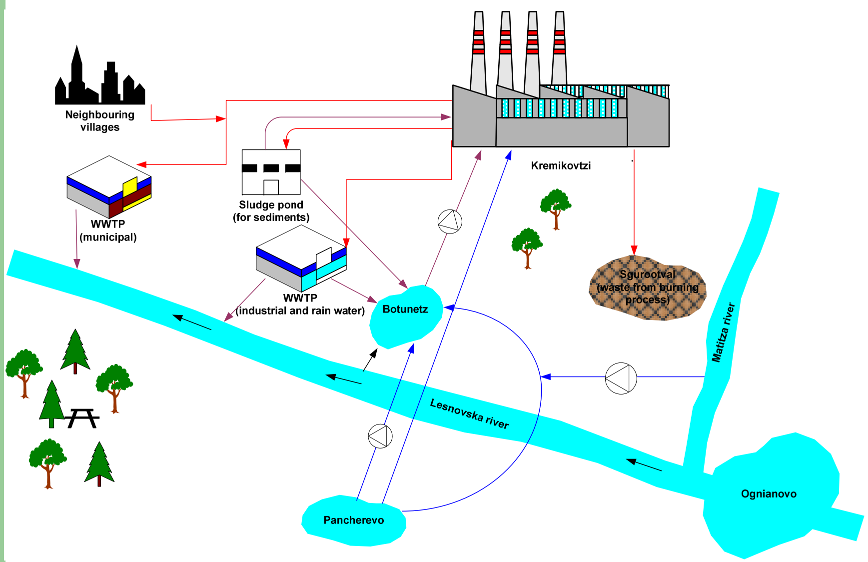
- **Kremikovtzi is a steal producing company, one of the largest water consumers in the region, equivalent to water demands for a city of 600000 inhabitants**
- **Water demands for the plant amound to 550 million m³ / year, a significant percentage of which is recycled within the plant.**
- **The plant takes about 50-60 million m3 /year fresh water from two reservoirs, 2 rivers and from groundwater sources.**
- **Complex operational rules**

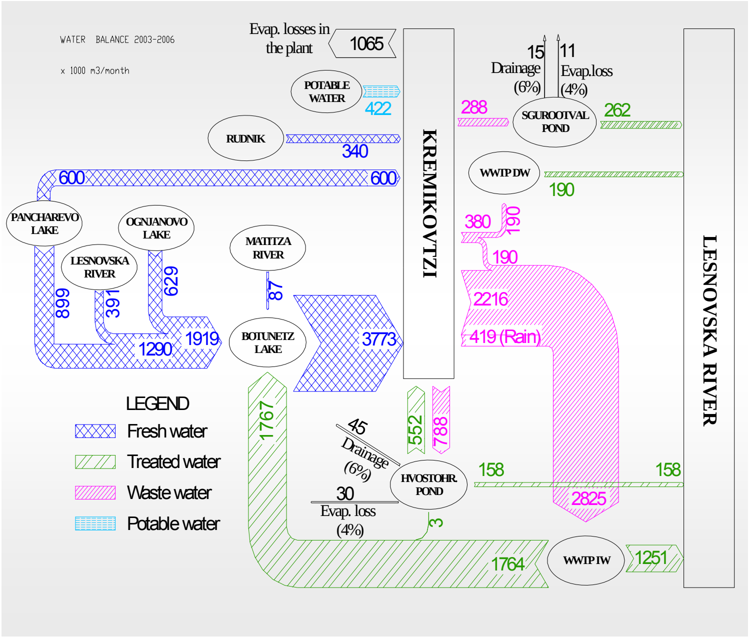
(Very) Complex Water system!

1.2. Objectives of the study

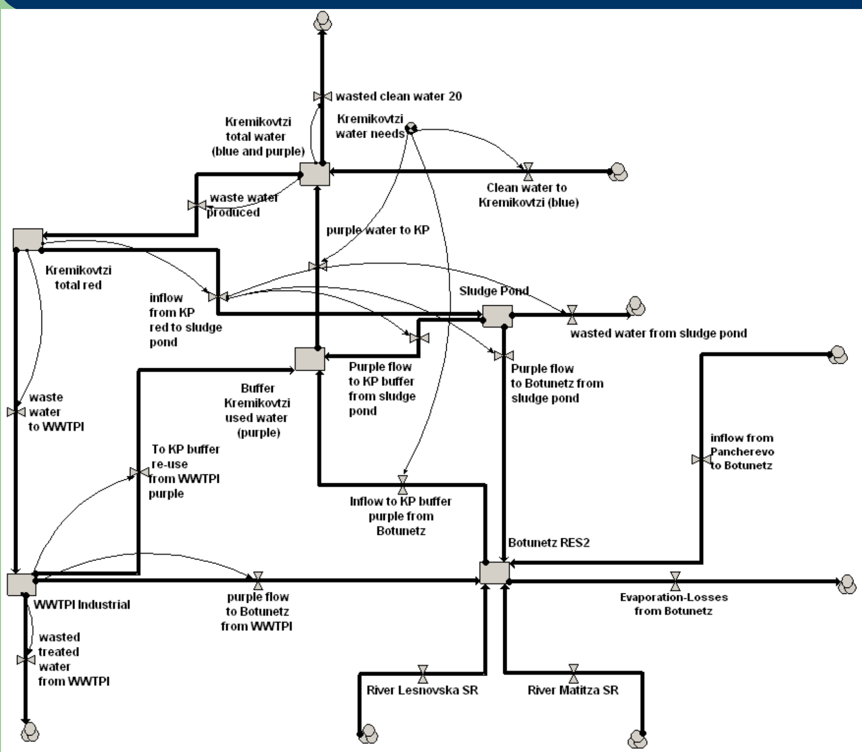
- Assessment of the current state (data collection, balances, water management of all process units);
- Assessment of the improvement potential;
- Recommendations for water saving measures

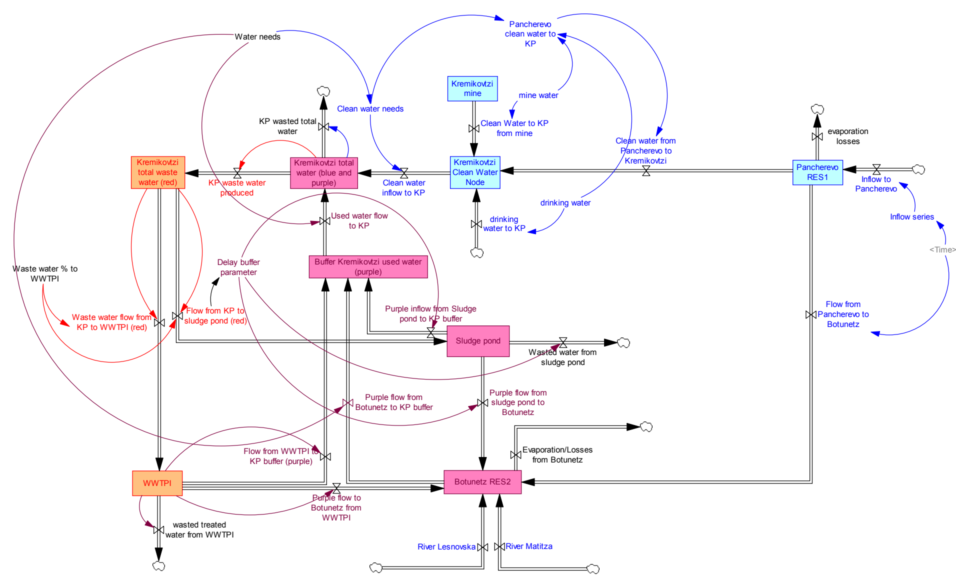
1.3. Methods - water balances





1.3. Methods - System Dynamic Modeling (SDM) supported by two softwares



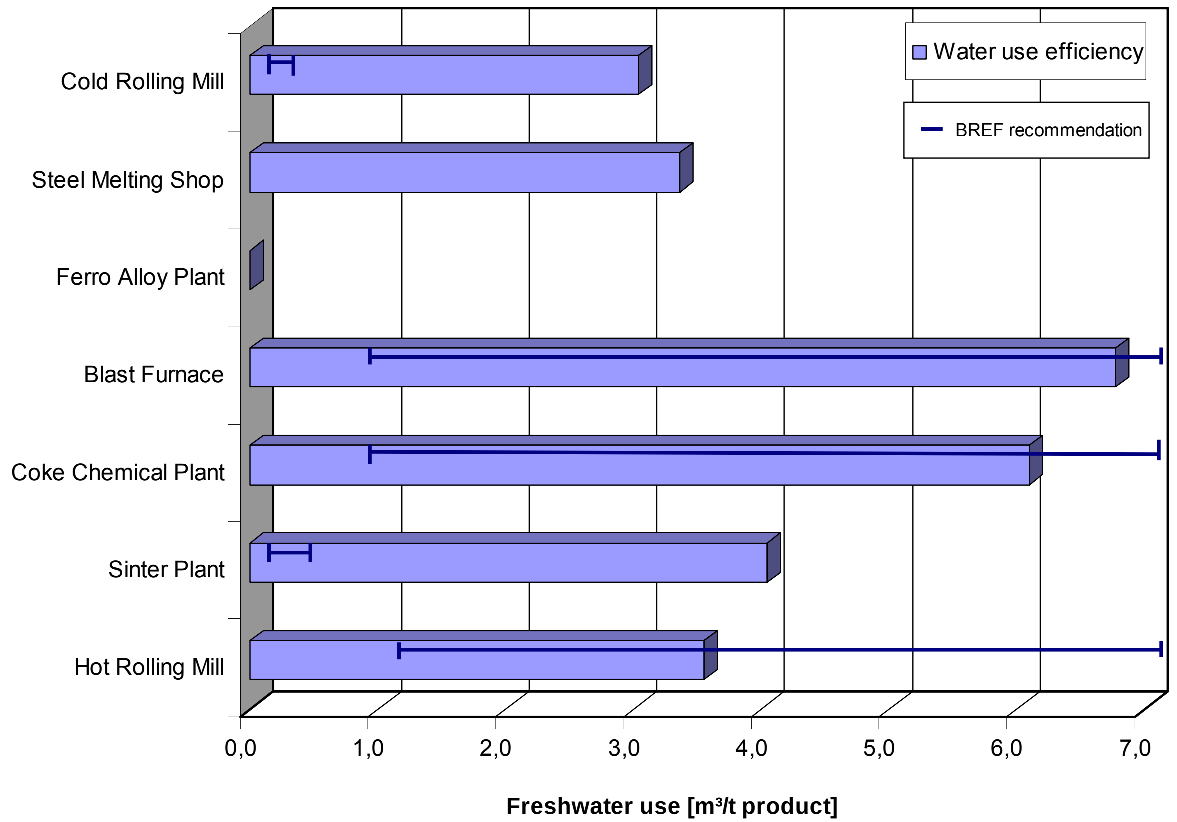


SIMILE **VENSIM**

1.4. Results: Current situation at Kremikovtzi

- Very large use of industrial (fresh) water (50 - 61million m^3/a);
- Seasonal limits for industrial water supply imposed by the MOEW;
- Water reuse well below industry standards in spite of 91% recycling rate;
- Lack of modernisation of the technological processes in terms of industrial water saving

1.4. Results: Comparison with BREF (Best available technology reference documents)

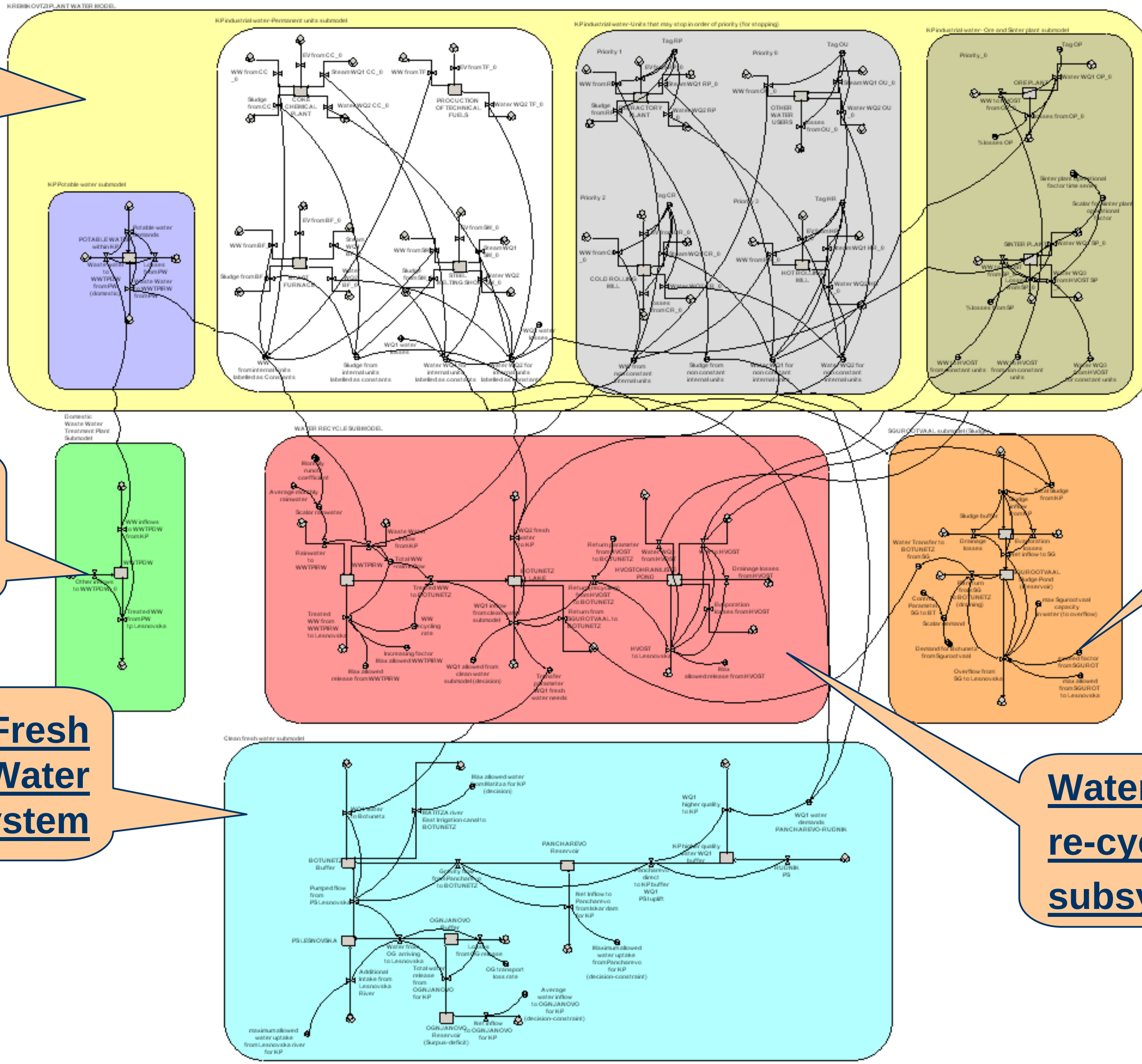


1.4. Results: Final SDM Model Kremikovtzi

KP plant internal subsystem

Domestic Waste Water

Clean Fresh Water subsystem



Sludge Pond

Water re-cycling subsystem

1.4. Results: Application of the SDM for Kremikovtzi

- Generating various potential operational **scenarios**, based on:

  - Different climatic conditions *"normal", "dry" and "very dry" years*
  - Different industrial water *recycling* rates at the WWTP (*%*)
  - Different *operational rules/hierarchies* for the water resources
  - Different *priorities* for the water demands for industrial units
  - *Monthly* time step (on a monthly basis)

1. *Reduce the plant fresh water needs*
2. *Improve the rate of water re-use*
3. *Study operational policies for "normal", "dry" and "very dry" years and their impacts on the plant and the water resources*

1.4. Results: Calculations of the recycling ratio using SDM

Normal	1.1	Recycle 70%	0.504
year	1.2	Recycle 65%	0.476
	1.3	Recycle 60% A (Increased Pancharevo-Reduced Lesnovska)	0.447
	1.4	Recycle 60% B (*Current status*)	0.447
	1.5	Recycle 75%	0.533
Dry	2.1	Recycle 90%	0.579
year	2.2	Recycle 90%+ Return WQ3 from Hvosto	0.622
Very dry	3.1	All units on	0.628
year	3.2	OP stops	0.623
Recycle	3.3	OP stops+ Other water users (Priority 0)	0.637
95%	3.4	OP stops+ Non permanent units (Priority 1)	0.630
	3.5	OP stops+ Non permanent units (Priority 2)	0.630
	3.6A	OP stops+ Non permanent units (Priority 3)	0.601
	3.6B	OP stops+ Non permanent units (Priority 3)+ Pancherevo excess to Botu	0.601
	3.7.1A	OP stops+ Non permanent units (Priority 3)+ SP 5/6	0.591
	3.7.2A	OP stops+ Non permanent units (Priority 3)+ SP 4/6	0.579
	3.7.2A	OP stops+ Non permanent units (Priority 3)+ SP 3/6	0.567
	3.7.1A	OP stops+ Non permanent units (Priority 3)+ SP 5/6+ Pancherevo excess	0.591
	3.7.2A	OP stops+ Non permanent units (Priority 3)+ SP 4/6+ Pancherevo excess	0.579
	3.7.2A	OP stops+ Non permanent units (Priority 3)+ SP 3/6+ Pancherevo excess	0.567
	3.8.1	OP stops+ SP 5/6	0.617
	3.8.2	OP stops+ SP 4/6	0.611
	3.8.3	OP stops+ SP 3/6	0.604

1.4. Results: Main conclusions of the scenarios

1. **"Normal" year: the system total recycling rate can increase from 44.4% (today) to 53.8% by recycling 75% of treated industrial waste water (instead of 60% today), saving on average 400×10^3 m^3/month of freshwater intake.**

2. **"Dry year" scenarios: It is possible to keep all units operating normally, if the industrial waste water recycling rate is set at 90%.**

3. **"Very dry year" scenarios: Hierarchical closure of some units and different recycled and fresh water allocation rules can keep the plant's most important units operating and minimize the deficit at the clean freshwater sources.**

1.4. Results: Measures for optimization of the industrial water utilization in Kremikovtzi

- Improvement of the efficiency of industrial water cooling systems;
- Modernization of the high pressure pump station at the hot rolling mill plant;
- Implementation of system for utilization of condensate;
- Optimization of the operation of pump aggregates

Mitigation Option 2. Exploring the water saving potential in the domestic sector

2. 1. Aim

2. 2. Methods

2. 3. Household survey results

2. 4. Bayesian networks application

2. 5. Main findings – WDM program

2.1. Aims of the study

- Understand citizen’s attitudes to water conservation
- Identify best options for reducing domestic water demand in Sofia
- Developing methods to support participatory planning for water demand management implementation

2.2. Methods

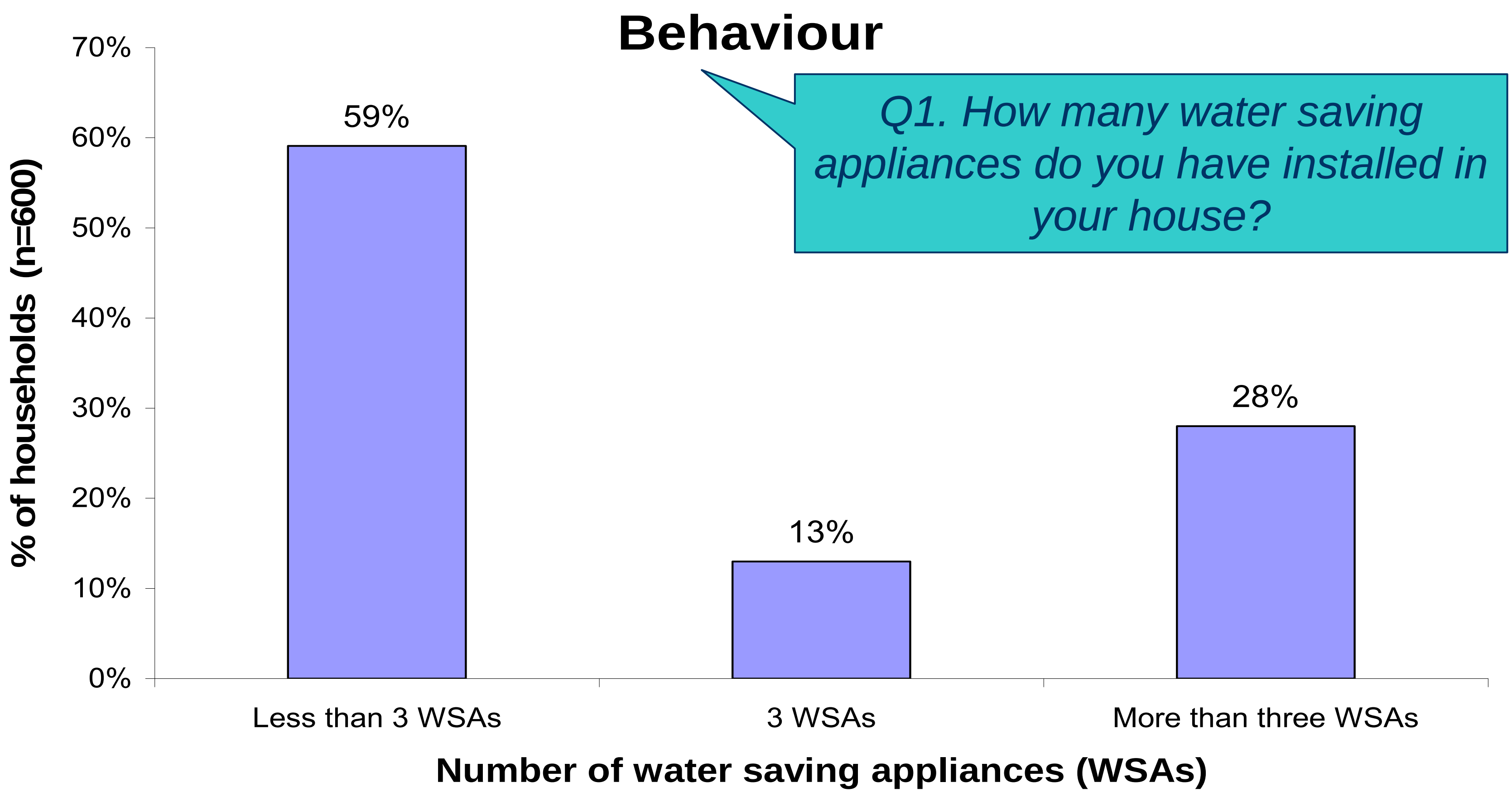
- Household survey

  In order to help citizens to participate in water conservation we need to understand why people display water saving behaviour:

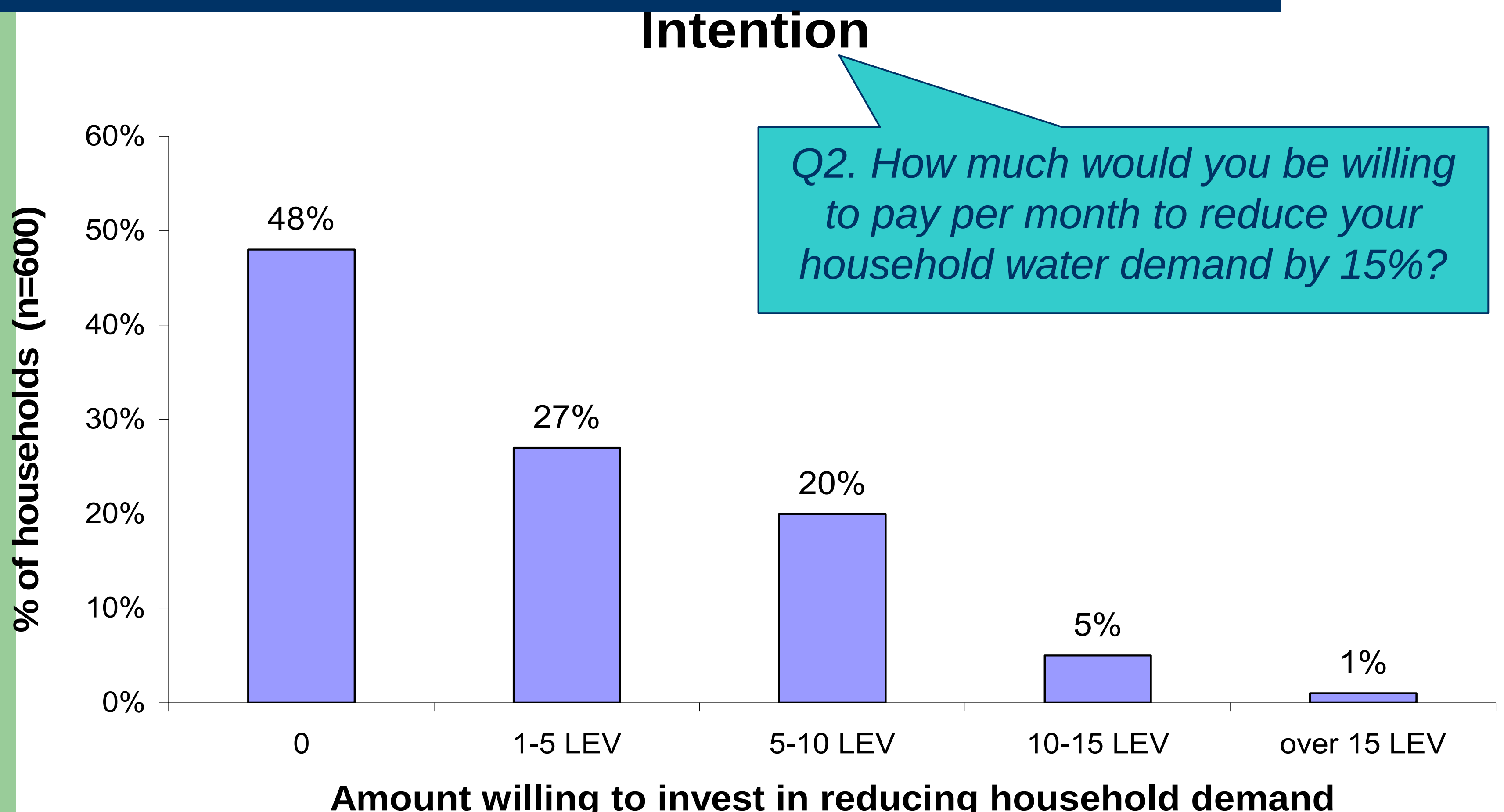
  - **Intention** – willingness to invest money or time in water saving
  - **Ability** – knowledge about how to reduce demand, ability to pay for saving water, access to water saving technology
  - **Attitude** – It's good / not good to save water
  - **Subjective norms** – environmental concerns, financial reasons, community awareness

- Bayesian networks

2.3. Household survey results (1)

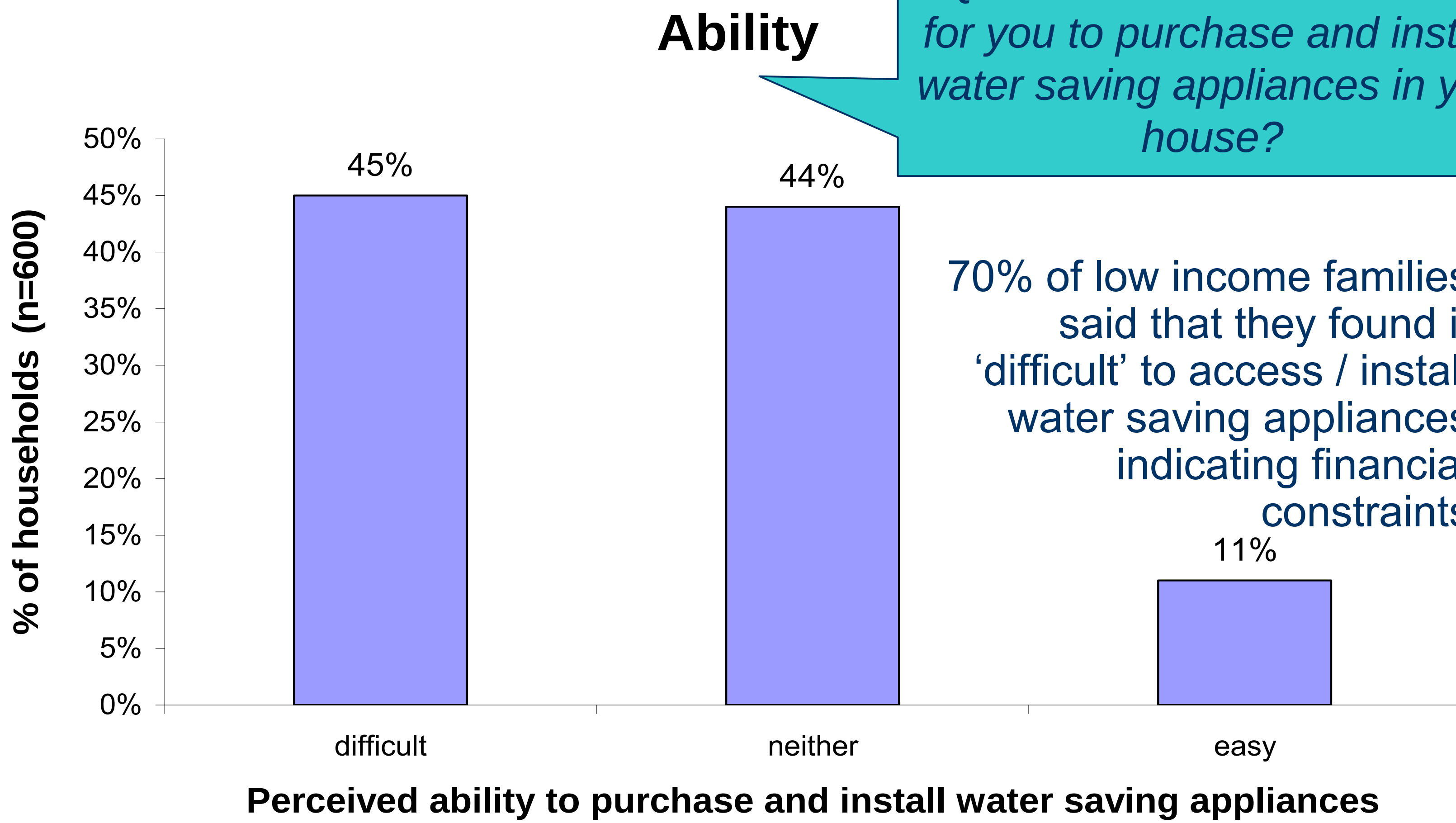


2.3. Household survey results (2)



2.3. Household survey results (3)

Q5. How difficult would it be for you to purchase and install water saving appliances in you house?



70% of low income families said that they found it 'difficult' to access / install water saving appliances indicating financial constraints

2.3. Household survey conclusions

Policy instruments are required to:

a) improve citizen’s knowledge about how to reduce demand,

b) provide financial support (e.g. free installation, rebates on water saving technology)

c) improve citizen’s access to water saving technology

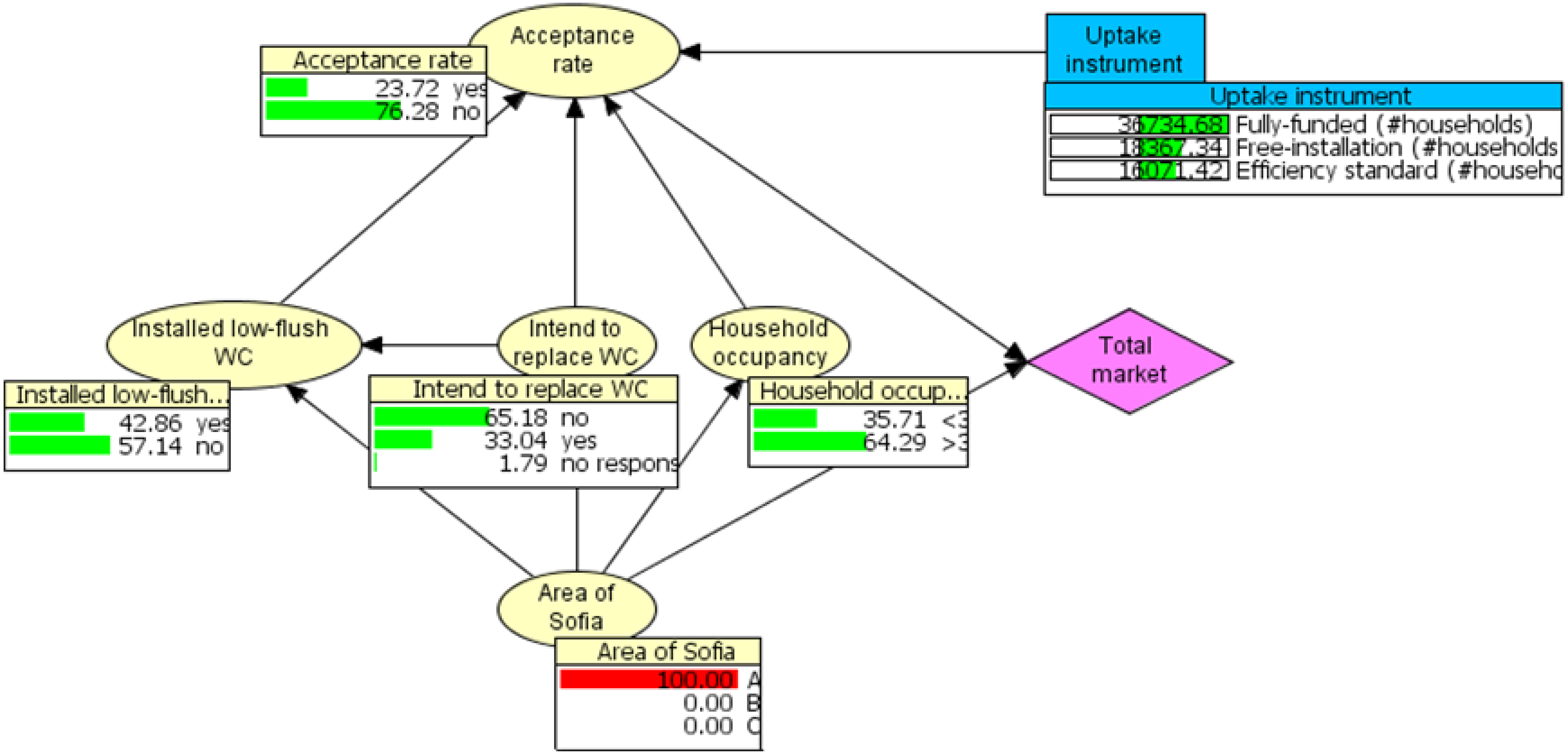
2.4. Use of Bayesian networks to support participatory planning for water demand management implementation

A. The use of Bayesian networks to evaluate implementation conditions for water saving technology
B. The use of Bayesian networks to explore the causes and effects of the 1993-1995 Sofia water crises

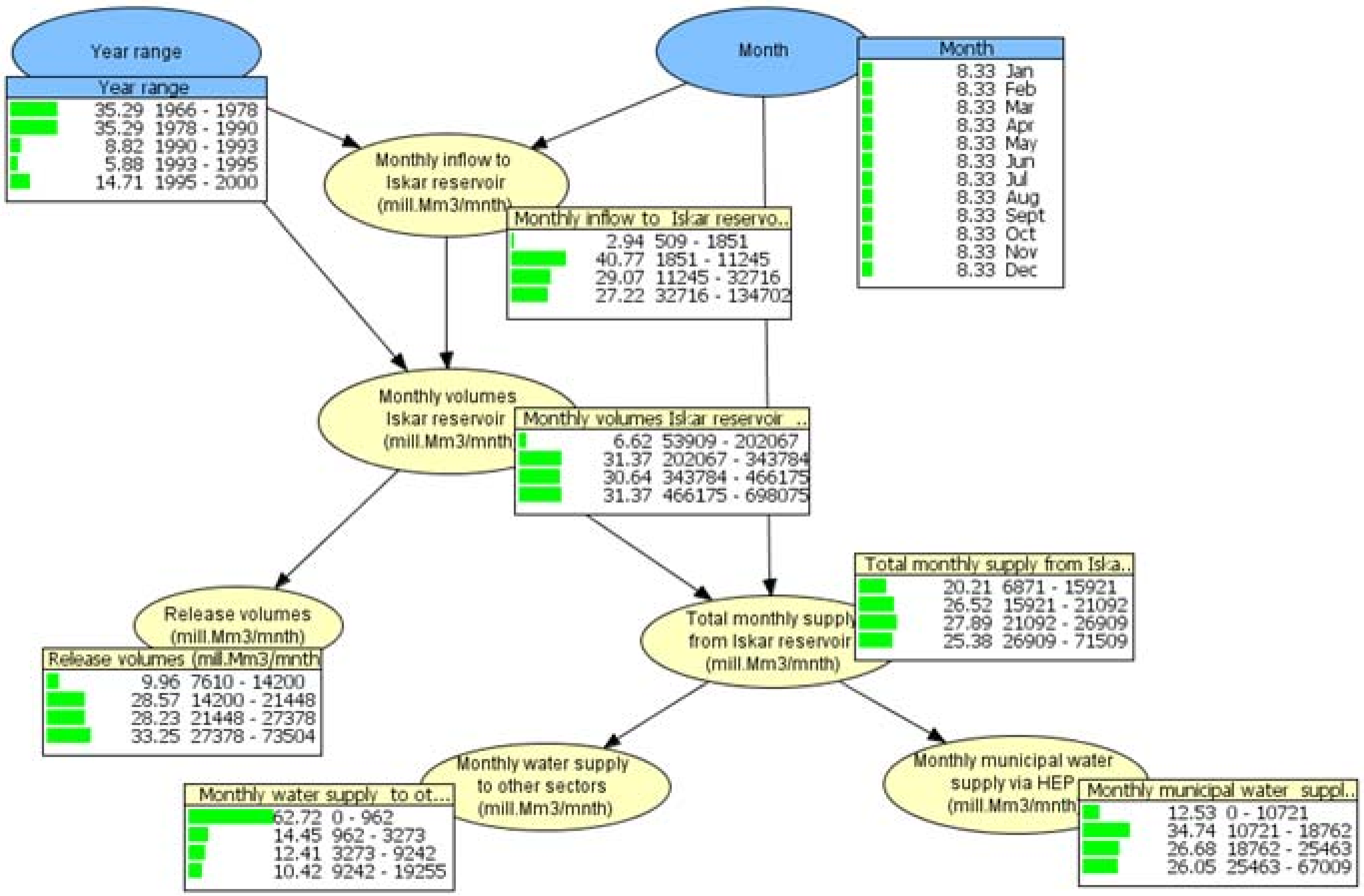
2.4. A. Use of Bayesian network in WDM programs

- Any WDM program needs to incorporate two basic elements:
  - a *measure* - ‘what to do’
  - an *instrument* - ‘how to do it
- Bayesian network assists in forecasting the ‘total market’ for a specific water conservation measure (low-flush WCs) and in examining whether uptake potential varies for different neighbourhoods.

2.4. A. The use of Bayesian networks to evaluate implementation conditions for water saving technology



2.4. B. The Bayesian network water balance model



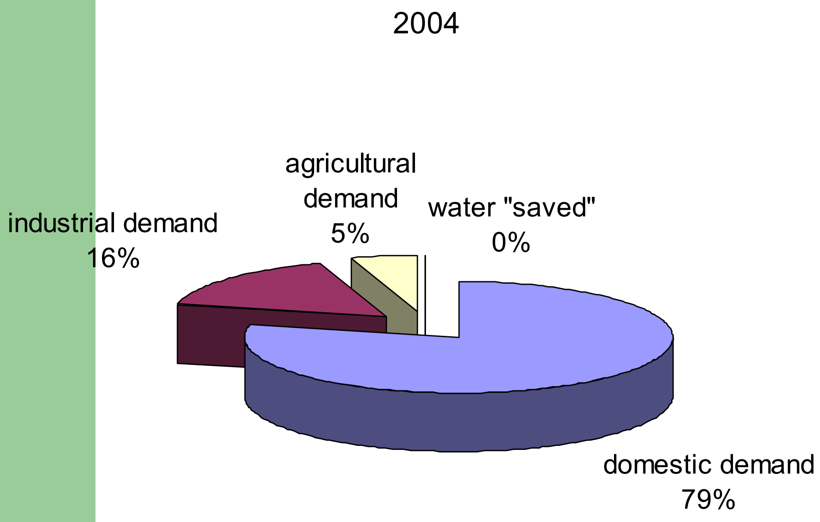
2.4. B. Use of the model to explore the causes and effects of the 1993-1995 Sofia water crises

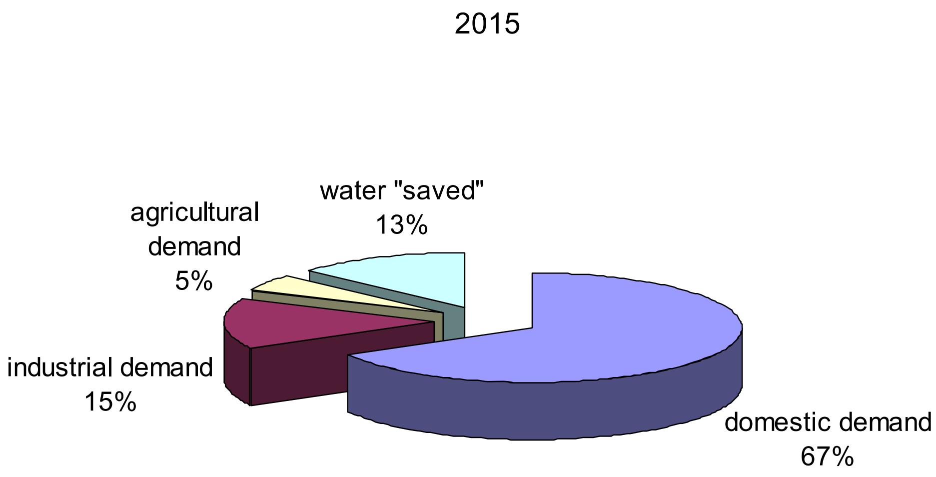
	1966-1978	1978-1990	1990-1993	1993-1995	1995-2000
Inflow	Monthly inflow to Iskar reser... 1.39 509 - 1851 38.19 1851 - 11245 29.86 11245 - 32716 30.56 32716 - 134702	Monthly inflow to Iskar reser... 0.00 509 - 1851 47.22 1851 - 11245 26.39 11245 - 32716 26.39 32716 - 134702	Monthly inflow to Iskar reser... 13.89 509 - 1851 41.67 1851 - 11245 19.44 11245 - 32716 25.00 32716 - 134702	Monthly inflow to Iskar reser... 20.83 509 - 1851 33.33 1851 - 11245 25.00 11245 - 32716 20.83 32716 - 134702	Monthly inflow to Iskar reser... 0.02 509 - 1851 33.89 1851 - 11245 40.98 11245 - 32716 25.10 32716 - 134702
Year	Year range 100.00 1966 - 1978 0.00 1978 - 1990 0.00 1990 - 1993 0.00 1993 - 1995 0.00 1995 - 2000	Year range 0.00 1966 - 1978 100.00 1978 - 1990 0.00 1990 - 1993 0.00 1993 - 1995 0.00 1995 - 2000	Year range 0.00 1966 - 1978 0.00 1978 - 1990 100.00 1990 - 1993 0.00 1993 - 1995 0.00 1995 - 2000	Year range 0.00 1966 - 1978 0.00 1978 - 1990 0.00 1990 - 1993 100.00 1993 - 1995 0.00 1995 - 2000	Year range 0.00 1966 - 1978 0.00 1978 - 1990 0.00 1990 - 1993 0.00 1993 - 1995 100.00 1995 - 2000
Reservoir volume	Monthly volumes Iskar reservo... 0.00 53909 - 202067 31.94 202067 - 343784 26.39 343784 - 466175 41.67 466175 - 698075	Monthly volumes Iskar reservo... 2.08 53909 - 202067 34.72 202067 - 343784 45.83 343784 - 466175 17.36 466175 - 698075	Monthly volumes Iskar reservo... 19.44 53909 - 202067 58.33 202067 - 343784 22.22 343784 - 466175 0.00 466175 - 698075	Monthly volumes Iskar reservo... 70.83 53909 - 202067 29.17 202067 - 343784 0.00 343784 - 466175 0.00 466175 - 698075	Monthly volumes Iskar reservo... 0.00 53909 - 202067 6.67 202067 - 343784 21.67 343784 - 466175 71.67 466175 - 698075

2.5. Demand management programs

Program	Demand management options	Potential reduction	Time horizon	Payback period
Minimum	Education/Awareness campaign Outdoor restrictions	2-5%	3 months	Less than 5 years
Moderate	Pressure reduction program Water efficient appliance standard	10-15%	2-5 years	5-10 years
Maximum	Increase leakage reduction effort Household water appliance retro-fit	20-30%	3-5 years	Over 10 years

Conclusions of the two options: Forecasted water saving potential in 2015





Team publications on these topics

- Dimova G., Tarnacki K., Melin T., Ribarova I., Vamvakeridou-Lyroudia L., Savov N. and Witgens T. (2007). The water balance as a tool for improving the industrial water management in the metallurgical industry – Case study Kremikovtzi Ltd., Bulgaria, IWA 6th Conference on Wastewater reclamation and Reuse for sustainability, 9-12 October. Antwerpen, Belgium
- Tarnacki K., Ribarova I., Drużyńska E., Dimova G., Wintgens T. and Melin T. (2007). Water stress mitigation in the industrial sector – common approach in the Przemsza (Poland) and Iskar (Bulgaria) river catchments, World Water Week 2007, Stockholm
- Vamvakeridou-Lyroudia, L.S., Savic, D.A., Tarnacki K., Wintgens T., Dimova, G. and Ribarova I. (2007). Conceptual/System Dynamics Modelling Applied for the Simulation of Complex Water Systems, in *Water Management Challenges in Global Change*, Proc. Int. Conf. CCWI 2007 and SUWM 2007, Ulanicki, B., Vairavamoorthy, K., Butler, D., Bounds, P.L.M. Memon, F.A. (Eds), Leicester UK, 3-5 Sept. 2007, Taylor & Francis Group, London UK, pp. 159-167.
- Vamvakeridou-Lyroudia and Savic D.A. (2008). System Dynamics Modelling: The Kremikovtzi Water System, Report No.2008/01, Centre for Water Systems, School of Engineering, Computing and Mathematics, University of Exeter, Exeter, U.K., 132p, accessible at www.ex.ac.uk/cws
- Inman D., Simidchiev D., Dimitrov G., Jeffery P (2007). Water Demand Management in Sofia: Mapping expert knowledge to deveop computer based Decision support tools to facilitate WDM implementation, Proceeding of IInd International Conference and Exhibition on water resources, technologies and services Bulaqua 2007, p.257-267
- Inman, D. A., Jeffrey, P.J., Simidchiev, D. (2008). Elicitation of expert knowledge to develop decision support tools for use in water demand management planning. Water Science & Technology, Vol 7, 5-6, 53-60
- Documentation and model available to download free from the internet at the website of the Centre for Water Systems, Exeter University: http://www.centres.ex.ac.uk/cws/projects/35-water-resources-management/13-aquastress