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science for global insight

Economic costs of human and climate changes impact on water resources: Application of IIASA global hydro-economic modeling framework

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Impacts World 2017

Half our planet's population are water insecure… uncertain futures

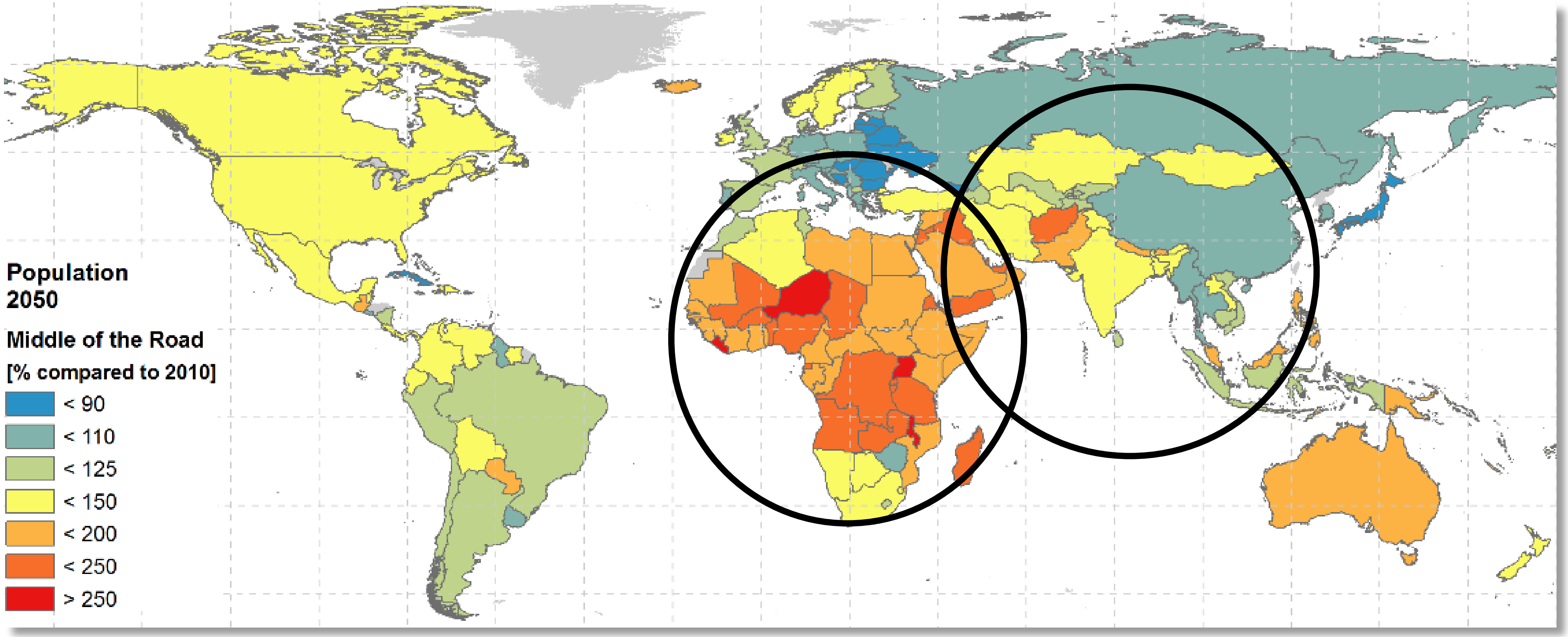
Absent or unreliable WSS

Food security and Irrigation

The impacts of unmitigated variability including floods & droughts

Degraded water environments

Population and Development Continues



Middle of the Road scenario (SSP2)

33% more people by 2050 compared to 2010 globally
(6.8 billion to 9.1 billion)

Population in [billion]
GDP [1000 billion US$/yr]
GDP per cap (PPP) in [1000US$/cap/yr]

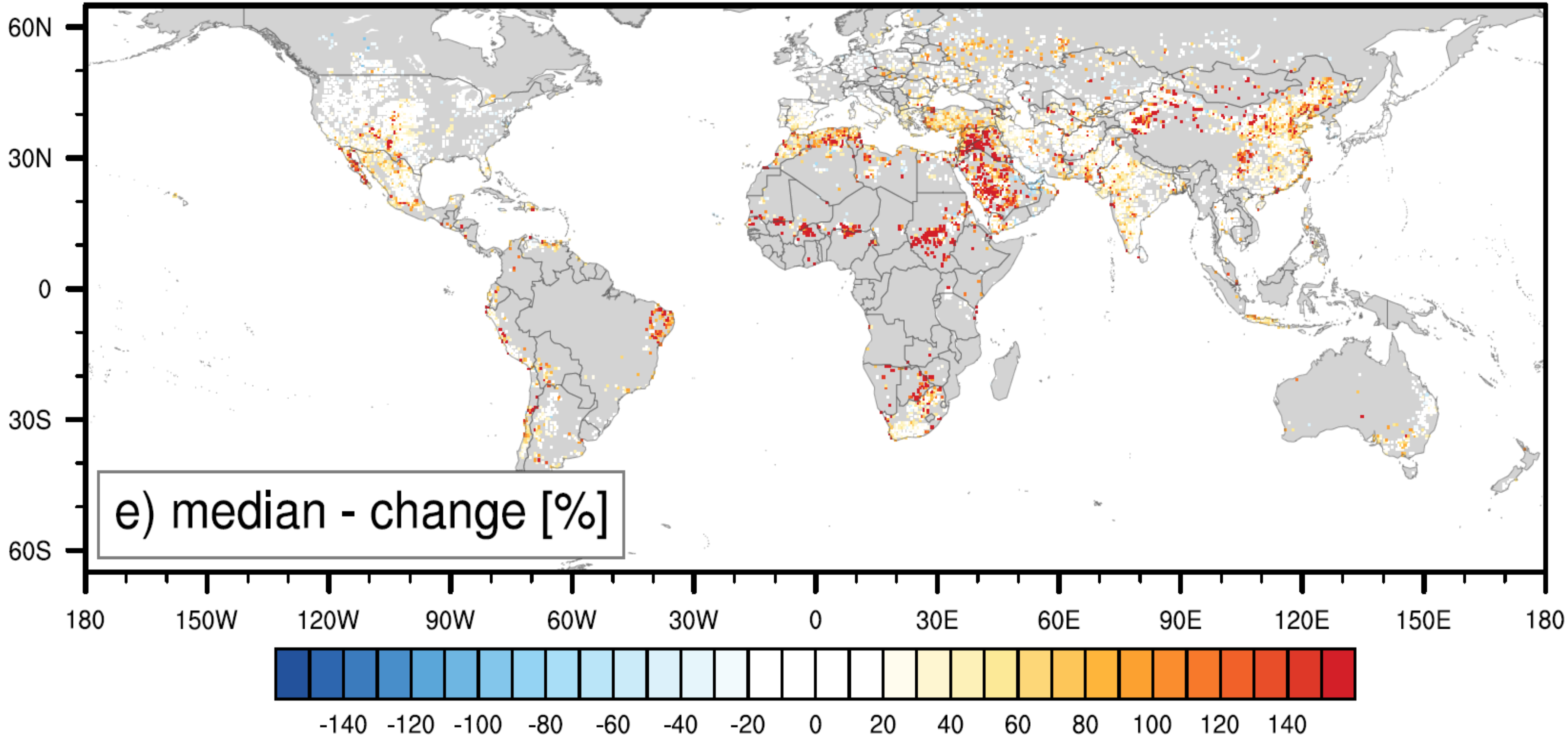
Africa

Pop:	1.0 to 2.0	2 times more
GDP:	2.8 to 19.2	7 times more
GDP pc:	2.7 to 9.5	3.5 times more

Asia

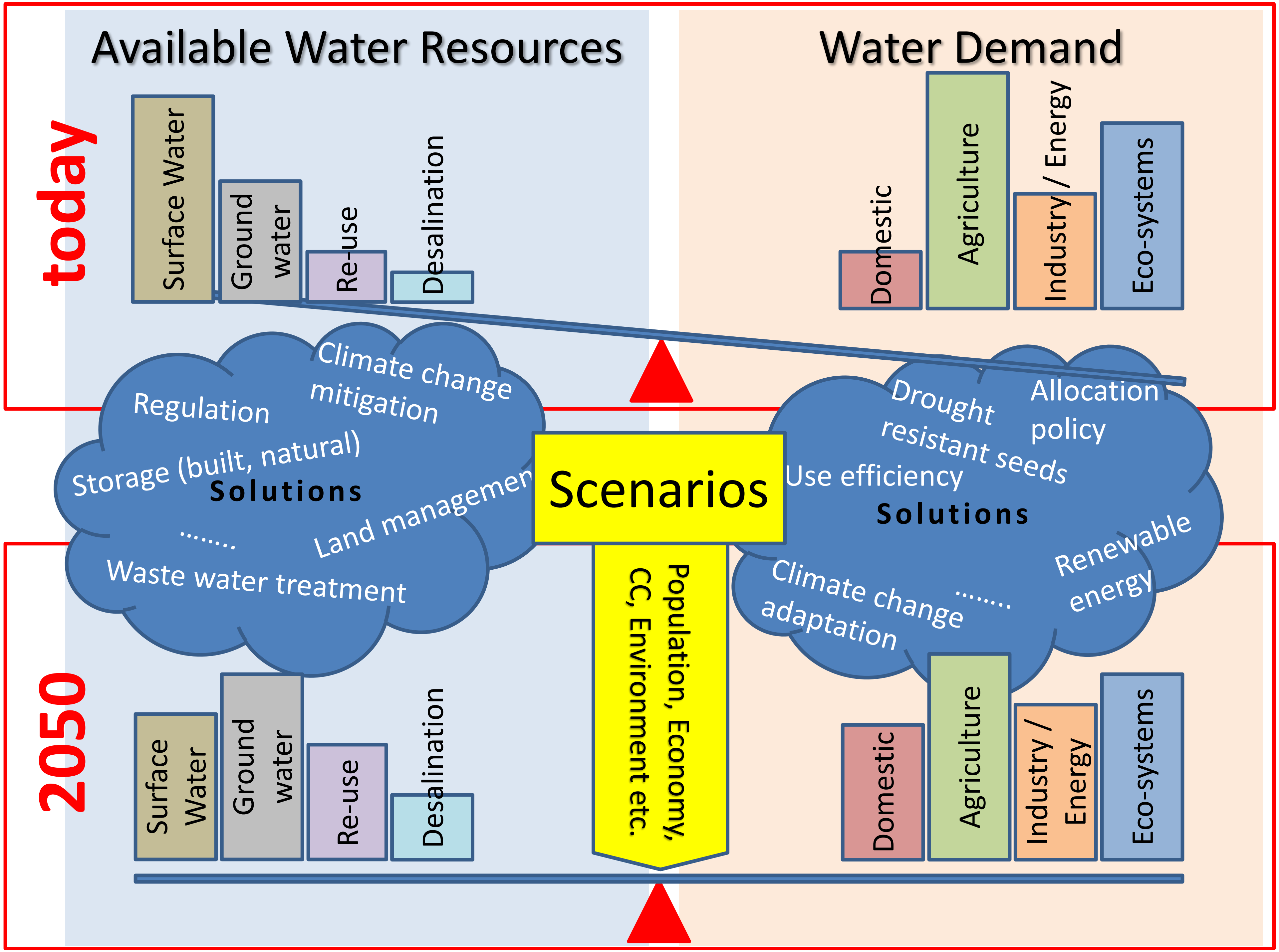
Pop:	4.1 to 5.1	1.3 times more
GDP:	26 to 123	5 times more
GDP pc:	6.2 to 24.1	4 times more

Change in water scarcity conditions between 2010 and 2050



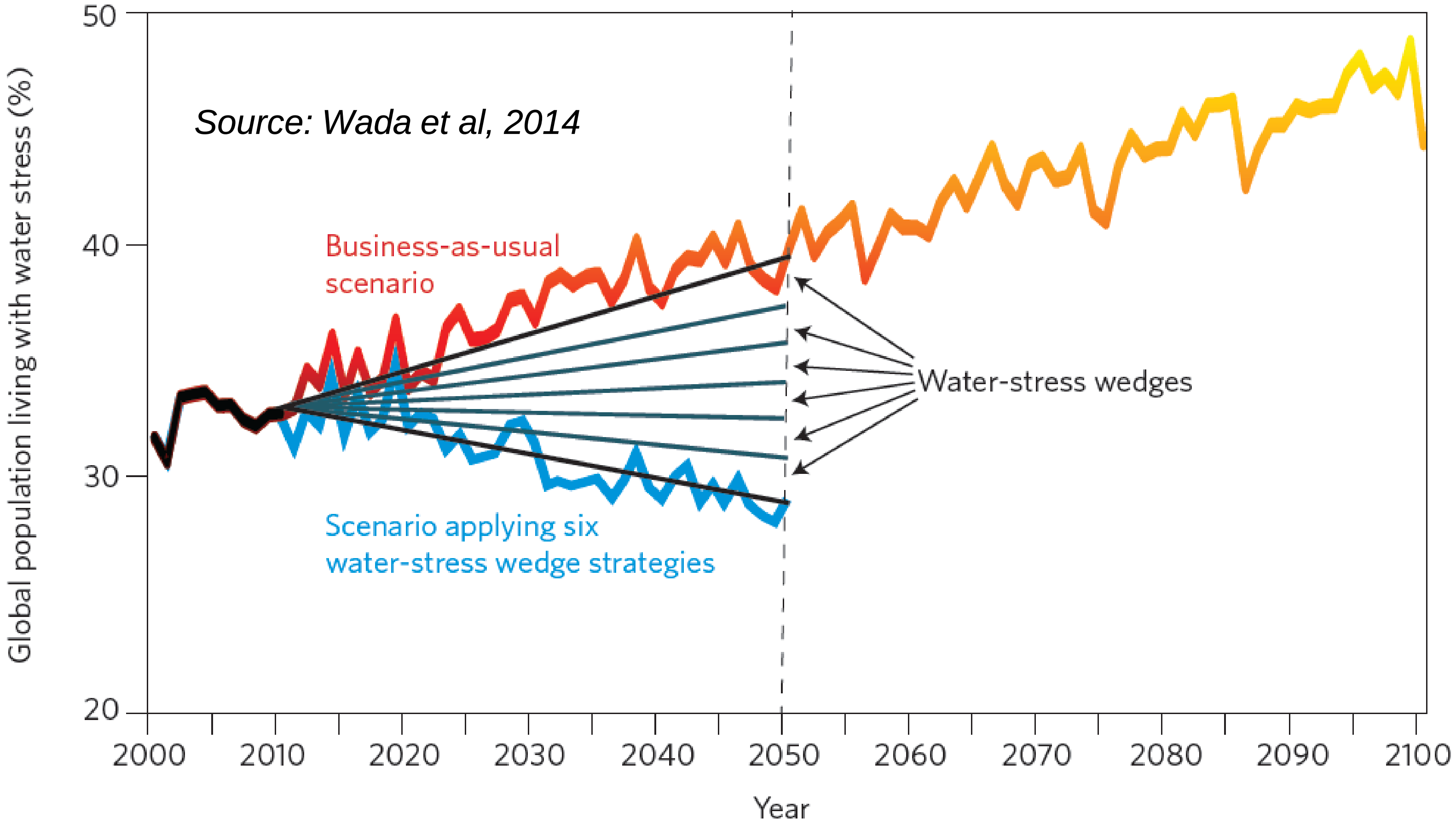
Source: Greve et al. Forthcoming

Modeling approach


Available Water Resources
Water Demand
today
Surface Water
Ground water
Re-use
Desalination
Domestic
Agriculture
Industry / Energy
Eco-systems
Climate change mitigation
Regulation
Storage (built, natural)
Solutions
Land management
....
Waste water treatment
Scenarios
Drought resistant seeds
Allocation policy
Use efficiency
Solutions
Renewable energy
Climate change adaptation
....
Population, Economy, CC, Environment etc.
2050
Surface Water
Ground water
Re-use
Desalination
Domestic
Agriculture
Industry / Energy
Eco-systems

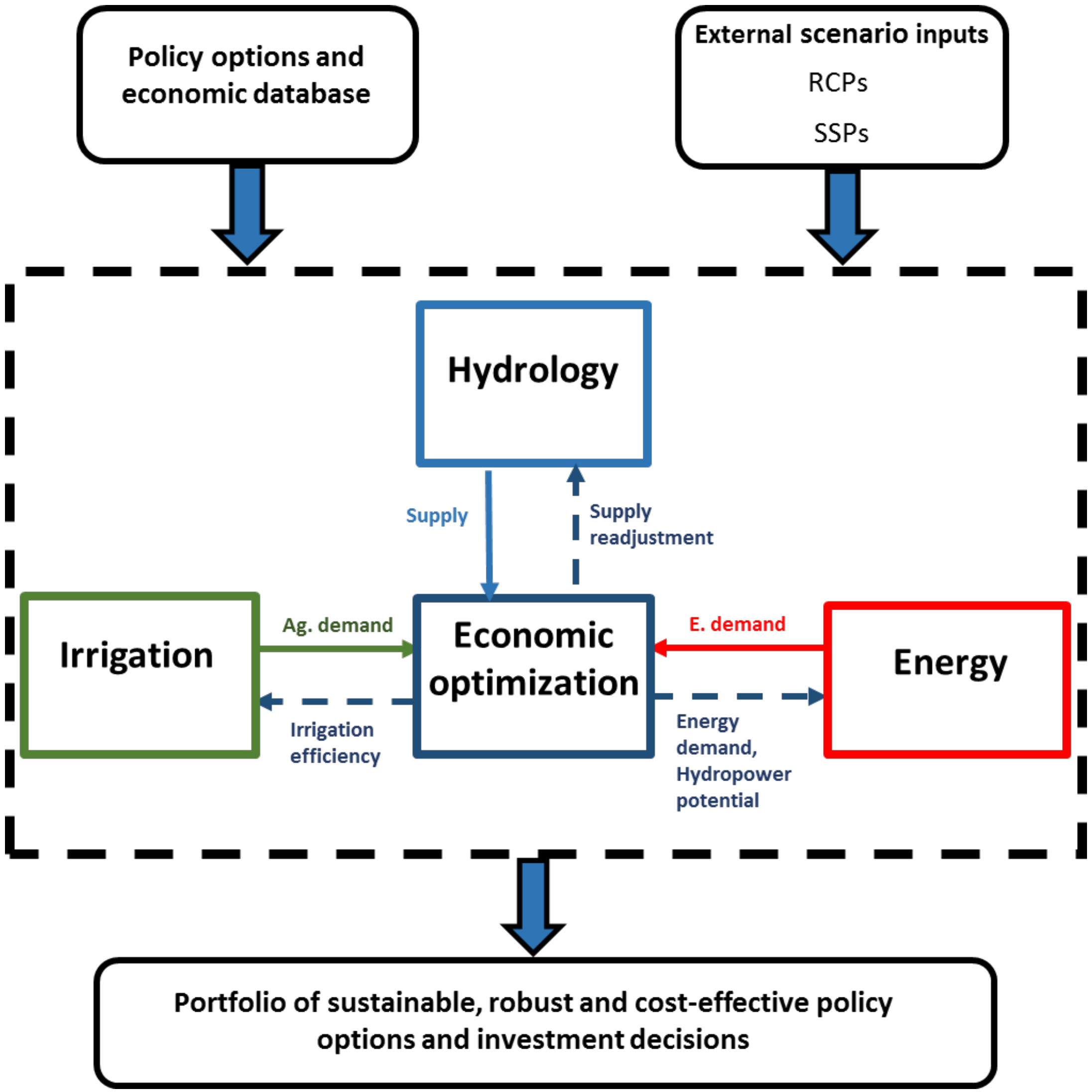
Reducing risks of water stress

Water-stress wedge strategies:
efficiency; recycling; reservoir expansion, desalination, etc.



What strategy is best to implement where and when? How much will it cost? How will this impact land and energy use?

Hydro-economic modeling framework



Key features represented in the model:

Drivers: Demand growth; Resource availability; Climate change; etc.

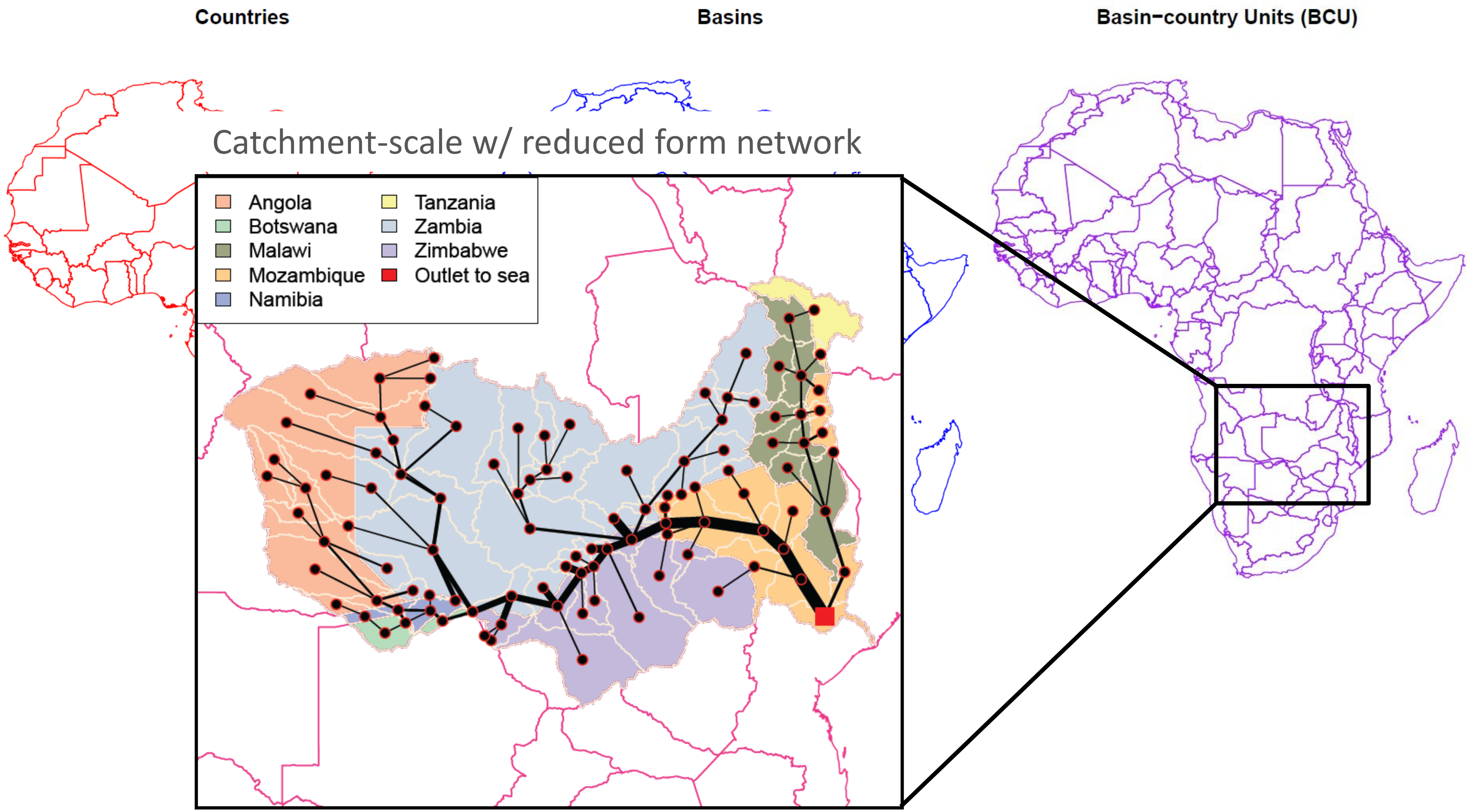
Processes: Reservoir management; Irrigation use; Electricity generation; Water pumping; End-use efficiency; Wastewater treatment; etc.

Impacts: Prices; Demands; Emissions; Water quality; Environmental flow; Groundwater depletion; Resource security; etc.

Decisions: Extract resources; Operate infrastructure; Expand infrastructure; Trade resources

Innovations

Multi-scale modeling incorporating basin-level decision making



Mathematical formulation

Objective function:

$$Min\ C^{npv} = \sum_{m,b,t} \frac{C^{tot}_{m,b,t}}{(1+\delta)^t} \quad (1)$$

Subject to:

$$S_{i,t} - S_{i,t-1} = Q^{in}_{i,t} - Q^{out}_{i,t} \quad (2)$$

$$\sum_{s} \gamma_{s,d} \cdot Q^{out}_{s,t} \geq r_{d,t} \quad (3)$$

$$Q^{out}_{m,t} \leq \phi_m \cdot z_{m,t} \quad (4)$$

$$z_{m,t+1} - z_{m,t} - z^{new}_{m,t} + z^{ret}_{m,t} = 0 \quad (5)$$

Adaptation options

Supply enhancement	Demand management
▪ Build/enlarge dams ▪ Rainwater harvesting ▪ Drill/improve wells ▪ Reuse of wastewater ▪ Desalination ▪ Reprogram reservoir operation ▪ Inter-basin transfer	▪ Efficient irrigation technologies ▪ Efficient domestic water appliances ▪ Energy cooling technologies ▪ Better allocation rules ▪ Better crop management ▪ Improving education ▪ Controlling population growth

Scenario analysis

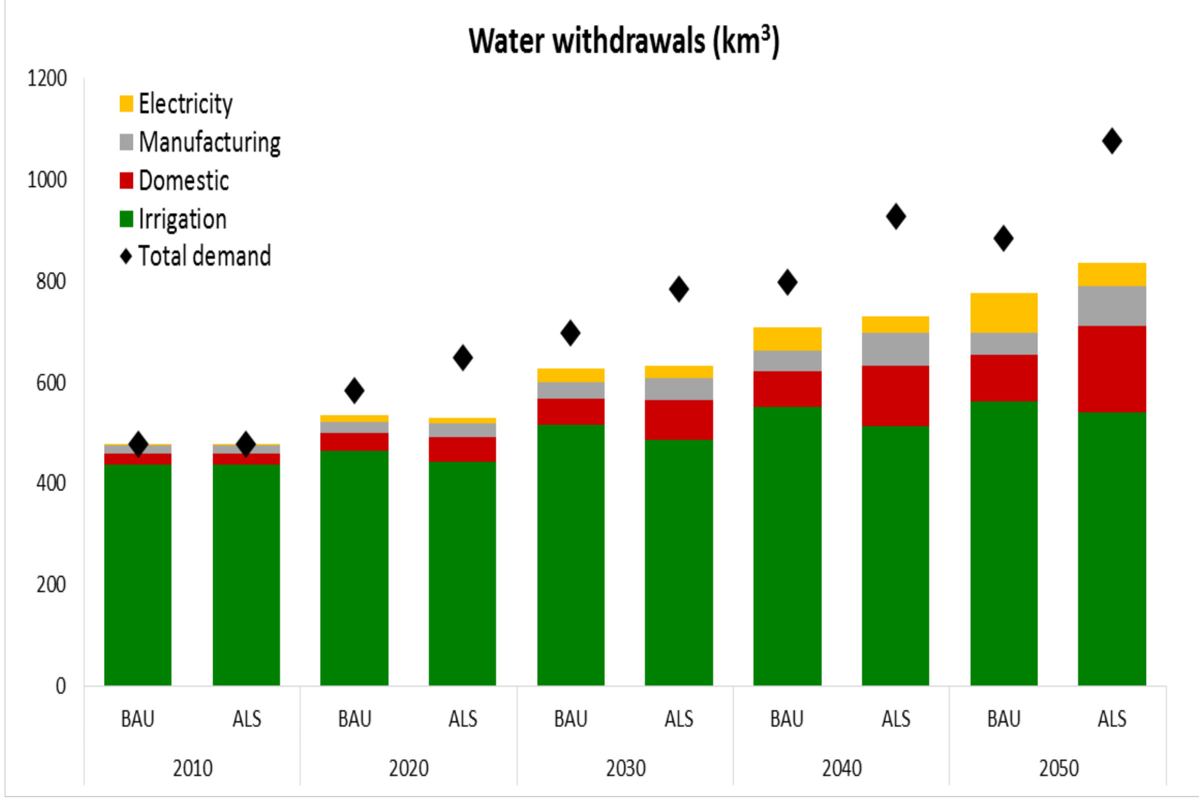
Two scenarios:

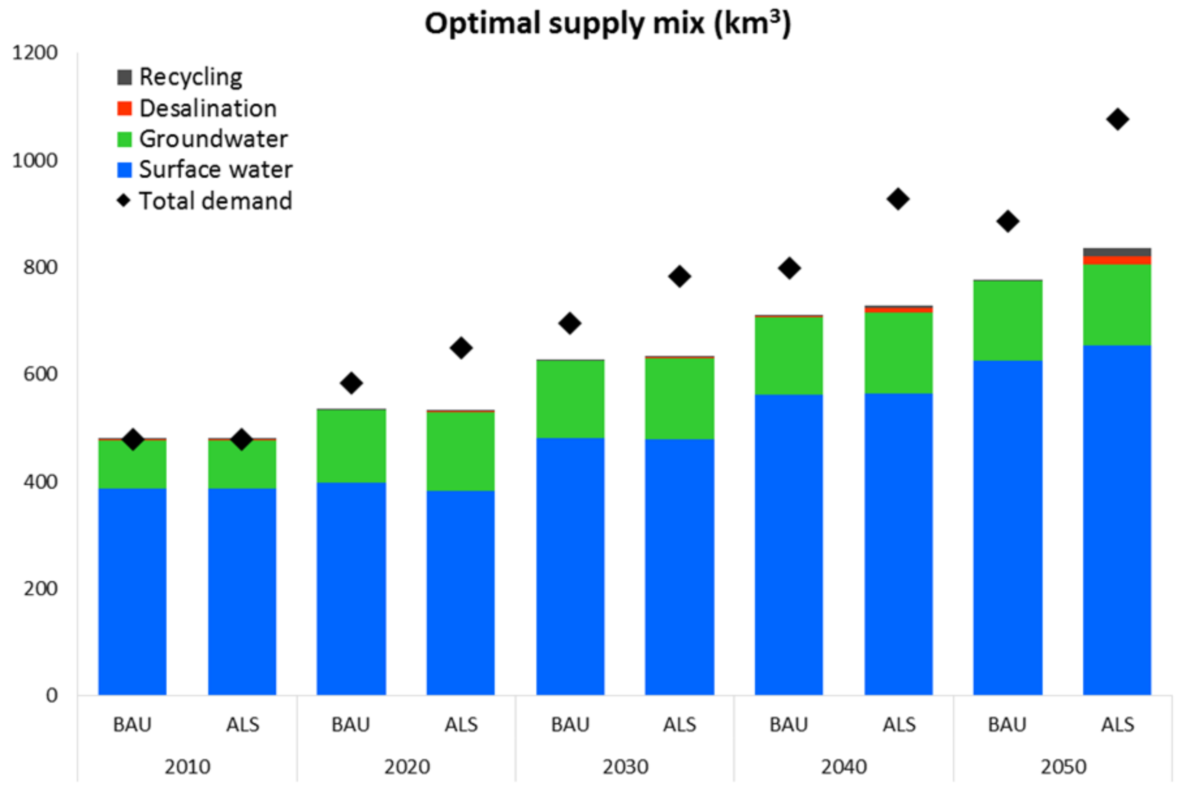
1/ Business as usual (***BAU***): SSP2-RCP6.0

2/ Alternative scenario **(*ALS*)**: water demand is increasing over time in all water sectors due to human development and water availability is reduced because of climate change impacts

Results

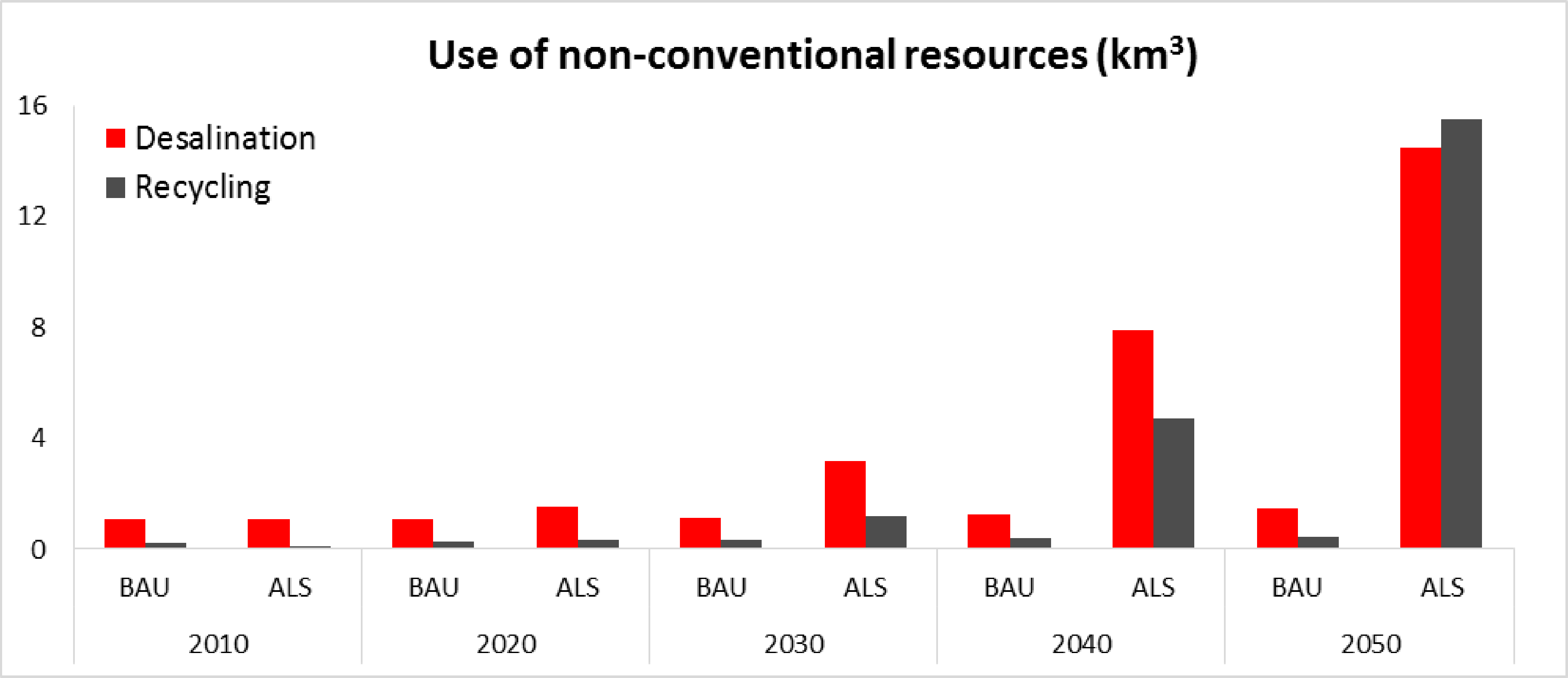
1/ Water withdrawals by sector and source





Results

2/ Supply expansion



Related Publications

- Satoh Y., Kahil T., Byers E., et al. Multi-model and multi-scenario assessments of Asian water futures: the Water Futures and Solutions (WFaS) initiative. Earth's Future 5, doi:10.1002/2016EF000503.
- Kahil T, Ward F. Albiac J., et al. Hydro-economic modeling with aquifer-river interactions to guide sustainable basin management. Journal of Hydrology 539 (2016): 510-524.
- Kahil T., Connor J. Albiac J. Efficient water management policies for irrigation adaptation to climate change in Southern Europe. Ecological Economics 120 (2015): 226-233.
- Kahil T., Dinar A., Albiac J. Modeling water scarcity and droughts for policy adaptation to climate change in arid and semiarid regions. Journal of Hydrology 522 (2015): 95-109.

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Thank you for your interest in this work!!!