integrated land use planning for managing climate mitigation, biodiversity, and food production

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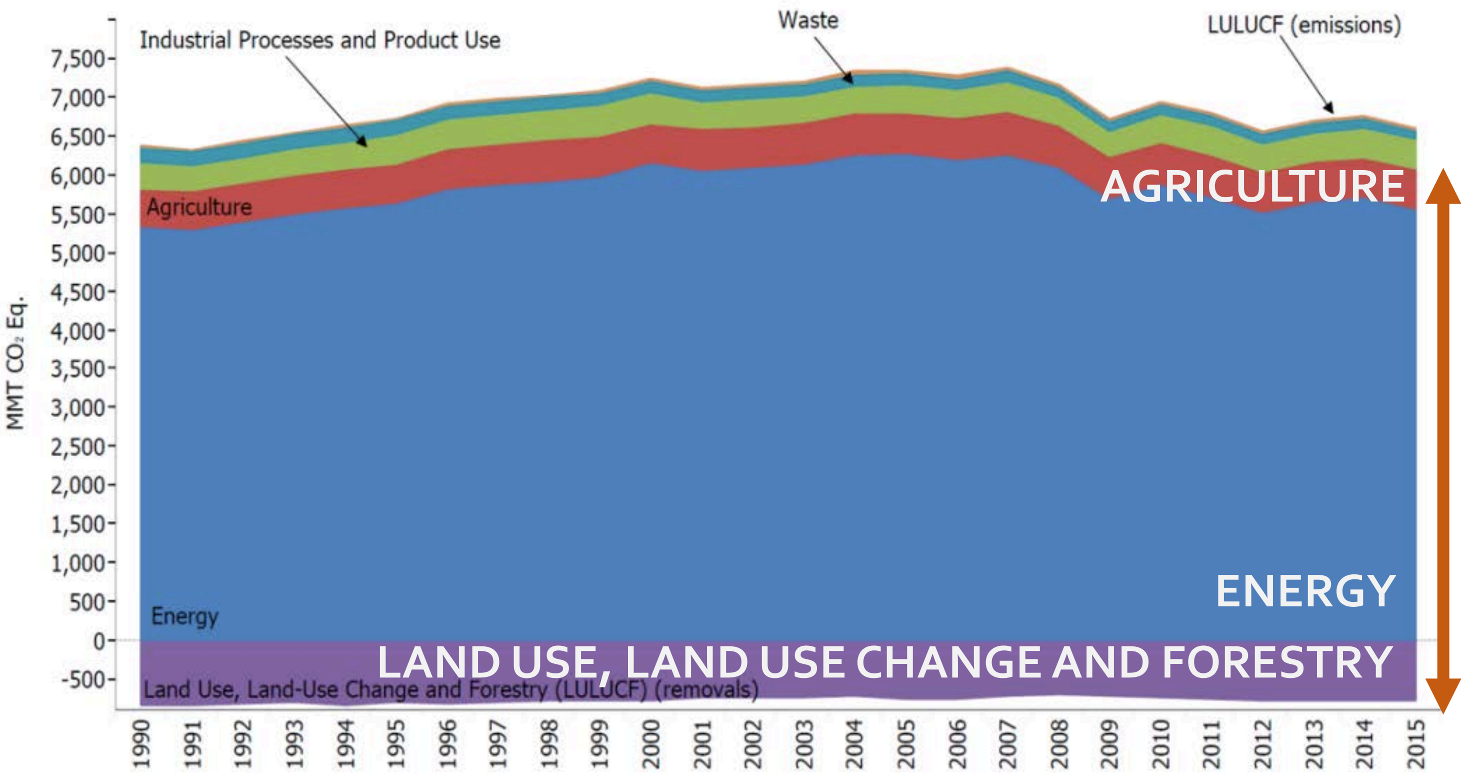
Low Emissions Solutions Conference
September 20, 2017

Land use based climate mitigation strategies

U.S. GHG Emissions and Sinks by Sector (MMT CO2 Eq.)



These sources and sinks have a land use component

US EPA 2017: Inventory of US Greenhouse Gas Emissions and Sinks

Land use based climate mitigation strategies

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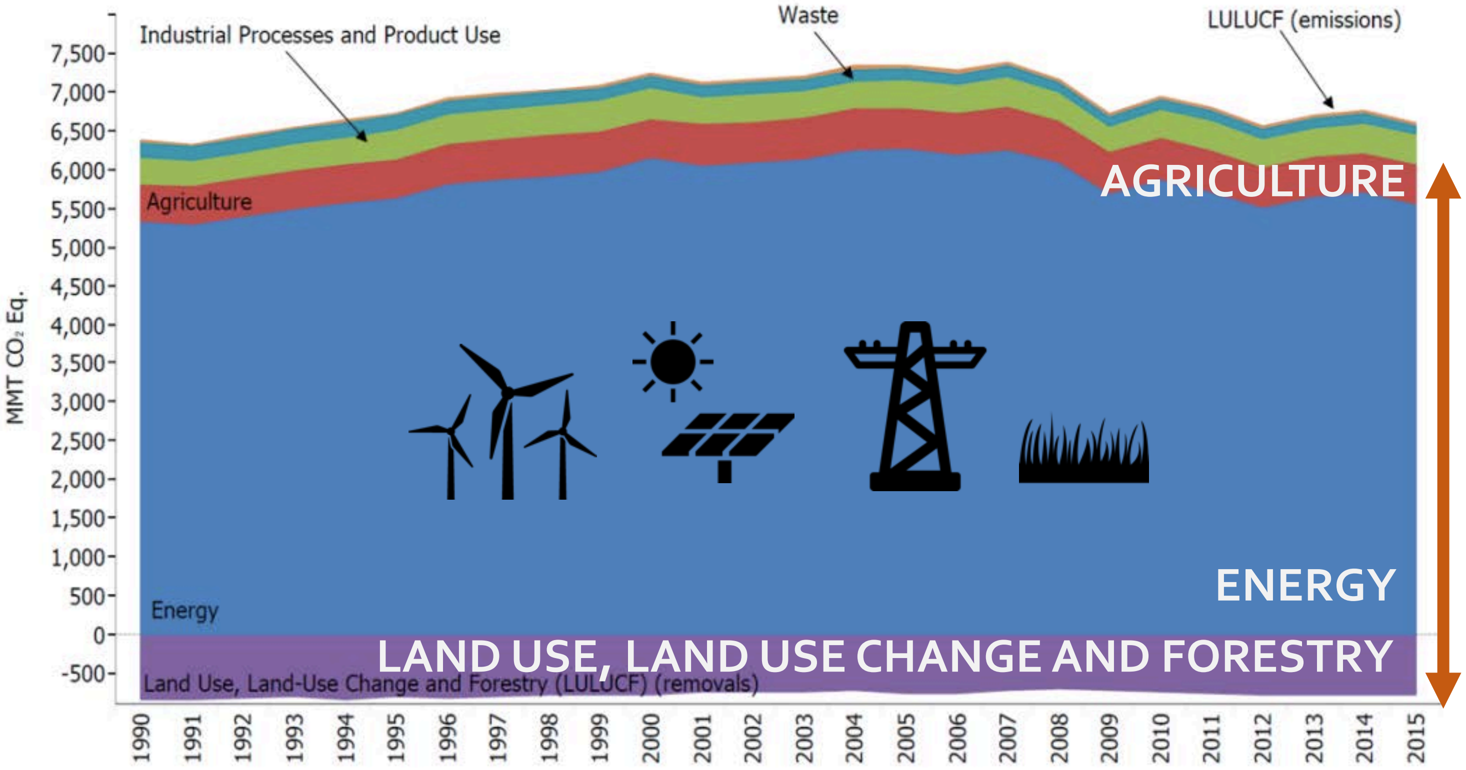


These sources and sinks have a land use component

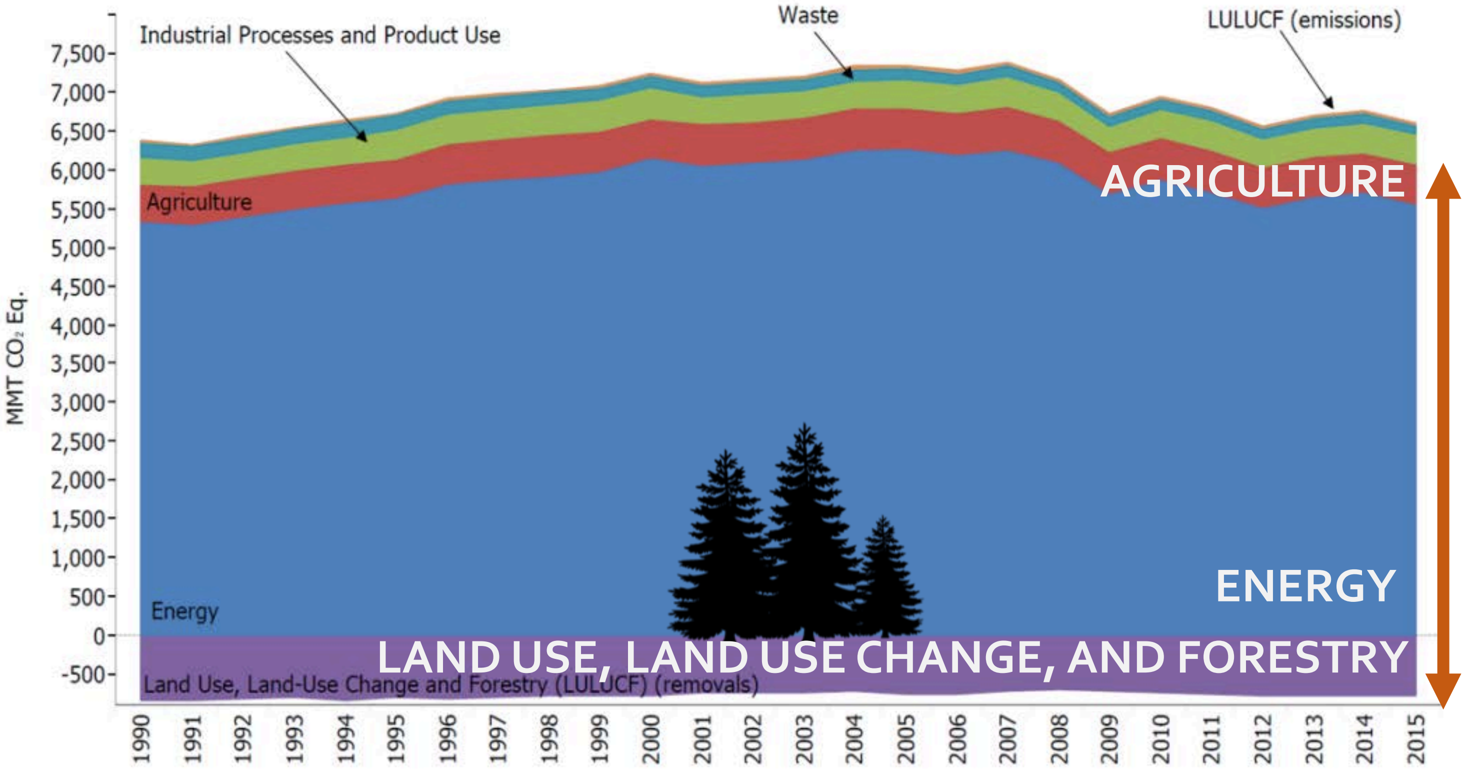
US EPA 2017: Inventory of US Greenhouse Gas Emissions and Sinks

Land for energy production needs

- Renewable energy siting
- Oil and gas extraction
- Bioenergy (purpose grown feedstocks)

Land use based climate mitigation strategies

U.S. GHG Emissions and Sinks by Sector (MMT CO2 Eq.)



US EPA 2017: Inventory of US Greenhouse Gas Emissions and Sinks

These sources and sinks have a land use component

Terrestrial biological carbon sequestration

- Re- and afforestation
- Forest management (selective harvesting; fire and pest management)

Land use based climate mitigation strategies

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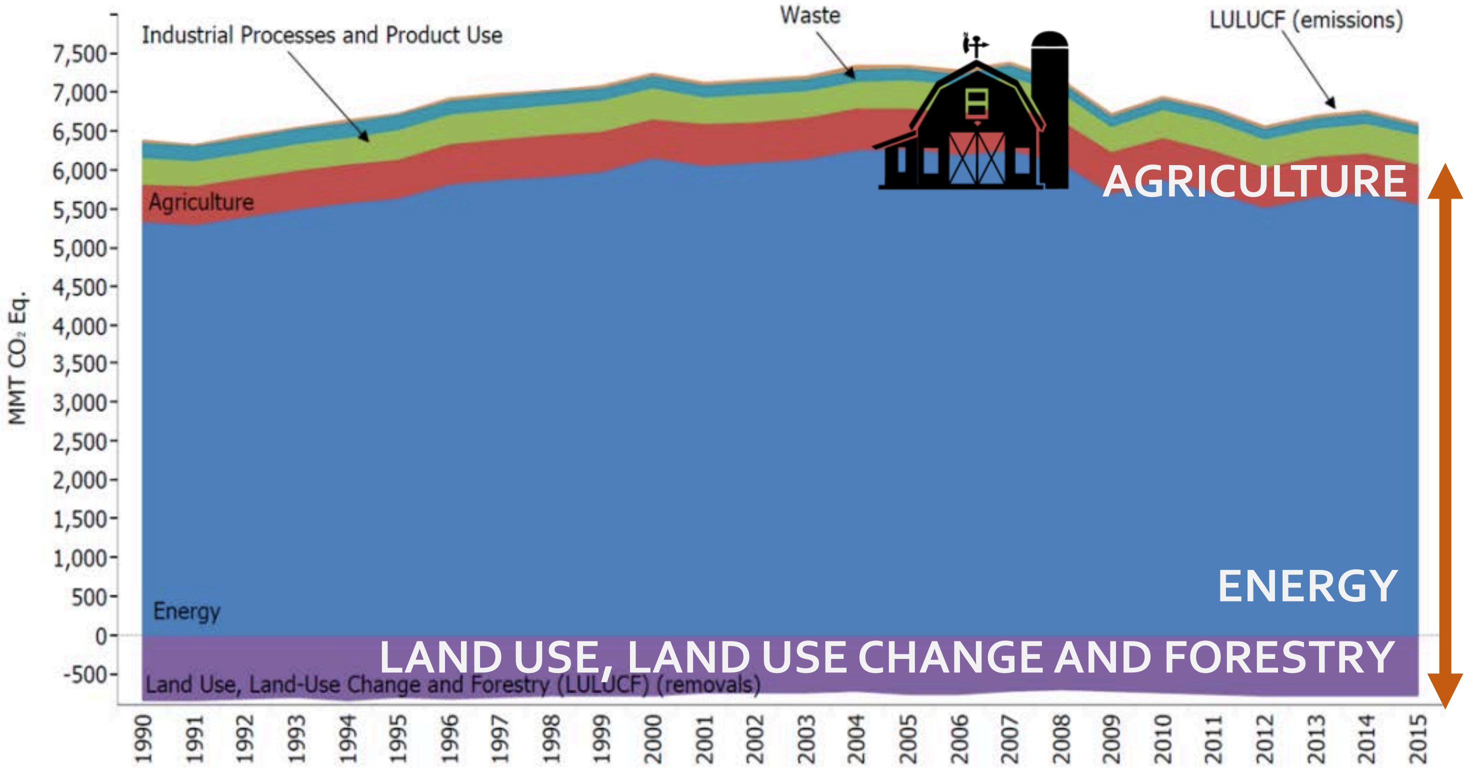


US EPA 2017: Inventory of US Greenhouse Gas Emissions and Sinks

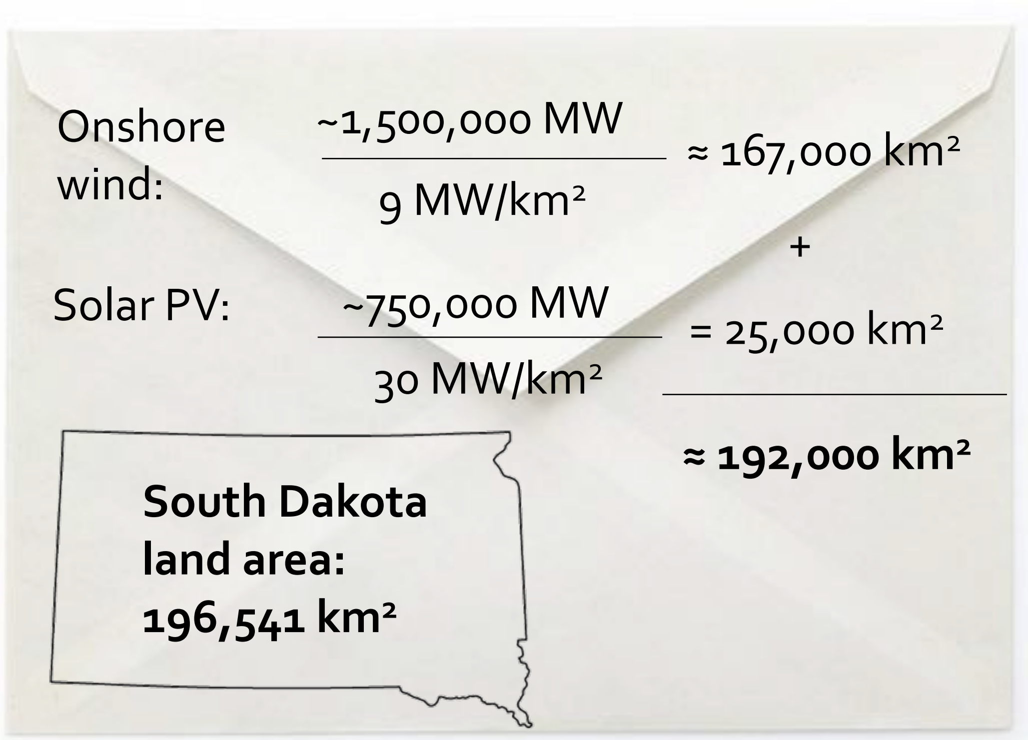
These sources and sinks have a land use component

Agricultural GHG

- Agricultural emissions (9% of total US emissions) from soil management, enteric emissions and manure management
- Agricultural byproducts for bioenergy

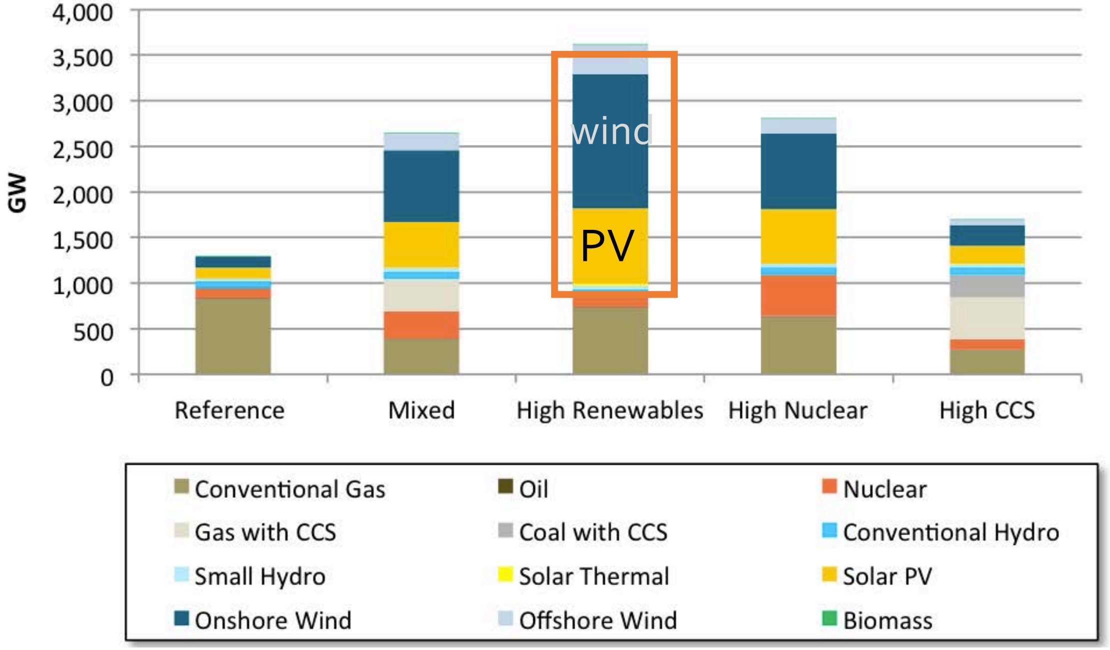
Land use planning for climate mitigation is a scaling problem with hard constraints

Technological scale (the scale of transformation): Large scale deployment of technologies have land use requirements and consequences that need to be anticipated and effectively managed.



For example, just electricity alone…

Williams et al. 2014; 80% below 1990 by 2050



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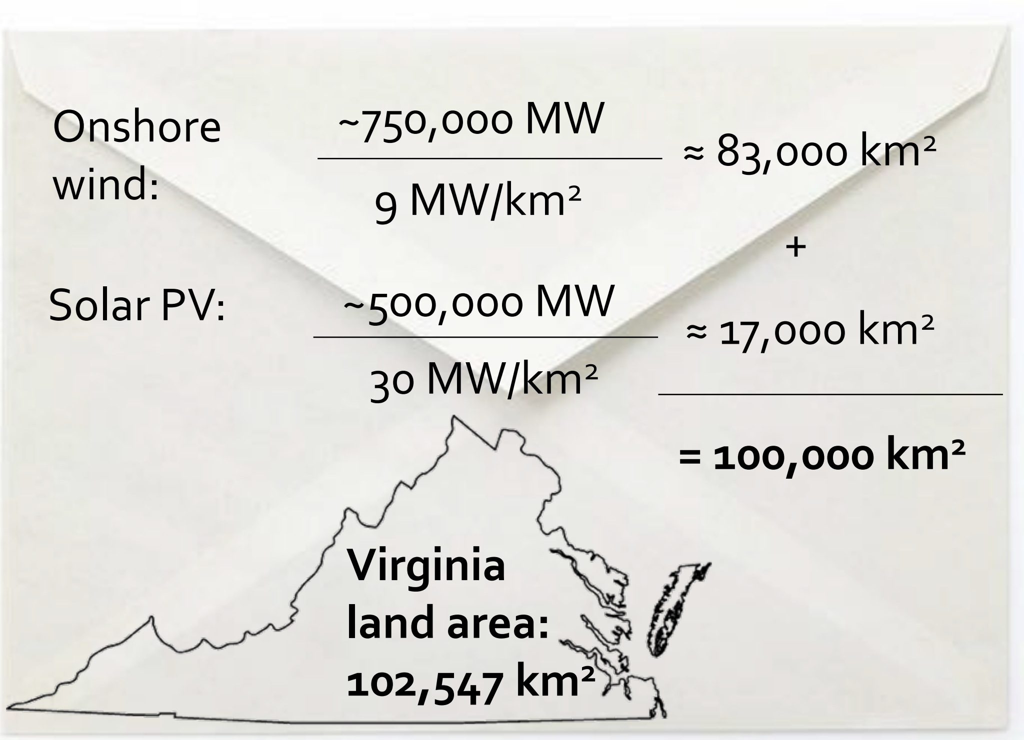

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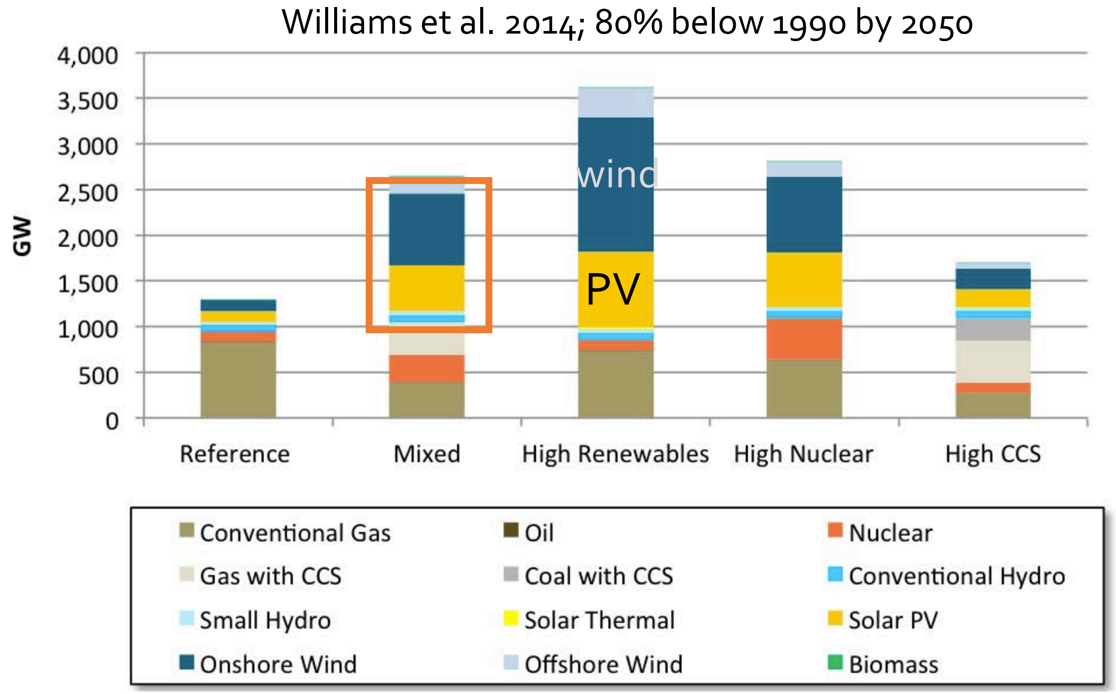


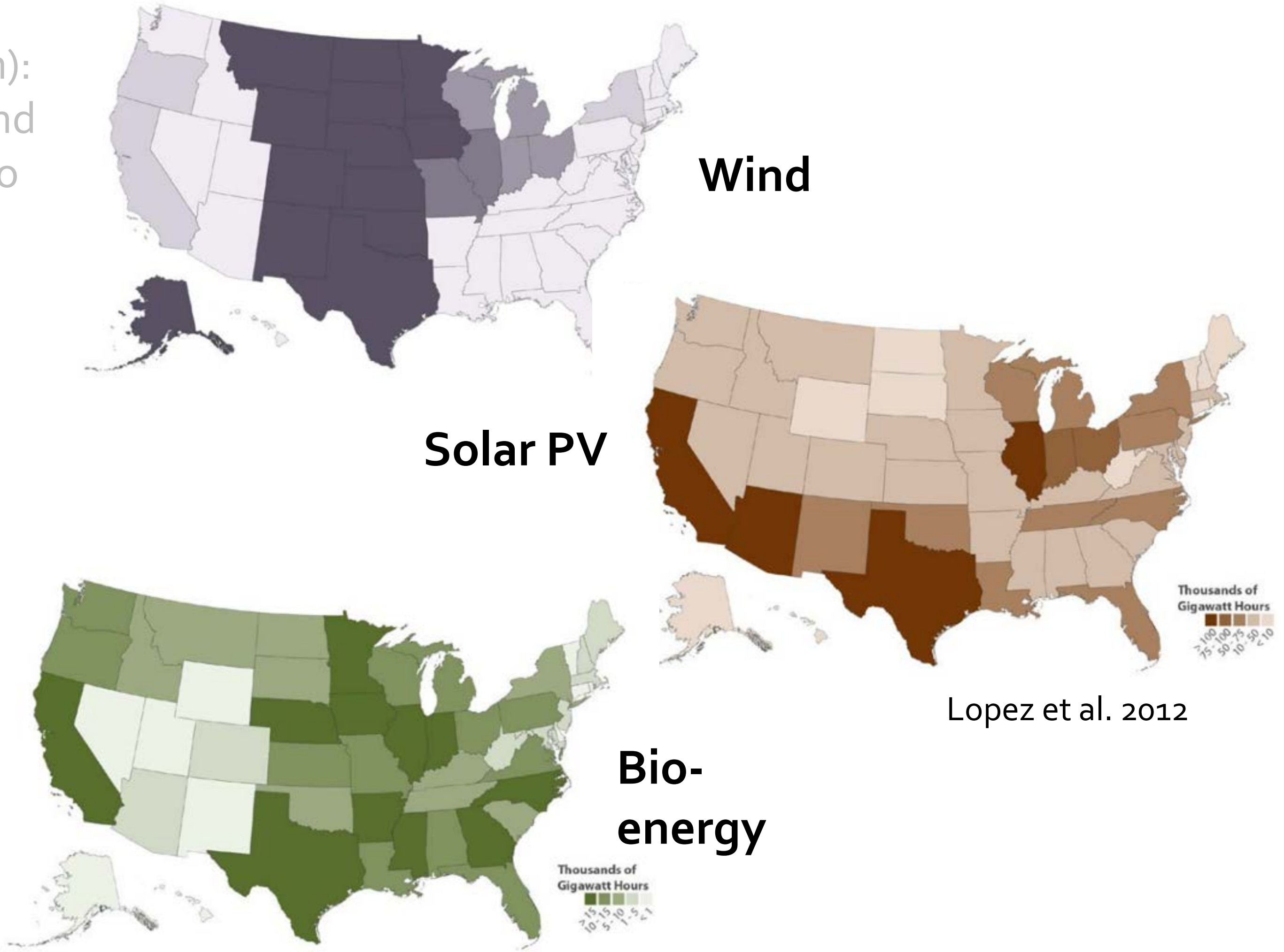
…not including

- transportation fuel from bioenergy
- additional area reforested?
- acres of farmland under improved management?

Land use planning for climate mitigation is a scaling problem with hard constraints

Technological scale (the scale of transformation): Large scale deployment of technologies have land use requirements and consequences that need to be anticipated and effectively managed

Geographic scale (the area of transformation): Multiple competitors means multiple technologies, policies, market tools need to be leveraged or transferred over large jurisdictional areas.



Lopez et al. 2012

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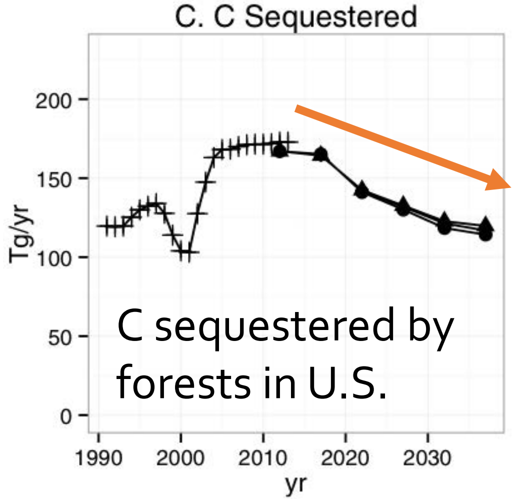
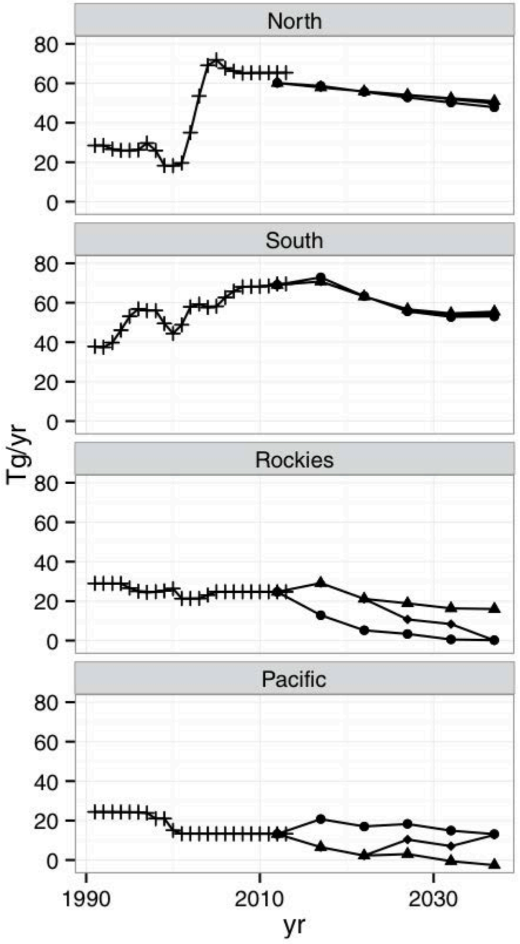
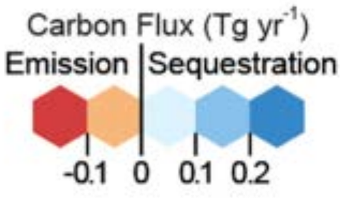
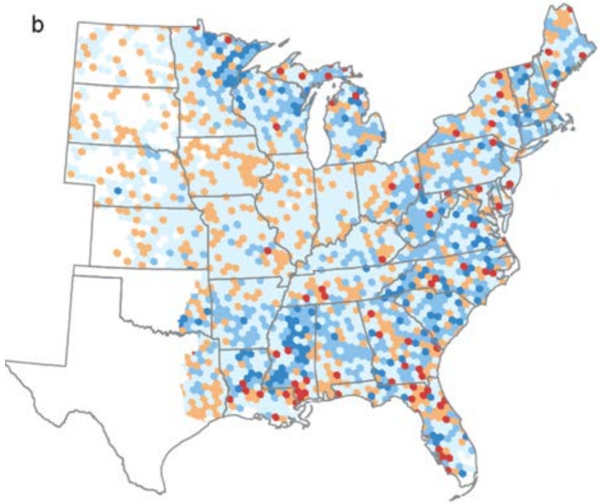








Woodall et al. 2015

Wear and Coulston 2015

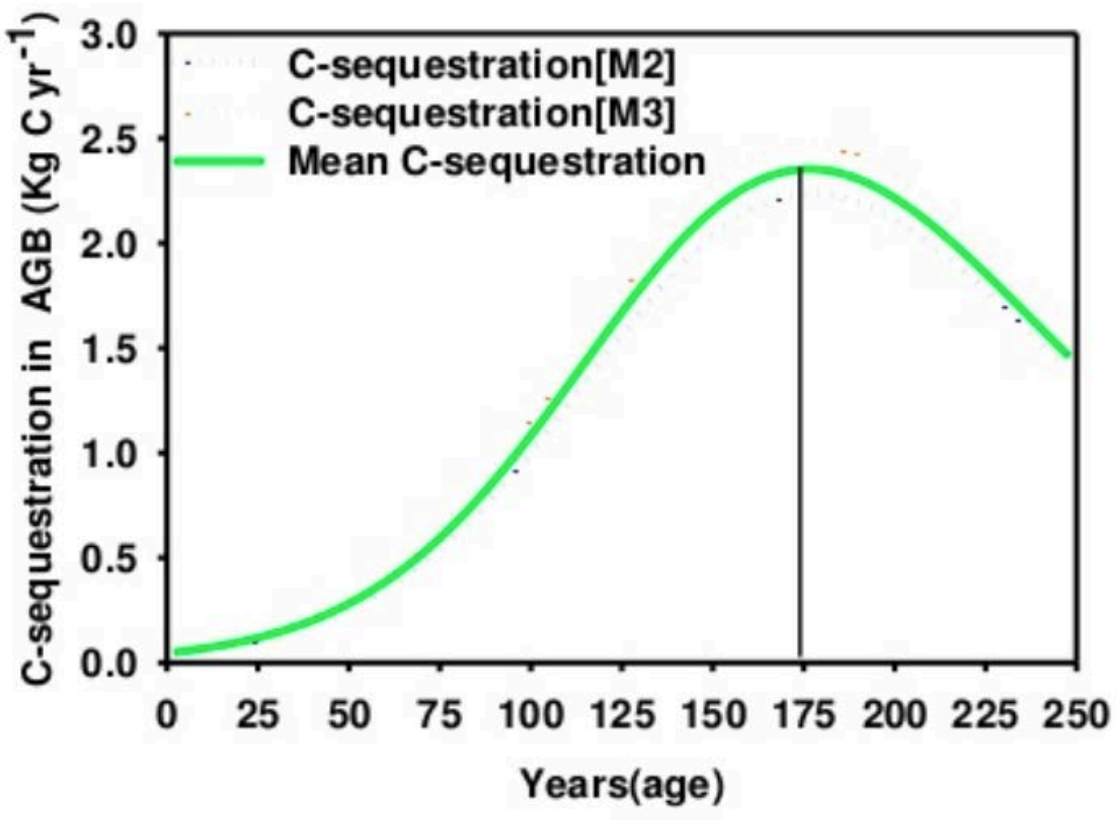
Land use planning for climate mitigation is a scaling problem with hard constraints

Technological scale (the scale of transformation): Large scale deployment of technologies have land use requirements and consequences that need to be anticipated and effectively managed

Geographic scale (the area of transformation): Multiple competitors means multiple technologies, policies, market tools need to be leveraged or transferred over several jurisdictional areas.

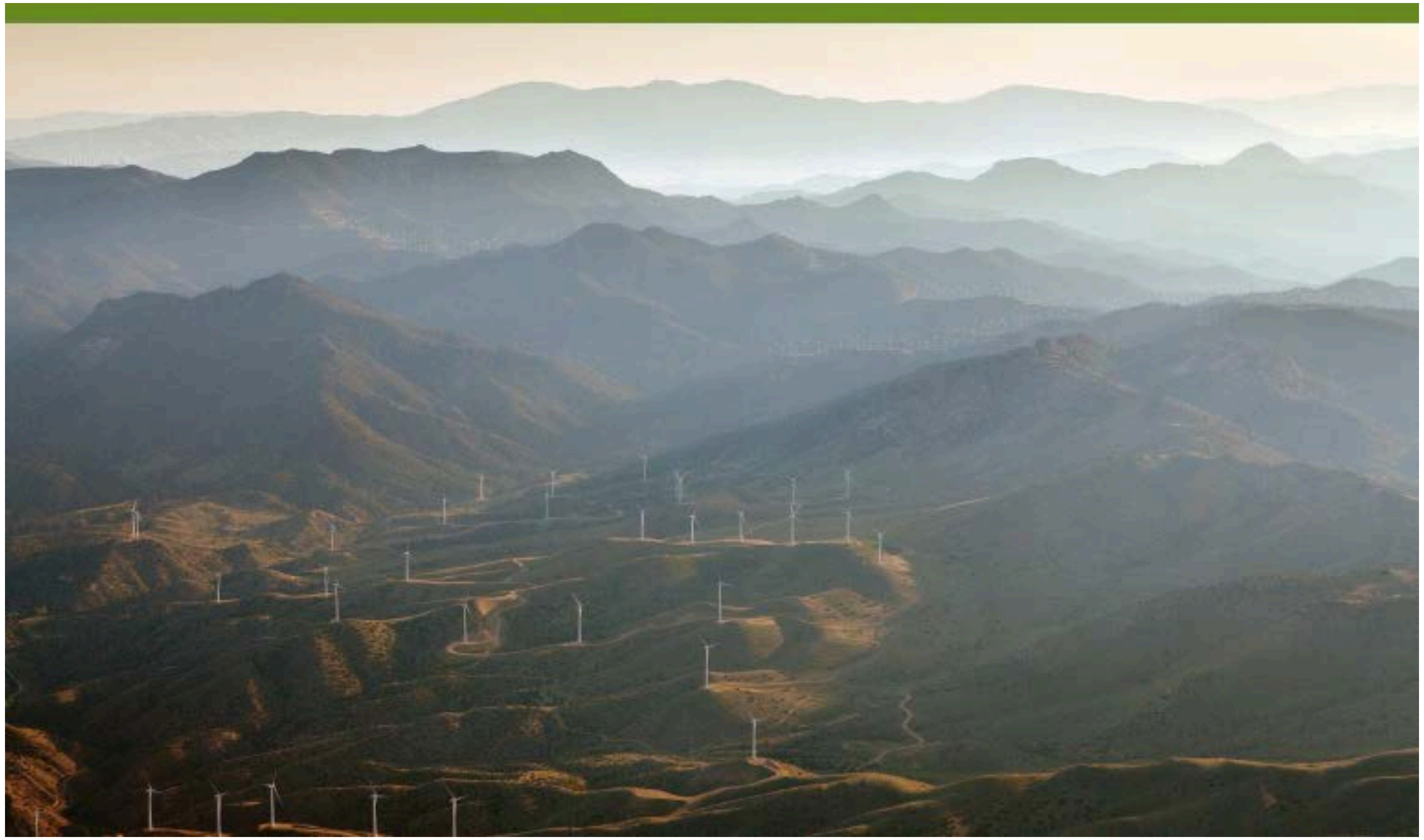
Time scale (the timing of transformation): Forest growth rates peak then slow, so forest aging is a significant driver of sequestration. Power plant and high-voltage transmission lines construction can have significant lead times (5-10 yrs).

Mean annual C sequestration rate per tree



Mokira et al. 2016 (ICRAF presentation)

Land use planning for energy and biodiversity
a case example of planning for n=2 factors



Wind turbines in the Mojave desert outside the main area of the Tehachapi corridor in California. © Ian Shive

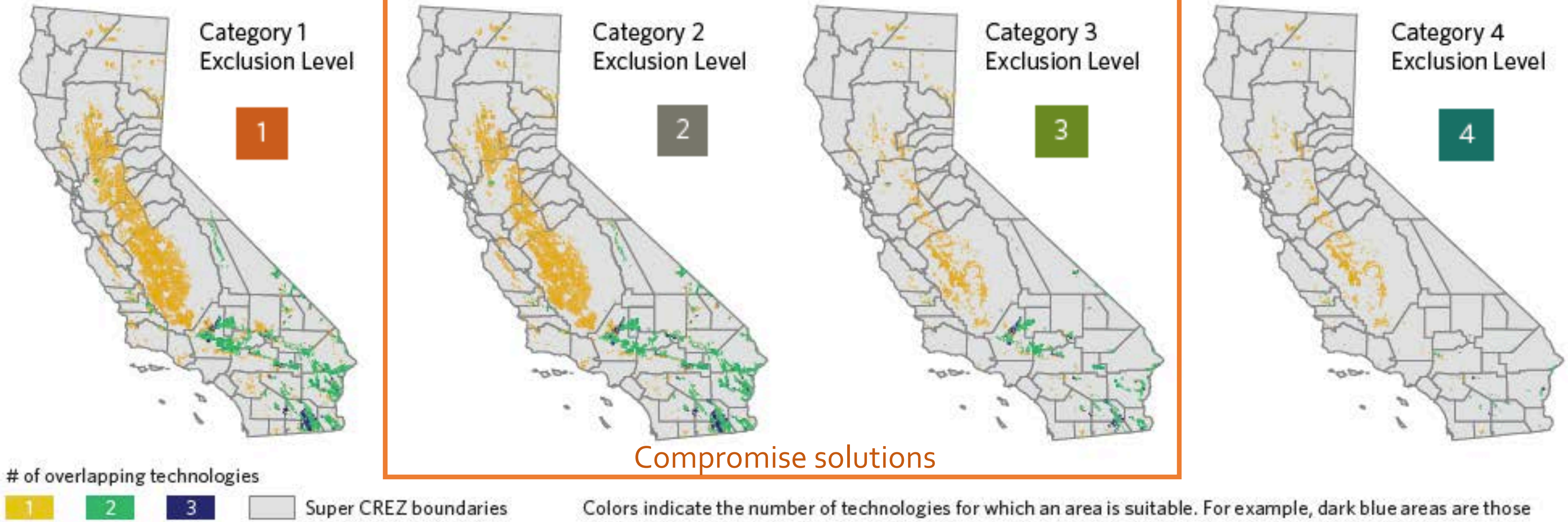
Senate Bill 350 increases California's renewable electricity procurement goal from 33% by 2020 to 50% by 2030.

This will increase the use of Renewables Portfolio Standard (RPS) eligible resources, including solar, wind, biomass, geothermal, and others.

Land use planning for energy and biodiversity

a case example of planning for n=2 factors

Increasing protection of areas with conservation value

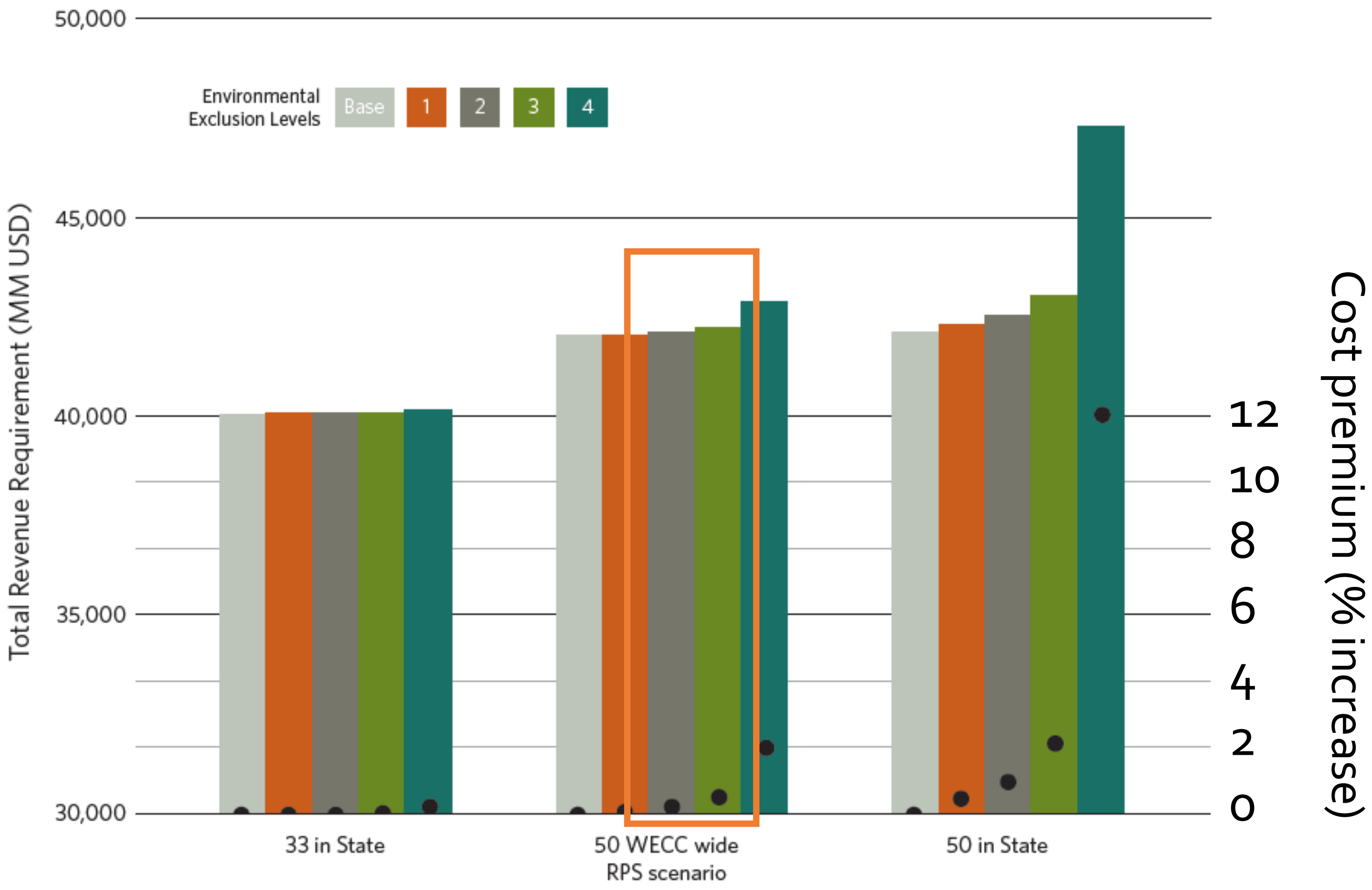


Compromise solutions

Colors indicate the number of technologies for which an area is suitable. For example, dark blue areas are those that are suitable for any possible combination of three out of the four technologies (e.g., wind, solar PV, solar CSP). The maps show suitable sites for Category 1 exclusion level through Category 4 exclusion level.

Wu et al. 2015

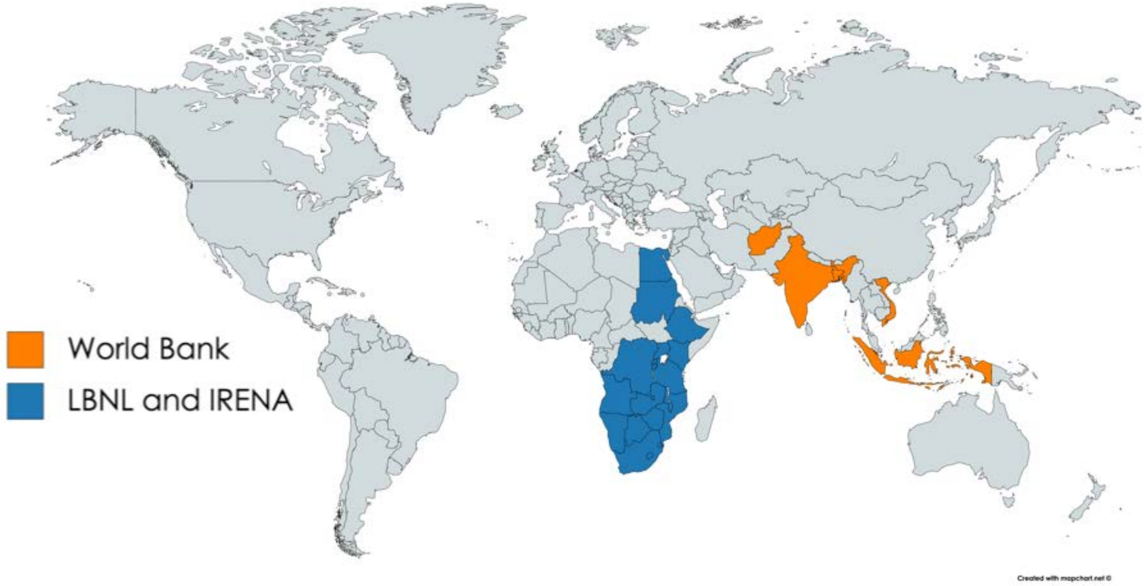
Land use planning for energy and biodiversity
a case example of planning for n=2 factors

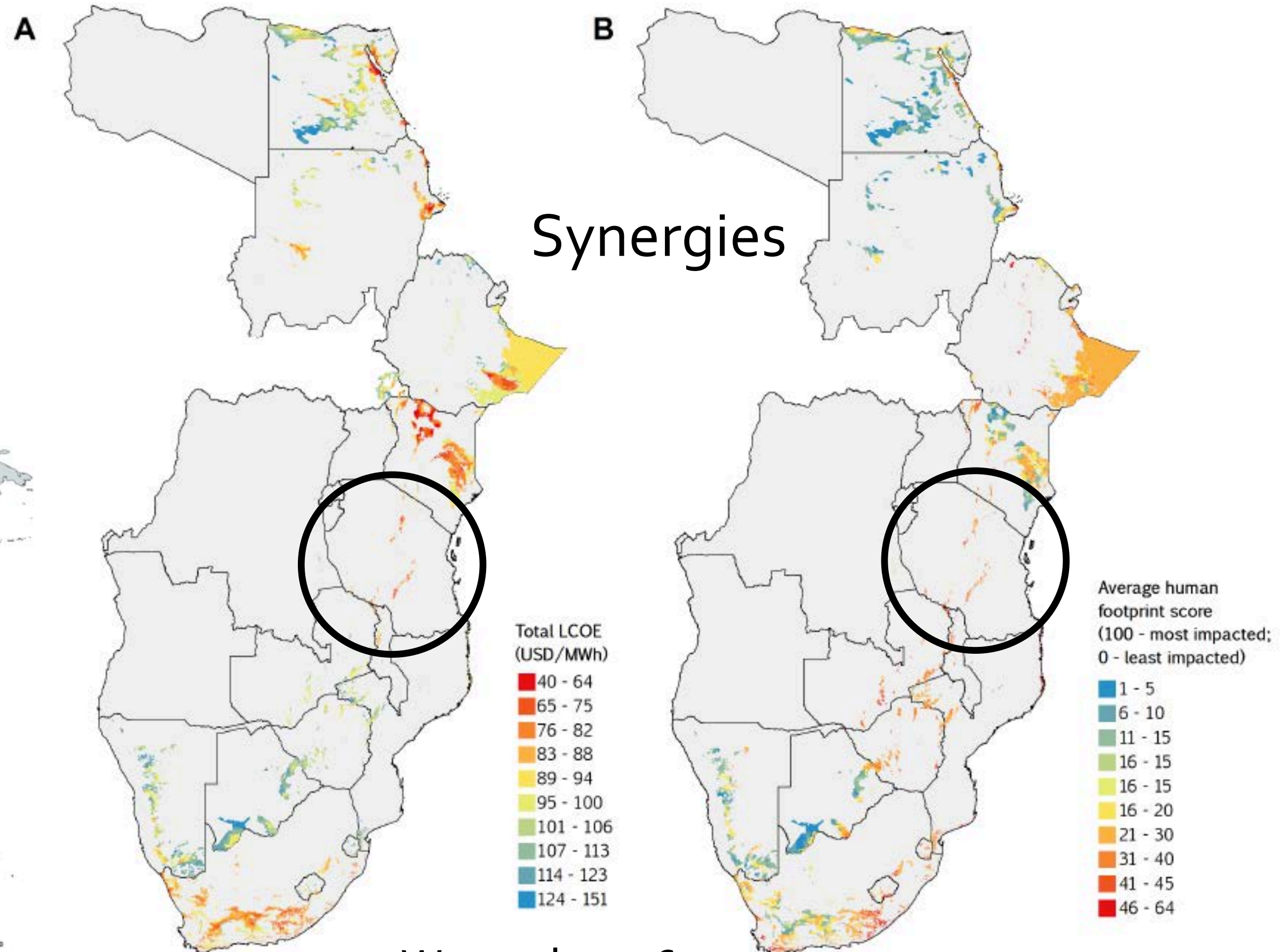


Wu et al. 2015

Managing multiple land use factors

Multi-criteria Analysis for Planning Renewable Energy (MapRE)

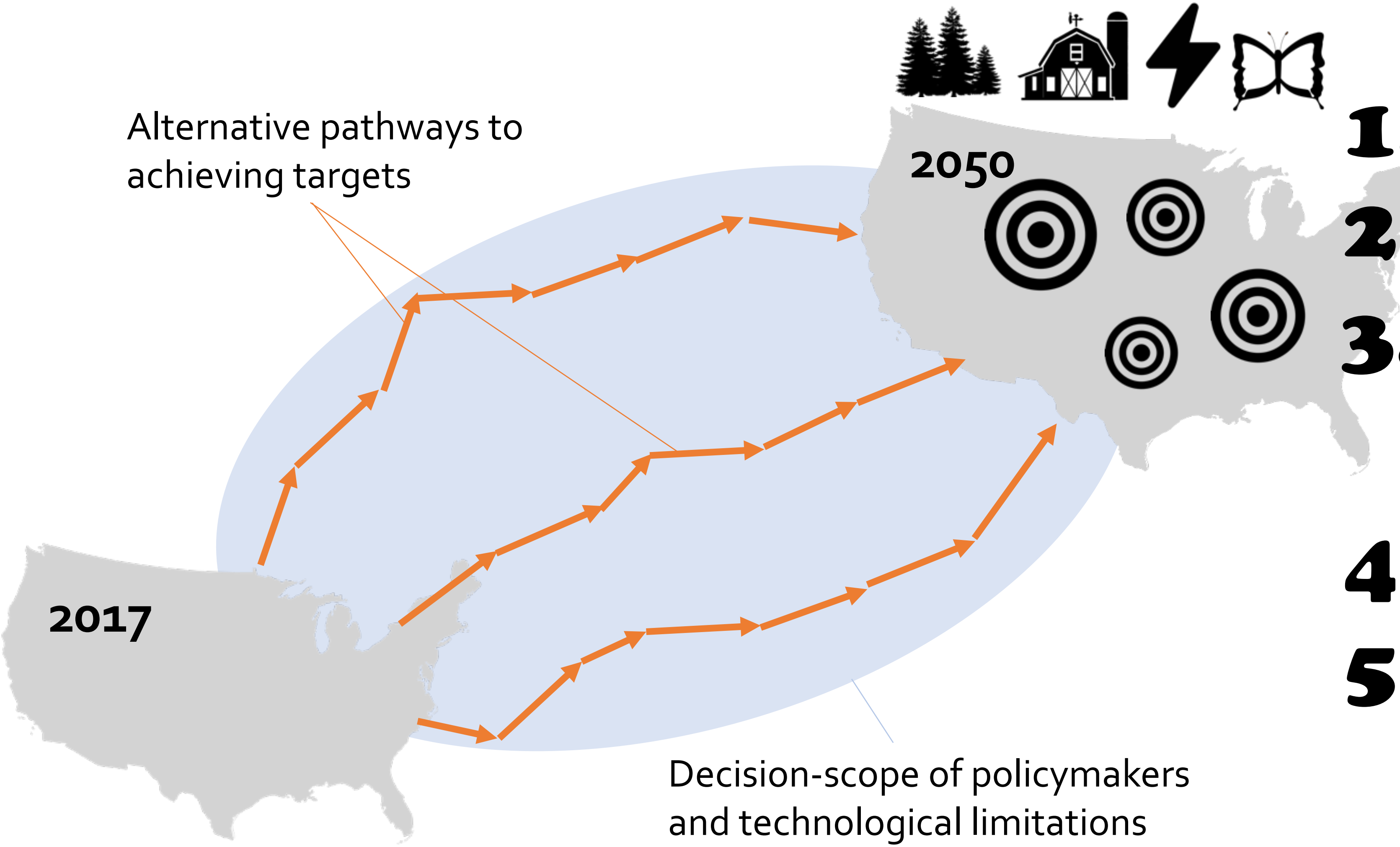




Wu et al. 2016

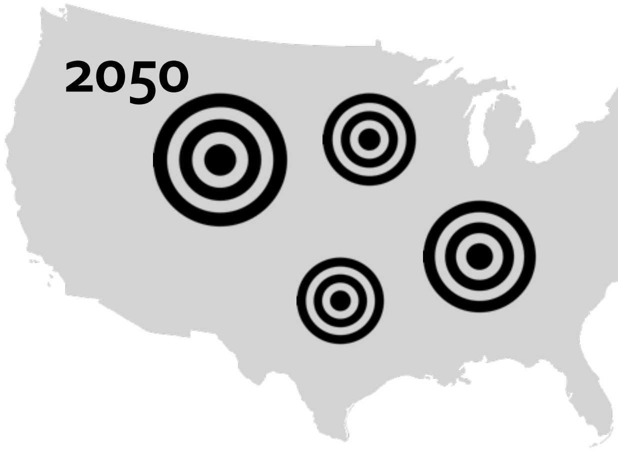
How could we approach sustainable land use planning for n = 4+ objectives?

Backcasting sustainable land use pathways



1. Set targets
2. Evaluate trade-offs
3. Identify possible technology, policy, market solutions
4. Construct pathways
5. Evaluate pathways using decision-making metrics

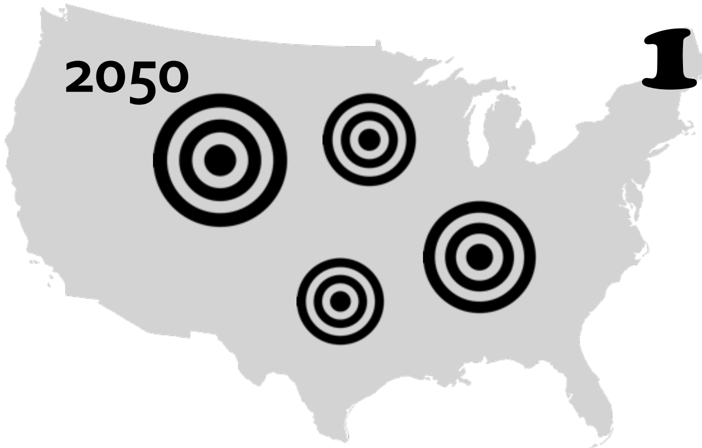
Backcasting sustainable land use pathways



1. **Set targets**
   - Habitat protected or restored
   - Land and forest based carbon sequestration
   - Crop production
   - Energy production

Backcasting sustainable land use pathways

Expanding protected areas from 13% to 17% (Venter et al. 2014)



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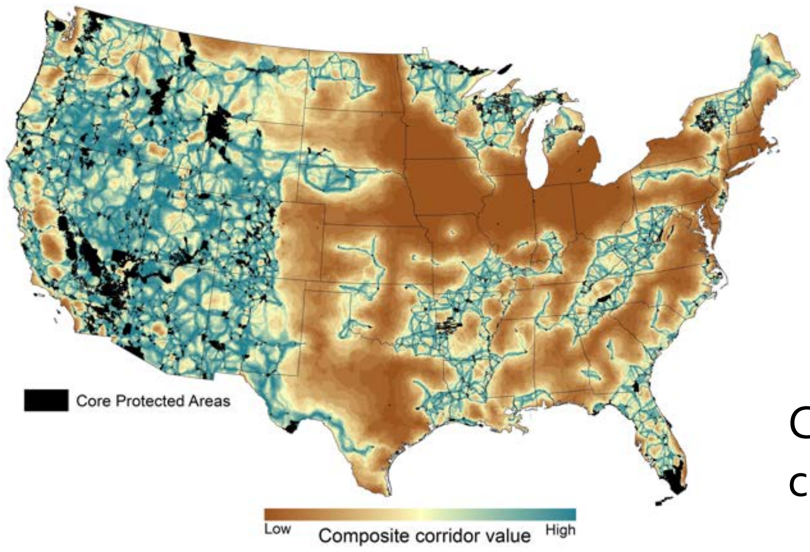


Corridors that provide linkages between core protected areas (Belote et al. 2016)

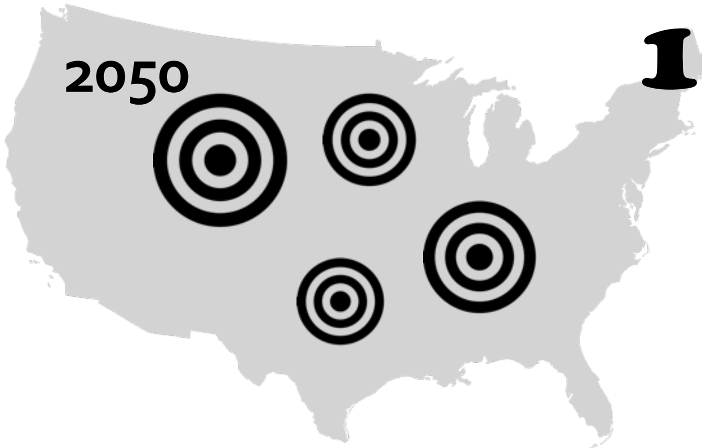
Backcasting sustainable land use pathways

Table 1. U.S. Greenhouse Gas Emissions in 1990 and 2012, with 2050 Target

	1990	2012	2050 Target
	$MtCO2_e$	$MtCO2_e$	$MtCO2_e$
CO_2 from fossil fuel combustion	4745	5066	**750**
Fossil fuel CO_2 per capita	19.0	16.1	**1.7**
Gross other GHG emissions	1485	1435	1309
Land use and forestry sink	-831	-979	-979
Net GHG emissions	5399	5522	**1080**

Data source for 1990 and 2012 emissions: (US EPA, 2014)

DDPP Williams et al. 2014



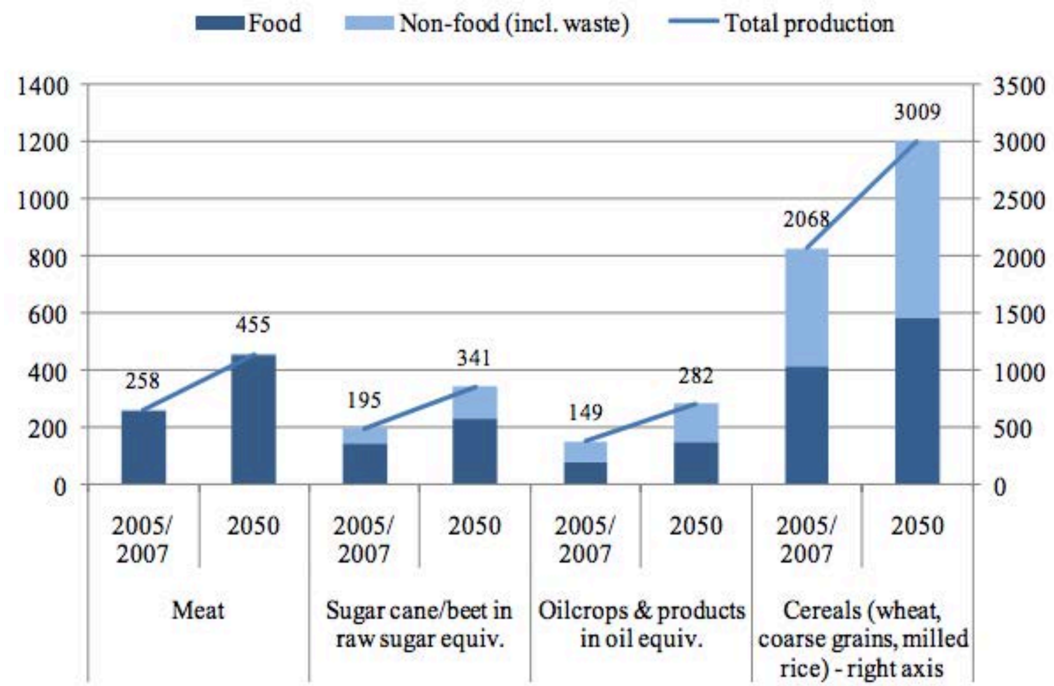
2050

1. Set targets

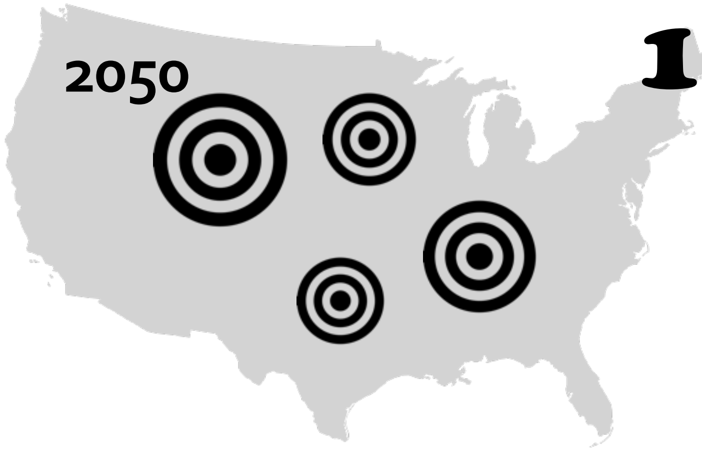
- Habitat protected or restored
- **Land and forest based carbon sequestration**
- Crop production
- Energy production

Backcasting sustainable land use pathways

World ag production and use, major products
(million tonnes)



Alexandratos and Bruinsma (2012). World Agriculture towards 2030/2050



2050

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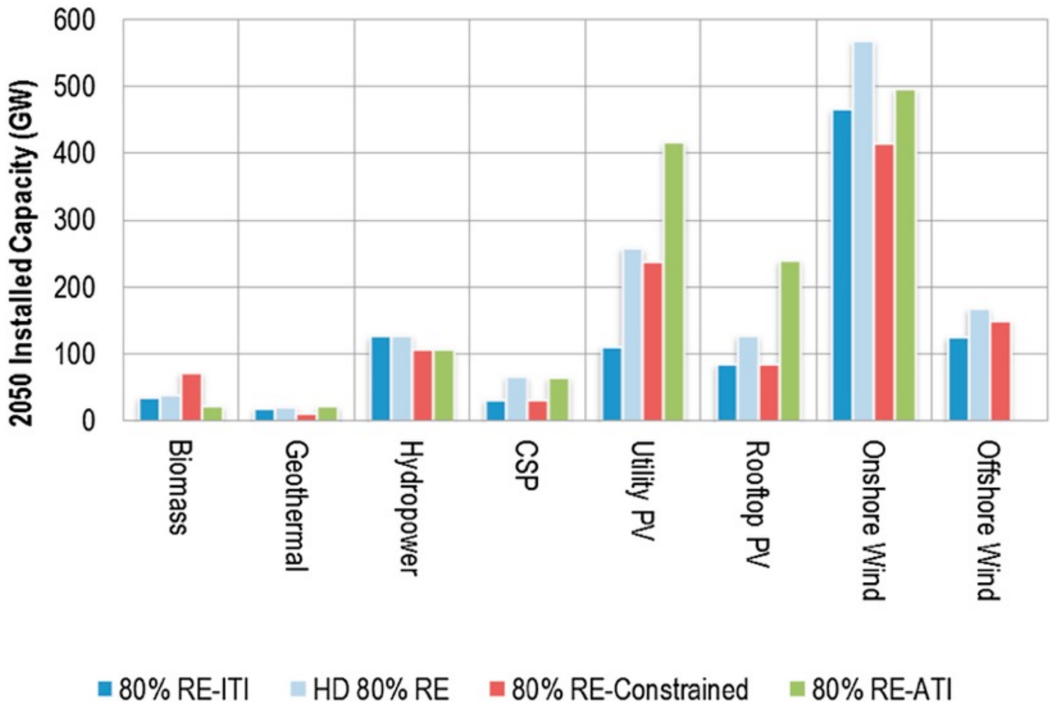
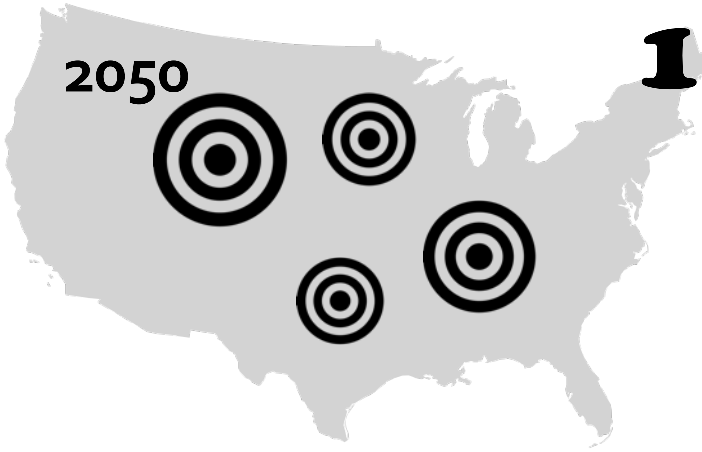
Backcasting sustainable land use pathways



Mai et al. 2014; 80% RE by 2050

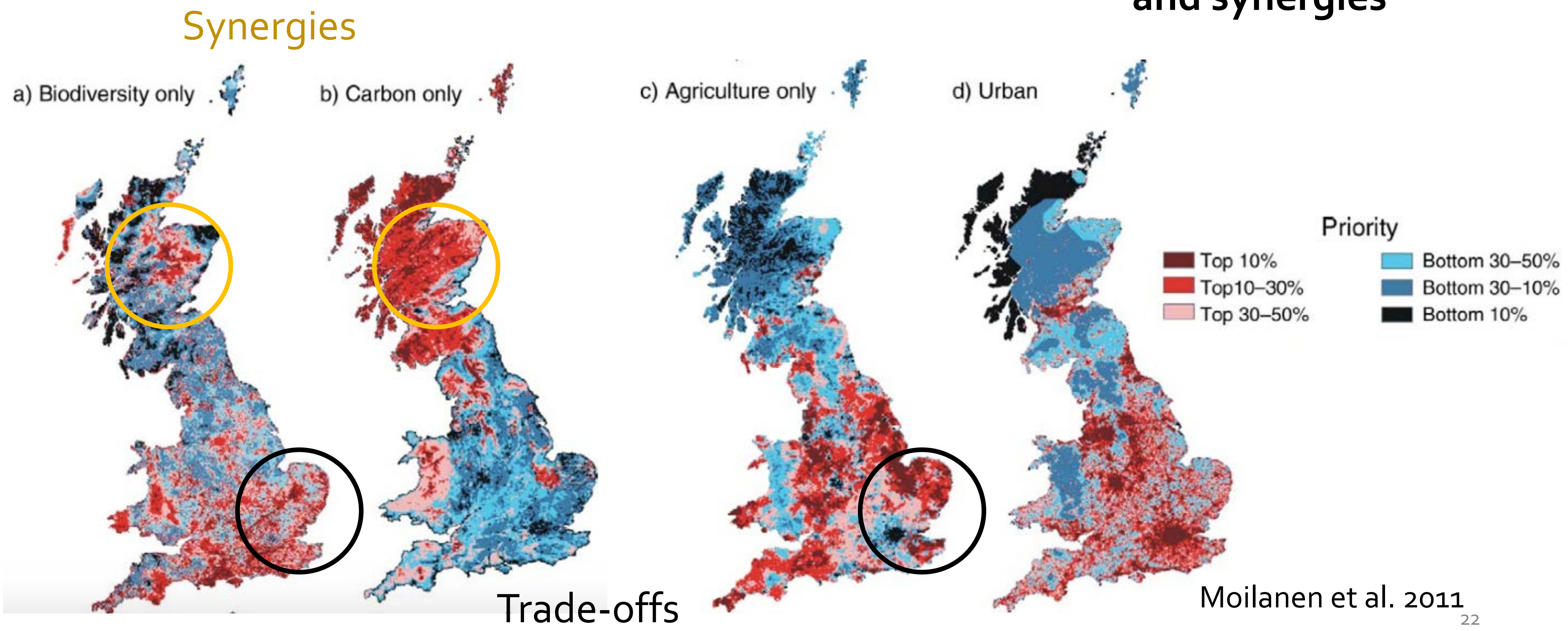


2050

1. **Set targets**
   - Habitat protected or restored
   - Land and forest based carbon sequestration
   - Crop production
   - **Energy production**

Backcasting sustainable land use pathways

2. Evaluate trade-offs and synergies



Moilanen et al. 2011

Backcasting sustainable land use pathways

PRIMARY OBJECTIVE

SECONDARY OBJECTIVE

	Carbon	Energy	Agriculture	Conser-vation
Carbon				
Energy				
Agriculture				
Conser-vation				

3. Identify possible technology, policy, market, or management sustainability solutions to meet targets

Backcasting sustainable land use pathways

PRIMARY OBJECTIVE

SECONDARY OBJECTIVE

	Carbon	Energy	Agriculture	Conser-vation
Carbon	●			
Energy				
Agriculture				
Conser-vation	●			

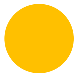
3. Identify possible technology, policy, market, or management sustainability solutions to meet targets

- Reforestation policies
- Harvest management
- Carbon credits
- Timber markets

Backcasting sustainable land use pathways

PRIMARY OBJECTIVE

SECONDARY OBJECTIVE

	Carbon	Energy	Agriculture	Conser-vation
Carbon				
Energy				
Agriculture				
Conser-vation				

3. Identify possible technology, policy, market, or management sustainability solutions to meet targets

- Improved land use efficiency via:
  - Higher hub heights for wind
  - Co-locating wind and solar
- Regulatory or market incentives to repowering aging sites

Backcasting sustainable land use pathways

PRIMARY OBJECTIVE

SECONDARY OBJECTIVE

	Carbon	**Energy**	**Agriculture**	**Conser-vation**
Carbon				
Energy				
Agriculture			●	
Conser-vation				

3. Identify possible technology, policy, market, or management sustainability solutions to meet targets

- Yield improvements via
  - Soil improvement
  - Irrigation
  - Integrated pest management

Backcasting sustainable land use pathways

PRIMARY OBJECTIVE

SECONDARY OBJECTIVE

	Carbon	Energy	Agriculture	Conser-vation
Carbon				●
Energy				
Agriculture				
Conser-vation				●

3. Identify possible technology, policy, market, or management sustainability solutions to meet targets

- Habitat restoration
- Increase extent of protected areas

Backcasting sustainable land use pathways

PRIMARY OBJECTIVE

SECONDARY OBJECTIVE

	Carbon	Energy	Agriculture	Conser-vation
Carbon			●	
Energy				
Agriculture				
Conser-vation				

Solutions that actively manage trade-offs

3. Identify possible technology, policy, market, or management sustainability solutions to meet targets

- No till agriculture
- Precision agriculture to minimize N inputs
- Rotational or mixed cropping

Backcasting sustainable land use pathways

PRIMARY OBJECTIVE

SECONDARY OBJECTIVE

	Carbon	Energy	Agriculture	Conser-vation
Carbon				
Energy			●	
Agriculture		●		
Conser-vation				

Solutions that actively manage trade-offs

3. Identify possible technology, policy, market, or management sustainability solutions to meet targets

- Co-locating pastureland or cropland with wind or solar farms
- Growing purpose-grown biomass on marginal land

Backcasting sustainable land use pathways

PRIMARY OBJECTIVE

SECONDARY OBJECTIVE

	Carbon	Energy	Agriculture	Conser-vation
Carbon				
Energy				
Agriculture	●			●
Conser-vation				

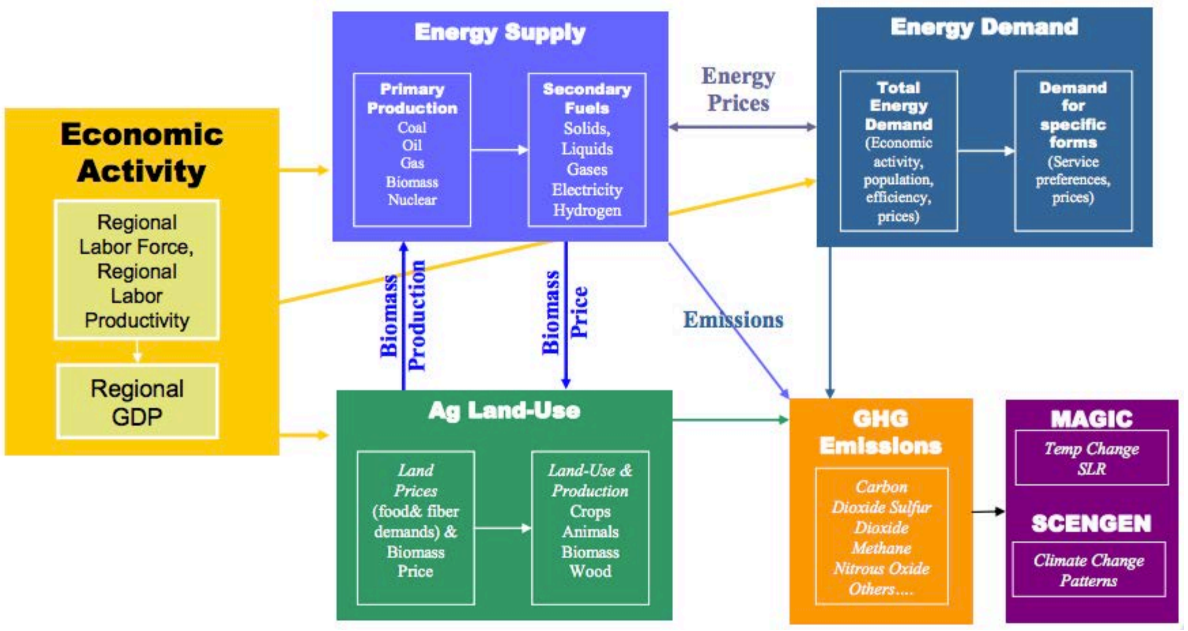
Solutions that actively manage trade-offs

3. Identify possible technology, policy, market, or management sustainability solutions to meet targets

- Conservation Reserve Program

Backcasting sustainable land use pathways

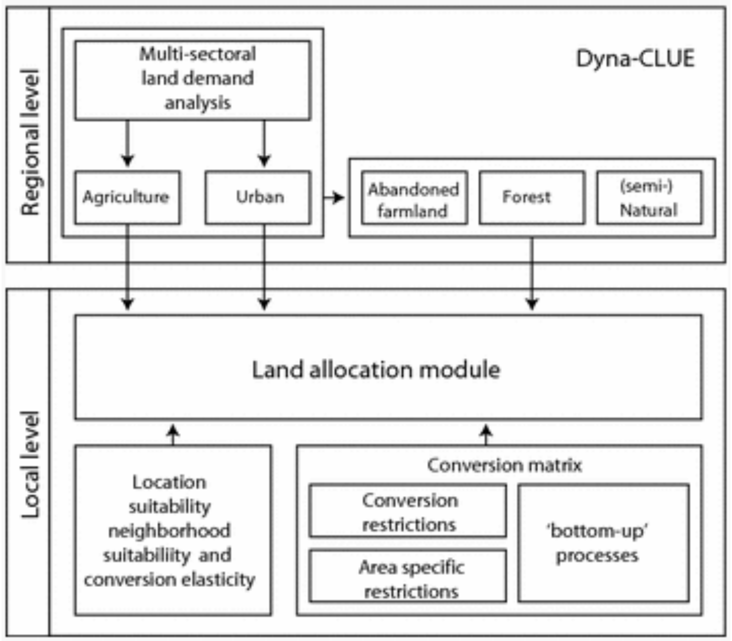
Integrated Assessment Models (e.g., GCAM)



Wise et al. 2009 (MiniCAM example; updated to GCAM)

4. Construct pathways

Sequential land allocation (optimization)



Verberg and Overmars 2009

Based on matching supply with demand and maximizing an objective

Top down ⟷ **Bottom up**

More **endogenously** determined — More **exogenously** determined

Backcasting sustainable land use pathways

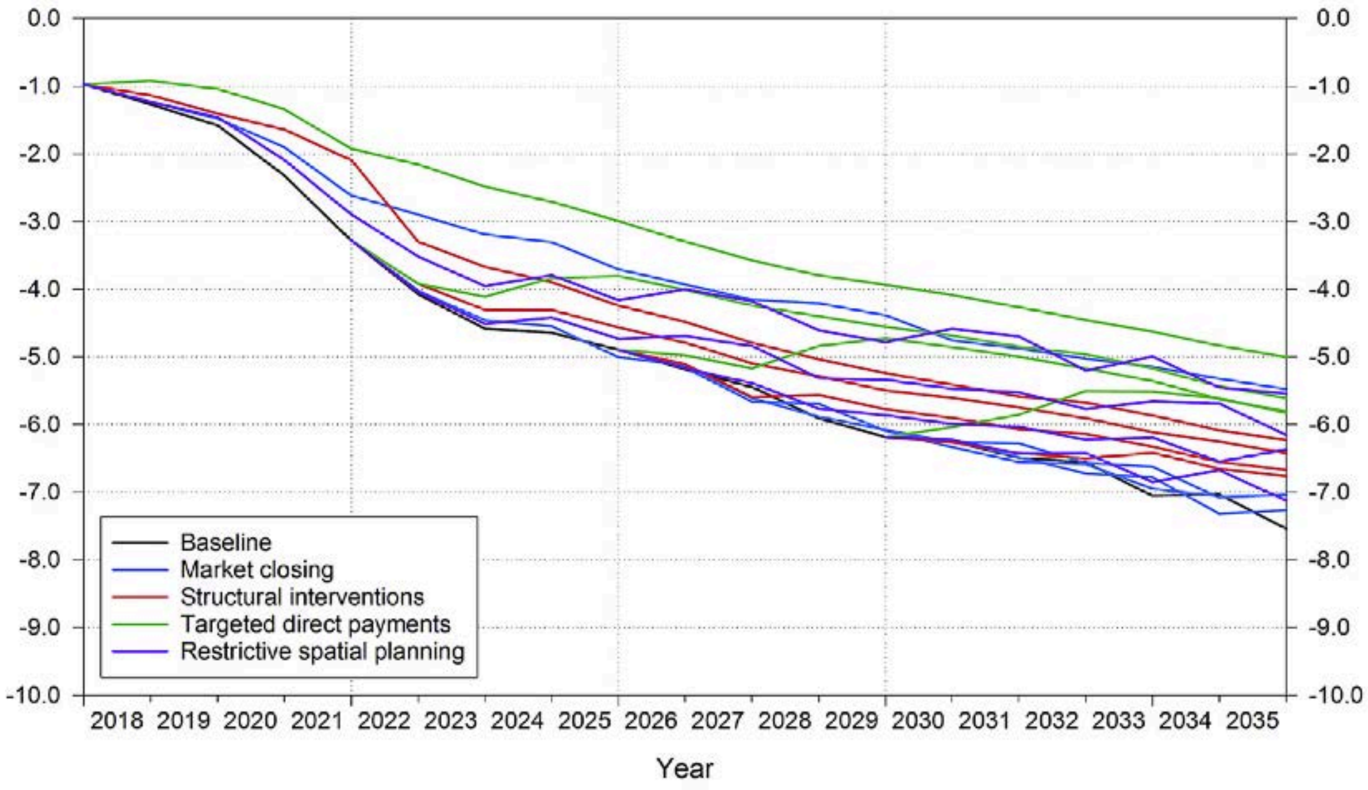
5. Evaluate pathways using decision-making metrics

Price of key commodity crops

Levelized cost of electricity

Average carbon abatement cost

Percent change in species ranges



Enabling conditions for pathways analysis

FABLE: **F**orests, **A**griculture, **B**iodiversity, **L**and, and **E**nergy

- Global linkages

Global pathways

↕ ↕

Country 1 pathway ↔ Country 2 pathway

- Stakeholder engagement and participation
  - Government
  - private-sector
  - NGOs
  - land owners

- Interdisciplinary collaboration between practitioners and academics
  - Climate
  - Agriculture
  - Conservation
  - Energy

- Regional and local land use planning

References

- Alexandratos, N. and J. Bruinsma. 2012. World agriculture towards 2030/2050: the 2012 revision. ESA Working paper No. 12-03. Rome, FAO.
- Belote RT, Dietz MS, McRae BH, Theobald DM, McClure ML, Irwin GH, et al. (2016) Identifying Corridors among Large Protected Areas in the United States. PLoS ONE 11(4): e0154223. https://doi.org/10.1371/journal.pone.0154223
- Lopez, A., B. Roberts, D. Heimiller, N. Blair, and G. Porro. U.S. Renewable Energy Technical Potentials: A GISBased Analysis. NREL/TP-6A20-51946 July 2012
- Mai, Trieu, David Mulcahy, M Maureen Hand, and Samuel F Baldwin. 2014. Envisioning a renewable electricity future for the united states. *Energy* 65:374-386
- Moilanen, Atte, Barbara J Anderson, Felix Eigenbrod, Andreas Heinemeyer, David B Roy, Simon Gillings, Paul R Armsworth, Kevin J Gaston, and Chris D Thomas. 2011. Balancing alternative land uses in conservation prioritization. *Ecological Applications* 21 (5): 1419-1426. Web
- Venter, Oscar, Richard A Fuller, Daniel B Segan, Josie Carwardine, Thomas Brooks, Stuart HM Butchart, Moreno Di Marco, Takuya Iwamura, Liana Joseph, and Damien O'Grady. 2014. Targeting global protected area expansion for imperiled biodiversity. *PLoS Biol* 12 (6): e1001891
- Verburg, Peter H and Koen P Overmars. 2009. Combining top-down and bottom-up dynamics in land use modeling: Exploring the future of abandoned farmlands in europe with the dyna-clue model. *Landscape Ecology* 24 (9): 1167. Web
- Wear, David N and John W Coulston. 2015. From sink to source: Regional variation in US forest carbon futures. *Sci Rep* 5:16518
- Williams, James H, Benjamin Haley, Fritz Kahrl, Jack Moore, Andrew D Jones, Margaret S Torn, and Haewon McJeon. 2014. Pathways to Deep Decarbonization in the United States Sustainable Development Solutions Network and Institute for Sustainable Development and International Relations
- Wise, Marshall, Katherine Calvin, Allison Thomson, Leon Clarke, Benjamin Bond-Lamberty, Ronald Sands, Steven J Smith, Anthony Janetos, and James Edmonds. 2009. Implications of limiting CO2 concentrations for land use and energy. *Science* 324 (5931): 1183-1186
- Woodall, C W, B F Walters, J W Coulston, A W D'Amato, G M Domke, M B Russell, and P A Sowers. 2015. Monitoring network confirms land use change is a substantial component of the forest carbon sink in the eastern united states. *Sci Rep* 5:17028
- Wu, Grace C, Margaret S Torn, and James H Williams. 2015. Incorporating land-use requirements and environmental constraints in low-carbon electricity planning for california. *Environ Sci Technol* 49 (4): 2013-2021