

Meeting Global GHG Emissions Reduction Targets: EMF24 Scenarios with TIAM-World

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Energy Systems Modelling Addressing Energy Security and Climate Change
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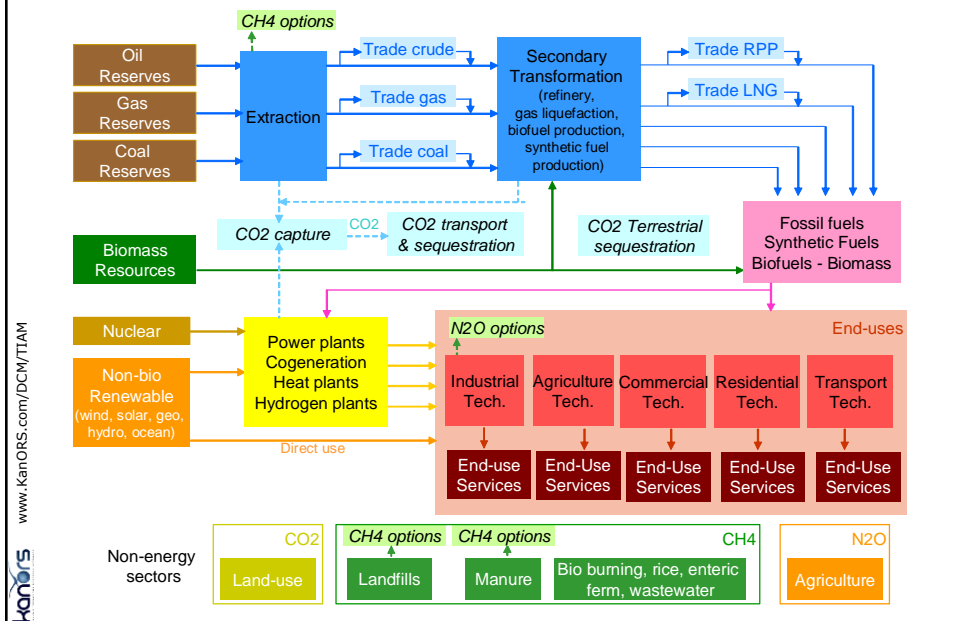
TIAM Regions

Africa*	China	Other Developing Asia*
Australia-New Zealand	Europe (EU30)	Other Eastern Europe
Canada	India	Russian Federation
Central Asia and Caucase	Japan	South Korea
Central and South America*	Mexico	United States
	Middle-East*	

* OPEC and Non-OPEC countries are separated in primary and secondary sectors
⇒ appropriate modelling of oil production strategies and oil price control by OPEC countries

Code	Name	Countries	Code	Name	Countries
AFR	Africa	Algeria, Angola, Benin, Botswana, Cameroon, Congo, Democratic Republic of Congo, Côte d'Ivoire, Egypt, Eritrea, Ethiopia, Gabon, Ghana, Kenya, Libya, Morocco, Mozambique, Namibia, Nigeria, Senegal, South Africa, Sudan, United Republic of Tanzania, Togo, Tunisia, Zambia, Zimbabwe, and Other Africa*.	MEA	Middle East	Bahrain, Islamic Republic of Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, United Arab Emirates, Yemen, and Turkey, Cyprus.
			MEX	Mexico	Mexico
AUS	Australia, New-Zealand, Oceania	Australia, New-Zealand, Oceania	ODA	Other Developing Asia	Bangladesh, Brunei Darussalam, Cambodia, Chinese Taipei, Indonesia, DPR of Korea, Malaysia, Mongolia, Myanmar, Nepal, Pakistan, Philippines, Singapore, Sri Lanka, Thailand, Vietnam and Other Asia**
CAC	CentralAsia&Caucase	Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan, Armenia, Azerbaïdjan, Georgia	OEE	Other EastEurope	Belarus, Moldova, Ukraine, Albania, Bosnia-Herzegovina, Croatia, Macedonia, Montenegro, Serbia (Kosovo)
CAN	Canada	Canada	RUS	Russia	Russia
CHI	China	China	SKO	South Korea	South Korea
CSA	Central & South America	Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Netherlands Antilles, Nicaragua, Panama, Paraguay, Peru, Trinidad and Tobago, Uruguay, Venezuela and Other Latin America.	USA	USA	USA
			EUR	Europe 27+	Austria, Belgium, Bulgaria, Cyprus, Switzerland, Czech Republic, Germany, Denmark, Estonia, Spain, Finland, France, Greece, Hungary, Ireland, Iceland, Italy, Lithuania, Luxembourg, Latvia, Malta, Netherlands, Norway, Poland, Portugal, Romania, Sweden, Slovenia, Slovakia, United Kingdom
IND	India	India			
JPN	Japan	Japan			

TIAM – Reference Energy System



TIAM-WORLD (A. Kanudia, M. Labriet, R. Loulou)

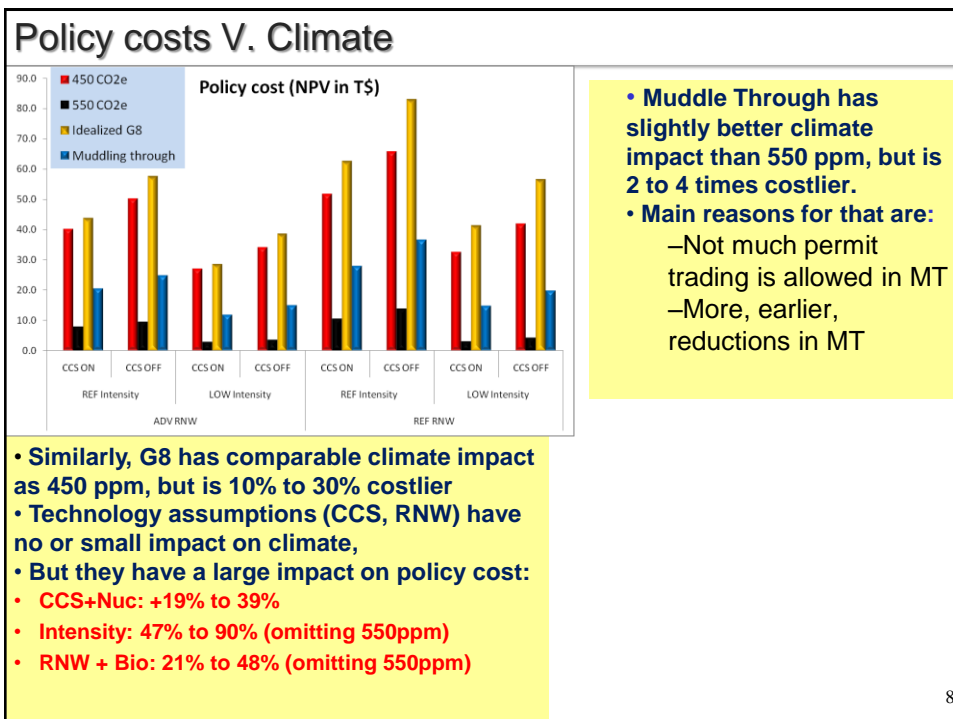
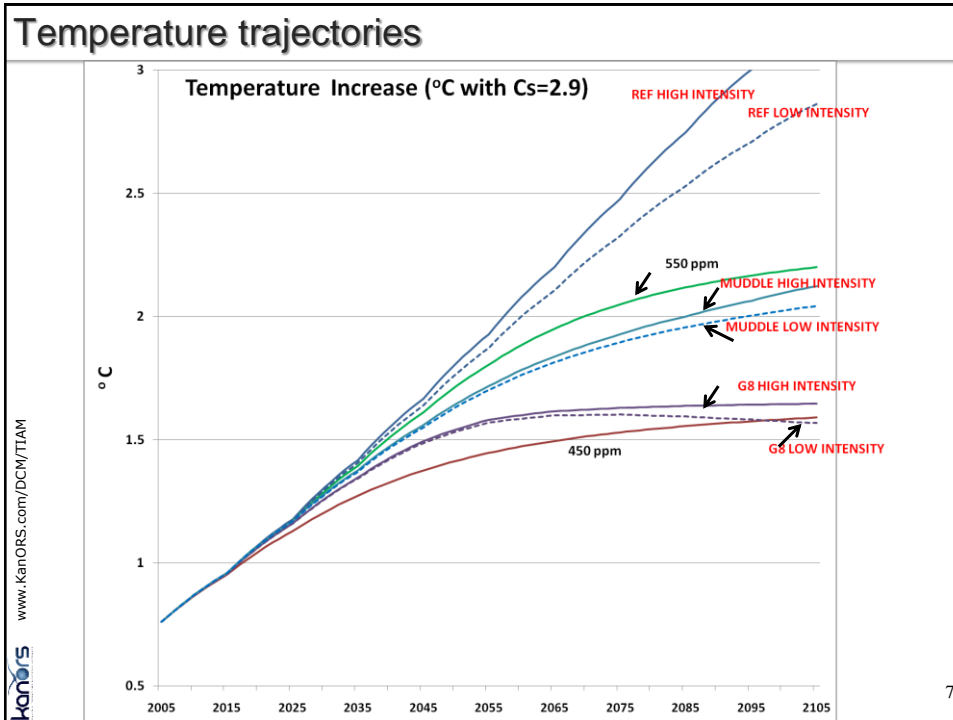
- **16 Region Global Energy-Industry-Environment Partial Equilibrium, technology rich Model developed by the authors (2002-2010), with partial support from ETSAP**
- **Many enhancements since last EMF22 study (2009)**
 - **16 regions:** EU and Russia now represented as specific regions
 - **More synthetic fuels and technologies, with and w/o CCS, from fossil and biomass**
 - **Trade of most energy forms (including biofuels, RPP)**
 - **Major updates of current and future technologies:**
 - Solar, Geothermal, Wind electricity plants,
 - Bioenergy potentials, Biorefineries.
 - More accurate representation of short-term RNW power plants and biorefineries,
 - Higher short-term penetration of nuclear in some countries (eg. China); lower long-term potential penetration.
 - **More mitigation options:**
 - More flexibility in all end-use sector processes (more electrification and "biofueling" options, continuous efficiency improvements until 2100)
 - More abatement options for CH4/N2O from Agriculture, Landfills, Wastewater
 - Exogenous but scenario dependent emissions and/or forcing of FC gases and of other anthropogenic causes
 - Slightly reduced forestry potential (only avoided deforestation)
 - **More realistic, smoother, penetration rates of new technologies**
 - **Re-calibration of 2010 and 2015 GDP's and energy services.**
 - **Slightly lower long term GDP growth rates in some countries**
- **Energy and emissions leakage in G3 regions is allowed**

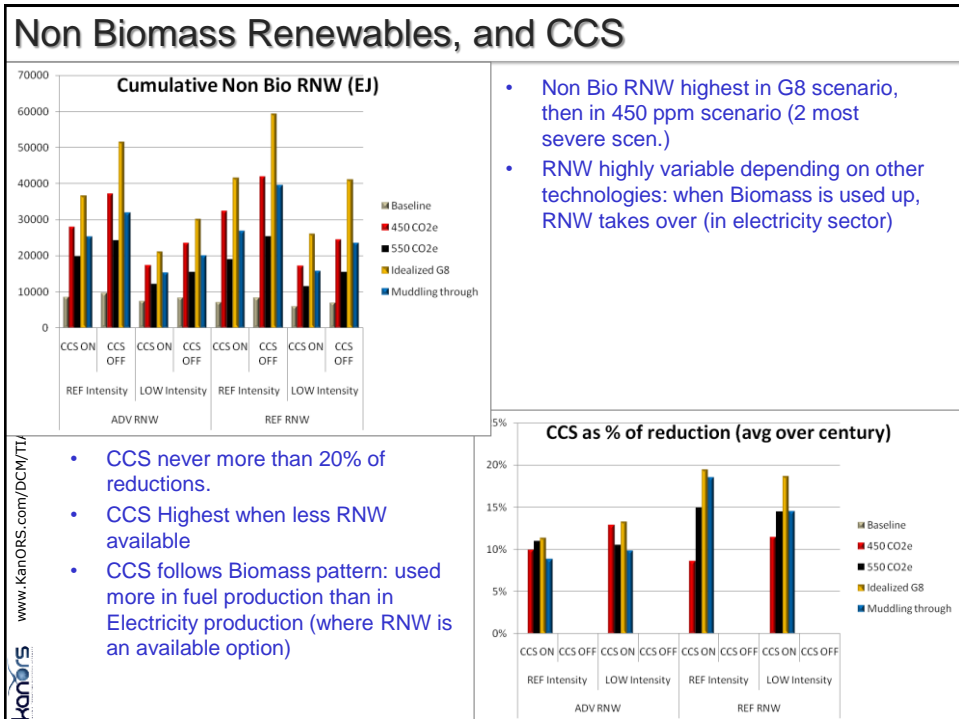
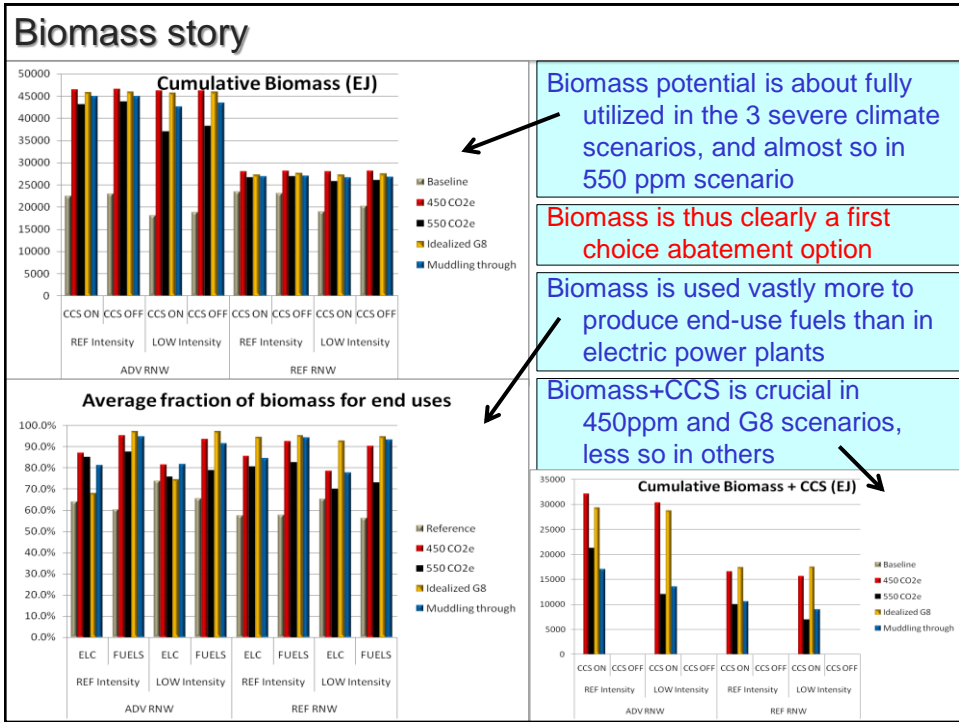
EMF24: Scenario definition

Technology Dimension								
Energy intensity	Ref		Low		Ref		Low	
CCS	On	Off	On	Off	On	Off	On	Off
Nuclear energy	On	Off	On	Off	On	Off	On	Off
Wind & Solar	Adv	Adv	Adv	Adv	Ref	Ref	Ref	Ref
Bioenergy potential	High	High	High	High	Low	Low	Low	Low
Policy Dimension								
Baseline	1	2	3	4	15	16	27	28
450 CO2e	33	34	5	17	18	19	35	36
550 CO2e	6	7	8	9	20	21	29	30
Idealized G8	37	38	10	22	23	24	39	40
Muddling through	11	12	13	14	25	26	31	32

EMF 24: Policy scenarios

- **Group I: 80% reduction by 2050; 2% annual reduction after that**
 - USA, Japan, Canada, Australia, New Zeal, and “Greater Europe”, consisting of EU-27, Norway, Switzerland, and Iceland, and the Non-EU Eastern European countries including Belarus, Ukraine, Moldova, Georgia.
- **Group II: different in the two scenarios**
 - China, India, Brazil, South Africa, OECD members Korea, Mexico, and Turkey, and most other countries in Asia, Latin America, and Africa.
- **Group III: unconstrained emissions**
 - Russia, the (Central) Asian Former Soviet Union countries (Armenia, Azerbaijan, Uzbekistan, Turkmenistan, Kyrgyzstan, Tajikistan and Kazakhstan), as well as Middle East OPEC countries Saudi Arabia, Iran, Iraq, Algeria, Libya, Kuwait, Qatar, and UAE.



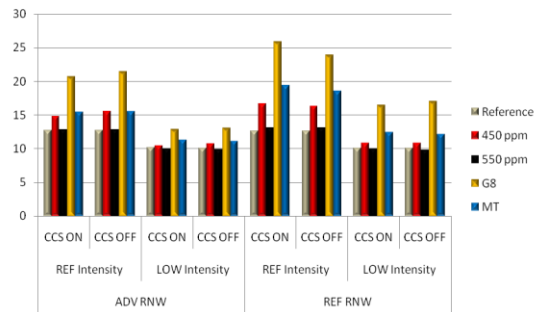


Final Energy (ZJ)

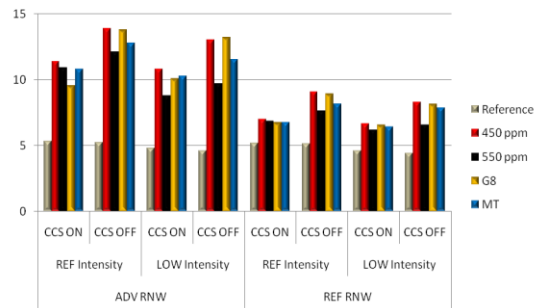
- Electricity total remarkably large in severe scenarios, especially G8.
- There is **more** electricity when there is **less** biomass, because less final biofuels and thus need to reduce emissions from Electricity sector.
- Biofuels very important, as already noted.
- Hydrogen and direct renewables small, but not negligible (8 to 20 EJ/yr each, on average over the 21st century)
- Fossil fuels retreat sharply from Reference scens, avg share is less than 25% in G8 scenario

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Cumulative Final Electricity (ZJ)

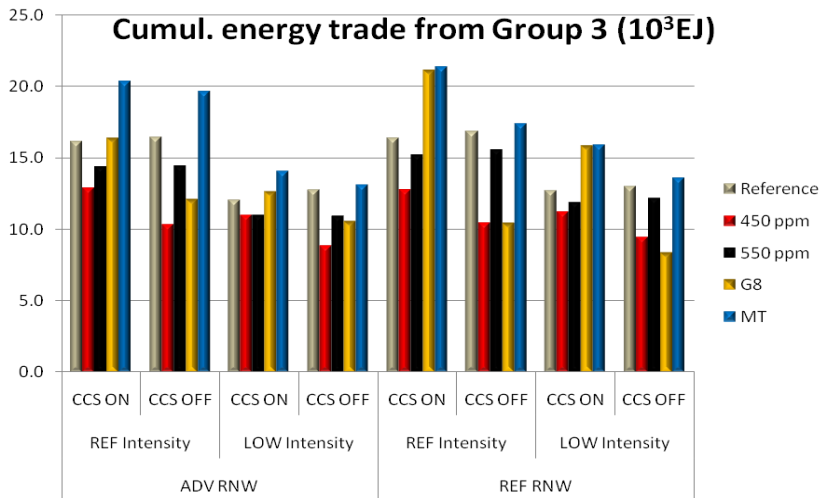


Cumulative Final Biofuels (ZJ)



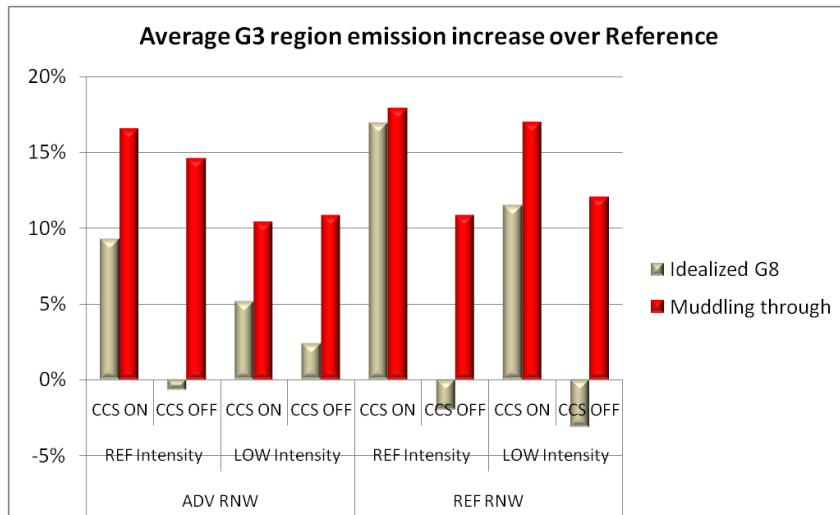
Energy Trade Leakage from G3 countries

Cumul. energy trade from Group 3 (10³EJ)



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Emission leakage in G3 countries

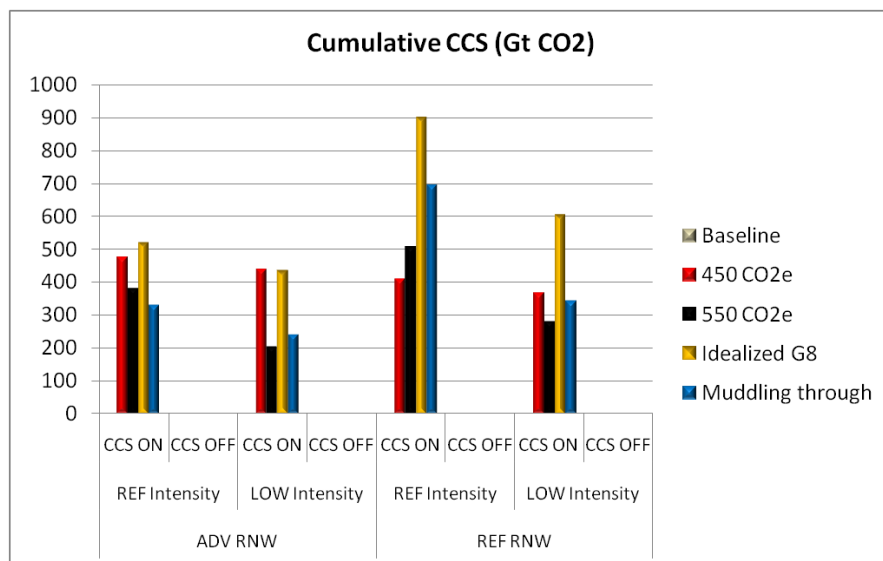


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10 to 18 % emission leakage in Muddle Through scenario
-3 to 12% emission leakage in G8 scenario
Leakage affects the global climate in these scenarios (not compensated by additional reductions in other regions)

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Total CCS



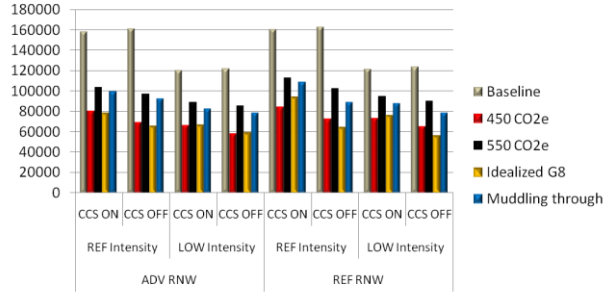
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16

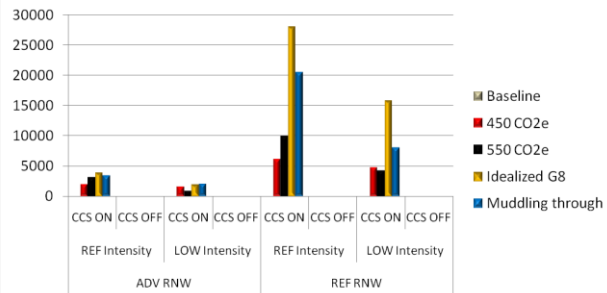
Primary Fossil Energy

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Cumulative Primary Fossil Energy (EJ)



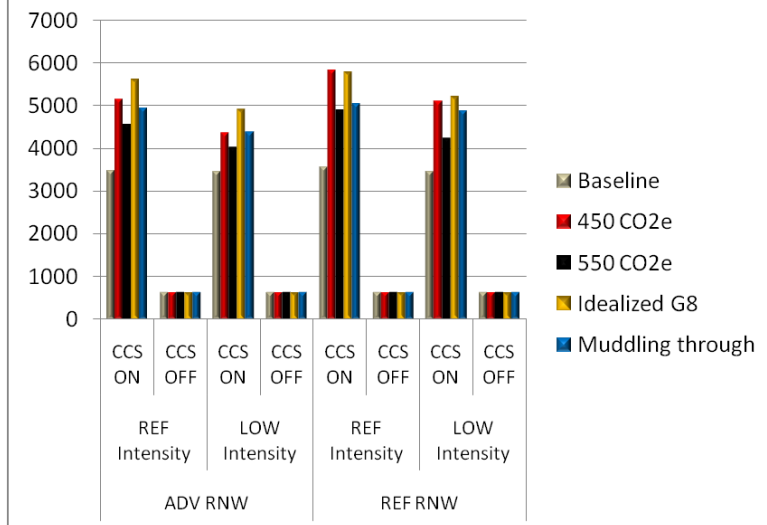
Cumulative Primary Fossil with CCS (EJ)



Nuclear

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Cumulative Nuclear (EJ)



A tentative synthetic storyline

- Complex interplay of biomass, CCS, and RNW, in two sectors: electricity and fuel production.
- Electrification of all end-use sectors is an important option for climate scenarios, increases markedly in severe scenarios and even more so in scenarios with less Biomass.
- Fuels from Biomass is another major option, fully utilized in severe scenarios, especially in industry and transportation sectors.
 - First choice is Biomass+CCS, but allocated differently to ELC and FUELS sectors, depending on the availability of Renewables. When Biomass is scarce, more electricity (using RNW) is produced to reduce emissions in end-use sectors.
 - Electricity from RNW is massively adopted to 'top up' Biomass+CCS.
 - When Biomass is restricted, more RNW is adopted, but also fuel production from fossil with CCS
- G8 scenario might well be a viable climate strategy: only moderately more expensive than 450ppm, and has similar climate impacts.
- M-T scenario is close to 550 ppm, but at much higher cost. MT induces significant leakage of energy trade and emissions