Bio-Energy with Carbon Storage (BECS): a Sequential Decision Approach to the threat of Abrupt Climate Change

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<u>BECS Concept</u>

BECS combines two near-zero emissions <u>technology types</u>

1. Bio-Energy
   - Production of biomass – waste retrieval [MSW],
     annual crops [sugar], plantations [which are the focus of ‘being prepared’].
   - Utilisation of biomass – power production, CHP, biogas, pyrolysis to syngas, fermentation, etc.
2. Fossil fuel Carbon Storage permanently
   (c.f. temporary sequestration in near-surface ‘sinks’)
   - Underground (aquifers, coal bed methane, tertiary oil recovery)
   - In the oceans (dispersed – behind oil tankers on return trips?
     – concentrated on ocean bed – dry ice?

COMBINE THEM

AND YOU HAVE

A NEGATIVE EMISSIONS ENERGY SYSTEM :

THE MORE GAS YOU GUZZLE THE **GREENER** YOU ARE !!

[***not quite true as there is an environmental constraint on how much land is used to produce the biomass***]

AIMS OF THIS PRESENTATION

1. Explain motivation:
   - Positive Options in Abrupt Climate Change Insurance
   - Sequential Decisions
   - Robust Strategy
   - Ancillary Benefits

2. Describe two Models:
   - Fuel/Fibre/Farming/Faces to Feed Land Allocation Model for Energy/Environment Sustainability
   - Landowner's Optimal Land Allocations
   - FLAMES: simulation model operational since ~1997
   - LOLA: new – econ. rationality added to FLAMES

3. Present Model Results and Caveats

4. Conclusion is a question

<u>Positive Options in Abrupt Climate Change Insurance</u>

- Abrupt Climate Change "haunts the climate change problem"
  – IPCC TAR WG3 Chapter 10

- NAS Report "Abrupt Climate Change: Inevitable Surprises"
  (ACC is a regime change in a non-linear dynamic system)

- Typically a NLDS regime change is heralded by precursor signals

- A Positive Option in insurance theory is a low cost 'be prepared' physical investment to ameliorate risks

Noah's Ark	}build them at low cost : live
Nuclear fall out shelters	}live in them at high cost if it
	}rains - be it a Biblical deluge
	}or nuclear ash

If there is a threshold we may need a negative emissions energy system, as provided by BECS.

Particularly if it is an integral threshold - the climate can take so much warming for so long, but, e.g. not for long enough to melt polar sea ice, so we may need to get temperatures down after the present or near future peak, which means get C levels back towards or below pre-industrial.

Zero emissions [solar, wind, etc] will not do the job but only trend asymptotically to the by now elevated levels in terrestrial and near-surface ocean layers. BECS sucks CO_2 out of the atmosphere, generates useful energy and pumps the CO_2 back underground.

Sequential Decisions

BECS on a large scale implies large scale land use change and involves decisions to:

1. Grow biomass [low cost]
2. Use biomass as energy system raw material
   [low cost if no stranded assets involved]
3. Capture and store CO_2 emissions from large point sources [high cost but not undertaken unless also for competing fossil fuel]

The modelling focus is on plantations to facilitate de-coupling of carbon in atmosphere reductions from energy technology change, thus avoiding stranded assets

Sequential decisions in the North

1. Farm support; build biomass stock for energy security concerns
2. Technology development; precautionary demonstration against oil price risks
3. In response to ACC precursor signals

Sequential decisions in the South

1. End unsustainable use of natural firewood
2. Modern rural energy; energy security and econ take-off (liquid fuel exports).
3. In response to ACC precursor signals

Manhattan Project style actions taken over the following decade in response to scientific news of Abrupt Climate Change precursors

1 Retrofitting of all large point source fossil and bio fuel emitters with CCS technology
2 All new large fossil and bio fuel plant fitted with CCS technology
3 A system of gathering pipelines installed to collect captured CO_2 and deliver to below ground storages
4 All long rotation policy land converted to short rotation mainly bio-fuel production with the part grown bio-mass material used wholly for biofuel
5 Shift from half to full atp for non-fuel renewable energy and technological progress.

(These could be outcomes of shift to very high C-price, but other measures, such as absorption portfolios protect consumers and may be preferable)

The effect of these measures is that emissions fall
from .025tC/GJ to .015tC/GJ per ton of fossil fuel and
from zero to – 0.01tC/GJ per ton of biofuel ,
with biofuel supply rapidly dominating the market.

<u>Robust Strategy</u>

A. Start doing things with long lead times
[build the Ark before the rain starts]
B. Choose options with low sunk costs or with alternative uses
i.e.

Acquire needed information [research is relatively low cost]

- Focus climate science effort on developing capacity to recognise precursor signals [hopefully recommendation of IPCC 4th Assessment Report]
- Develop Carbon Capture and Storage technology [US DOE doing it – good]
- Explore for deep aquifer storages near potential biomass production sites

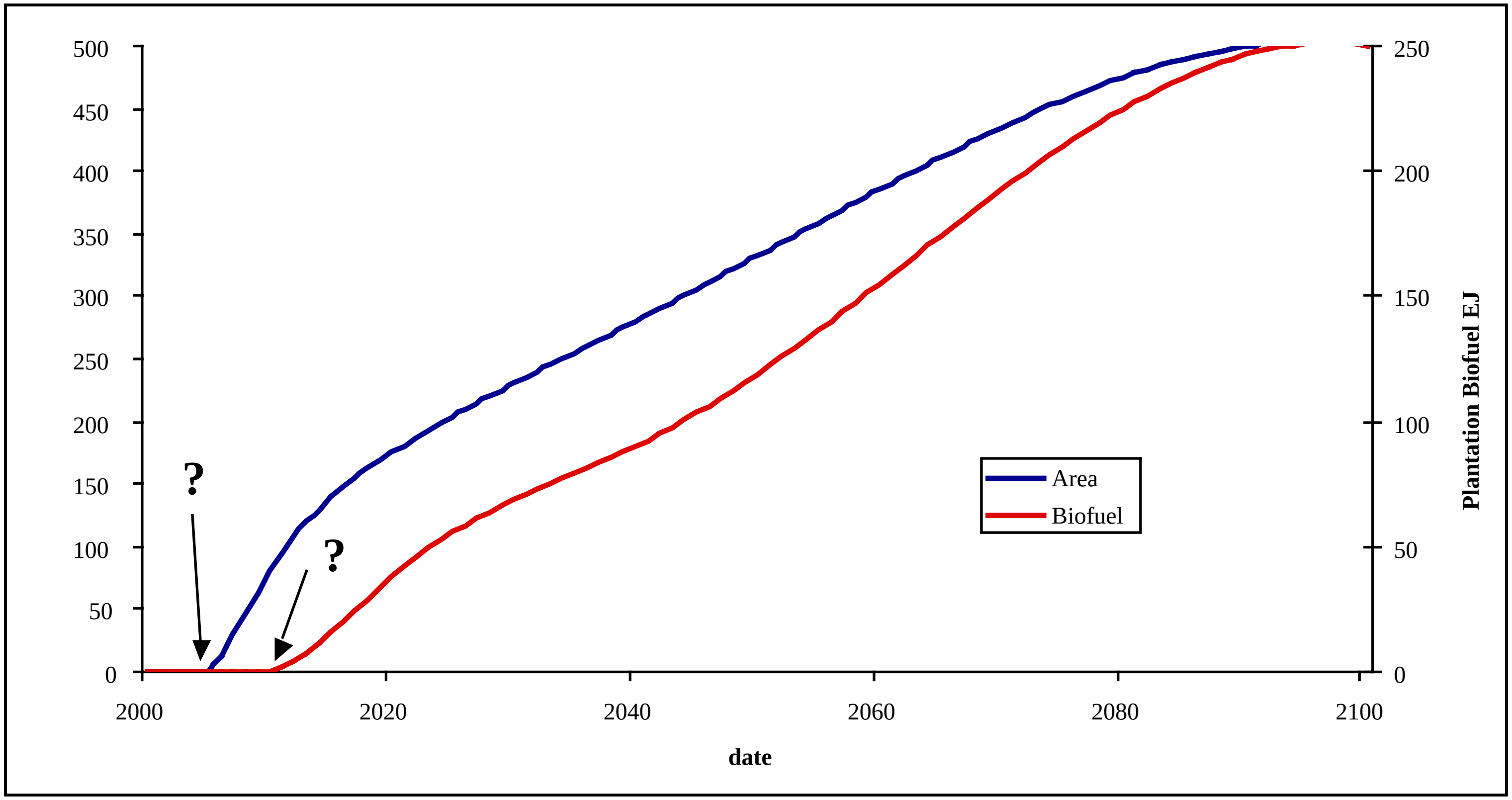
Begin land use change programme,

- whatever is the maximal rate of land use change, the earlier the start the more can be done
- sequential decisions 1 and 2 are robust due to ancillary benefits even if no ACC
- if no eventual need for bio-fuel, plantation timber will replace mined natural forest with bio-diversity and conservation benefits

Begin programme of capacity building for country-driven projects

- need for community friendliness [else sabotage risk] and hence need for large number of small and medium biomass projects
- need to develop institutional capacity to train people to start all these projects
- such ‘barefoot merchant bankers’ will drive sustainable rural development and growth take-off even if no ACC

<u>And</u> these programmes are needed anyway in any low emissions scenario that responds effectively to Gradual Climate Change [Kyoto weakness on land use change – see Concluding Question]



A back of Envelope calculations

1. Energy security

500 GJ/Ha-yr x 500 million Ha = 250 EJ annually
[[half current best commercial practice in Brazil
x
40 per cent of cultivable land said by IPCC to be available after allowing for growing food supplies]]

30 per cent conversion displaces 75 EJ gasoline annually = 120 EJ crude
(assuming 5/8 high value fractions)

= 12,000EJ per century = 12,000 x 24 mtoe = ~ 2.2 millions of millions of barrels of oil, over twice global proved reserves
Say 1½ allowing for a slow start in first few decades.

Ancillary Benefits

- Stimulation of the pattern of land use change that is needed to meet the raw material demands of the bio-energy component embodied in most low emissions scenarios (i.e. address market coordination failure and other barriers to entry facing bio-energy)
- Hence earlier and lower CO_2 reductions than under Kyoto style focus on ‘domestic action’
- Restoration of the pre-industrial tree coverage (differently located, owing to human settlement, but restoring the former capability of forests to act as lungs to the living earth)
- Empowerment of many developing countries to initiate their own ‘country-driven’ projects as the building blocks of their own sustainable energy development path
- Potential export led growth for such countries as bio-based liquid fuels take an increasing role in global transportation fuel supply, stimulating global macro-economic growth
- Improved security of liquid fuel supplies, and reduced dependence on unstable mid-East oil supplies
- Improved farm support in agricultural surplus developed regions

That covers the motivation part of this presentation

Next we will describe modeling that treats landowners as having the choice between:

- Leaving land as wilderness
- Conventional farming
- Short rotation for energy raw material production
- Long rotation forestry for
    - temporary sequestration and
    - subsequent commercial joint production of
        - timber
        - energy raw material

The Models

Common features of FLAMES and LOLA

Partial equilibrium approach modeling dynamic demand and supply in three markets:

- "Fuel": basic $C_xH_yO_z$ raw material with global current price ~$2/GJ.
- "Timber": basic timber product industry raw material price ~$130/ton after separation from joint product bio-fuel at process cost ~$90/ton.
- "Land": ~6bHa of non-barren, non conservation forest land that can be used commercially for farming or forestry or otherwise left to wilderness.

Demands grow with population and per-capita living standards; supplies of fuel and land products grow with technological progress.

Parameters are adjusted to achieve, in the without-policy case :

- Constant prices broadly consistent with historic patterns
- Emissions paths to mimic reference case (i.e. no new scenarios)

Policy is represented by land allocations to two activities – long rotation plantations and short rotations which are both joint producers of timber and bio-mass for energy in proportions (different for the two activities) determined by relative prices.

Net policy costs are met by a tax on fossil carbon emissions.

FLAMES: progress, features and results

- Recent work has seen the development of multi-region models, with trade in fossil fuel, in bio-fuel, and in timber.
- Also of an ACC response variant of the global model. Here we report on the global model and this variant.
- Rotation lengths are fixed (35 years for long rotation = half the modeled time horizon, 1 year for short rotation)
- Technological progress is nil at 3tons C per Ha-yr for long rotation;

  rises from 6 to 18 tons C per Ha-yr for short rotation over 70 years

  (240 to 720 GJ/Ha cf current best commercial practice 1300 for sugar cane, 1000 for eucalypt).
- Post-harvest land use

  is 50% to short rotation, 50% to farming for long rotation,
  100% to continued short rotation for short rotation
- Reference scenarios two cases considered mimicking, respectively, IS92 business as usual and Tellus/Greenpeace fossil free energy scenarios; "Kyoto" is treated as half way between

Scenario	b.a.u.	f.f.e.s.	'Kyoto'
Parameter			
Growth of per capita fuel demand[a]	.0274	.0274-atp[b]	·0274-atp/2
Tech progress with fossil fuel supply	.035	.02[c]	.0275
Growth of fossil fuel emissions[d]	.015	0	.0075

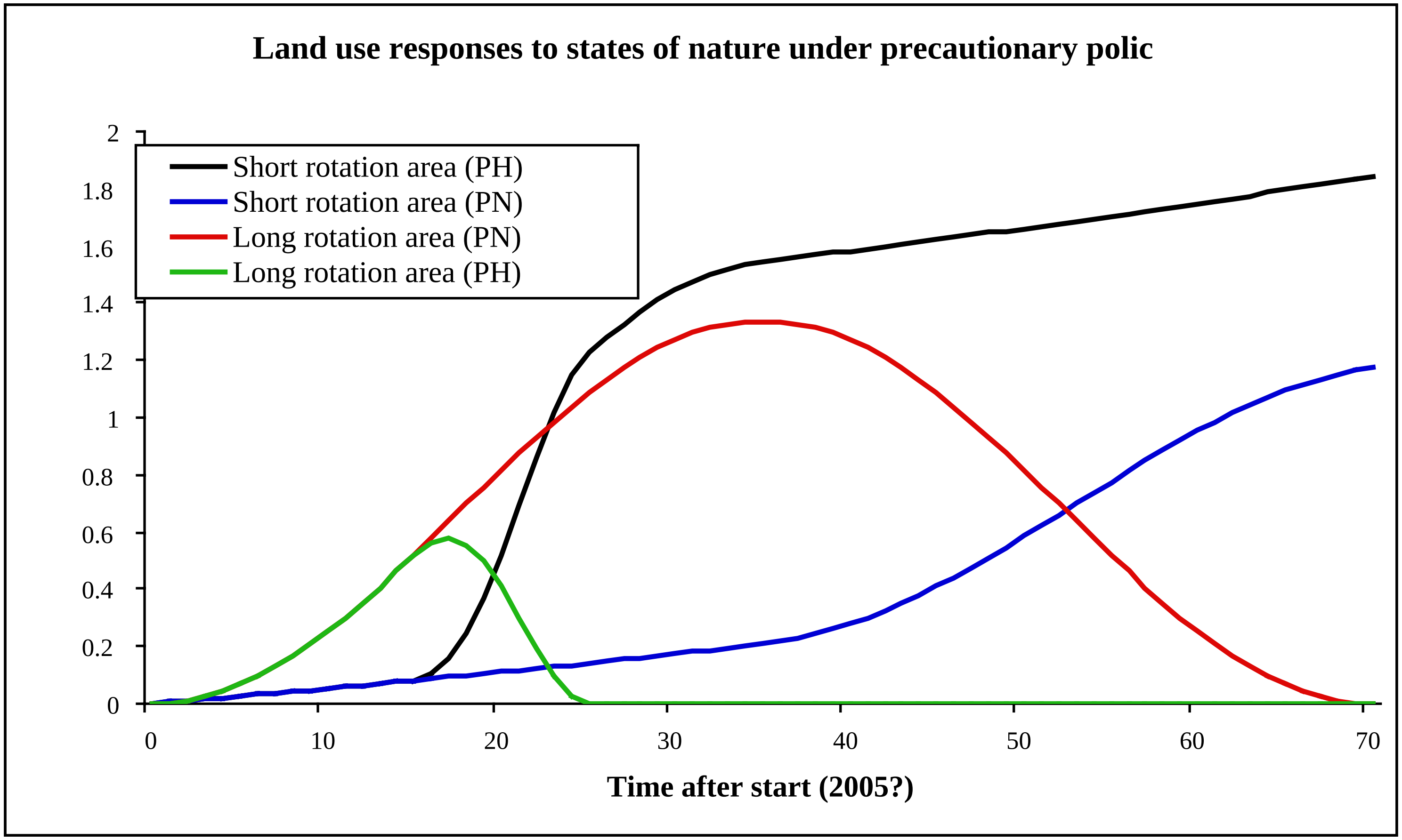
[a] population increase averages .0076 (World Bank central projection) giving balanced supply and demand growth of 3.5 per cent and long term constant energy prices under b.a.u.

[b] accelerated technical progress with renewable energy and energy efficiency from year 10 to 30 with compensating later slowing to represent technical limits (see Read, 1999)

[c] fossil fuel research discouraged by policy, leading to more rapid cost increases

[d] assumes 2 % p.a. de-carbonization from fuel switching

Policy driven global land allocations under a ‘be prepared For Abrupt Clmate Change with and without precursor signals two decades hence (H=nature horrid, N=nature nice)



Another back of Envelope calculation

Carbon in atmosphere under 'Manhattan Project' urgency (in response to 'H')

Area under long seq curve = ½ x 20yrs x .6 GHa x 3tC/Ha-yr = 18Gt C

Area under short rotation curve to 2030 =

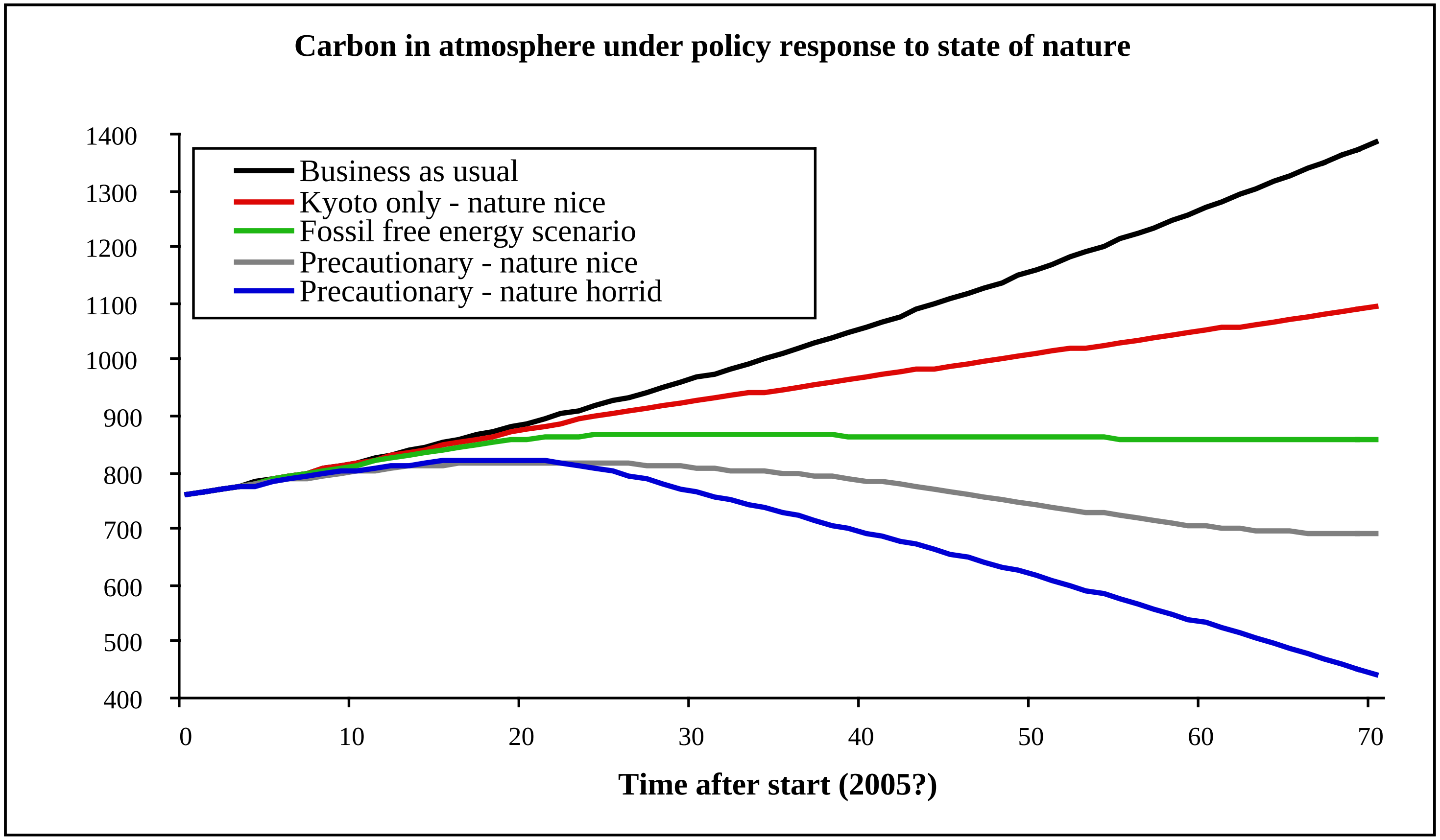
½ x 10 yrs x 1.2Gha x 10tC/Ha-yr = 60Gt C

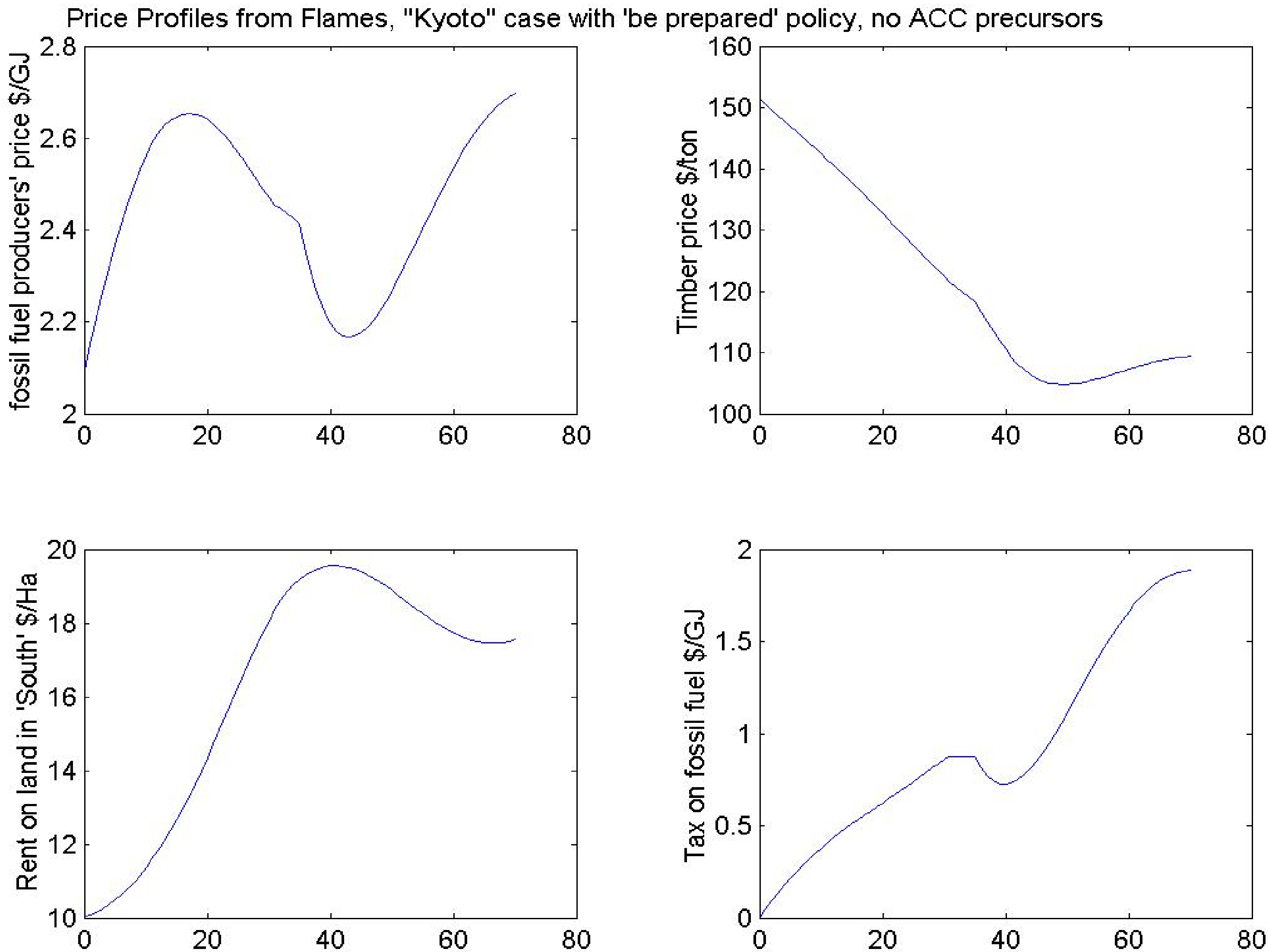
Assume 90 per cent replacement of Fossil fuel C emissions
= ~70 Gt C not emitted
= 35 ppm below "f.f.e.s." trajectory or ~400ppm

By 2040 a further 10 yrs x 1.4Gha x 12tC/Ha-yr = ~150Gt C not emitted

Total = ~80 ppm below "Kyoto" trajectory by 2040. Remaining reductions under 'Manhattan Project' urgency, as illustrated in fig 2, is due to CCS technology used with fossil fuel point source emissions, to increased energy efficiency and to more non-fuel renewables (wind etc.).

Gigatons C in atmosphere (= ~2 x ppm C_{at}) for three reference scenarios and with 'be prepared' policy related to 'Kyoto' case with and without response to ACC precursors after 2020. Note that negative emissions energy system is needed to get below 330ppm.





Price Profiles from Flames, "Kyoto" case with 'be prepared' policy, no ACC precursors
fossil fuel producers' price $/GJ
2.8
2.6
2.4
2.2
2
0
20
40
60
80
Timber price $/ton
160
150
140
130
120
110
100
0
20
40
60
80
Rent on land in 'South' $/Ha
20
18
16
14
12
10
0
20
40
60
80
Tax on fossil fuel $/GJ
2
1.5
1
0.5
0
0
20
40
60
80

LOLA: progress, features and results

N.B. this presentation is subtitled

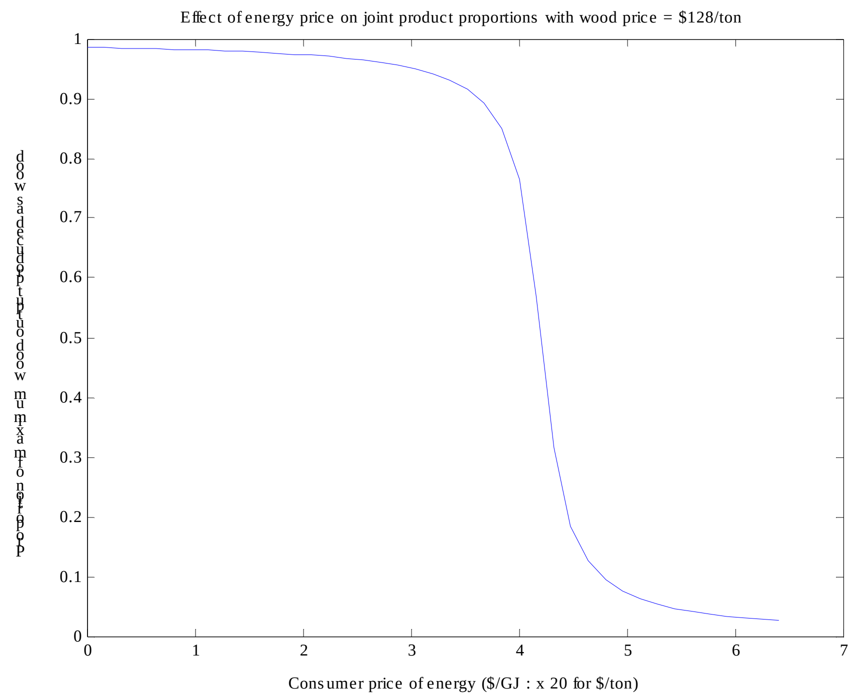
"towards incentive-compatible modeling of land use change policy impacts."

The implausible price profiles generated by FLAMES show need for optimizing model in which inter-temporal arbitrage (mediated by landowners' felling and replanting decisions) smoothes out the sharp shifts in price trends.

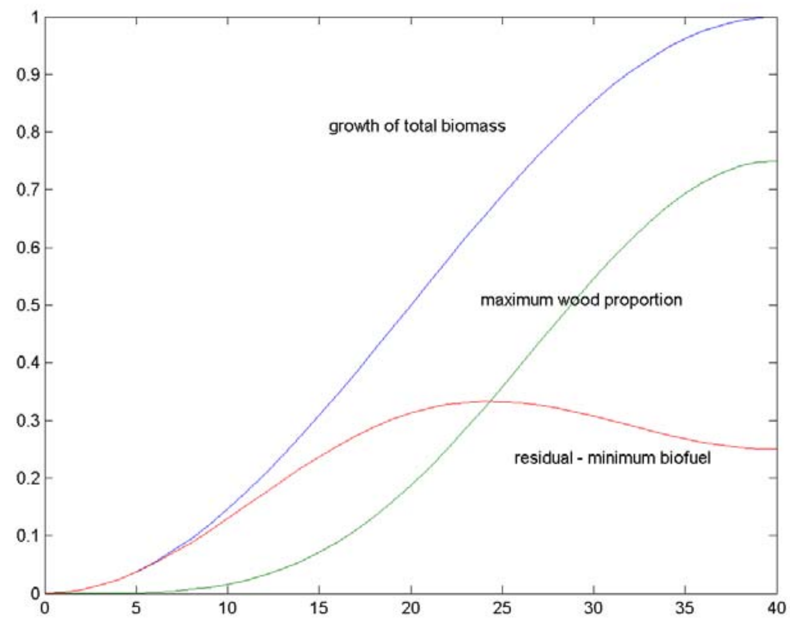
So far the behaviour of landowners growing existing forests and policy-induced long rotations has been modeled. Features include:

- Non-linear (S-shaped) growth of which a non-linear (S-shaped) proportion is usable as timber, but can be used for fuel, rising to 75 per cent of total biomass.
- After full growth in 40 years there is a plateau for 20, followed by linear decline (due to e.g. forest fires ?) over a final 40 years.
- Proportions of harvested woody material to each use is price dependent, as in FLAMES
- A tax transfer to meet costs of policy land planting and rents until end of land use change (35 years)
- Objective function is to maximize welfare (consumer surplus minus variable costs) implying price taking, jointly in the markets for timber and, in competition with fossil fuel.
- Landowners commercial rate of return is a constraint on welfare maximisation

Relative Price and Age dependency of joint products of long rotation plantation



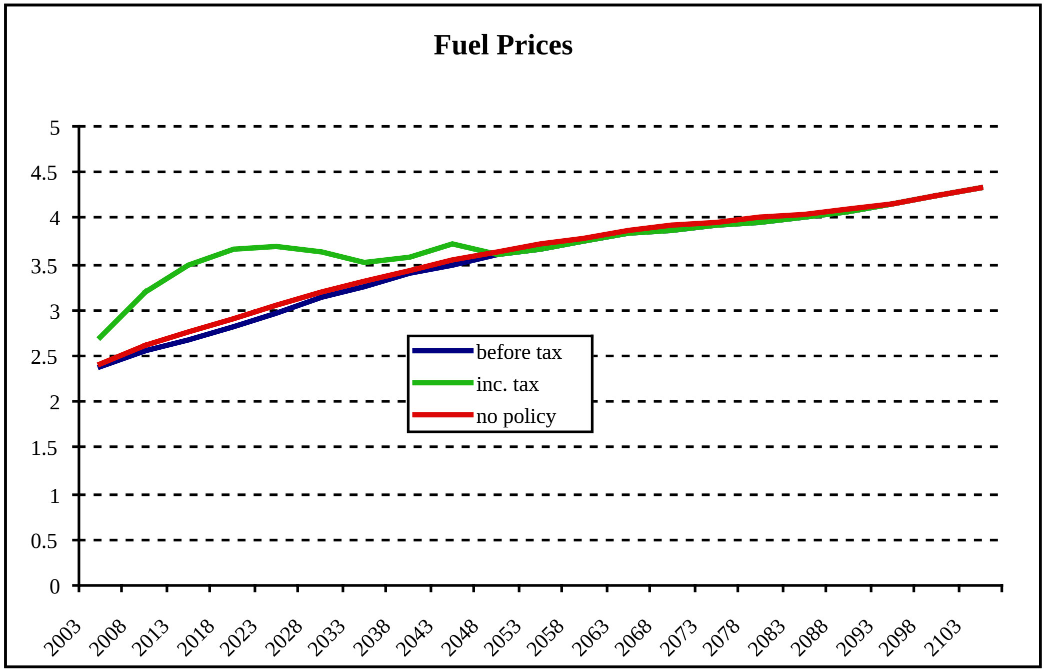
Price effect



Age effect

Price Profiles

fuel price with and without policy land at 10% commercial return along with the policy transfer (fossil fuel tax) needed to fund the policy.



Provisional inferences

- Price profiles are smoothed out by optimizing behaviour.
- Policy driven land use change induces policy leakage through reduced replanting by existing foresters (this is anticipated in FLAMES).
- Providing landowners are price-takers, their required rate of return does not greatly impact on the pattern of harvesting and replanting.

Comments

The short rotation component of policy driven land use change has yet to be incorporated in the model.

The claim in the abstract regarding impact on carbon in atmosphere has yet to be substantiated but seems plausible given the assumptions that underlie the FLAMES modeling of this aspect.

Caveats

1. Optimization modeling (LOLA) in early stages

2. Low C_{at} levels require, in addition, high energy efficiency and increased use of non-fuel renewables as in f.f.e.s. scenario [but note that driven by ACC precursors, not GCC as in f.f.e.s.]

3. Land use is assumed ‘Maximal’
   [have you got a better guess?]

4. Need for capacity building

IN CONCLUSION: A question

Why, given its win-win-win-win potential, is the global bio-energy solution to the Climate Change issue ignored or down-played in policy formation ??

Win 1 – early and effective stabilisation and medium term reductions in atmospheric carbon.
Win 2 – potential to respond effectively to Abrupt Climate Change
Win 3 – increased energy security and resistance to potential oil price increases
Win 4 – sustainable economic prospects for landowners both in developed and developing countries

A Possible answer

- Market co-ordination failure between suppliers of bio-energy raw material and potential users separated by decades, oceans, language and culture

- Unfortunate self-perpetuating error in the negotiations [that ended, almost – i.e. all bar Russia – at Marrakesh] due to maintained assumption that best policy is to price up carbon through TEPs, ignoring need to drive technology change.

Maybe it's time to try again in context of Art 3.3 of the 1992 Rio Convention, looking at the grounds for early action provided by threats of ACC.
If so, it is hoped that these models towards a better outcome second time round