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The Effects of Increased Cycling on Local & Global Green House Gas Emissions

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Lee Honors College Honors Thesis:

The Effects of Increased Cycling on Local & Global Greenhouse Gas Emissions

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WESTERN MICHIGAN UNIVERSITY
Lee Honors College

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III. Introduction

Throughout history, the human species has been able to out-think most major problems facing us, we are amazing animals after all. Humans are the only species proved to have language, consciousness, and culture — all of which came over time with our outstandingly intelligent and adaptable brains. We've developed systems to harness the power of earth (minerals), air (wind energy), fire (combustion), and water (irrigation and also hydro energy); and we've also invented tools, workarounds, and cycles to overcome biological, physical, and other myriad roadblocks for us. Even thousands and thousands of years ago human beings were manipulating and disturbing their environments; yes we caused anthropologic changes in animal patterns and probably plant distribution back then, however those effects seem minuscule compared to what we started doing after the industrial revolution. The pillaging of coal, oil, and natural gas from beneath our planet's surface and then selling, shipping, and burning of said unrenewable fuels has damaged the Earth. For a couple of centuries any local community has been able to contribute to global atmospheric pollution, which brings multi-faceted consequences for the entire planet. But this isn't even the worst part! The worst of it is that until late, lack of urgency and comparatively meager action hasn't helped slow (not to mention reverse) companies', or communities', or countries' atmospheric impact. This apathy displayed by the human race is unacceptable. As an American I am a lead contributor to this problem.

One problem we haven't overcome yet manifests as the unescapable consequences only we are to blame for. — As residents of the Earth we have a responsibility to upkeep the planet's health and to not diminish the health of its other residents as well, at least for the sake of future life and our own posterity. This includes spreading awareness of global climate change and reversing its effects immediately. — Society's current residential, commercial, and industrial practices threaten the biosphere's health and ultimately all future life on Earth. When the tripolar states of business, civil society, and government aren't supporting reversal of this real global

threat, the best thing to do is to get active: become involved locally, in as many circles as you can to help spread concern for whatever issue you're passionate about. Together through community organization we may raise more attention to issues like the impending sequela of anthropogenic climate change. But while we're not out doing our part together, we can still help make change on an individual basis.

Being an environmentalist, I've already edited my routines and habits to minimize electricity waste, use energy efficient options, and always unplug unnecessary appliances, so then I turned to my personal transportation; I figured owning a perfectly good bicycle, being in decent physical shape, and living in a city where I could easily substitute short drives with bike rides constituted a change. How do I transport myself most? via car. Where do I drive to most? either to school or to a friend's house which is normally located near school. Also, ample (though very unsafe) sidewalks and bike lanes run most of the way, and campus has many bike racks all over the place. — It seems as though cycling will be my next environmental focus, let's follow this idea a little further.

The initial idea for my thesis came to me one day while I was considering all the changes I could make to how I live in order to benefit the planet greater: I concluded one easy change I could make that would certainly have an impact over time would be to substitute biking into my regular commuting patterns. As I mauled over the idea while actually biking around town, I began exploring finer details like just how much difference can one biker make and expanded on other tangents too. What's a(the) huge(st) biological/ecological problem humans have yet to solve? Omnipresent climate change! What's the leading cause of global climate change? Atmospheric pollutants, specifically Green House Gas emissions (GHG), which trap

heat rays in a continuous warming cycle. Where are GHG emissions sourced from? From generating electricity mostly, but transportation comes in as a close second, with industry third, followed by commercial & residential, and lastly, agriculture.[1]

*For this project when I mention GHG, if not otherwise stated, I'm focusing on CO_2*eq* emissions for the sake of numbers and consistency. CO_2 is by far the most released Green House Gas, and may have many chemical variants of itself added into the biosphere, so I felt the *CO_2 equivalent* ratio (which takes all variations of CO_2 and combines them into one balanced number) would be the most consistent unit to measure by.

[1] "Sources of Greenhouse Gas Emissions." Greenhouse Gas Emissions, United States Environmental Protection Agency, 14 Feb. 2017, https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions. Accessed 9 Apr. 2017.

IV. Questions

A. First I want to know how many students living off campus and how many students living on campus transport themselves to and from class via an automobile; and I also want to know how many commutes a week the student body generates. Next I will calculate how many total annual commutes the WMU student body drives each academic year.

B. After that I'll calculate the total annual carbon footprint of these commuting habits. Just how much CO_2*eq* are we the students adding to the atmosphere every year? Once I find this, I can create distinct projections using different miles per gallon rates and also different biking compliance rates in order to predict annual carbon saved in various scenarios.

C. After I create, analyze, and experiment with my realistic predictions, I'll start to look at larger pictures. Such as, would increased cycling actually help achieve WMU's Climate Neutrality Goal noticeably quicker? And what about, just how much would WMU students' increased cycling efforts reduce the overwhelming GHG burden that plagues our biosphere?

D. Finally, I want to know if a similar shift to bicycle commuting occurred at all universities nationwide, would any adverse impacts of climate change be prevented? Or in other words, if every American college student were to adhere to my projections, could we prevent imminent disastrous repercussions?

V. Methods

I began by asking how many students commute to and from school via an automobile of some sort. This answer was only the first of many complications down the road: I had to quantify all students living on campus who commute (often multiple times a day) via automobile, as well as the students living off campus who commute (most multiple times a day) via automobile and identify where those students were commuting from, *x* amount of times per day. I analyzed the WMU Office of Sustainability (OfS) Transportation Survey of 2011 and the Survey of 2014 results to quantify approximately how many students were driving, carpooling, or taking public transportation to/from campus as compared to those walking, biking, skateboarding, or otherwise transporting themselves (see Figure 13 & Figure 16); how many times a day those students were commuting (see Figure 12 & Figure 15); as well as where they were commuting from. — It is acknowledged that the larger offenders are in fact the faculty and professors, as they usually live within 30 miles of WMU, and thus drive much longer commutes to get to WMU than most students do. What little data that's available on faculty and professor transportation is not extensive enough to base my thesis around, so instead we're focusing on student behavior.

Next I had to estimate distances each category of student was driving. I analyzed the 2011 WMU OfS Transportation Survey results to find not only how many students commute but also from where they commuted (Figure 14 & Figure 17). I calculated mean distances traveled and multiplied these distances by three different miles per gallon values, 20 mpg, 25 mpg, & 30mpg, and then multiplied those results by the amount of CO_2*eq* emitted per gallon of gasoline burned (19.64 lbs)[2] to end up with total off campus commuting carbon emissions per week. I repeated the process by figuring out how many on campus students drive to class, and where from they drive, and estimated where they likely drive to. Once more I multiplied these distances

[2] "How much carbon dioxide is produced by burning gasoline and diesel fuel?." nnsa.energy.gov, US Energy Information Administration, 21 May 2014, https://nnsa.energy.gov/sites/default/files/nnsa/08-14-multiplefiles/DOE%202012.pdf. Accessed 23 May 2017.

by 20 mpg, 25 mpg, & 30mpg, and then multiplied those results by 19.64 lbs. of CO_2*eq* for total on campus commuting carbon emissions per week. I added up the “on campus” and “off campus” emission values, multiplied the three milage scenarios by how many times each weekday’s classes meet (28-30 times, depending) an academic year, and then scaled results up to represent all the student body, to find Western Michigan University’s total CO_2*eq* emissions per academic year due to student commuting. Based on 2014 predictions calculated in the 2011 WMU OfS Transportation Survey, WMU students driving in 2017 will emit 17,368 tons of CO_2, WMU staff driving in 2017 will emit 5,325 tons of CO_2,[3] and as a campus, drivers will emit 22,693 tons of CO_2 in 2017 (see Figure 10).

Once I calculated exactly how much carbon dioxide every commute adds to our atmosphere, I could make carbon sink projections. It came time to apply those nine distinct net calculations and create two new probable yet reasonable compliance rates for students transitioning to cycling instead of driving (see Supplemental Materials for calculations, scenarios, and projections): I came up with one “good case” ratio, Scenario A, and one “better case” ratio, Scenario B. I settled on projecting scenario A as substituting driving vehicles that get 25 mpg immediately with a 10% biking compliance rate that grows compliance by 0.5% each year, and on projecting scenario B as substituting driving vehicles that get 25 mpg immediately with a 25% biking compliance rate that grows compliance by 1.5% each year. (This time around I’ll have to pay attention to the extra variable of “compliance growth rate per year” in my formulas!) After settling on these carbon sink projections, I calculated the next half a century’s commuting emissions. I found that by simply reducing driving by “Scenario A” would help WMU reach its overall Carbon Neutrality Date goal by mid 2060, nearly five years early; if we achieve “Scenario B” WMU would reach its carbon neutrality goal by mid 2058, nearly seven years early!

[3] Pancella, Paul, and Harold Glasser. "Western Michigan University's 2012 Climate Action Plan." , 13 Apr. 2012. Accessed 20 Apr. 2017.

To accurately calculate if a similar shift in bicycle commuting occurred at all universities nationwide, what adverse effects of climate change (if any) could be prevented, I compared the adverse effects of our current emissions path, RCP 8.5 or “business as usual,” with the effects in an optimistic emissions path, RCP 4.5 or “the Paris Agreement.” Afterwards, I multiplied the difference of our two scenarios by the proportional amount of carbon saved by nationwide compliance, in order to find the proportional change to adverse conditions (assuming emissions and adverse effects are correlated linearly, which realistically, they probably are not). The first impact I wanted to study was drought risk in the American Southwest and Central plains. Benjamin Cook, Toby Ault, and Jason Smerdon wrote a research article together over this exact impact analyzing the change in the Palmer Drought Severity Index, as well as in soil moisture measurements across time. Cook et al. modeled that by end of century if present behaviors continue (RCP 8.5), the Central Plains will be at a 97% risk of having decadal droughts (11+ years), and at 85% risk of having multidecadal droughts (35+ years), according to the Palmer Drought Severity Index. Under the RCP 4.5 scenario, by end of century the Central Plains would be at a 95% risk of decadal droughts, and at a 72% risk of multidecadal droughts (see Figure 1 & Figure 2).[4] If we multiply the difference between these two scenarios by the proportional change to adverse conditions our national compliance rate of biking students could have, we find that such a shift to cycling would lower decadal drought probability by 0.0002%, and would lower multidecadal drought probability by 0.0016% — not necessarily earth-shattering results.

Another group of scientists, Katharine Hayhoe, Jeff VanDorn, Vaishali Naik, and Donald Wuebbles, analyzed future temperature and precipitation projections in the American Midwest. Hayhoe at al. found that if we continue emitting as usual by midcentury (2040 - 2069) there will likely be 14 “hot days” per decade above 100$^{\circ F}$ in Great Lakes states, and by end of century (2070 - 2100) there will likely be 31 days per decade above 100$^{\circ F}$(see Figure 3 & Figure 4). If

[4] Cook, Benjamin I., Toby R. Ault, and Jason E. Smerdon. "Unprecedented 21st century drought risk in the American Southwest and Central Plains." , American Association for the Advancement of Science, 2015. Accessed 20 Apr. 2017.

we follow the Paris agreement and can reduce emissions to the RCP 4.5 projection, Great Lakes states would only have 4 days per decade above 100°F during midcentury, and by end of century would only have 8 days above 100°F(see Figure 5).[5] If we calculate how many of these hot days per decade we could save by following the national compliance rate for biking, compared to the RCP 8.5 projection, we could prevent 0.0012 hot days per decade by mid century and 0.00275 hot days per decade by end of century. As compared to the RCP 4.5 projection we could prevent 0.00048 hot days per decade by midcentury and 0.0011 hot days per decade by end of century — essentially negligible results. This same group of scientists also analyzed heat wave risk across nine large cities in the American Midwest: Chicago, Cincinnati, Cleveland, Des Moines, Detroit, Inianapolis, Milwaukee, Minneapolis, and St. Louis (see Figure 7). I found the difference in heat waves per decade for each city (RCP 8.5 projection vs RCP 4.5 projection again), I multiplied those numbers by our proportional amount of carbon saved by biking constant to find “heat waves prevented per decade.” I assumed each city’s heatwaves killed the same amount of people that the study’s baseline heatwave killed: the Chicago heat wave of 1995 that killed 739 people over five days. After totaling up the deaths prevented per decade in each city, I found that my national biking compliance rate could save 19 lives a decade (see Figure 16 for basic calculations; see Supplemental Materials for detailed calculations). Even though this may seem like a tiny digit, this result is probably the easiest to connect with, and may hold the most value, as we’re discussing saving real people from death via bicycling.

[5] Hayhoe, Katharine, Jeff VanDorn, Vaishali Naik, and Donald Wuebbles. "Climate Change in the Midwest Projections of Future Temperature and Precipitation." , 2009. Accessed 20 Apr. 2017.

VI. Results/Conclusion

WMU's total annual CO_2*eq* emissions for 2017 are calculated to be around 108,038 ton, as found in an Excel file used to calculate numbers and figures for the 2012 WMU Climate Action Plan, given to me by the gracious and helpful Jeff Spoelstra of WMU's Office for Sustainability.

Based on 2014 predictions calculated in the 2011 WMU OfS Transportation Survey, WMU students driving in 2017 will emit 17,368 tons of CO_2, WMU staff driving in 2017 will emit 5,325 tons of CO_2, and as a campus, drivers will emit 22,693 tons of CO_2 in 2017.

I was able to calculate that under 10% biking compliance (Scenario A) we'd only emit 100,708 tons CO_2*eq* and by increasing that compliance by 0.5% a year, WMU can achieve Carbon Neutrality four and a half years early, and by 2065 can be saving save 1,020 fewer tons of CO_2*eq* annually. Under 25% compliance (Scenario B) we'd emit 100,258 fewer tons CO_2*eq* and by increasing that compliance by 1.5% a year, WMU can achieve Carbon Neutrality six and a half years earlier, and by 2065 be saving 2,550 tons of CO_2*eq* emissions annually.

After this, I calculated that if all U.S. collegiate students followed Scenario A, by 2065 we would emit 861,900 fewer tons of CO_2*eq* emissions annually; and if all U.S. collegiate students followed Scenario B, by 2065 we could save 2,154,750 tons of CO_2*eq* annually (0.005% of global CO_2*eq* emissions in 2014).[6]

[6] "Global Carbon Emissions," ProOxygen, 2017, https://www.co2.earth/global-co2-emissions. Accessed 15 May 2017.

VII. Discussion

A. Are we going to save the world? How much will this actually effect our present day atmosphere's health, and what does that mean for the Earth's future battling Climate Change? Simply put, biking will not save the climate change crisis. The results explored in this study showed me that no, this behavioral shift will not solve the problem by any means; however it highlights the importance and the effect of "small" actions over long periods of time. The more people we can get involved in change, and the longer they commit to bettering our biosphere, the larger impact we will have collectively.

This project allowed me to explore an intriguing topic, while challenging me every step of the way. From logistics to time management to data collection to projections to the very logical way of thinking I used in order to tackle roadblocks and make connected calculations; figuring out realistically what effects of climate change my school's students could possibly mitigate has been quite the ride. I am excited to expand upon the many topics discussed by this paper in future work; probably in graduate school soon.

B. Sin Can Chou et al. in Brazil assessed temperature and precipitation levels over South America under RCP 4.5 and RCP 8.5 scenarios (see Figure 9). From their findings, I focused on analyzing the difference in Summer mean precipitation in midcentury and by end of century under both projections (see Figure 8). Under high emissions, during mid century the Amazon rainforest could see a 0.000048% reduction in precipitation, and by end of century also a 0.000048% reduction. If we can lower our emissions to the Paris agreement, the Amazon may only see a reduction of 0.000019% during mid century, and also a similar reduction of 0.000019% by end of century.[7] If these trends were to continue all year around, under RCP 8.5

[7] Chou, Sin Chan, André Lyra, Caroline Mourão, Claudine Dereczynski, and Isabel Pilotto. "Assessment of Climate Change over South America under RCP 4.5 and 8.5 Downscaling Scenarios." , 27 Nov. 2014. Accessed 20 Apr. 2017.

the Amazon would suffer a 0.004310% reduction in annual precipitation soon, or under RCP 4.5 the world's largest rainforest and most biodiverse land could suffer only a 0.001724% reduction in annual precipitation. — Presently the rainforest typically sees 2,623 mm of rain per year. Over centuries the Amazon could dry up, and we could lose countless species, medicines, and myriad other natural wonders from this world forever.

VIII. Appendix

A. Figures and Graphs

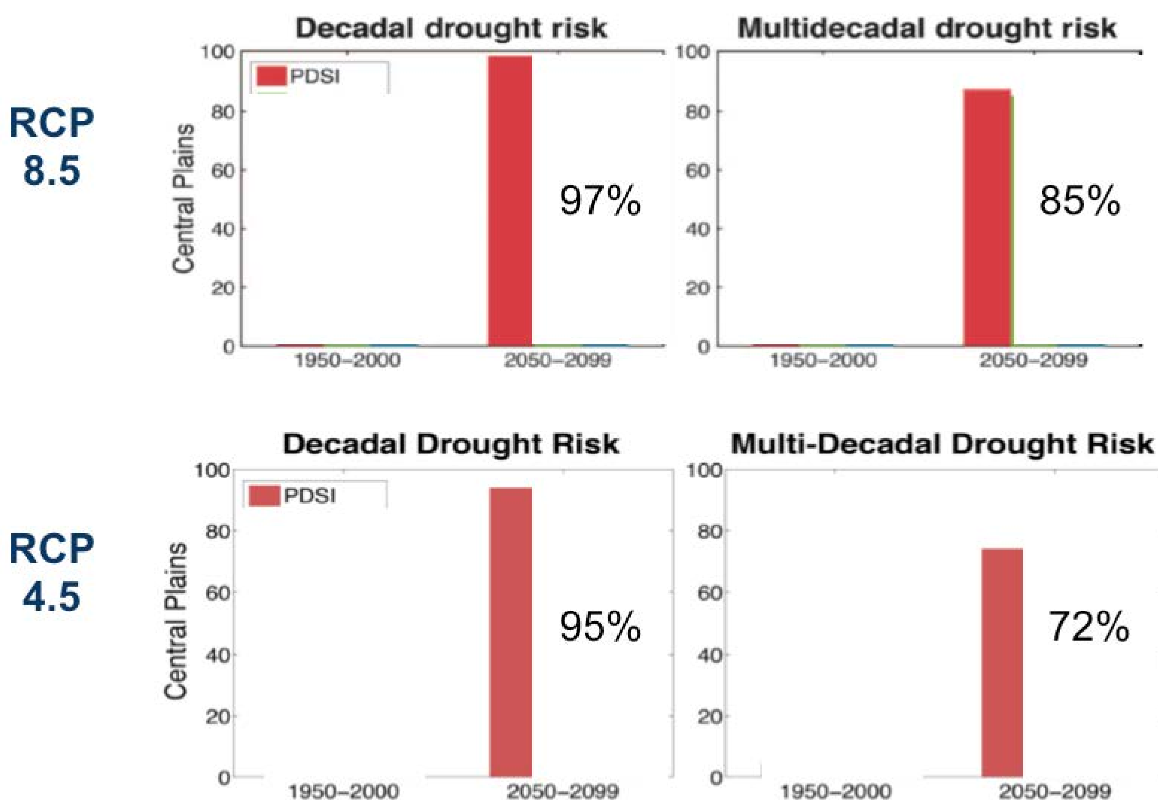
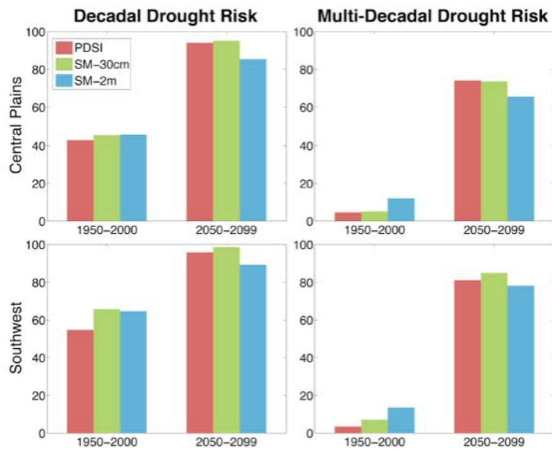


Figure 1



Supplementary Material Figure 13: Same as Figure 5 from the main manuscript, but for the RCP 4.5 scenario.

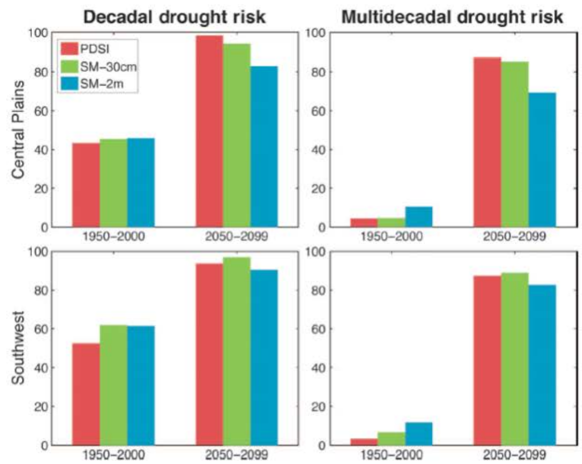


Fig. 5. Risk (percent chance of occurrence) of decadal (11-year) and multidecadal (35-year) drought, calculated from the multimodel ensemble for PDSI, SM-30cm, and SM-2m. Risk calculations are conducted for two separate model intervals: 1950–2000 (historical scenario) and 2050–2099 (RCP 8.5). Results for the Central Plains are in the top row, and those for the Southwest are in the bottom row.

Figure 2

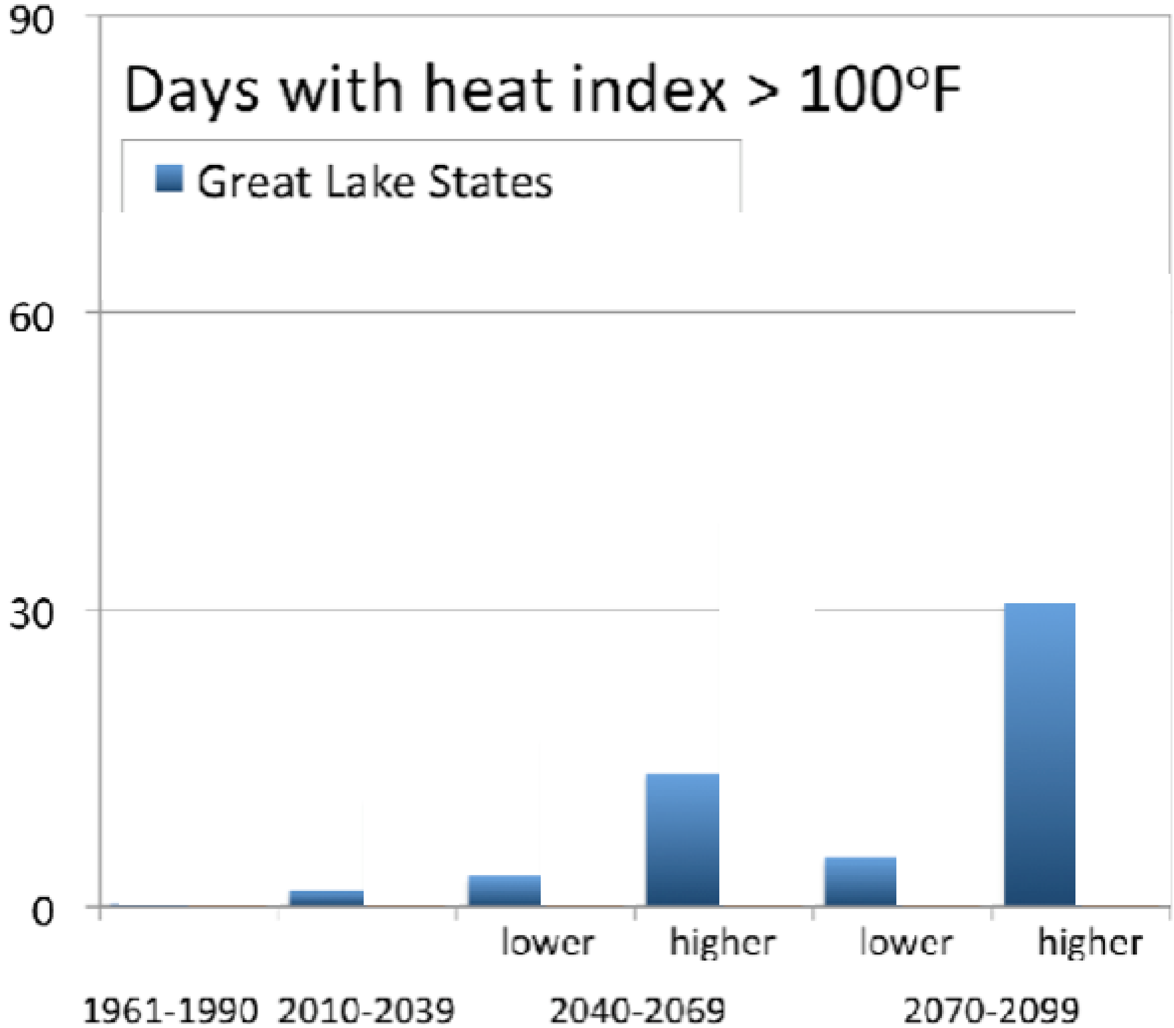

Days with heat index > 100°F
Great Lake States
90
60
30
0
lower
higher
lower
higher
1961-1990
2010-2039
2040-2069
2070-2099

Figure 3

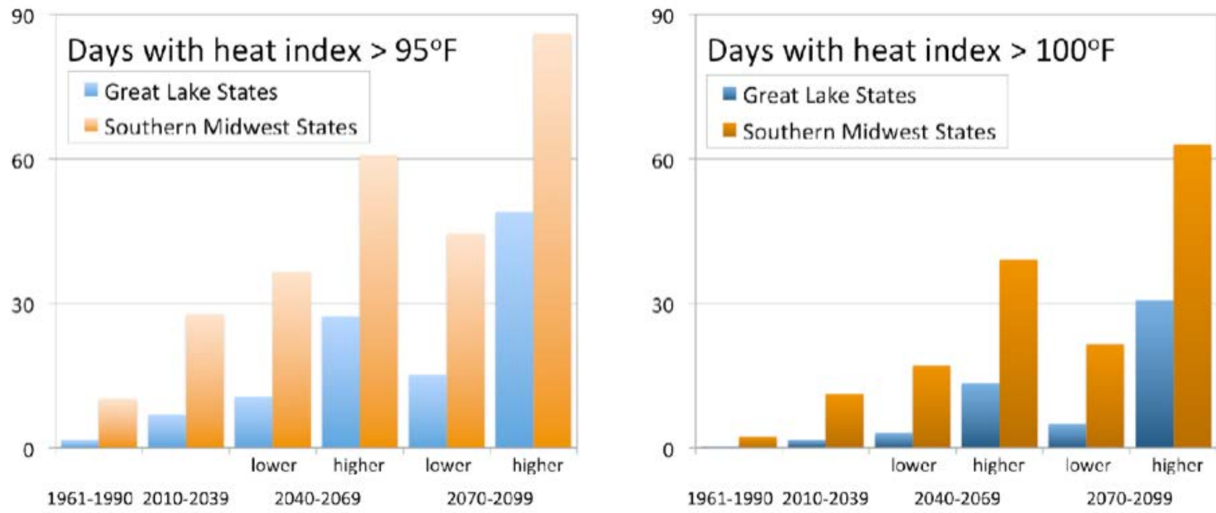

Days with heat index > 95°F
Great Lake States
Southern Midwest States
90
60
30
0
lower
higher
lower
higher
1961-1990
2010-2039
2040-2069
2070-2099
Days with heat index > 100°F
Great Lake States
Southern Midwest States
90
60
30
0
lower
higher
lower
higher
1961-1990
2010-2039
2040-2069
2070-2099

Figure 4

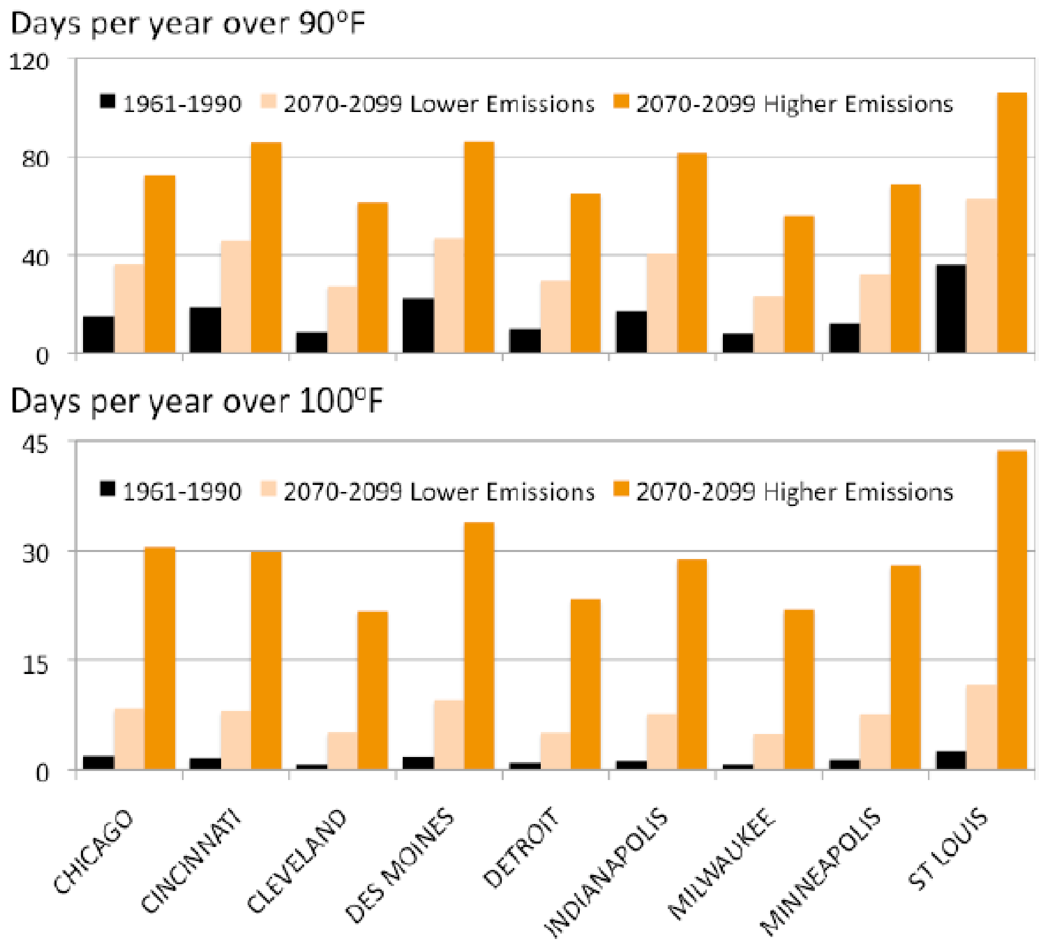


Figure 5. Historical simulated and projected future number of days over 90°F and 100°F for 9 Midwest urban centers under lower and higher emissions for 2070-2099. Value shown are the average of 3 AOGCMs.

Figure 5

City	2070-2099		Difference in heat waves per decade	Proportional amount of carbon saved	Heat waves prevented per decade	Deaths prevented per decade
	Lower	Higher				
CHICAGO	4.22	27.44	23.2	0.00012	0.0011	2.08
CINCINNATI	1.44	21.44	20.0	0.00012	0.0010	1.80
CLEVELAND	0.33	11.11	10.8	0.00012	0.0005	0.97
DES MOINES	4.33	34.44	30.1	0.00012	0.0014	2.70
DETROIT	1.44	19.33	17.9	0.00012	0.0009	1.61
INDIANAPOLIS	2.11	24.56	24.5	0.00012	0.0011	2.02
MILWAUKEE	0.78	12.67	11.9	0.00012	0.0006	1.07
MINNEAPOLIS	1.89	19.67	17.8	0.00012	0.0009	1.60
ST LOUIS	11.11	59.89	48.8	0.00012	0.0023	4.38
	(B1)	(A1F)				

Chicago Heat Wave 1995 =
739 deaths over five days

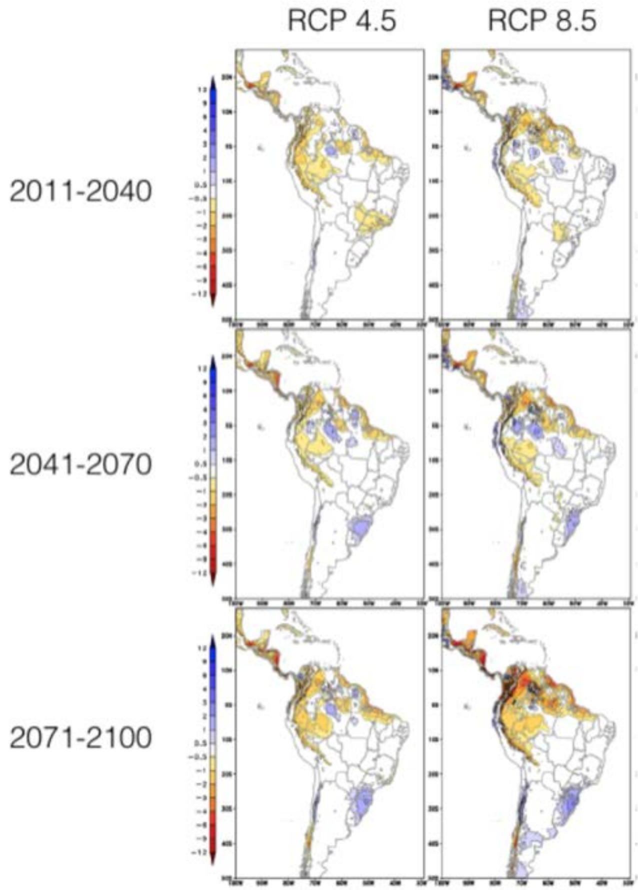
Total deaths prevented per decade = **19 people saved**

City	1961-1990	2010-2039	2040-2069		2070-2099	
			Lower	Higher	Lower	Higher
CHICAGO	0.11	1.33	2.56	11.78	4.22	27.44
CINCINNATI	0.11	0.61	0.67	7.78	1.44	21.44
CLEVELAND	0.00	0.17	0.11	2.78	0.33	11.11
DES MOINES	0.56	2.22	3.11	15.11	4.33	34.44
DETROIT	0.11	0.83	1.00	7.00	1.44	19.33
INDIANAPOLIS	0.22	0.61	1.00	9.78	2.11	24.56
MILWAUKEE	0.00	0.22	0.67	4.44	0.78	12.67
MINNEAPOLIS	0.11	0.50	0.89	7.33	1.89	19.67
ST LOUIS	1.33	6.44	10.11	29.56	11.11	59.89

Table 3. Simulated frequency of Chicago 1995-like heat waves; in units of number of events per decade for the time period indicated. Values shown are the average of 3 AOGCMs for higher and lower emission scenarios.

Figure 7

Figure 8



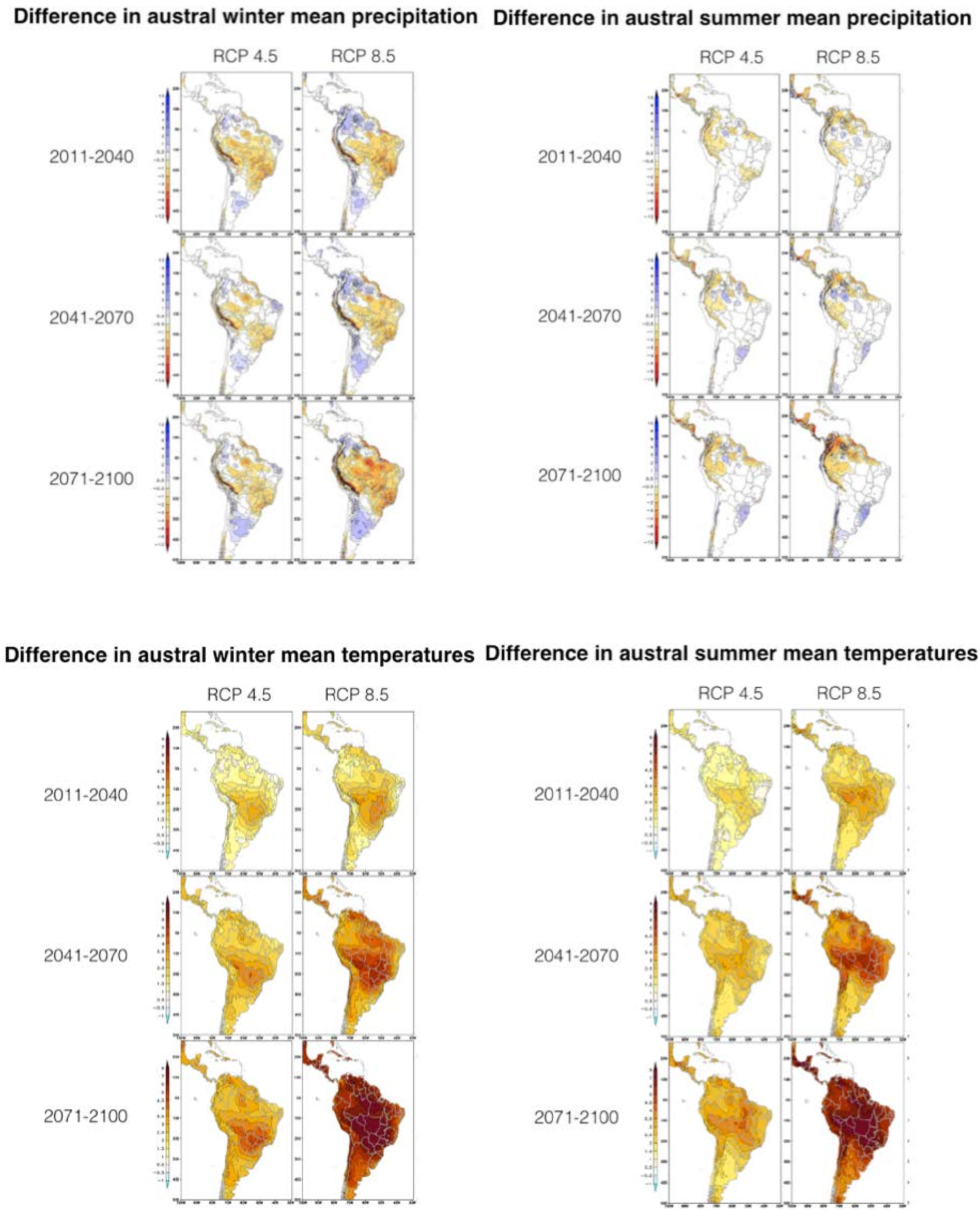

Difference in austral winter mean precipitation
Difference in austral summer mean precipitation
RCP 4.5
RCP 8.5
2011-2040
2041-2070
2071-2100
Difference in austral winter mean temperatures
Difference in austral summer mean temperatures

Figure 9

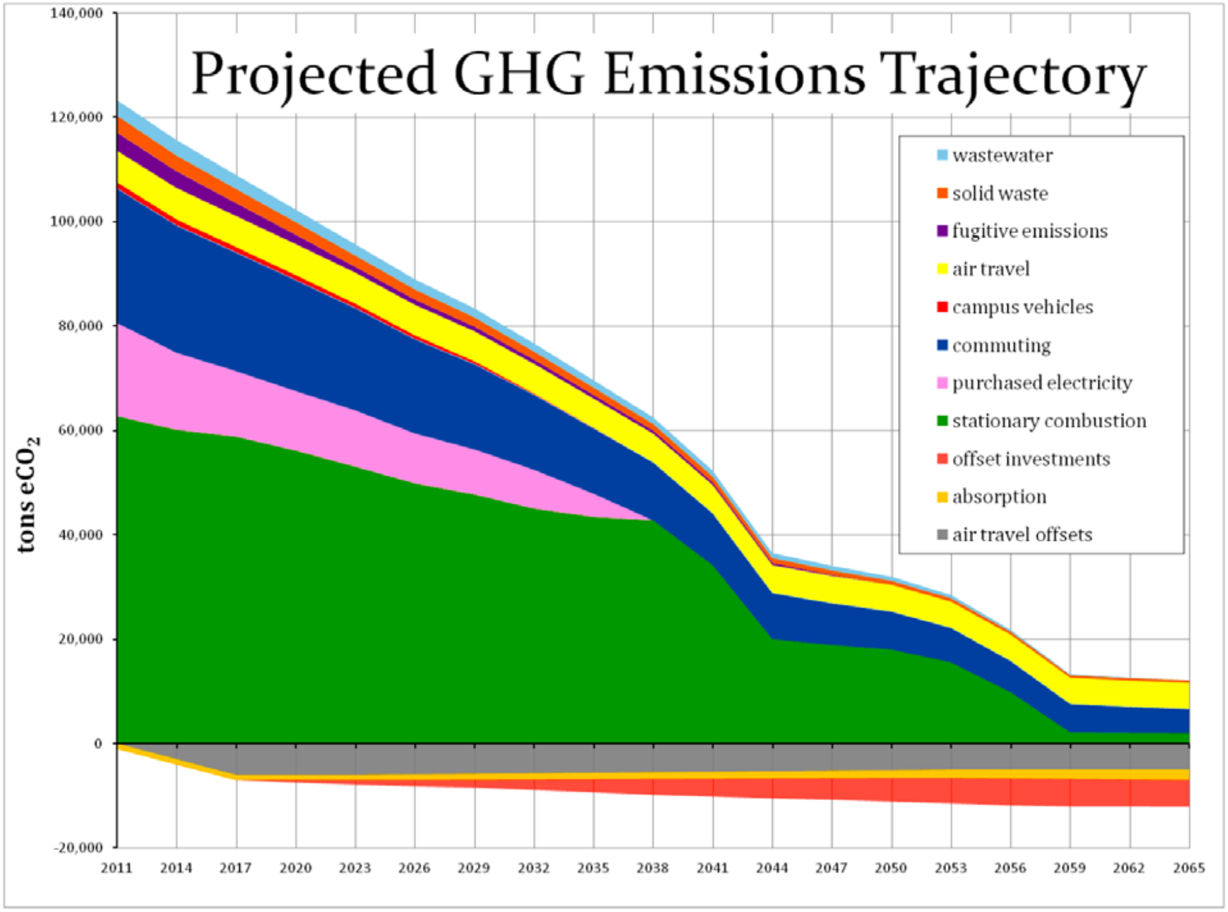


Figure 7. Proposed trajectory for GHG Emissions from present to target date. Categories are the same as Fig. 2. Strategies which subtract emissions are shown as negative on the vertical scale

Figure 10

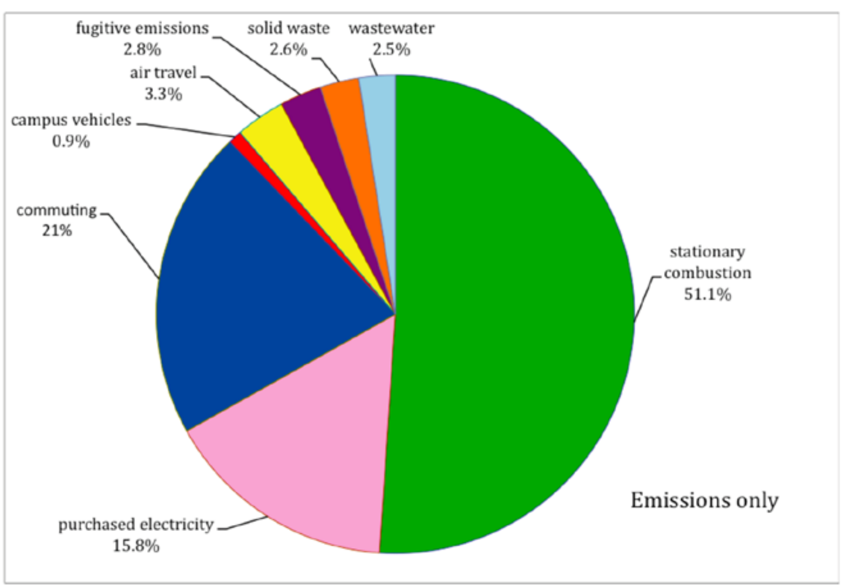


Figure 2. WMU GHG Emissions by source, as % of total emissions, data from 2009 GHG inventory

Figure 11

5. How do you commute to campus?

	0	1	2	3	4	5	Response Total	Response Average
Personal car	11.32% (80)	7.92% (56)	2.97% (21)	4.38% (31)	6.36% (45)	67.04% (474)	**707**	**3.88**
Bicycle	72.63% (398)	8.03% (44)	6.75% (37)	4.93% (27)	3.83% (21)	3.83% (21)	**548**	**0.71**
Metro Transit	55.99% (318)	11.44% (65)	4.75% (27)	8.1% (46)	7.22% (41)	12.5% (71)	**568**	**1.37**
Bronco Transit	65.27% (359)	10.36% (57)	6% (33)	6.36% (35)	5.09% (28)	6.91% (38)	**550**	**0.96**
Walk	48.42% (276)	11.05% (63)	10.53% (60)	9.82% (56)	8.6% (49)	11.58% (66)	**570**	**1.54**
Carpool	49.64% (274)	19.02% (105)	11.23% (62)	7.61% (42)	7.61% (42)	4.89% (27)	**552**	**1.19**
Motorcycle/scooter/moped	95.3% (507)	1.69% (9)	0.94% (5)	0.75% (4)	0.75% (4)	0.56% (3)	**532**	**0.12**
							Total Respondents	**734**
							(skipped this question)	337

Figure 12

7. How do you commute to campus?

	0	1	2	3	4	5	Response Total	Response Average
Personal car	60.15% (160)	12.78% (34)	10.9% (29)	6.39% (17)	4.89% (13)	4.89% (13)	**266**	**0.98**
Bicycle	86.77% (223)	5.06% (13)	3.11% (8)	1.17% (3)	2.72% (7)	1.17% (3)	**257**	**0.32**
Metro Transit	45.59% (119)	16.86% (44)	11.11% (29)	11.49% (30)	8.43% (22)	6.51% (17)	**261**	**1.4**
Bronco Transit	8.39% (24)	8.39% (24)	10.49% (30)	17.13% (49)	25.52% (73)	30.07% (86)	**286**	**3.33**
Walk	1.05% (3)	1.05% (3)	2.8% (8)	10.49% (30)	22.38% (64)	62.24% (178)	**286**	**4.39**
Carpool	49.02% (125)	22.35% (57)	13.33% (34)	7.84% (20)	4.71% (12)	2.75% (7)	**255**	**1.05**
Motorcycle/scooter/moped	98.83% (253)	1.17% (3)	0% (0)	0% (0)	0% (0)	0% (0)	**256**	**0.01**
							Total Respondents	**294**
							(skipped this question)	777

Figure 13

Figure 14

9. What area do you live nearest to?

	Response Total	Response Percent	Points	Avg
On campus	**9**	**1%**	**n/a**	**n/a**
W. Michigan and Fraternity Village	**119**	**16%**	**n/a**	**n/a**
Solon and West Main	**81**	**11%**	**n/a**	**n/a**
Vine Neighborhood	**68**	**9%**	**n/a**	**n/a**
Other Kalamazoo neighborhood	**137**	**19%**	**n/a**	**n/a**
Portage	**86**	**12%**	**n/a**	**n/a**
Other, please specify view	**241**	**33%**	**n/a**	**n/a**
Total Respondents	**728**	**100%**		
(skipped this question)		343		

8. How many commuter times to campus?

	0	1	2	3	4 or more	Response Total	Points	Avg
Monday	12.2% (93)	56.56% (431)	24.41% (186)	4.33% (33)	2.49% (19)	762	n/a	n/a
Tuesday	7.35% (56)	59.19% (451)	25.46% (194)	4.59% (35)	3.41% (26)	762	n/a	n/a
Wednesday	10.1% (77)	58.14% (443)	24.41% (186)	4.59% (35)	2.76% (21)	762	n/a	n/a
Thursday	8.27% (63)	58.4% (445)	25.07% (191)	5.12% (39)	3.15% (24)	762	n/a	n/a
Friday	24.44% (186)	55.06% (419)	16.56% (126)	1.84% (14)	2.1% (16)	761	n/a	n/a
Saturday	78.55% (597)	17.11% (130)	3.03% (23)	1.05% (8)	0.26% (2)	760	n/a	n/a
Sunday	83.55% (635)	13.03% (99)	2.37% (18)	0.92% (7)	0.13% (1)	760	n/a	n/a
					Total Respondents	762		
					(skipped this question)	618		

Figure 15

6. campus destinations

	Drive alone	Carpool	Metro Transit	Bronco Transit	Motorcyle, Mope	Walk	Bike	Skateboard	Response Total	Points	Avg
Monday	7.17% (37)	0.97% (5)	1.94% (10)	39.92% (206)	0% (0)	48.26% (249)	1.55% (8)	0.19% (1)	516	n/a	n/a
Tuesday	5.86% (30)	2.15% (11)	2.34% (12)	39.84% (204)	0% (0)	47.85% (245)	1.76% (9)	0.2% (1)	512	n/a	n/a
Wednesday	5.8% (29)	1.4% (7)	1.6% (8)	40.2% (201)	0.2% (1)	49% (245)	1.6% (8)	0.2% (1)	500	n/a	n/a
Thursday	5.86% (30)	2.34% (12)	2.54% (13)	40.82% (209)	0% (0)	46.68% (239)	1.56% (8)	0.2% (1)	512	n/a	n/a
Friday	7.38% (36)	2.25% (11)	3.69% (18)	36.07% (176)	0% (0)	48.98% (239)	1.43% (7)	0.2% (1)	488	n/a	n/a
Saturday	15.62% (60)	8.59% (33)	9.64% (37)	6.77% (26)	0% (0)	56.77% (218)	2.34% (9)	0.26% (1)	384	n/a	n/a
Sunday	17.23% (61)	8.76% (31)	2.82% (10)	5.93% (21)	0% (0)	62.43% (221)	2.54% (9)	0.28% (1)	354	n/a	n/a
								Total Respondents	341		
								(skipped this question)	1039		

Figure 16

4. Where on campus do you live?

	Response Total	Response Percent	Points	Avg
Ackley/Shilling Hall	40	12%	n/a	n/a
Bigelow Hall	2	1%	n/a	n/a
Britton/ Hadley Hall	37	11%	n/a	n/a
Burnham Hall	29	9%	n/a	n/a
Davis Hall	11	3%	n/a	n/a
Draper/ Siedschlag Hall	27	8%	n/a	n/a
Elmwood Apartments	13	4%	n/a	n/a
Eicher/ LeFevre Hall	25	7%	n/a	n/a
French Hall	14	4%	n/a	n/a
Garneau/ Harvey Hall	27	8%	n/a	n/a
Goldsworth Valley Apartments	10	3%	n/a	n/a
Harrison/ Stinson Hall	32	9%	n/a	n/a
Henry Hall	17	5%	n/a	n/a
Hoekje Hall	1	0%	n/a	n/a
Spindler Hall	7	2%	n/a	n/a
Stadium Drive Apartments	7	2%	n/a	n/a
Western View Apartment	25	7%	n/a	n/a
Zimmerman Hall	17	5%	n/a	n/a
Total Respondents	341	100%		
(skipped this question)		1039		

Figure 17

B. Sources

1. "Sources of Greenhouse Gas Emissions." Greenhouse Gas Emissions, United States Environmental Protection Agency, 14 Feb. 2017, https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions. Accessed 9 Apr. 2017.

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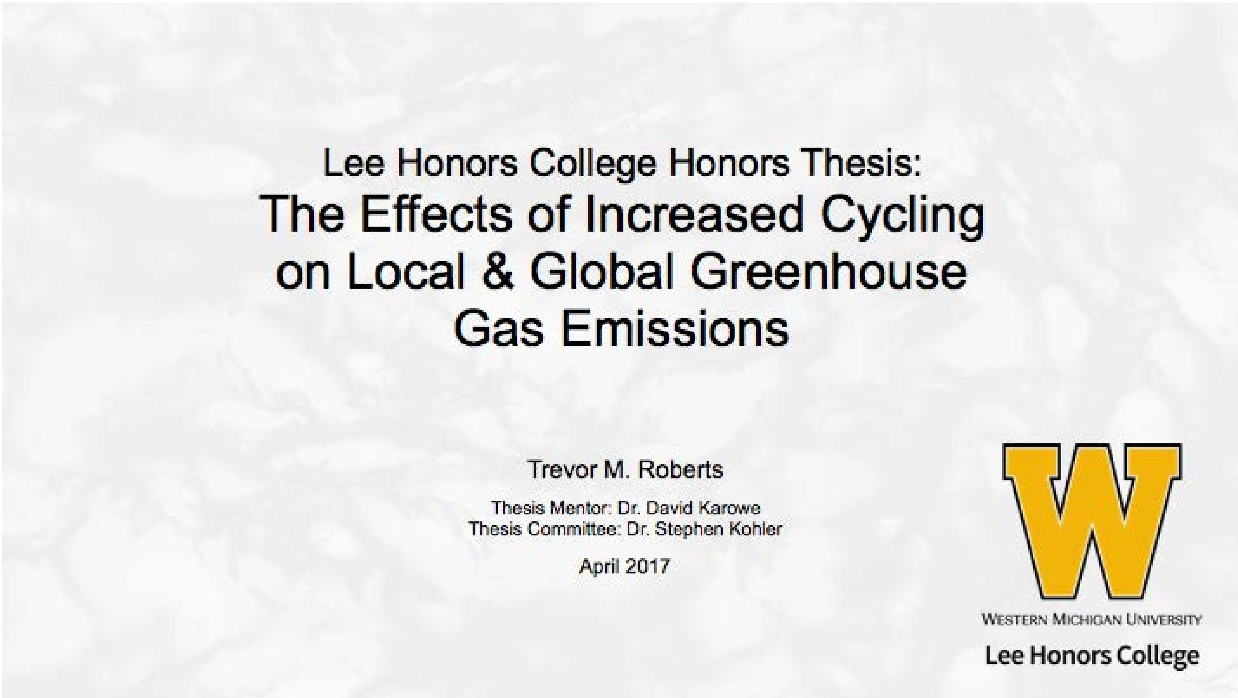
5. Hayhoe, Katharine, Jeff VanDorn, Vaishali Naik, and Donald Wuebbles. "Climate Change in the Midwest Projections of Future Temperature and Precipitation." , 2009. Accessed 20 Apr. 2017.

6. “Global Carbon Emissions,” ProOxygen, 2017, https://www.co2.earth/global-co2-emissions. Accessed 15 May 2017.

7. Chou, Sin Chan, André Lyra, Caroline Mourão, Claudine Dereczynski, and Isabel Pilotto. "Assessment of Climate Change over South America under RCP 4.5 and 8.5 Downscaling Scenarios." , 27 Nov. 2014. Accessed 20 Apr. 2017.



C. Presentation

Slide 1

Slide 2

What Causes Climate Change?

- Variation in the sun's energy reaching Earth (over millennia)
- Changes in greenhouse gasses (GHGs), which trap heat in Earth's atmosphere
- Changes in the reflectivity of Earth's atmosphere and surface

CO_2 = 76% of global GHG molecules

97.5% of the world's climate scientists agree that humans are the primary cause of current climate change.

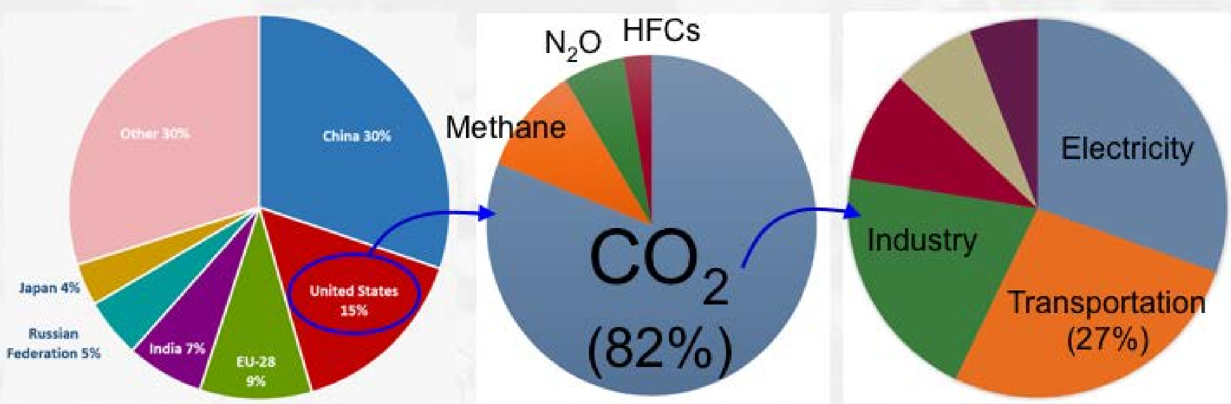
Adverse impacts will be proportional to future emissions

Slide 3

How Am I Causing Climate Change?

Global CO_2 emissions in 2014

United States greenhouse emissions in 2014



Slide 4

How Can I Cause Less Climate Change?

I can be energy savvy: unplug appliances, use LED light bulbs, leave the heat/AC off

I can recycle: recycle paper, plastics, glass, metals, and other materials

I can be an activist: volunteer time for climate action groups, take part in local/state political events

However, I drive places. A lot of places. A lot of short distances too.

Worst of all, I don't use this shiny new bike I just received nearly enough……

I can bike more: switch from car commuting to bike commuting

Slide 5

Can We Combat Climate Change with Bikes?

Research Questions

1. **How many tons of CO_2 do WMU students add to the atmosphere by driving to and from class?**
2. **How much CO_2 emissions would be prevented by a plausible shift by WMU students to bicycle commuting?**
3. **What effect would a shift to bicycle commuting have on the year in which WMU achieves carbon neutrality?**
4. **If a similar shift to bicycle commuting occurred at all universities nationwide, would any adverse impacts of climate change be prevented?**

Slide 6

Step One: Determine how many times per week/month/year WMU students drive to and from class

- Students on campus (from different dorm buildings/parking lots)
- Students off campus (from different living areas around Kalamazoo)
- Students drive multiple times a day to/from class

2014 WMU Office for Sustainability Transportation Survey included:

- Proportion of students who drove individually or carpooled regularly
- How many times a day these students commuted every day of the week
- Where they commuted from
- Assumed where they parked on campus

Slide 7

In 2014, there were 23,914 WMU students

The number of commutes differed among days

	None	1	2	3	4+
Monday	7.5%	18.9%	35.3%	20.4%	18.0%
Tuesday	6.79%	17.9%	34.57%	22.22%	18.5%
Wednesday	5.81%	19.2%	34.25%	22.63%	18.0%
Thursday	6.21%	17.39%	38.82%	20.5%	17.1%
Friday	19.37%	23.49%	31.11%	12.7%	13.3%
Saturday	50.69%	20.14%	18.06%	5.21%	5.9%
Sunday	52.31%	22.42%	15.66%	4.63%	5.0%

The number of days differed among semesters

	Fall	Spring	Summer I	Summer II
Monday	14	14	7	7
Tuesday	15	15	8	6
Wednesday	15	15	8	7
Thursday	14	15	7	8
Friday	14	14	7	8
Saturday	13	14	7	7
Sunday	13	14	7	7

- Totaled on-campus commutes per week & off-campus commutes per week
- Calculated commutes per academic year
- Scaled results up to whole WMU student body

Slide 8

Step Two: Calculate total CO_2 emissions from WMU student car commuting

- According to the US Energy Information Administration, **burning one gallon of gasoline emits 19.64 lbs. of CO_2**
- How much gas is burning per commute?

- Calculated CO_2 emissions for **three distinct scenarios:**

  I multiplied total distance driven (obtained from survey) by the three distinct average fuel efficiencies of 20 mpg, 25 mpg, or 30 mpg

Slide 9

How many tons of CO_2 do WMU students add to the atmosphere by driving to and from class?

Calculated from 2014 emissions:

- WMU students driving in 2017 will emit 17,368 tons of CO_2
- WMU staff driving in 2017 will emit 5,325 tons of CO_2
- As a campus, drivers will emit **22,693 tons of CO_2** in 2017

Slide 10

Research Questions

1. How many tons of CO_2 do WMU students add to the atmosphere by driving to and from class?
2. **How much CO_2 emissions would be prevented by a plausible shift by WMU students to bicycle commuting?**
3. What effect would a shift to bicycle commuting have on the year in which WMU achieves carbon neutrality?
4. If a similar shift to bicycle commuting occurred at all universities nationwide, would any adverse impacts of climate change be prevented?

Slide 11

How much CO_2 emissions would be prevented by a plausible shift by WMU students to bicycle commuting?

First I calculated 9 different projections:	Carbon not emitted in 2017:
20 mpg w/ 10% compliance	7405 tons
20 mpg w/ 15% compliance	7593 tons
20 mpg w/ 20% compliance	7781 tons
25 mpg w/ 10% compliance	7280 tons
25 mpg w/ 15% compliance	7405 tons
25 mpg w/ 20% compliance	7530 tons
30 mpg w/ 10% compliance	7330 tons
30 mpg w/ 15% compliance	7480 tons
30 mpg w/ 20% compliance	7630 tons

Slide 12

How much CO_2 emissions would be prevented by a plausible shift by WMU students to bicycle commuting?

Afterwards, I settled on my two realistic, achievable scenarios:

Scenario 1:

10% biking compliance
↑ 0.5% per year
(average fuel efficiency 25 mpg)

Scenario 2:

25% biking compliance
↑ 1.5% per year
(average fuel efficiency 25 mpg)

Slide 13

Research Questions

1. How many tons of CO_2 do WMU students add to the atmosphere by driving to and from class?
2. How much CO_2 emissions would be prevented by a plausible shift by WMU students to bicycle commuting?
3. **What effect would a shift to bicycle commuting have on the year in which WMU achieves carbon neutrality?**
4. If a similar shift to bicycle commuting occurred at all universities nationwide, would any adverse impacts of climate change be prevented?

Slide 14

What effect would a shift to bicycle commuting have on the year in which WMU achieves carbon neutrality?

- Next step: project my two sink scenarios on top of **WMU's 2012 Climate Action Plan**:

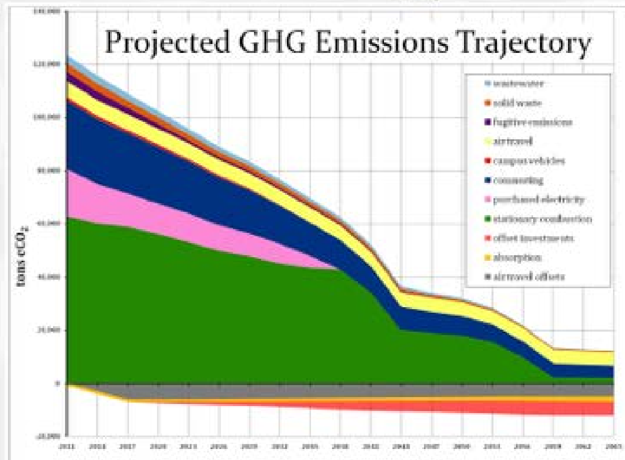
WMU's Climate Neutrality goal = 2065

10% biking compliance
↑ 0.5% per year
(drivers @25 mpg)

1

25% biking compliance
↑ 1.5% per year
(drivers @25 mpg)

2



Slide 15

What effect would a shift to bicycle commuting have on the year in which WMU achieves carbon neutrality?

- Similar to the first 9 projections, I used Excel to calculate annual carbon sink for Scenario 1 & Scenario 2
- This time, I had to pay attention to the extra variable of *growth rate per year*
- Once I had my formulas entered, for each year I individually subtracted the two new sink values from WMU's net emissions, monitoring when our emissions value reaches less than our sink value in each case

Slide 16

Even a moderate shift to bicycle commuting would accelerate the rate at which WMU achieves climate neutrality

Scenario 1

10% biking compliance
↑ 0.5% per year
(average fuel efficiency 25 mpg)

WMU reaches carbon neutrality 4.5 years earlier

WMU would emit **1,020 fewer tons** of CO_2 annually by 2065

U.S. would emit **861,900 fewer tons** of CO_2 annually by 2065

Scenario 2

25% biking compliance
↑ 1.5% per year
(average fuel efficiency 25 mpg)

WMU reaches carbon neutrality 6.5 years earlier

WMU could be saving **2,550 tons** of CO_2 annually by 2065

U.S. would emit **2,154,750 fewer tons** of CO_2 annually by 2065

Slide 17

Research Questions

1. How many tons of CO_2 do WMU students add to the atmosphere by driving to and from class?
2. How much CO_2 emissions would be prevented by a plausible shift by WMU students to bicycle commuting?
3. What effect would a shift to bicycle commuting have on the year in which WMU achieves carbon neutrality?
4. **If a similar shift to bicycle commuting occurred at all universities nationwide, would any adverse impacts of climate change be prevented?**

Slide 18

If a similar shift to bicycle commuting occurred at all universities nationwide, would any adverse impacts of climate change be prevented?

- Quantified real world adverse impacts of climate change
- Compared the "business as usual" scenario with the "Paris Agreement" scenario
- Multiplied the difference in two scenarios by the proportional amount of carbon saved by nationwide compliance
- Gives us the proportional change to adverse conditions, assuming emissions and adverse effects are correlated linearly

Slide 19

Quantifying real world adverse impacts of climate change

The Intergovernmental Panel on Climate Change (IPCC) has calculated various, internationally recognized, Representative Concentration Pathways (RCP) scenarios that project atmospheric health in multiple situations

RCP 8.5 ≈ SRES A1F

RCP 4.5 ≈ SRES B2

"Biz as Usual"
4° ↑ by 2100
1200 ppm

"Paris Agreement"
2° ↑ by 2100
550 ppm

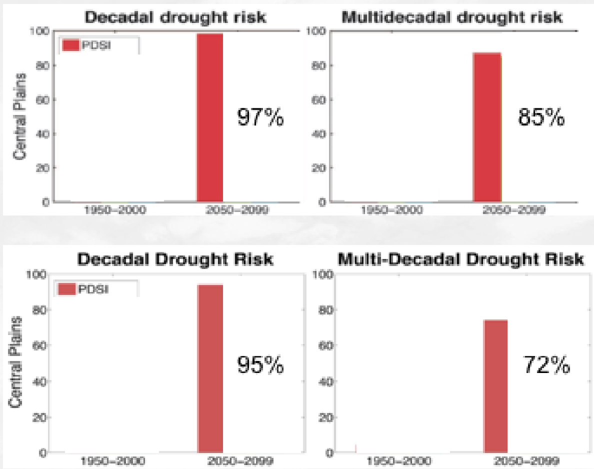
Slide 20

Will increased bicycle commuting alter 21st century drought risk in the American Central Plains?

Cook et al. (2015) modelled the probability of decadal (11 yr.) and multidecadal (35 yr.) droughts from 2050-2100 under two emissions scenarios

RCP 8.5

RCP 4.5

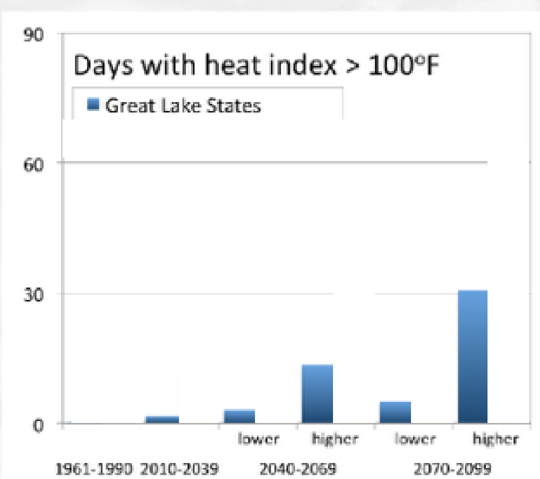


Effect on decadal drought probability:
-2%*0.00012 = -0.0002%

Effect on multidecadal drought probability:
-13%*0.00012 = -0.0016%

Slide 21

Will increased bicycle commuting alter 21st century drought risk in the American Central Plains?



Cook et al. (2015)

Hot Days in Great Lakes states:

(High A1F) 2040 - 2069 = 14 days per decade
(High A1F) 2070 - 2100 = 31 days per decade

(Low B1) 2040 - 2069 = 4 days per decade
(Low B1) 2070 - 2100 = 8 days per decade

Slide 22

Slide 23

Will increased bicycle commuting alter 21st century drought risk in the American Central Plains?

Hot Days in Great Lakes states:

(High A1F) 2040 - 2069 = 14 days
(High A1F) 2070 - 2100 = 31 days

(Low B1) 2040 - 2069 = 4 days
(Low B1) 2070 - 2100 = 8 days

Hot days prevented if all USA college students followed WMU's biking example:

(High A1F) 2040 - 2069 = 0.00120 days
(High A1F) 2070 - 2100 = 0.00275 days

(Low B1) 2040 - 2069 = 0.00048 days
(Low B1) 2070 - 2100 = 0.00110 days

Results are basically negligible

Slide 24

Will increased bicycle commuting alter 21st century heat wave risk across the American Midwest?

City	2070-2099 Lower (B1)	2070-2099 Higher (A1F)	Difference in heat waves per decade	Proportional amount of carbon saved	Heat waves prevented per decade	Deaths prevented per decade
CHICAGO	4.22	27.44	23.2	0.00012	0.0011	2.08
CINCINNATI	1.44	21.44	20.0	0.00012	0.0010	1.80
CLEVELAND	0.33	11.11	10.8	0.00012	0.0005	0.97
DES MOINES	4.33	34.44	30.1	0.00012	0.0014	2.70
DETROIT	1.44	19.33	17.9	0.00012	0.0009	1.61
INDIANAPOLIS	2.11	24.56	24.5	0.00012	0.0011	2.02
MILWAUKEE	0.78	12.67	11.9	0.00012	0.0006	1.07
MINNEAPOLIS	1.89	19.67	17.8	0.00012	0.0009	1.60
ST LOUIS	11.11	59.89	48.8	0.00012	0.0023	4.38

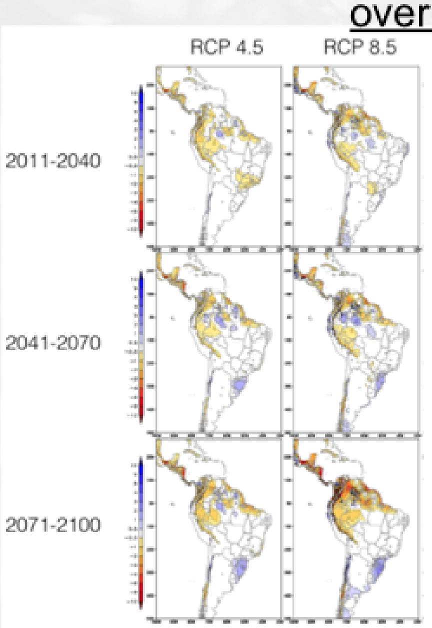
Chicago Heat Wave 1995 = 739 deaths over five days

Total deaths prevented per decade = **19 people saved**

Hayhoe et al. (2009)

Slide 25

Will increased bicycle commuting alter 21st century precipitation over the Amazon Rainforest?



Difference in summer mean precipitation (%)	Amazon Rainforest	Per season
(Low RCP 4.5) 2011 - 2040	-0.000010	-0.000862
(Low RCP 4.5) 2041 - 2070	-0.000019	-0.001724
(Low RCP 4.5) 2071 - 2100	-0.000019	-0.001724
(High RCP 8.5) 2011 - 2040	-0.000024	-0.002155
(High RCP 8.5) 2041 - 2070	-0.000048	-0.004310
(High RCP 8.5) 2071 - 2100	-0.000048	-0.004310

Chou et al. (2014)

Over centuries, the Amazon could dry up...

Slide 26

Are we going to save the planet by cycling?

No.

Slide 27

Citations:

- Pancella, Paul, and Harold Glasser. "Western Michigan University's 2012 Climate Action Plan." , 13 Apr. 2012. Accessed 20 Apr. 2017.
- Cook, Benjamin I., Toby R. Ault, and Jason E. Smerdon. "Unprecedented 21st century drought risk in the American Southwest and Central Plains." , American Association for the Advancement of Science, 2015. Accessed 20 Apr. 2017.
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Slide 28