Supplementary Materials: How Do Dietary Choices Influence the Energy-System Cost of Stabilizing the Climate?

David Bryngelsson, Fredrik Hedenus, Daniel J. A. Johansson, Christian Azar and Stefan Wirsenius

1. Method

1.1. Dietary Scenarios

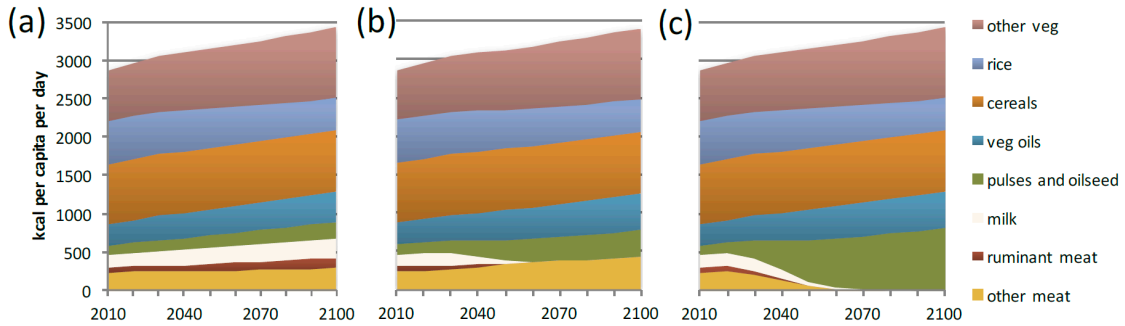

Figure S1. Global average consumption for (**a**) *Reference*, (**b**) *Climate Carnivore*, and (**c**) *Vegan* diets, expressed in kcal per capita per day.

1.2. Discount Rate

The choice of discount rate is value laden and there is no generally accepted value. We use a 5% discount rate for this study to be usable in comparisons with the literature, such as IPCC (p. 449, [1]). Actual investment decisions tend to be made based on discount rates at (more or less) that level.

Postponement of action as the main mechanisms for cost savings for the alternative diets makes the results very dependent on the choice of discount rate. A high discount rate values future payments less than a low discount rate. This means that the cost-saving effect of a low-emission diet is stronger the higher the discount rate, while a low discount rate reduces the benefits from an alternative diet, assuming that the climate goal is within reach without changing the diet. The decarbonization of the energy system eventually needs to be paid for if any climate goal is to be met and the value of postponing such a payment is higher for higher discount rates. With a hypothetical discount rate of 0 there is no financial gain in postponing the payments.

1.3. Data Tables

The same regions were used as in [2]; however, we merged Western and Eastern Europe to one region EUR. The regions are Sub-Saharan Africa (AFR), Centrally planned Asia (CPA), Europe (EUR), Former Soviet Union (FSU), Latin America & the Caribbean (LAM), Middle East and North Africa (MEA), North America (NAM), Pacific OECD (PAO), South Asia (SAS), and Pacific Asia (PAS).

We assume a linear convergence towards an assumed maximal feed efficiency. As feed-efficiency development has stalled in Sub-Saharan Africa, South Asia and Pacific Asia in the last 40 years, they are not assumed to reach the maximal feed-efficiency by 2100, see Table S1.

Table S1. Feed-efficiency for different kinds of animal food products over time. Numbers are expressed as MJ gross energy in feed/MJ metabolizable energy in edible product**.**

Region	Product	2000	2050	2100
AFR	Ruminant meat (non-dairy)	237	169	101
	Pork and poultry meat	16	11	6
	Whole milk	47	37	27
	Dairy bulls meat	100	71	43
CPA	Ruminant meat (non-dairy)	99	75	51
	Pork and poultry meat	11	8	6
	Whole milk	11	8	5
	Dairy bulls meat	54	37	20
EUR	Ruminant meat (non-dairy)	60	55	51
	Pork and poultry meat	7	7	6
	Whole milk	8	7	5
	Dairy bulls meat	23	21	20
FSU	Ruminant meat (non-dairy)	65	58	51
	Pork and poultry meat	9	8	6
	Whole milk	12	9	5
	Dairy bulls meat	25	22	20
LAM	Cereals	0	0	0
	Ruminant meat (non-dairy)	155	106	56
	Pork and poultry meat	13	10	6
	Whole milk	20	14	8
	Dairy bulls meat	77	52	28
MEA	Ruminant meat (non-dairy)	161	106	51
	Pork and poultry meat	10	8	6
	Whole milk	20	13	5
	Dairy bulls meat	52	36	20
NAM	Ruminant meat (non-dairy)	60	55	51
	Pork and poultry meat	7	7	6
	Whole milk	7	6	5
	Dairy bulls meat	25	22	20
PAO	Ruminant meat (non-dairy)	73	62	51
	Pork and poultry meat	7	7	6
	Whole milk	9	7	5
	Dairy bulls meat	30	25	20
PAS	Ruminant meat (non-dairy)	148	99	51
	Pork and poultry meat	11	8	6
	Whole milk	18	12	5
	Dairy bulls meat	81	54	27
SAS	Ruminant meat (non-dairy)	440	277	115
	Pork and poultry meat	14	10	6
	Whole milk	23	15	7
	Dairy bulls meat	198	125	52

Based on data in [3], we fit a relationship for dairy, dairy bulls and beef between the rations and feed efficiency. We find that feed rations of cereals, protein fodder and forages depend on feed efficiency, E, as $A \times E^{-a}$, whereas residues go as $b \times \ln(E) + B$. We use the same a and b for all regions but adjust A and B for each region to fit the present feed ratio. Thereby take in to consideration the overall changes in feed ratios due to increased feed-efficiency but also differences in regional endowments. What is not covered by the other feedstuffs is covered from pasture. We further assume some upper limits. For instance, no more than 45% of the feed in the dairy sector can originate from cereals. The data used can be found in Tables S2–S4.

Table S2. Feed rations in 2000.

Region	Product	Cereals	Protein	Forages	Residues	Pasture
AFR	Ruminant meat (non-dairy)	0%	-	-	30%	70%
	Pork and poultry meat	40%	5%	-	55%	0%
	Whole milk	0%	-	-	22%	78%
	Dairy bulls meat	0%	-	-	44%	56%
CPA	Ruminant meat (non-dairy)	0%	-	-	31%	69%
	Pork and poultry meat	55%	15%	-	30%	0%
	Whole milk	0%	-	-	27%	73%
	Dairy bulls meat	0%	-	-	33%	67%
EUR	Ruminant meat (non-dairy)	7%	-	43%	9%	41%
	Pork and poultry meat	70%	25%	-	5%	0%
	Whole milk	12%	10%	70%	3%	5%
	Dairy bulls meat	12%	-	65%	7%	16%
FSU	Ruminant meat (non-dairy)	14%	-	32%	8%	46%
	Pork and poultry meat	70%	25%	-	5%	0%
	Whole milk	15%	3%	30%	8%	45%
	Dairy bulls meat	15%	-	40%	6%	39%
LAM	Ruminant meat (non-dairy)	2%	-	5%	20%	73%
	Pork and poultry meat	50%	15%	-	35%	0%
	Whole milk	8%	-	-	12%	80%
	Dairy bulls meat	3%	-	8%	18%	72%
MEA	Ruminant meat (non-dairy)	2%	-	5%	34%	59%
	Pork and poultry meat	60%	20%	-	20%	0%
	Whole milk	8%	-	5%	32%	56%
	Dairy bulls meat	9%	-	8%	40%	44%
NAM	Ruminant meat (non-dairy)	19%	-	33%	4%	44%
	Pork and poultry meat	70%	25%	-	5%	0%
	Whole milk	25%	10%	60%	5%	0%
	Dairy bulls meat	37%	-	37%	3%	23%
PAO	Ruminant meat (non-dairy)	8%	-	30%	12%	50%
	Pork and poultry meat	70%	25%	-	5%	0%
	Whole milk	25%	6%	45%	4%	20%
	Dairy bulls meat	10%	-	27%	13%	50%
PAS	Ruminant meat (non-dairy)	0%	-	4%	31%	65%
	Pork and poultry meat	60%	15%	0%	25%	0%
	Whole milk	3%	1%	20%	37%	40%
	Dairy bulls meat	0%	-	10%	33%	57%
SAS	Ruminant meat (non-dairy)	0%	-	-	56%	44%
	Pork and poultry meat	45%	8%	-	48%	0%
	Whole milk	0%	-	17%	34%	49%
	Dairy bulls meat	0%	-	8%	48%	45%

Table S3. Feed rations in 2050.

Region	Product	Cereals	Protein	Forages	Residues	Pasture
AFR	Ruminant meat (non-dairy)	1%	-	1%	24%	73%
	Pork and poultry meat	52%	13%	-	35%	0%
	Whole milk	1%	1%	5%	19%	74%
	Dairy bulls meat	1%	-	1%	39%	59%
CPA	Ruminant meat (non-dairy)	1%	-	10%	27%	62%
	Pork and poultry meat	61%	19%	-	20%	0%
	Whole milk	1%	1%	21%	24%	53%
	Dairy bulls meat	1%	-	21%	27%	51%
EUR	Ruminant meat (non-dairy)	9%	-	42%	8%	41%
	Pork and poultry meat	70%	25%	-	5%	0%
	Whole milk	19%	14%	43%	1%	23%
	Dairy bulls meat	14%	-	50%	6%	30%
FSU	Ruminant meat (non-dairy)	16%	-	42%	6%	36%
	Pork and poultry meat	70%	25%	-	5%	0%
	Whole milk	32%	5%	37%	4%	22%
	Dairy bulls meat	15%	-	49%	4%	31%
LAM	Ruminant meat (non-dairy)	6%	-	16%	14%	64%
	Pork and poultry meat	58%	19%	-	23%	0%
	Whole milk	20%	1%	5%	8%	66%
	Dairy bulls meat	7%	-	16%	12%	65%
MEA	Ruminant meat (non-dairy)	6%	-	19%	27%	47%
	Pork and poultry meat	64%	22%	-	14%	0%
	Whole milk	22%	1%	11%	26%	39%
	Dairy bulls meat	15%	-	16%	35%	35%
NAM	Ruminant meat (non-dairy)	16%	-	42%	3%	39%
	Pork and poultry meat	70%	25%	-	5%	0%
	Whole milk	33%	13%	43%	4%	8%
	Dairy bulls meat	35%	-	46%	1%	18%
PAO	Ruminant meat (non-dairy)	12%	-	42%	9%	37%
	Pork and poultry meat	70%	25%	-	5%	0%
	Whole milk	35%	10%	45%	1%	9%
	Dairy bulls meat	15%	-	39%	10%	36%
PAS	Ruminant meat (non-dairy)	1%	-	15%	25%	60%
	Pork and poultry meat	64%	19%	-	17%	0%
	Whole milk	8%	2%	27%	32%	31%
	Dairy bulls meat	1%	-	22%	27%	50%
SAS	Ruminant meat (non-dairy)	1%	-	2%	49%	48%
	Pork and poultry meat	55%	15%	-	31%	0%
	Whole milk	1%	1%	24%	29%	45%
	Dairy bulls meat	1%	-	18%	41%	40%

Table S4. Feed rations in 2100.

Region	Product	Cereals	Protein	Forages	Residues	Pasture
AFR	Ruminant meat (non-dairy)	5%	-	6%	15%	74%
	Pork and poultry meat	67%	23%	-	10%	0%
	Whole milk	2%	2%	6%	15%	76%
	Dairy bulls meat	3%	-	2%	30%	65%
CPA	Ruminant meat (non-dairy)	2%	-	32%	19%	46%
	Pork and poultry meat	69%	24%	-	8%	0%
	Whole milk	3%	2%	22%	18%	54%
	Dairy bulls meat	4%	-	50%	17%	29%
EUR	Ruminant meat (non-dairy)	11%	-	42%	6%	41%
	Pork and poultry meat	70%	25%	0%	5%	0%
	Whole milk	34%	23%	43%	-	0%
	Dairy bulls meat	15%	-	50%	5%	30%
FSU	Ruminant meat (non-dairy)	16%	-	42%	3%	39%
	Pork and poultry meat	70%	25%	0%	5%	0%
	Whole milk	45%	15%	40%	-	-
	Dairy bulls meat	15%	-	50%	2%	33%
LAM	Ruminant meat (non-dairy)	16%	-	42%	2%	40%
	Pork and poultry meat	68%	24%	0%	8%	0%
	Whole milk	45%	3%	6%	-	46%
	Dairy bulls meat	15%	-	50%	1%	34%
MEA	Ruminant meat (non-dairy)	16%	-	42%	14%	28%
	Pork and poultry meat	69%	25%	-	7%	0%
	Whole milk	45%	6%	12%	16%	21%
	Dairy bulls meat	15%	-	46%	24%	14%
NAM	Ruminant meat (non-dairy)	16%	-	42%	1%	41%
	Pork and poultry meat	70%	25%	-	5%	0%
	Whole milk	35%	17%	43%	2%	3%
	Dairy bulls meat	35%	-	50%	-	15%
PAO	Ruminant meat (non-dairy)	16%	-	42%	5%	37%
	Pork and poultry meat	70%	25%	-	5%	0%
	Whole milk	35%	19%	45%	-	1%
	Dairy bulls meat	26%	-	50%	6%	18%
PAS	Ruminant meat (non-dairy)	6%	-	42%	12%	40%
	Pork and poultry meat	69%	24%	-	7%	0%
	Whole milk	37%	11%	31%	22%	0%
	Dairy bulls meat	4%	-	50%	16%	30%
SAS	Ruminant meat (non-dairy)	11%	-	28%	33%	28%
	Pork and poultry meat	68%	23%	-	9%	0%
	Whole milk	10%	6%	27%	19%	38%
	Dairy bulls meat	7%	-	50%	27%	16%

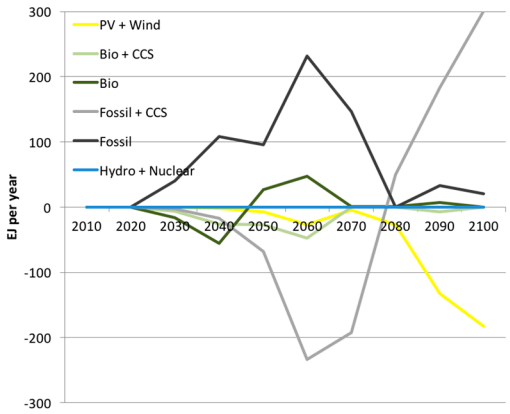

Figure S2. The differences in energy system development between the *Vegan* and *Reference* scenarios.

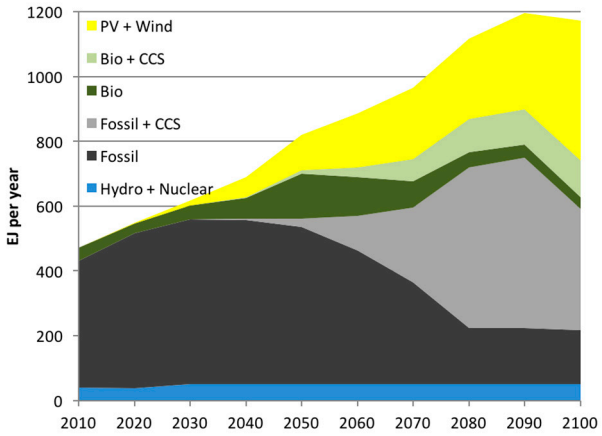

Figure S3. Global primary energy supply in EJ/year for staying below the 2 °C limit with the *Vegan* diet and 150 EJ/year bioenergy potential.

References

1. Clarke, L.; Jiang, K.; Akimoto, K.; Babiker, M.; Blanford, G.; Fisher-Vanden, K.; Hourcade, J.-C.; Krey, V.; Kriegler, E.; Lo'schel, A.; et al. Assessing transformation pathways. In *Climate Change 2014: Mitigation of Climate Change*; Edenhofer, O., Pichs-Madruga, R., Sokona, Y., Farahani, E., Kadner, S., Seyboth, K., Adler, A., Baum, I., Brunner, S., Eickemeier, P., et al., Eds.; Cambridge University Press: Cambridge, UK; New York, NY, USA, 2013.
2. International Institute for Applied Systems Analysis. GGI Scenario Database, 2nd ed. Available online: http://www.iiasa.ac.at/web-apps/ggi/GgiDb/dsd?Action=htmlpage&page=regions (accessed on 28 November 2014)
3. Hedenus, F.; Wirsenius, S.; Johansson, D.J.A. The importance of reduced meat and dairy consumption for meeting stringent climate change targets. *Clim. Chang.* **2014**, *124*, 79–91.