Zentrum für Entwicklungsforschung
Center for Development Research
University of Bonn

Water-Energy-Food (WEF) Nexus analysis in Central Asia using a hydro-economic model with extended energy supply-demand accounts

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by Dr. Maksud Bekchanov

Motivation:

- Water scarcity is growing challenge in many river basins across the world
- Hydro-economic models have been effectively applied for efficient water allocations
- However, energy requirements for water operations are often ignored in these modeling assessments
- Therefore, this study aims at showing the effects of energy supply and demand constraints on efficient water allocations

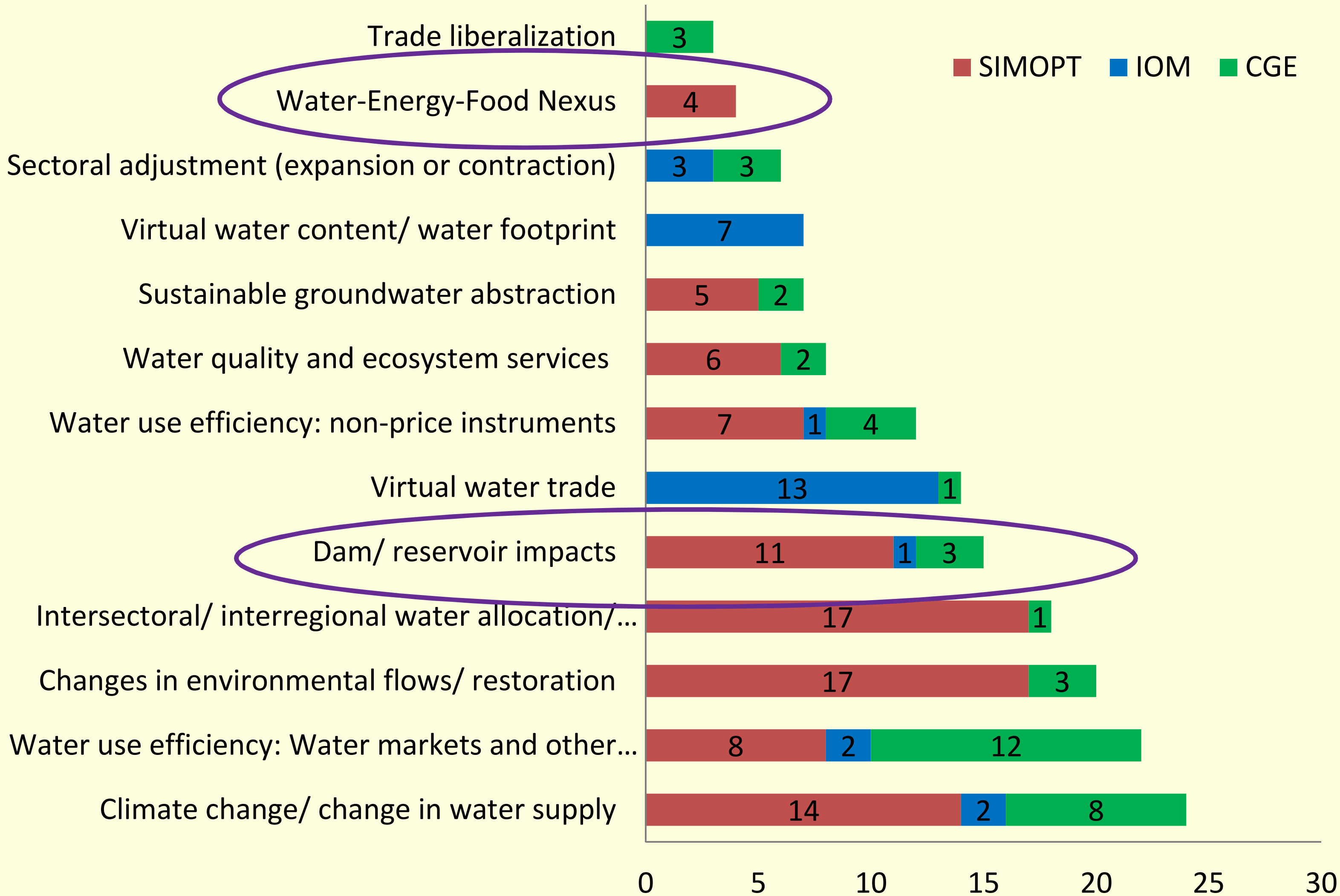
Hydro-economic models (HEMs):

- A tool for efficient water allocation
- Water scarcity, water conflicts, climate change
- Inter-sectorial water distribution (agriculture, M&I, hydropower, ecosystems)
- Water balance/accounting at basin scale
- Marginal value (scarcity cost) of water

Need for hydro-economic model with extended energy-supply component (HEM+EN):

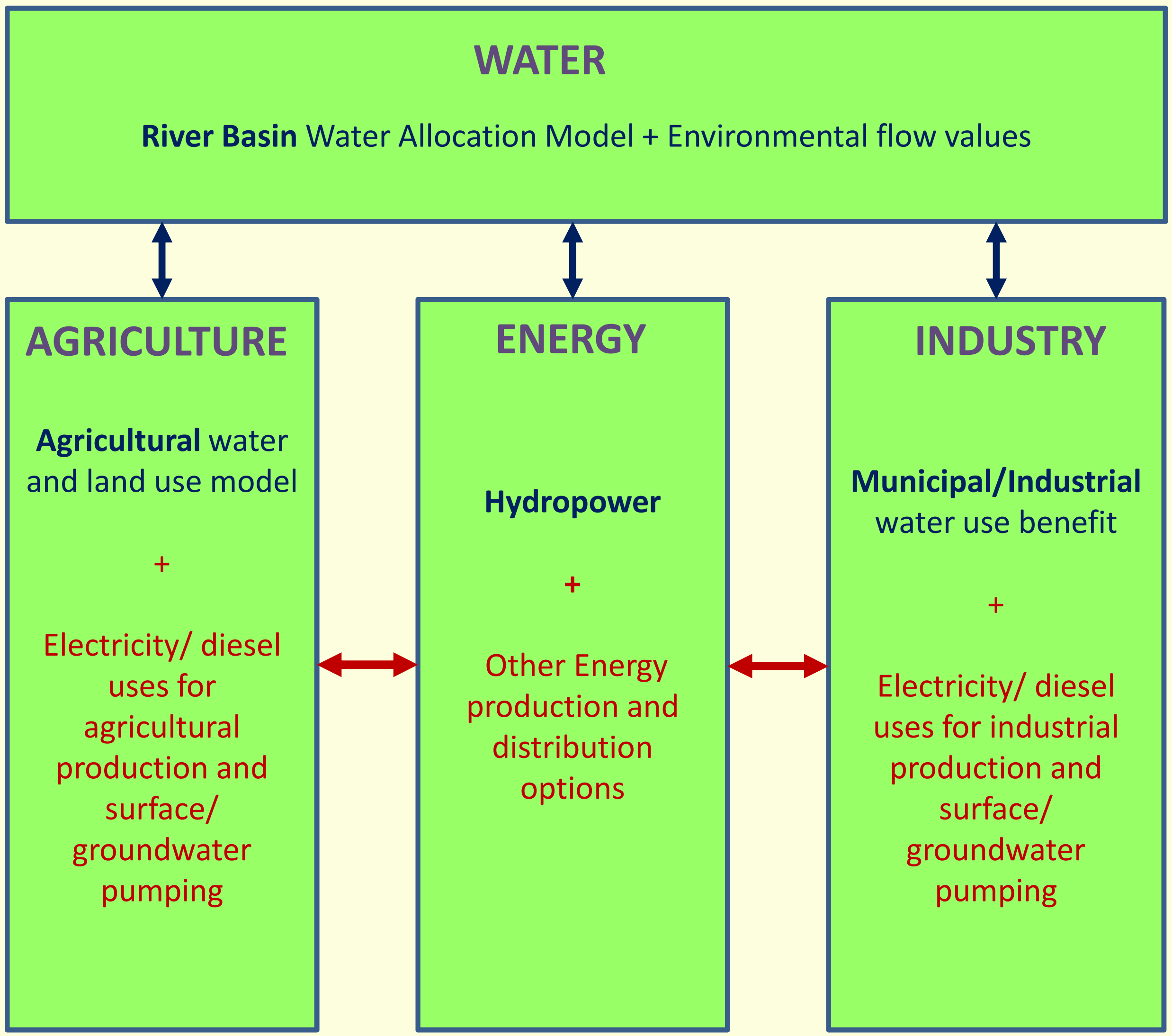
- Water supply, water treatments, irrigation heavily depends on energy access
- Solar and wind energy for heating, irrigation water pumping, water treatment
- Water for thermal power plants, mining, and biofuels

Themes in hydro-economic modeling studies:

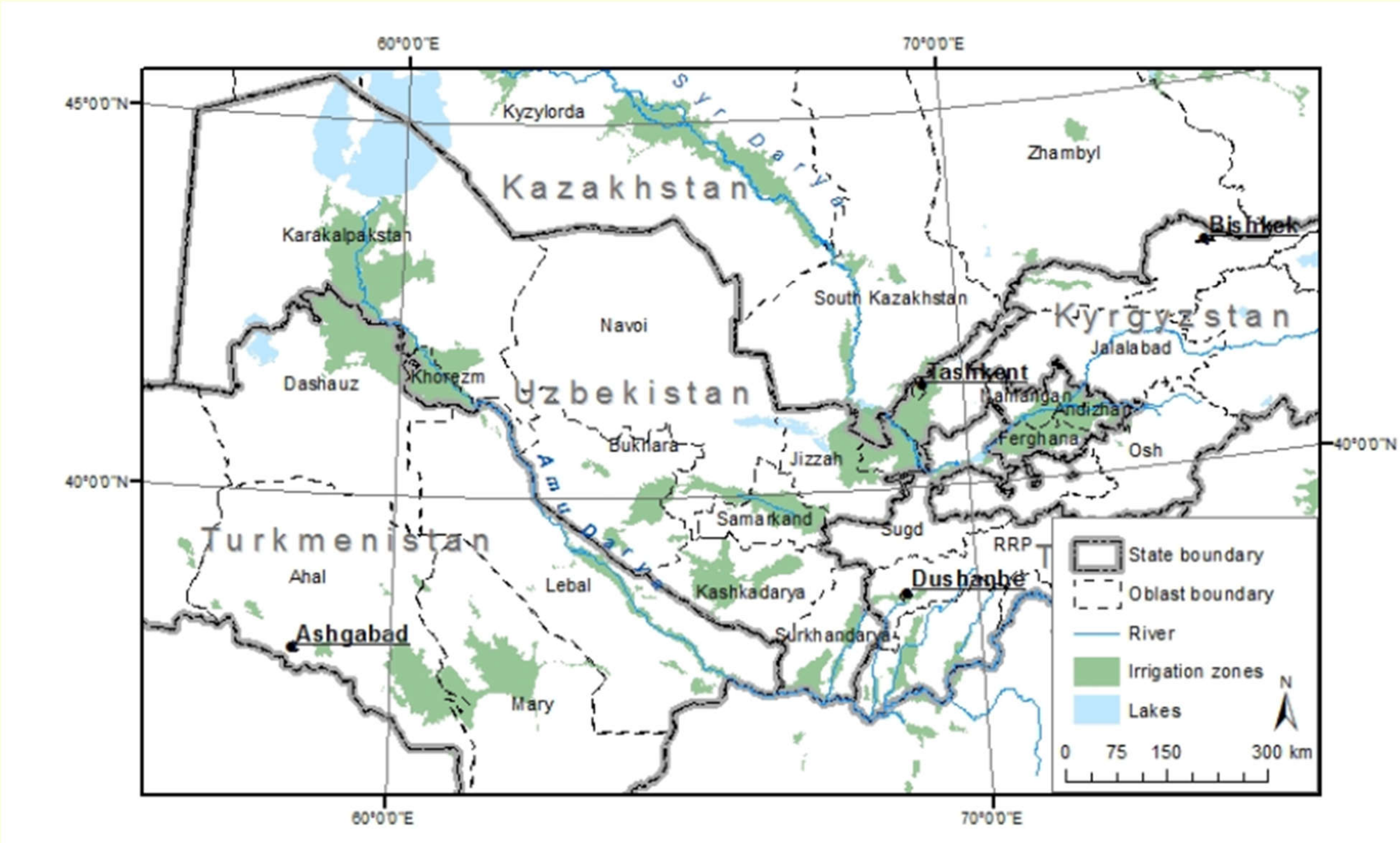


Source: Bekchanov et al. (2016) (Systematic review of hydro-economic modeling applications)

Novelties of HEM with energy supply and demand (balance) component (HEM+EN)

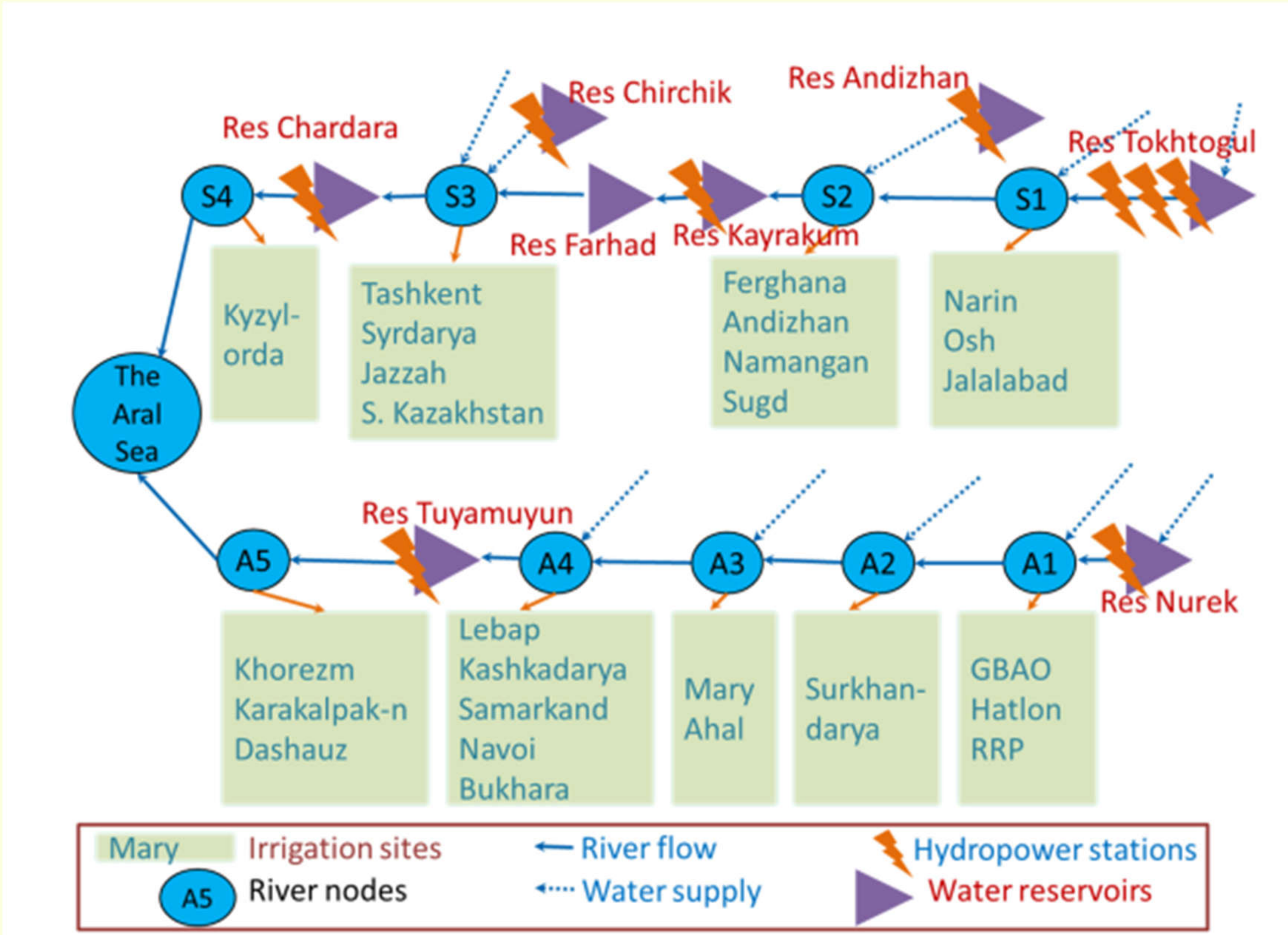


The Aral Sea basin (over 8 million ha irrigated lands, water scarcity, hydropower *versus* irrigation development, heavy dependence on fossil fuel uses, low water and energy productivity)



Source: Bekchanov and Lamers (2016) (The Effects of Energy Constraints on Water Allocation Decisions…)

River basin network scheme

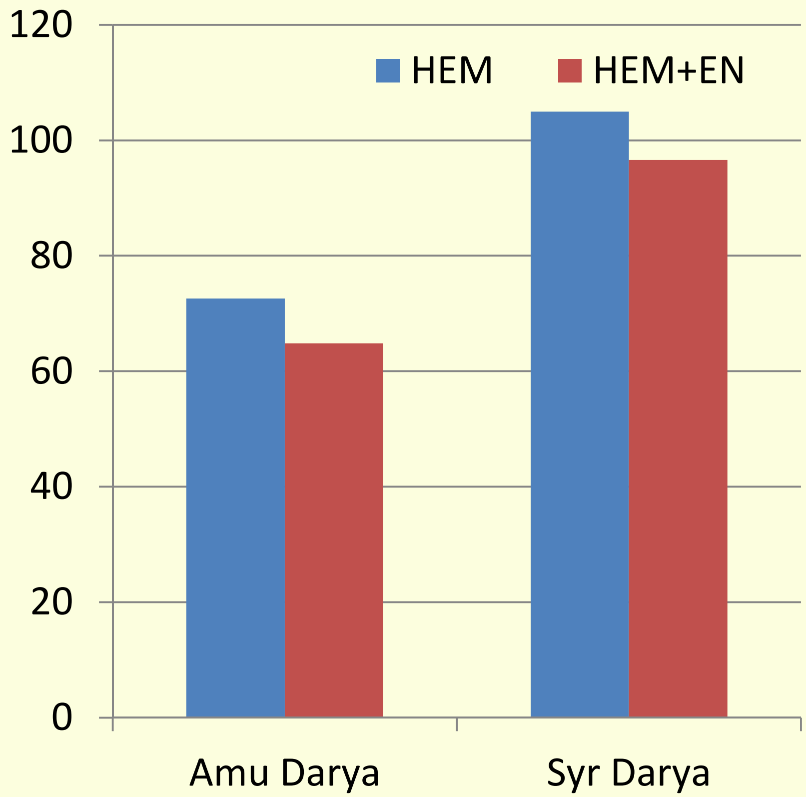


Source: Bekchanov and Lamers (2016) (The Effects of Energy Constraints on Water Allocation Decisions…)

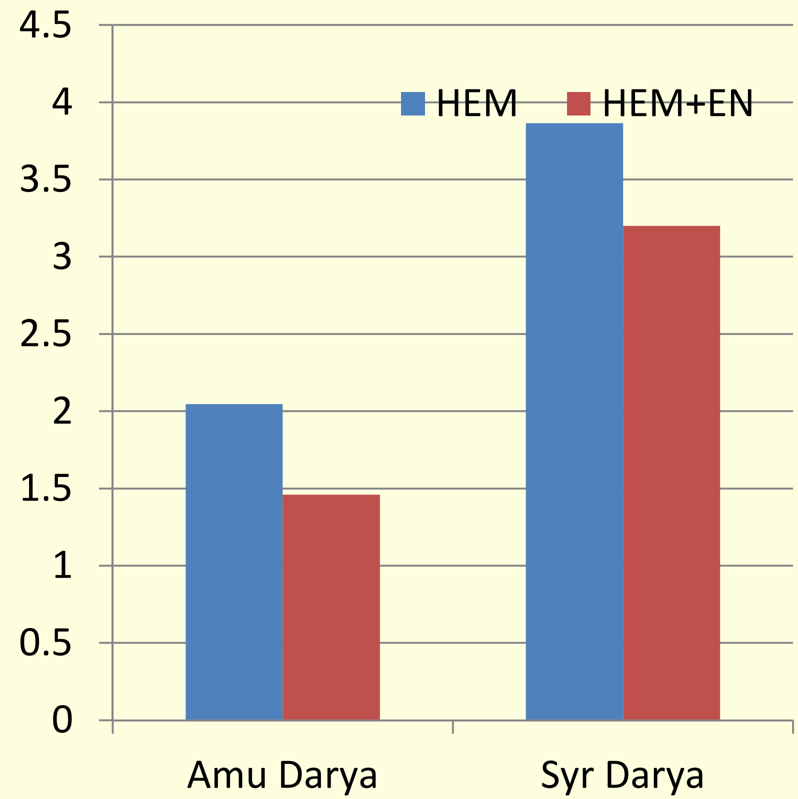
Hydro-economic model with extended energy supply and demand component:

- Maximize benefits from irrigation, energy production, environmental flows
- Water supply and demand at basin scale (detailed)
- Energy supply (including renewables) and demand (detailed for irrigation)
- Crop production patterns
- Other land, production capacity constraints

Energy to Water Impact: Optimal water allocations (km³) at basin scale according to HEM and HEM+EN

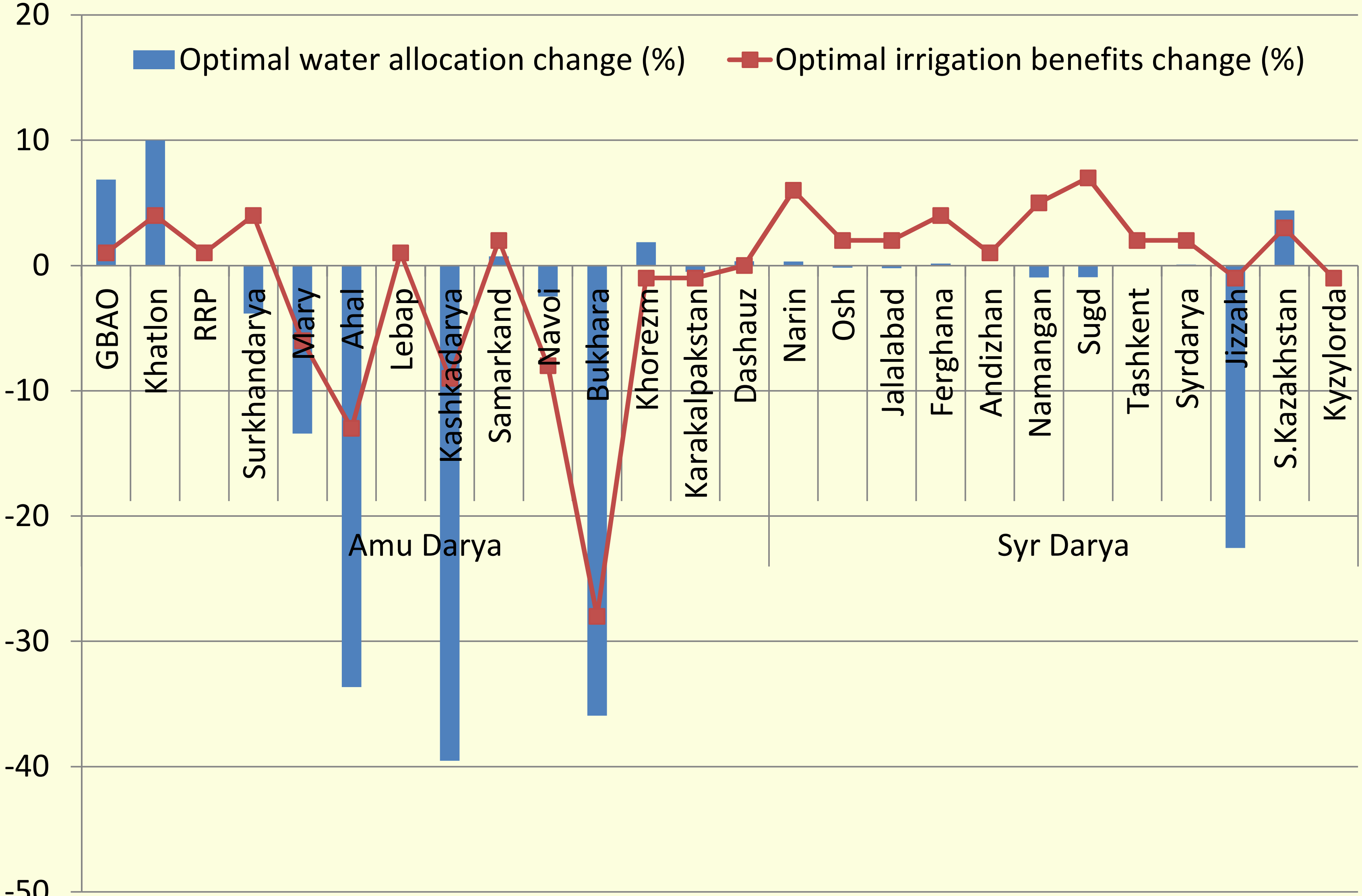


Surface water

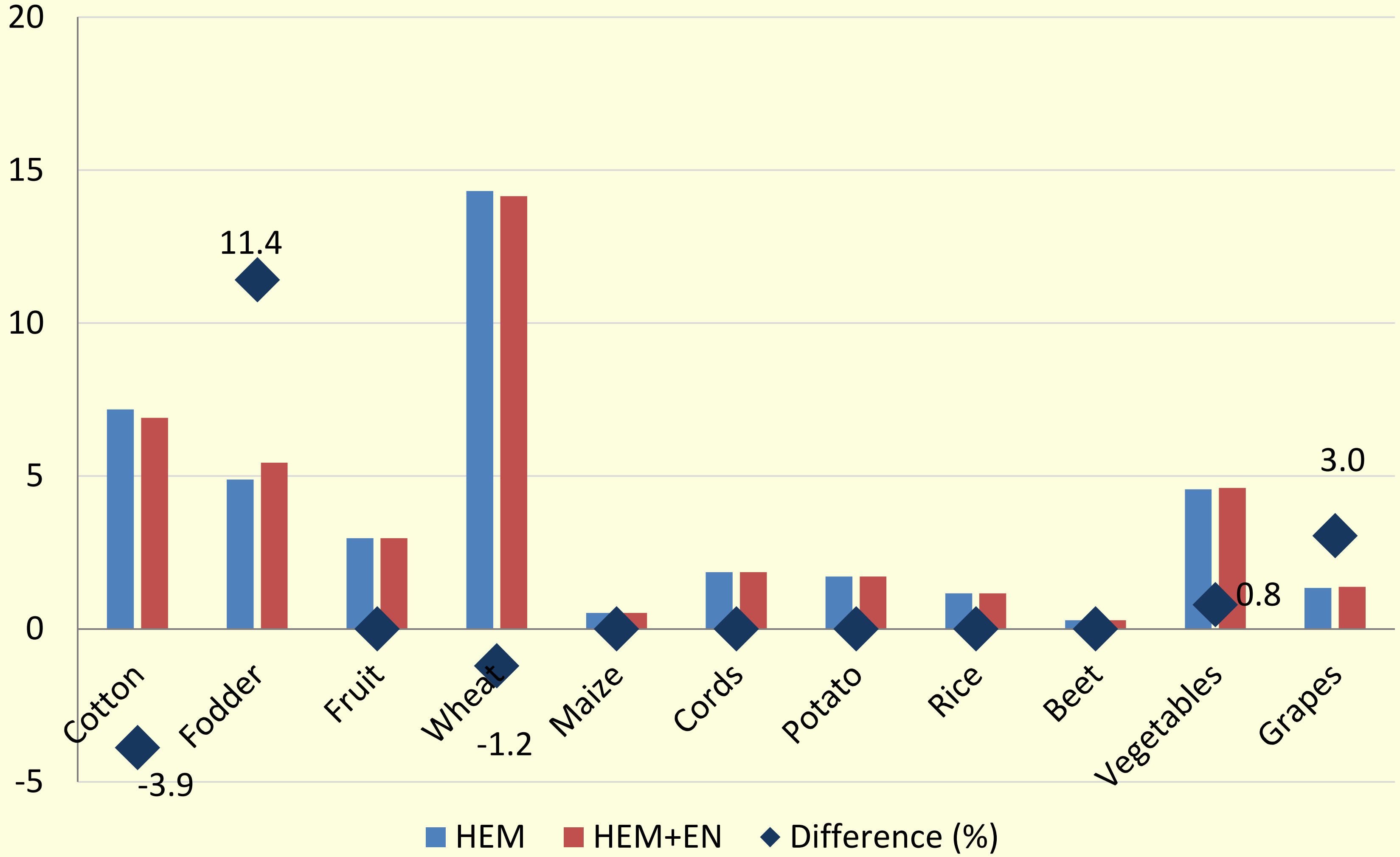


Ground water

Water to Food Impact: Differences (%) between HEM and HEM+EN results on optimal water uses and irrigation benefits by provinces



Energy to Agriculture Impact: Optimal crop outputs (million tons) at basin scale according to HEM and HEM+EN

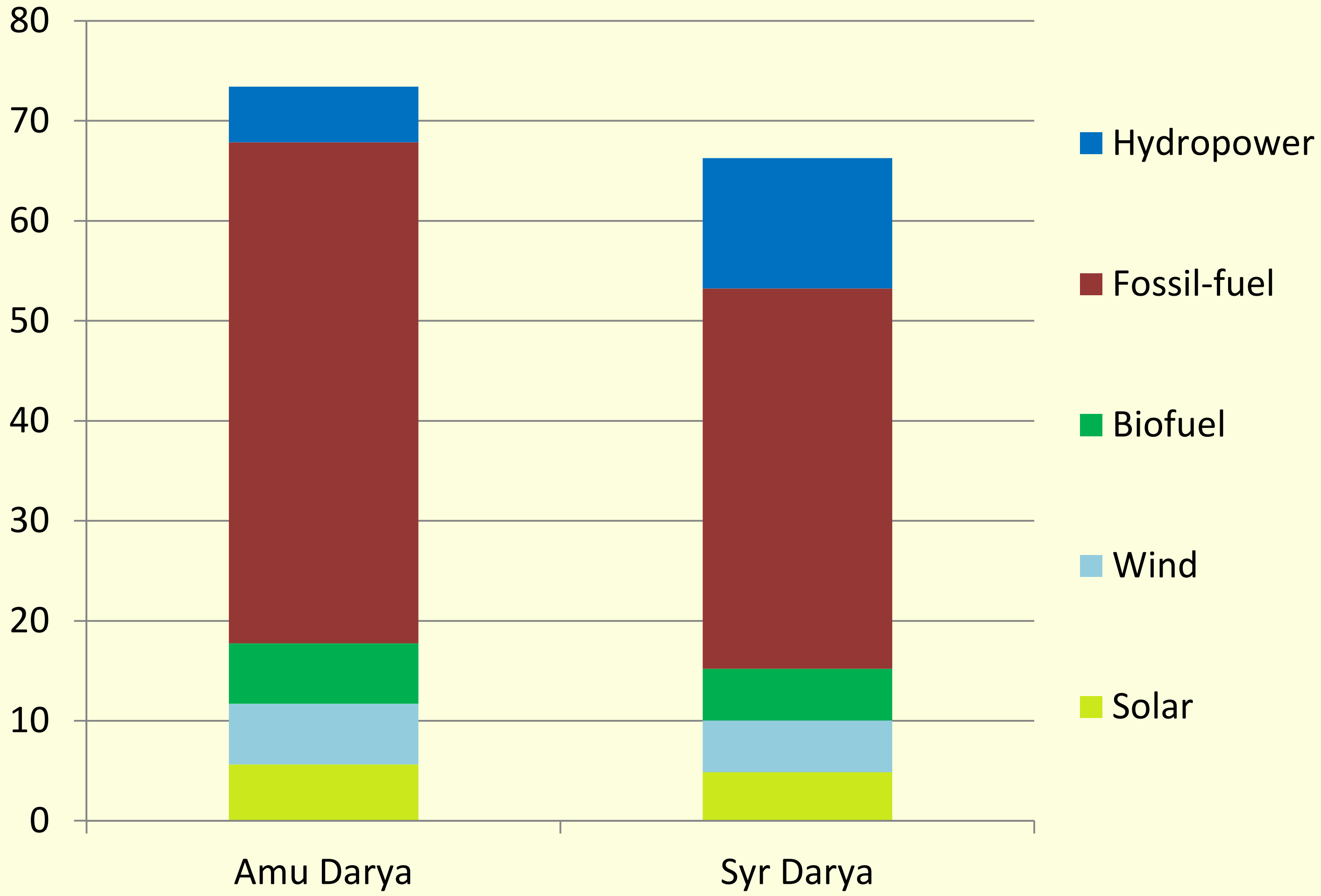


Irrigation Water supply to Energy Impact: Optimal hydropower production benefits according to HEM and HEM+EN

Basin	Provinces	Hydropower Benefits (million USD)		Difference between Exp1 and Exp2 (%)
		Exp1: Without Energy Block	Exp2: With Energy Block	
Amu Darya	Nurek	183	189	3
	Tuyamuyun	7	9	28
Syr Darya	Tokhtogul (KG)	101	99	-2
	Kurupsay (KG)	30	29	-2
	Tashkumir (KG)	16	16	-2
	Shamaldisay (KG)	6	5	-2
	Uchkurgan (UZ)	21	20	-2
	Andizhan (UZ)	9	10	12
	Kayrakum (TJ)	9	9	0
	Farhad (UZ)	1	1	1
	Shardara (KZ)	5	5	7
	Chirchik (UZ)	28	31	11
	Total:	**413**	**422**	**2**

Source: Bekchanov and Lamers (2016) (The Effects of Energy Constraints on Water Allocation Decisions…)

Optimal energy production sources (million MWh)



Conclusions:

- Consideration of the energy supply and balance constraints considerably change optimal water allocations

- Optimal water allocations decrease substantially in irrigation sites located in higher altitudes than node or depend on long and unlined irrigation channels

- Renewable energy options may have limited role for irrigation due to low irrigation profitability but can be important option when their costs decrease in the long run

Further improvements:

- Food demand component
- Interlinkages between energy and food markets
- Game theory/ governance/ issue linkage
- Landscape/ ecosystem services
- GHG emission balances, water quality