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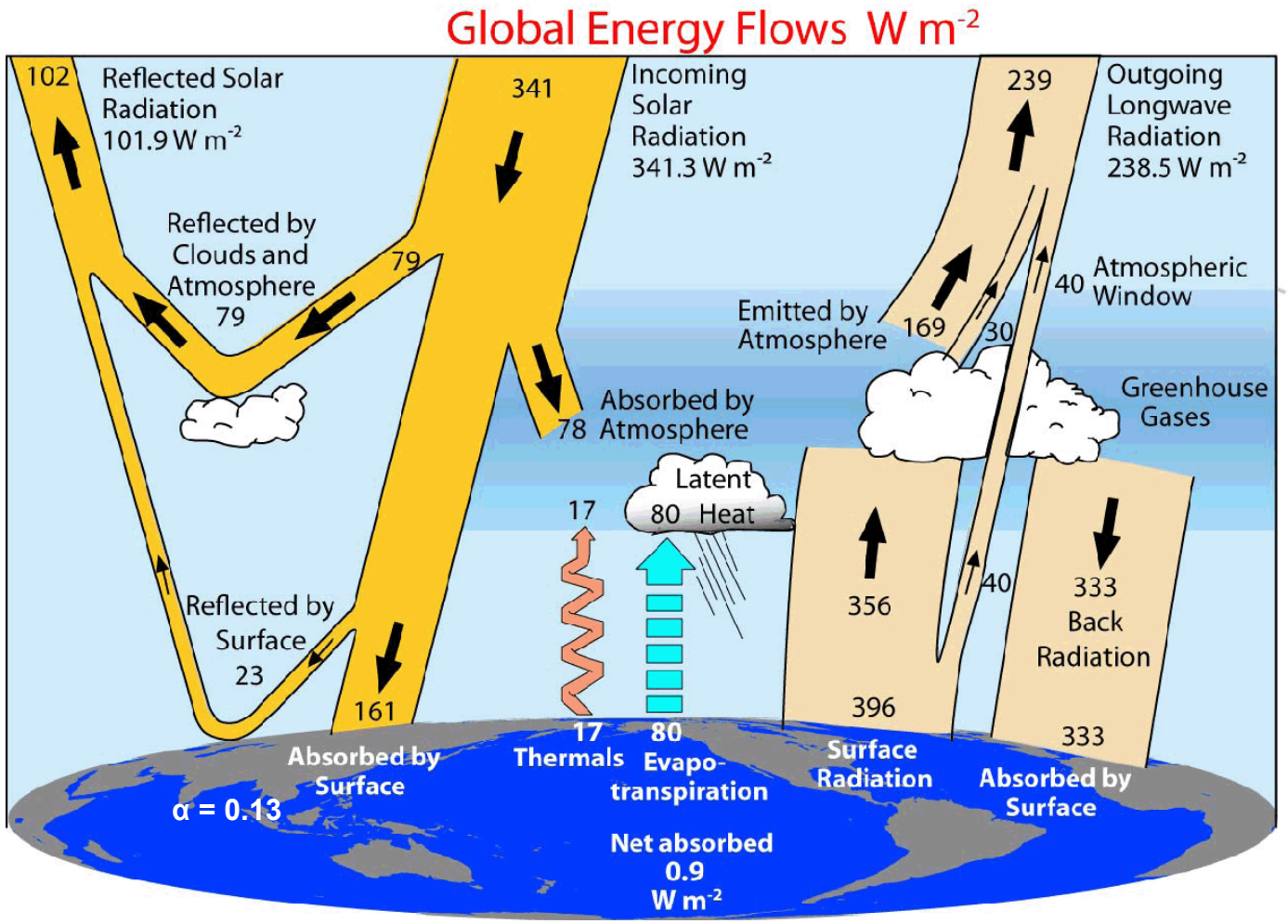
Radiative Forcing Impacts of Norwegian Forest Bioenergy: Forest Dynamics and the Albedo Effect

Ryan M. Bright & Anders H. Strømman
Industrial Ecology Program, Energy and Process Engineering
NTNU, Trondheim

Glen P. Peters
Center for International Climate and Environmental Research – Oslo (CICERO)

E-mail: anders.hammer.stromman@ntnu.no

The Global Radiation Balance



$F = \sigma T^4$

The surface albedo controls 54% of the shortwave budget (Graphics IPCC)

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Albedo is important at high latitudes

Table 1 Albedo parameter values before and after forestation

Land cover	α_0 (dark soil)	α_0 (medium soil)	α_0 (light soil)	α_s
Arable cropland	0.18	0.19	0.21	0.78
Dense coniferous forest	0.14	0.14	0.15	0.26

Source: Betts, *Nature*, (2000), see also Randerson et.al

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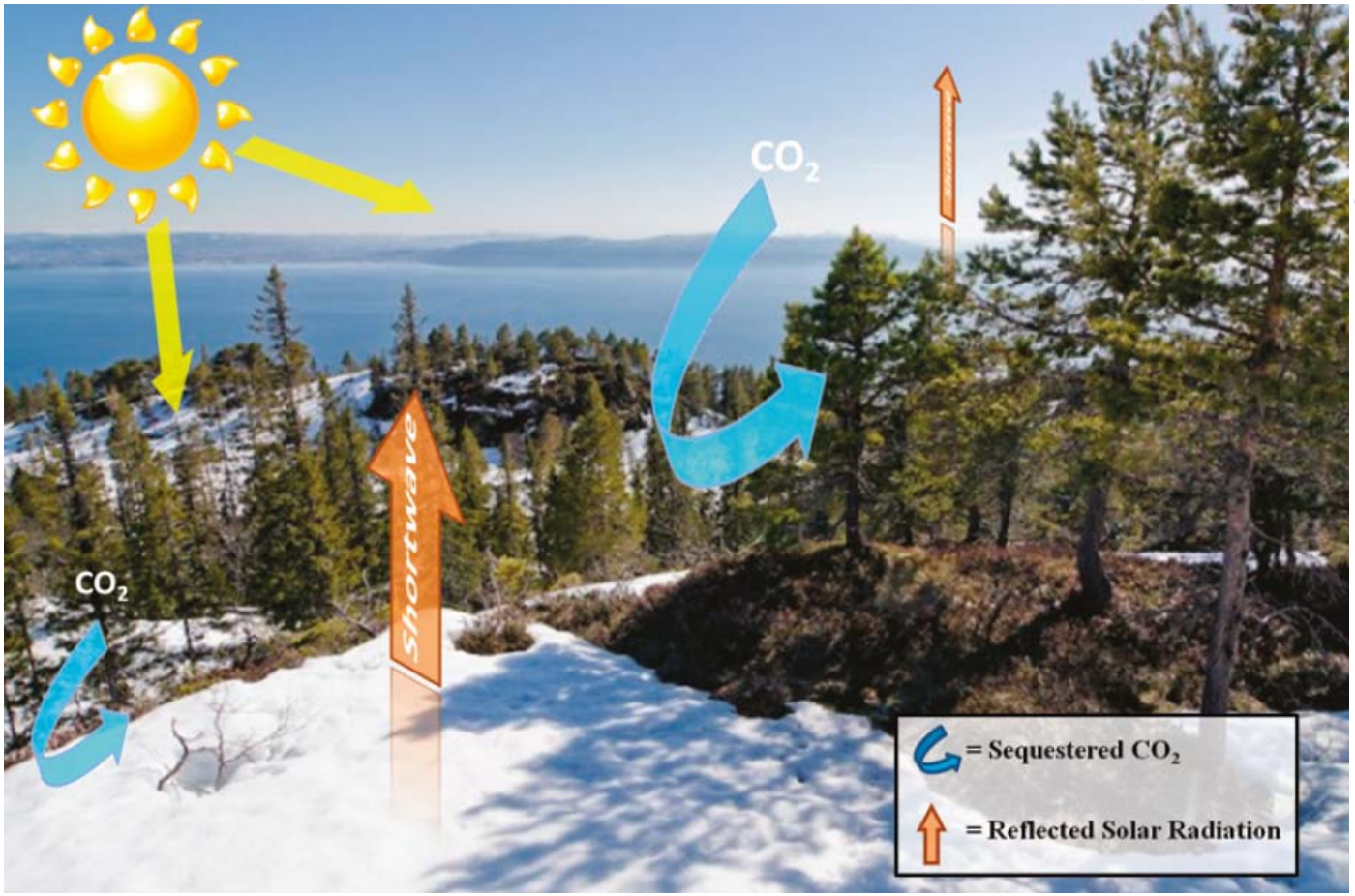
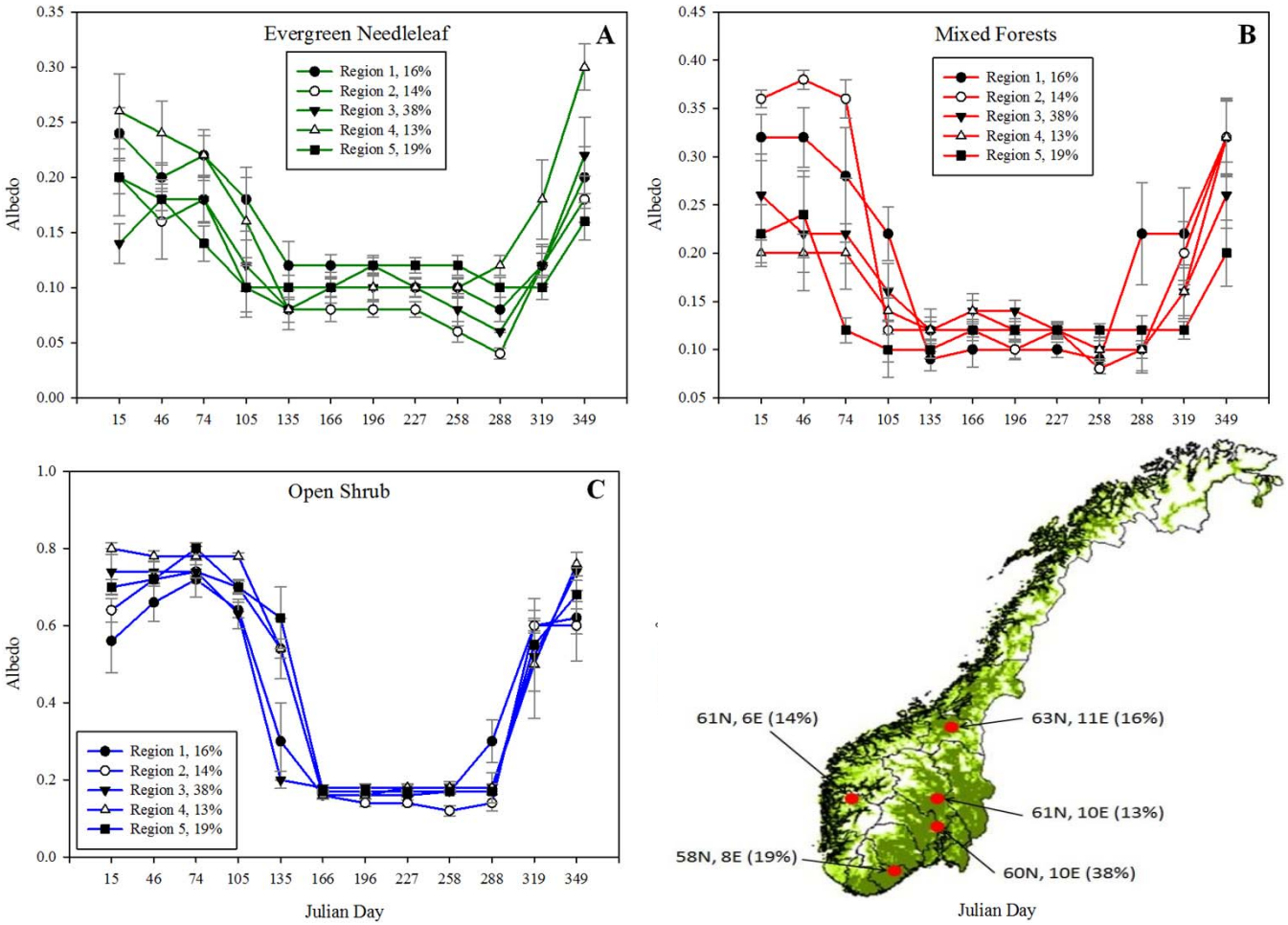
Overarching Research Question

How important is albedo for the assessment of climate impacts of Norwegian (Boreal) forest biofuels.



Before assessing scenarios : Establish basic buliding blocks

Determine Albedo Coefficients for mature forests and clear cut areas



Actual sky surface albedo data is provided by NASA's moderate-resolution imaging spectroradiometer, or MODIS (MCD43A1 BRDF/Albedo Product, Collection 5)
High quality w/snow cover, cloud-cleared results.
Data are retrieved for a 9-yr time series spanning January 2001 to December 2009 for each site.

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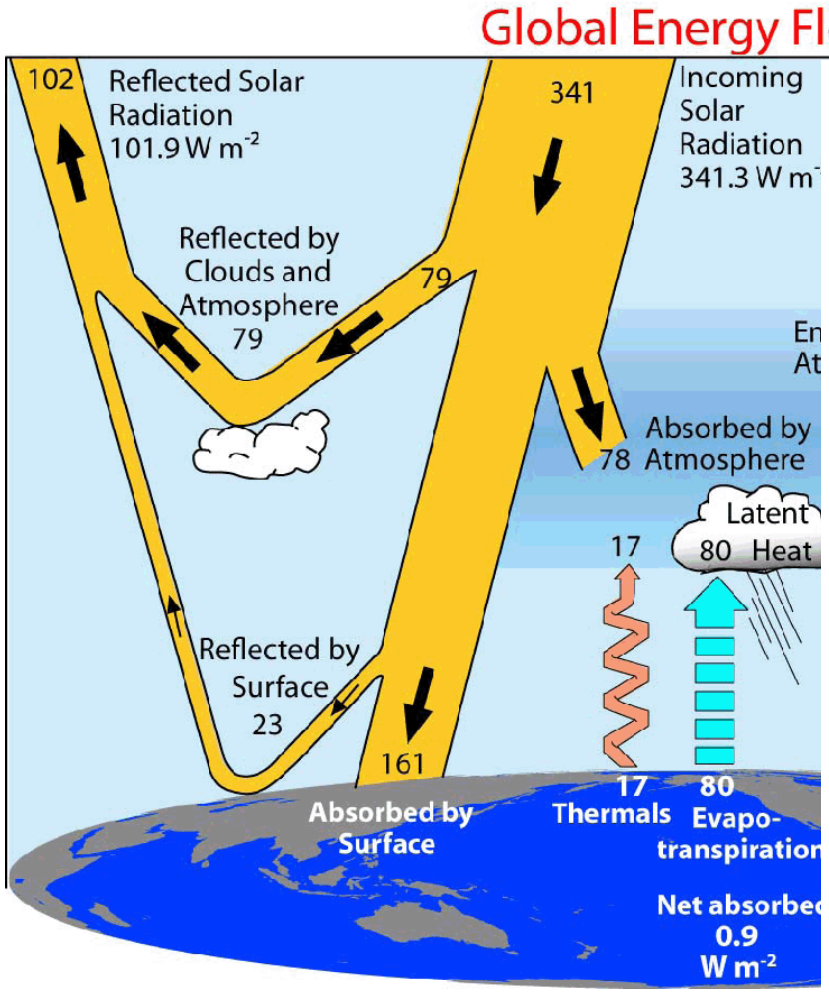
From top of the atmosphere and back again With Fu-Liou



For each location and land class
⇒ Monthly average albedo (9 yrs.)
⇒ Monthly incoming solar radiation (9 yrs.)
⇒ Cloud cover (3 yrs.)

⇒ Mean annual values of Delta SW at top of the athposphere

Global average: 239 W/m2

Needleleaf forests:	141 W/m2
Mixed forests:	139 W/m2
Open shrub:	125 W/m2

Albedo and forest regrowth

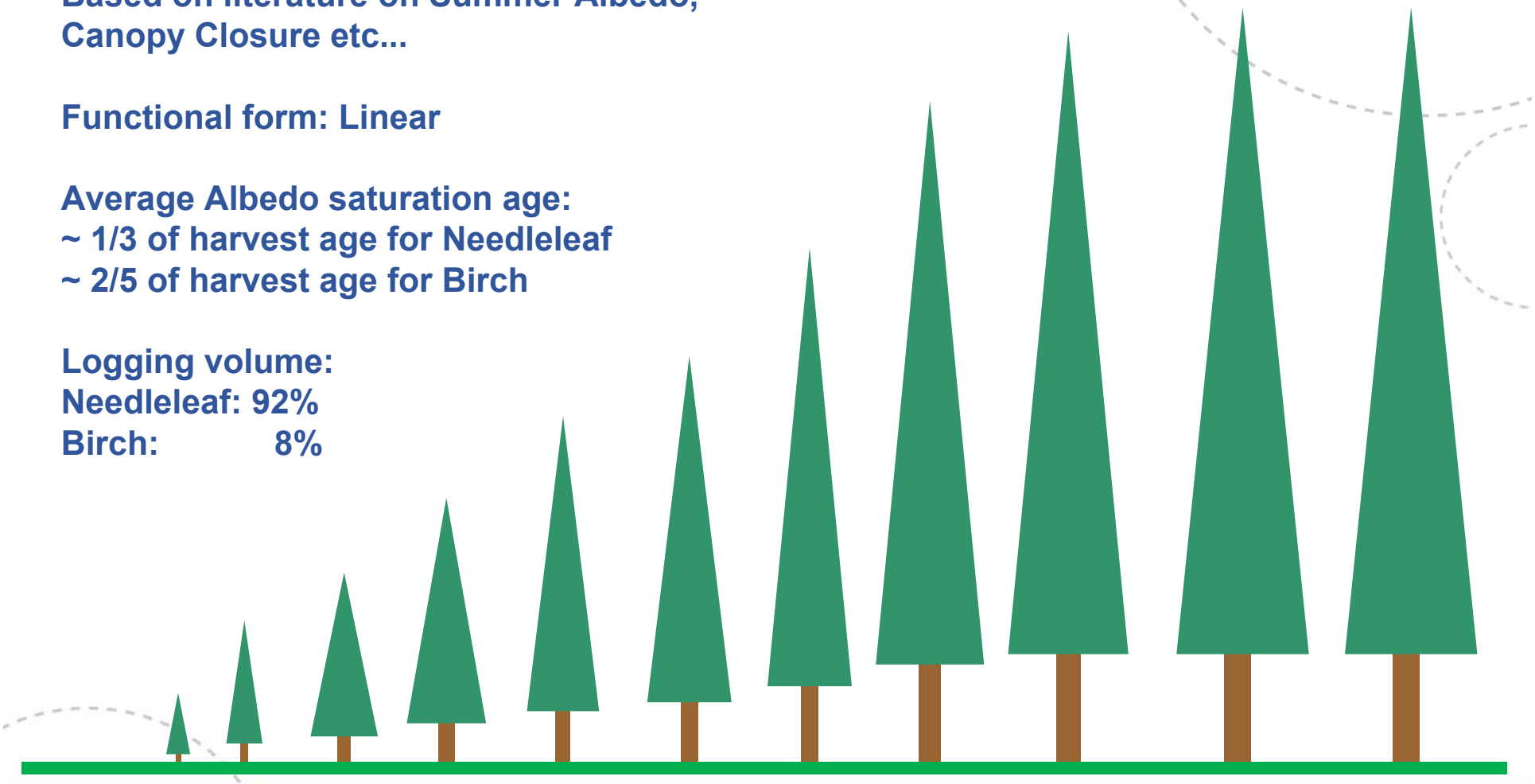
No data on albedo vs age class for Norway

Based on literature on Summer Albedo,
Canopy Closure etc...

Functional form: Linear

Average Albedo saturation age:
~ 1/3 of harvest age for Needleleaf
~ 2/5 of harvest age for Birch

Logging volume:
Needleleaf: 92%
Birch: 8%



Scenario Analysis

Scenario: Increase of logging to 15 Mm3/yr from 8.3Mm3/yr for the production of transportation biofuel in Norway for the next 100 years.

Biomass chips converted to FTD at η=45%, substitutes fossil diesel, at "vehicle". GHG: CO2, N2O, CH4

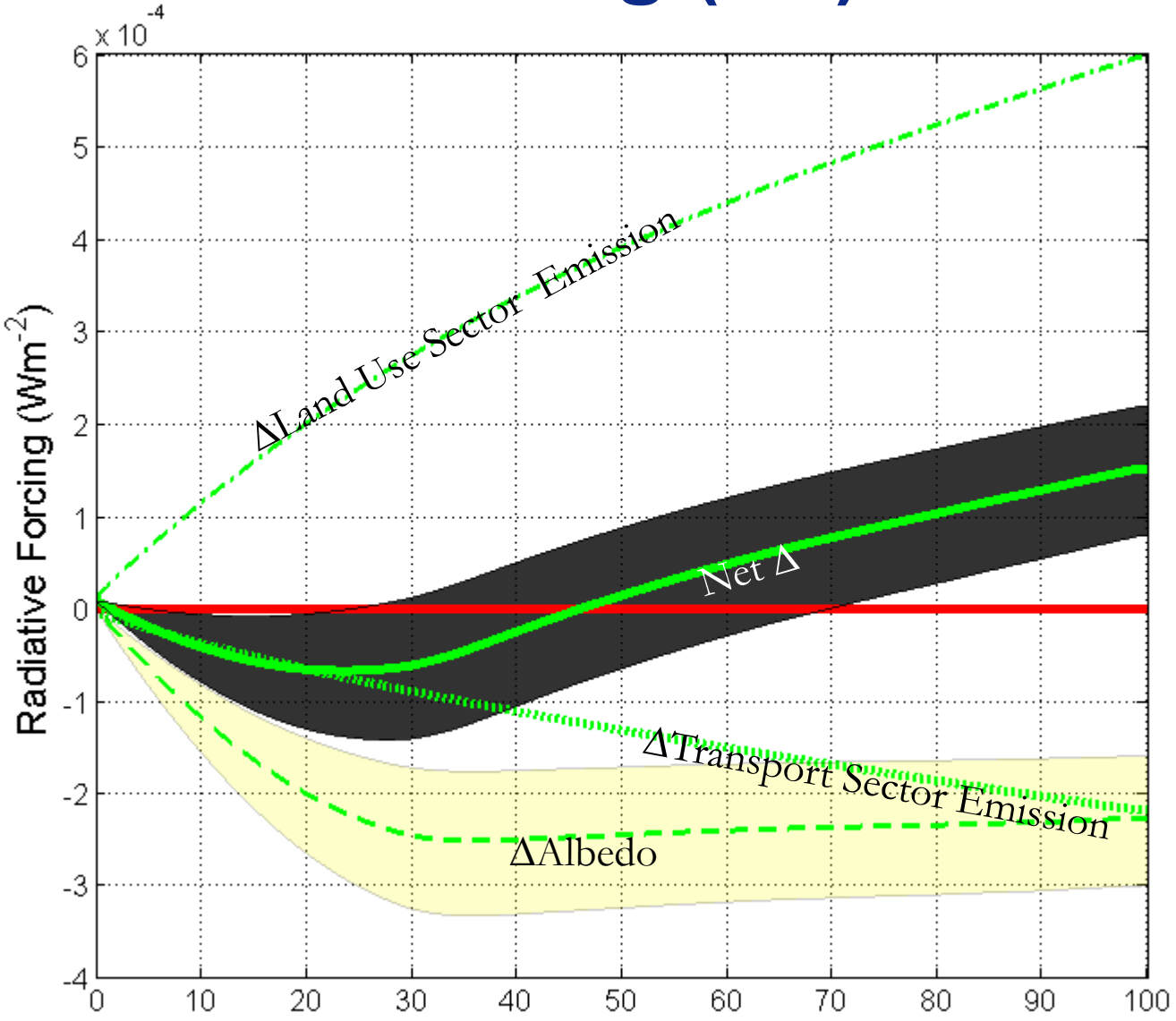
Landscape-level forest simulation model using data from Norway's 7th National Forest Inventory

Carbon accounting is done following IPCC's "Gain-Loss" (atmospheric flux) method

6 Carbon pools: Above ground living, Below ground living, Litter, Dead wood, Soil organic, Harvested wood products (including biofuels)

Yasso07 soil carbon model parameterized for Norwegian conditions is implemented to account for fluxes in soil organic C-pools

Radiative Forcing (RF) - FTD



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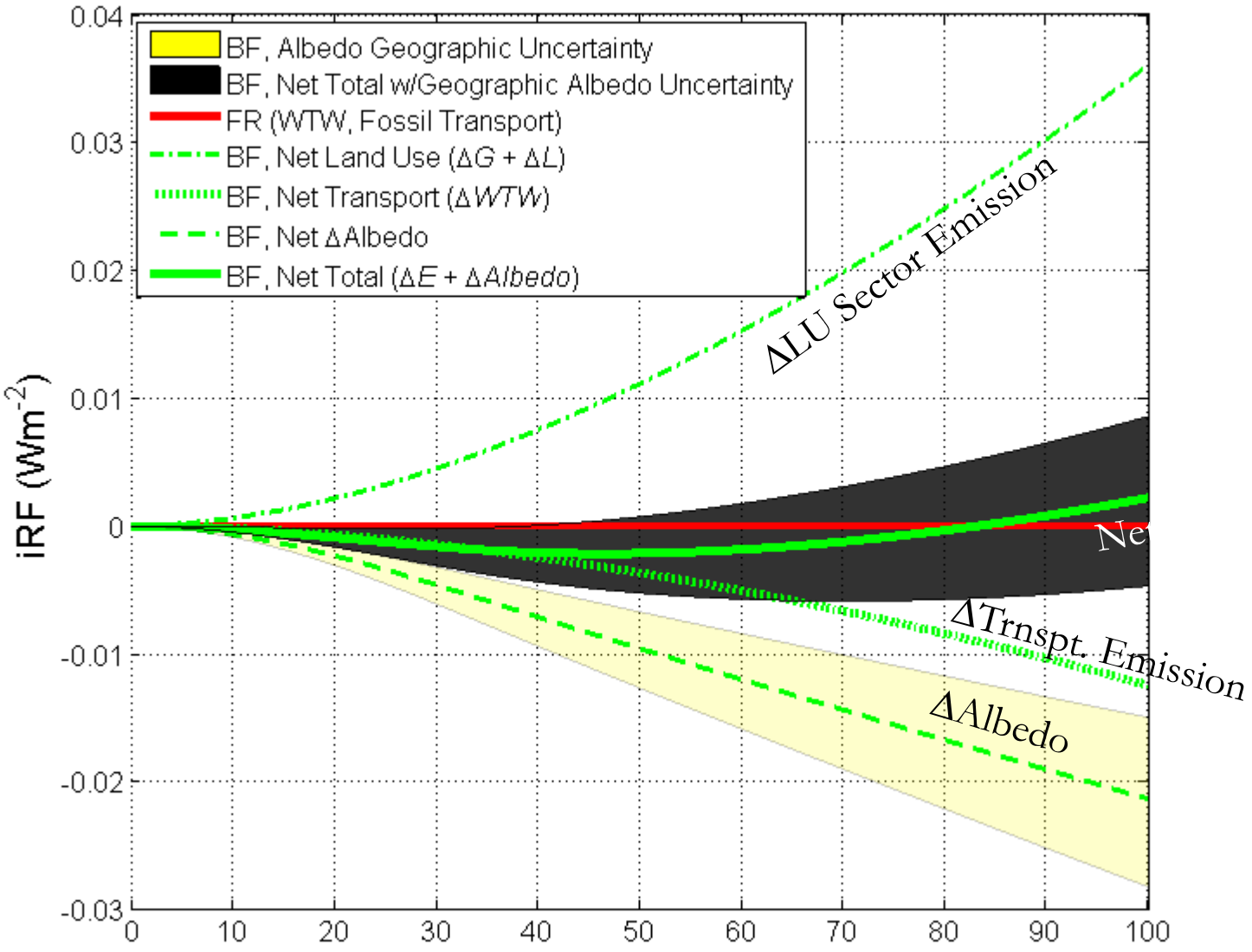
Integrated Radiative Forcing (iRF) - FTD



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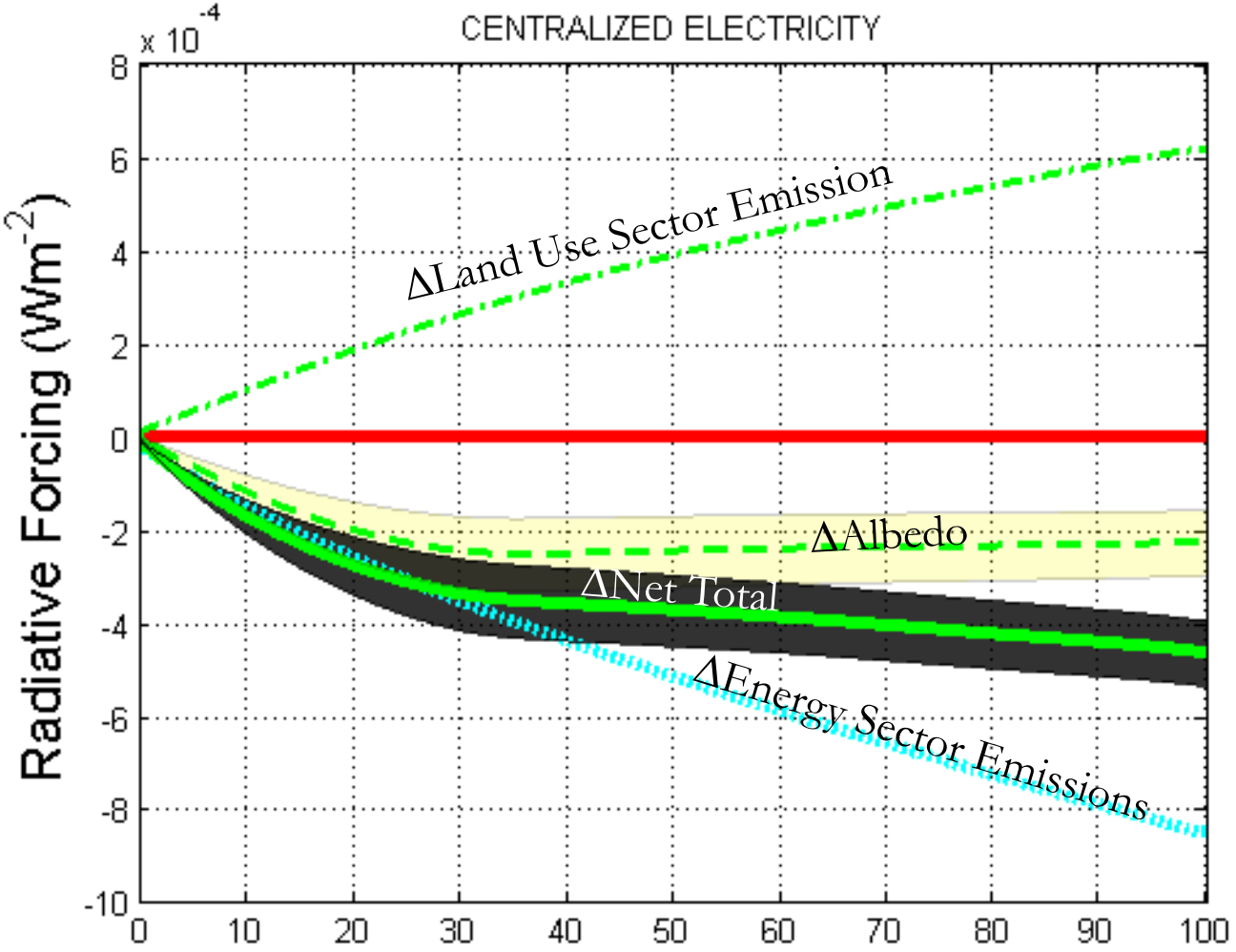
Radiative Forcing (RF) – Bio vs Coal



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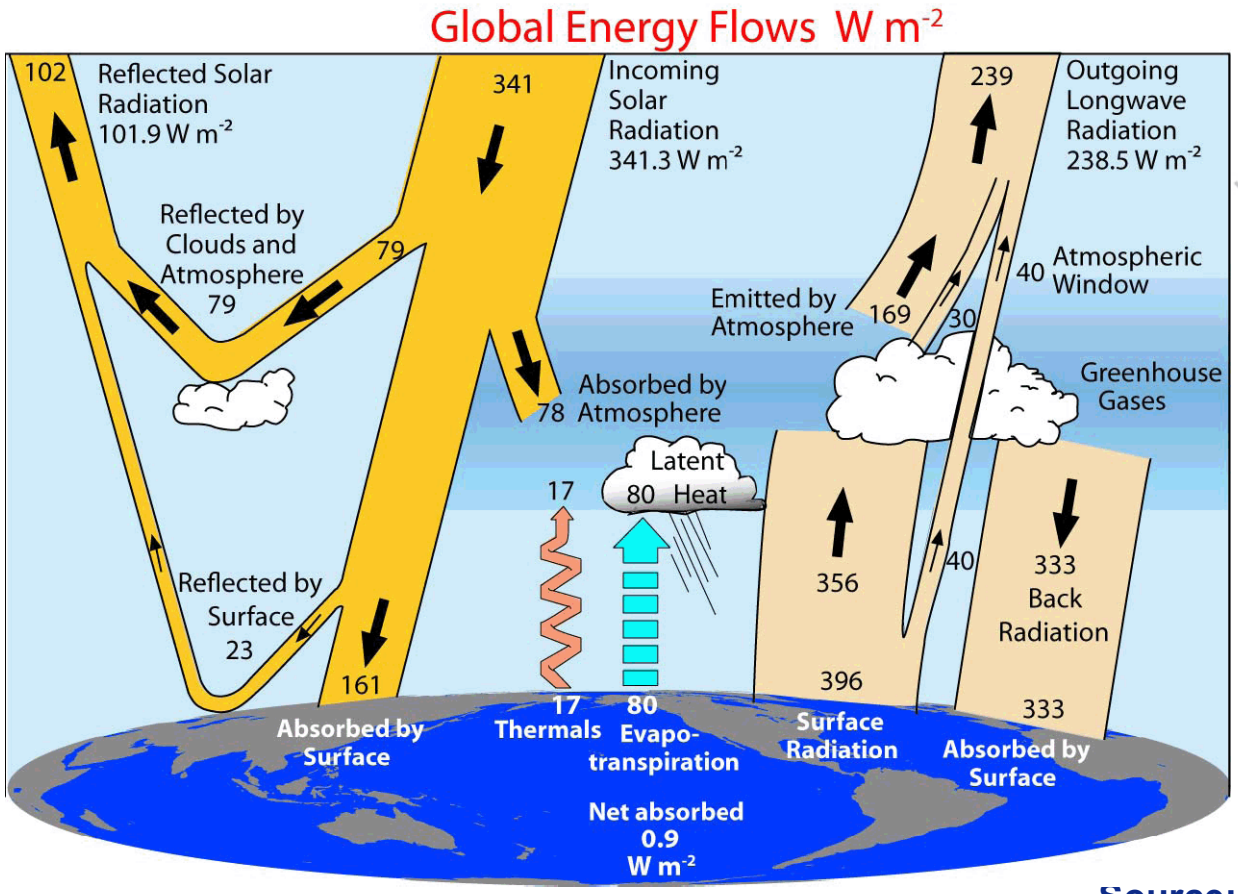
There is more to do beyond GHG…



Source: IPCC

- Biogeophysical interactions also play a prominent role in regulating climate and should not be forgotten' (See Bonan, Science 2008)

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Summary, Uncertainty, & Conclusions

- Albedo changes in forests benefit climate in short-term only; Long-term climate benefits mostly accrue through fossil substitution effects → Efficiency matters!
- Short-term forest management strategies should focus on enhancing carbon sinks and albedo simultaneously in light of tradeoffs between the two
  - Enhancing carbon sink productivity, for example, through species switching, fertilization, etc. may negate albedo-enhancing efforts like delayed regeneration, shortened rotation periods, etc.
- Uncertainties:
  - Stem largely from albedo modeling:
    I. The functional form of the albedo time profile following harvest
    II. No hard-linking of land use with albedo data
- Future research efforts should focus….
  - *On stand level albedo modeling* → How do specific silviculture and management decisions affect physical properties of forests, and how do these properties affect albedo developments in time?
  - *On understanding the tradeoffs between albedo and the carbon cycle* → Which specific management strategies will optimize mitigation benefits when albedo/carbon cycle tradeoffs are considered?
  - *On other biogeophysical parameters* → How will changes in other biophysical factors affecting the hydrologic cycle and the surface energy budget affect climate, both locally and globally?
  - *On understanding the impacts of climate change feedback mechanisms* → How will the long-term albedo and carbon cycle dynamics be shaped by climate changes itself?