Water Resources and Integrated Assessment Modelling

Presentation at FIDS Water Resources Symposium
May 12, 2014

Evan Davies, University of Alberta

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ENGINEERING U of A

My History with FIDS (2003-2008)

* My mother → Gordon McBean → Prof. Simonovic

* September 2003: Started PhD
* December 2007: Defended PhD
  * "*Modelling Feedback in the Society-Biosphere-Climate System*"

* January 2008: Started PostDoc
* February 2009: Completed PostDoc
  * "*Energy Sector for ANEMI*"

* July 2009 → University of Alberta

The "FIDS Experience"

* Social aspects are what I remember best
  * Annual picnics at Fanshawe Reservoir
  * Christmas dinners with FIDS

  * Dinner/Beer/Movie nights with other students/PDFs
  * Weddings and other celebrations
  * Weekly meetings and the wait in the FIDS offices…

The FIDS Cohort in 2005

In Photo (from left): Prof Simonovic and Tanja; Juraj, Timea and Natalie Cunderlik; me; Jamie Prodanovic (Thomas), Pat Prodanovic; Ibrahim, Seba, and Abeer El-Baroudy

The FIDS Cohort in 2007

In Photo (from left): Evan and Yufei Davies; Khaled Akhtar; Jordan Black; Ponselvi Jeevaragagam; Sean Gettler; Pat and Jamie Prodanovic (Thomas); Angela Peck; Prof Simonovic and Tanja

FIDS Members (2003-2008)

* Shohan Ahmad (MSc, PhD)
* Khaled Akhtar (PhD)
* Taslima Akter (PhD)
* Vasan Arunachalam (PDF)
* Elizabeth Bowering (MSc)
* Juraj Cunderlik (PDF)
* Evan Davies (PhD, PDF)
* Ibrahim El-Baroudy (PhD)
* Hyung-Il Eum (PDF)
* Ponselvi Jeevaragagam (PhD)
* Subhankar Karmakar (PDF)
* Angela Peck (MSc, PhD)
* Pat Prodanovic (MSc, PhD)
* Rajesh Shrestha (PDF)
* Tarana Solaiman (PhD)
* Dragan Sredojevic (MSc)

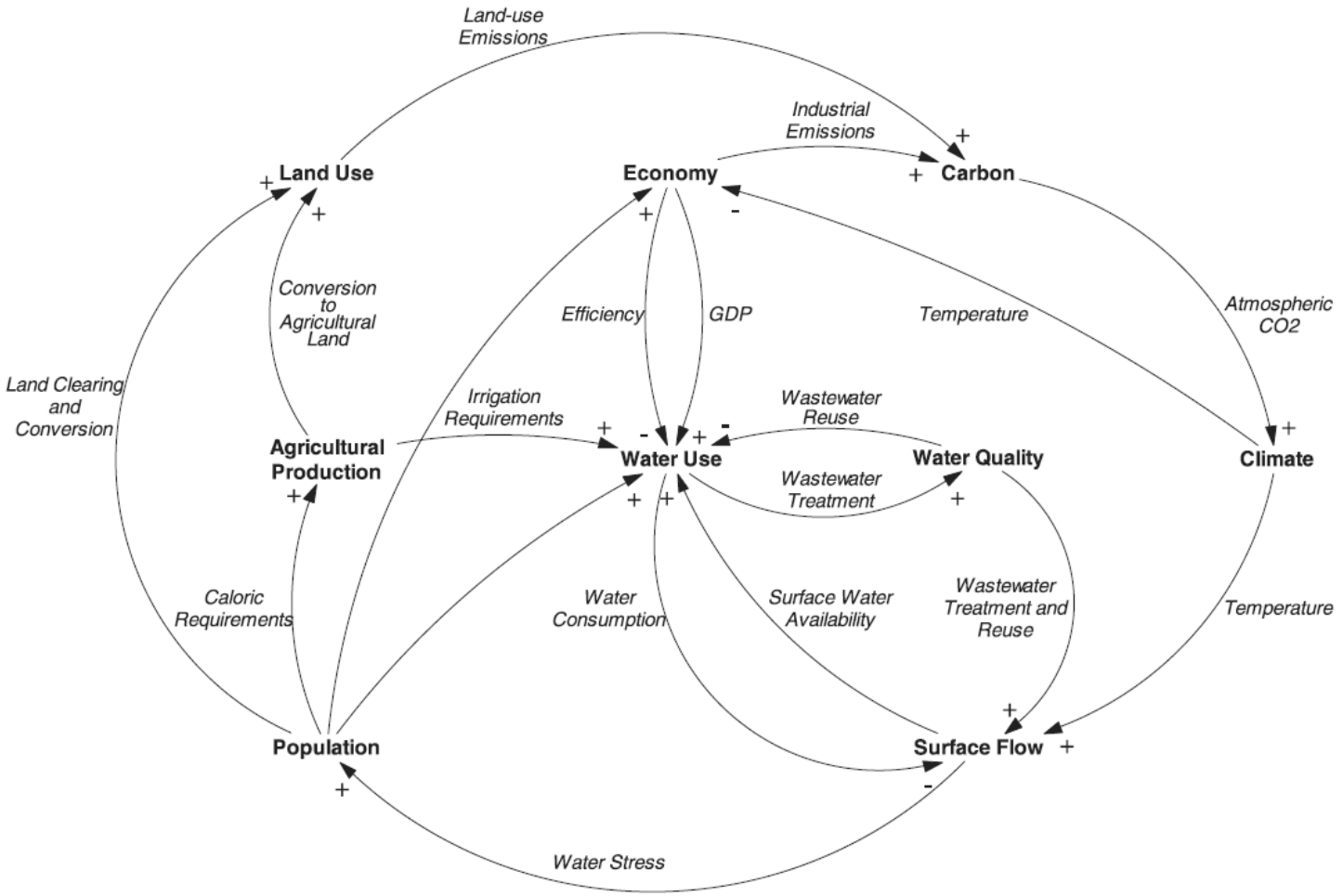
Memories of FIDS

Research at FIDS

* PhD research was also enriching…
  * I learned a lot! And started to focus on *water*
  * Four years of research on **one topic** (with lots of parts)
    * System dynamics, simulation and global change
    * Water use, climate change, socio-economic development
    * The hydrological cycle, carbon cycle, and climate policy
    * Agriculture and energy systems
* *Now, my attention is divided!*

My Work at FIDS: PhD Thesis

ANEMI: System dynamics model of water and global change

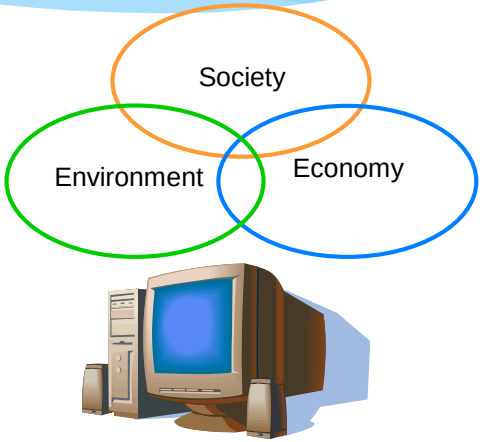


PhD Research Goals

1. Examine how climate change affects long-term sustainability

2. Provide a tool to policy-makers

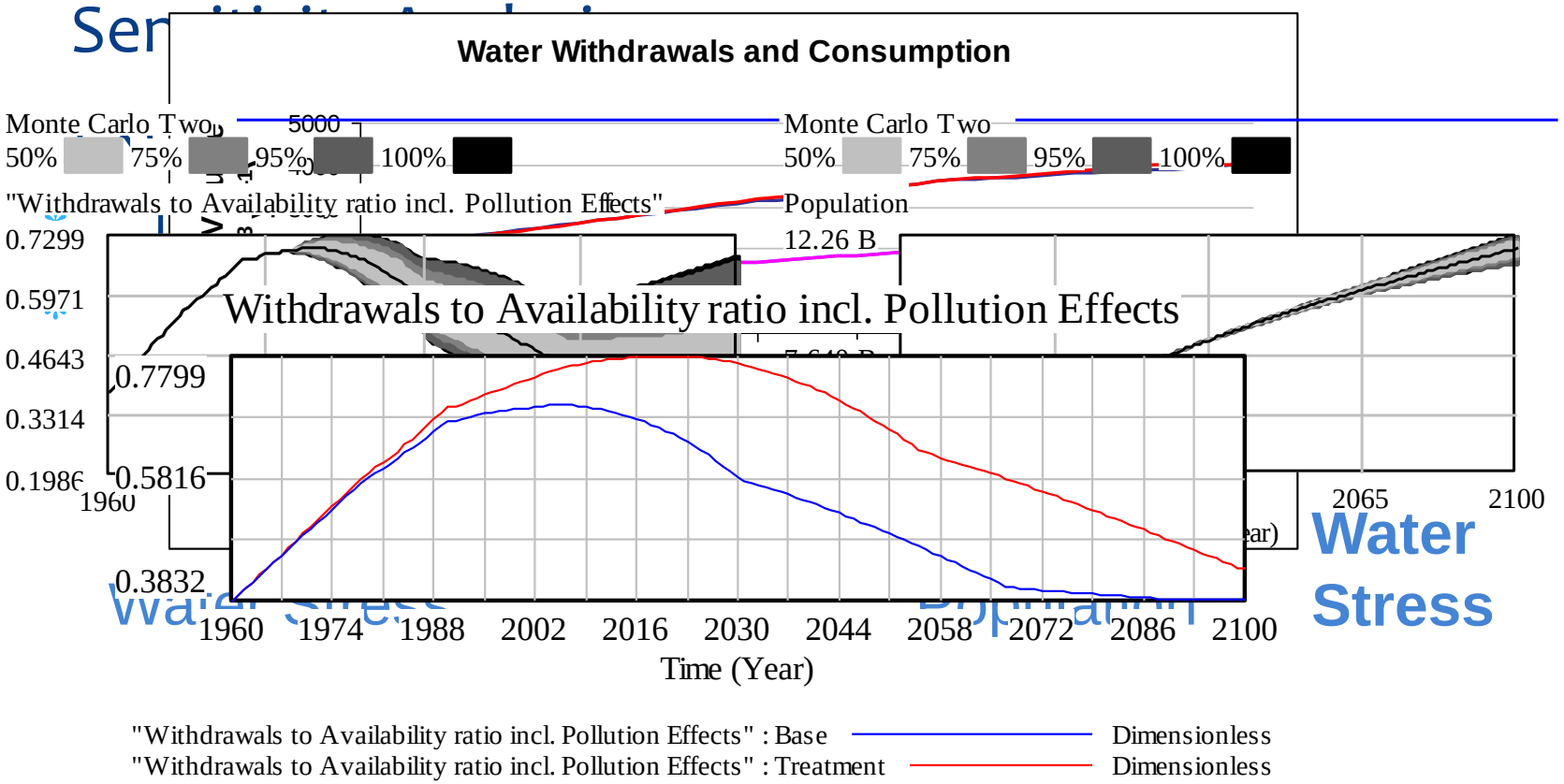
3. Stress importance of feedbacks



Understanding → better policy

Experimental Approach

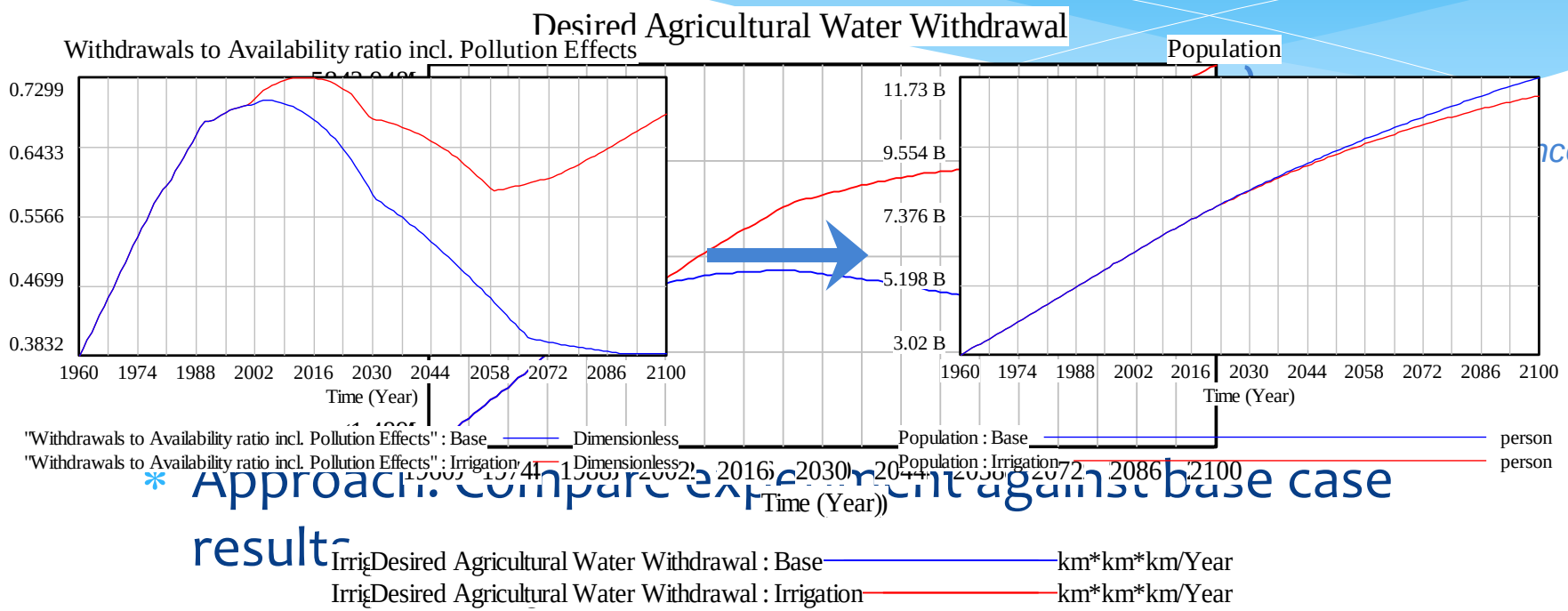
1. Performance Assessment
2. Sen
3.



Water Stress

Sample Results: Irrigation

Feedback Effects



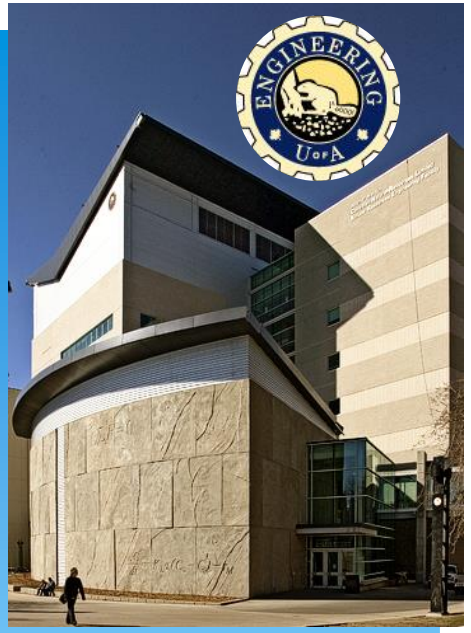
* Approach: Compare experiment against base case results

Result: More Food causes Lower Population?

Reason: More Irrigation means more Pollution!

Lessons Learned at FIDS

* Copying from Prof Simonovic…
  * Regular (weekly) meetings with my students
  * Treat students as “junior colleagues”
  * Respond quickly and supportively
  * Provide them the tools they need to succeed
  * Require excellence and hard work, but humanely



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University of Alberta (2009-now)

Current Work

Water Resources Engineering

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Research Overview

- **System dynamics/integrated assessment**
  - ***Examples follow…***
    - *Water-Energy nexus*
    - *Drought management*
    - *Irrigation sector planning*
  - Also Wastewater treatment/biomass production/SRWC
- Deficit irrigation and reservoir management
- First Nations water use/quality
- Urban stormwater/stormwater ponds

Integrated Assessment and Global Water Resources

With Page Kyle, Joint Global Change Research Inst.
Mohamad Hejazi, Joint Global Change Research Inst.
Jae Edmonds, Joint Global Change Research Inst.
Leon Clarke, Joint Global Change Research Inst.
And others

Integrated Assessment and Global Change

* Work with JGCRI (2009-present)
  * *Joint Global Change Research Institute, Washington DC*

* Use large-scale models to understand *big picture* of climate and global environmental change:

  * Climate change: General Circulation Models (GCM)
  * Global change: Integrated Assessment Models

Model: "GCAM"

* **Integrated Assessment (IA) Models** simulate "global change"
  * Focus on human-environment connections
  * Clarify feedbacks between climate, energy, economic etc. policy alternatives
  * Provide insight unavailable from disciplinary science

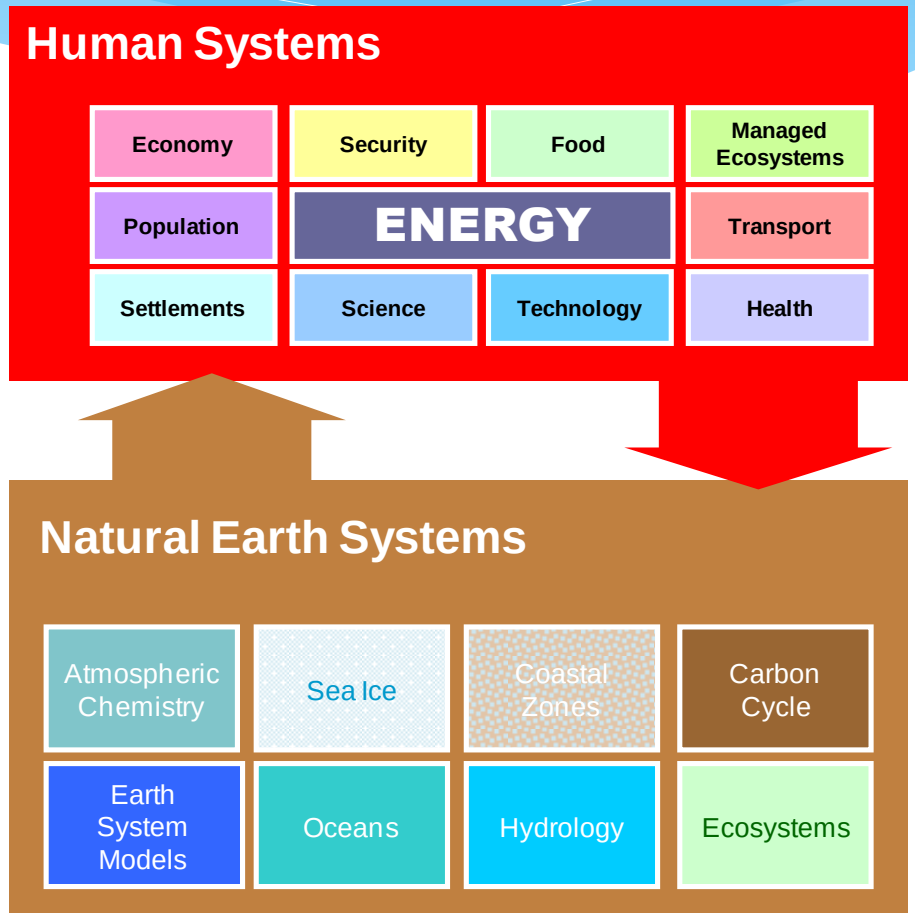


Image courtesy of J. Edmonds, JGCRI

GCAM

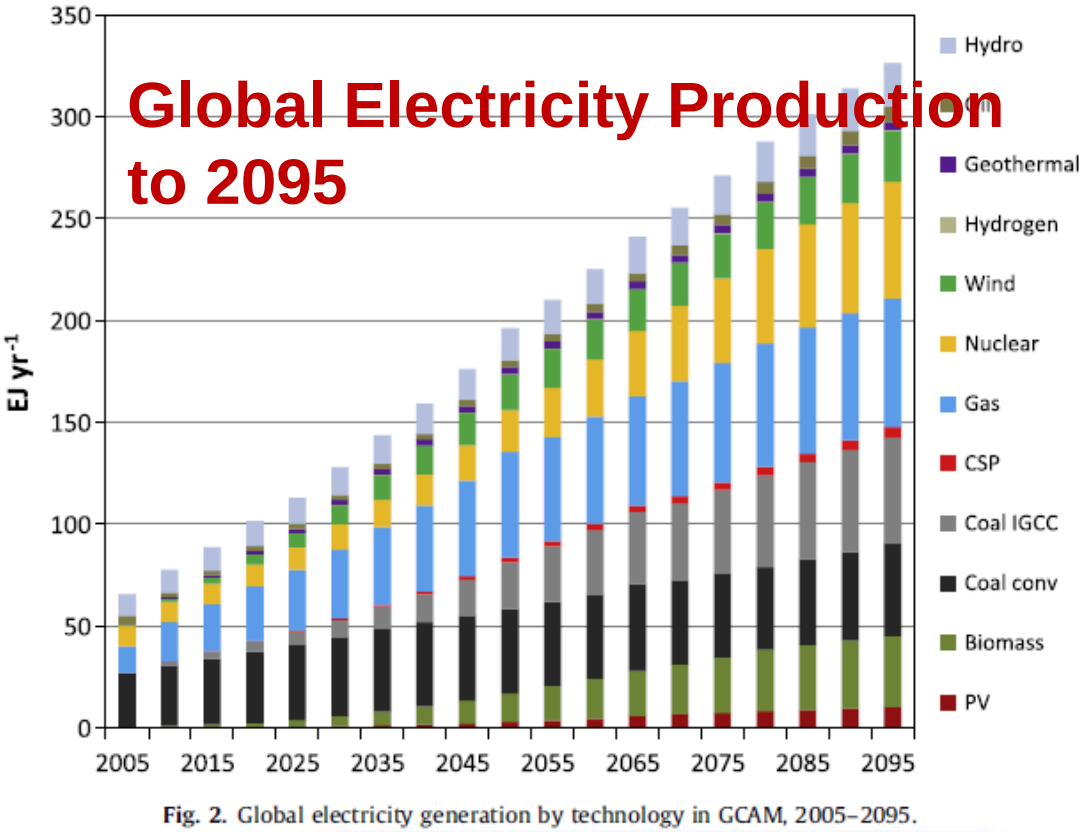


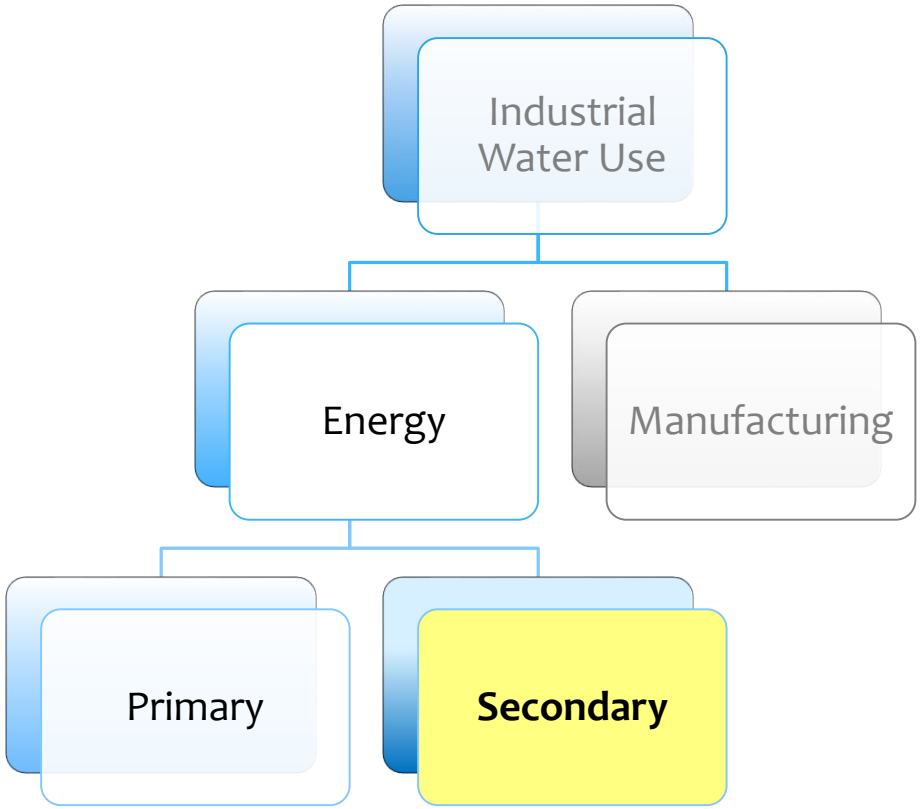
Fig. 2. Global electricity generation by technology in GCAM, 2005–2095.

- Research model
- **GCAM human Earth systems model has Economic, Energy and Land-use systems**
- Technologically detailed
- Fourteen geopolitical regions
- **Runs through 2095 in 5-year time-steps**

Courtesy of J. Edmonds, JGCRI

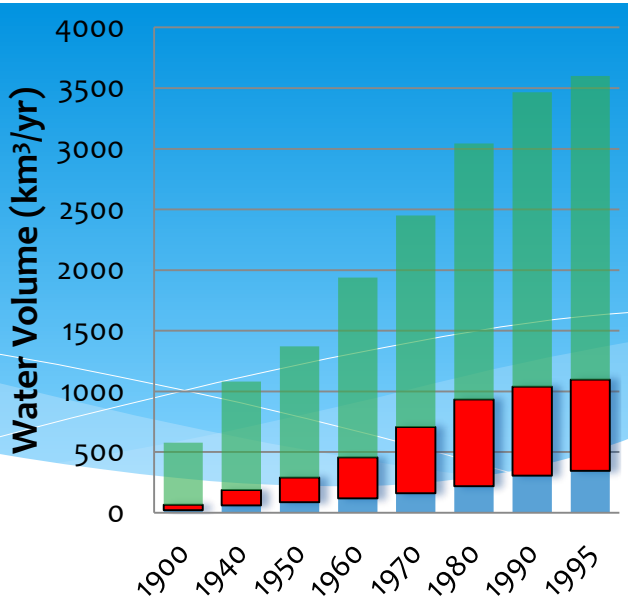
(Fig. 2 from Davies et al., 2013)

Focus: Water for energy



* Starting point: Water for Energy
  * Water for primary energy
    * *Coal*
    * *Oil*
    * *Natural Gas*
    * *Uranium*
    * *Less…*
  * **Water for secondary energy**
    * Electricity generation
    * Cooling water
    * *MORE…*

Model Use: Research Questions

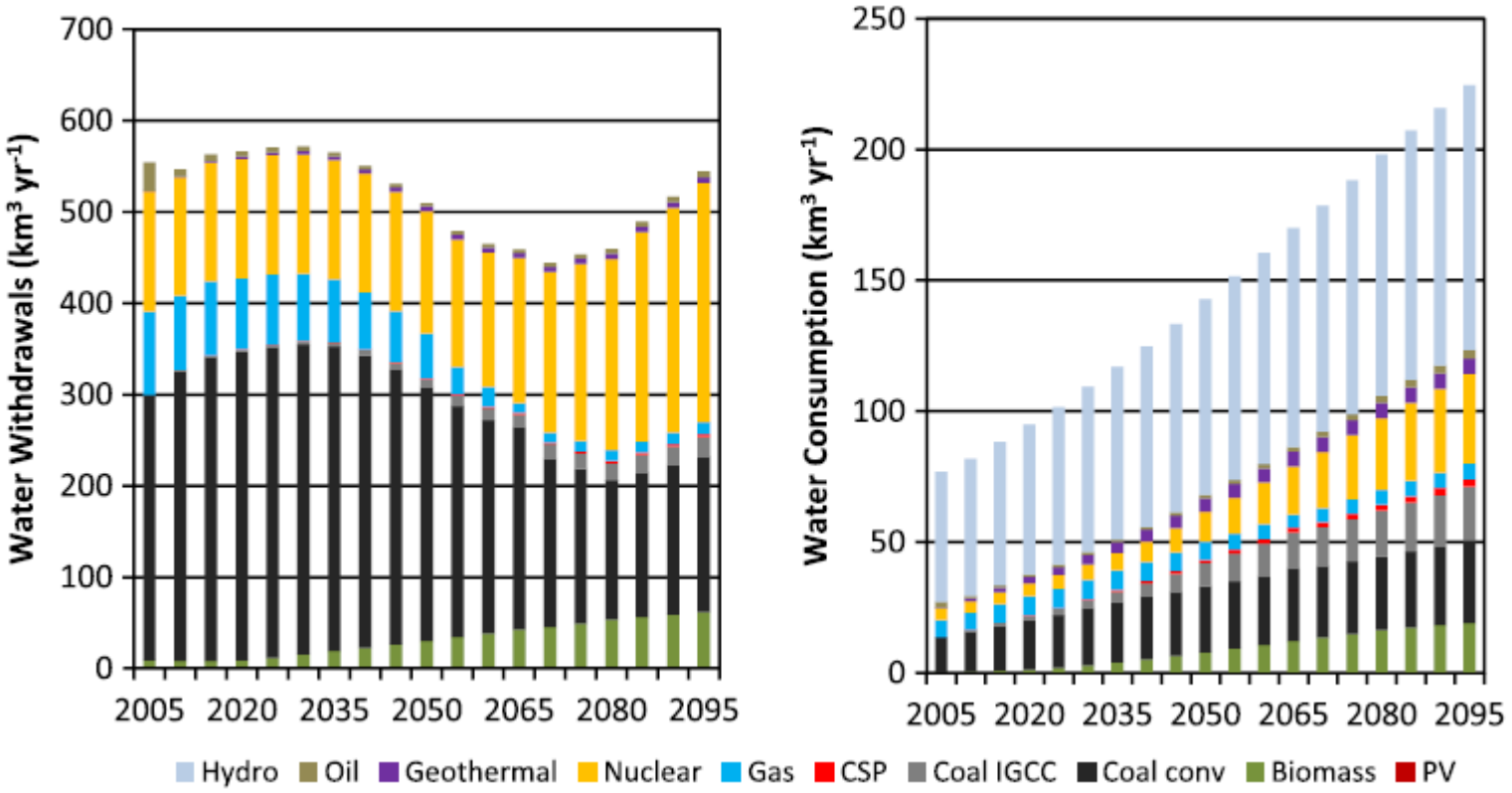


1. How much water used by GCAM regions for **energy production**:
   * Now?
   * To 2100?

2. What are **key factors** affecting water use?
   * Effects of electricity technology and cooling system choices

3. How does water use change with electricity mix?
   * Policy Analysis: Effects of **climate policy**

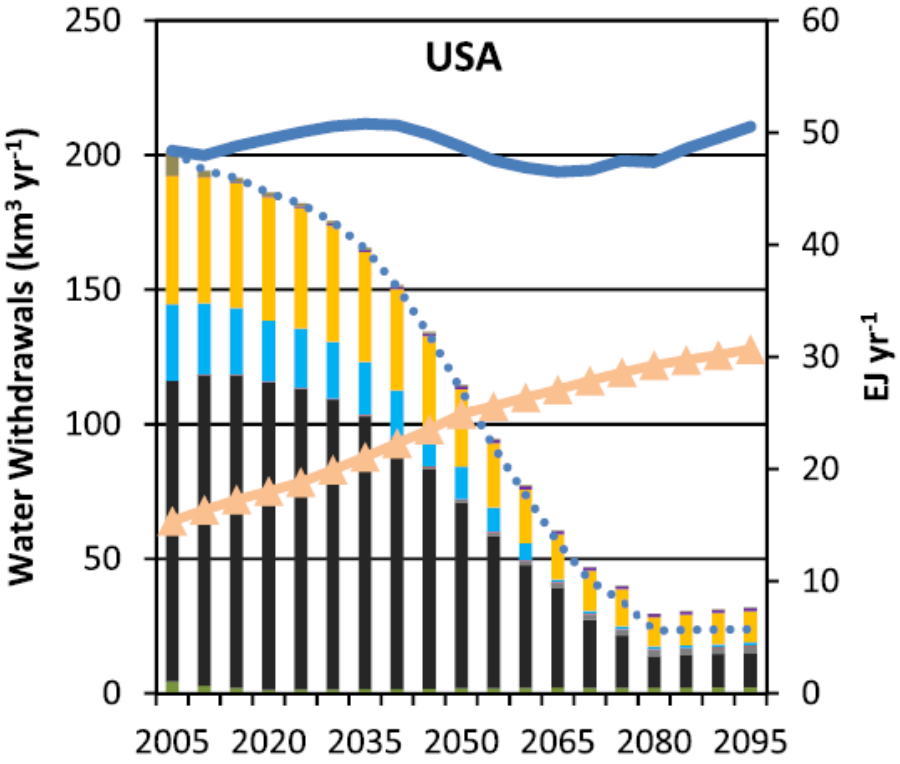
The global picture – withdrawal and consumption



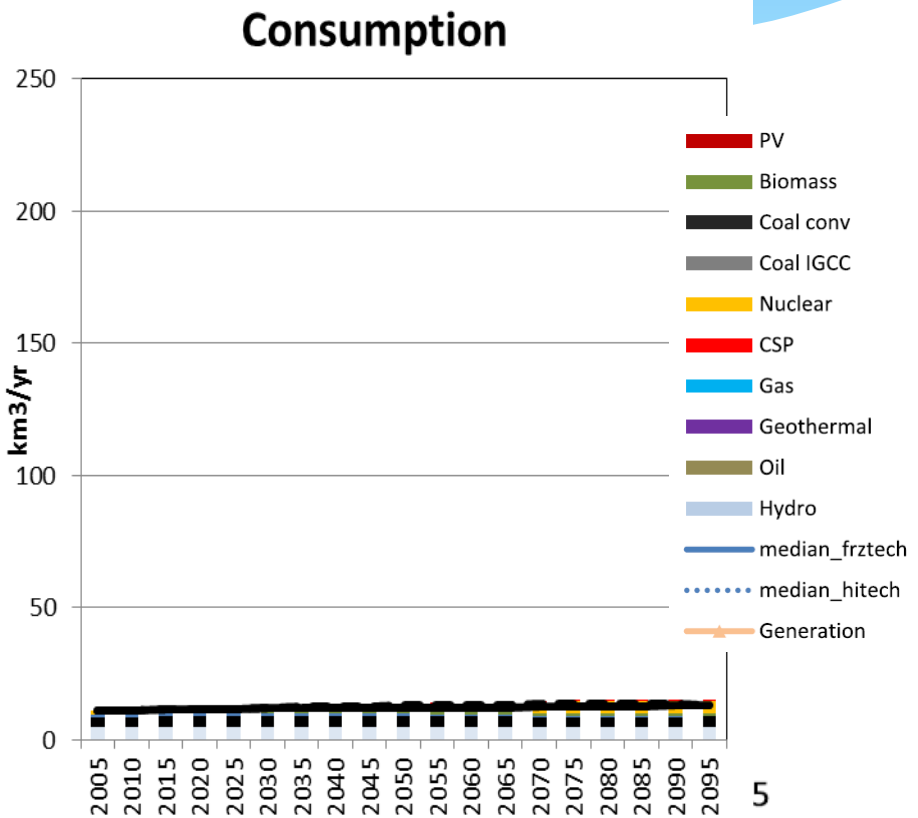
Withdrawal **Consumption**

Davies et al. (2013), *ADWR*

U.S. – water withdrawal and consumption



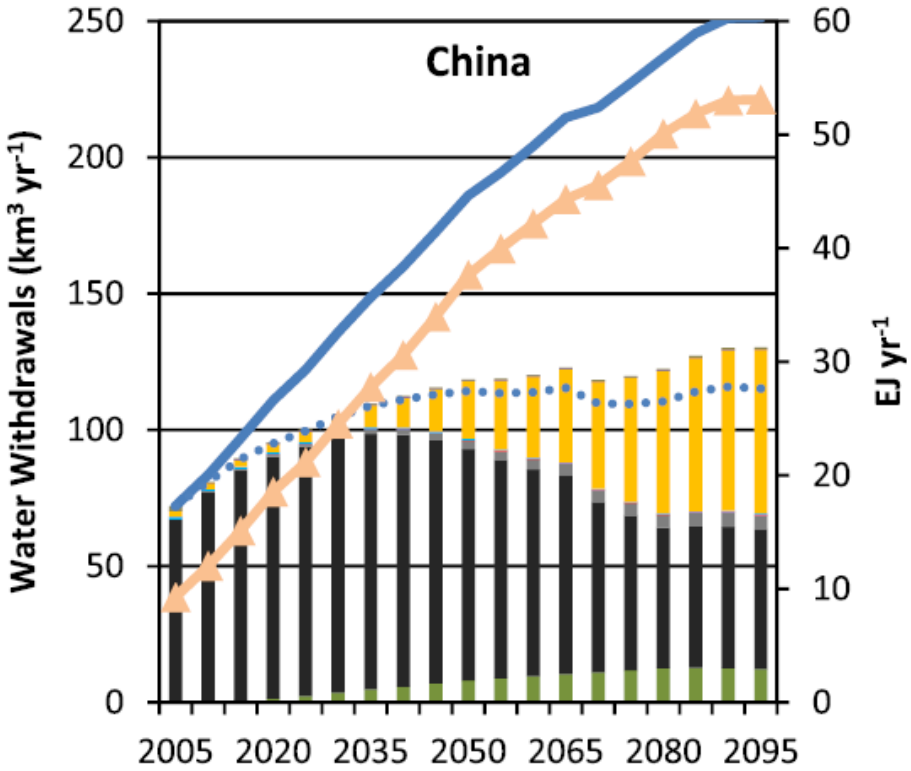
Withdrawal



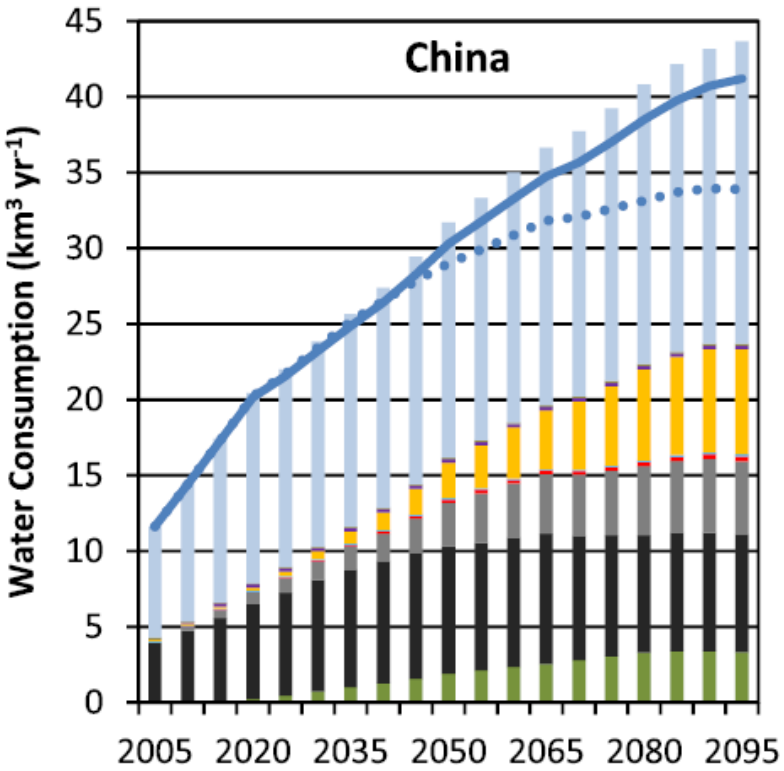
Consumption

Davies et al. (2013)

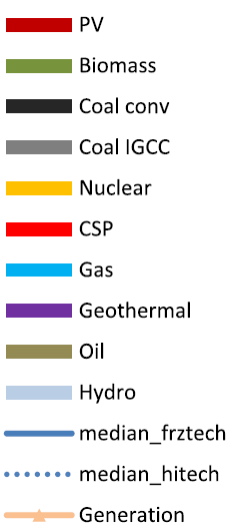
China – water withdrawal and consumption



Withdrawal



Consumption

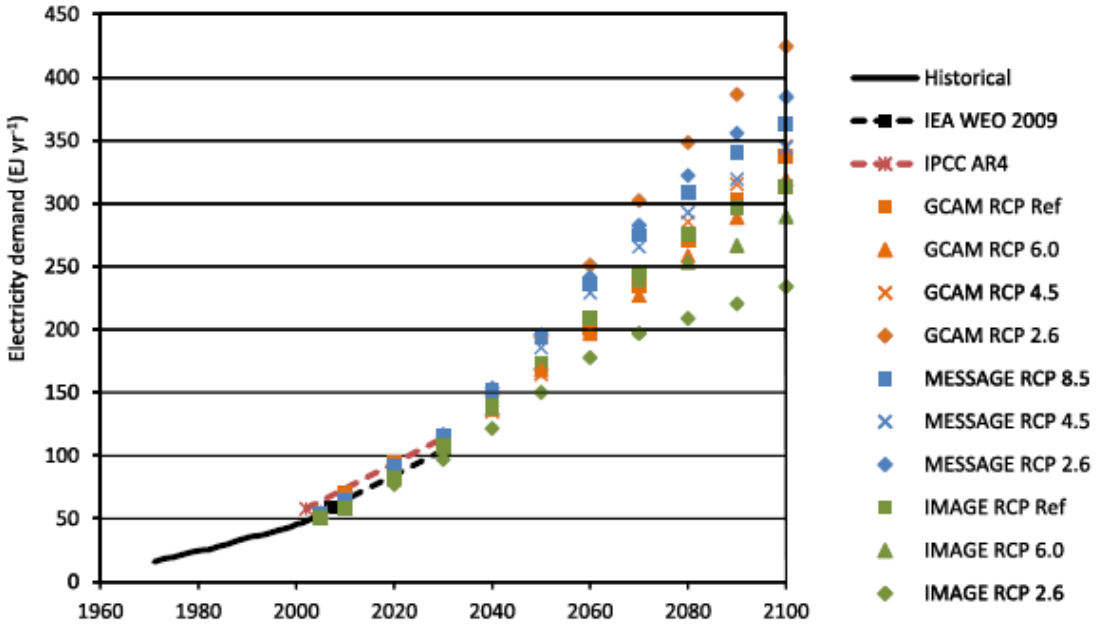


Davies et al. (2013)

What if electricity changes too?

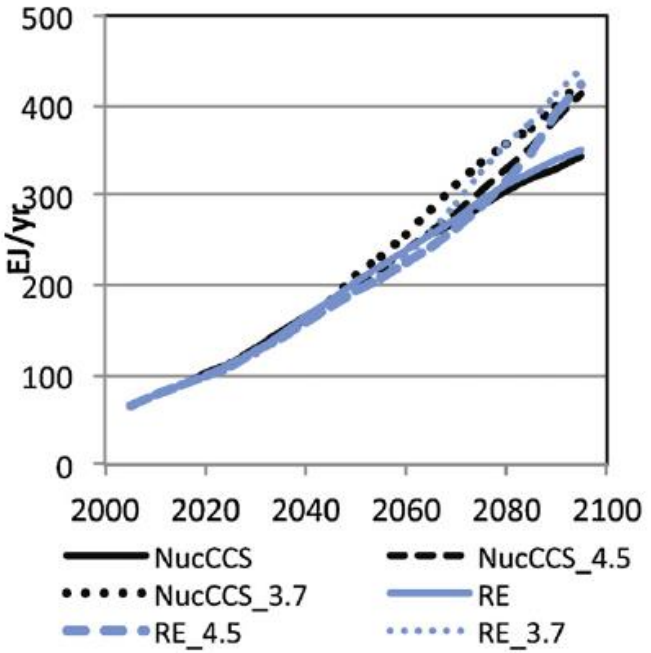
Its production depends on model, and climate and energy policy!

Different Models:



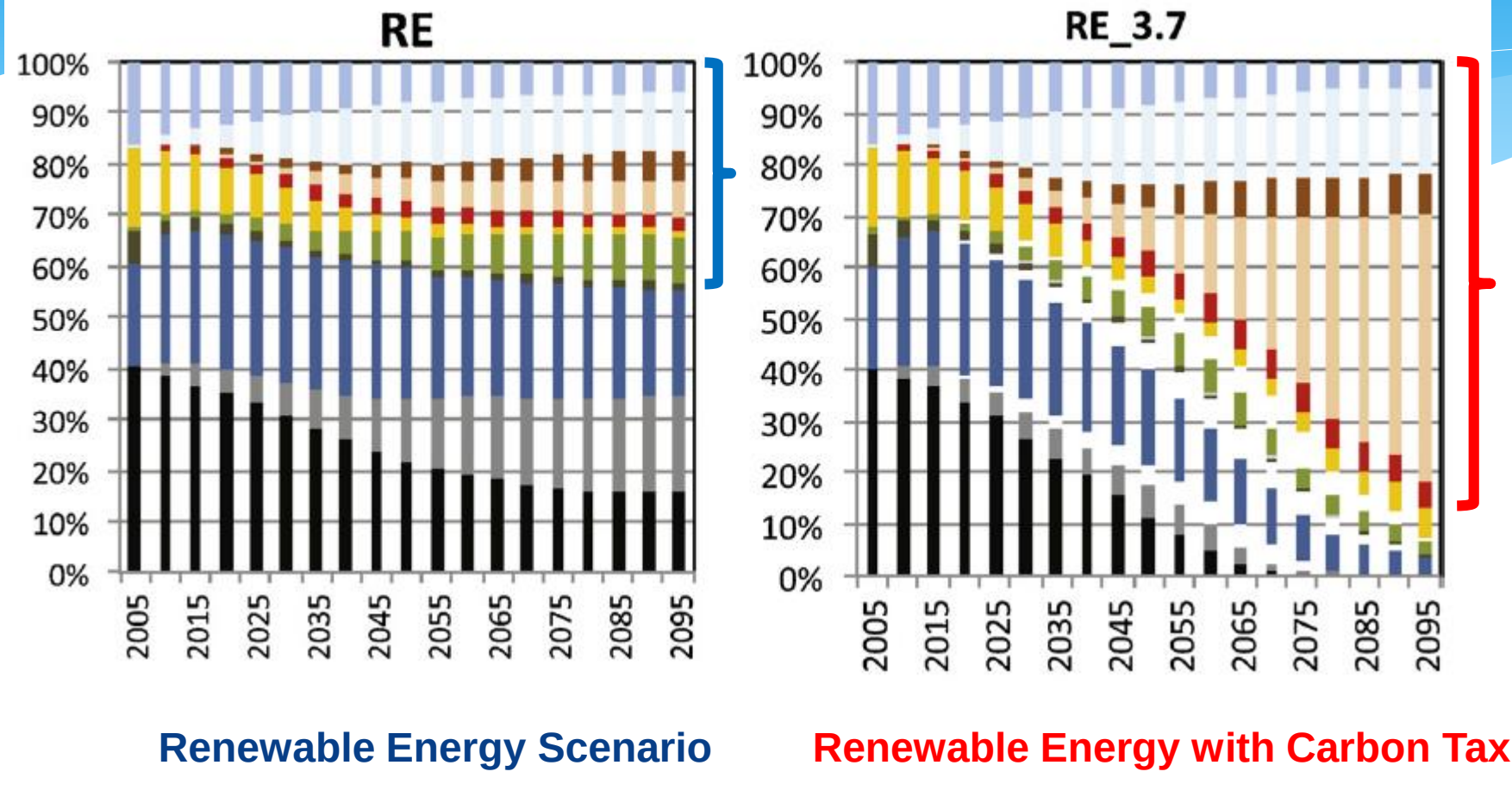
Davies et al. (2013), *ADWR*

Climate and Energy Policy:



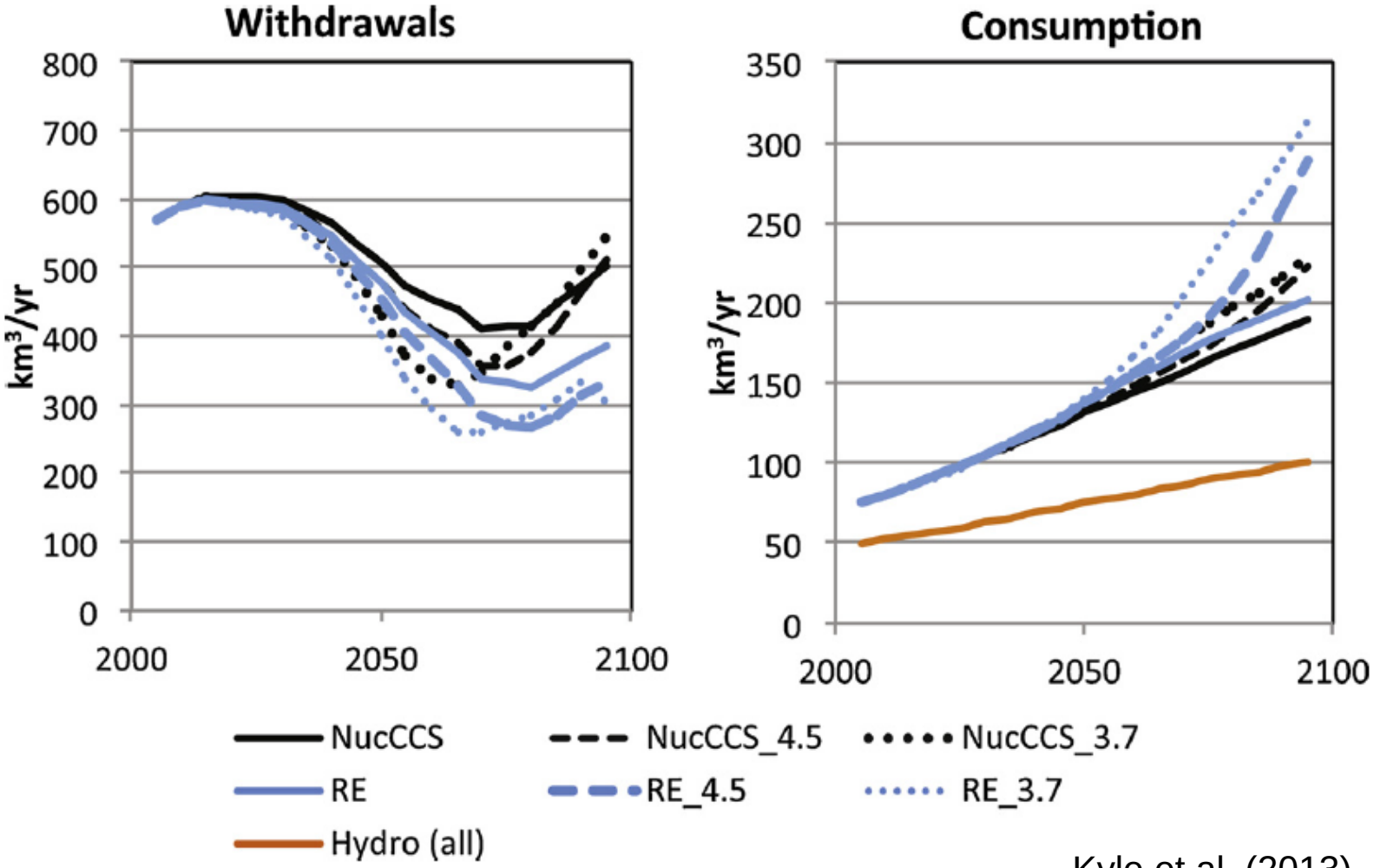
Kyle et al. (2013), *IJGGC*

Shifts in Electricity – policy effects



Kyle et al. (2013), *IJGGC*

Effects on Water Use



Kyle et al. (2013), *IJGGC*

The Invitational Drought Tournament: Drought preparedness capacity building

With Kai Wang, University of Alberta
Xuanru Wang, University of Alberta
Harvey Hill, Agriculture and Agri-food Canada
Monica Hadarits, Agriculture and Agri-food Canada
Richard Rieger, Agriculture and Agri-food Canada

Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada
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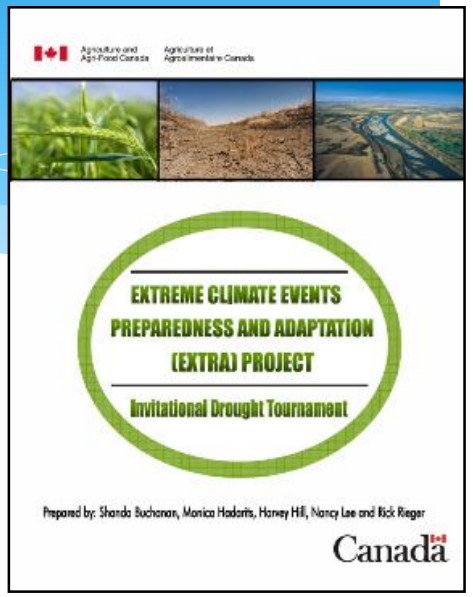
Invitational Drought Tournament (IDT): 2011-now

* Decision-support framework developed by Agriculture Canada
  * Helps institutions address drought preparedness
  * Uses **gaming format** to identify gaps and vulnerabilities in plans
  * Creates forum for multi-disciplinary stakeholders to discuss climate preparedness and adaptation

  * *Competition drives engagement*

* To date, 5+ IDTs run:
  * Calgary, Feb. 2011
  * Saskatoon, Mar. 2012
  * Kelowna, Nov. 2012
  * Saskatoon, Mar. 2013

Running a Drought Tournament



* **Teams** of 4-6 players, representing
  * Policy
  * Water
  * Agriculture
  * Environment
  * Industry
  * Or… *Students*

Calgary Tournament

Saskatoon

* **Goal**: Reduce drought risk over the short- and long-term by:
  * maximizing economic potential
  * minimizing social stress
  * improving environmental conditions

Pillars of Sustainable Development

Running a Drought Tournament

* In the fictitious **Oxbow Basin,** IDT teams
  * Are guided through a multi-year drought scenario of unknown duration and intensity
    * Choose each year among set list of policies to adapt to and mitigate drought impacts
    * Can also innovate
      → *new policies*
  * Have set budget

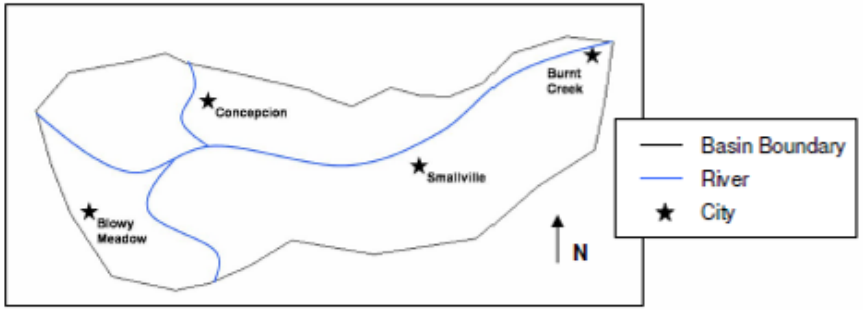
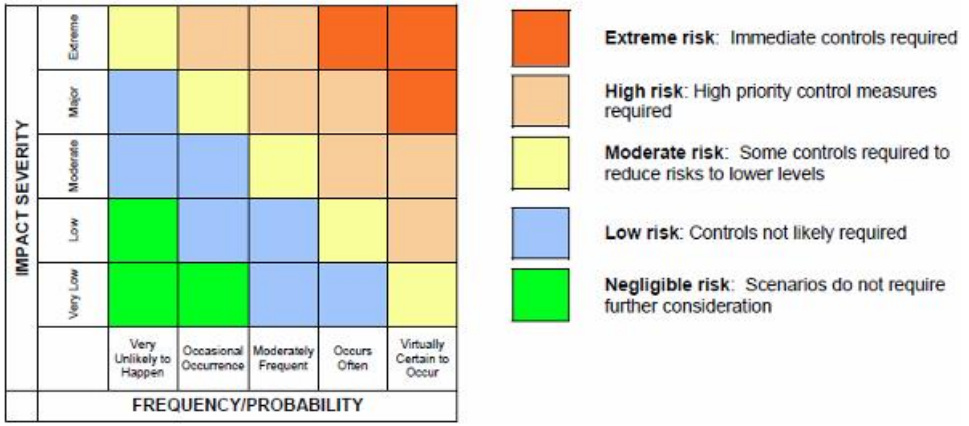


Figure 1: Oxbow basin, Canada

Game Scoring Approach: Calgary

* A competition: Each adaptation option has a score
  * Economic
  * Social
  * Environmental
  * Meets short-term needs (1 year)
  * Meets long-term needs (15 years)
* Scoring is based on a modified risk assessment
  * Team with the lowest score, i.e. lowest residual risk, wins



Comments from Observers and Participants in Calgary

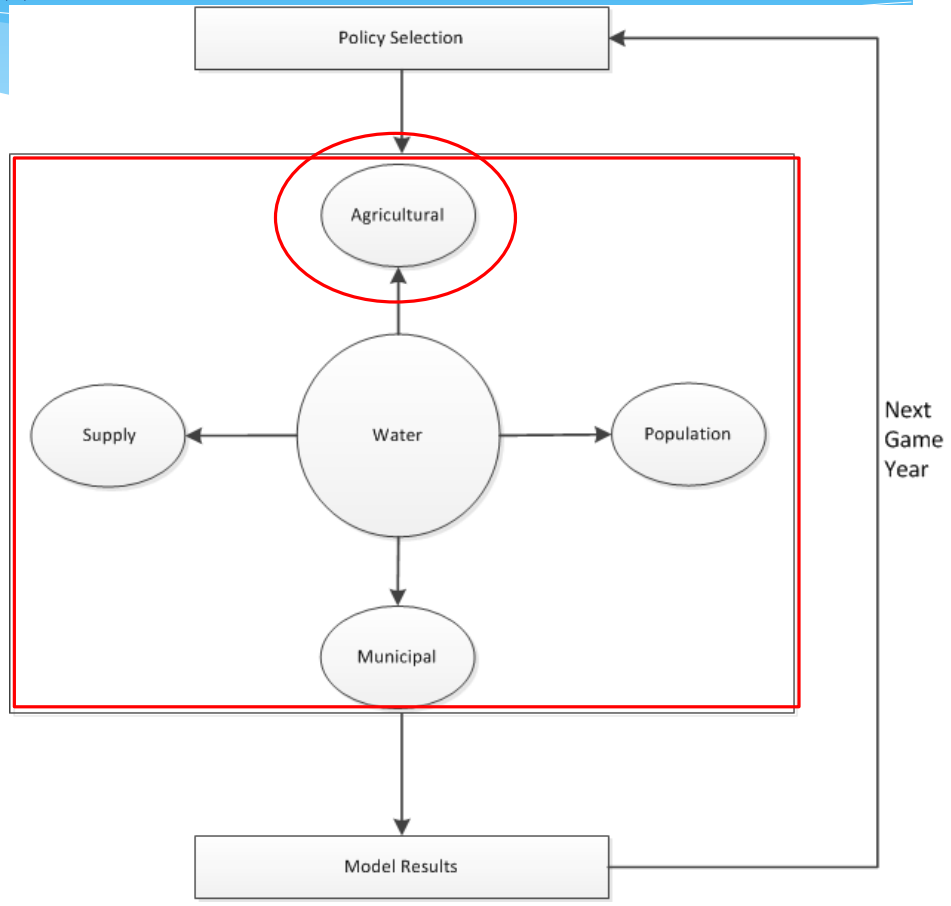
* "It takes adaptation-planning exercises to a new level, above and beyond an inventory of impacts and adaptation…"
* "Participants tended to work as a team vs. competitively in their sector roles"
* "…the tournament has strong potential for testing the application of science to adaptation decision making."
* "It [the IDT] encourages teams to develop a group vision for the basin"
* *"An automated process for running the game would allow for more adaptation choices"*

Pilot Game Challenges and Recommendations

* The water balance scenario was static
  * Development of simulation model → University of Alberta
* Development of online tools or software to automate scoring and other aspects of the scenario
* Funding strategy needs to be flexible and proactive
* Revision to scoring for transparency

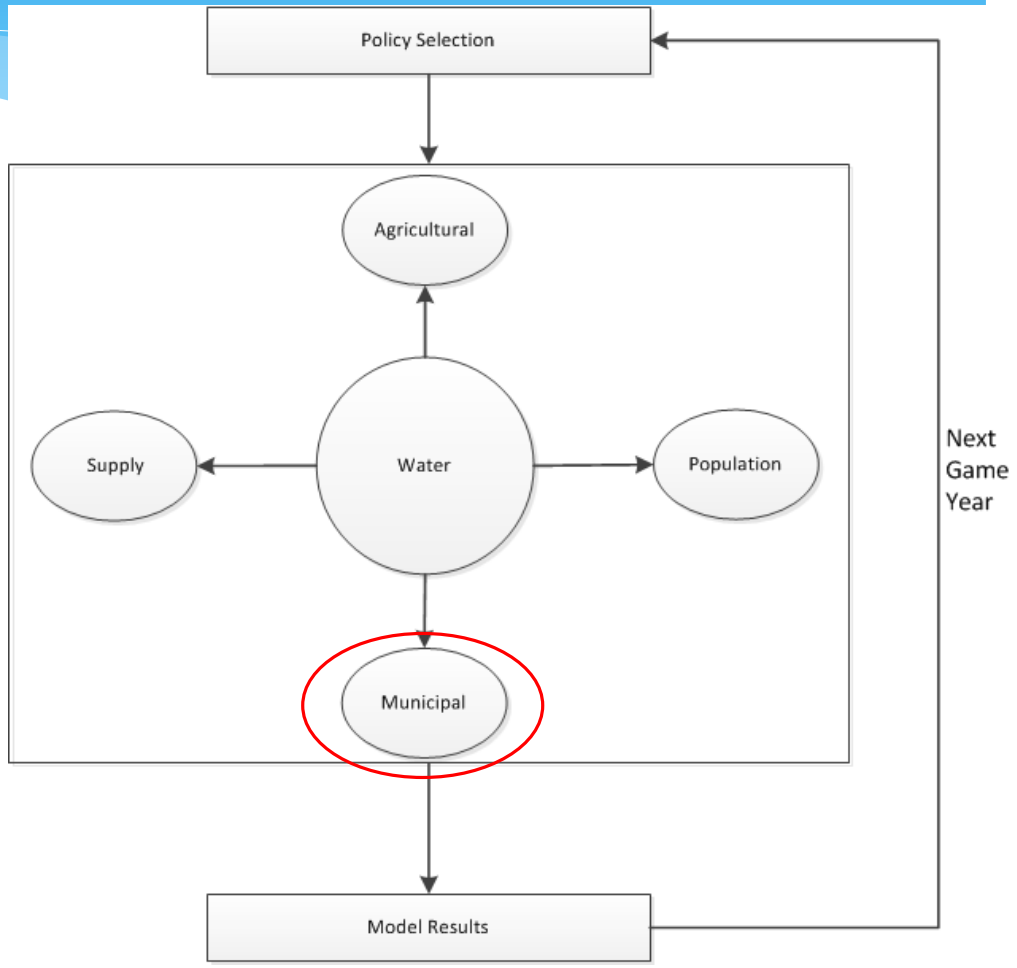
The IDT Model

- System Dynamics "gaming"
- Model Components
  - Agriculture
    - Land: rain-fed, irrigated
    - Crop: forage, grain, oilseed, vegetables, grass
    - Livestock: dairy, beef, pigs, chickens
  - Supply
    - Base flow
    - Reservoir drawdown
    - Build additional reservoir

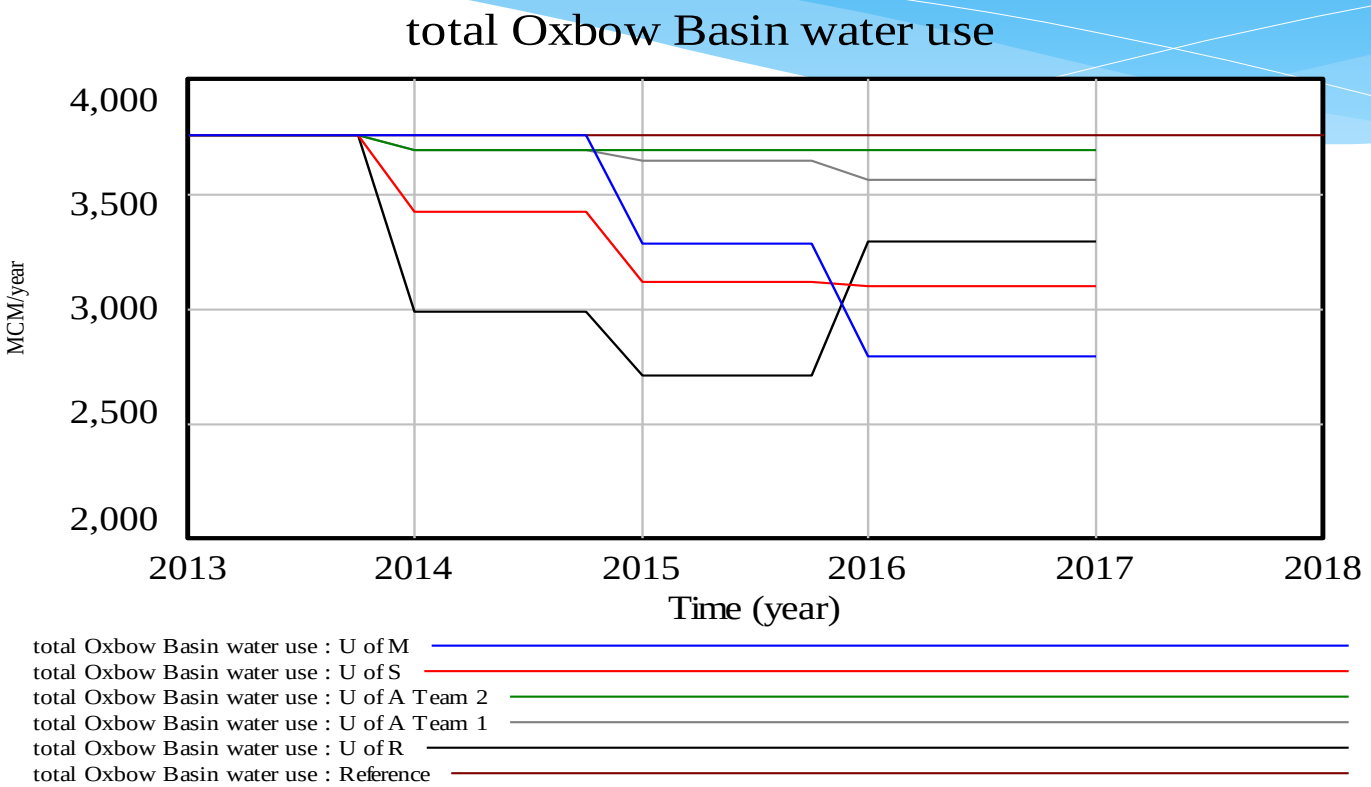


Model Components and Structure

- Municipal
  - Indoor:
    - Kitchen
    - Laundry
    - Bathing
    - Toilet flushing
  - Outdoor
- Population
  - Municipal
  - Rural

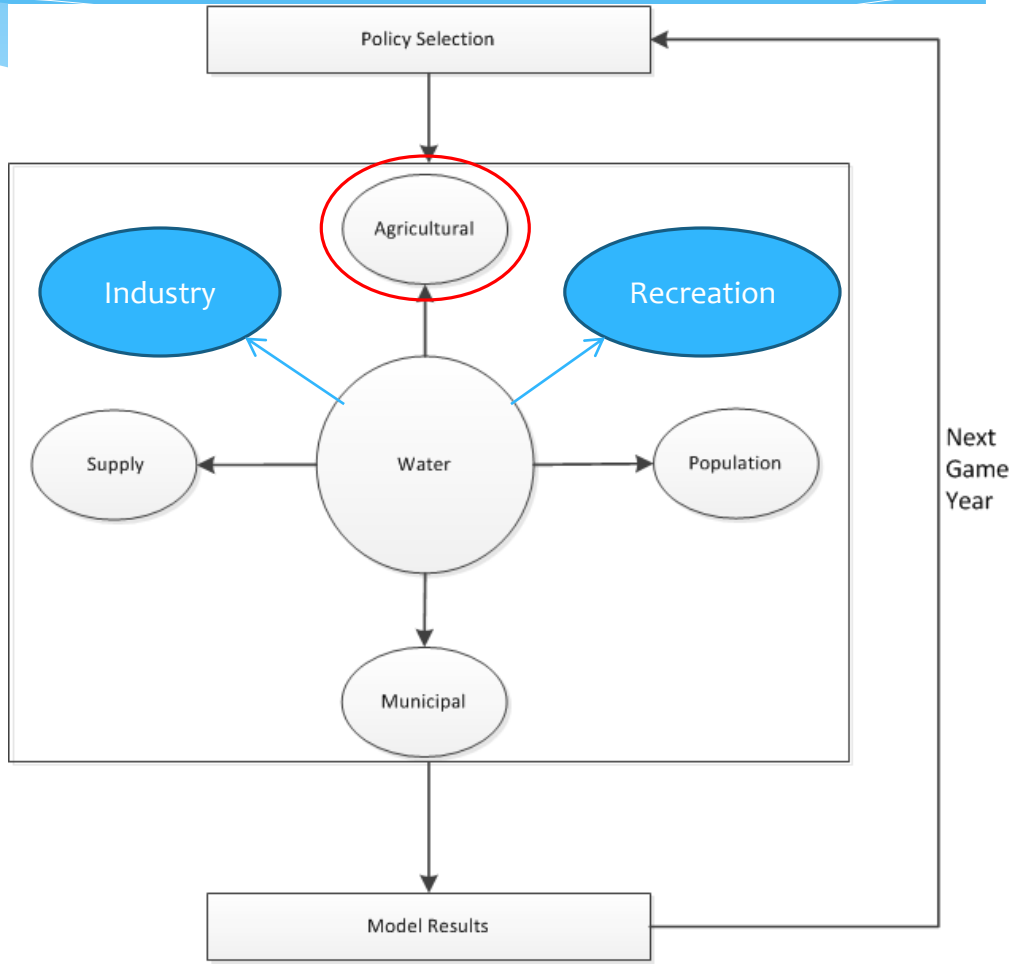


IDT Saskatoon Results

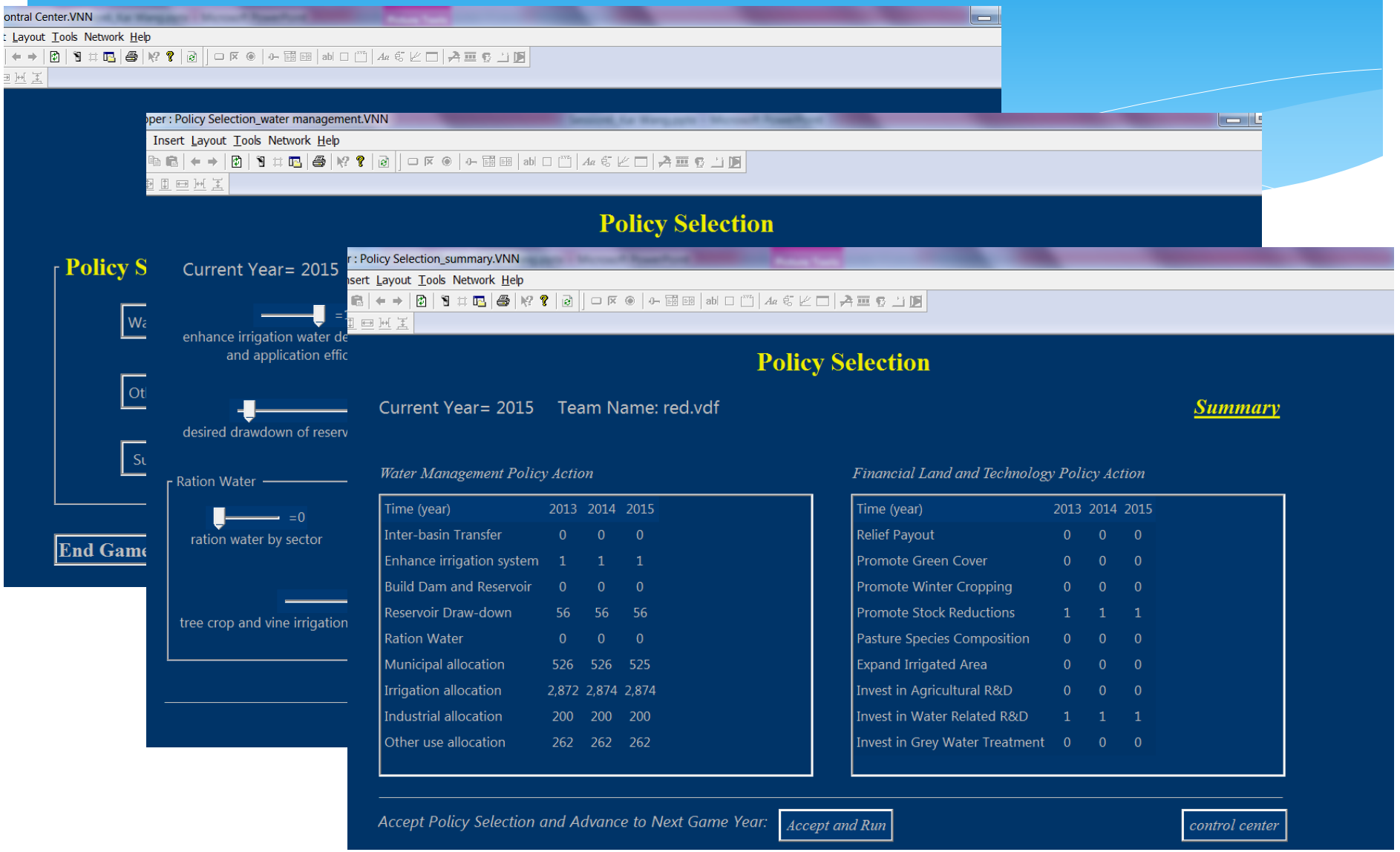


2nd Version of Model

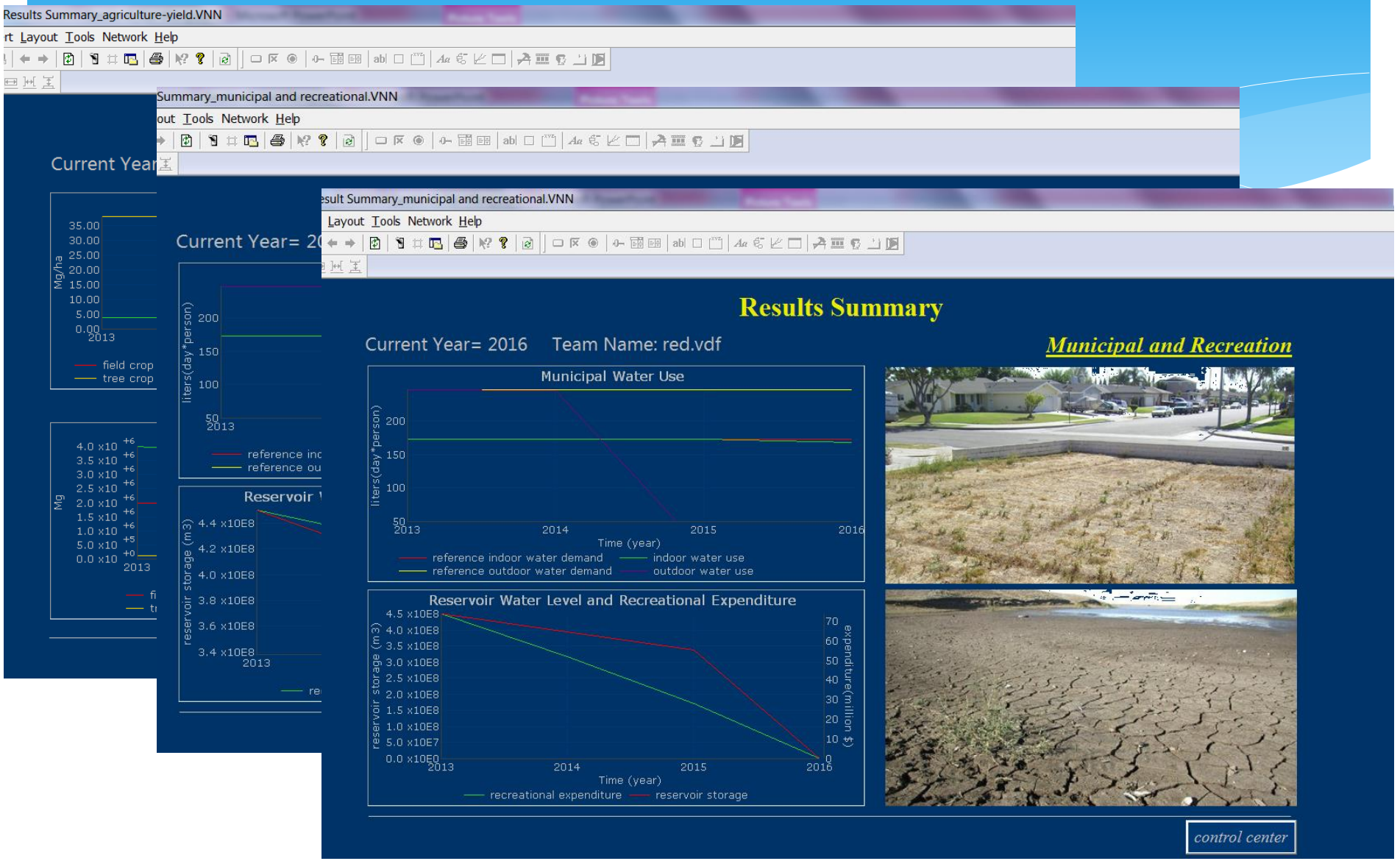
* Model Expansion
  * Industrial water use
    * Metal mining
    * Non-metal mining
    * Coal mining
    * Thermal and hydro power generation plants
  * Recreational water use
    * Reservoir park
  * Tree crop and vine water use
    * Apple
    * Cherry
    * Grape



Model Control Center and Policy Selection



Result Summary



Systems modelling for a sustainable irrigation in Alberta to 2035

With Mohamed Ammar, Engineering
Miles Dyck, Renewable Resources
Scott Jeffrey, Agricultural Economics
Feng Qiu, Land Use Economics
Jim Unterschultz, Economics

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Alberta Land Institute

Project Problem Statement

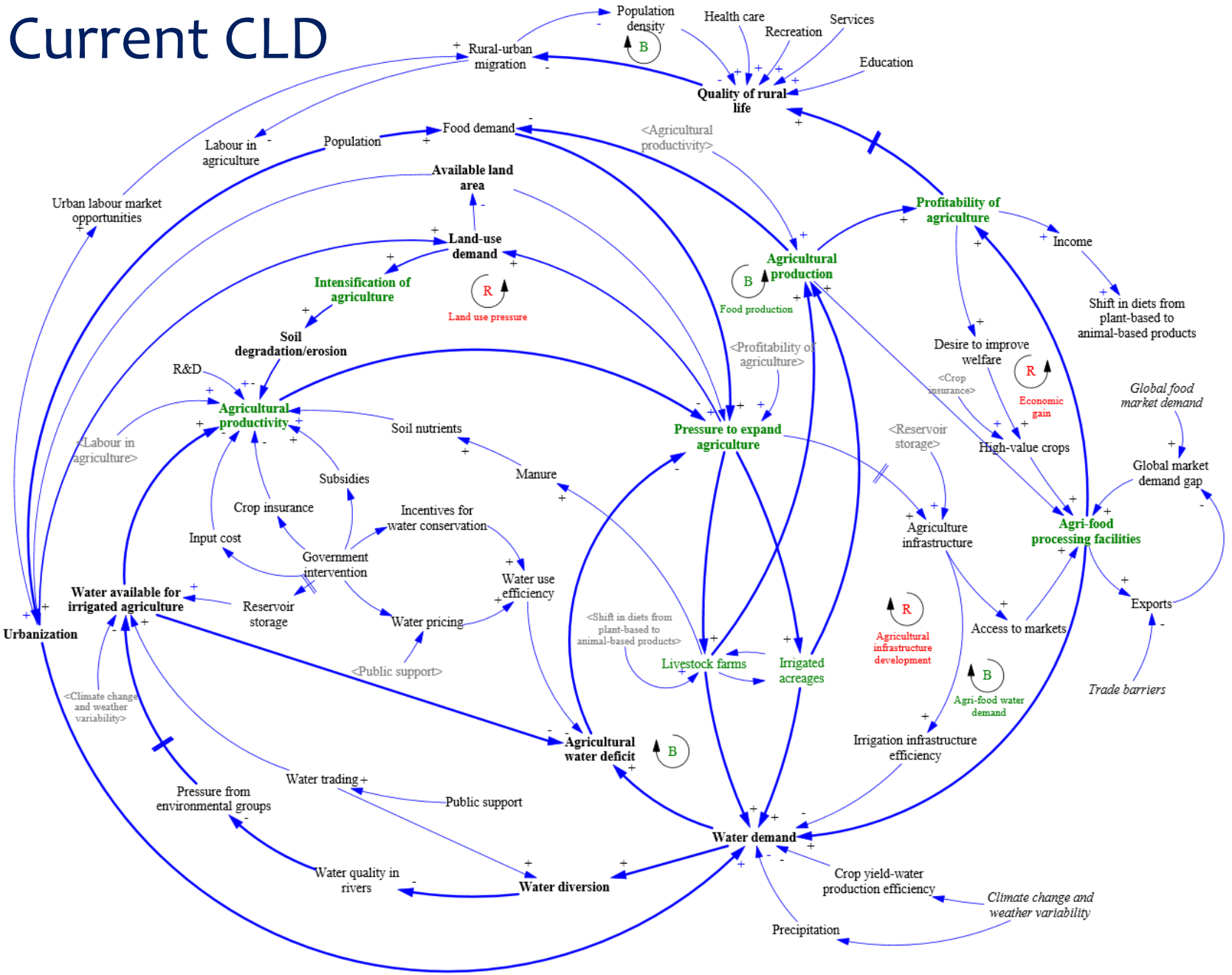
* Project from 2013-2016

* Irrigated agriculture is largest consumer of surface water in Southern Alberta
  * Expansion of irrigation over the next 25 years
    * Increase agricultural water and land requirements
    * Occurs within context of ongoing socio-economic development → increased demands for land and water

Project Aims

- Identify key social, economic, and environmental variables in the agricultural system of Southern Alberta
- Identify land-use, water management, agricultural, and financial policies for irrigated agriculture and their linkages with other systems

Current CLD


Population density
Health care
Recreation
Services
Education
Rural-urban migration
Quality of rural life
Labour in agriculture
Population
Food demand
<Agricultural productivity>
Urban labour market opportunities
Available land area
Land-use demand
Profitability of agriculture
Income
Intensification of agriculture
Agricultural production
Food production
Land use pressure
Shift in diets from plant-based to animal-based products
Soil degradation/erosion
<Profitability of agriculture>
Desire to improve welfare
<Crop insurance>
Economic gain
R&D
Agricultural productivity
Soil nutrients
Pressure to expand agriculture
<Reservoir storage>
Global food market demand
High-value crops
<Labour in agriculture>
Subsidies
Manure
Global market demand gap
Crop insurance
Incentives for water conservation
Agriculture infrastructure
Agri-food processing facilities
Input cost
Government intervention
Water use efficiency
Water available for irrigated agriculture
Reservoir storage
Water pricing
Exports
Urbanization
<Shift in diets from plant-based to animal-based products>
Agricultural infrastructure development
Access to markets
Livestock farms
Irrigated acreages
Agri-food water demand
Trade barriers
<Public support>
<Climate change and weather variability>
Irrigation infrastructure efficiency
Agricultural water deficit
Water trading
Pressure from environmental groups
Public support
Water demand
Water quality in rivers
Water diversion
Crop yield-water production efficiency
Climate change and weather variability
Precipitation