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Implications of future energy choices in the energy-water-land nexus




WREF Forum: Energy-Water Nexus: An International Perspective

Robin L. Newmark
Jordan Macknick, Garvin Heath, Sean Ong, Paul Denholm, Robert Margolis, Billy Roberts

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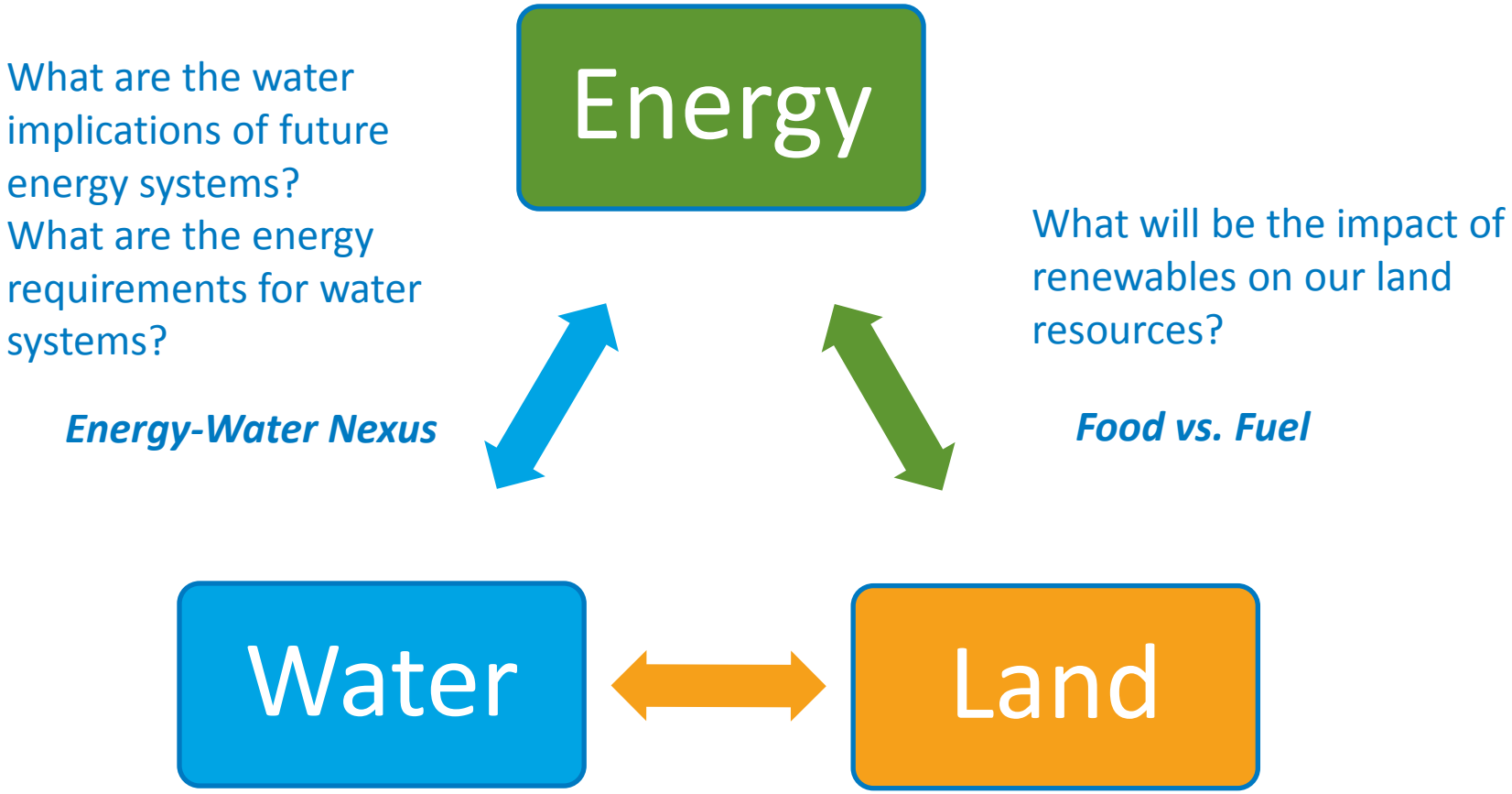
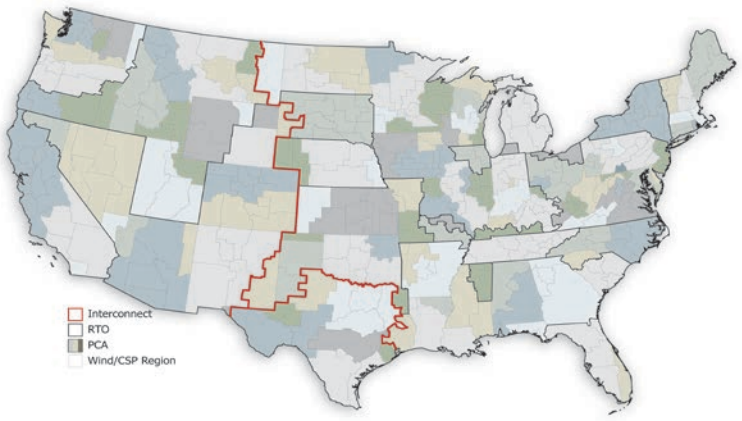
Energy-Water-Land Nexus

What role can renewable energy play in our future?



We analyze different Clean Energy Standards (CES) utilizing the Regional Energy Deployment System (ReEDS) model



134 Power Control Areas
356 Solar and Wind Resource Regions

Constraints:

- Electricity demand
- Reserve requirements
- Regional resource supply
- State and Federal policy
- Transmission

Resources/Technologies:

- Conventional (fossil and nuclear)
- Renewables
- Storage
- Demand-side technologies

Clean Energy Standard (CES)

- 2011 State of the Union Address
- 80% of electricity from clean sources by 2035
- Partial clean energy credit for high efficiency natural gas, carbon capture and storage technologies
- Cost/performance data utilized:
  - **AEO 2011 (EIA Annual Energy Outlook)**
  - **B&V 2011 (Black and Veatch independent estimates)**
- Cooling system policy

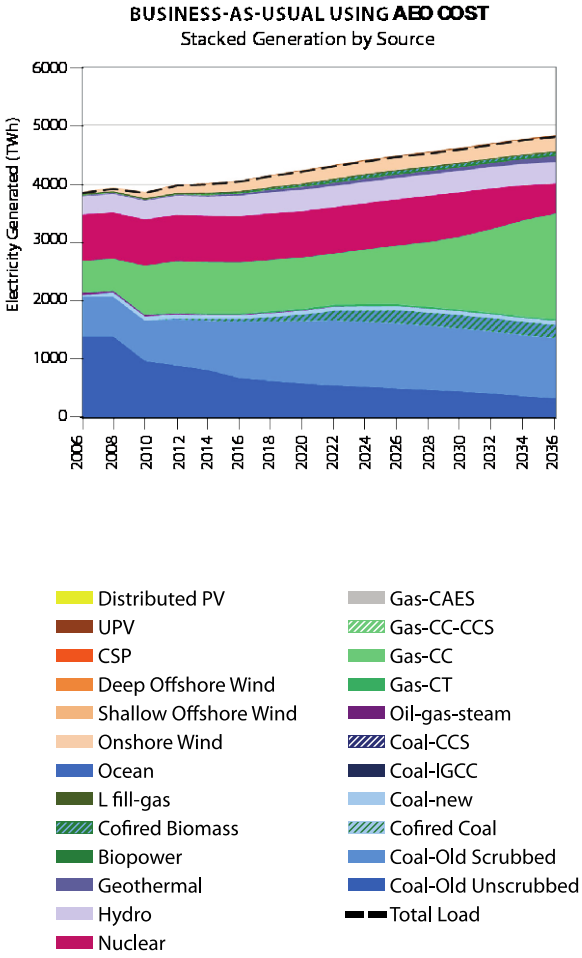
Biofuels: Billion Ton Study

- 2011 update to 2005 report
- Displace 30% of U.S. petroleum consumption
- Sustainably produce 1 billion dry tons of biomass for energy annually

Short, W., Blair, N., Sullivan, P., and T. Mai. ReEDS Model Documentation: Base Case Data and Model Description. NREL Report. 2009.

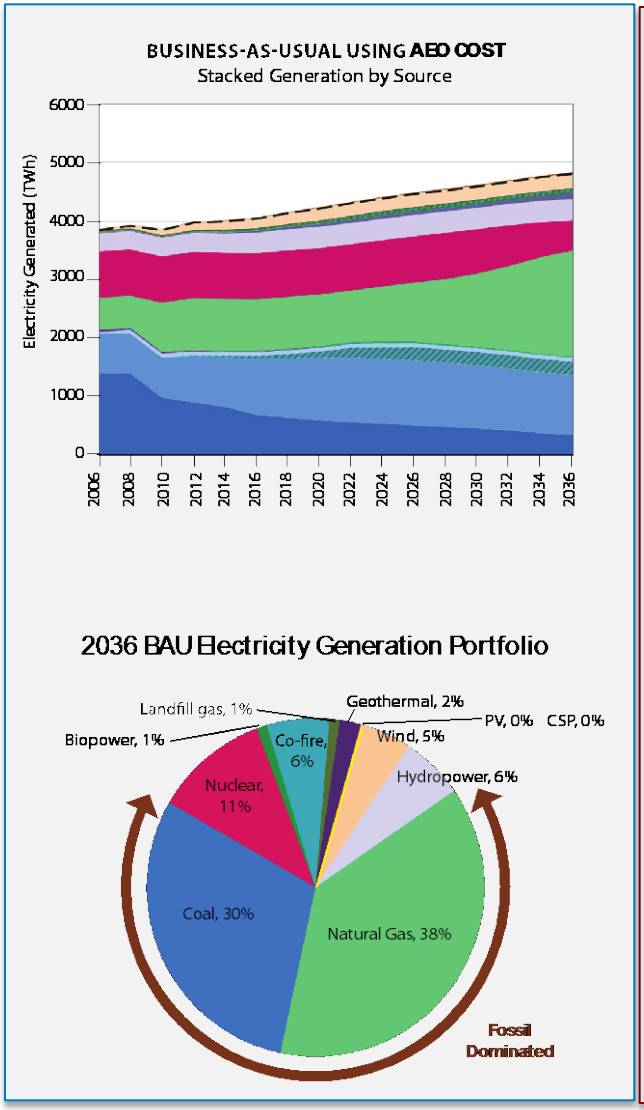
U.S. Department of Energy. 2011. *U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry. R.D. Perlack and B.J. Stokes (Leads), ORNL/TM-2011/224. Oak Ridge National Laboratory, Oak Ridge, TN. 227p.*

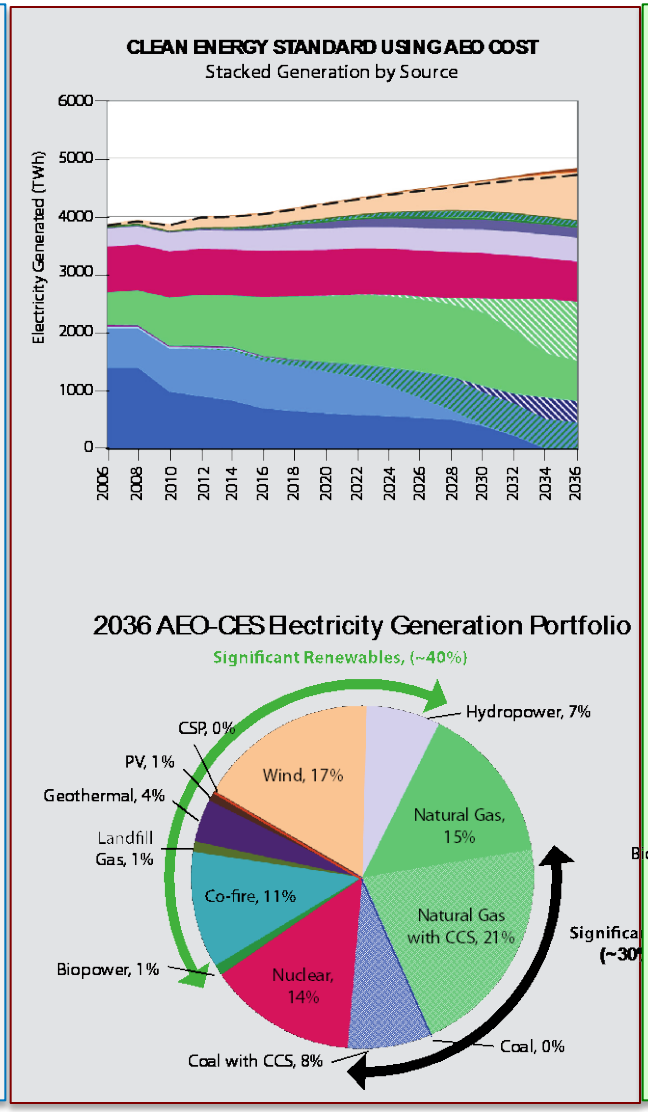
Different cost/performance assumptions create different pathways to an 80% Clean Energy Standard by 2036

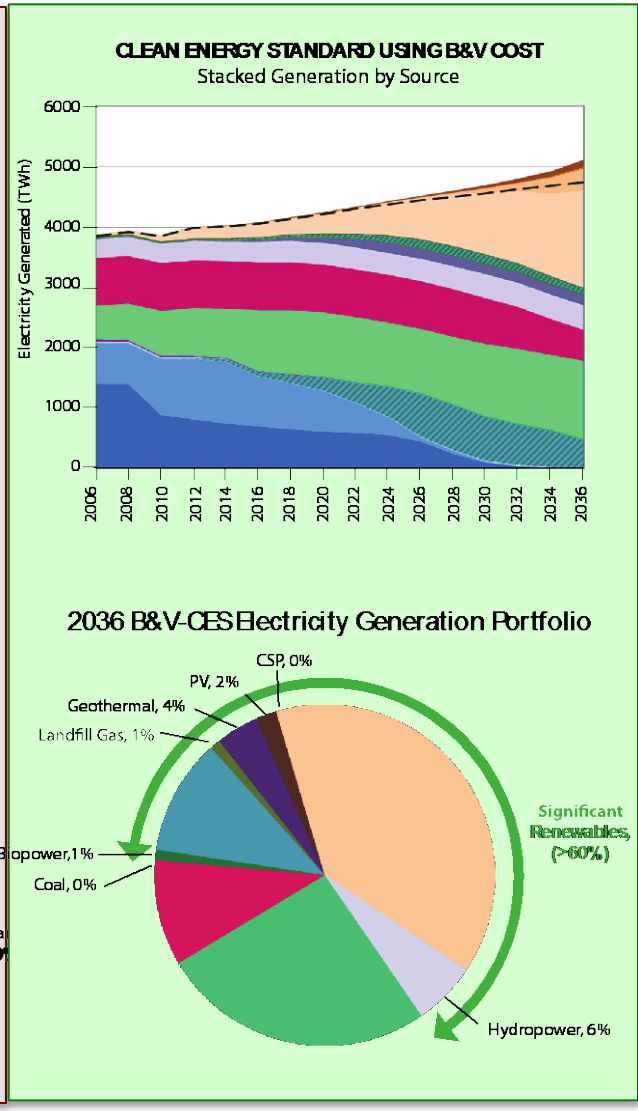


Source: Steinberg *et al., (forthcoming)*

Different cost/performance assumptions create different pathways to an 80% Clean Energy Standard by 2036



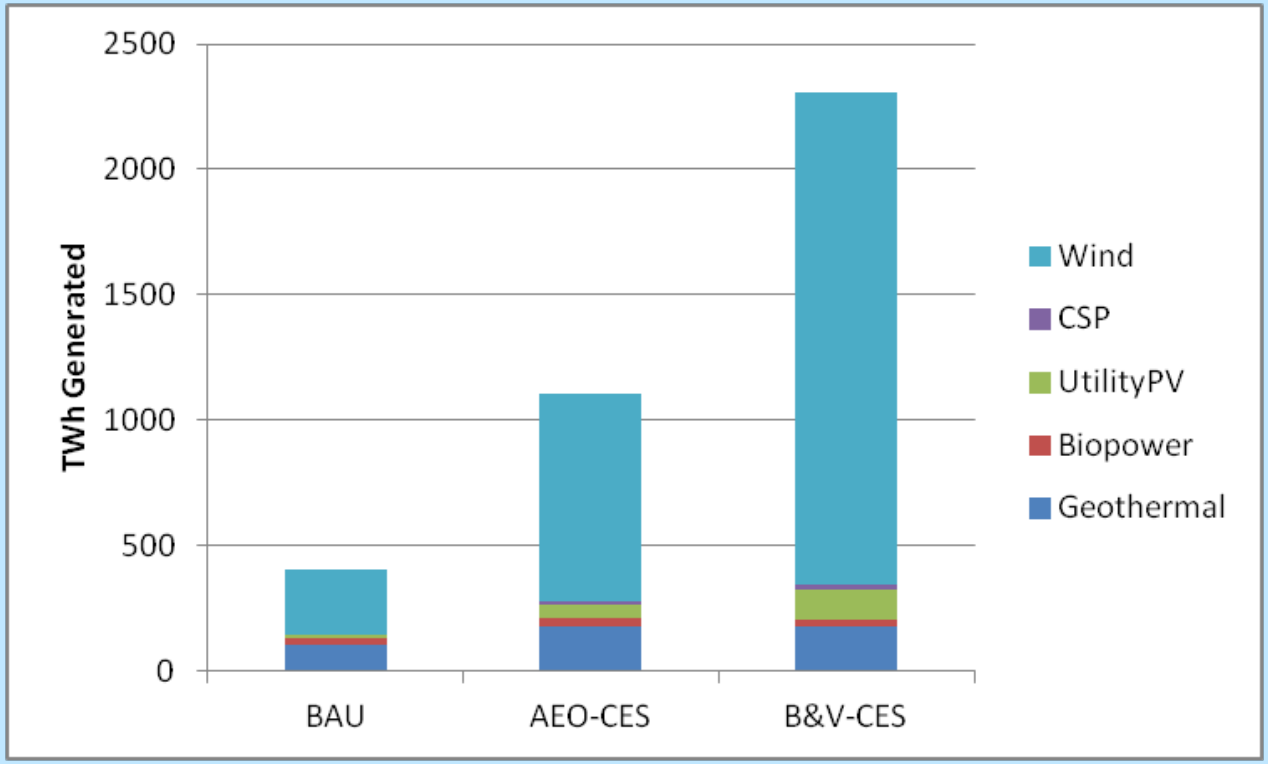




Source: Steinberg *et al., (forthcoming)*

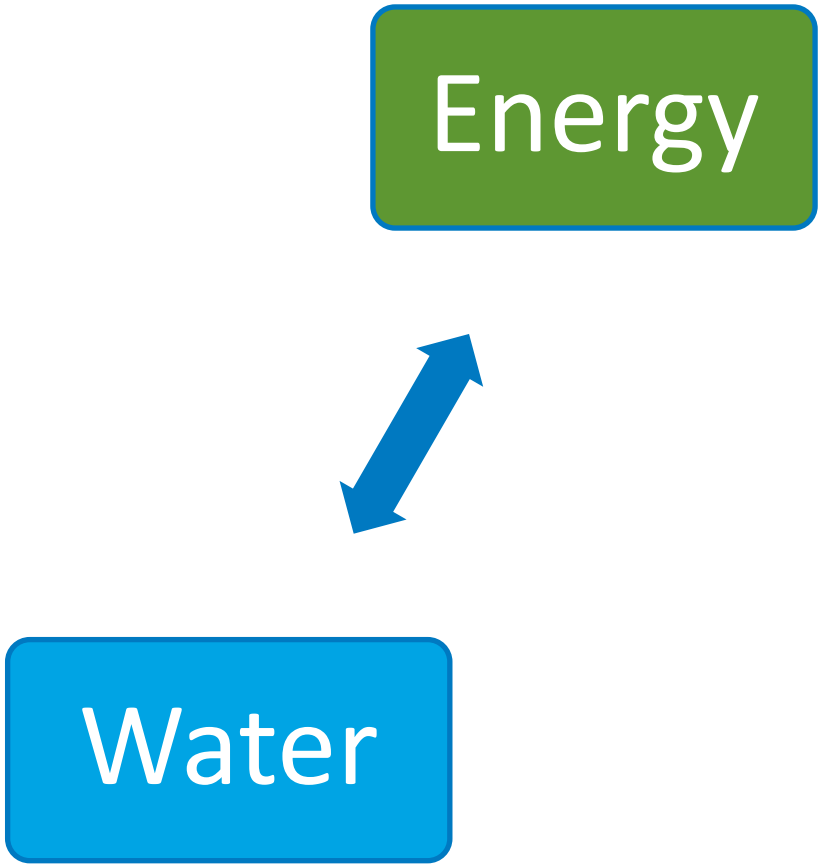
Different cost/performance assumptions create different pathways to an 80% Clean Energy Standard by 2036

Renewable penetration by 2036



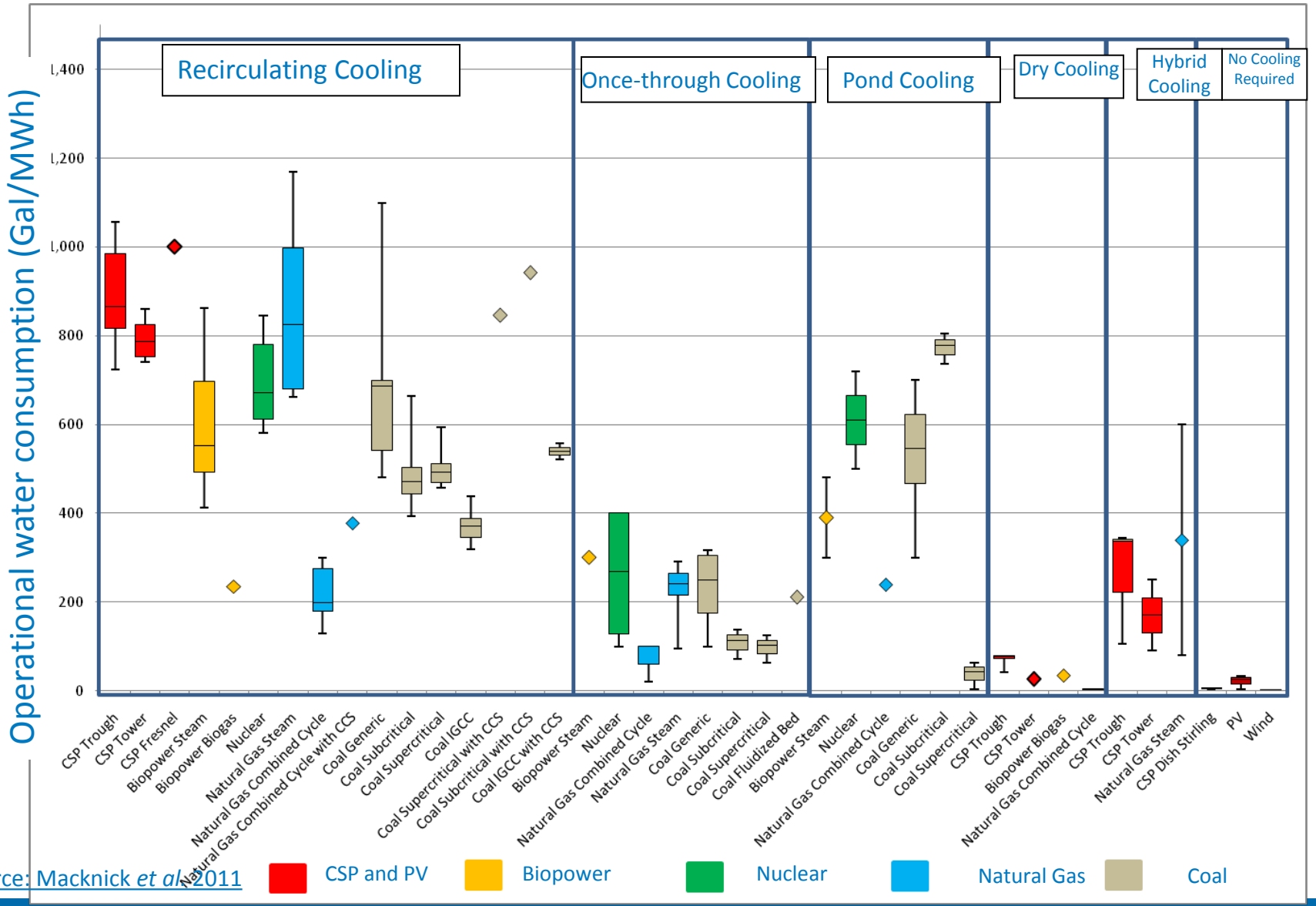
Source: Steinberg *et al., (forthcoming)*

What are the Energy-Water implications?



Water impacts for electricity generation technologies range widely

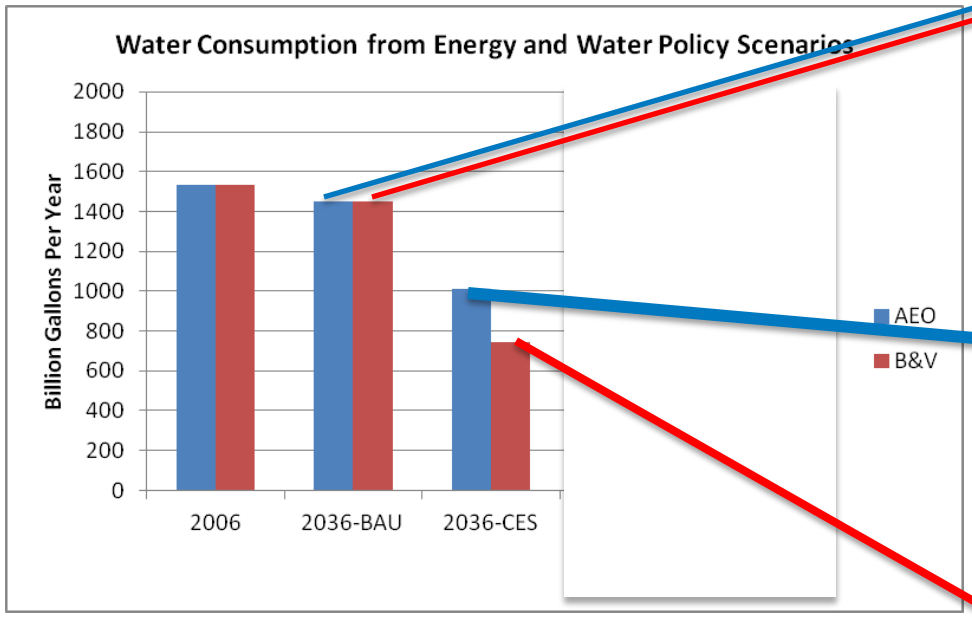
Operational water *consumption* factors for electricity generating technologies



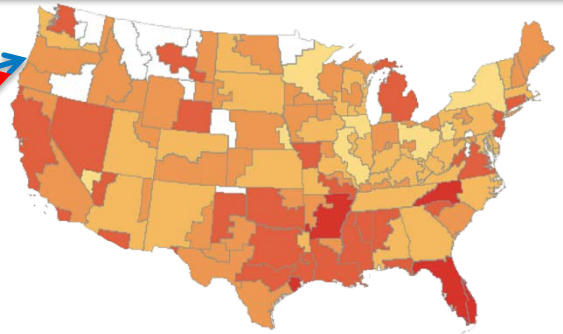
Source: Macknick *et al.* 2011

CES scenario: National trends in power sector water intensity

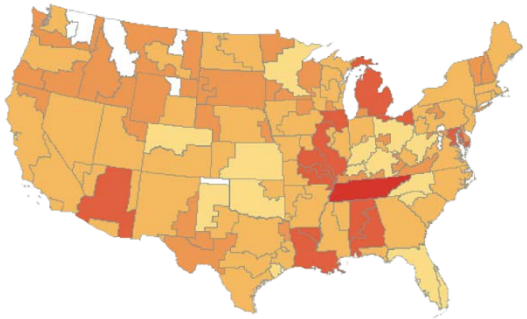
Consumption decreases to different extents



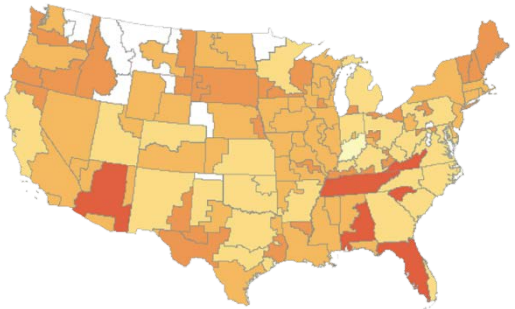
BAU 2036 vs 2006



CES AEO 2036 - 2006



CES B&V 2036 - 2006



CHANGES IN CONSUMPTION (BILLIONS OF GALLONS)
< -30
-30 - -50
-10 - -1
-1 - 1
1 - 10
10 - 30
> 30

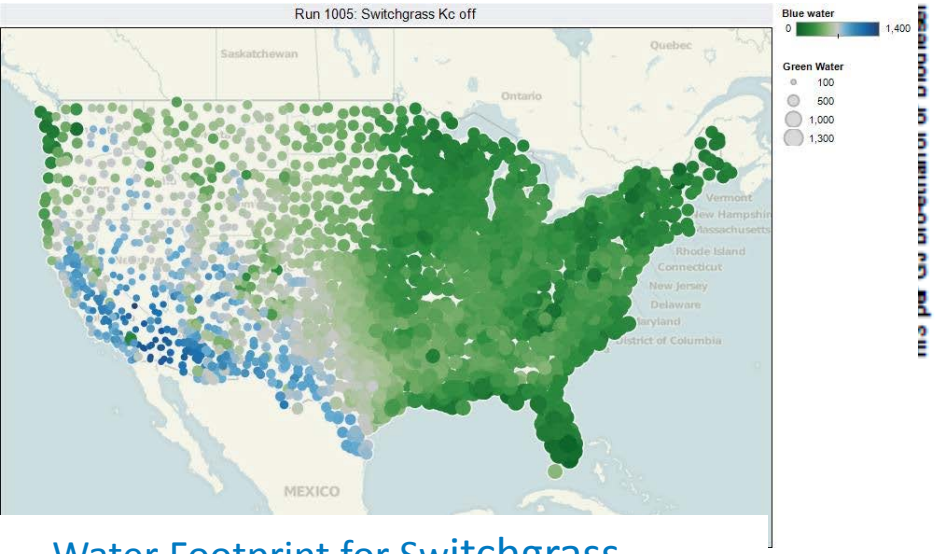
Regional impacts vary

Climate change may enhance impacts locally and regionally

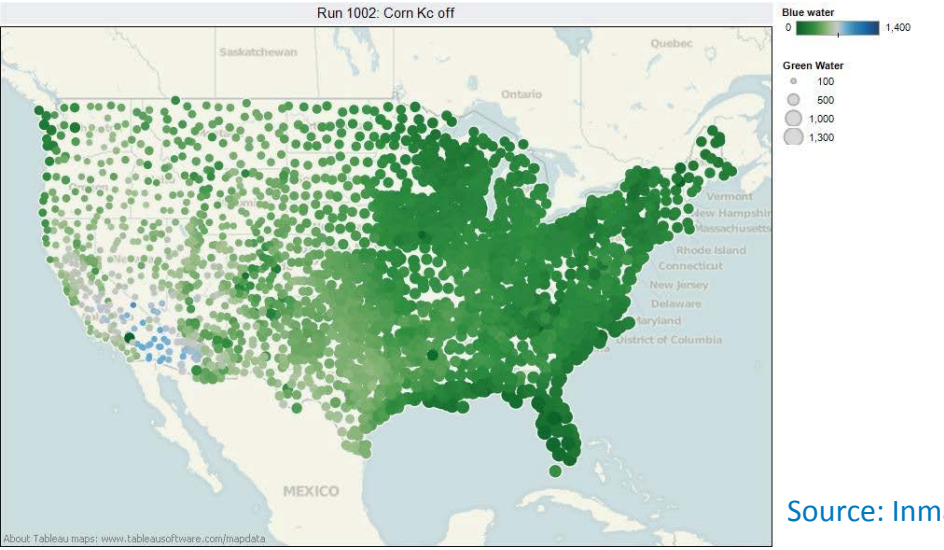
Source: Newmark et al., 2011

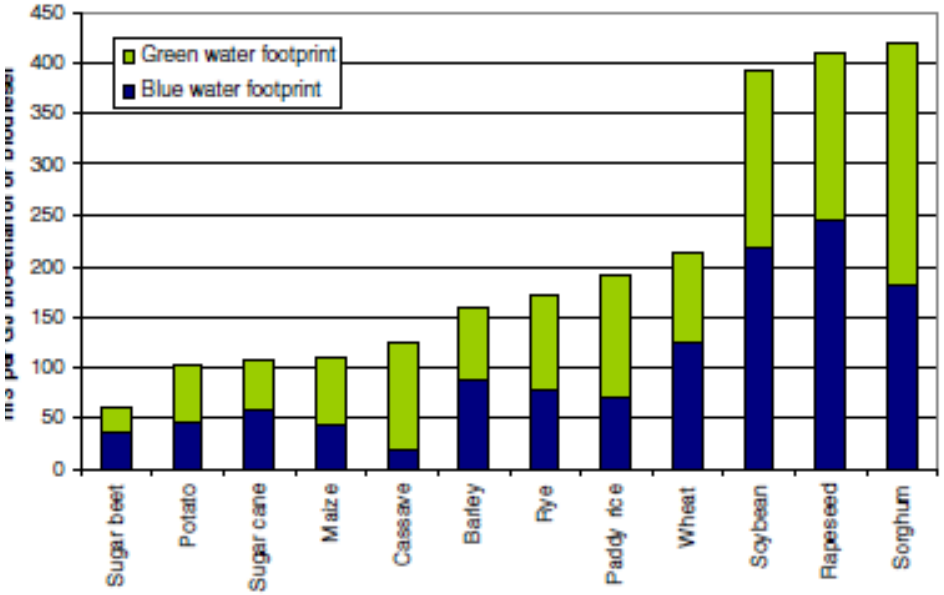
Water use for biofuel production is highly variable and depends on crop type and location

Water Footprint for Corn



Water Footprint for Switchgrass





Source: Gerbens-Leenes *et al., 2009*

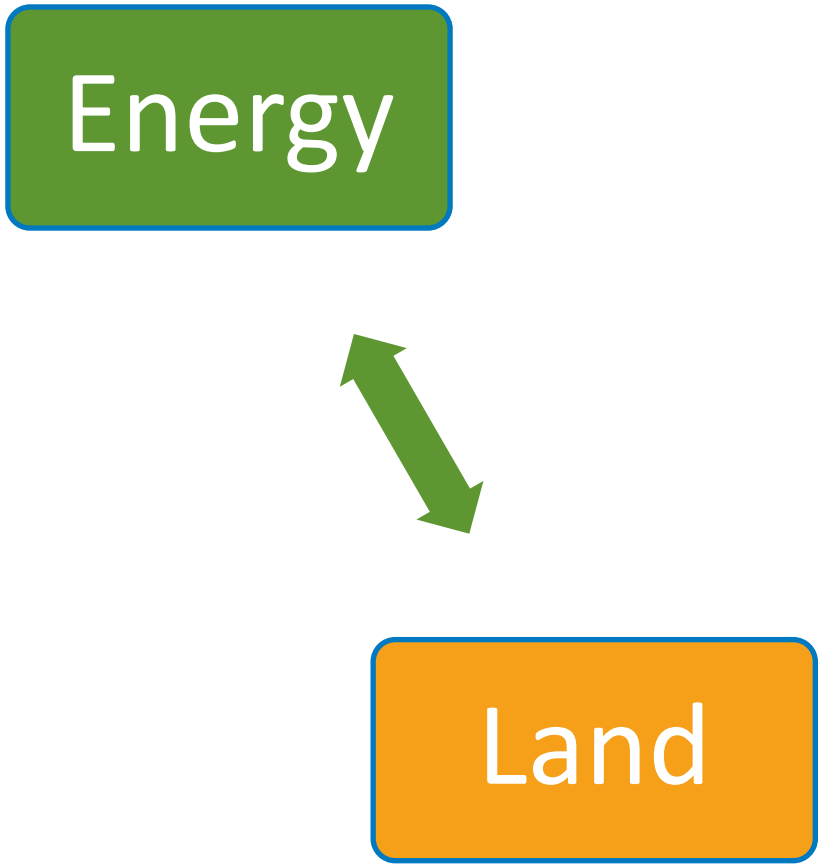
Some crops require more water, regardless of location

Irrigation requirements vary spatially

Irrigated energy crops could result in local or regional competition for water

Source: Inman *et al., (forthcoming);*

What are the Energy-Land implications?



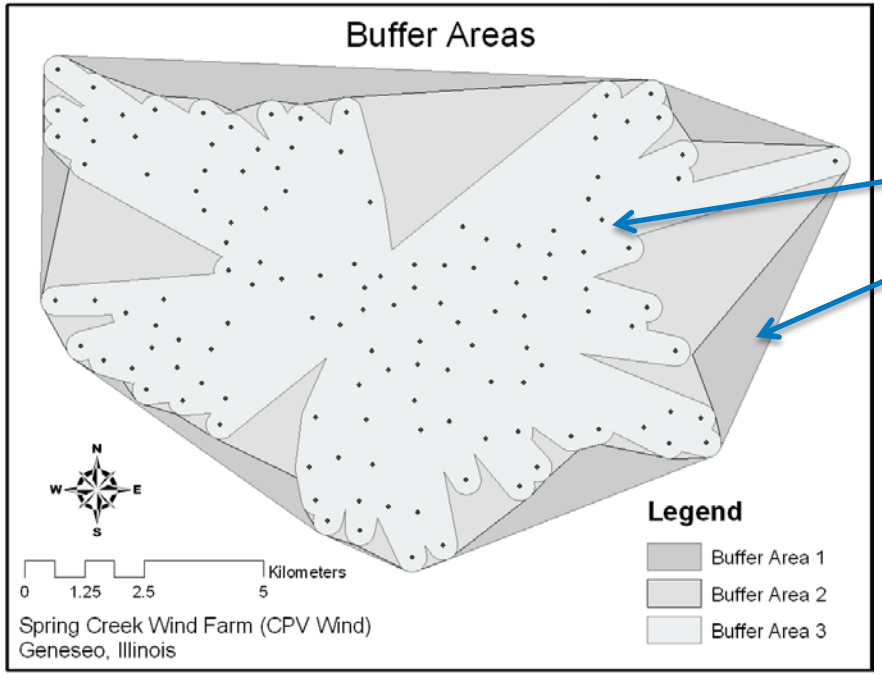
What is the land footprint of renewables?

It depends on your definition

NEW YORK TIMES

June 7, 2011

Meeting California's RPS would require:
"5 Manhattans" for Solar
"70 Manhattans" for Wind



Primary accounting methods

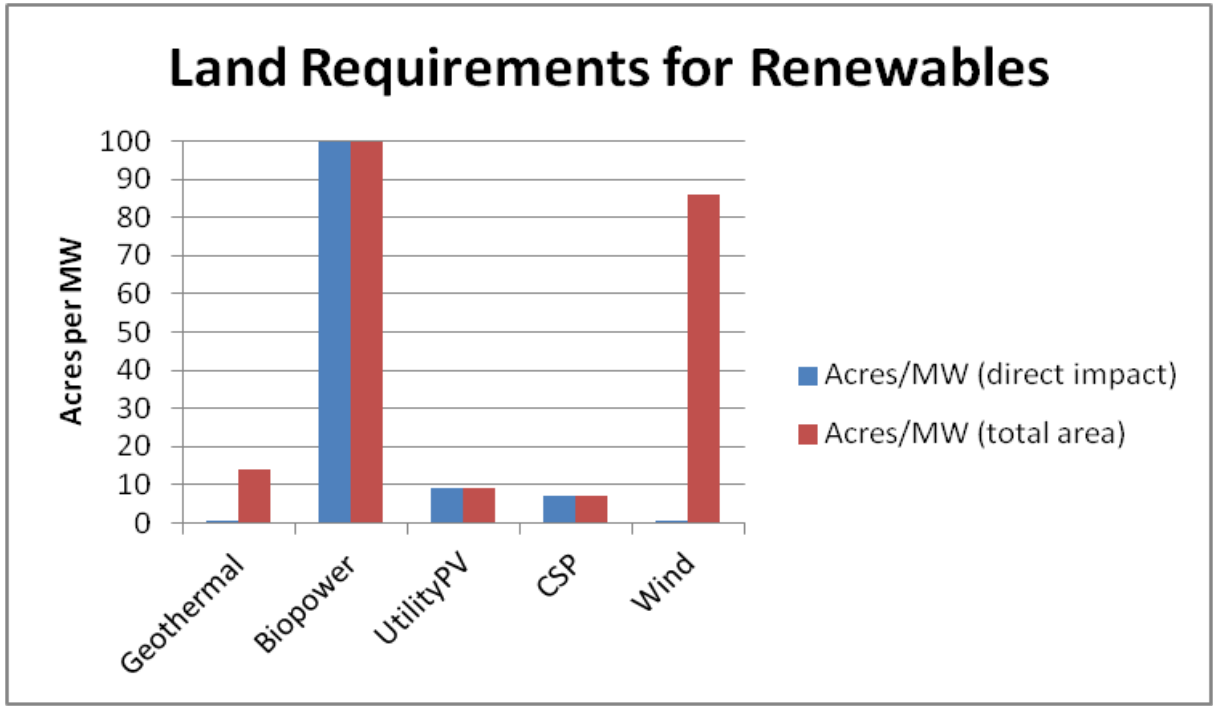
Direct Impact

Total Plant Area Impact

Land footprint estimates for renewable technologies differ widely based on the metric used

Wind and geothermal land footprints vary ***by 1-2 orders of magnitude***

Land footprints for solar PV, CSP, and biopower are similar under both definitions



(Acres/MW)	Geothermal[1]	Biopower[2]	Utility PV[3]	CSP[4]	Wind[5]
Direct Impact	0.6	900	9	7	0.7
Total Area	14	900	9	7	86

1. Pimentel, 2002; Geothermal PEIS Ch. 4, 2008. Assumes 85% capacity factor, per ReEDS model assumptions
2. IEA, 2007
3. Solar PEIS Appendix M, 2010
4. Solar PEIS Appendix M, 2010. Averages land impacts from power tower (9 acres/MW) and parabolic trough (5 acres/MW)
5. Denholm *et al.,* 2009

What is the effective footprint?

Co-location of agriculture with wind and solar plants can reduce the overall land footprint for renewable energy technologies

Cows and pasture beneath panels in Massachusetts. *Courtesy: M. Lehan, 2011*

Sunflowers for oil production grown under panels in Wisconsin. *Courtesy: Milwaukee Journal Sentinel, 2011*

Tapping solar resources in non-irrigated corners of center pivot irrigation fields. *Source: Roberts, B. NREL Technical Report. TP-6A20-51330, 2011*

Wind farm co-located with a cattle operation.

Co-location can reduce the land footprint of renewables and reduce food vs. fuel conflicts

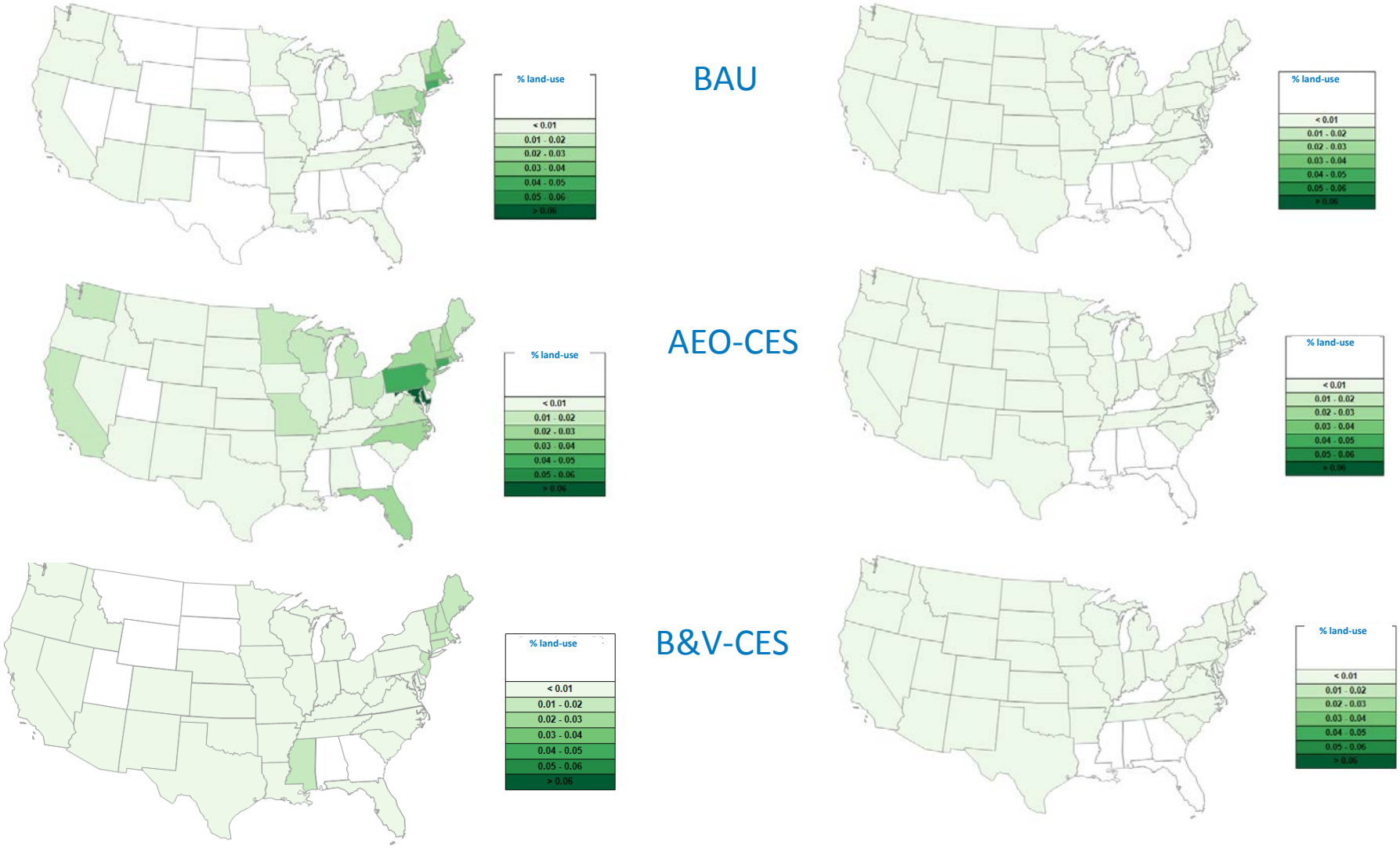
Wind farm co-located with an agriculture farm.

Land use for renewables makes up a small fraction of total state land area

Direct Impact Method

Example: Biopower and wind

Direct Impact Method



Biopower

Source: Newmark et al., 2011

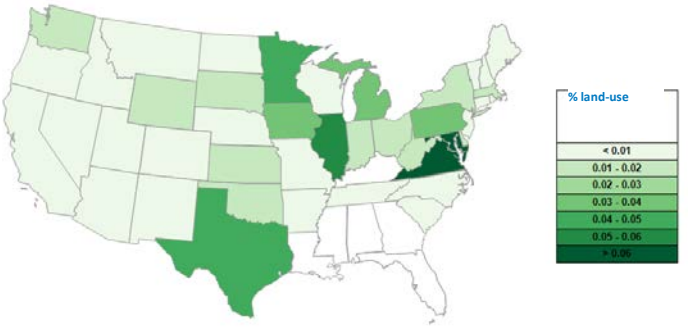
Wind

Land use for renewables makes up a small fraction of total state land area

Example: Biopower and wind

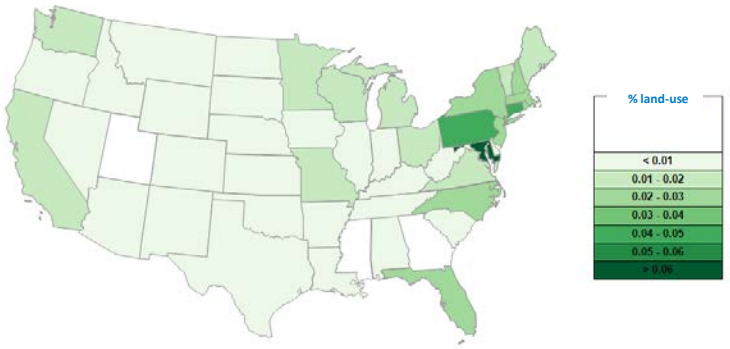
Total Area Method

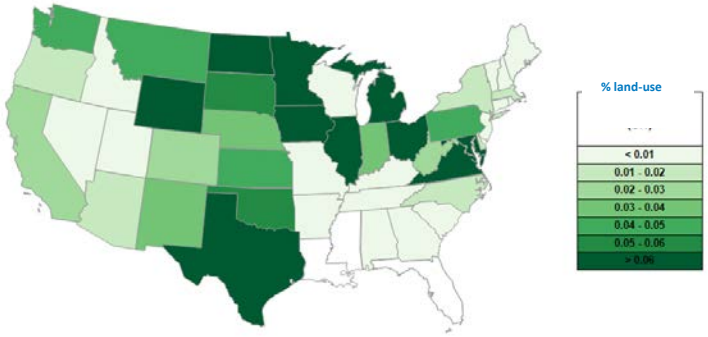
BAU



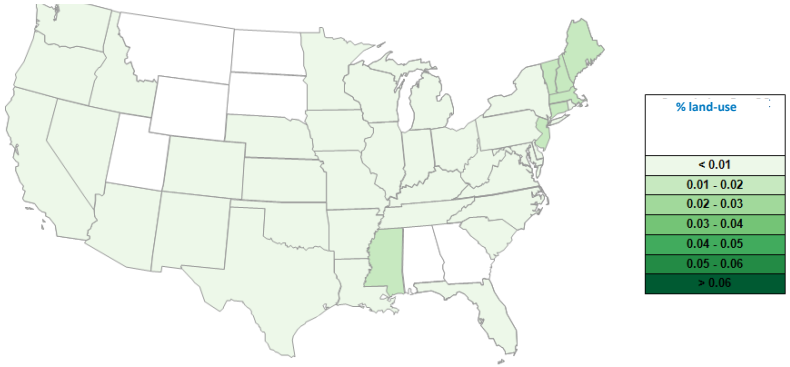
Total Area Method

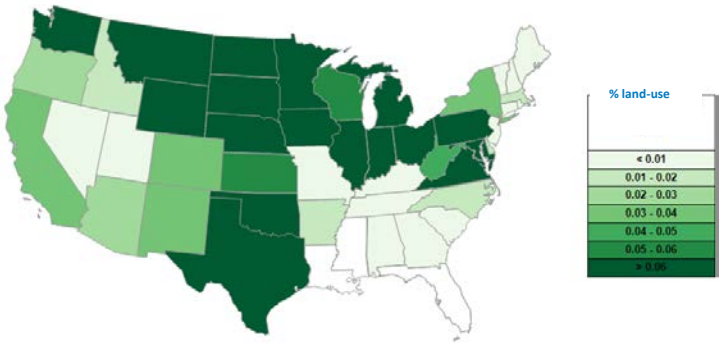
AEO-CES





B&V-CES





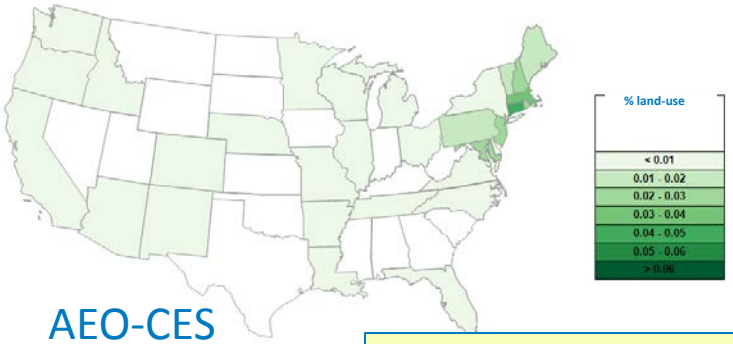
Biopower

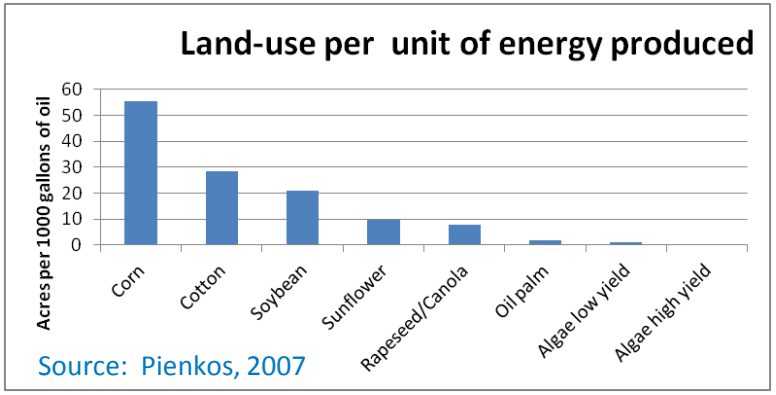
Source: Newmark et al., 2011

Wind

Land for biofuels may compete with land for biopower electricity and other agricultural uses

Business as usual

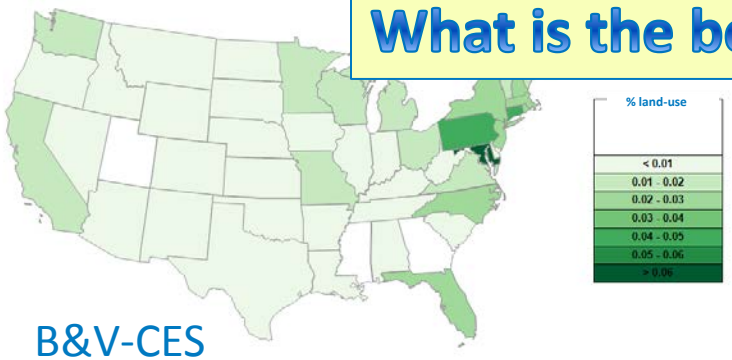


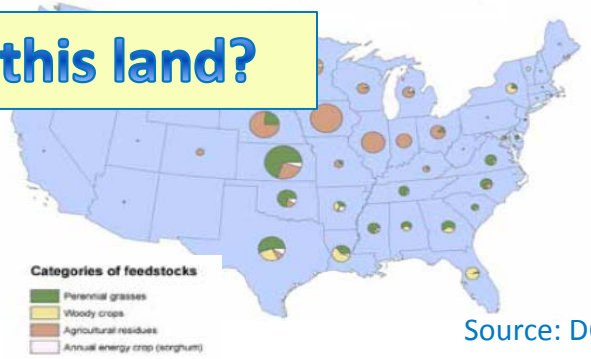


Source: Pienkos, 2007

AEO-CES

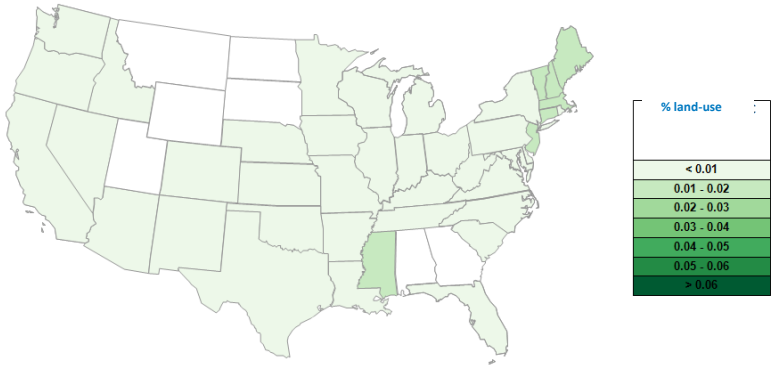
What is the best use of this land?





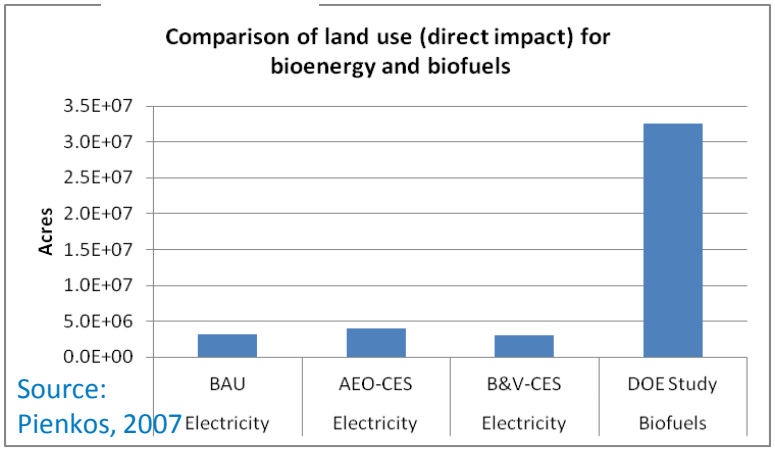
Source: DOE, 2011

B&V-CES



Biopower

Source: Newmark et al., 2011



Source: Pienkos, 2007

Summary

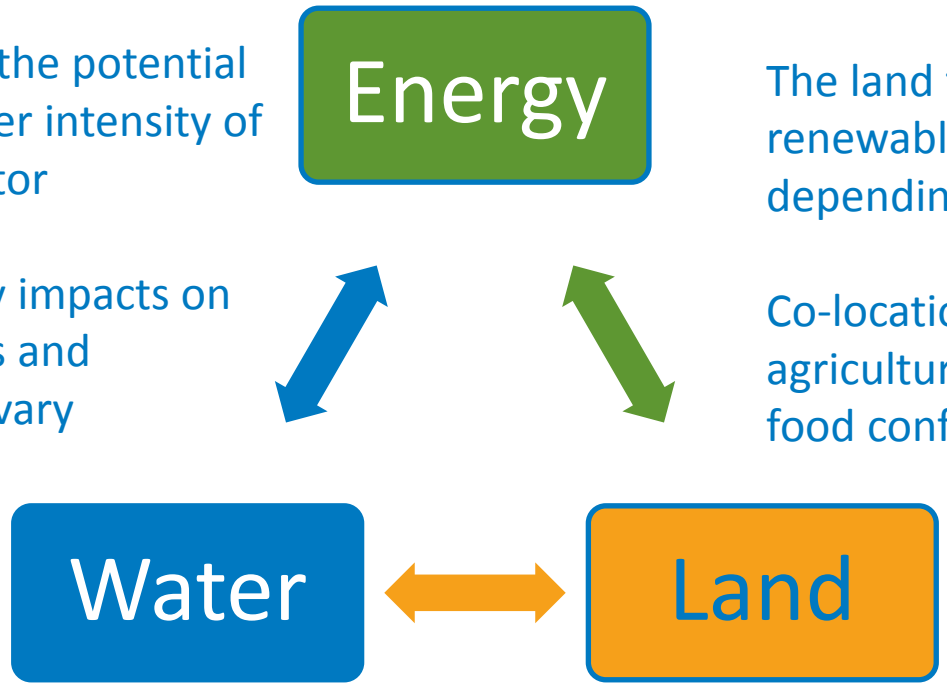
Future energy choices can have implications in the energy-water-land nexus.

Renewables can help achieve energy policy goals

Integrated planning is needed to support sustainable energy, water and food goals and help prevent unsustainable demands on land and water resources

Renewables have the potential to reduce the water intensity of our electricity sector

Renewable energy impacts on water withdrawals and consumption will vary geographically



The land footprint of renewables varies greatly depending on metrics used

Co-location of renewables with agriculture can mitigate fuel vs. food conflicts

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