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Energy Vulnerability to Climate Change: A regional perspective

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Principal

ESCC 2013-2015

Element 3

Managing Energy-Water Linkages

ESCC Meeting
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Beijing, People's Republic of China

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Central Asia Regional Economic Cooperation Program

INDUSTRIAL ECONOMICS, INCORPORATED

Goals of this work – assessing adaptation options

1. Contribute to a better understanding of challenges and opportunities for effective regional coordination of climate change adaptation

2. Build on national-level work already completed to identify adaptation priorities for Tajikistan, Kazakhstan, Uzbekistan, Turkmenistan, and Kyrgyz Republic

3. Connect to and refine existing efforts at regional scale

Energy Sector – Risks of Inaction in Responding to Climate Change

- A partial estimate indicates the physical impacts of climate change threaten to cause over $5 billion of dollars worth of damages over the next forty years, due to:

1. Reduction in water availability for hydropower
2. Increase in extreme events (floods, heat events)
3. Forecast increases in air temperatures lowering the efficiency of transmission and distribution infrastructure
4. Changes in the temperature and availability of cooling water for thermal power plants

What questions are we trying to answer?

- What does the latest climate science say about Central Asia's climate future?
- How big is the climate challenge for the energy sector in Central Asia?
- How can regional cooperation in climate change adaptation address the climate challenge?
- What adaptation options have the best economic returns, while also being wise to adopt in response to an uncertain climate future?

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Overview

- Our approach for adapting the energy sector to climate vulnerabilities - a regional perspective
- Preliminary results
- A brief introduction to decision-making under uncertainty – Robust Decision-Making
- Schedule for this work
- Discussion questions

Our Approach

What is needed for analysis of the complex energy and water systems of Central Asia?

1. Systems-level approach – all aspects of the energy system affect all others

2. Interdisciplinary team – intersectoral approach

3. Experience with climate change and adaptation options in Central Asia

4. Perspective on climate change adaptation: an overlay on existing challenges

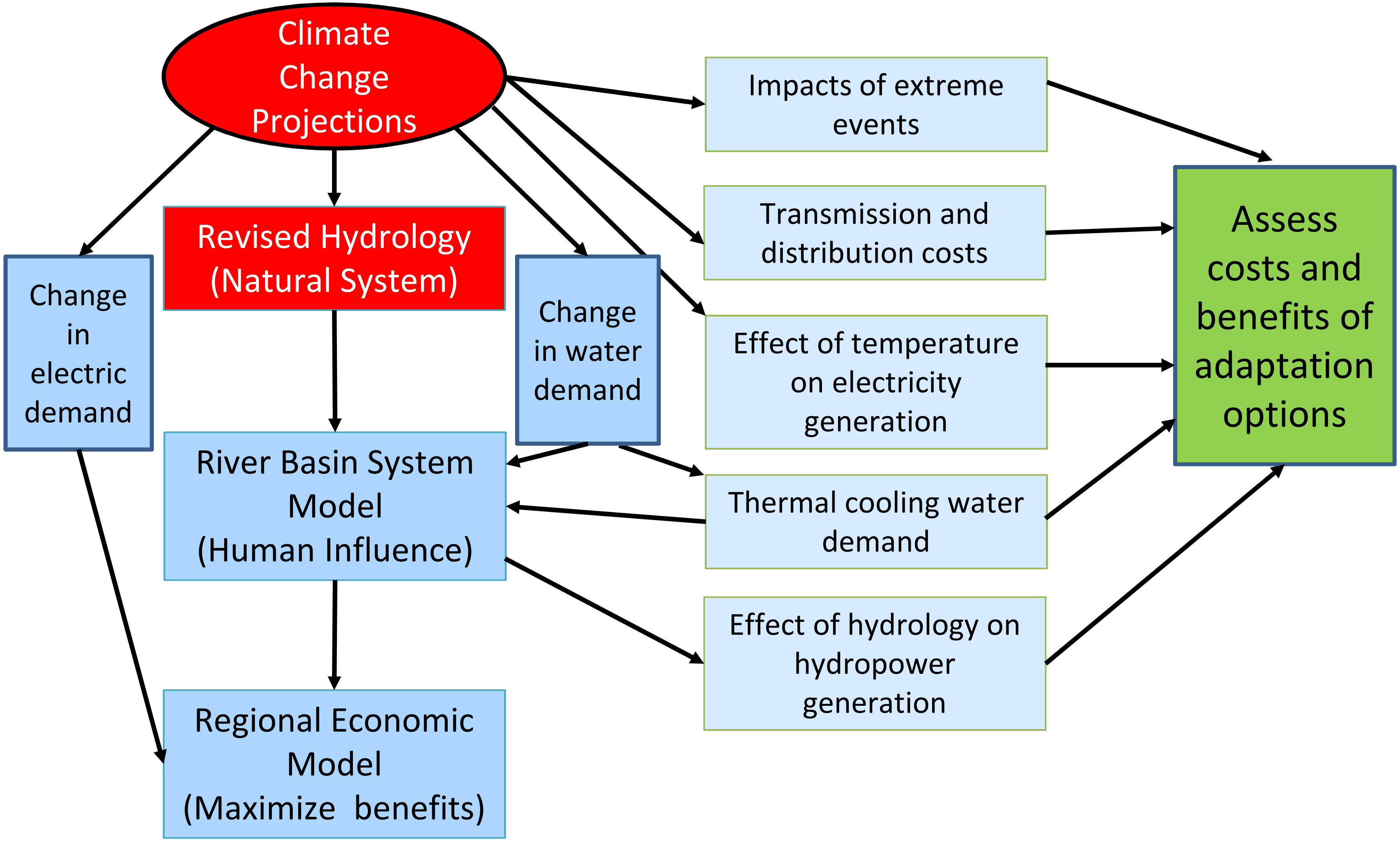
Key Members of Project Team

- ***James Neumann, Industrial Economics, Incorporated***: Project coordination and management, climate adaptation economics expertise
- ***Dr. Kenneth Strzepek***: Water Resource and Energy Engineer and Economics, Massachusetts Institute of Technology
- ***Dr. Peter Droogers, FutureWater***: Dutch consultancy with expertise in water resource modeling, prepared ADB-sponsored water resource and climate change assessment for Central Asia
- ***Dr. Allysa McCluskey***: Independent Consultant, working with Dr. Strzepek on analyses of climate vulnerabilities of energy sector

Conceptual Framework for This Work

Concept	Description	Example
Hazards	Climate change effects, including changes in precipitation, temperature, and frequency and intensity of extreme events.	Lower rainfall overall reduces the volume of water in rivers. Temperature is an important stressor for energy demand and transmission
Impacts	The effects on human activities that result from climate change hazards. More vulnerable assets face more pronounced impacts.	The *hazard* of lower rainfall reduces hydropower output. The *hazard* of higher temperature affects transmission efficiency and energy demand
Adaptation	Steps taken to reduce the impacts of climate change – identify “levers” and take action	Investments in water demand efficiency restore river flow; investments in transmission capacity enhance efficiency

HAZARD-IMPACT MODELS | IMPACT METRICS FOR ENERGY SYSTEM | ADAPTATION ANALYSES



Key hydrology/water sector models

- ***Spatial Processes in Hydrology model (SPHY):*** hydrologic model, translates climate scenarios to base flow, glacier melt, snow melt, and rainfall components of river flow – developed for region with ADB sponsorship

- ***Water Evaluation And Planning model (WEAP):*** Dynamic water balance model initially developed for ADB water sector adaptation work – enhanced for this work

- ***Basin Economic Allocation Model (BEAM):*** Regional economic model for the Aral Sea Basin with capabilities to assess broad range of policy and infrastructure options – originally developed with EU-IFAS funding

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Hazards

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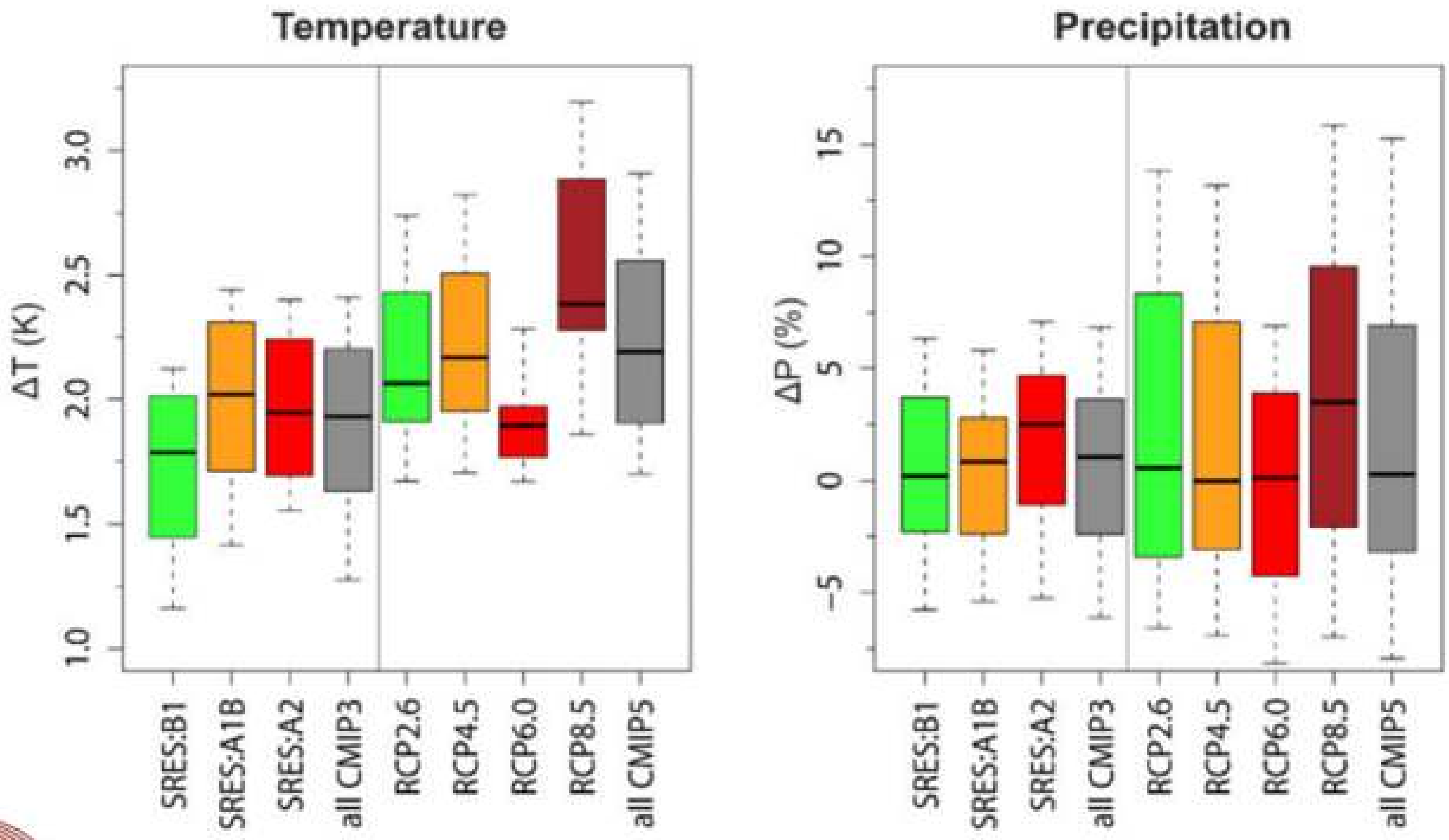
Differences in CMIP3 and CMIP5 climate change projections for the High Central Asian region (2031-2060 compared to 1961-1990).



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Four Climate Change “Marker Scenarios” (with results in 2080)

Marker scenario	GCM run	RCP	ΔT (°C)	ΔP (%)
Arid	FIO-ESM_r2i1p1	RCP8.5	+4.1	-23.1
Hot/dry	IPSL-CM5A-LR_r1i1p1	RCP8.5	+7.3	-20.3
Central	HadGEM2-ES_r2i1p1	RCP4.5	+4.1	+5.0
Warm/Wet	GISS-E2-H_r4i1p2	RCP4.5	+2.6	+17.7

Our Approach

Impacts

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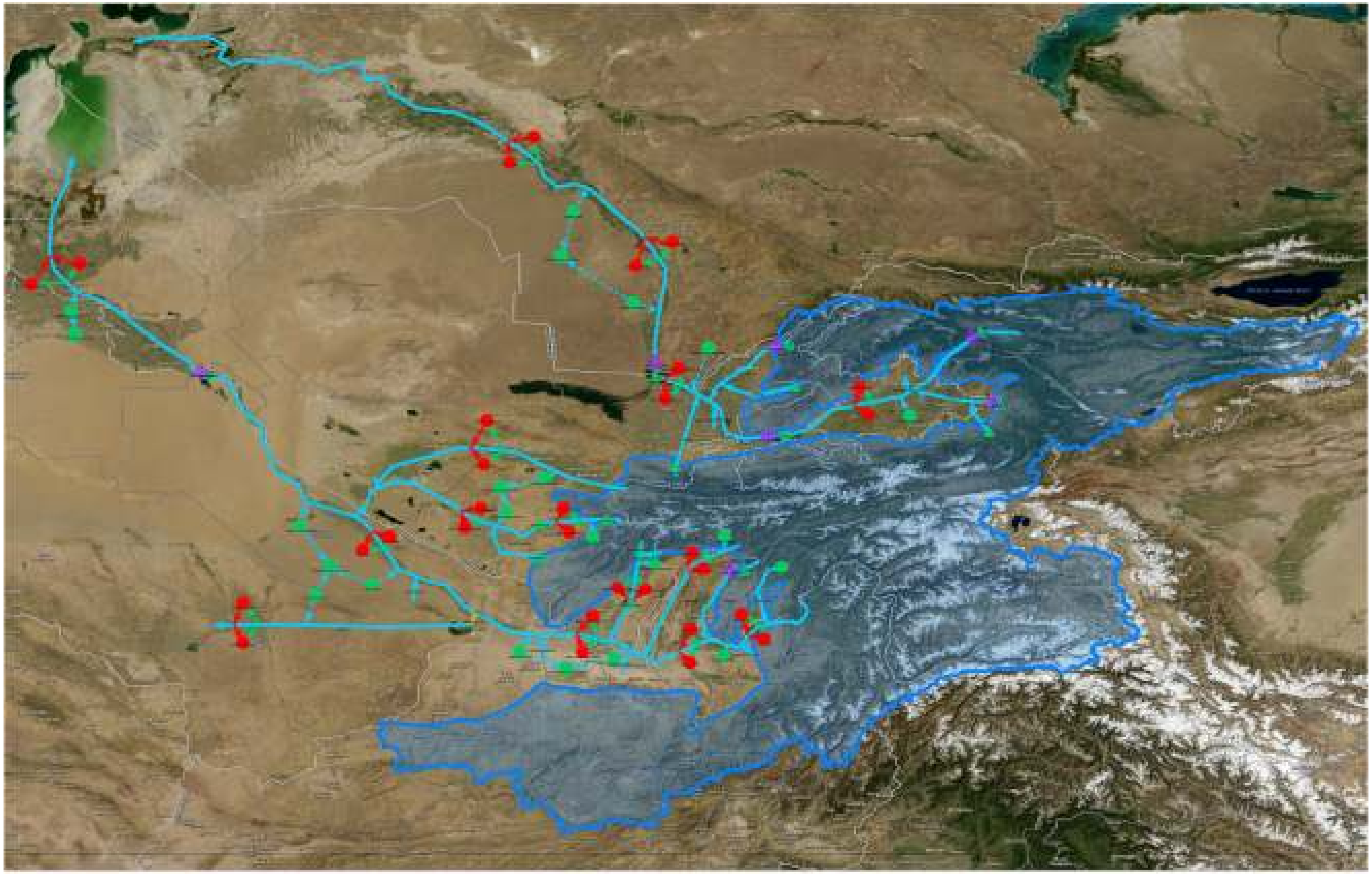
Visual Representation of the Central Asia Regional Energy-Water System



Existing hydropower reservoir characteristics of the WEAP-ARAL2014 model

Basin	Name	Country	Available Capacity (MW)	Primary usage	Full storage capacity (Mm3)	Dam height (m)
Amu Darya	Baipaza cascade[1]	TAJ	1510	Hydroelectricity	2268	180
	Chimkurgan	UZB	no data	Irrigation	500	33
	Gissarak	UZB	45	Hydroelectricity	170	138.5
	Nurek	TAJ	2997	Hydroelectricity	10500	300
	Pachkamar	UZB	no data	Irrigation	260	71
	Surkhandarya	UZB	0	Irrigation	800	30
	Tupalangsku	UZB	30	Hydroelectricity	500	40
	Tyuyamuyun	UZB	149	Hydro / irrigation	7800	80
Syr Darya	Akhangaran	UZB	21	Hydroelectricity	198	100
	Andijan	UZB	189	Hydro /irrigation	1900	121
	Charvak cascade[2]	UZB	899	Hydroelectricity	2860	200
	Chirchik cascade[3]	UZB	185	Hydroelectricity	100	210
	Farkhad	UZB	126	Hydroelectricity	350	27.5
	Kayrakkum	TAJ	126	Hydroelectricity	4160	32
	Kurpsaiskaja	KYR	796	Hydroelectricity	372	94
	Papan	KYR	20	Irrigation, supply	260	100
	Shardara	KAZ	99	Hydroelectricity	5700	28.5
	Taschkumyrskaja c.[4]	KYR	864	Hydroelectricity	222	108
	Toktogul	KYR	1192	Hydroelectricity	19500	215
	Zaamin	UZB	no data	Irrigation	51	73.5

Existing thermal power plants included in the WEAP-ARAL2014 model

Name	Country	Type	Capacity (MW)	Annual production (GWh)	Lat	Lon
Sirdarya	Uzbekistan	Gas	3000	14053	40.229	69.101
Taschkent	Uzbekistan	Gas	1860	8100	41.382	69.368
Navoi	Uzbekistan	Gas	1250	6665	40.157	65.310
Novo-Angren	Uzbekistan	Coal	2100	6188	40.923	69.817
Talimardjan	Uzbekistan	Gas	800	5059	38.481	65.632
Tachiatash	Uzbekistan	Gas	730	2753	42.318	59.555
Fergana	Uzbekistan	Oil	420	590	40.449	71.782
Angren	Uzbekistan	Coal	484	527	41.005	70.124
Kyzylorda	Kazakhstan	Gas	113	no data	44.901	65.357

Major Irrigation Demand Nodes

(1000 ha)	Crop area	Irrigated, gross	Irrigated, net	Drained area
Fergana Valley	1494	1244	1196	594
Dushanbe	148	92	83	12
Karakum desert	1214	1032	796	476
Kashkhadarya upstream	108	101	100	61
Kashkhadarya downstream	431	404	398	243
KurganTube	299	269	240	175
Kulyab	75	67	60	44
Kzylorda	182	278	272	206
Lebap	348	296	266	217
South Kazakhstan	409	492	479	192
Surkhandarya upstream	182	130	128	80
Surkhandarya downstream	273	195	192	121
Syrdarya, Tashkent, Jizakh	1340	1215	1085	797
Urgenc, Nukus, Aral Sea	1504	1461	1390	1161
Zeravshan Valley	1004	771	758	414

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Effects on Transmission and Distribution - Overview

- Temperature reduces transmission efficiency
- The following two stressor-response functions will be used:
  - For every 2°C increase in temperature, there will be a 0.05% increase in transmission losses
  - For every 2°C increase in temperature, there will be a 3% increase in transmission capacity losses
- Impacts will be based on current loadings and capacities of transmission lines, and current losses
- Adaptation options include upgrades and maintenance of transmission lines

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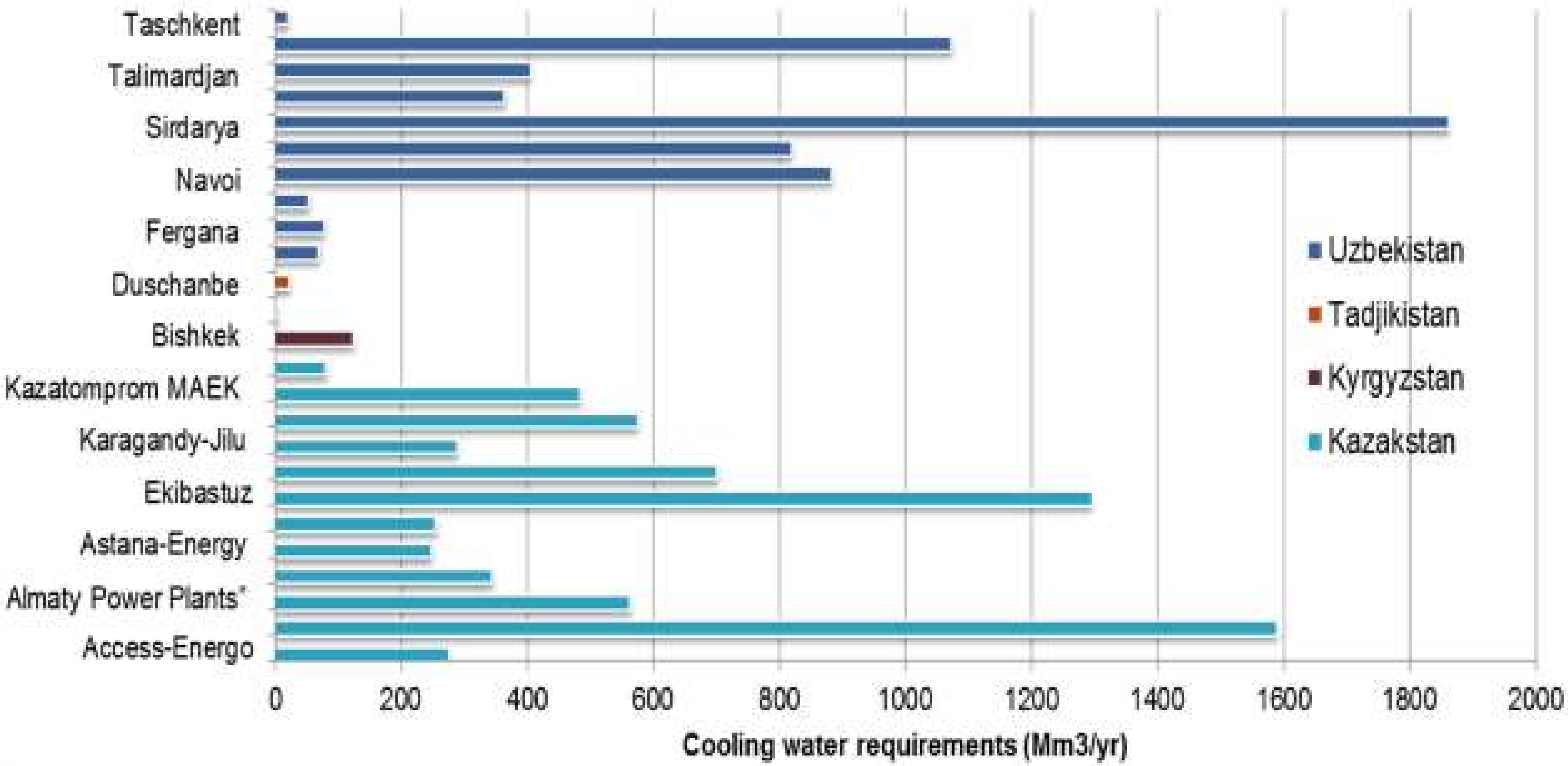
Schematic of Existing Transmission and Distribution

Preliminary Results

Impacts

Cooling water requirements derived from mean annual power production



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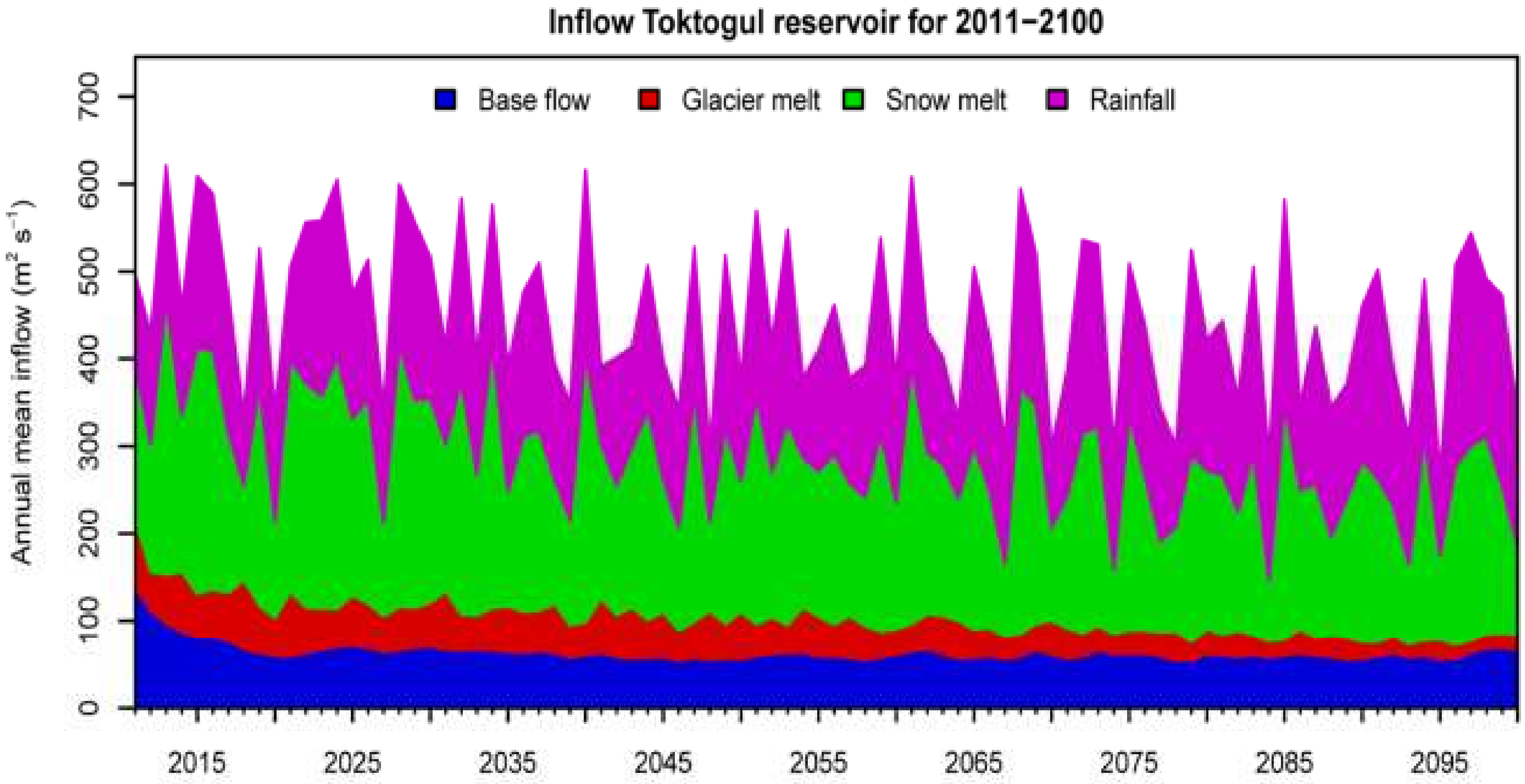
Hydrological forecast – Toktogul Reservoir



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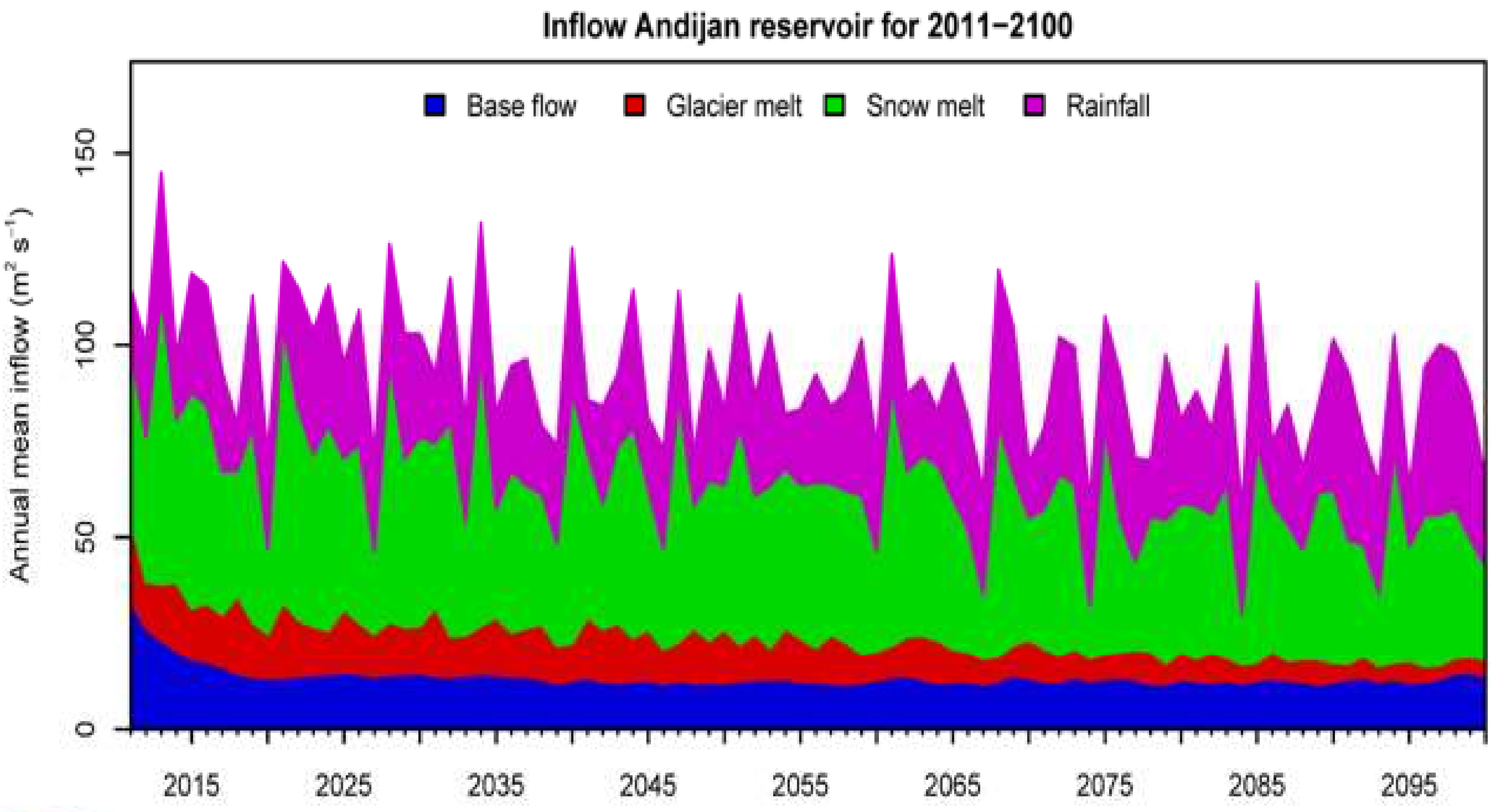
Hydrological forecast – Andijan Reservoir



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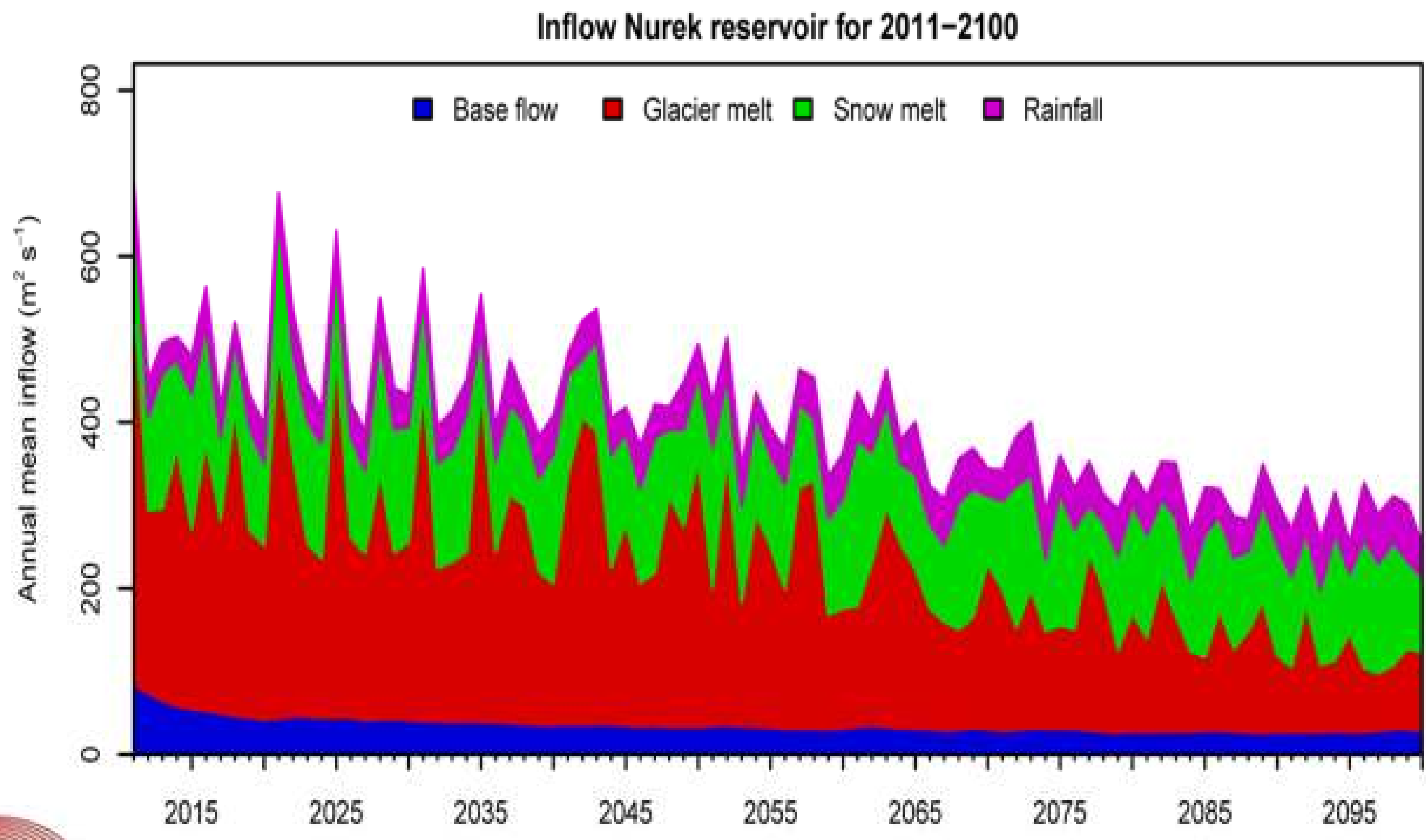
Hydrological forecast – Nurek Reservoir



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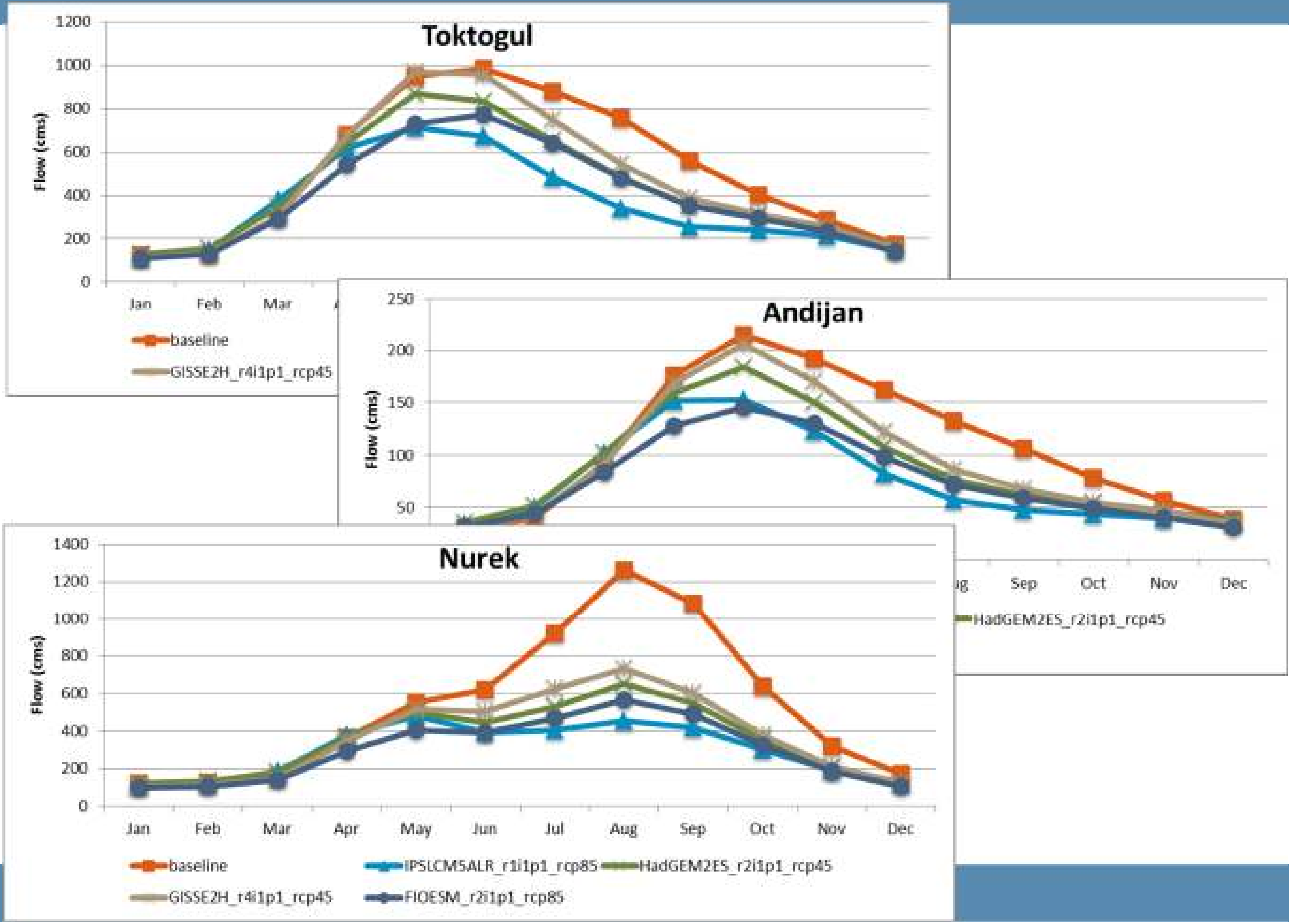
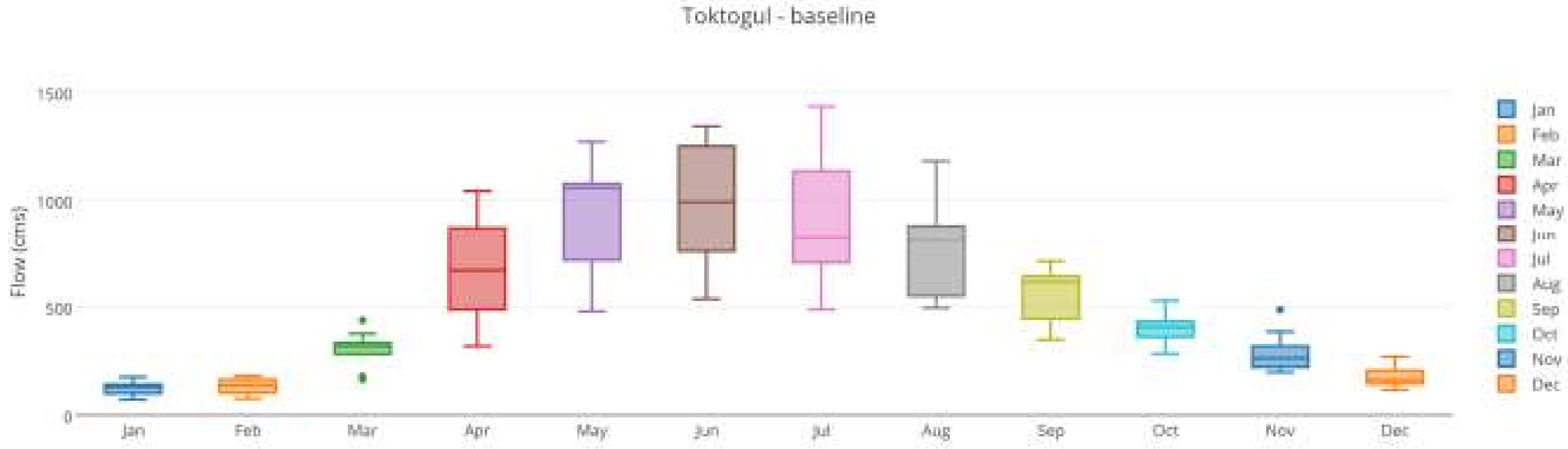
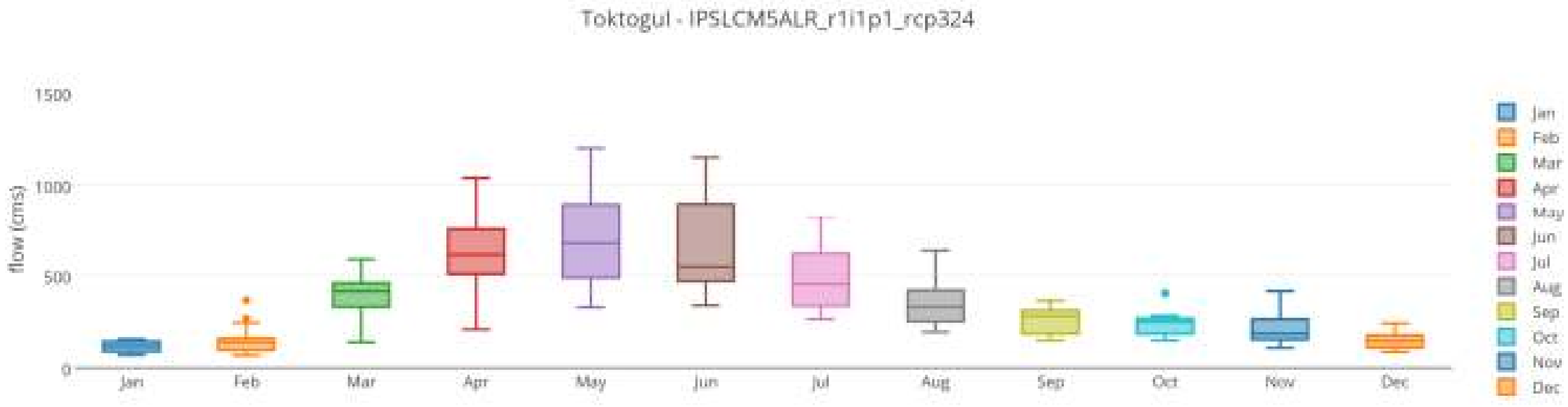
Large differences in flow across marker scenarios



Effect of climate change on variability of flows





Regional Scale Adaptation Options

Adaptation

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Examples of Climate-Smart Measures for the Energy Sector

Information Generation & Dissemination	Institutional Capacity Building	Policy Reform	Investment in Infrastructure
• **Turkmenistan, Uzbekistan & Kazakhstan**: Improve modeling of the effect of climate change on oil and gas production sites. • **Country-Level:** Train energy planners on tools and methodology to assess climate risks and vulnerability. • **Regional**: Share information on best practices for improving energy efficiency at household level and in industry.	• **Regional**: Enhance capabilities of hydromet to generate emergency forecasts and communicate them to emergency planners. • **Country-Level:** Develop contingency plans for better management of power plants under extreme climatic events.	• **Country-Level**: Establish policies to require energy providers to demonstrate the ability to respond to future climate stresses such as extreme heat. • **Country-Level:** Update engineering standards for energy generation and transmission infrastructure. • **Country-Level**: Implement policies to promote energy efficiency through demand control (such as tariff reform) and increase the efficiency of power generation. • **Regional**: Develop more efficient and economically beneficial regional energy markets.	• **Tajikistan**: Invest in infrastructure to harness hydropower potential. • **Kyrgyz Republic**: Invest in solar potential to help meet peak winter energy demand. • **Uzbekistan, Turkmenistan & Kazakhstan**: Utilize the more water-efficient combined cycle gas turbine (CCGT) technology in new thermal power plants to prepare for future water shortages. • **Country-Level:** Incorporate climate resilience into the maintenance, modernization and rehabilitation of existing energy assets. • **Country-Level:** Invest in more diverse portfolios of energy generation assets to enhance resilience to climate (and market) risks.

How will this approach inform Regional-Scale Action?

Examples of Regional Measures	Role for Regional Action	What are the benefits?
Develop more efficient and economically beneficial regional energy markets	-Implement policies to facilitate trade - Plan and operate infrastructure	Less wasteful energy capacity
Utilize the more water-efficient combined cycle gas turbine (CCGT) technology in new thermal power plants to prepare for future water shortages	- Identify and act on benefits of investments for regional water system	More water for other economic uses
Invest in more diverse portfolios of energy generation assets to enhance resilience to climate (and market) risks	- Direct energy planners to mainstream climate risks to energy generation	Less economic disruption from climate change
Incorporate climate resilience into the maintenance, modernization and rehabilitation of existing energy assets	- Develop plans to enhance generation efficiency	Less system downtime
Update engineering standards for energy generation and transmission infrastructure	- Direct investments to improve efficiency of regional electricity trade	Less generation and transmission losses to climate
Enhance capabilities of hydromet to generate emergency forecasts and communicate them to emergency planners	- Establish regional cooperation and information sharing	Value of information for emergency response

Dealing with Climate Uncertainty :

Robust Decision-Making

Adaptation

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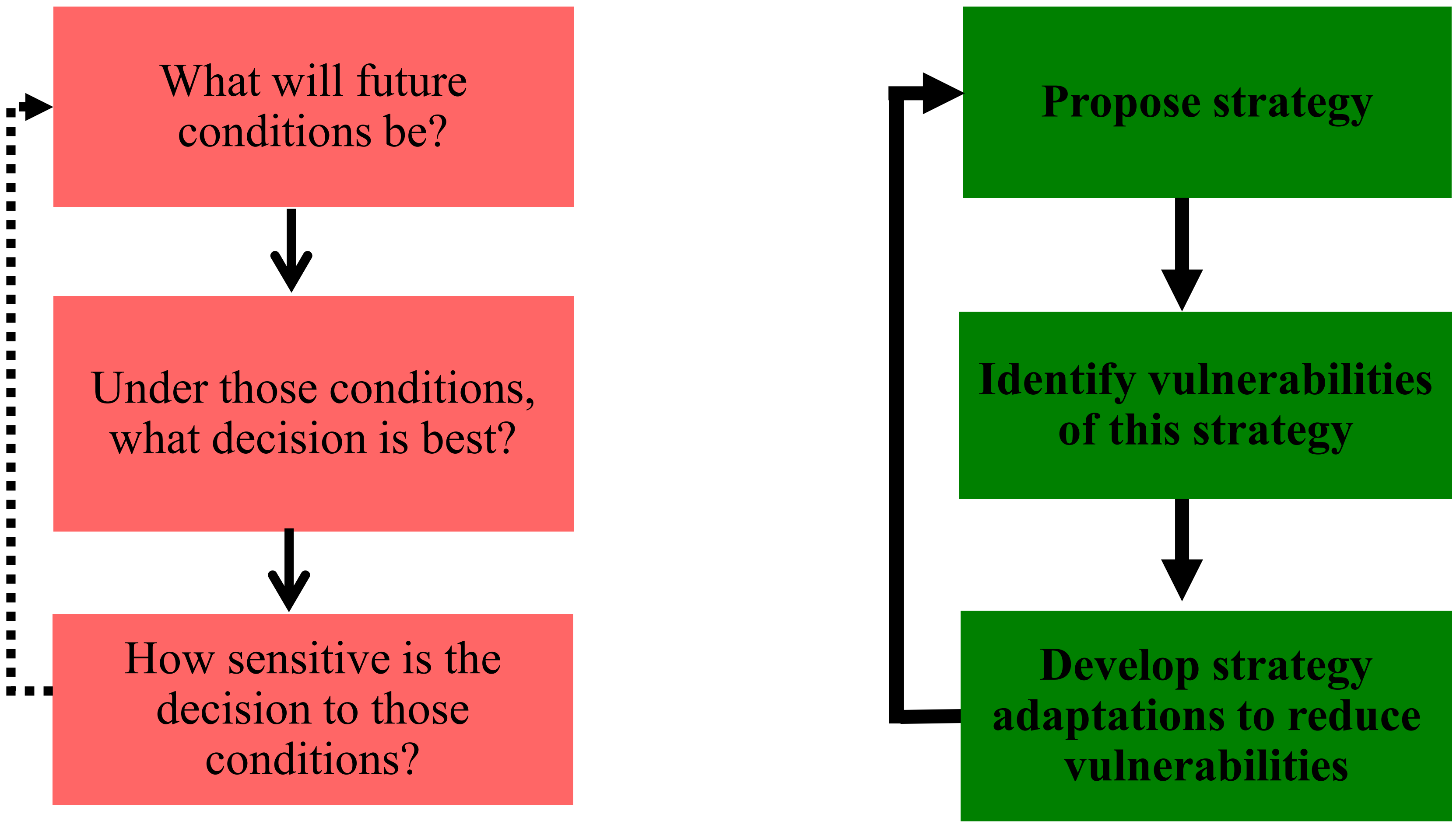
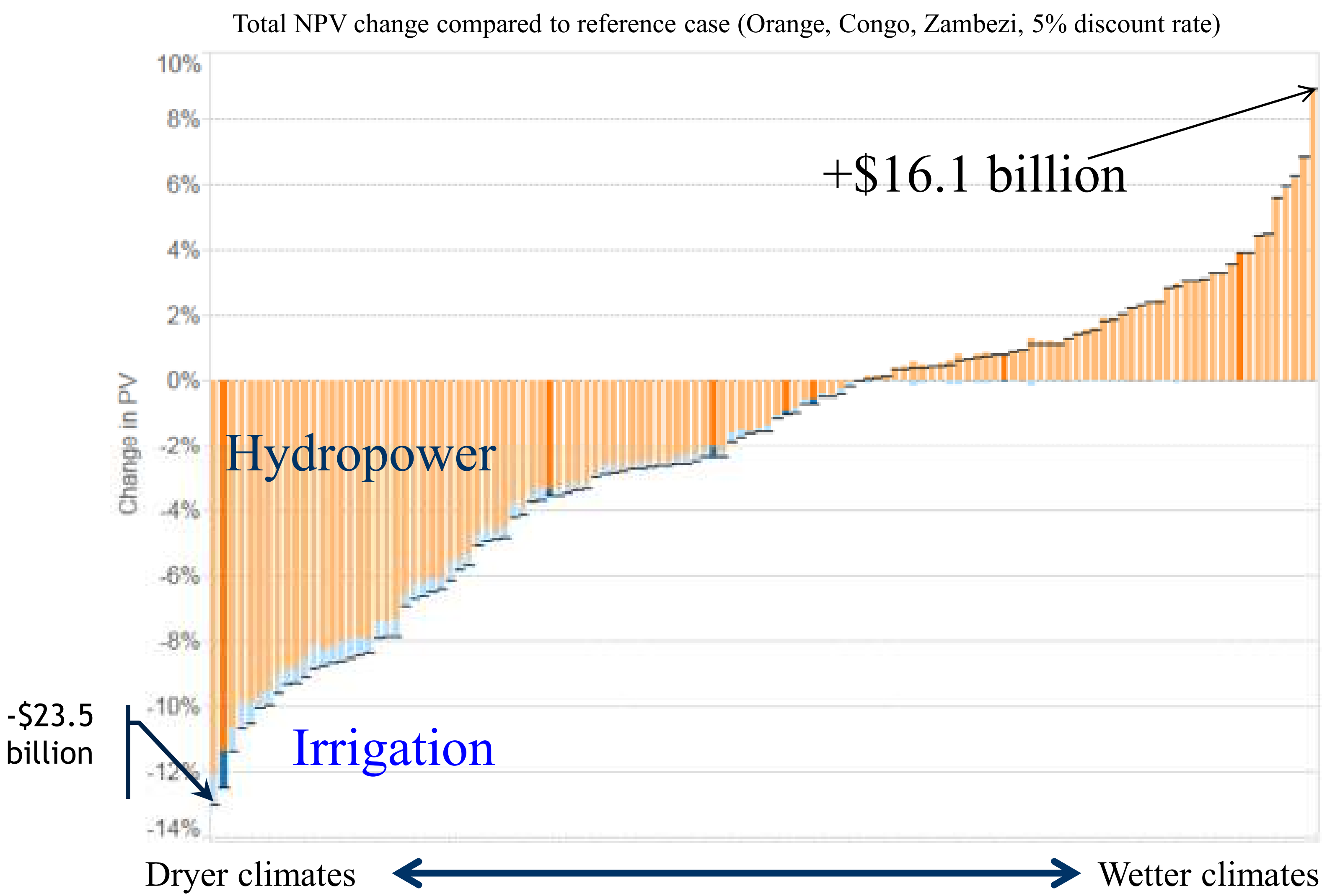
Robust Decision-Making, an alternative to prediction

Predict-then-act approach | Assess-risk-of-policy framework



Lempert, R. J., D. G. Groves, et al. (2006) A general, analytic method for generating robust strategies and narrative scenarios. *Management Science* **52**(4): 514-528.

Climate Change Leads to Economic Impacts, direction and magnitude is uncertain

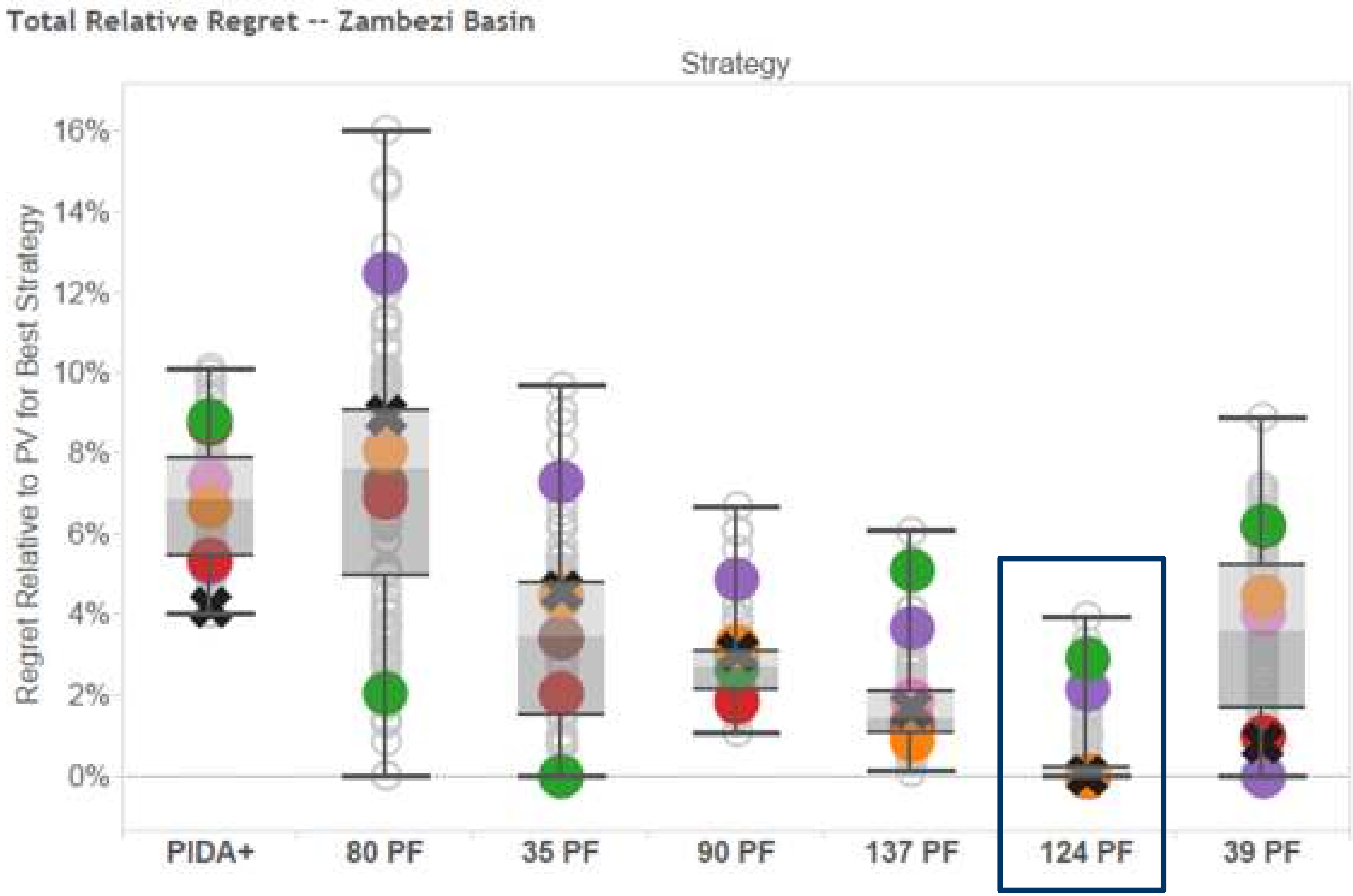


Allow for investments in adapting to a broad range of possible climate futures – levers

- Basin Level
  - Turbine capacity (-50%, -25%, 0%, +25%, +50%)
  - Reservoir storage (-50%, -25%, 0%)
  - Conveyance irrigation efficiency (75%, 85%, 95%)
  - Timing of infrastructure deployment

- Farm Level
  - Irrigated area (-50% to +50%)
  - Deficit irrigation (30%, 20%, 10%, 0%)
  - Field-level irrigation efficiency (60%, 70%, 80%)
  - Annual crop imports

One option - choose the strategy that Minimizes the Maximum regrets



Proposed Schedule

Initial results on impacts of climate change on the energy system	Mid-September 2014
Begin analysis of the economic impacts of water sector results	First results in late September 2014
Economic impact analyses for all components	Late September 2014
Consultations with national delegations (via Webinar)	End September 2014
Refinement of the data and methods, first assessment of adaptation options, draft report	October 2014
Second consultations with national delegations (in region and via Webinar)	October 2014
Completion of final report	November 2014

Discussion Questions

- What current climate impacts have you experienced to energy sector assets that concern you?

- What adaptation options (investments and policies) would you like to see evaluated in this framework (see list on slide 30)?

- What institutions in your country are in the best position to review our results in late September (for impacts) and late October (for regional adaptation priorities)?

- Can you review and improve our input data? Top priorities:
    1. Transmission network, node locations and capacities (GIS files)
    2. Hydropower plant capacities
    3. Thermal plant locations and capacities, cooling water technologies
    4. In-stream flow data
    5. Irrigation water demands