Interdependencies of Energy and Water

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Sandia National Labs

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Outline

- History
- Approach
- Goals
- Model and sub-models
- Results
- Future Work
- Conclusion

Our project builds on the following …

- Energy-Water Roadmap
  - Consortium of all National Labs
  - sponsor, who, when
- Energy-Water LDRD:
  - Goal is to develop model for calculating energy-water usage
    - Ultra detailed to the power-plant level
    - Missing high-level model and interdependencies
    - Provides detailed inputs to our model.
  - Energy-sector maps
- CADRe LDRD
  - Computer-assisted dispute resolution
  - Need more information here.

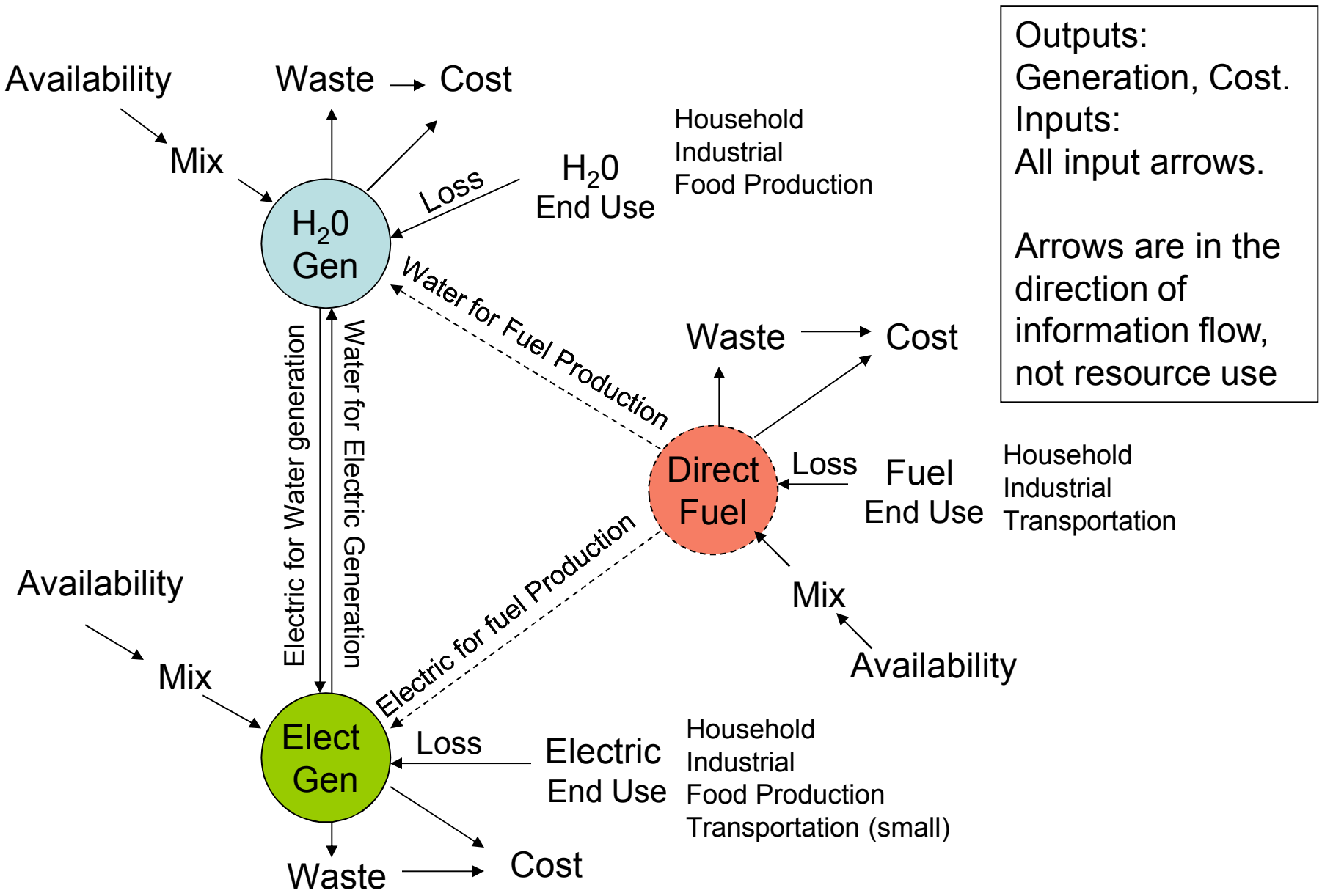
Goals

- Develop the top level model for Energy and Water interdependencies
  - The current LDRD provides inputs for Energy usage, availability, etc…
  - Build on the computer simulations from the CADRe LDRD
  - Use PowerSim as modeling program (Excel as backup)
  - Includes Electric, heating, and transportation, but
  - Does NOT model agriculture

- Use the model-based calculations to identify technologies or strategies that can simultaneously reduce nationwide energy and water demands with improved environmental impact.
  - For this class project, generate a simple example or two

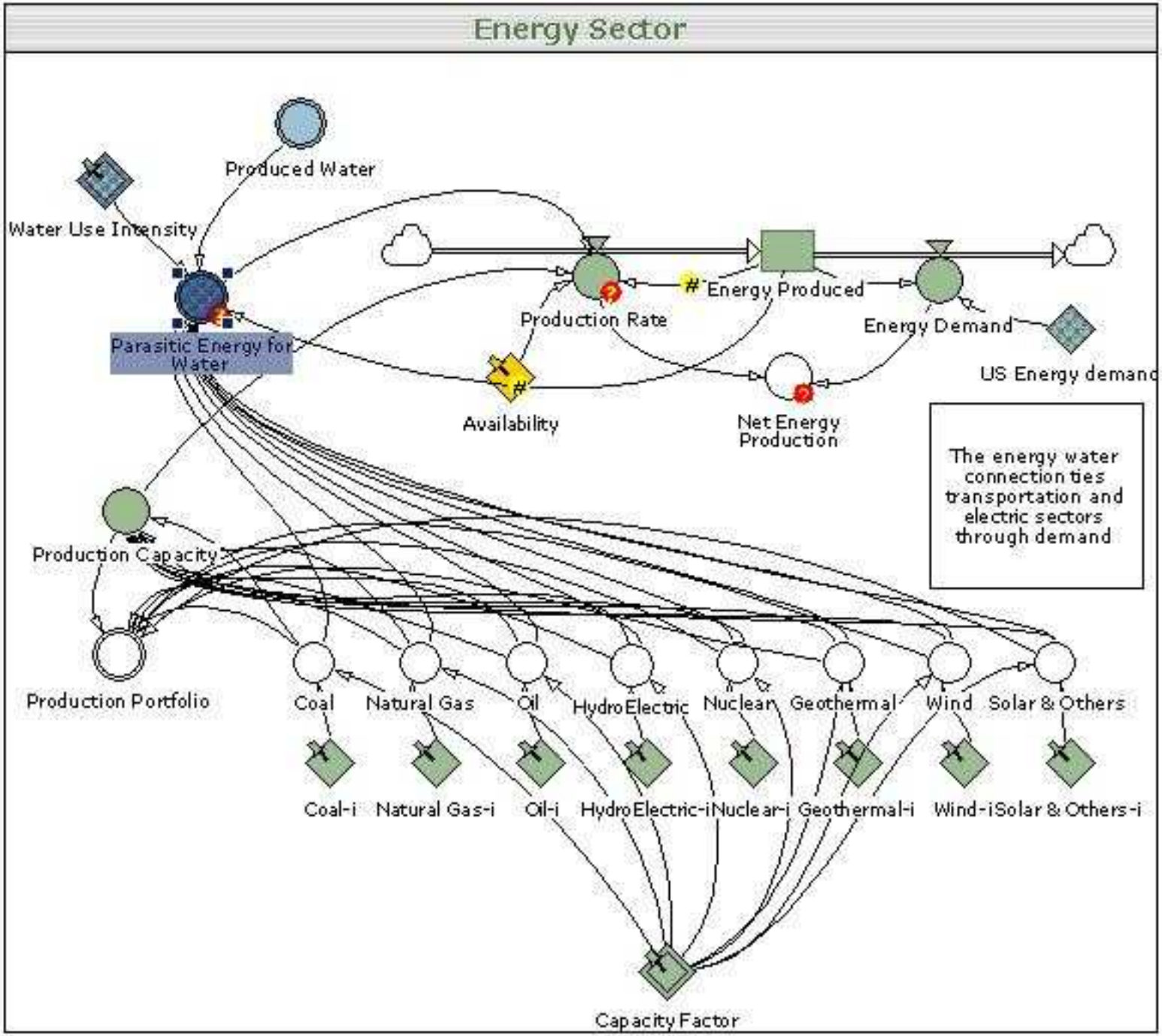
- Highlight areas for future work

Simplified Top Level Model

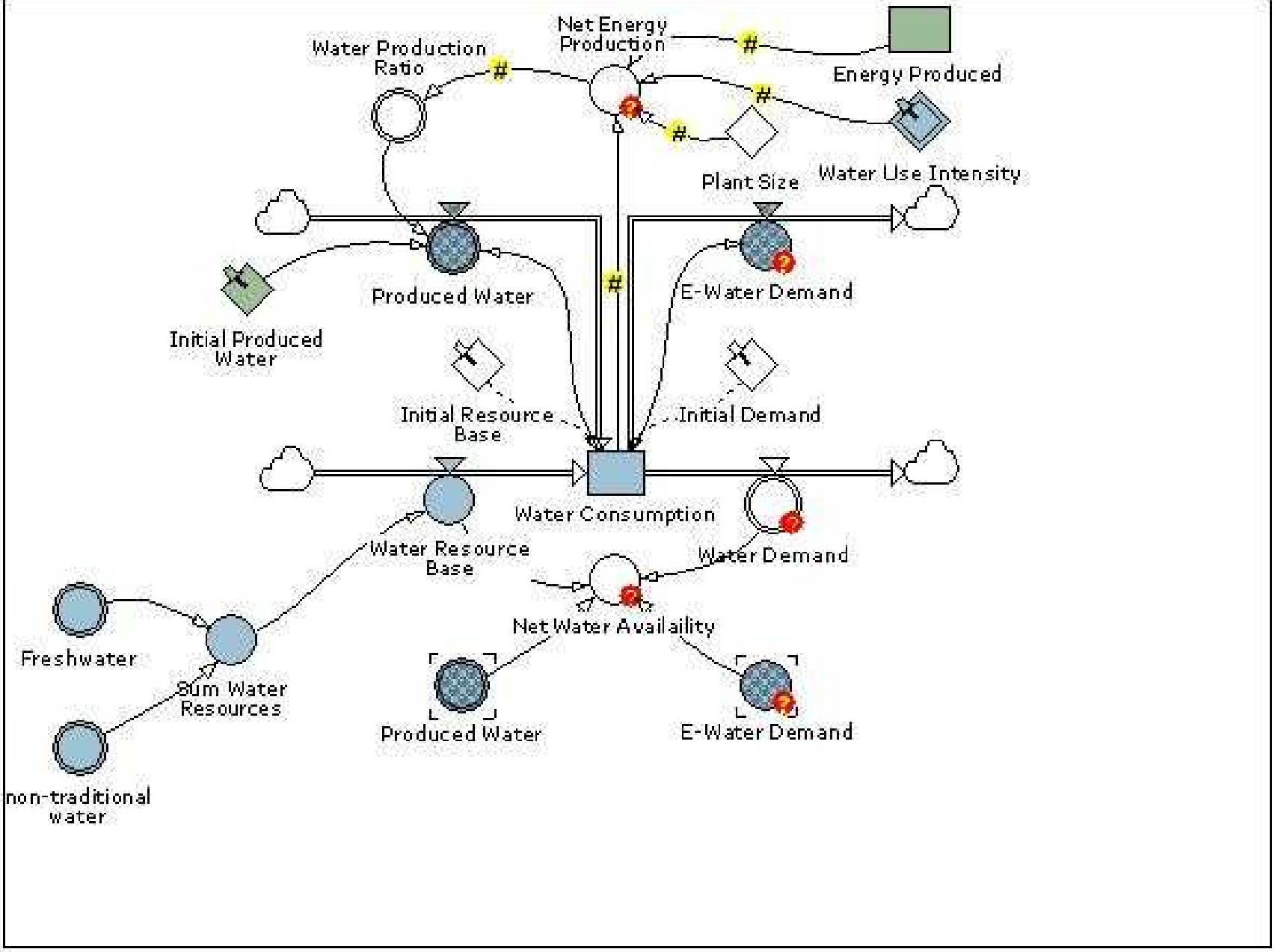


Outputs:
Generation, Cost.
Inputs:
All input arrows.

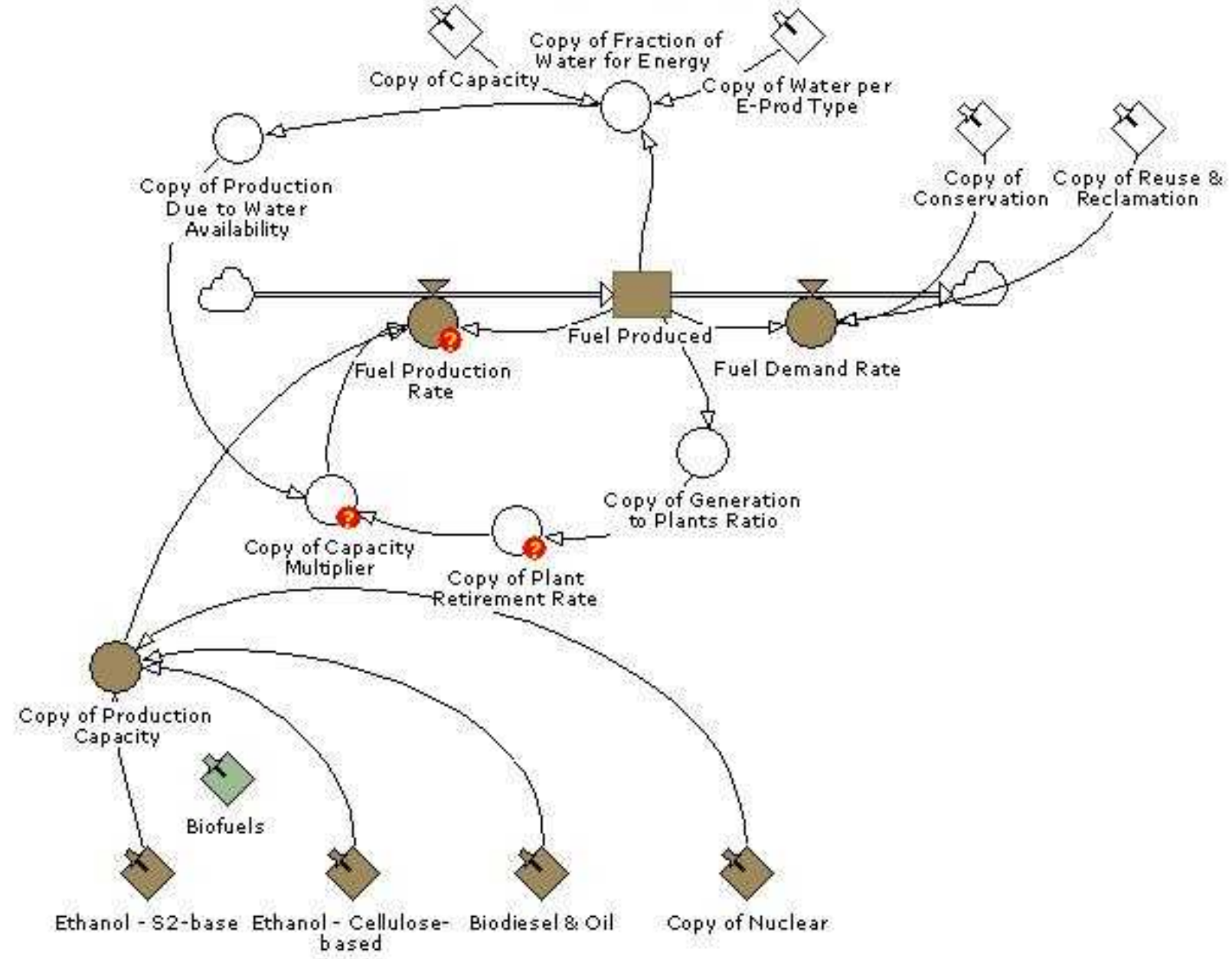
Arrows are in the direction of information flow, not resource use


Energy Sector
Produced Water
Water Use Intensity
Parasitic Energy for Water
Production Rate
Energy Produced
Energy Demand
US Energy demand
Availability
Net Energy Production
The energy water connection ties transportation and electric sectors through demand
Production Capacity
Production Portfolio
Coal
Natural Gas
Oil
HydroElectric
Nuclear
Geothermal
Wind
Solar & Others
Coal-i
Natural Gas-i
Oil-i
HydroElectric-i
Nuclear-i
Geothermal-i
Wind-i
Solar & Others-i
Capacity Factor

Water Sector



Transportation Sector



Required Information for model

- Electric Energy
  - Mix of energy sources (e. g. how much coal, wind, nuclear, etc…)
  - Water required for each source (gal/kWhr)
  - Cost to provide electricity of each source (in $/kWhr)
  - Carbon, pollution, and waste emissions from each source (tons/kWhr)
  - Trends with year

- Water Supply
  - Mix of water sources (how much surface, mined, desalination)
  - Electric required to process water from each source (kWhr/gal)
  - Cost of each source ($/gal)
  - Environmental impacts (e. g. tons of salt/gal)
  - Trends with year

- Fuel Supply
  - Mix of energy sources (e. g. how much gasoline, bio-fuel, electric)
  - Water required for each source (gal H2O/gal fuel)
  - Electricity required for each source (kWhr/gal)
  - Carbon, pollution, and waste emissions from each source (tons/kgal)
  - Trends with year

Simple Equations for Electric/Water Interdependency.

- $E_{total} = E_{demand} + k_1 W_{total}$
  - $k_1 W_{total}$ is the electricity required to process water.
    - k_1 in kWhr/gal.
  - E_{total} is the total electricity produced
  - E_{demand} is the total electricity used other than for processing water.
- $W_{total} = W_{demand} + k_2 E_{total}$
  - $k_2 E_{total}$ is the water required for the production of electricity.
    - k_2 in gal/kWhr.
  - W_{total} is the total water used
  - W_{demand} is the total water used other than for generating electricity
- Solving allows us to calculate the totals from the demand.
  - $E_{total} = (E_{demand} + k_1 W_{demand})/(1 - k_1 k_2)$
  - $W_{total} = (W_{demand} + k_2 E_{demand})/(1 - k_1 k_2)$

  - $k_{1*} k_2 E_{total}$ is the amount of electricity required to process cooling water

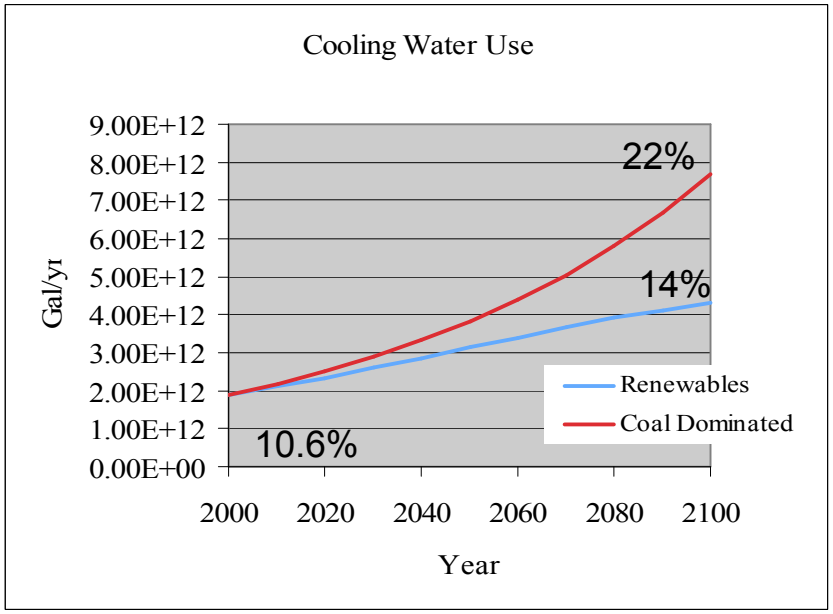
Two example questions

1. How does the use of water-friendly renewable energy (e. g. wind, PV) affect
   a) The amount of cooling water needed
   b) The amount of extra electricity needed to process the cooling water

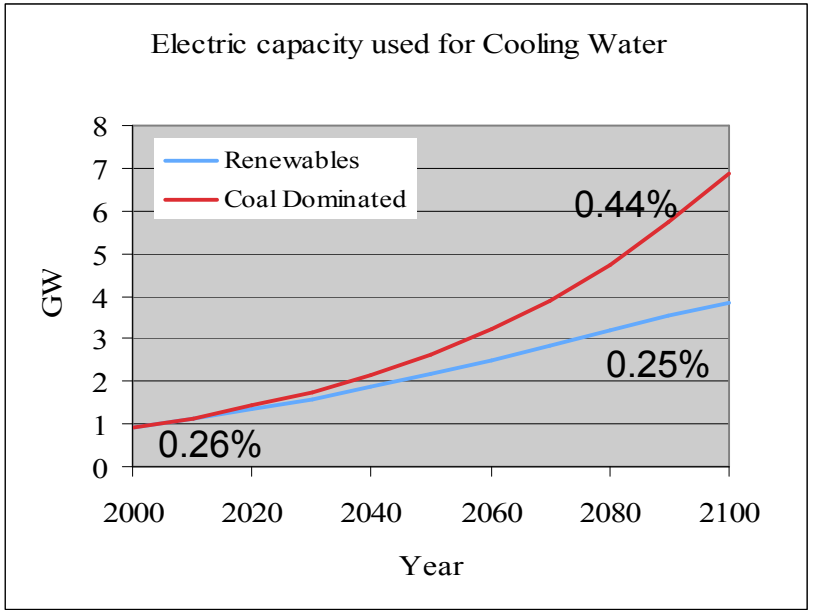
2. How does the use of desalinated water (with its abundance, but high energy cost) affect
   a) The amount of cooling water needed
   b) The amount of extra electricity needed to process the cooling water

Effect of renewable energy use in cooling water used and extra electric generation to process that cooling water

Cooling Water Used in the Production of Electricity



Extra Electric Generation required to process cooling water (kWhr)



Initial: 69% coal, 15% NG, 15% Nuclear, 1% renewable*

Final: 25% coal, 5% NG, 10% Nuclear, 60% renewable*, 100% carbon sequestration.

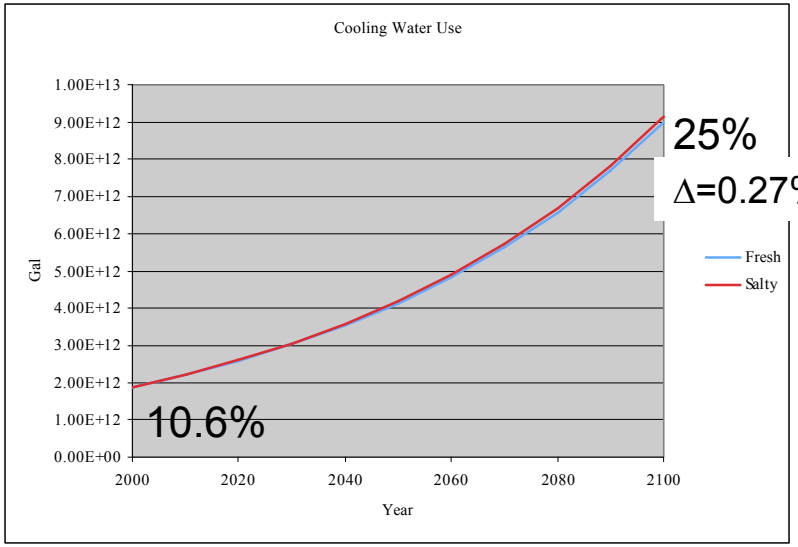
Final: 78% coal, 10% NG, 7% Nuclear, 5% renewable*, 0% carbon sequestration.

Water Init, 90% fresh, 10% desal, final: 50% fresh, 25% desal, 25% brackish,closed cycle cooling.

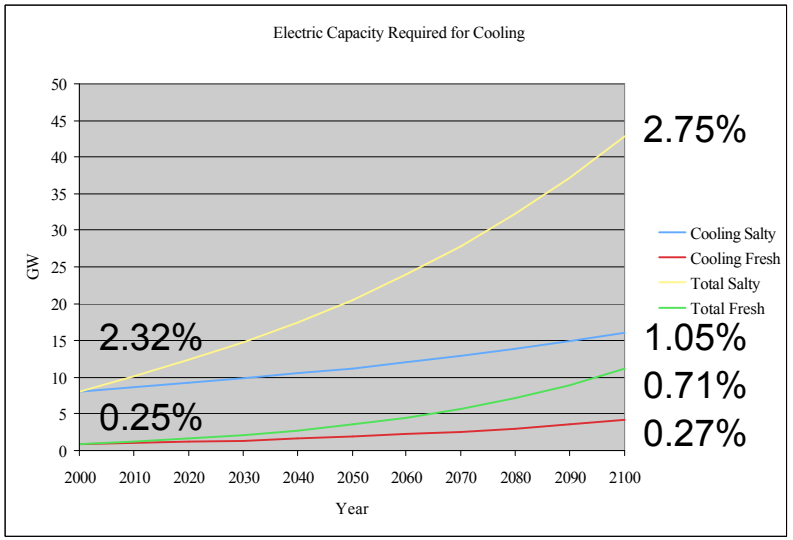
Electric/Water demand growth = 1.5%/yr and 0.5%/yr.

Increase in electric generation required if cooling water comes from desalination/brackish water plants

Cooling Water Used in the Production of Electricity



Extra Electric Generation required to process water/cooling water (kWhr)



Initial: 69% coal, 15% NG, 15% Nuclear, 1% renewable*
Final: 60% coal, 15% NG, 15% Nuclear, 10% renewable*, 100% carbon sequestration.
Water Init/final, 90% fresh, 5% desal, 5% brackish
Water final, 20% fresh, 40% desal, 40% brackish
Electric/Water demand growth = 1.5%/yr and 0.5%/yr.

Future Work: Model Enhancements

- Add geographic concerns and losses
  - Electric transport cost versus availability of renewable resources (e. g. sun in New Mexico, Wind in North Dakota).
  - Local water availability issues and the additive impacts to the national production capability
- Additional constraints on the energy mix
  - Time constants & “reality”
- How can we effectively add the cost of climate change and environmental impact?
  - If coastal cities are underwater 100-200 years from now, what is that cost today?
  - If growing regions are moved?
  - If animal and plant life are changed significantly?

Future Work: Questions for Society

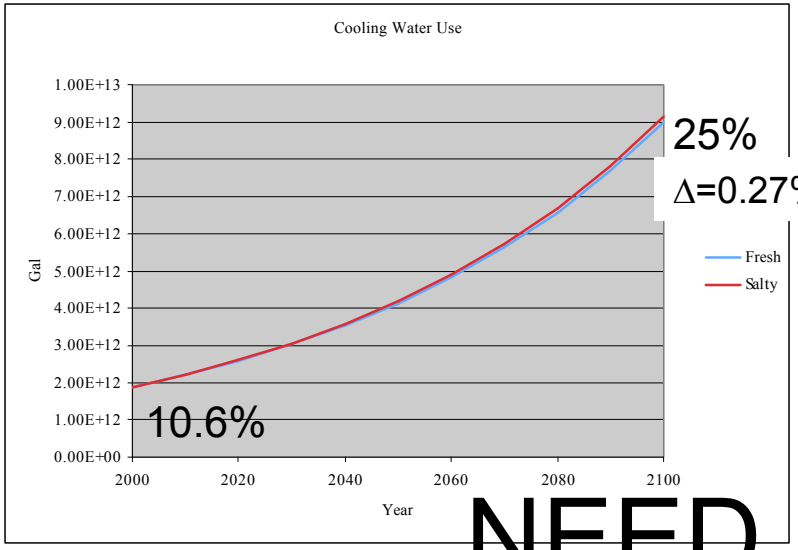
- What is the mix of energy generation and water processing that works most ‘cost effectively’ for the future
- Will conservation reduce the cost of energy?
- Does the use of plug-in hybrids cause
  - a great increase in water demand
  - extra electric demand that can be met by renewable energies?
- Are there a quantifiable impacts of energy storage, distributed power, micro-grids in terms of water and overall electric usage?

Conclusions

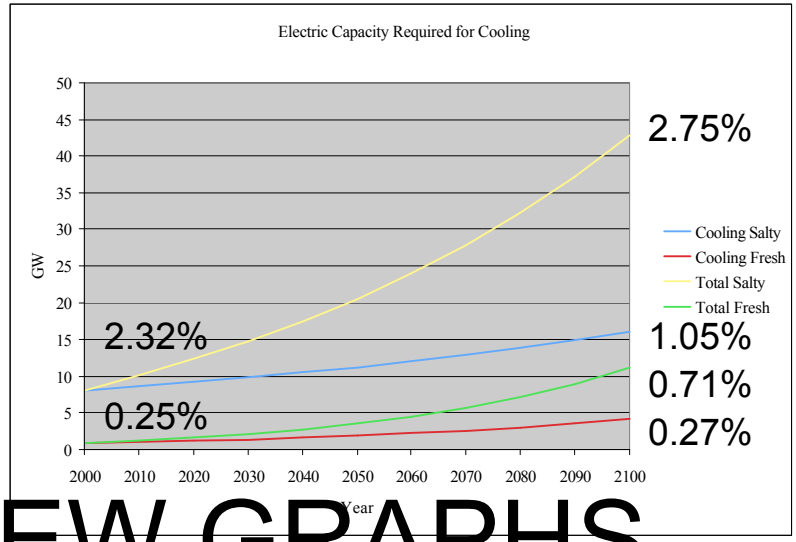
- Model developed that allows calculations of the interdependencies between water and electricity
- Our examples show a positive impact of renewable energy in (we hope)
  - reducing the cooling water demand,
  - reducing extra generation for water processing
  - If we could quantify the impact of the environmental impacts, they would be more cost-effective
- Much future work to be done.

Cost of Electric and Cooling (to be added if time)

Total Cost of Cooling Water Used in the Production of Electricity



Total Cost of Extra Electric Generation required to process water/cooling water (kWhr)



NEED NEW GRAPHS

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