Climate Change Impacts on Energy Systems, Focusing on Integrated, Multi-scale Modeling

Ian Kraucunas

PNNL

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WSAS Symposium

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What factors control the impacts of weather and climate on the electric grid?

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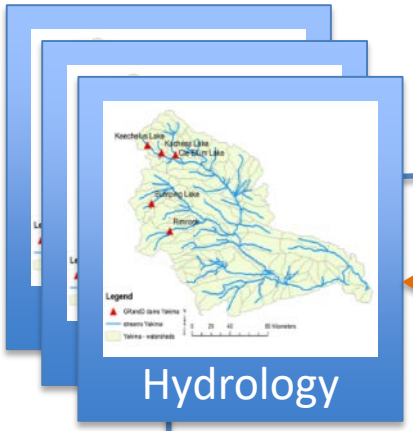
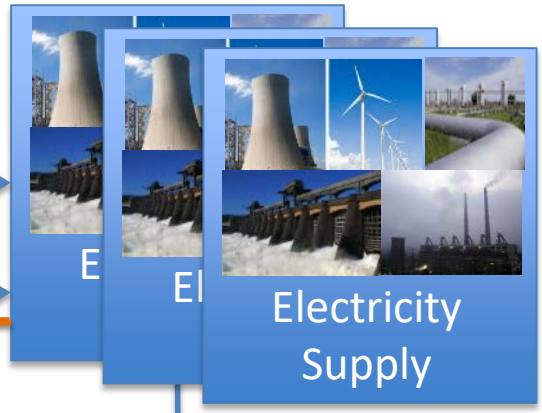
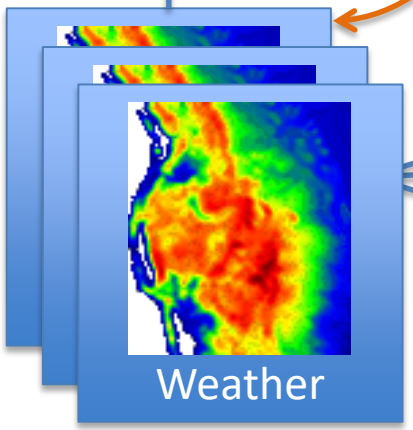


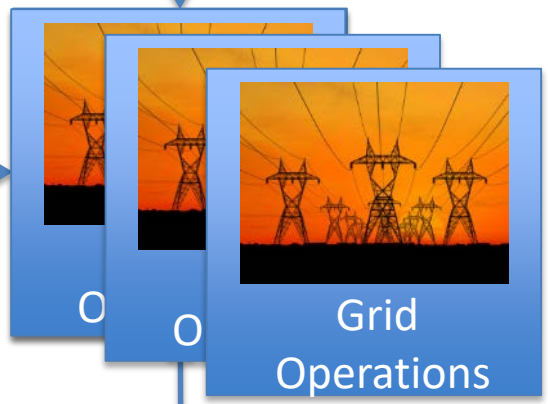
Water availability
- Hydropower
- Cooling water (amount and temperature)

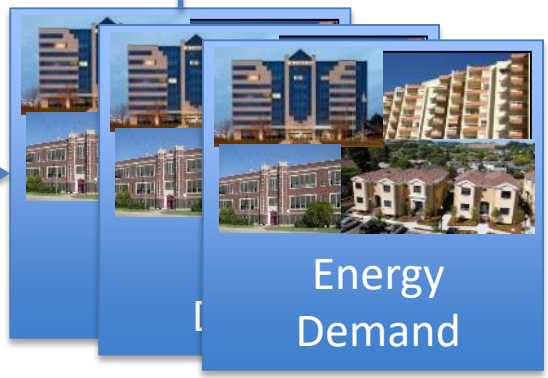
Feedbacks





Heat Waves:
- Reduced power plant capacity
- Reduced line ratings
- Increased cooling demand





Multiple climate scenarios

Multiple policy, socioeconomic, and technology scenarios

Key Questions
- Will future energy infrastructure be more or less vulnerable?
- What are the costs and benefits of resilience investments?
- What other factors must be accounted for (e.g., urbanization, air quality, feedbacks related to water use,…)
- What spatial and temporal scales, degree of coupling, data needs, etc., are required for accurate simulations?

How will climate change affect hydropower?

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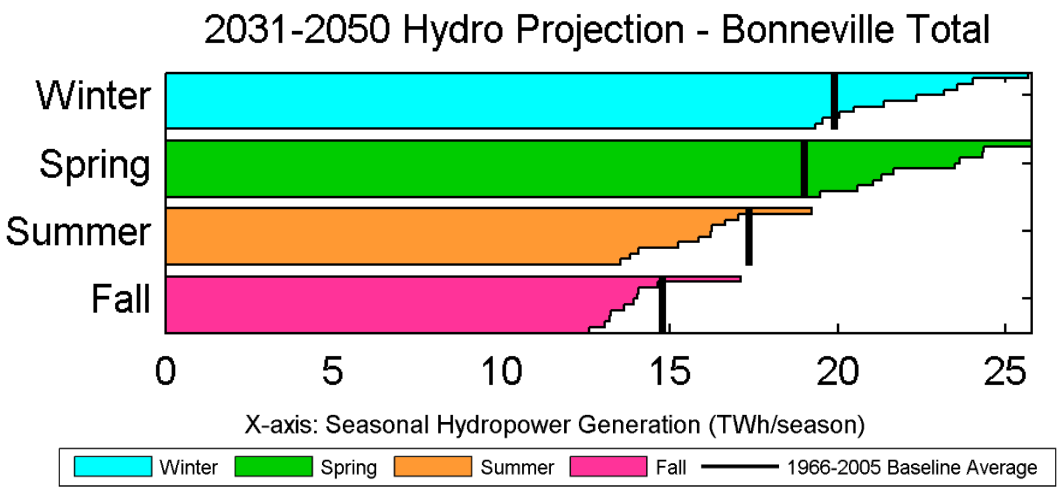
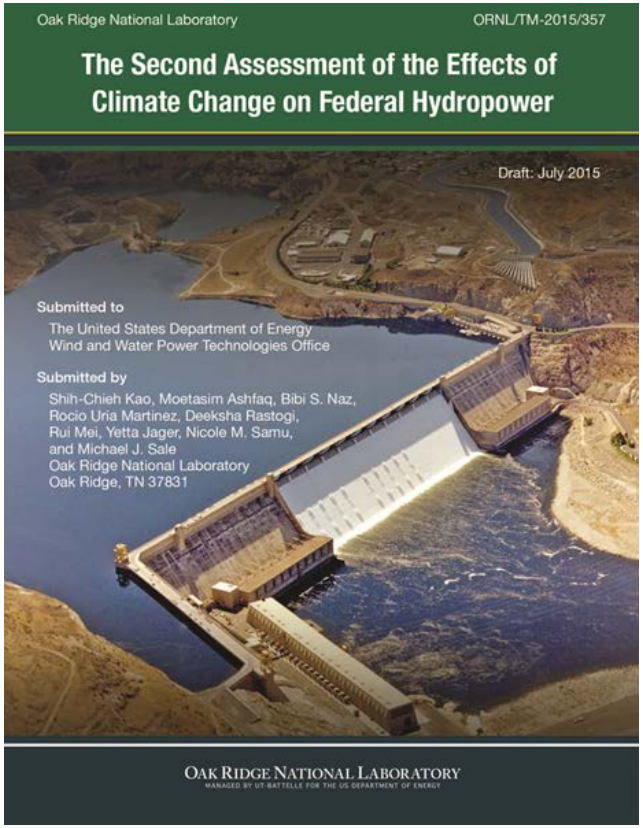
- DOE study using hydrology, dam operations, and river routing models driven by output from 10 different climate models
- Earlier snowmelt and change of runoff seasonality are the main factors affecting future hydropower generation.
- These changes are particularly strong in the Pacific Northwest, with sharp reductions in projected summertime flows

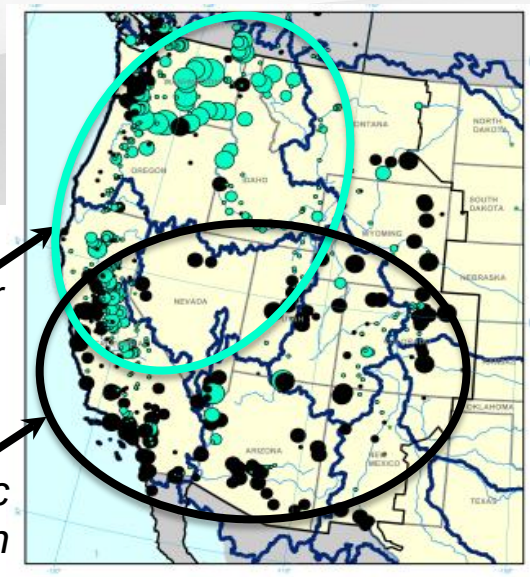


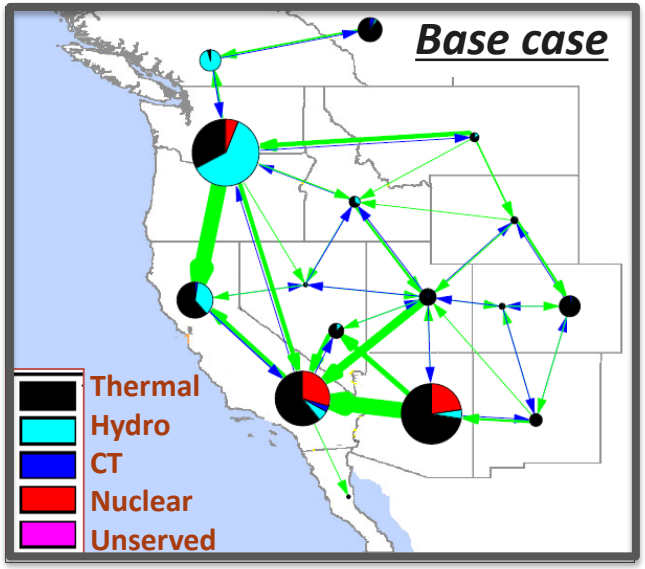


Could drought "break" the Western interconnection?

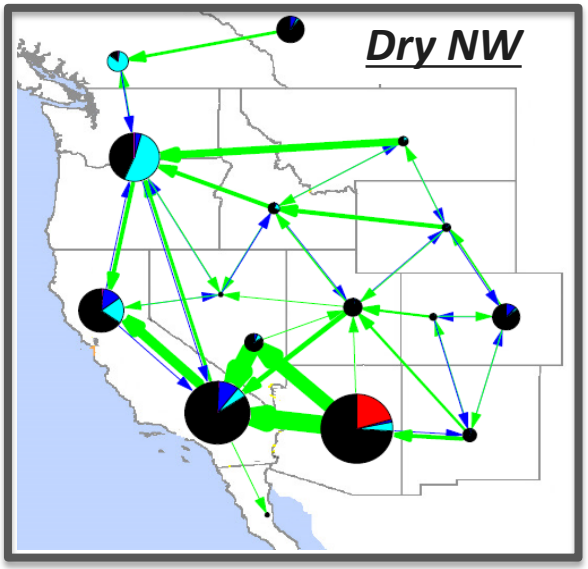
Voisin et al., 2016

- 69% of capacity relies on fresh surface water, but droughts in one region are often balanced by normal or wet conditions in the other
- To study vulnerability, used coupled regional hydrology and grid operations models with simulated historical weather for 30+ years

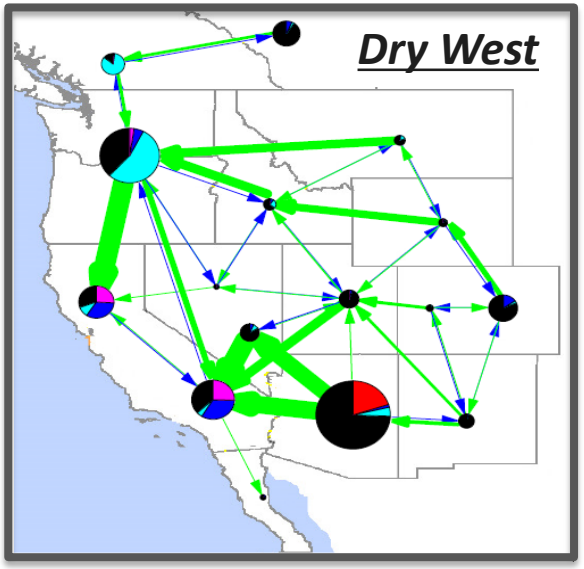




Base case:
- NW and Colorado export to CA
- Operating costs: $19.8 B



Drought with low hydropower:
- Larger import from Colorado, lower from NW
- Operating cost: $20.4 B

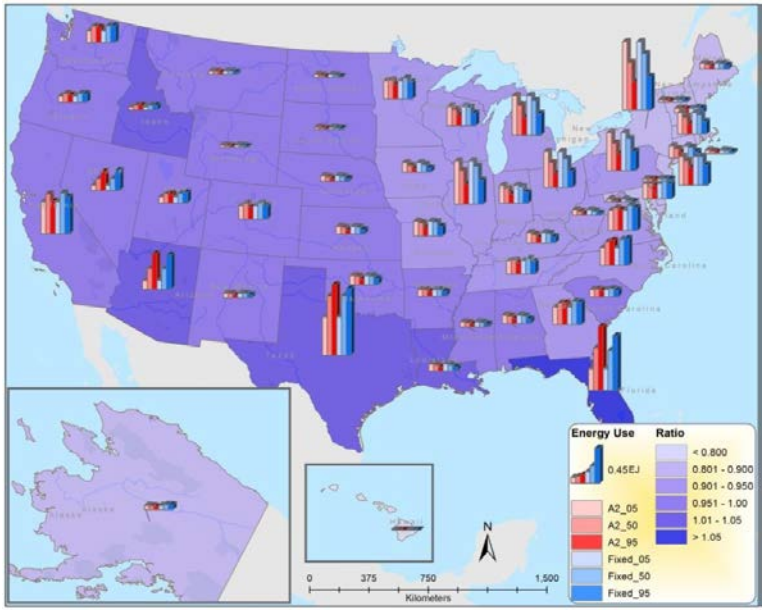


Drought with low hydro and thermoelectric generation:
- Unserved energy: 6%

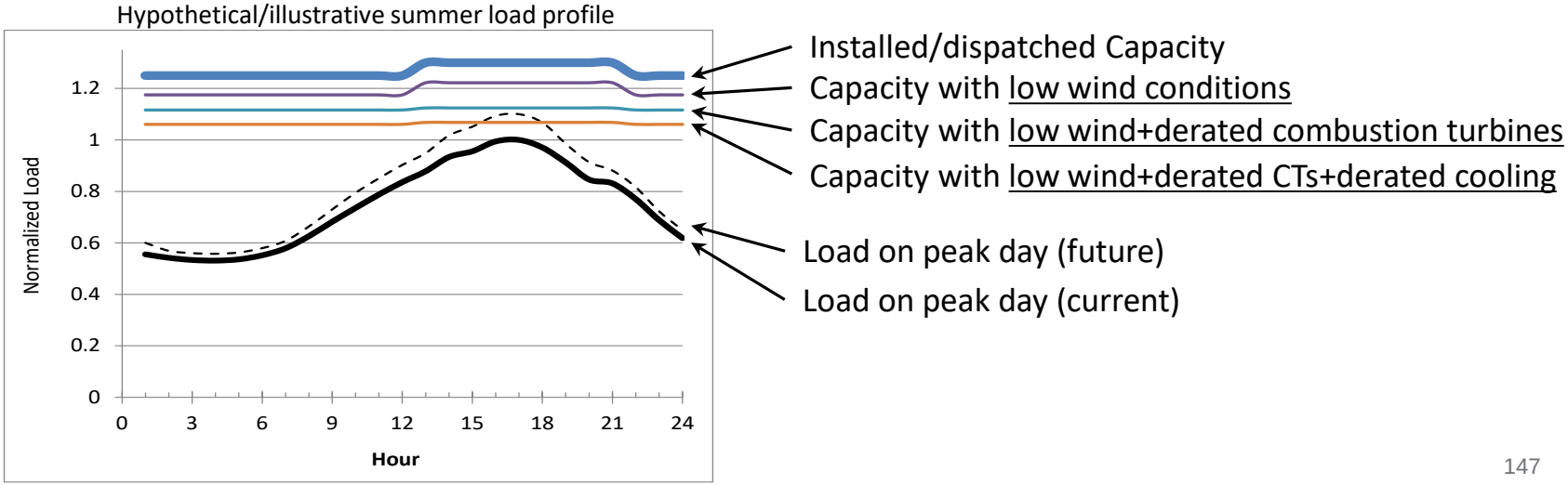
What about changes in energy demand?

- **Total** (annual average) building energy demand is generally projected to go down, due to reduced space heating in winter as well as improved building technology

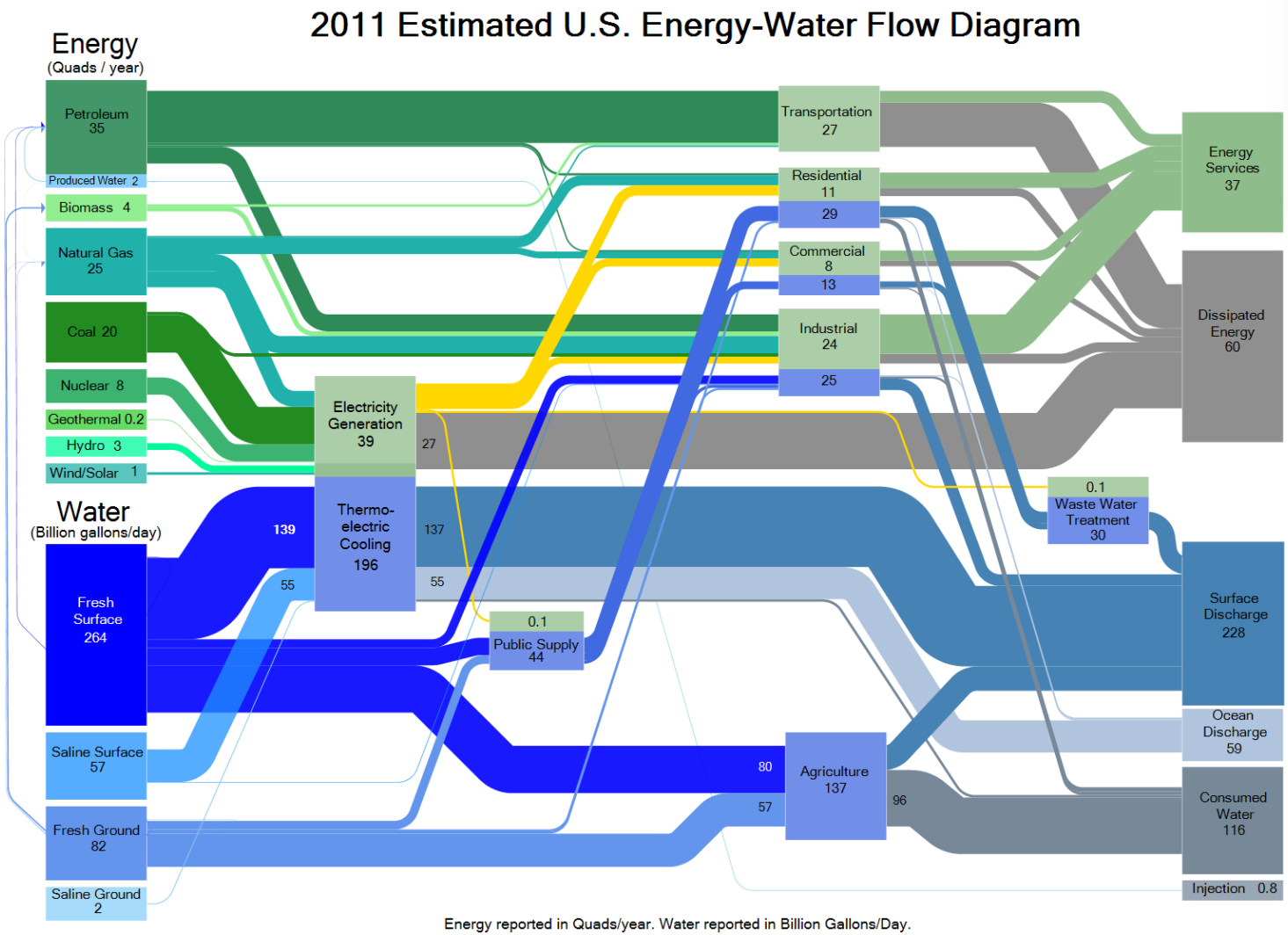
- However, **peak** energy demand is expected to go up in most locations due to higher maximum summer temperatures (i.e., the same weather events that lead to reductions in energy supply)

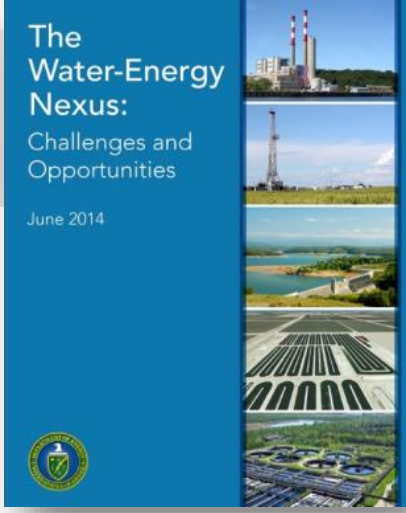


Zhou et al, 2014



DOE is particularly interested in exploring the Energy-Water Nexus





A long-term vision for DOE's Energy-Water Nexus Research

Unmet National Needs

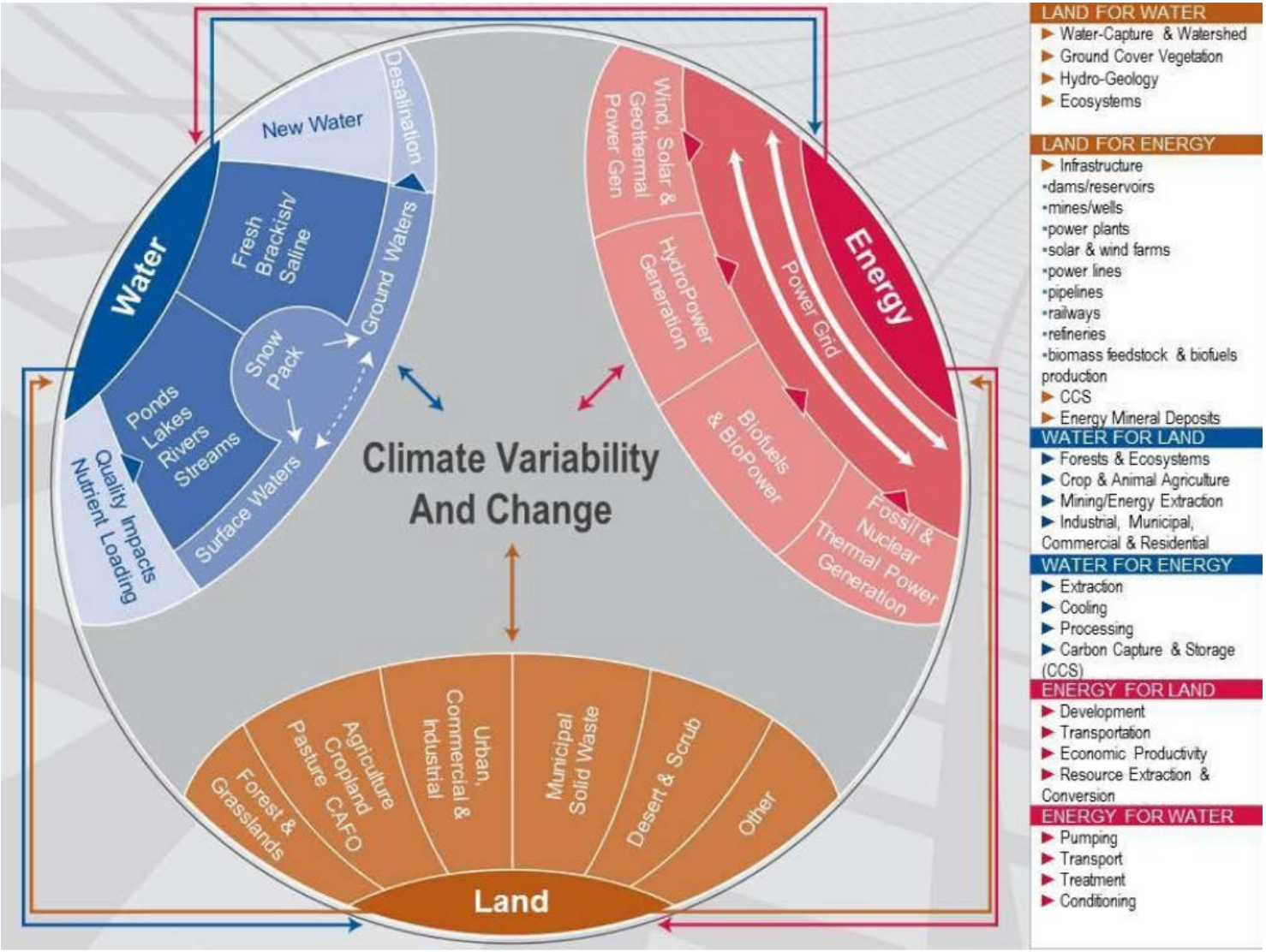
1. Eliminate energy sector freshwater consumption in water-stressed regions
2. Significantly reduce energy sector freshwater degradation
3. Carbon neutral water treatment and delivery systems
4. Eliminate grid operation inefficiencies and vulnerabilities associated with water

Outcomes Aligned with DOE Mission

Unique DOE Capabilities

It is also critical to account for interactions with the land surface (EWL Nexus)

Skaggs et al, 2012



For some questions, influence of land use change is comparable to climate change

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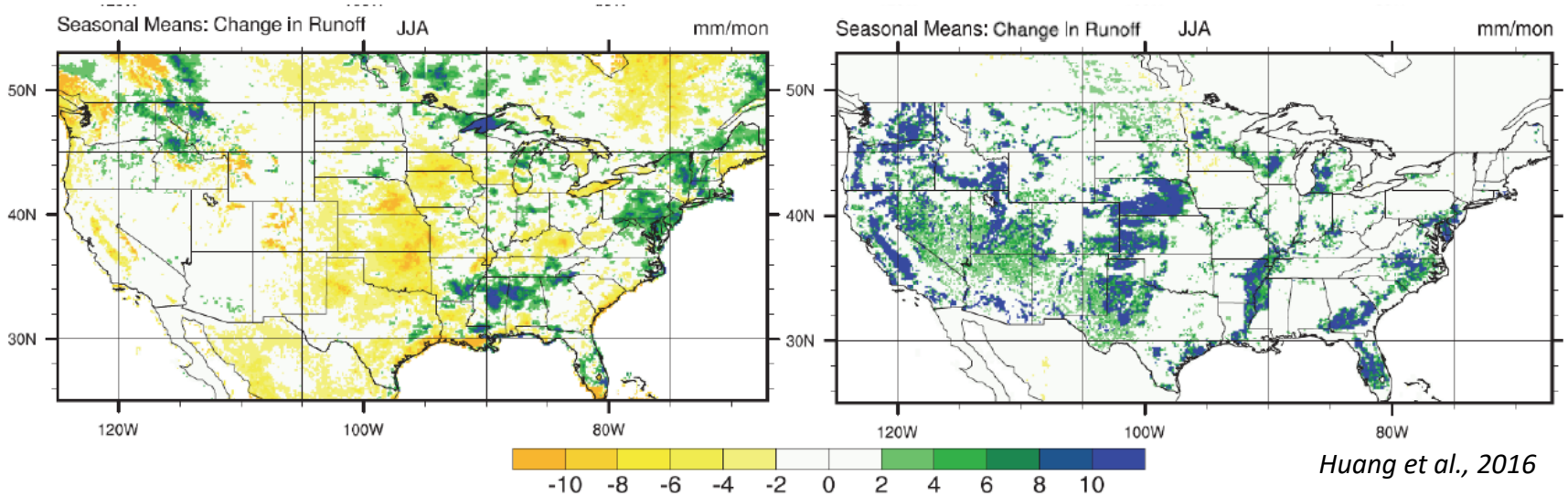
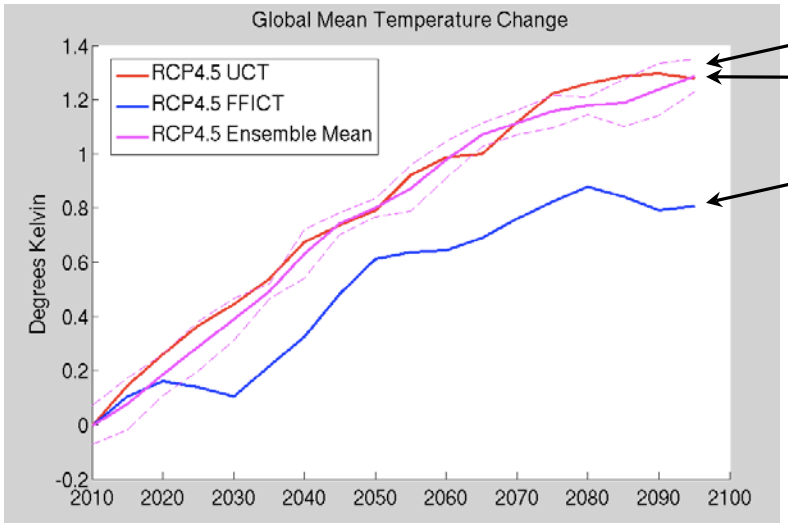
Climate change effect, RCP4.5 | **Land use change effect, RCP4.5**

Summer runoff



Huang et al., 2016



RCP4.5 scenario (multi-model ensemble)

RCP4.5 achieved through universal carbon tax

RCP4.5 with fossil fuel tax only (deforestation scenario)

Jones et al., 2015

Mitigation versus adaptation: Will efforts to reduce carbon emissions increase water stress?

Hejazi et al., PNAS, 2015

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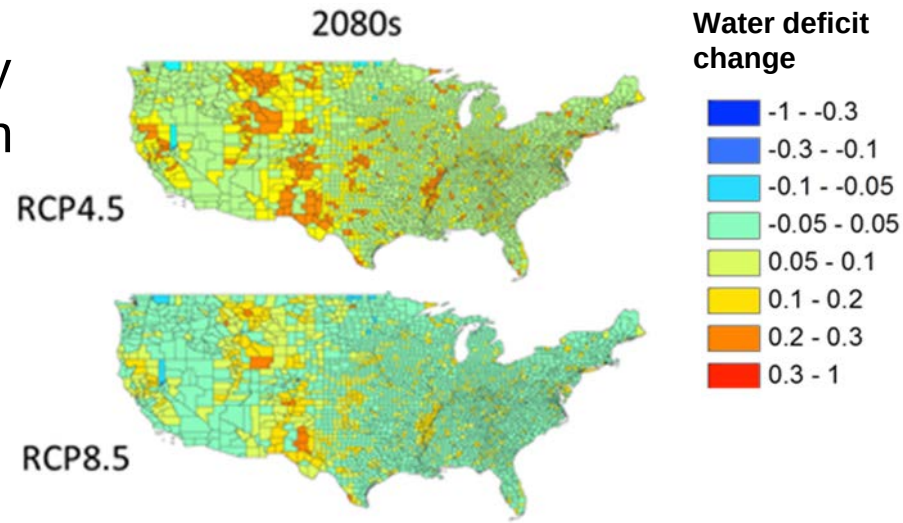
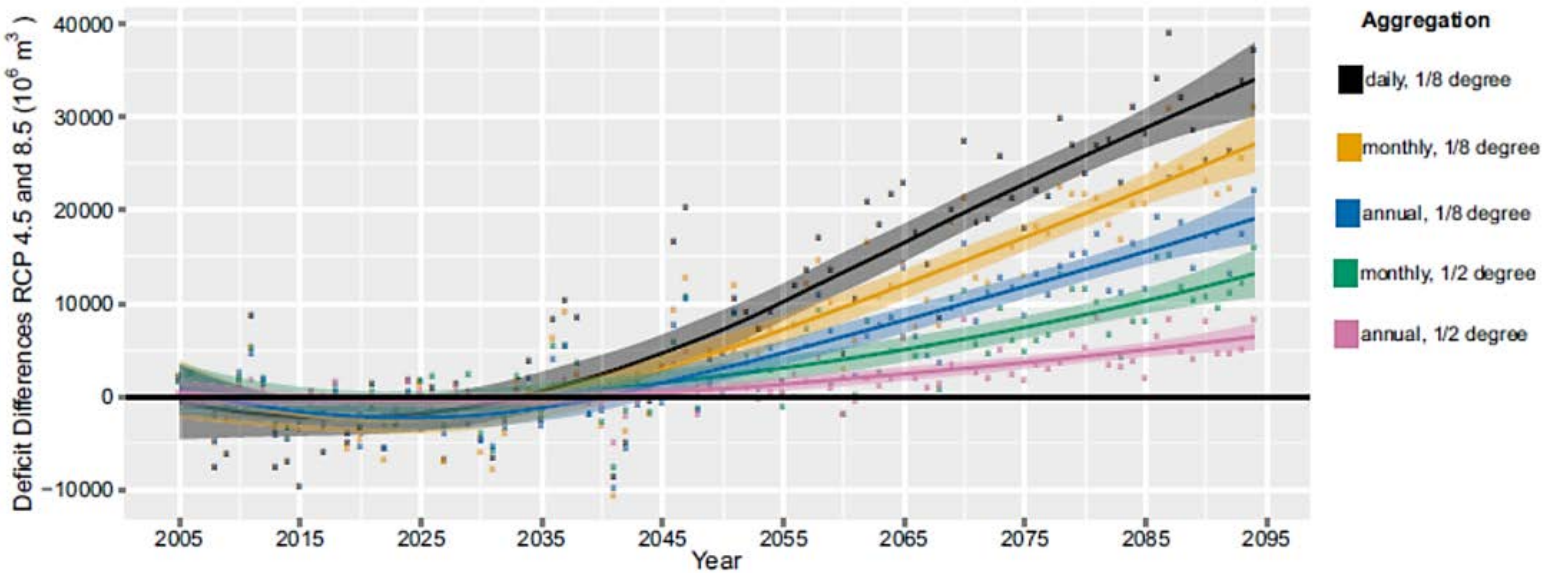
- Coupled an integrated assessment model with a land surface hydrology model to study projected changes in water supply and demand
- Water deficit projected to increase more under RCP4.5 than RCP8.5 (largely due to biofuel production)
- This result can only be resolved at high spatial and temporal resolution





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Thank you!

Ian Kraucunas
Atmospheric Sciences & Global Change Division
Pacific Northwest National Laboratory
ian.kraucunas@pnnl.gov
509-372-6713

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