EnergICE

A more realistic energy sector for the DICE model

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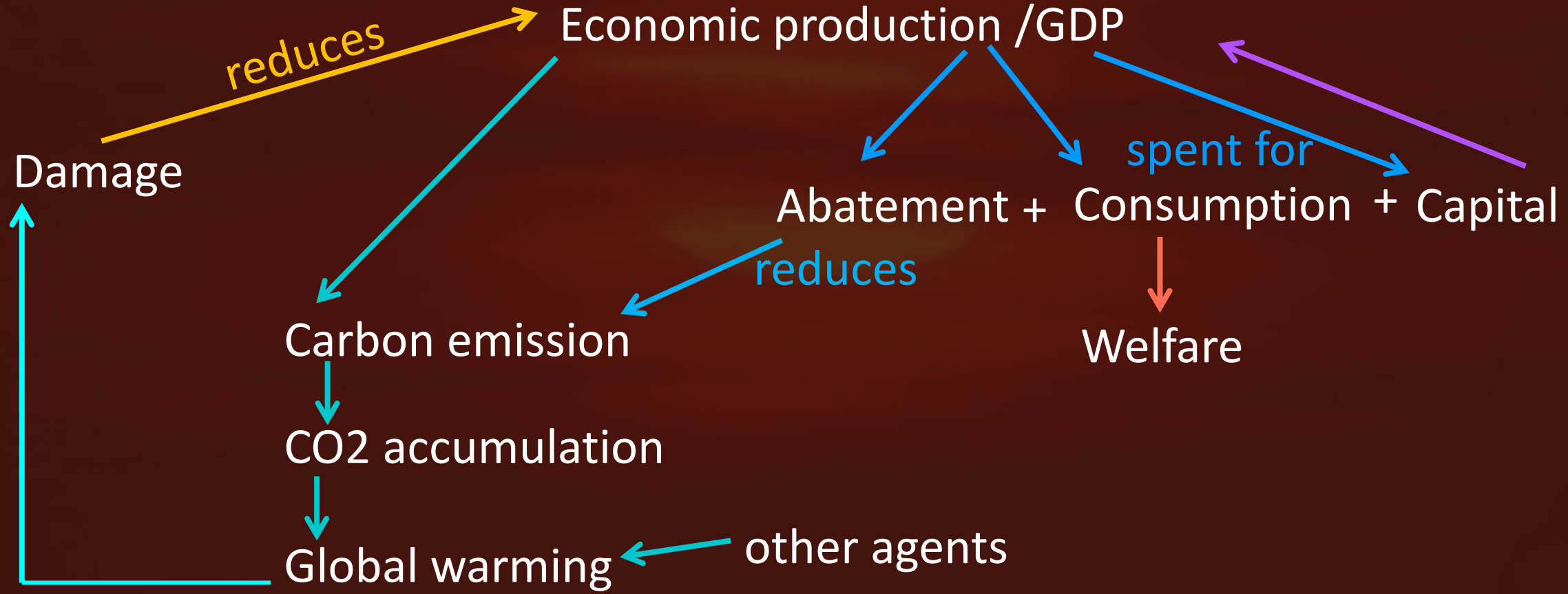
Original DICE: Model Structure

Dynamic **I**ntegrated model of **C**limate and the **E**conomy (W. Nordhaus)



DICE: use and criticism

Use

-- pionieering model of climate and economy by William Nordhaus (Nobel prize 2018)
-- very simple. Publicly available
-- used for teaching and as testbed model
(e.g. for geoengineering, climate damage assumptions,

Criticism

-- general criticism against simple IAMs (Pindyck …)
-- very low damage function ($D = k T^2$ => 5 degrees warming ≈ 6% GDP loss) => much discussed
-- setup of welfare, discounting => also much discussed
-- structure of abatement cost => largely ignored!
[Grubb et al., "Modelling Myths", WIRES, 2021]

Abatement cost and dynamics

Emissions: $E = (1-\mu) E_0$

μ = abatement (emission reduction fraction)
E_0 = emissions with no policy

Abatement cost: $$C_{abate}(t) = b_1(t)\mu(t)^{\beta} Y_{gross}(t)$$

Y_{gross} is GDP before subtraction of climate costs,
b_1 declines over time,
ß=2.6

Abatement cost and dynamics

Abatement cost: $\boldsymbol{C_{abate}(t) = b_1(t)\mu(t)^{\beta} Y_{gross}(t)}$

Problem 1: At time t, costs do not depend on the abatement done previously.

BUT: If we build a windmill this year, it will continue to save CO2 next year (at minimal cost)

Problem 2: Abatement always costs money, even 100 years after getting fully green…

BUT: If we have built many windmills, we get experienced and can do it cheaper
and save fuel-digging cost

DICE: climate protection is an ongoing cost
Reality: climate protection is a transition

[Grubb et al., "Modelling Myths", WIRES, 2021]

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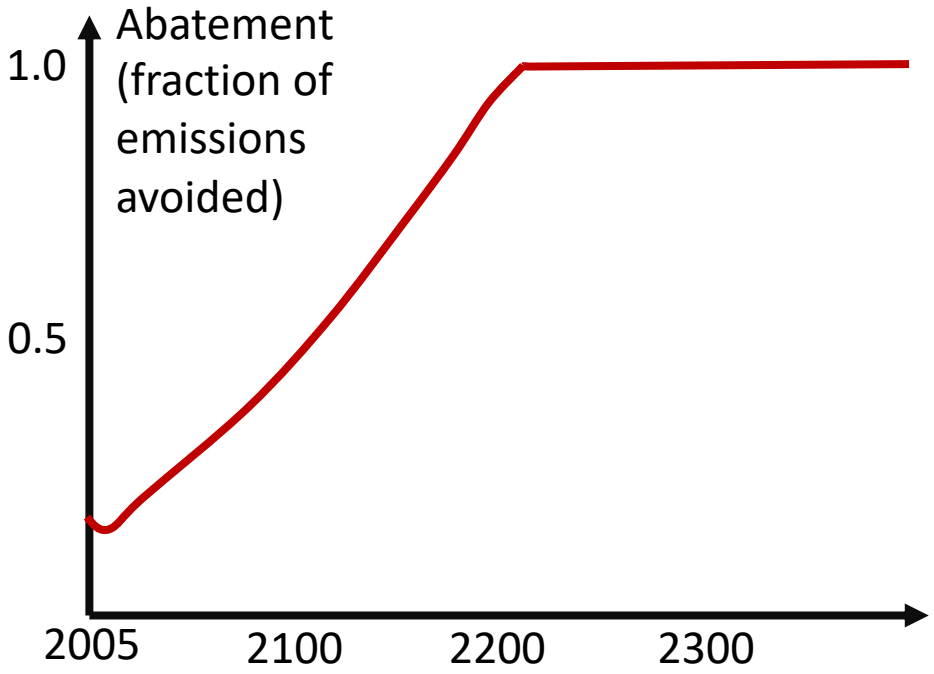
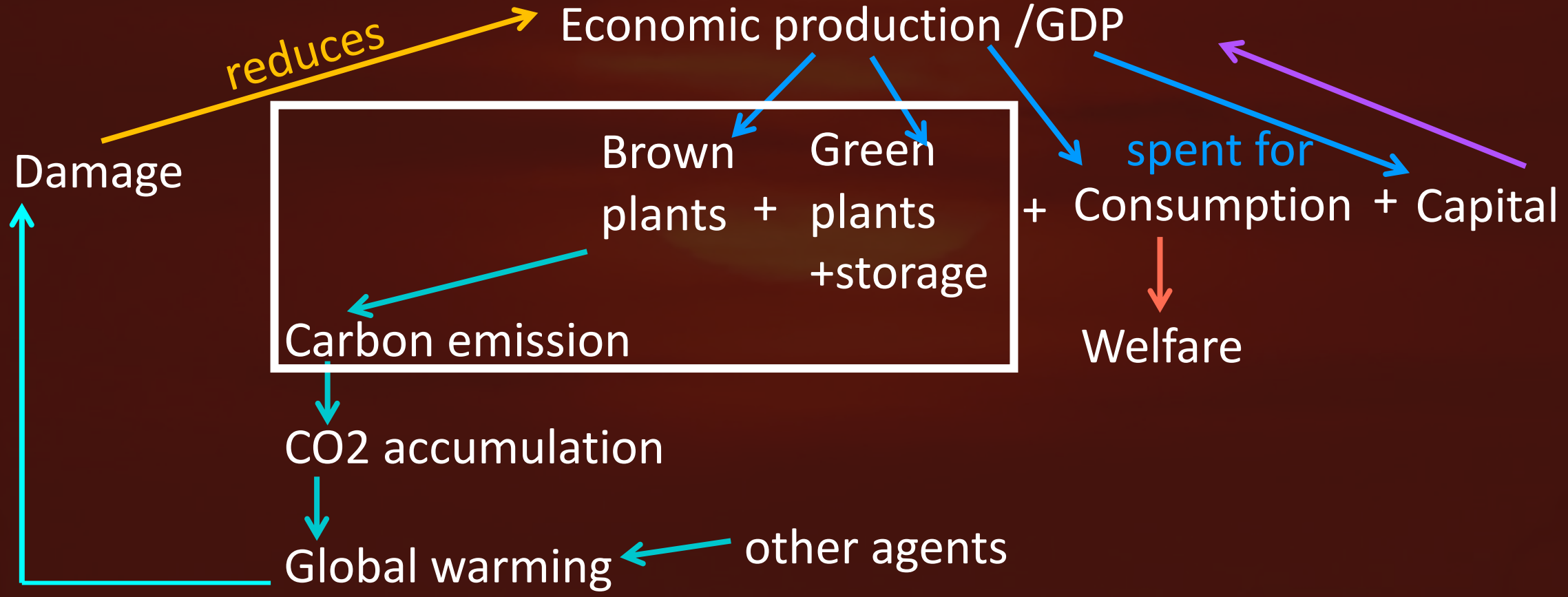
=> DICE generates very late abatement!



Source: Helwegen et al., 2019 (see below)
Precise timing depends also on e.g. climate parameters

New DICE: Model Structure

The **D**ynamic **I**ntegrated model of **C**limate and the **E**conomy



DICE with power plants (simple version, no storage)

“Brown” (coal) power plants

-- use fuel
- fuel cost (increases)
- emission

-- cheap to build

-- no learning

-- lifetime 60 years

“Green” (renewable) power plants

-- use renewables
- no operational costs
- no emission

-- initially expensive to build

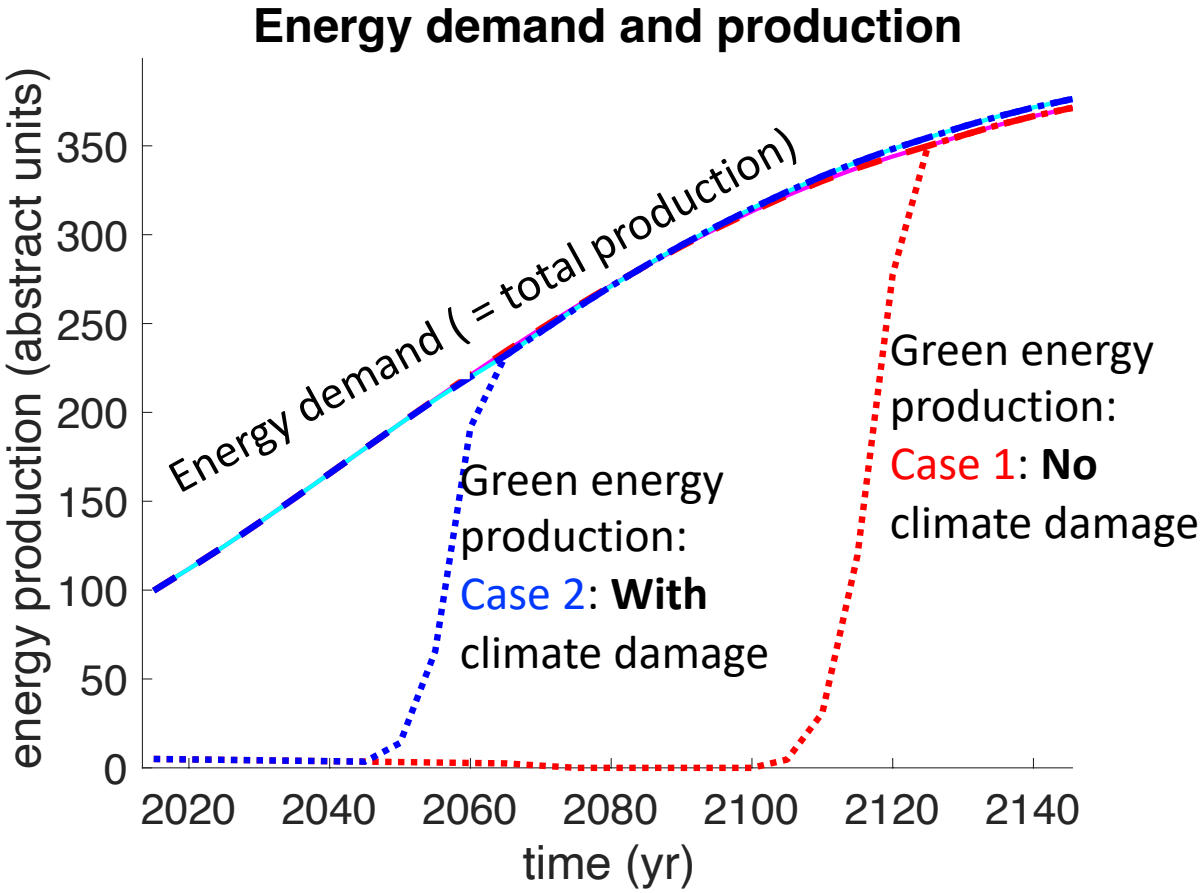
-- learning - by - doing

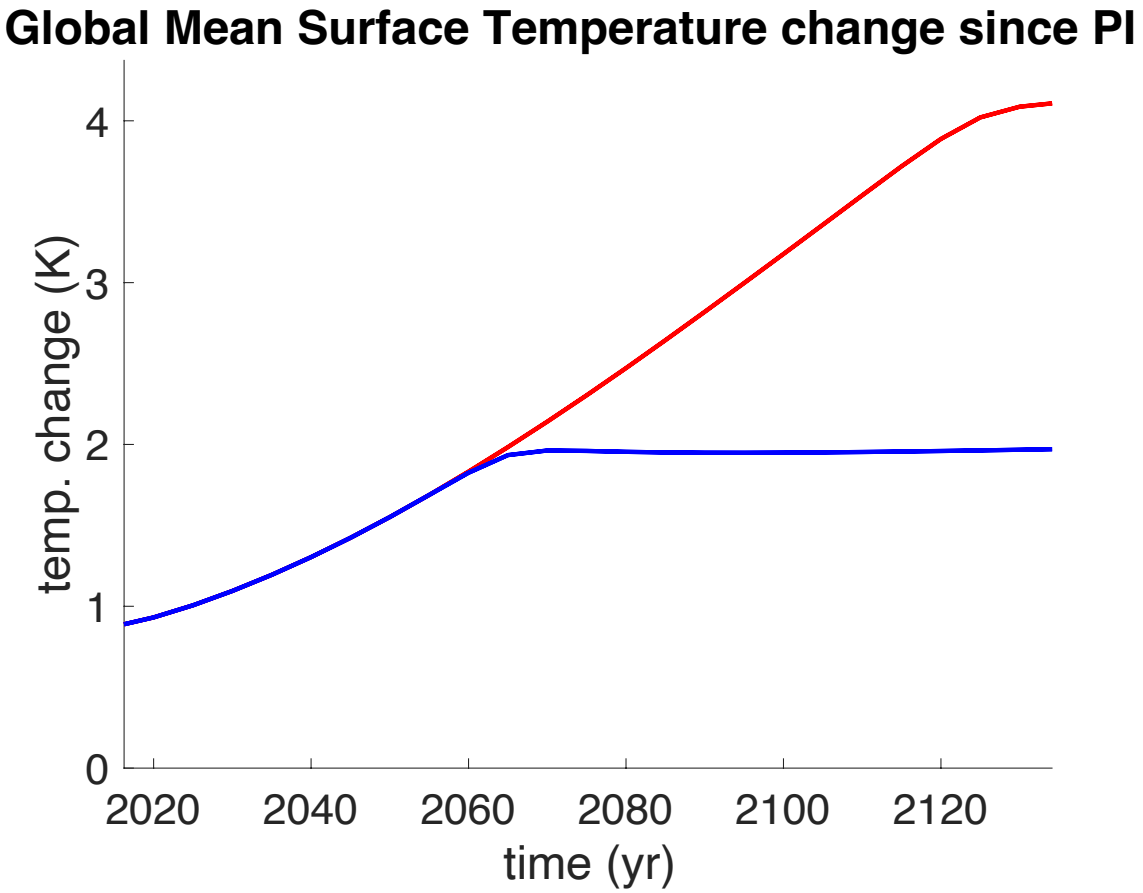
-- lifetime 60 years

“Abatement”: Each time step, decide how much green plants to build.
Brown plants will automatically be added when needed to fullfil energy demand.

Inspired by Brede and de Vries, 2013, and the DSK model by Lamperti et al

DICE with power plants (simple version)





Even Case 1, green transition occurs: Fuel gets expensive!

Transition earlier & faster than in DICE.

Costs depend only weakly on start date

DICE with power plants and intermittency

"Sunny" times:

-- green plants active
- can directly use green energy
- can store surplus (if we have storage)

"Dark" times:

-- green plants inactive
- can stored surplus if available
- else, need brown plants

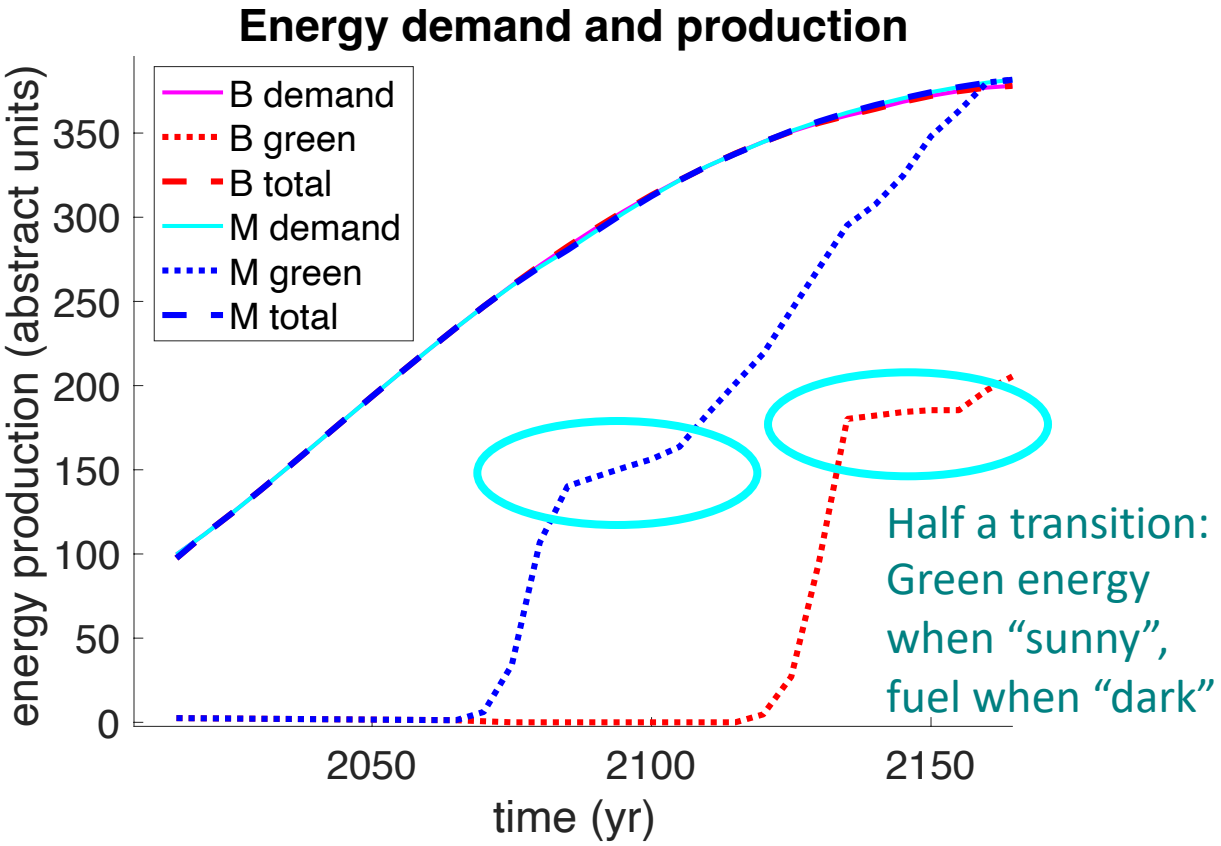
Storage facilities:
-- initially expensive
-- but learning-by-doing
-- efficiency < 1 (storage loss)

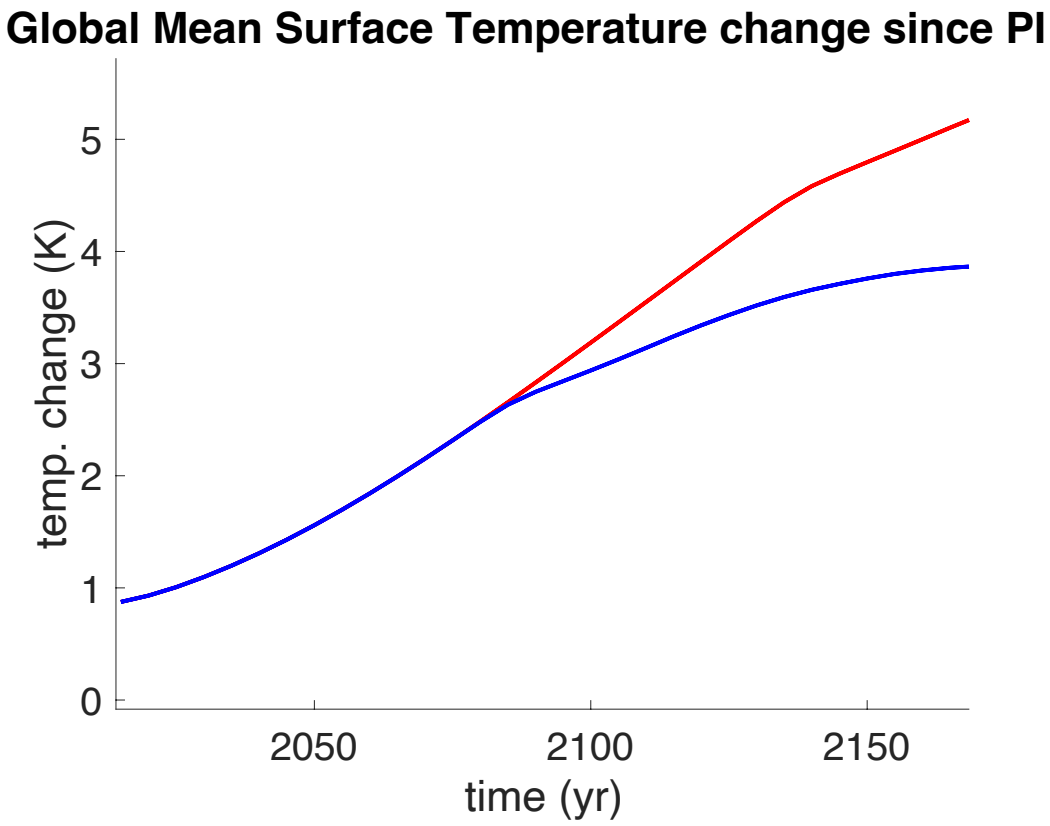
If ½ of time is "sunny", and storage efficiency is ½
=> need 3 times as many green plants than for "always sunny" case!

2 decision variables:
-- Nr of green plants built
-- Nr of storages built
+ enough brown plants to fulfill energy demand in dark times

DICE with power plants and intermittency

Case 2: with intermittency. Green energy available 1/2 of time. Efficiency of storage = 1/2.





New model (EnergICE):

-- still very stylised

-- captures transition-like character of decarbonisation

Application: Solar Radiation Management in DICE

Solar Radiation Management (SRM):

-- artificially cooling earth by reflecting incoming sunlight

-- here assumed to be Stratospheric Aerosol Injection (SAI)

Insert this into

-- original DICE *[Helwegen et al., 2019, ESD]*

-- EnergICE *[with BSc student Erwin Kemper]*

Classic DICE with SAI

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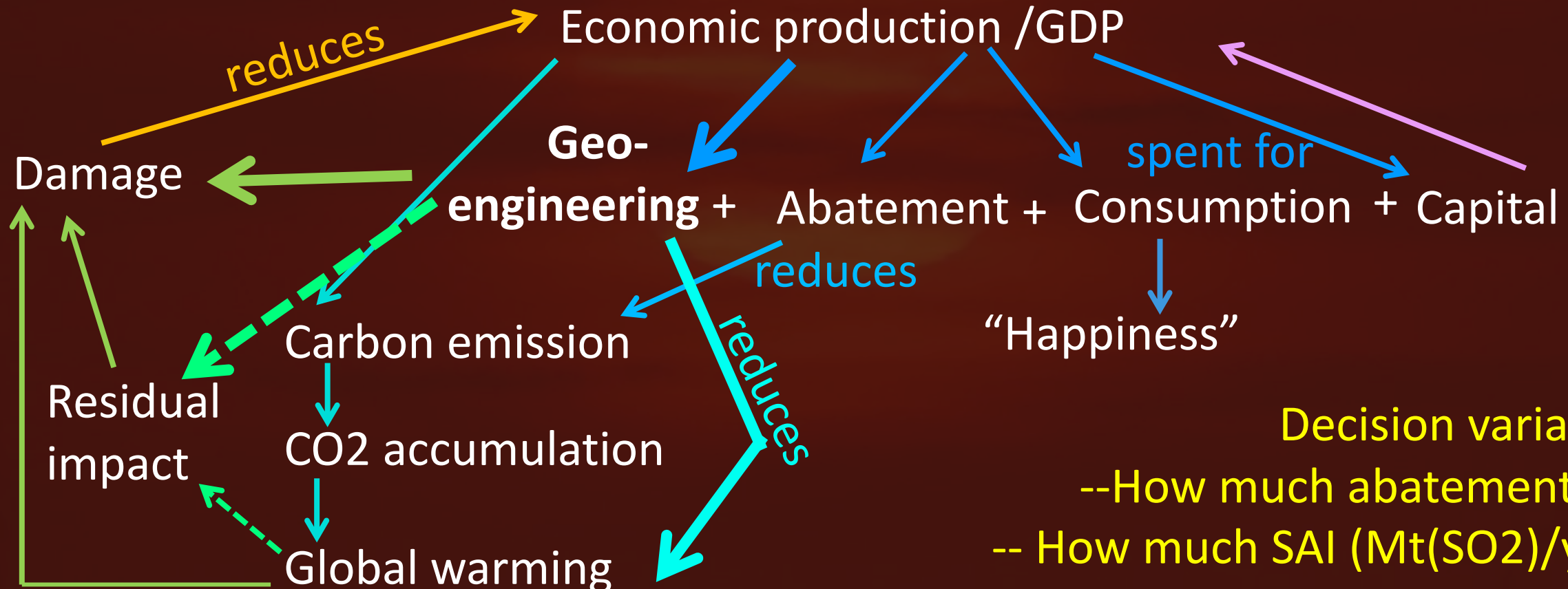
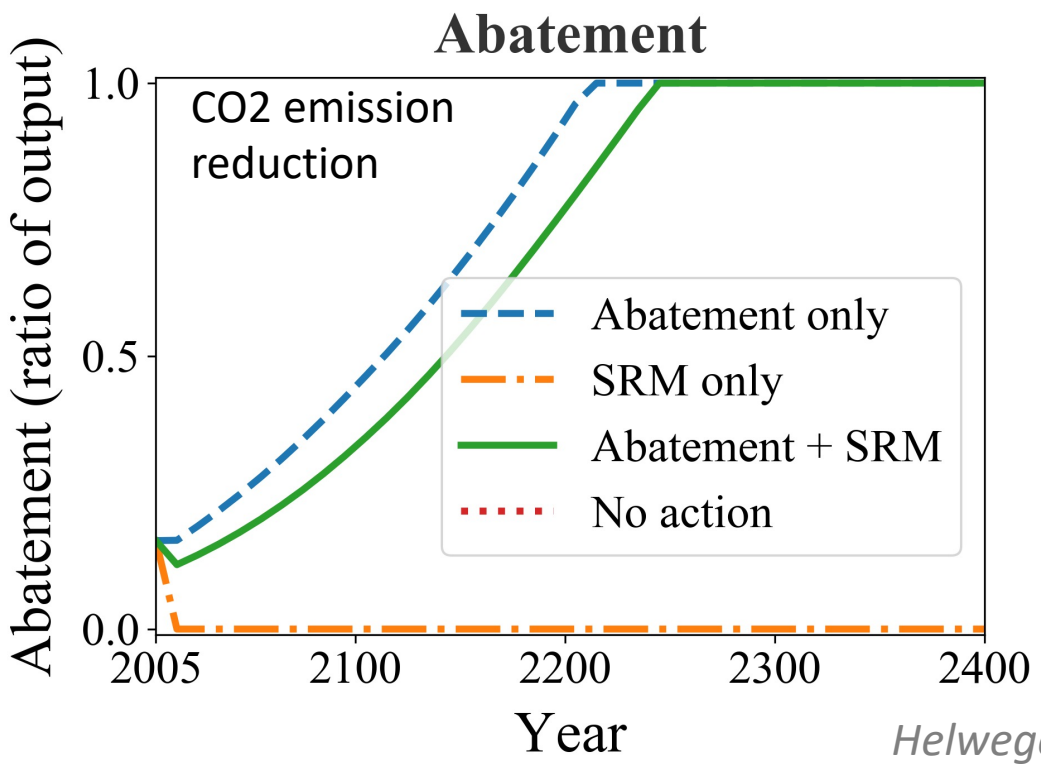


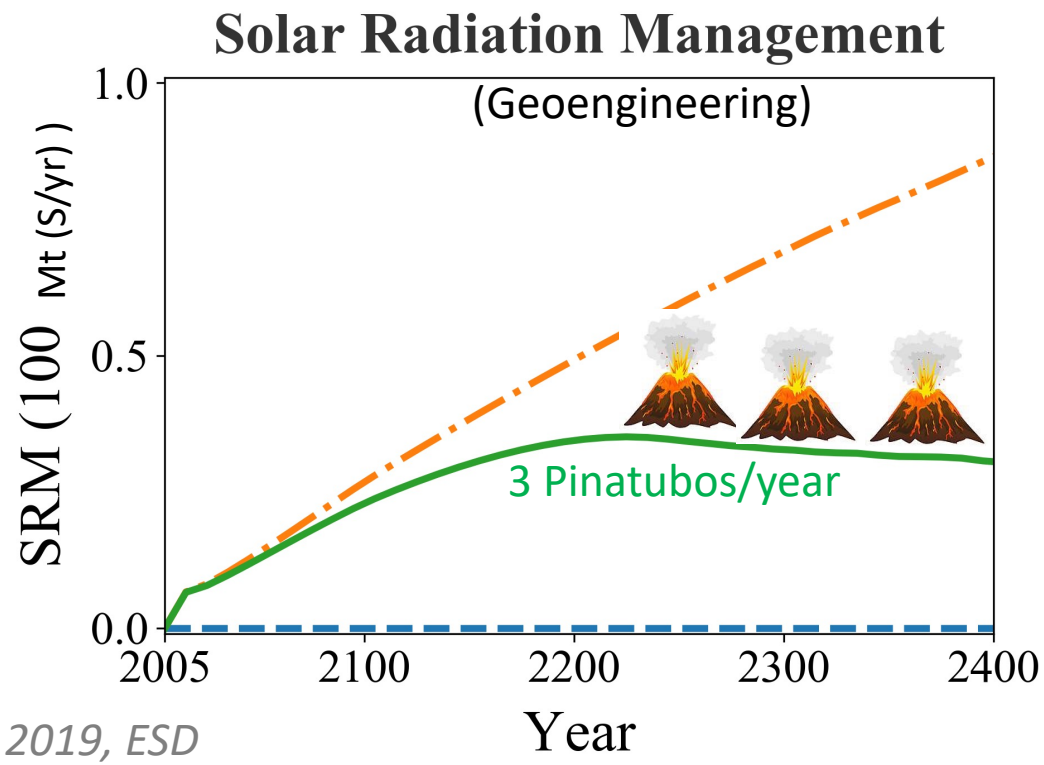
Decision variables:

--How much abatement (%)

-- How much SAI (Mt(SO2)/year)

Application: Solar Radiation Management in DICE



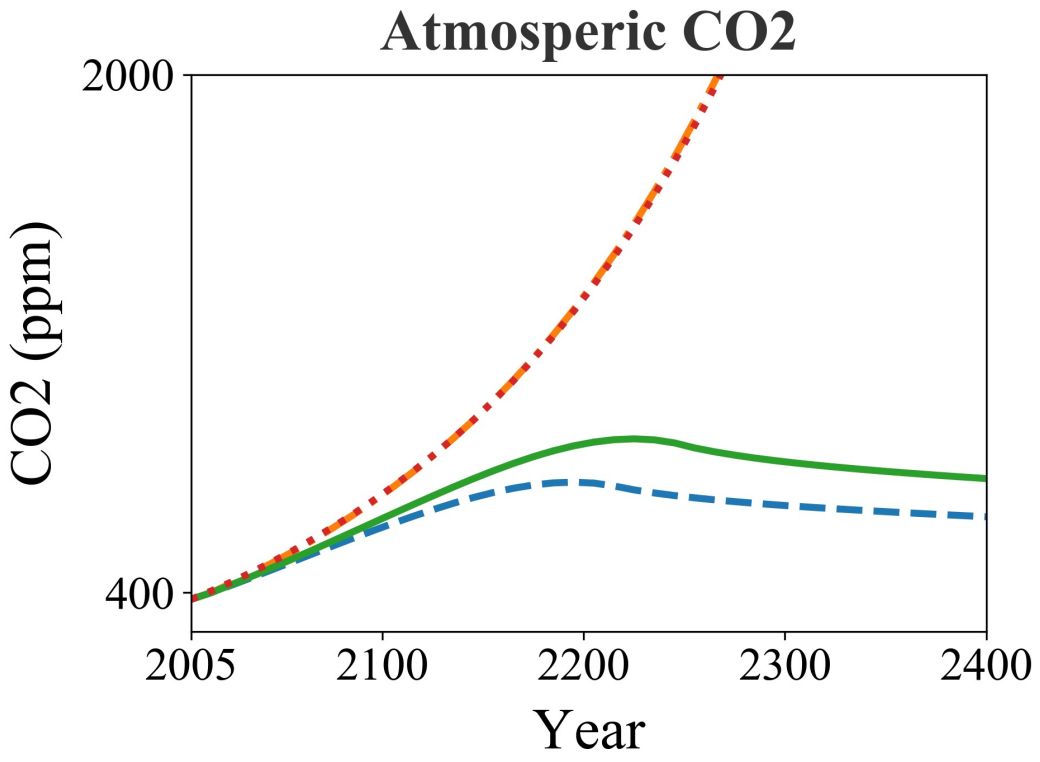


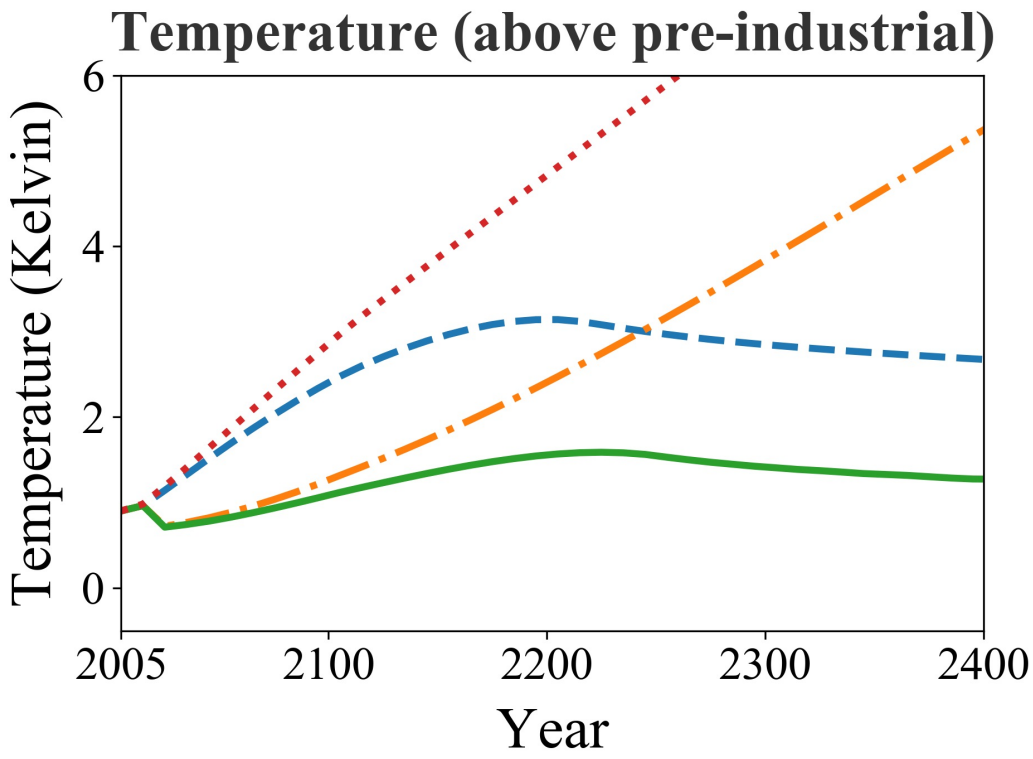
Helwegen et al., 2019, ESD

-- Geoengineering delays abatement, but does not replace it

-- With abatement, SRM is used at ≈3 Pinatubos / year (30Mt(S)/yr)

Application: Solar Radiation Management in DICE





-- Geoengineering delays abatement, but does not replace it

-- With abatement, Geoengineering remains limited to ≈3 Pinatubos / year (30Mt(S)/yr)

-- Only combination of Geo.+Abate keeps T<2K

Energy-DICE with SAI

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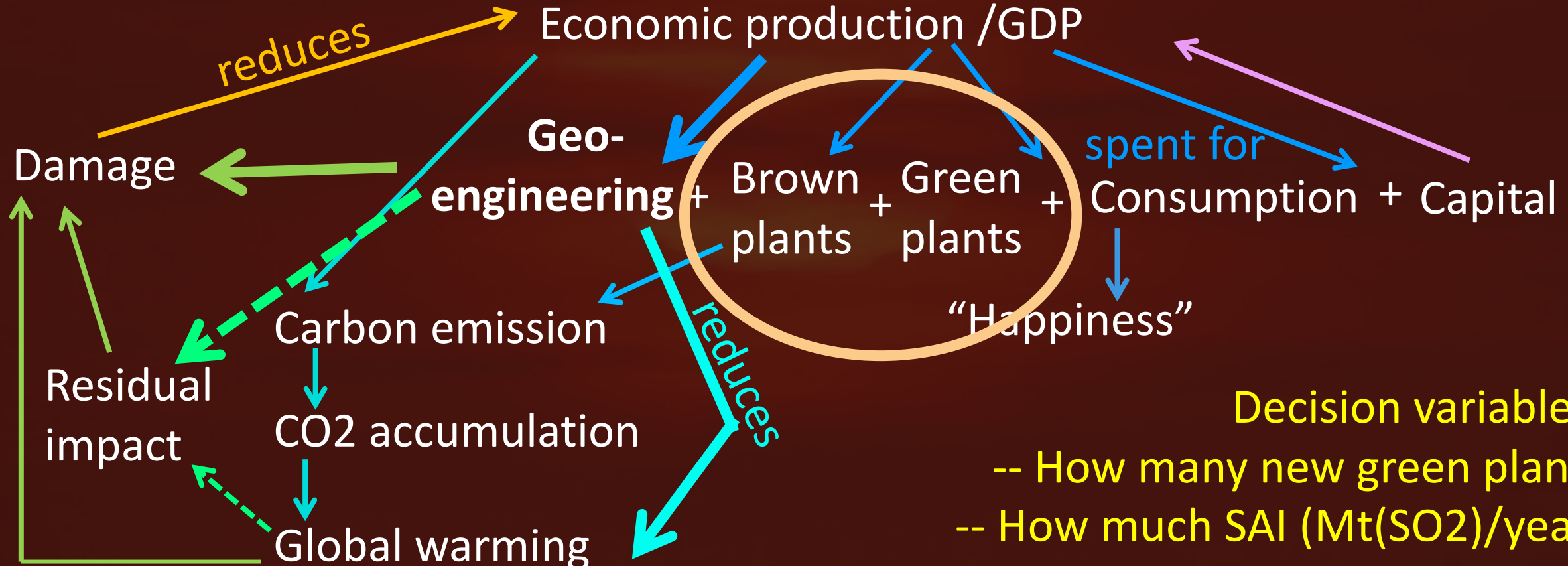
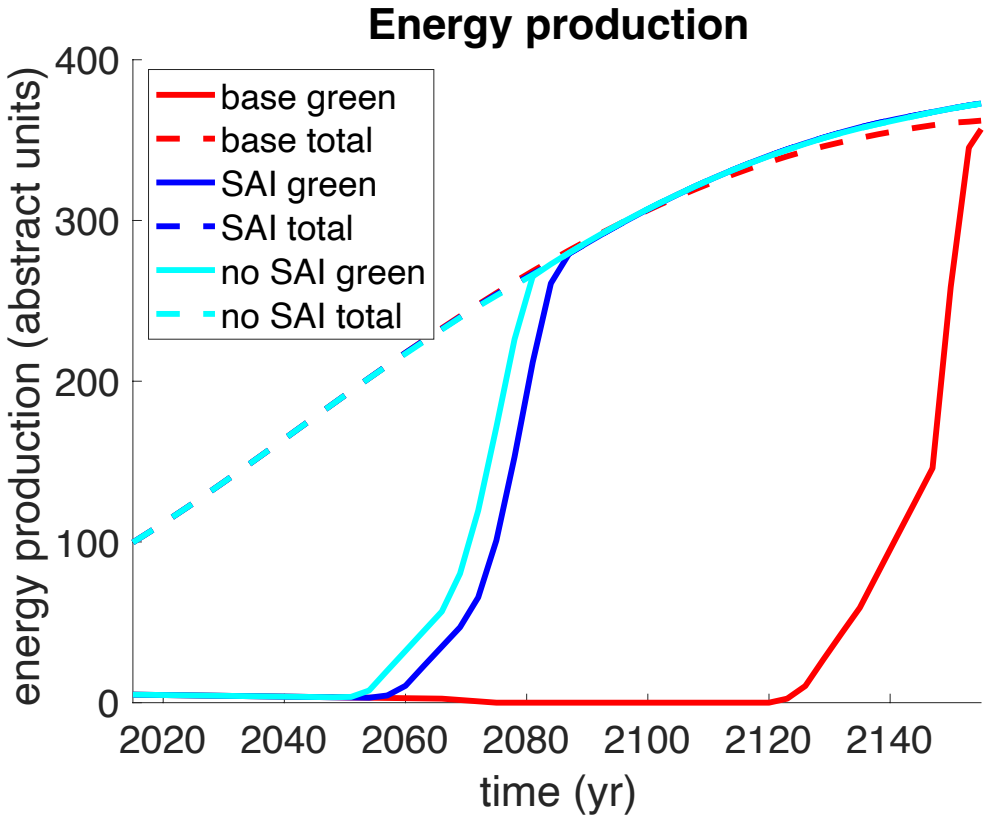


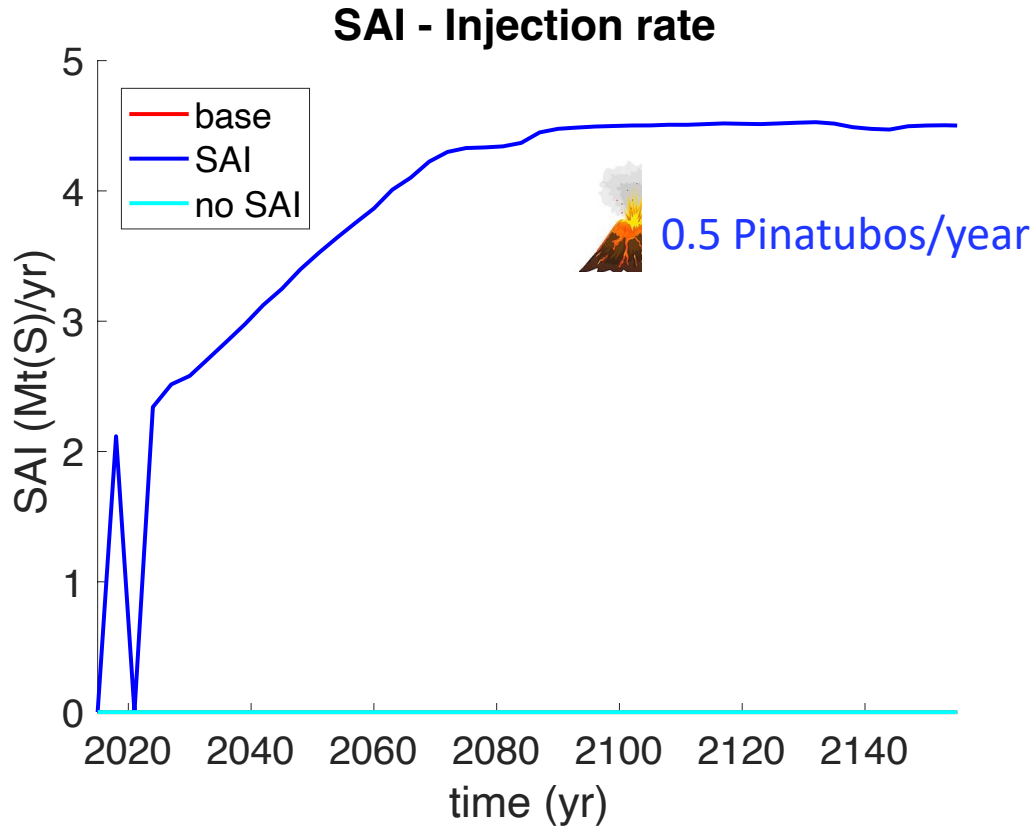
Decision variables:

-- How many new green plants

-- How much SAI (Mt(SO2)/year)

Application: Solar Radiation Management in DICE





-- Abatement hardly delayed by SRM availability: “need transition anyway, can do it now”

-- If SAI allowed, only about 5Mt/year is used (old DICE: 30Mt/year)

-- this is due to reduced need after more speedy green transition

Summary

DICE makes grossly unrealistic assumptions on abatment (emission reduction) cost.

-- cost independent on previous abatement (no investment, no learning)

-- cost remains forever (not transition-like)

EnergICE: green plant (and storage) investment as decision variable

-- captures transition-like character of decarbonisation

Choice of energy sector strongly influences "optimal" solar radiation management policy

=> is using DICE as test bed, energy sector matters!

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Some References

DICE

Overview paper (containing references to Nordhaus' many papers): Kellet, Weller, Faulwasser, 2019, "Feedback, dynamics, and optimal control in climate economics ", https://doi.org/10.1016/j.arcontrol.2019.04.003

Criticism of DICE's abatement cost

Grubb, Wieners, Yang, 2021 "Modelling Myths: On DICE and dynamic realism in integrated assessment models of climate change mitigation" https://wires.onlinelibrary.wiley.com/doi/full/10.1002/wcc.698

SRM in classic DICE

Helwegen, Wieners, Frank, Dijkstra, 2019, "Complementing CO_2 emission reduction by solar radiation management might strongly enhance future welfare" , https://doi.org/10.5194/esd-10-453-2019

Manuscripts on EnergICE, and SRM in EnergICE, are in preparation.