Technical Challenges to Attaining a Low Carbon Society:

The Case of Stabilization at 2.6 Wm^{-2}

1ST Annual Researchers Meeting of the International Research Network for Low-Carbon Societies

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(Presented by Jae Edmonds)

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Office of Science
U.S. DEPARTMENT OF ENERGY

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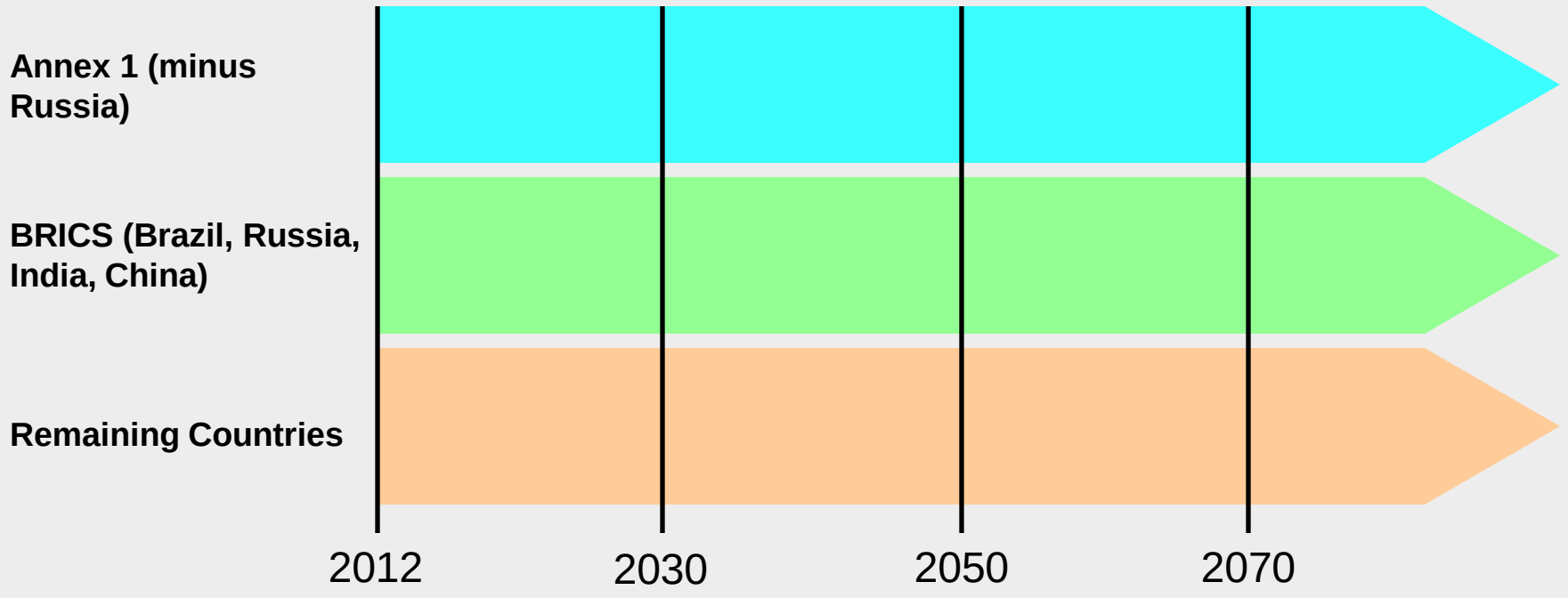
PNNL-SA-60765

A Quick Cross-walk between W/m^2, CO_2-e and CO_2 Concentrations

- Carbon and CO_2
- 1 ton C = 44/12 tons CO_2

Radiative forcing (2005=2.36 W/m2 Kyoto Gases)	**CO_2 Equivalent Concentration** (2005=435 ppm_e Kyoto gases)	**Atmospheric CO_2 Concentration** (2005=381 ppm)
2.6 W/m^2	450 ppm_e	383 ppm (depends on non-CO_2 gases)
3.7 W/m^2	550 ppm_e	445 ppm (depends on non-CO_2 gases)
4.5 W/m^2	650 ppm_e	520 ppm (depends on non-CO_2 gases)

Full Participation: All Begin Reductions Immediately: S1



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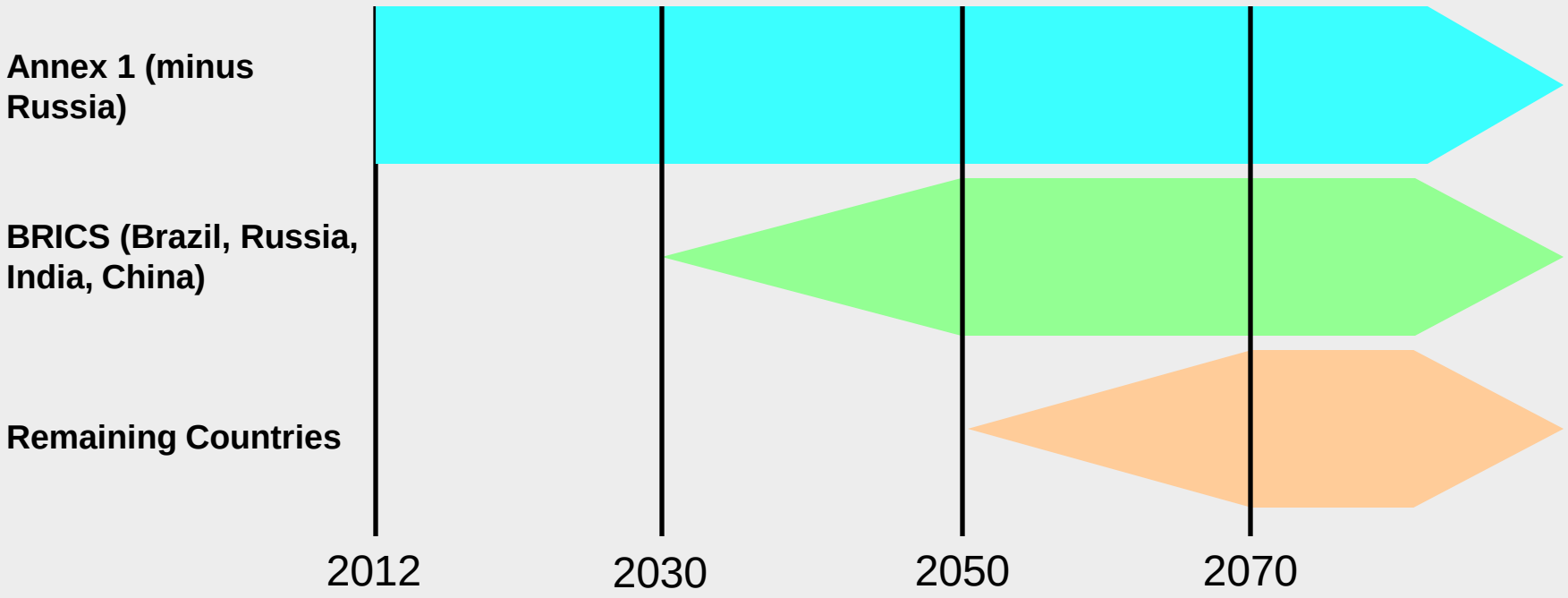
Delayed Participation: Regions Enter the Global Coalition over Time: S2



The delayed participation case explores the potential impacts of a one single possibility for delay in non-Annex I participation – it does not represent any real policy proposal. Mechanisms such as offsets may lead to policy structures that lie between the two cases explored in this study.

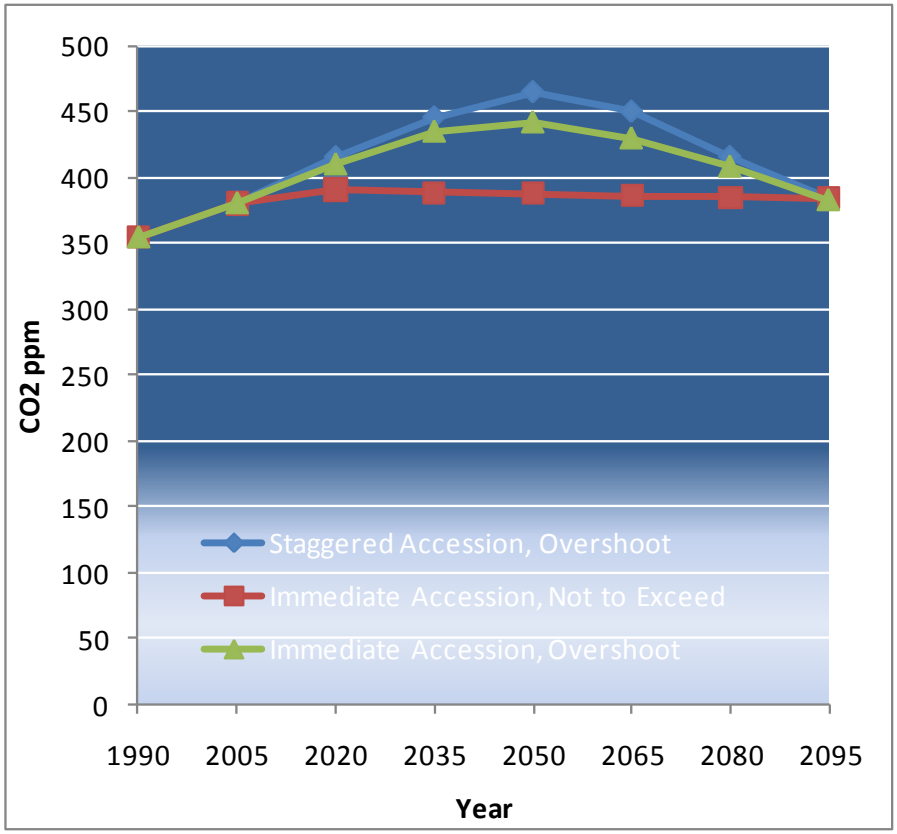
Which scenarios were the modeling groups able to provide?

	Model	650 CO2-e		550 CO2-e				450 CO2-e			
		Full	Delay	Full		Delay		Full		Delay	
		Not-to-Exceed	Not-to-Exceed	Not-to Exceed	Overshoot	Not-To-Exceed	Overshoot	Not-to Exceed	Overshoot	Not-To-Exceed	Overshoot
1	ETSAP-TIAM	+	+	+	+	+	+	+	+	XX	+
2	FUND	+	+	+	+	+	+	XX	+	XX	XX
3	GTEM	+	+	+	+	XX	+	XX	+	XX	XX
4	IMAGE	+	+	+	+	+	+	XX	XX	XX	XX
	IMAGE-BC	+	+	+	+	+	+	XX	+	XX	XX
5	MERGE Optimistic	+	+	+	+	XX	XX	XX	XX	XX	XX
	MERGE Pessimistic	+	+	+	+	+	+	XX	XX	XX	XX
6	MESSAGE	+	+	+	+	XX	+	XX	+	XX	XX
7	MiniCAM Base	+	+	+	+	XX	+	+	+	XX	+
	MiniCAM LoTech	+	+	+	+	XX	+	XX	+	XX	XX
8	POLES	+	+	+	+	XX	+	XX	XX	XX	XX
9	SGM	+	+	+	+	+	+	XX	XX	XX	XX
10	WITCH	+	+	+	+	+	+	XX	XX	XX	XX

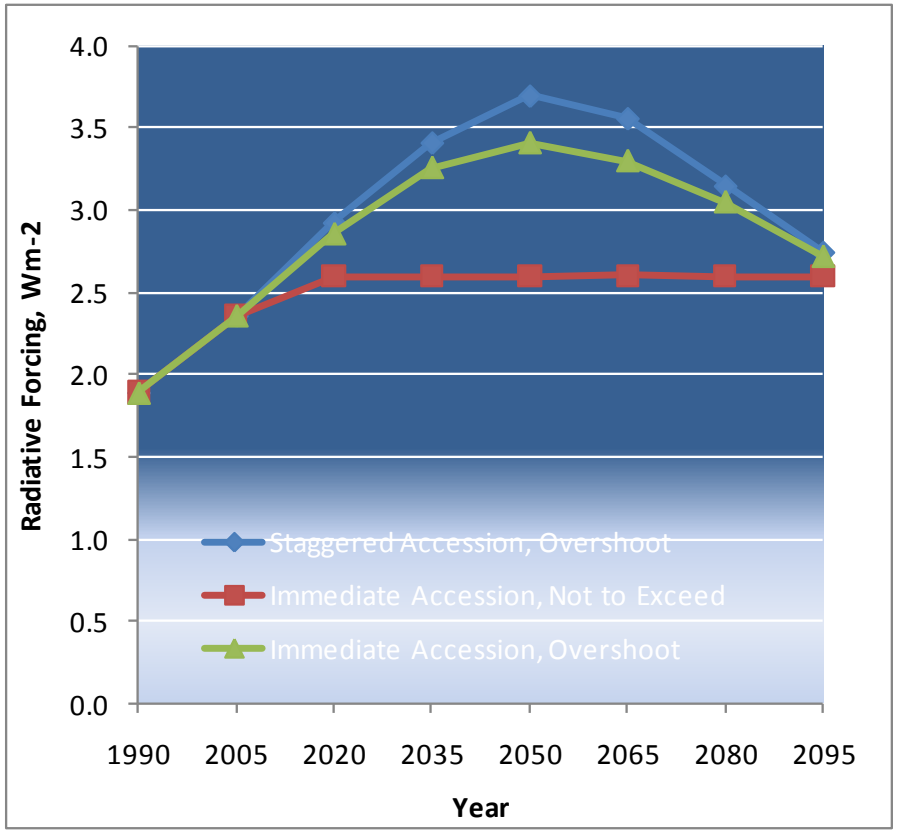
The GCAM Results For 2.6 Wm^{-2}

Emissions and Concentrations of CO_2

Atmospheric CO_2 Concentrations, ppmv



Radiative Forcing, Wm^{-2}



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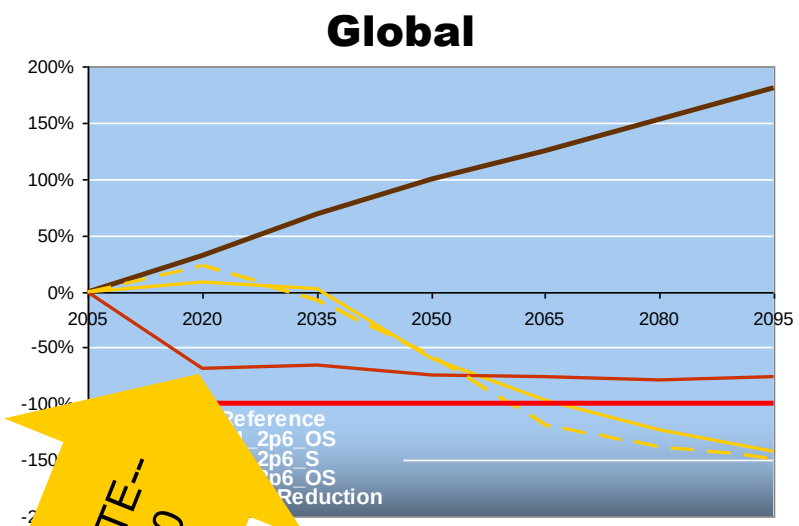
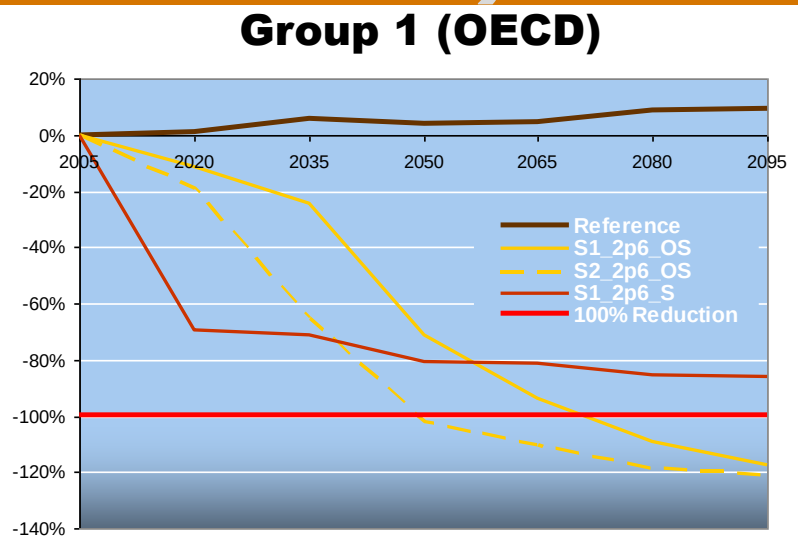
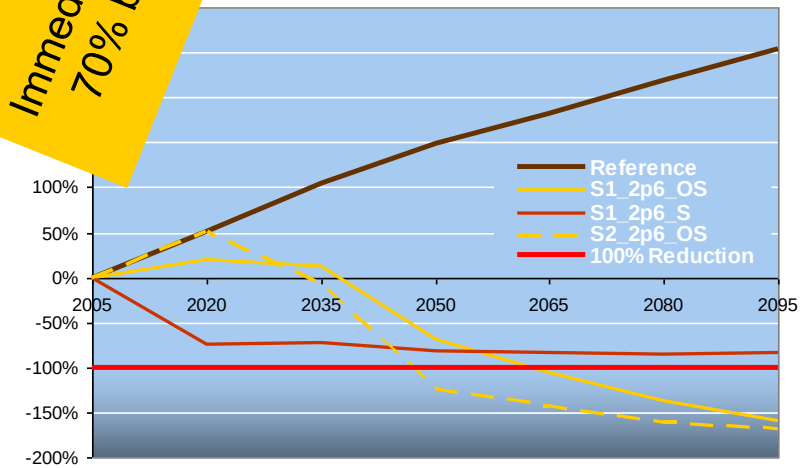
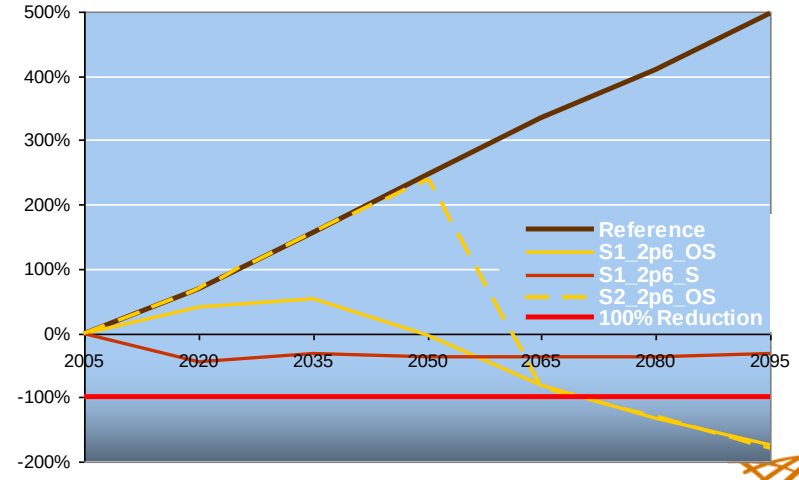
Emissions Mitigation: 2.6 W/m² (% reduction relative to 2005)





Immediate-NTE--
70% by 2020





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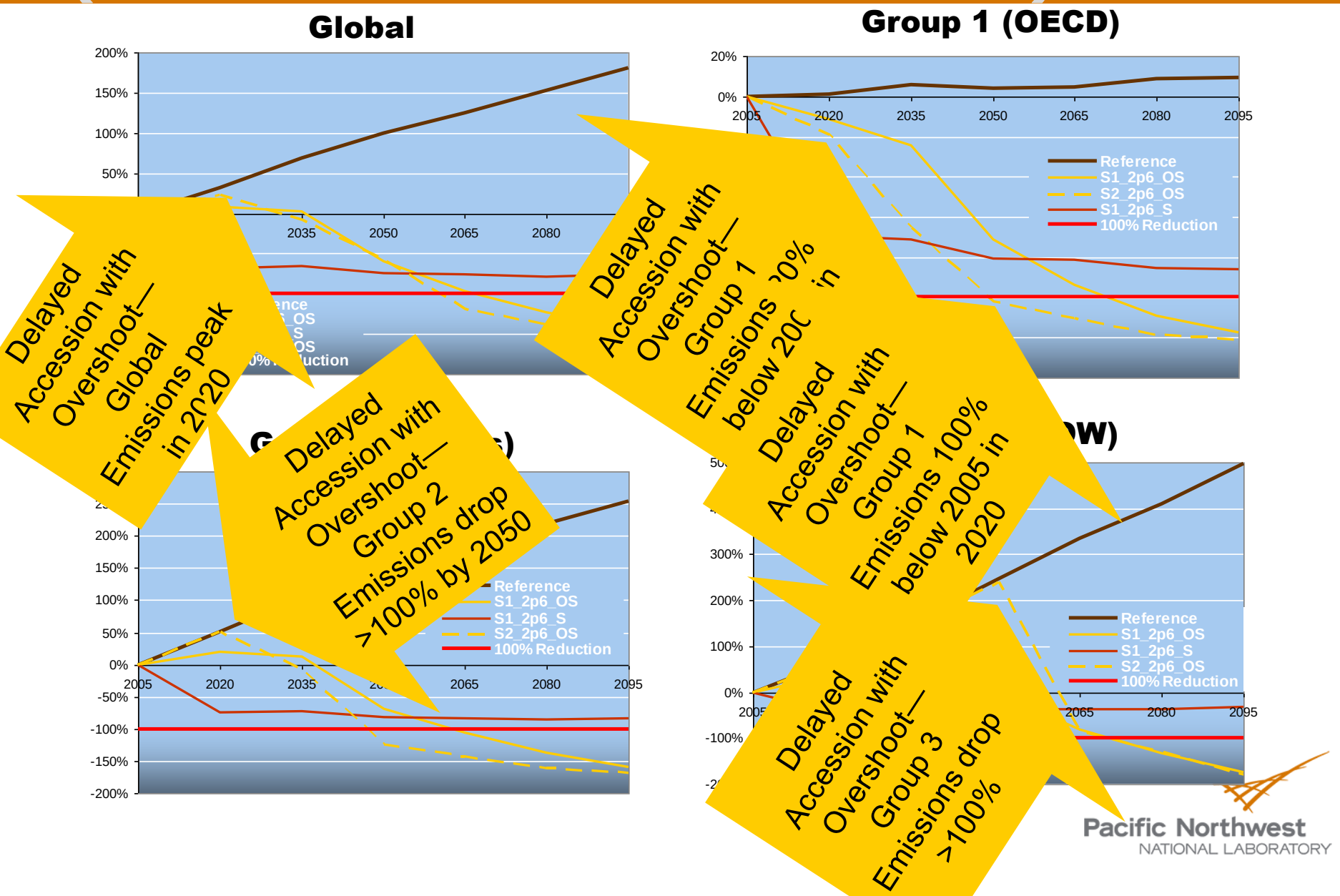

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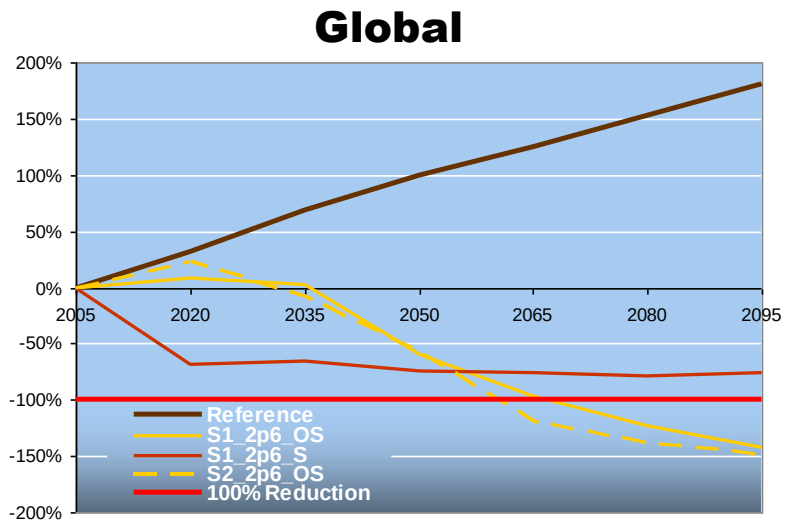
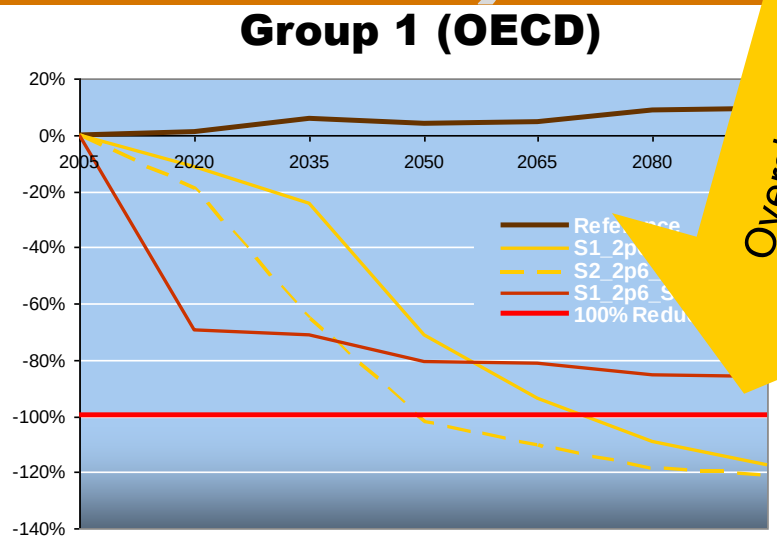
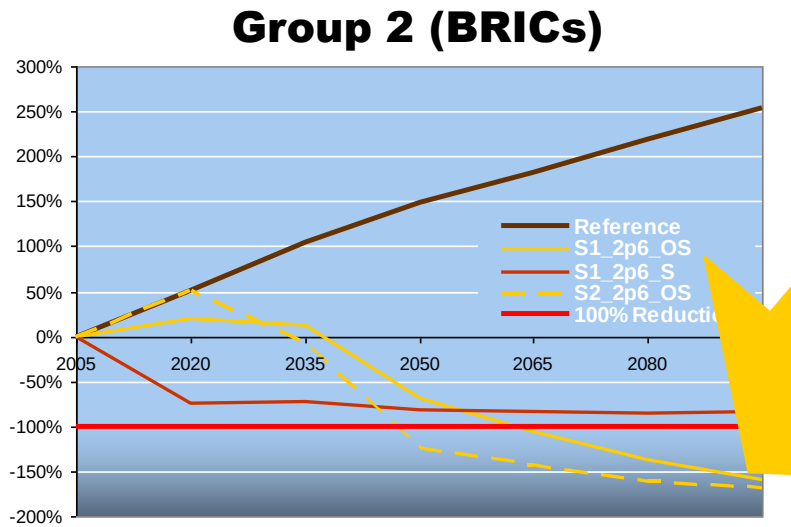
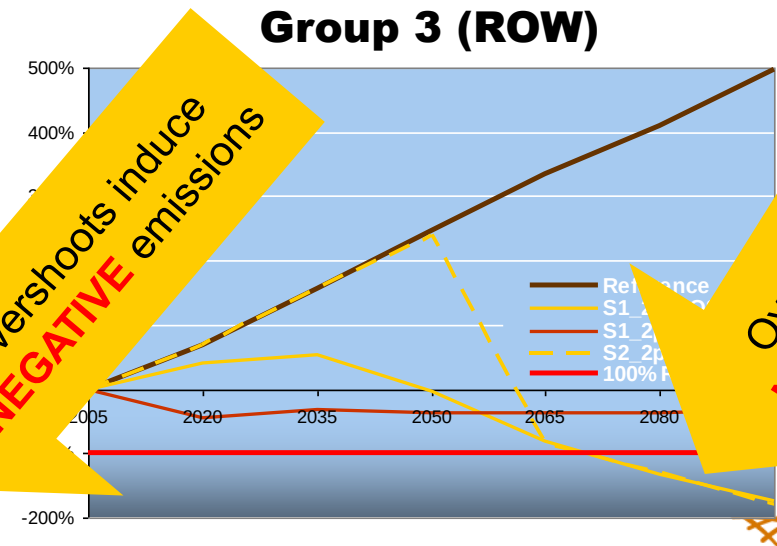




Overshoots induce NEGATIVE emissions





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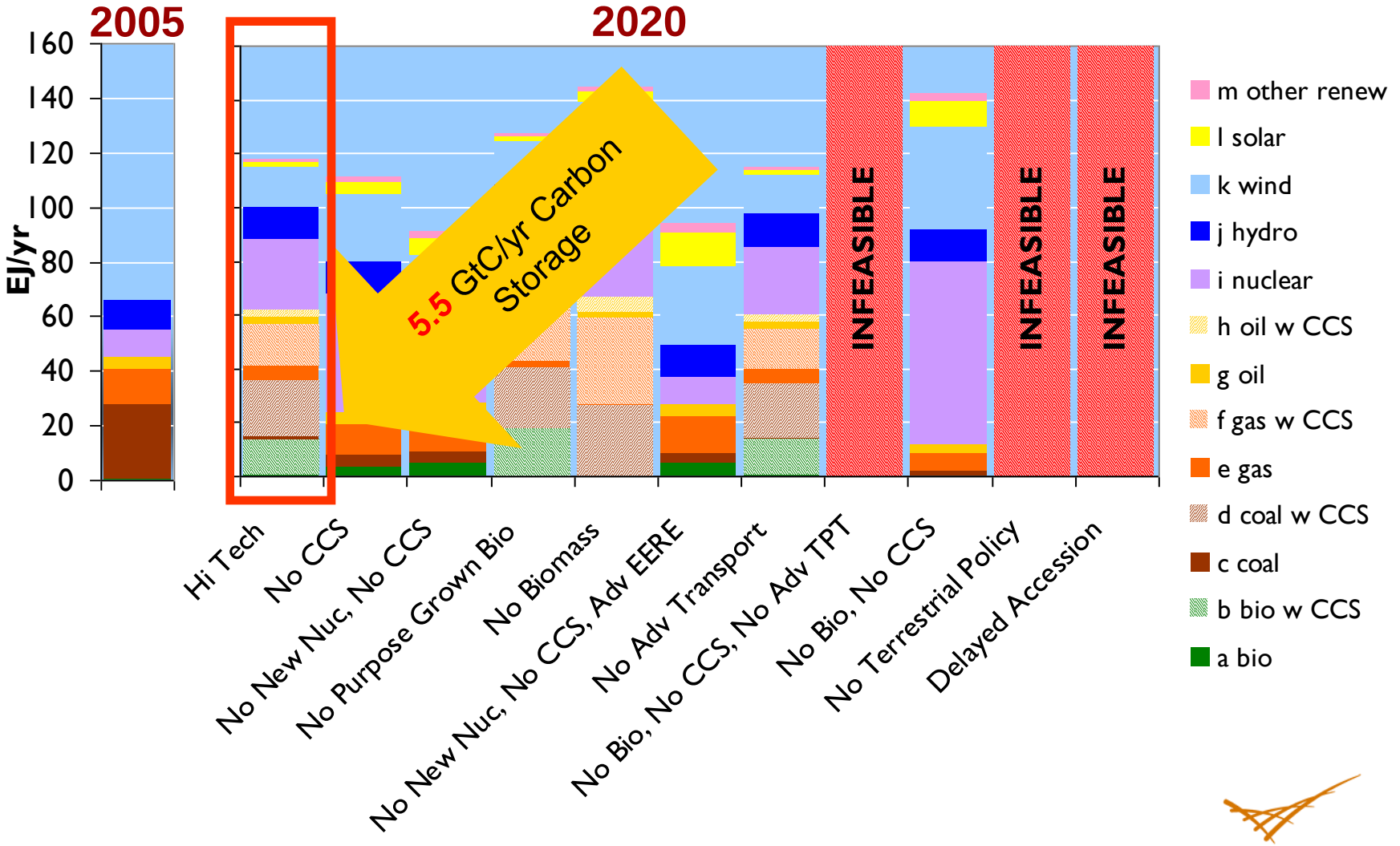
Electricity Generation: Immediate Accession, Not to Exceed 2.6 w/m²



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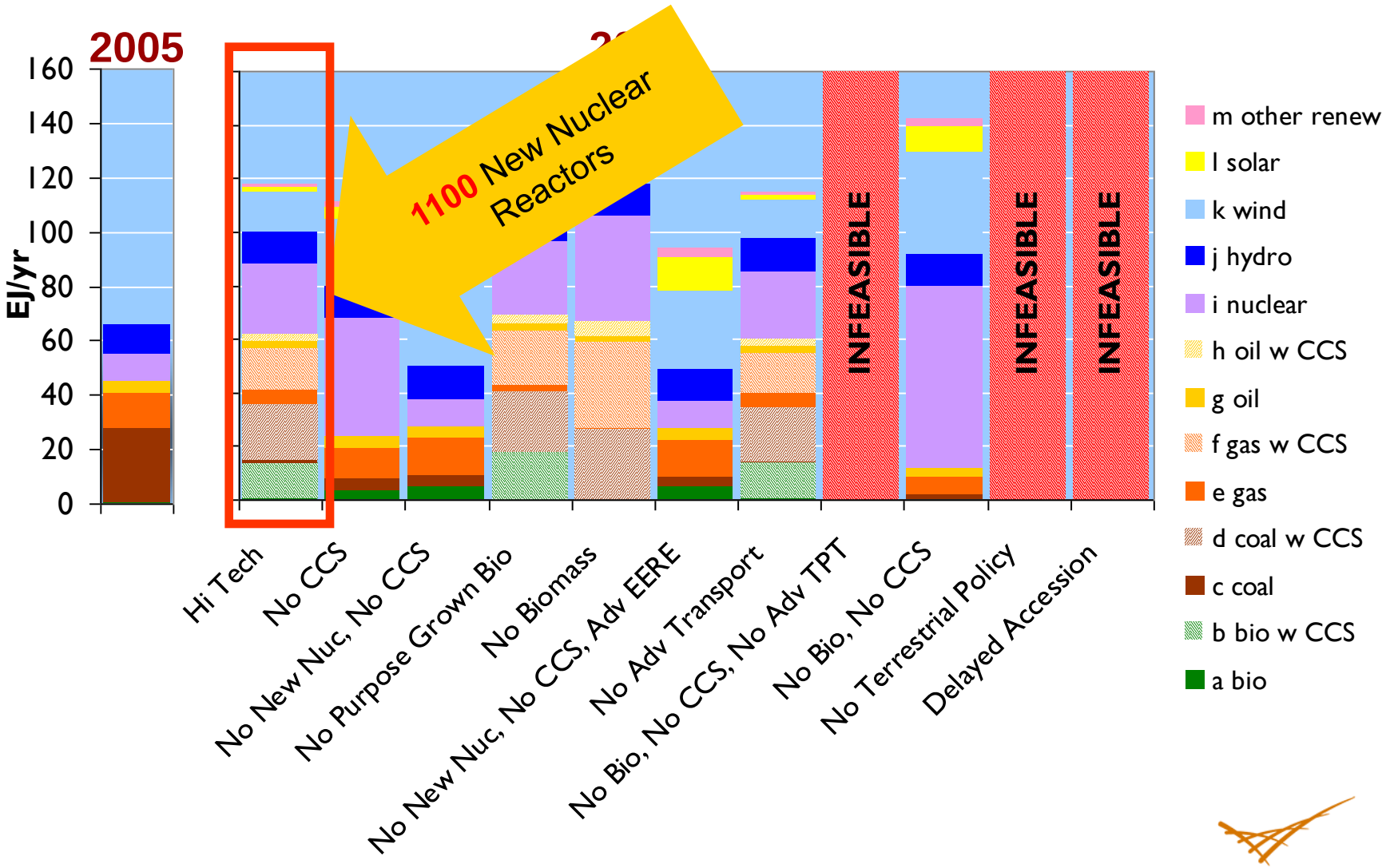

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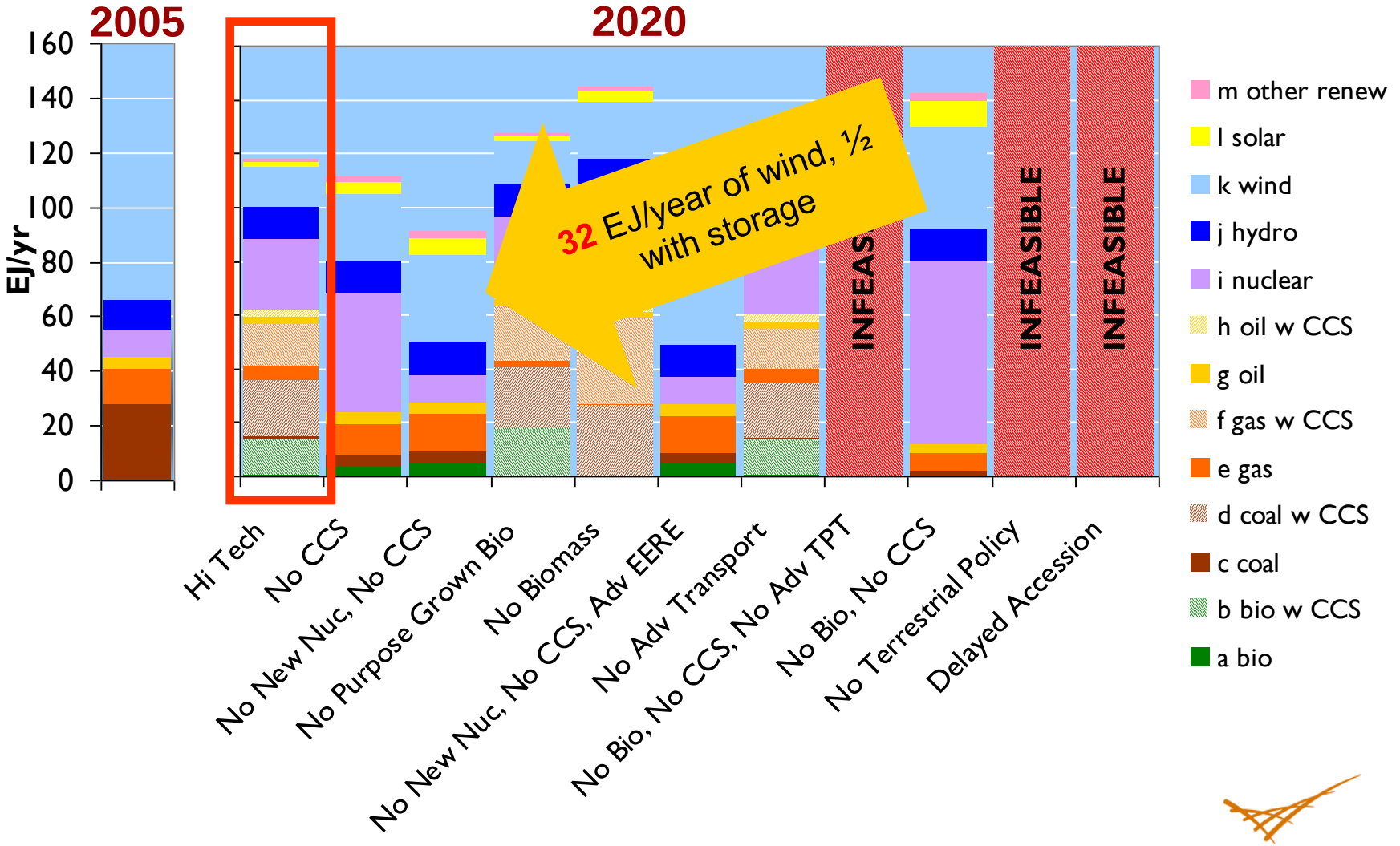

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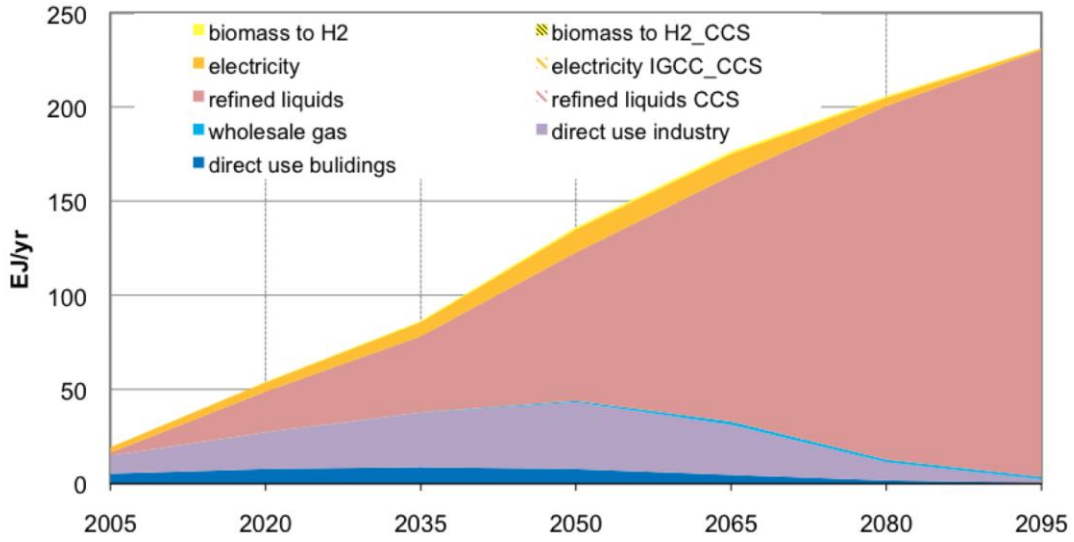
Where Does The Bioenergy Go?

Biomass Consumption by use: 450ppm Reference Technology (no CCS)



- Electricity sector has largely shifted away from biomass
- Without CCS option, there are limited carbon free options in refined liquids, biomass is important

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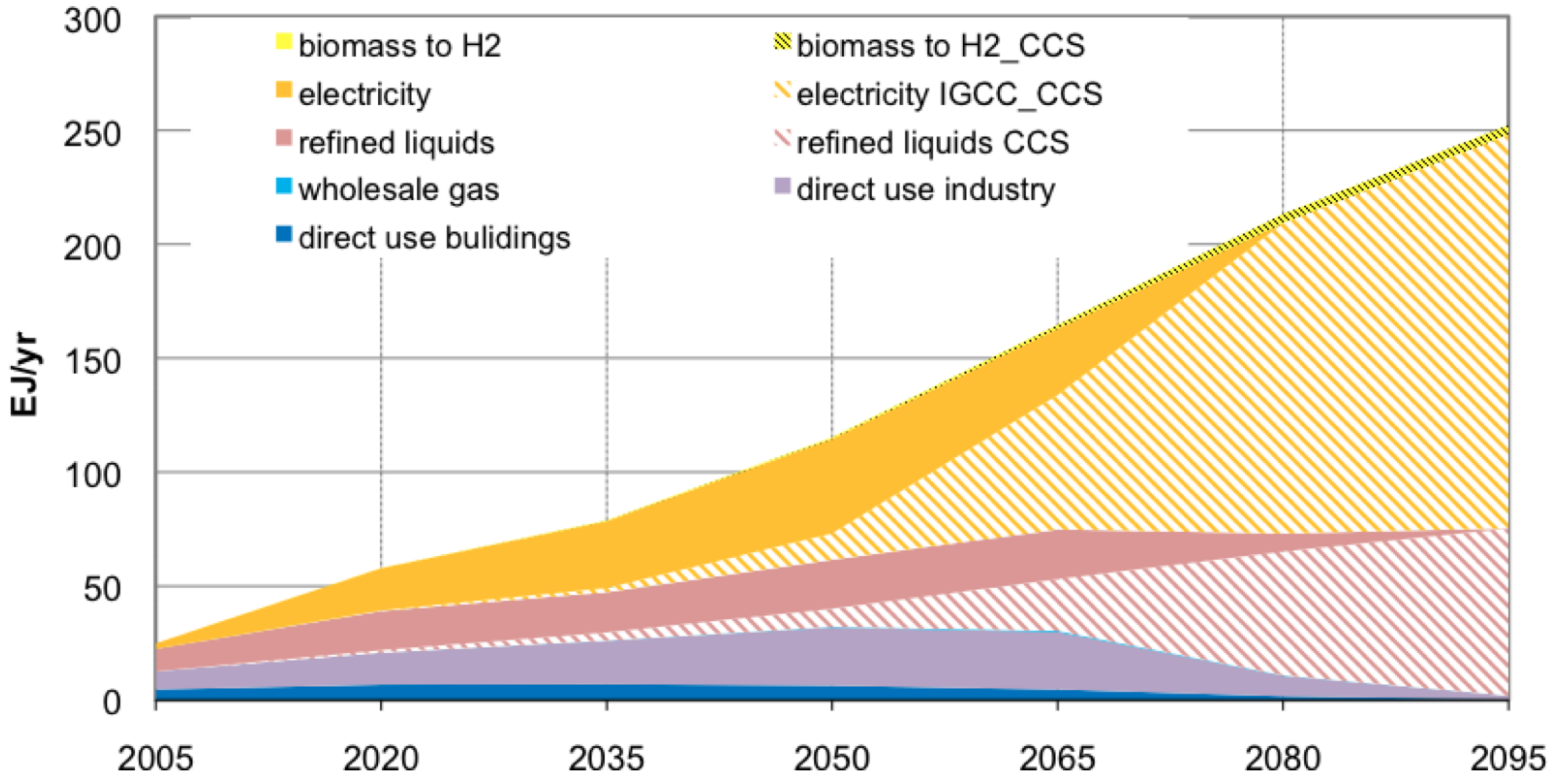
Biomass Consumption by use 450ppm Advanced Technology (with CCS)



- About 170 EJ in Electricity, and 73 EJ in refined liquids
- CCS is used heavily with high CO_2 prices in later years

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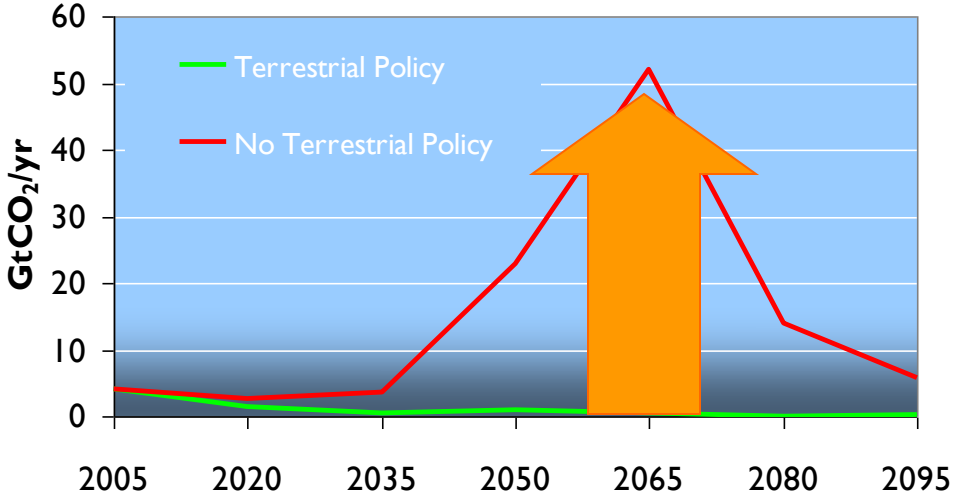
Land-use Policy & Leakage

CO_2 Emissions: With and Without a Terrestrial Policy

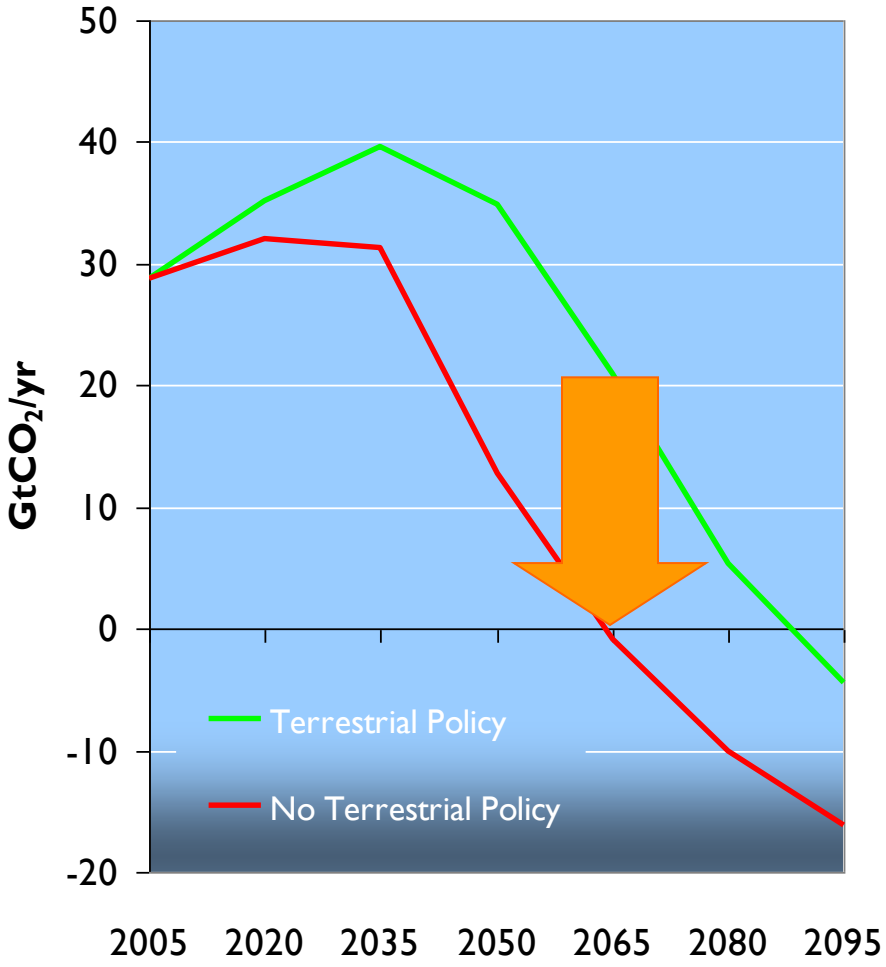
VALUING CARBON

- Decreases land use change emissions
- Increases allowable fossil & industrial emissions

Land Use Change Emissions



Fossil & Industrial CO2 Emissions



Immediate Accession, 3.7 W/m², Overshoot

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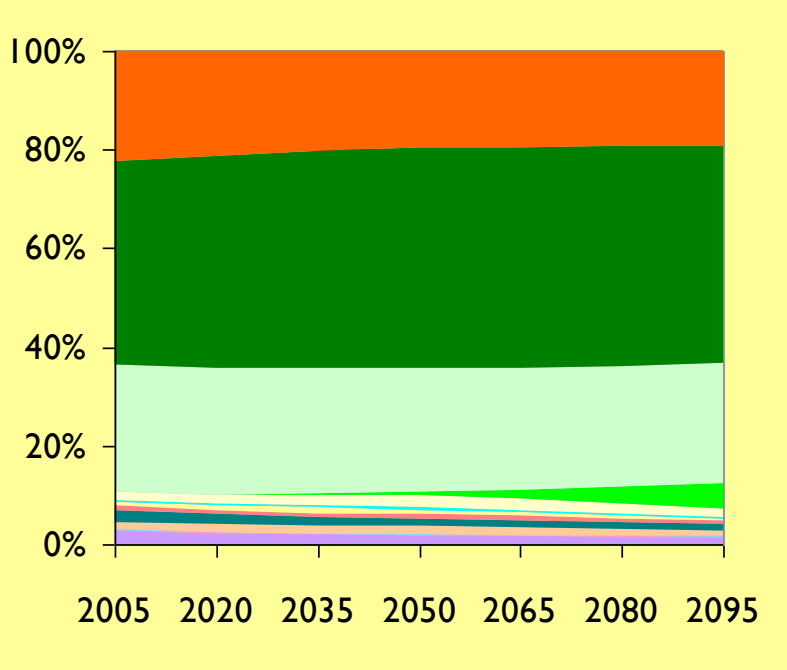
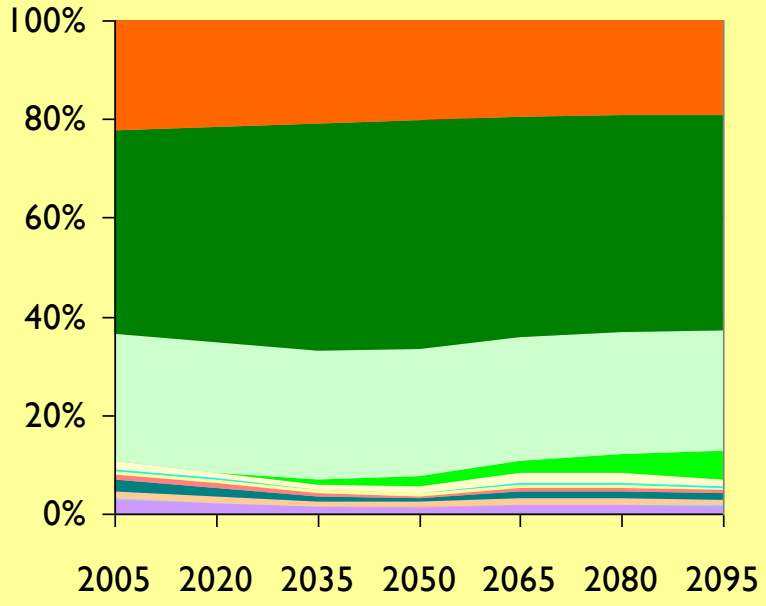
Land Allocation: 3.7 W/m² Overshoot

GROUP 1

Immediate Accession



Delayed Accession



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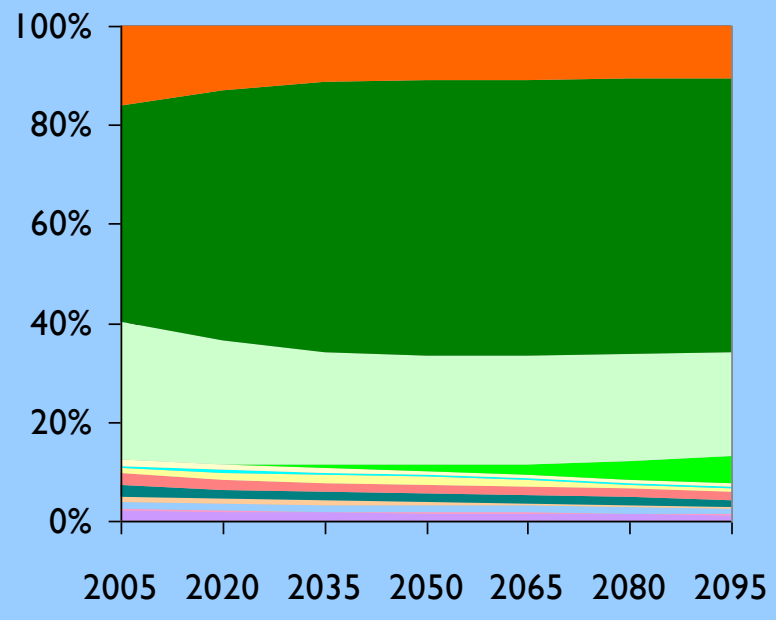
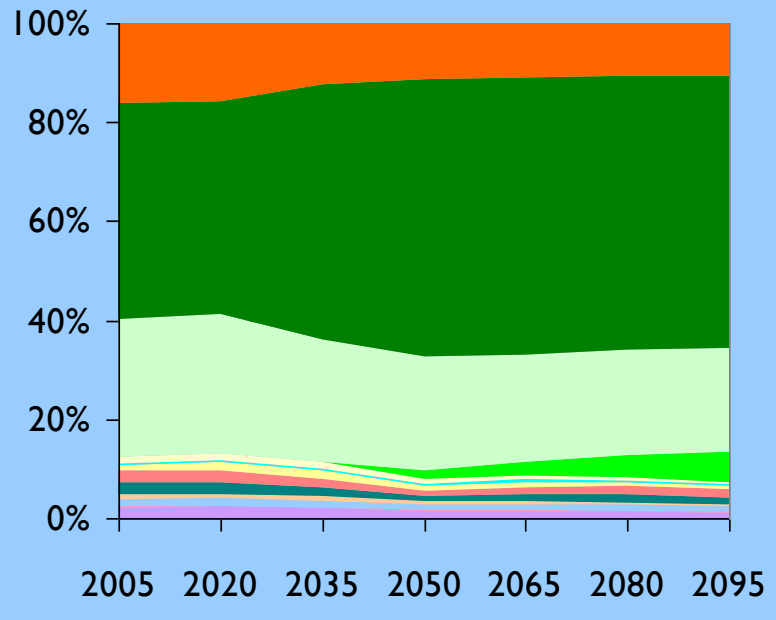
Land Allocation: 3.7 W/m² Overshoot

GROUP 2

Immediate Accession



Delayed Accession



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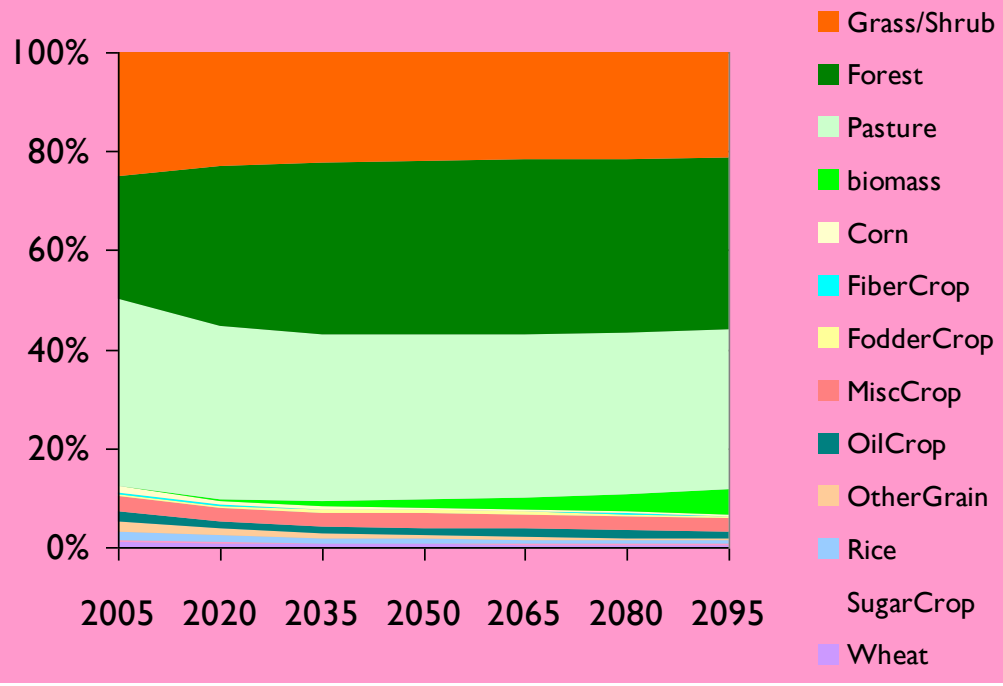
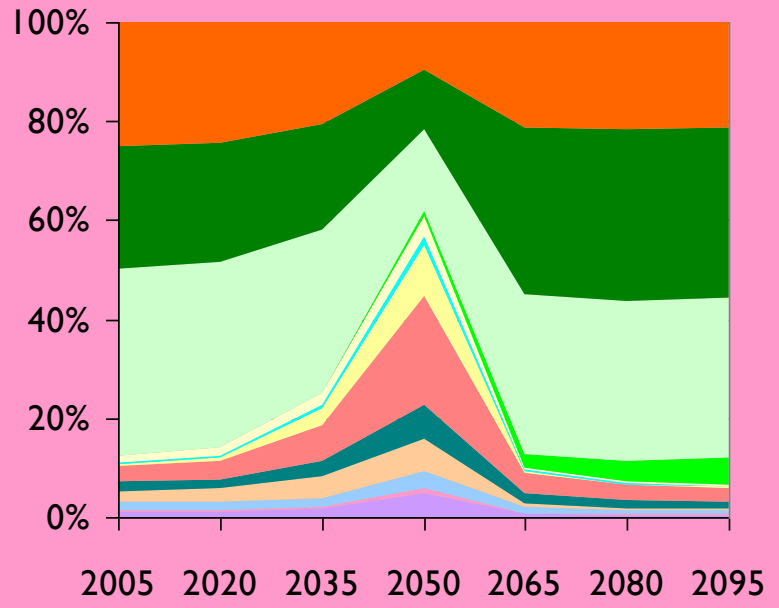
Land Allocation: 3.7 W/m² Overshoot

GROUP 3

Immediate Accession



Delayed Accession



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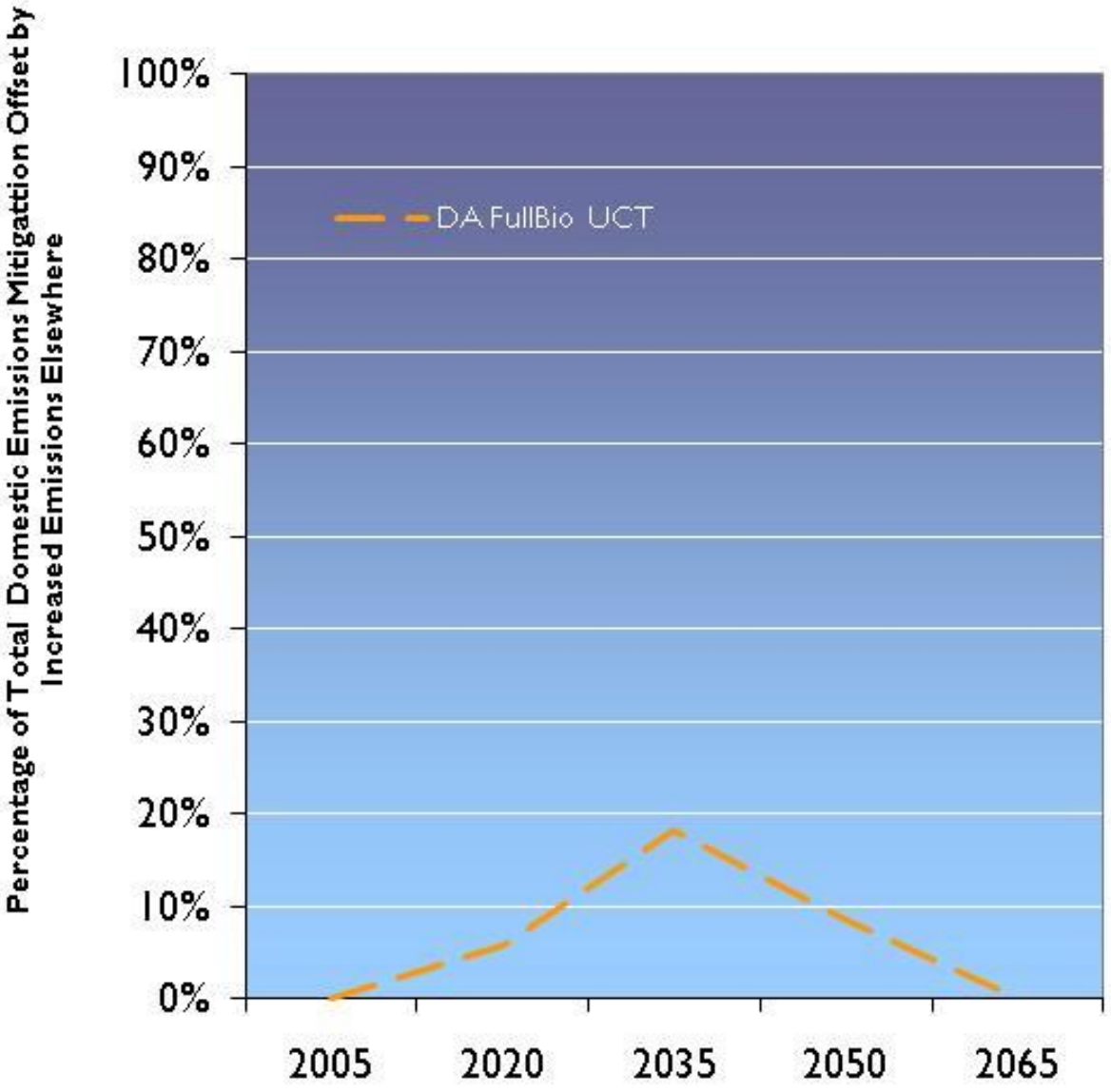
Land use Leakage: Overshoot, 3.7 Wm^{-2}



- Land-use leakage can be as high as 19%.

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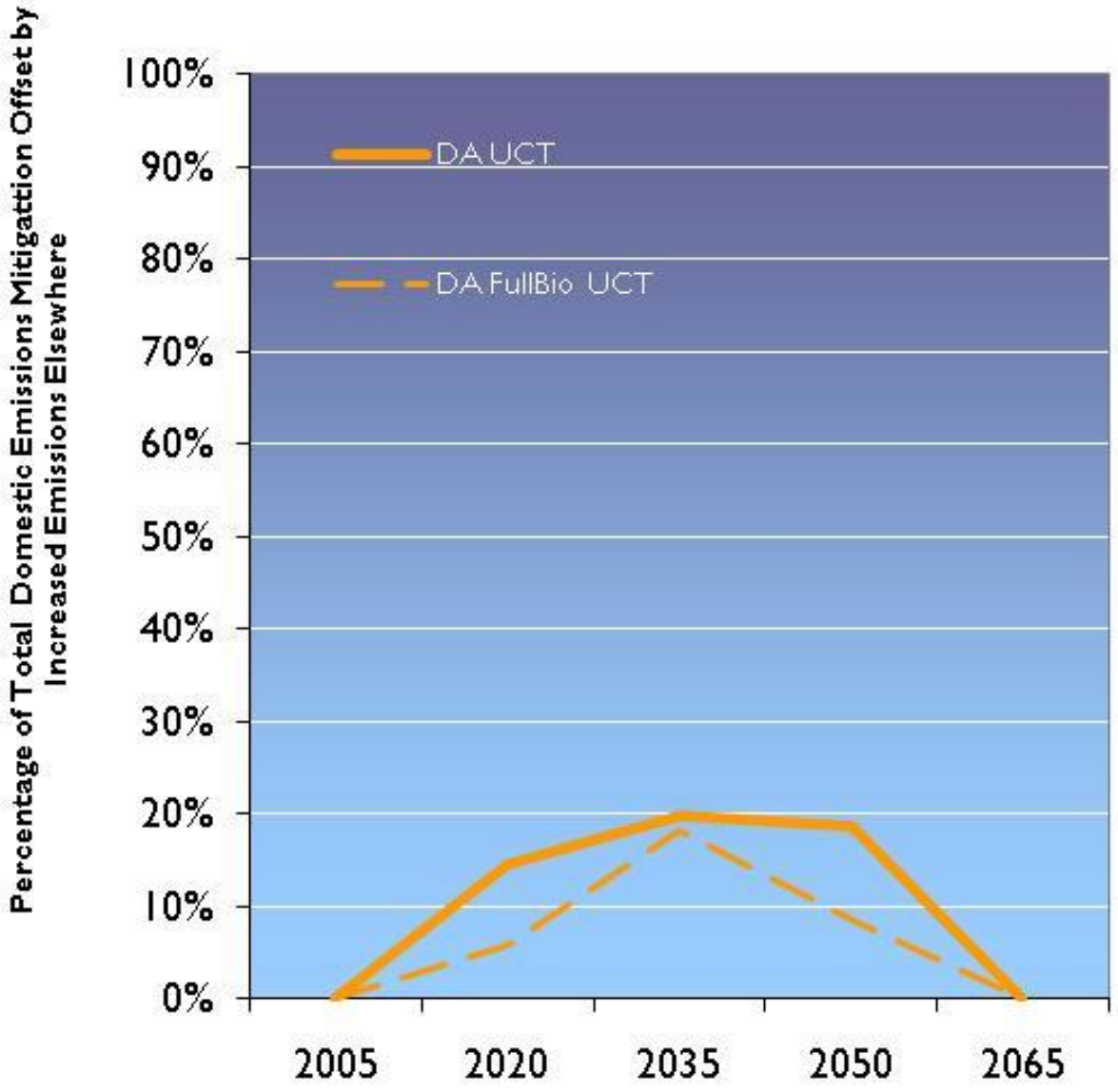
Land use Leakage: Overshoot, 3.7 Wm^{-2}



- Land-use leakage can be as high as 19%.
- It is driven as much by afforestation programs as by bioenergy.

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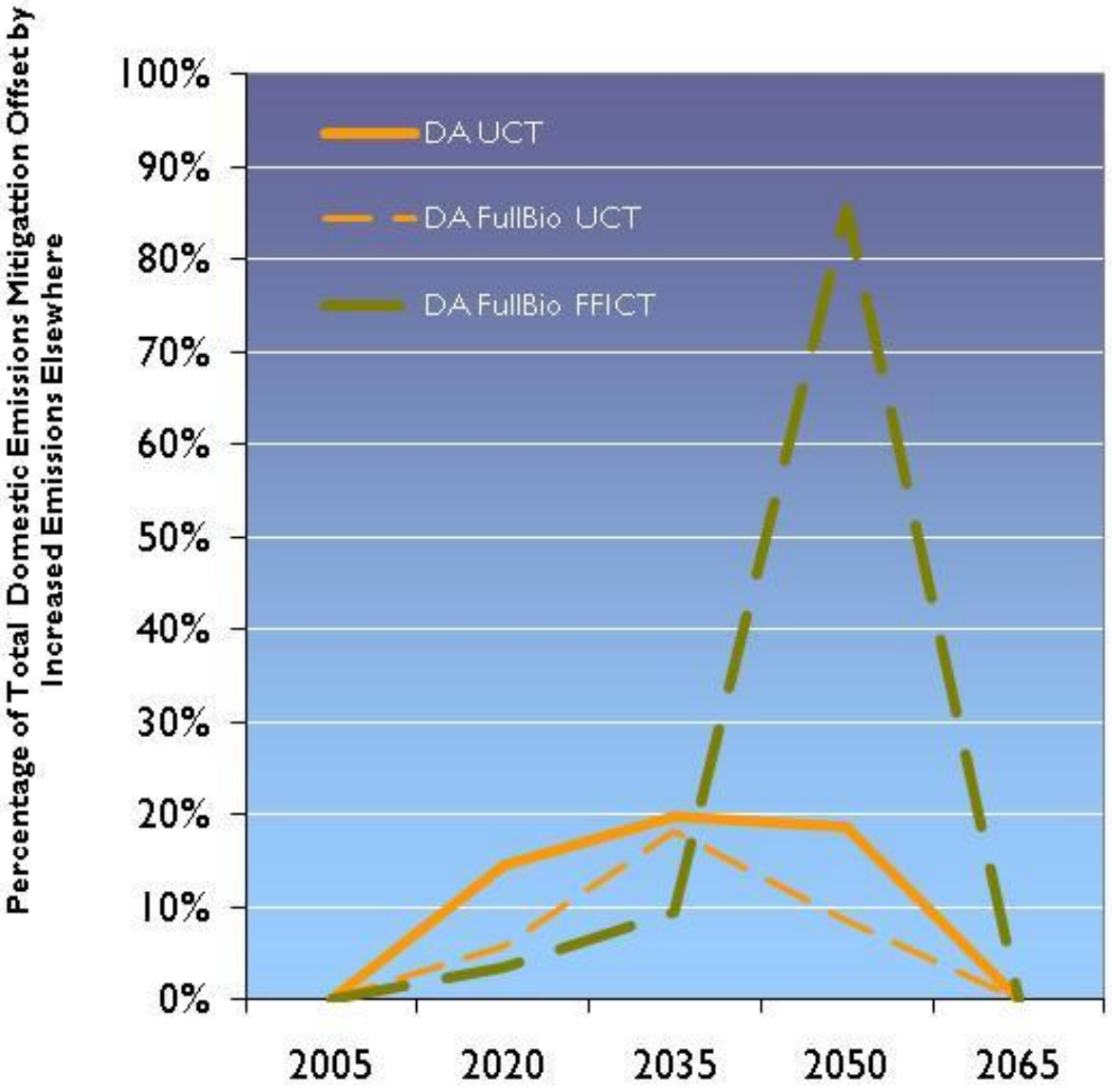
Land use Leakage: Overshoot, 3.7 Wm^{-2}



- Land-use leakage can be as high as 19%.
- It is driven as much by afforestation programs as by bioenergy.
- It can be even worse if terrestrial carbon is not valued.

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Summing up the Challenges of 2.6 Wm^{-2}

The Challenges of 450 CO_2-e
(*From the GCAM Paper: Calvin et al.*)

	Not-to-Exceed	Overshoot
Immediate Accession	1) Includes immediate participation by all regions 2) Includes 70% dramatic emissions reductions by 2020 3) Includes substantial transformation of the energy system by 2020, including the construction of 500 new nuclear reactors, and the capture of 20 billion tons of CO2 4) Includes a carbon price of $100/tCO2 globally in 2020 5) Includes a tax on land-use emissions beginning in 2020 6) Includes advanced technologies	1) Includes immediate participation by all regions 2) Includes the construction of 126 new nuclear reactors and the capture of nearly a billion tons of CO2 in 2020 3) Includes negative global emissions by the end of the century, and thus requires broad deployment of bioCCS technologies 4) Carbon prices escalate to $775/tCO2 in 2095 5) Possible without a tax on land-use emissions, but would result in a tripling of carbon taxes and a substantial increase in the cost of meeting the target.
Delayed Accession	X	1) Includes dramatic emissions reductions for Groups 2 and 3 at the time of their accession, 2) Includes negative emissions in Group 1 by 2050 and negative global emissions by the end of the century, and thus requires broad deployment of bioCCS technologies 3) Carbon prices begin at $50/tCO2, and rise to $2000/tCO2 4) Results in significant land-use leakage, where crop production is outsourced to non-participating regions resulting in a substantial increase in land-use change emissions in these regions

The Challenges of 450 CO_2-e
(*From the GCAM Paper: Calvin et al.*)

	Not-to-Exceed	Overshoot
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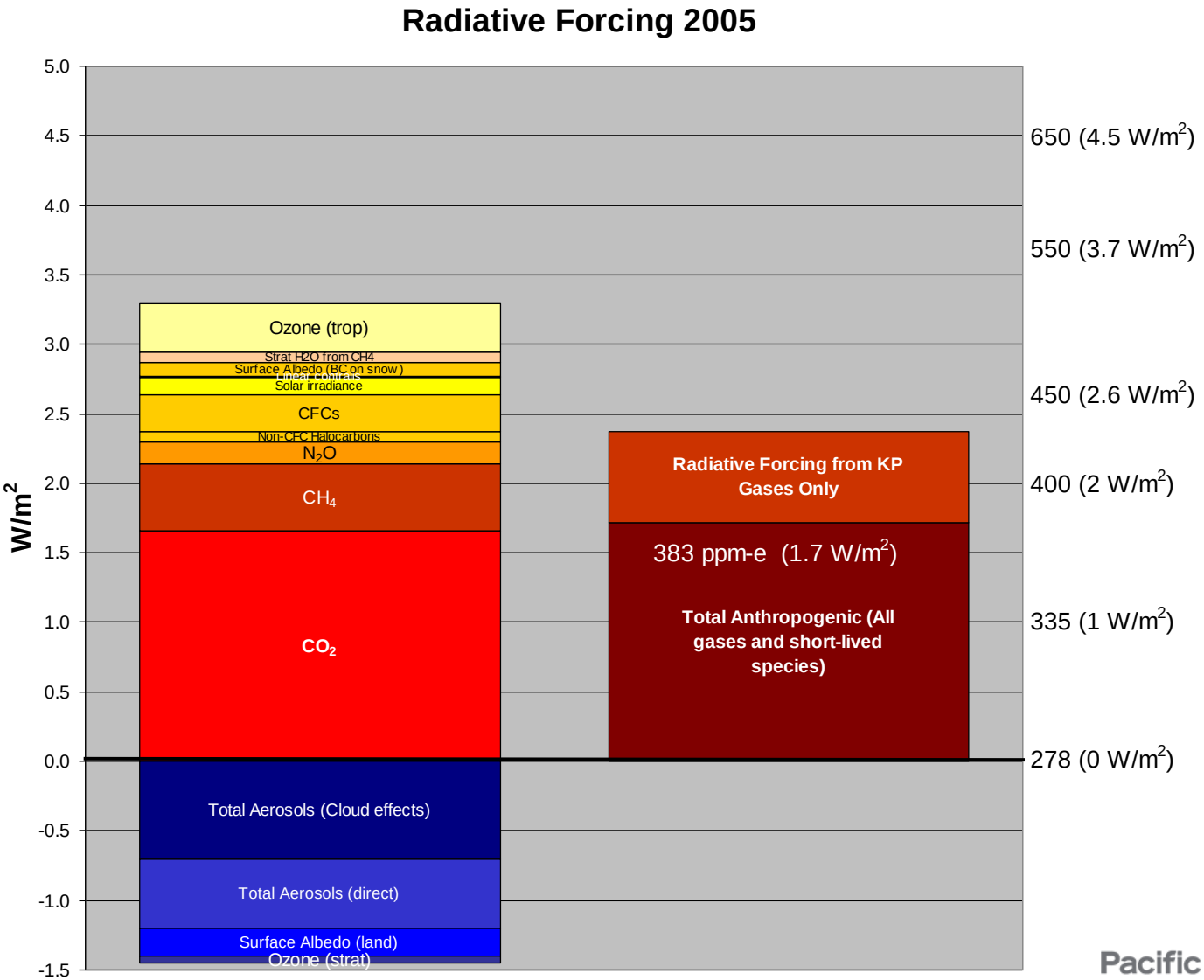
DISCUSSION

Radiative Forcing: All GHG's and SLS's



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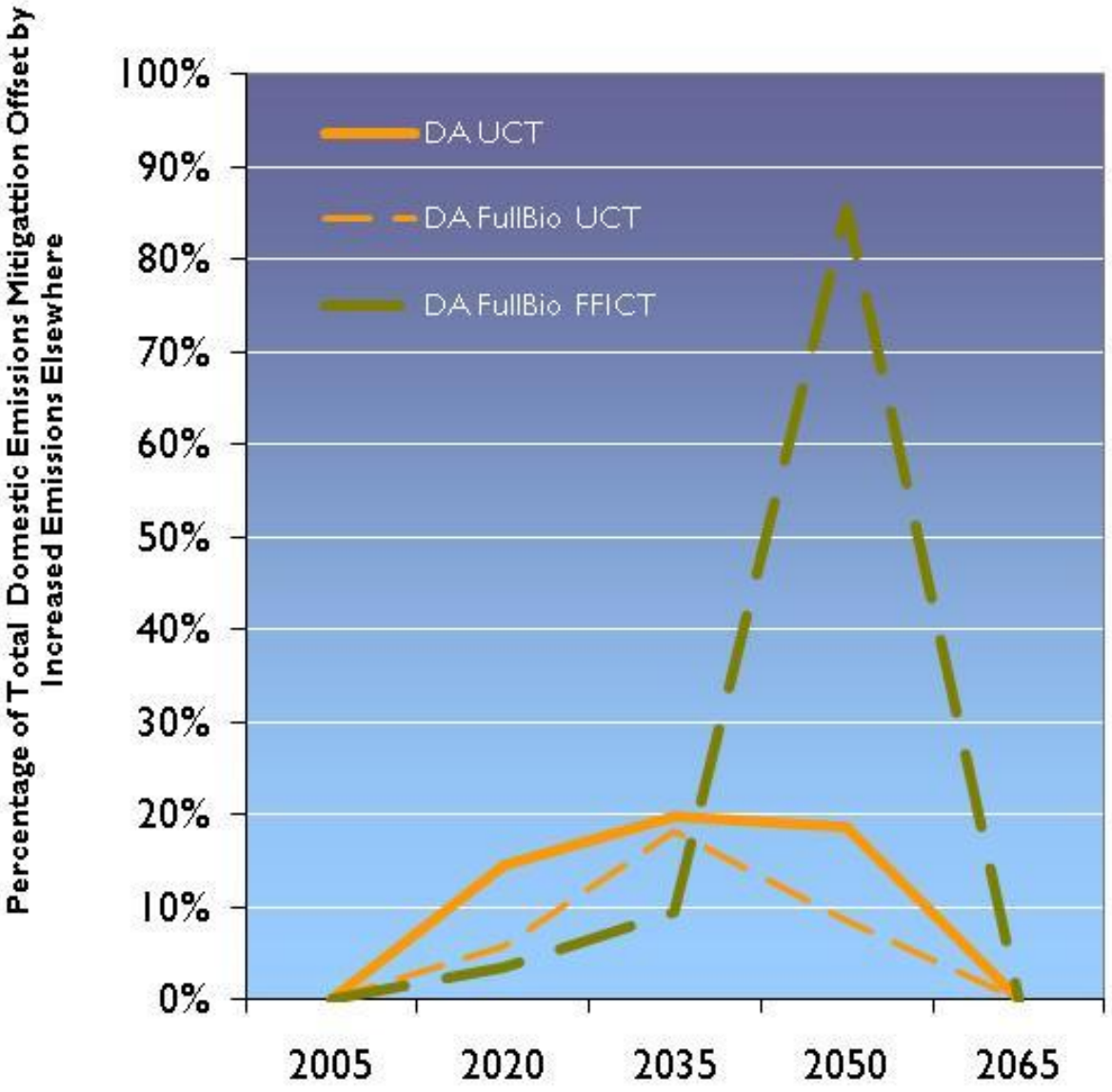
Land use Leakage: 3.7 Wm^{-2}



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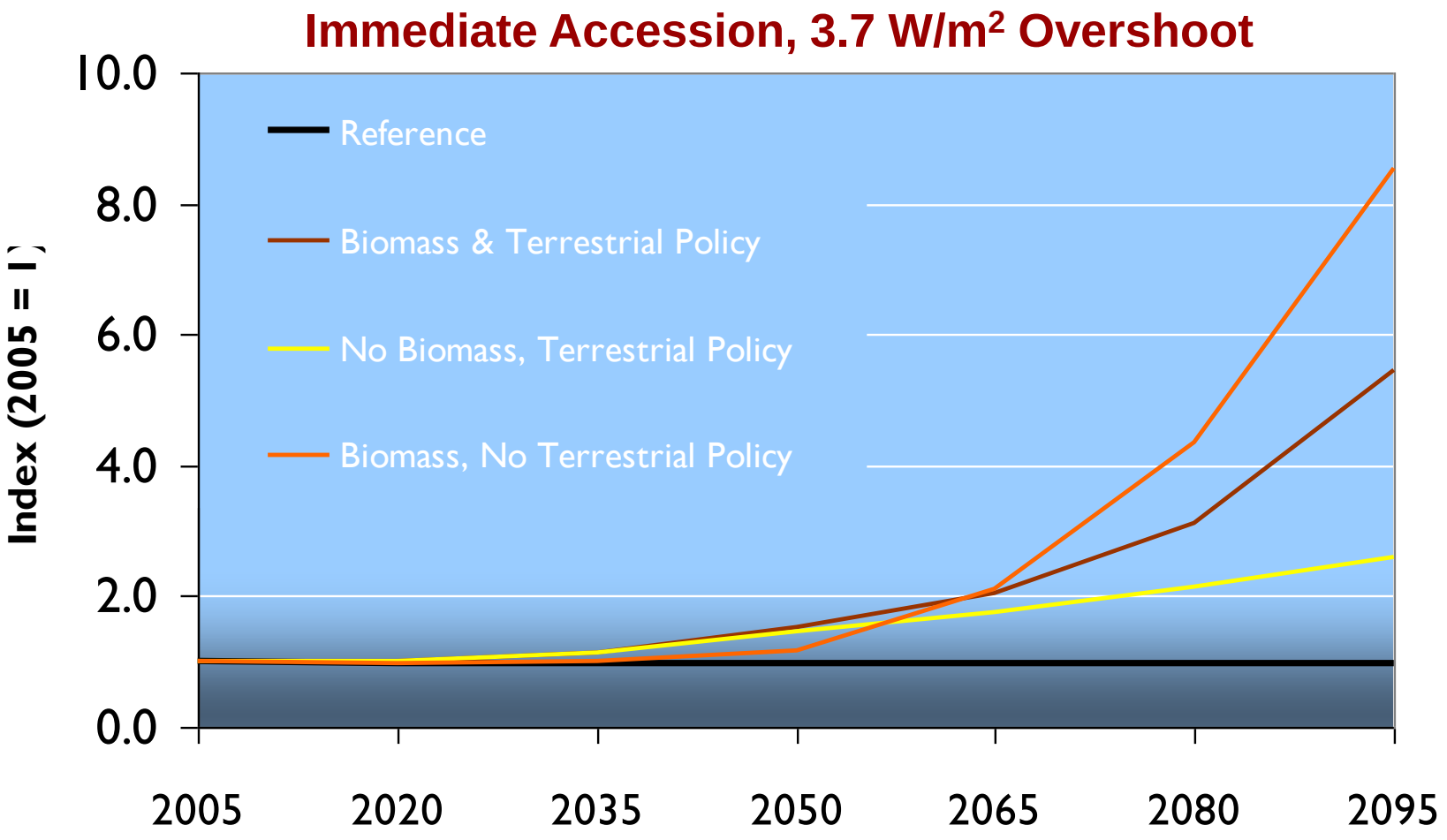
Wheat Prices



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