What can (and can't) the past teach us about the future?

Tami C. Bond and SoonKyu Jung
University of Illinois at Urbana-Champaign
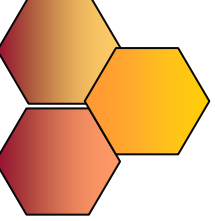*David Streets*
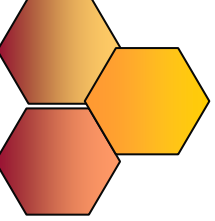Argonne National Laboratory

17 October 2006
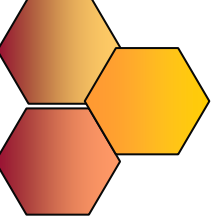AEROCOM Meeting – Emission Input
Virginia Beach, VA

outline

1. Quick reminder about carbonaceous aerosols
2. The (past) future (Streets *et al.* 2004)
3. The past (1850-2000)
   - biofuel emission methodology
   - fossil fuels by sector
   - technology changes
4. The (future) future

Technology governs emission rates.

Comparison of coal burned in power generation, industry, and domestic applications
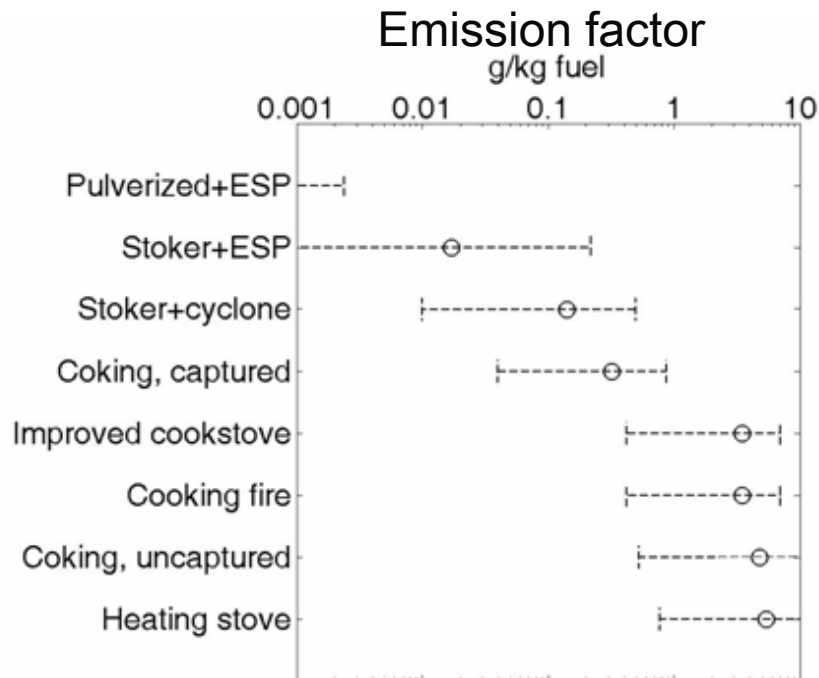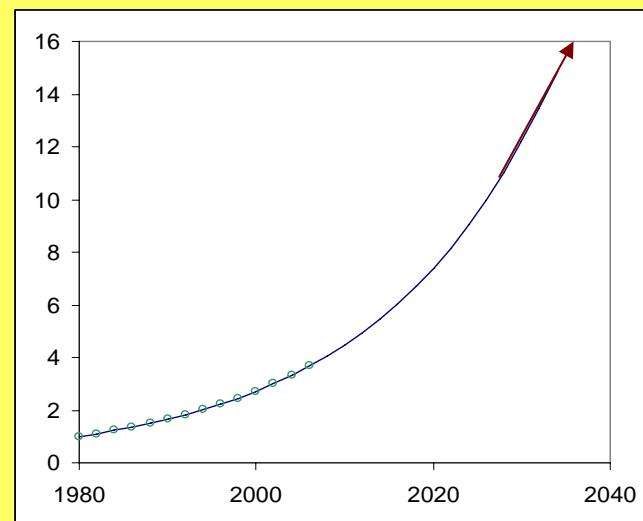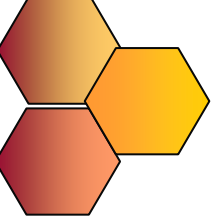
Aw, heck, just extrapolate…

- Some aspects of the future will be like the past. Some won't.

- Easy, amenable reductions get taken first. (Continued reduction in sectoral coefficients?)

- Emissions in a cleaner world will be increasingly driven by high emitters.
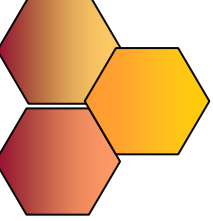

To Infinity and Beyond!!

Future modeling, round I
(Streets et al, 2004)

- Relied on IPCC-SRES scenarios
  - Scenarios prescribed sectoral growth, fuel switching
- Sectors divided into end uses
- Regionally-specific technology shifts within sectors
  - Technology turnover, acceptance rates, manufacturing growth
 - Largely "expert judgment" (i.e. *guesses*)

Representing technology shifts

- "diffusion" = spread of new technology (e.g. Rogers, 1962)

- "transformed normal" or "S-curve" represents technology diffusion

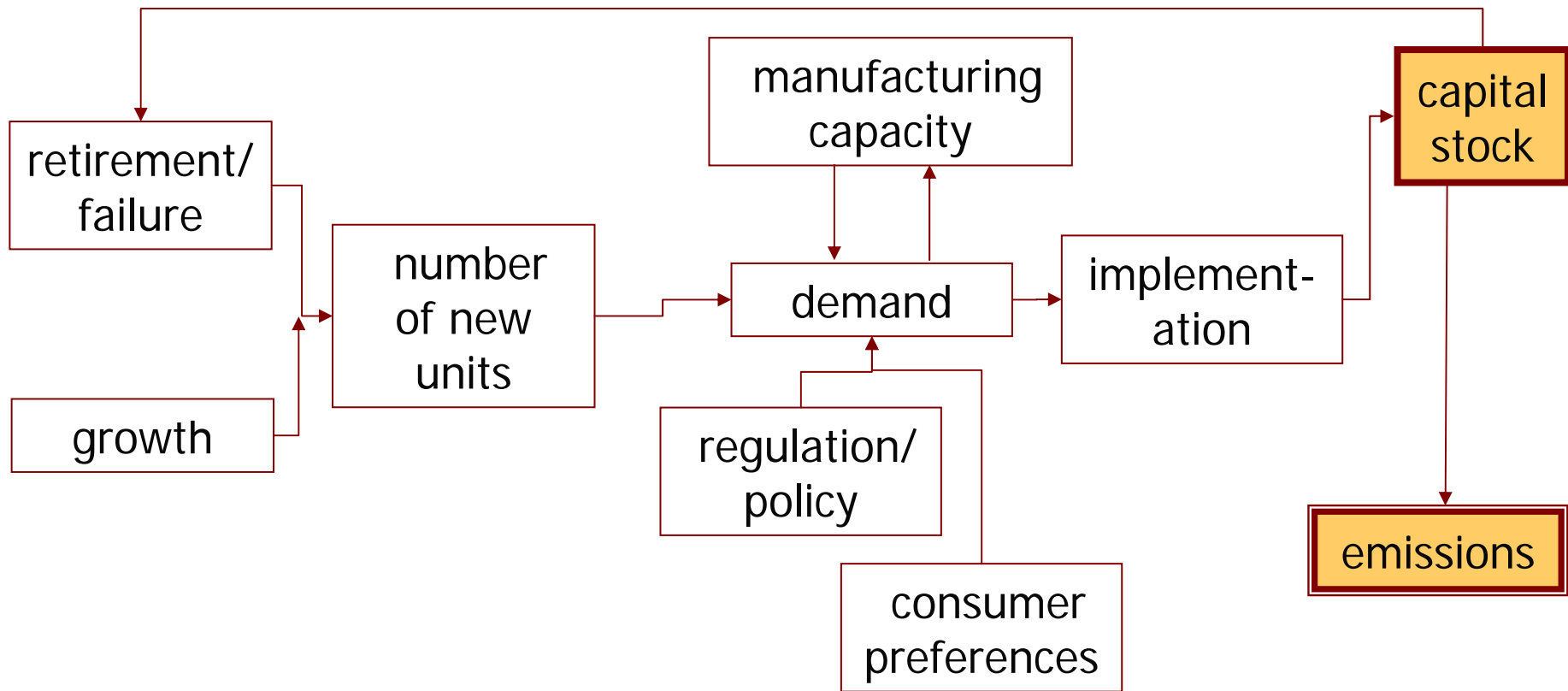- physical meaning: error function is solution to source diffusing into infinite space (heat, mass)

fraction of old technology (s=8)

time since introduction (years)
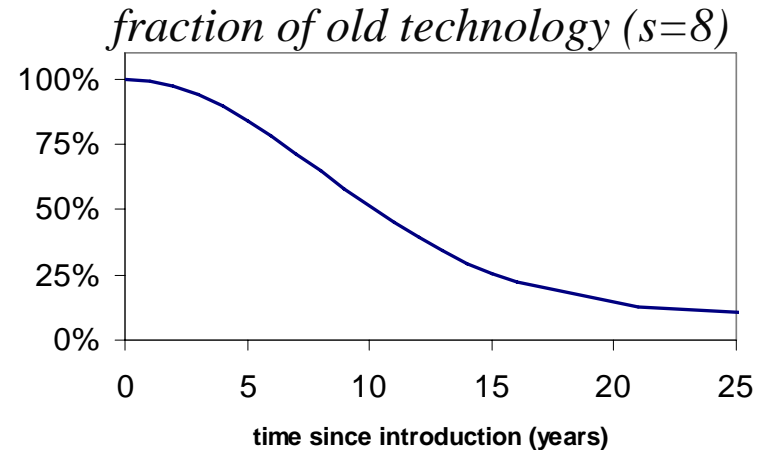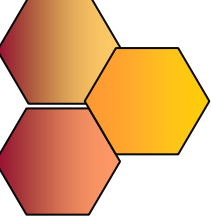
$$X(t) = (X_0 - X_f)e^{\left(-(t-t_0)^2/2s^2\right)} + X_f$$

initial fraction

transition time

final fraction
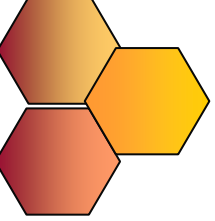
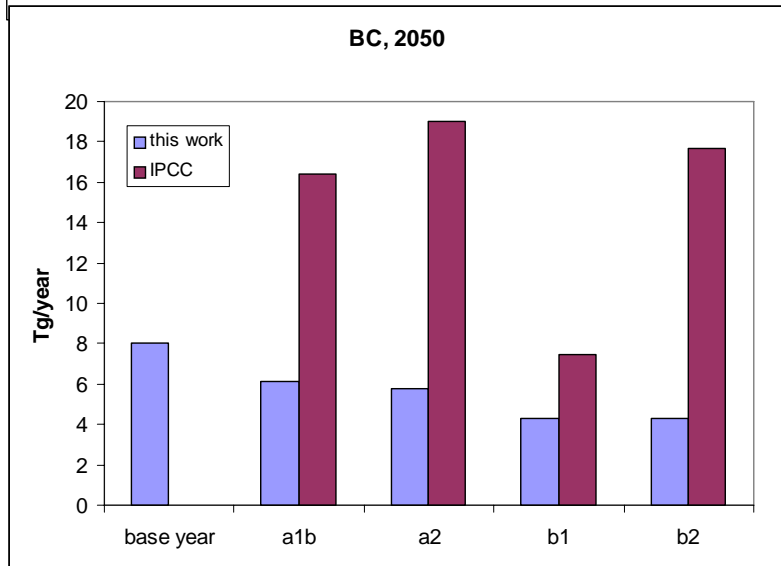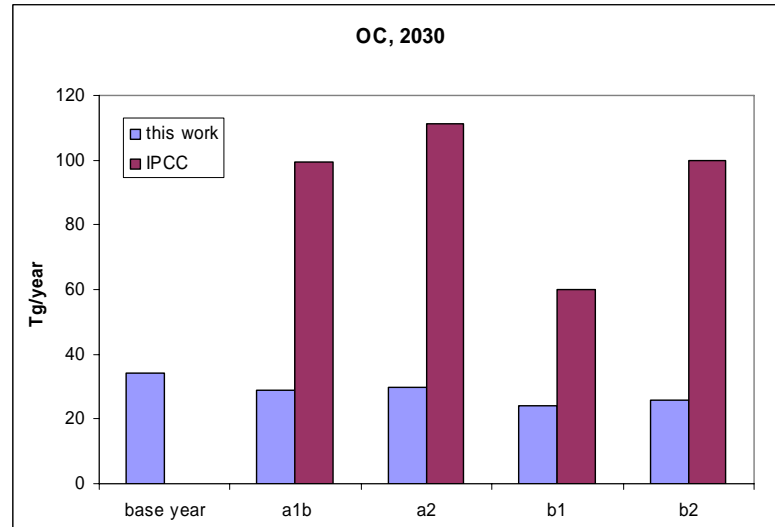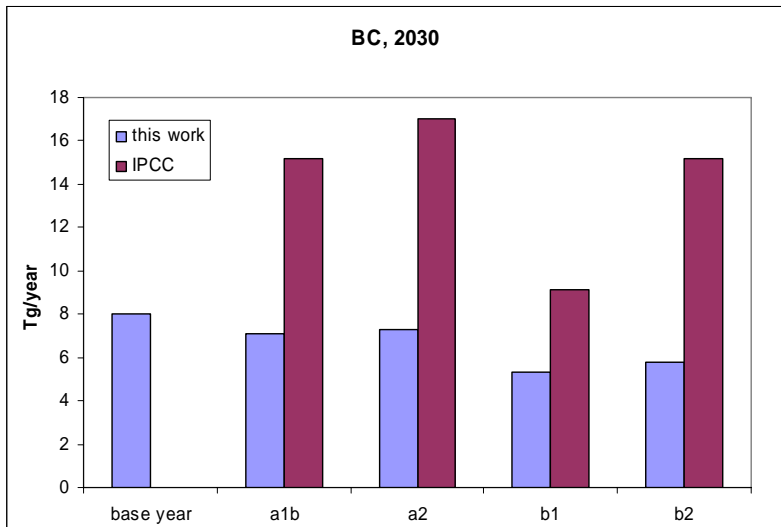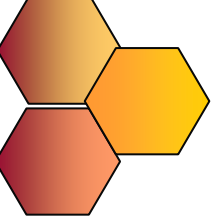# Mini-dynamic model

Fit S-curves to model results, used in emission model

Both BC and OC appear to decrease
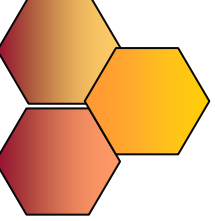## …but OC/BC ratio goes down (warming)
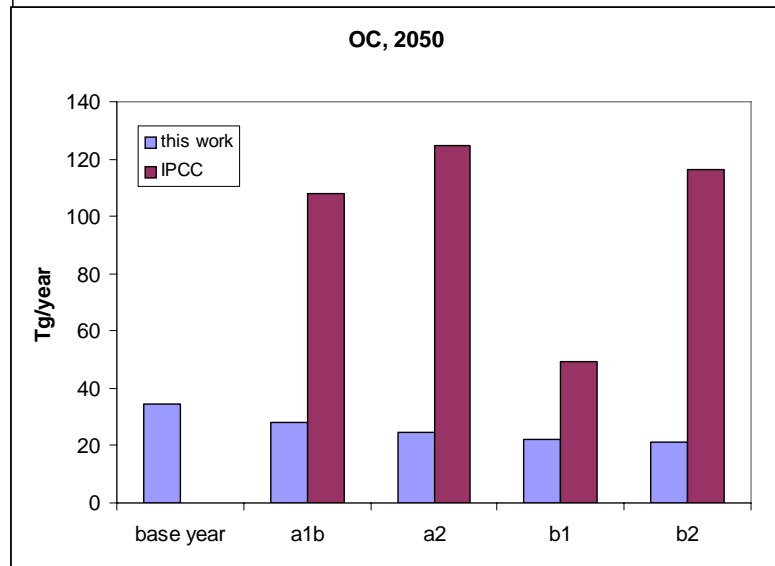
Global biofuel consumption

- Previous estimates:
  - Present-day consumption per capita, projected backward by population (EDGAR: rural population)
- Criticisms– May not account for…
  - Shift from biofuel to fossil fuel
  - Changes in habits (especially due to deforestation)
  - Use in industry
- New work considers these changes

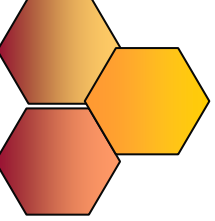*Fernandes et al, "Global Biofuel Use, 1850-2000", submitted to Global Biogeochemical Cycles, Sept 2006*

*Residential consumption*
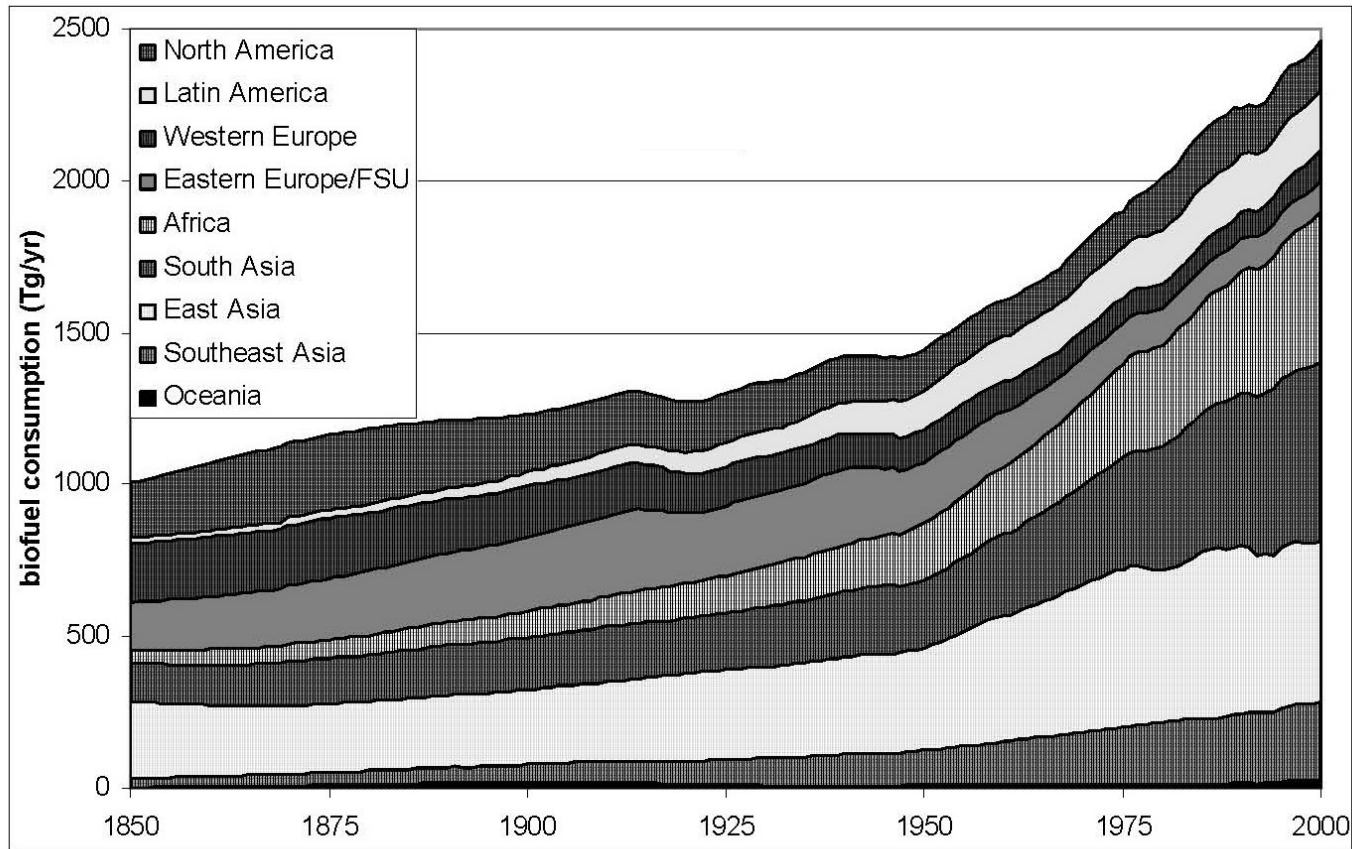
Fernandes et al., GBC, submitted

# Past fossil-fuel and biofuel: sectoral and end-use divisions

- "Sector" = economic sector
  - Electricity production, industry, domestic & "other", transportation
  - Technology varies greatly between sectors
- Important end uses divided
  - Transportation: road, ships, rail
  - Industry: transition of firing & control technology

> *Bond et al, "Historical emissions of black and organic carbon aerosol from energy-related combustion, 1850-2000", submitted to <u>Global Biogeochemical Cycles</u>, Sept 2006*
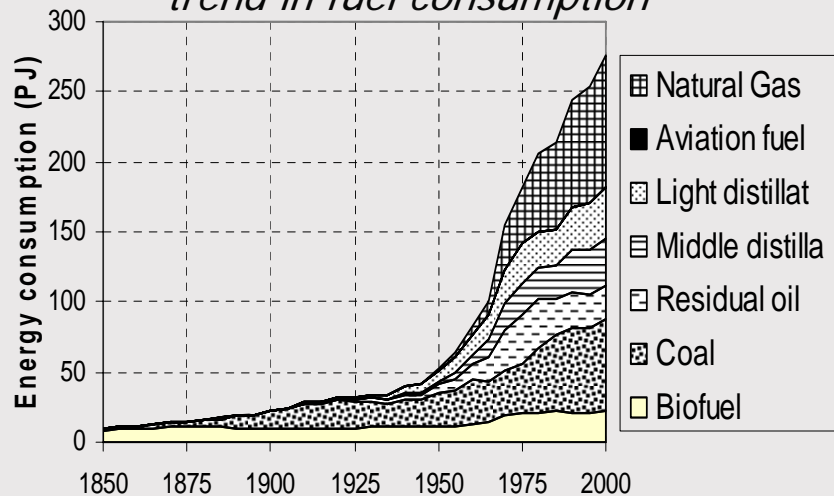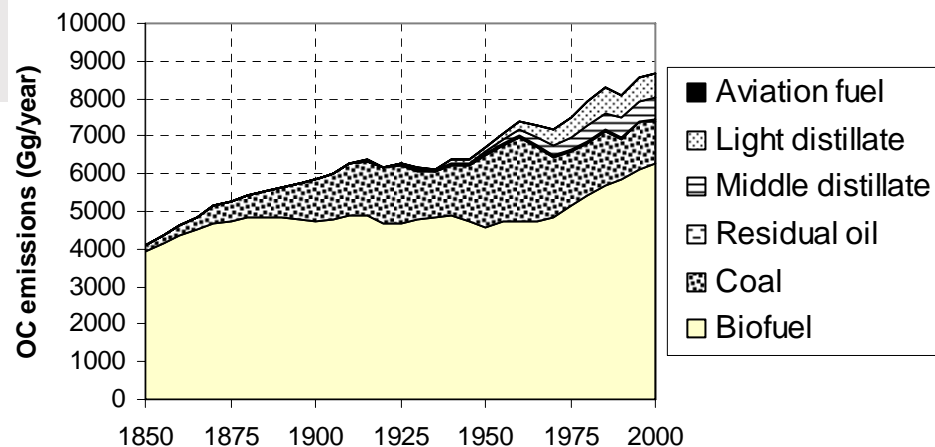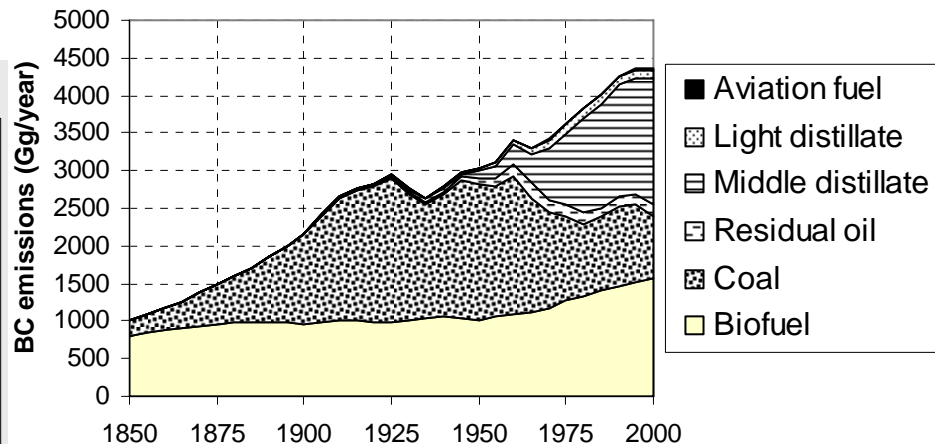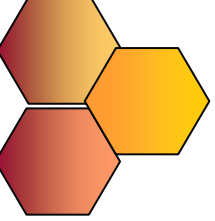
* production statistics
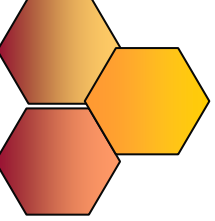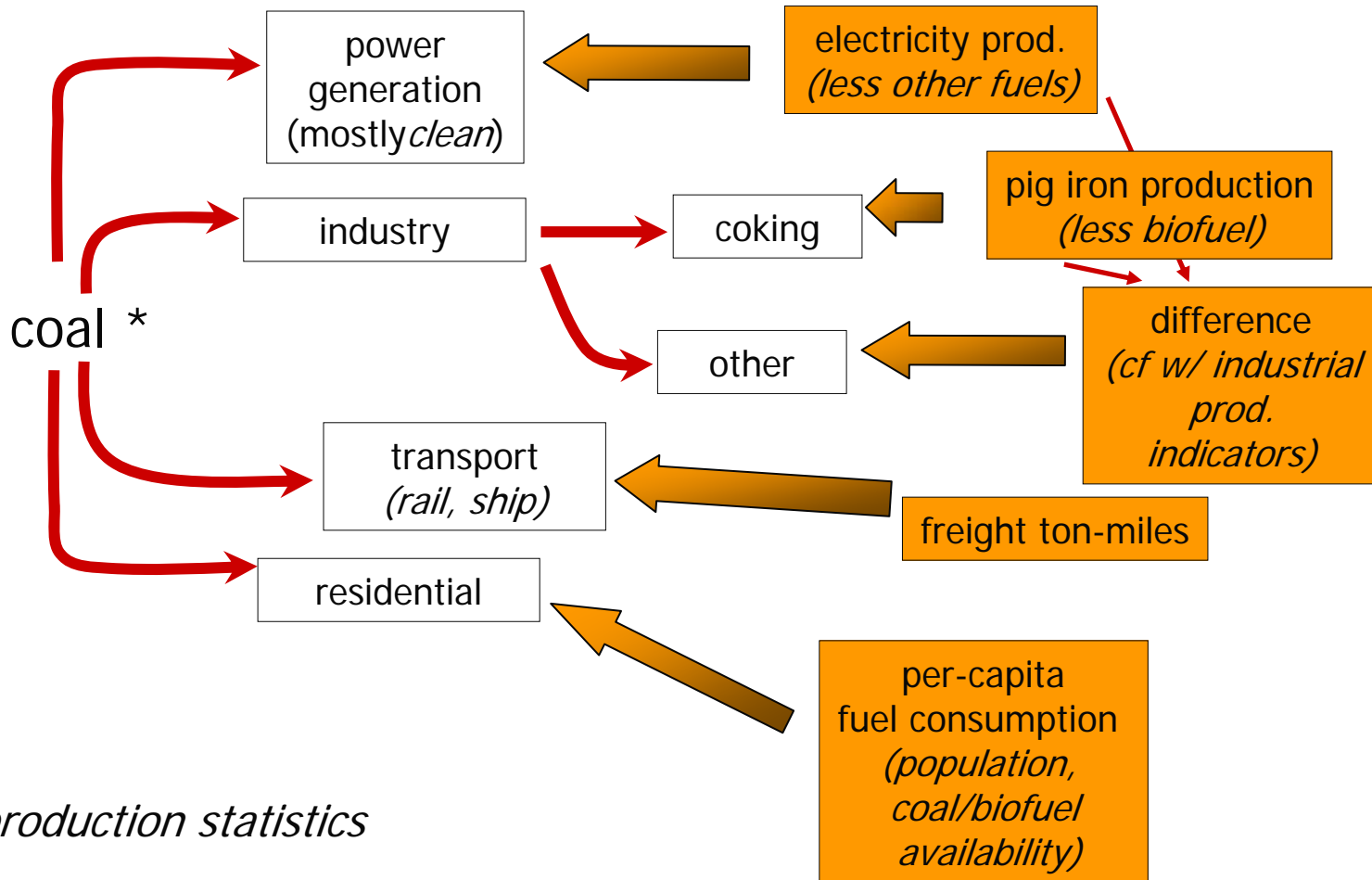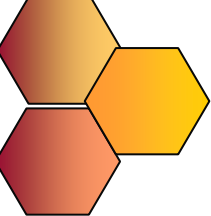
Trend of BC+OC emission has been far different than that of GHGs.

Compare with
trend in fuel consumption

Bond et al., GBC, submitted
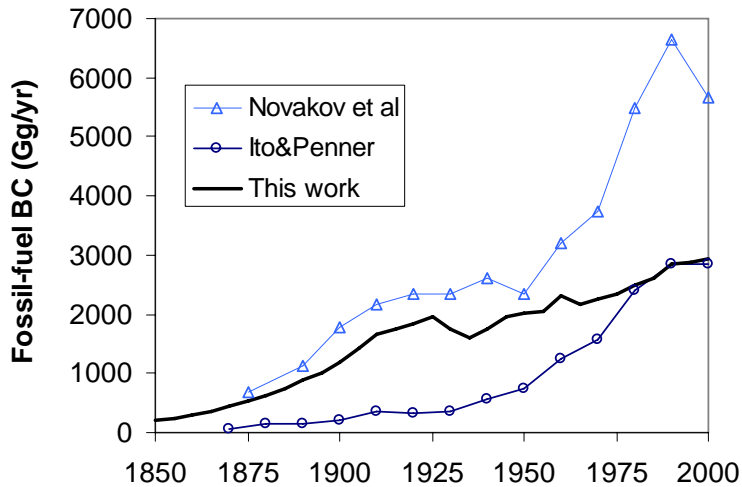
Bond et al., GBC, submitted
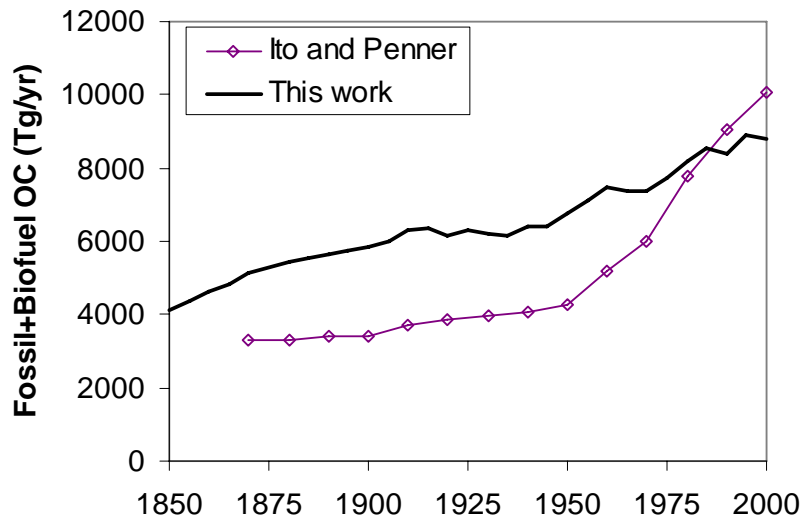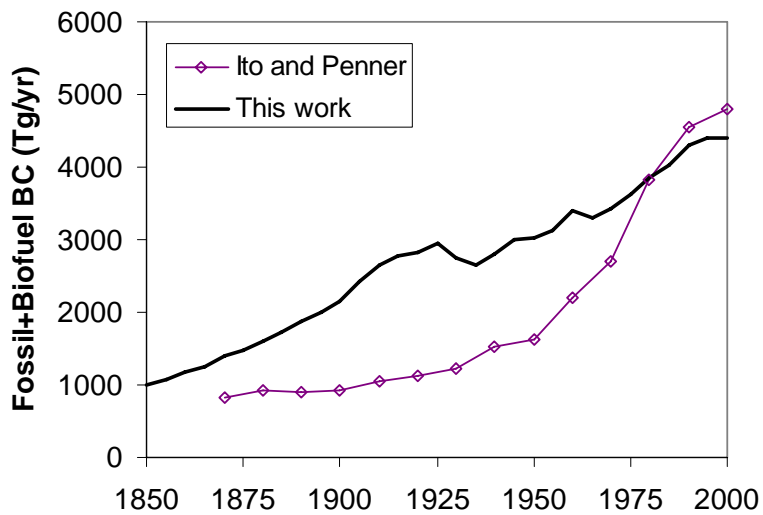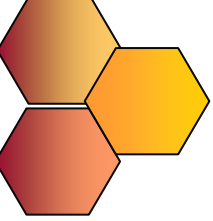
What have we learned from the past?
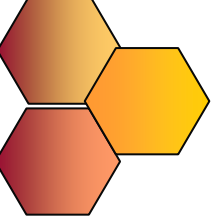
Fuel switching can happen rapidly

- ✦ Europe post-WWII
  - ■ Country by country data for residential sector indicate $s=7-12$ years
- ✦ Rail locomotives from steam to diesel
  - ■ s=9 years

Locomotive transitions
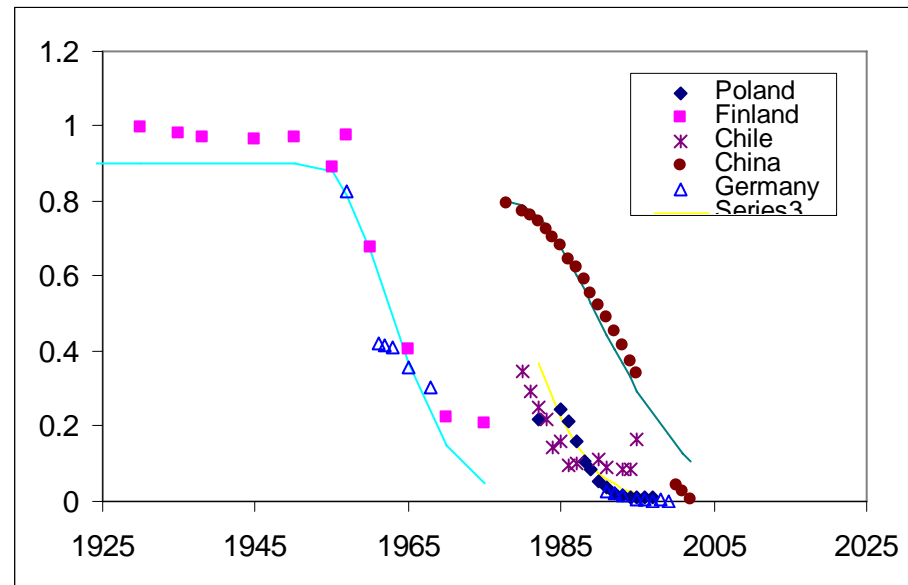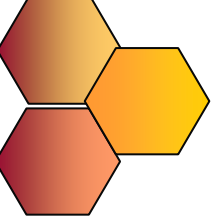
S-curves are not too bad!

United States: coal power gen
Cyclone → baghouse or ESP
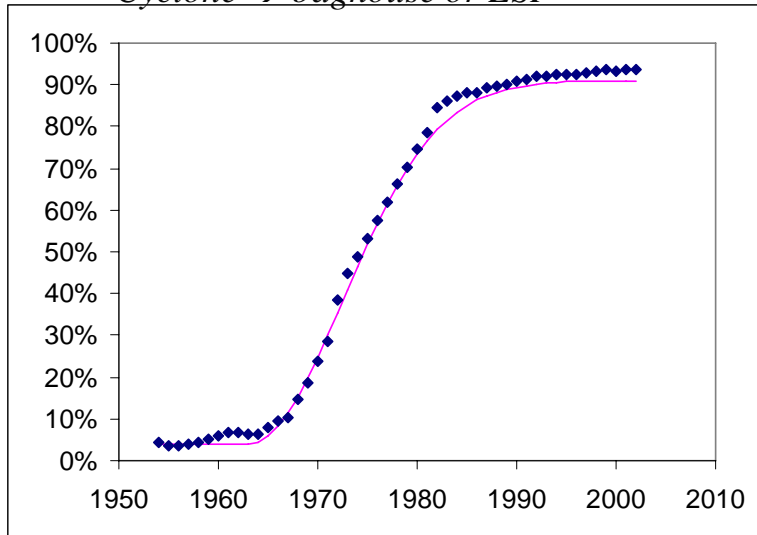
Kerosene fraction of fuel oil produced
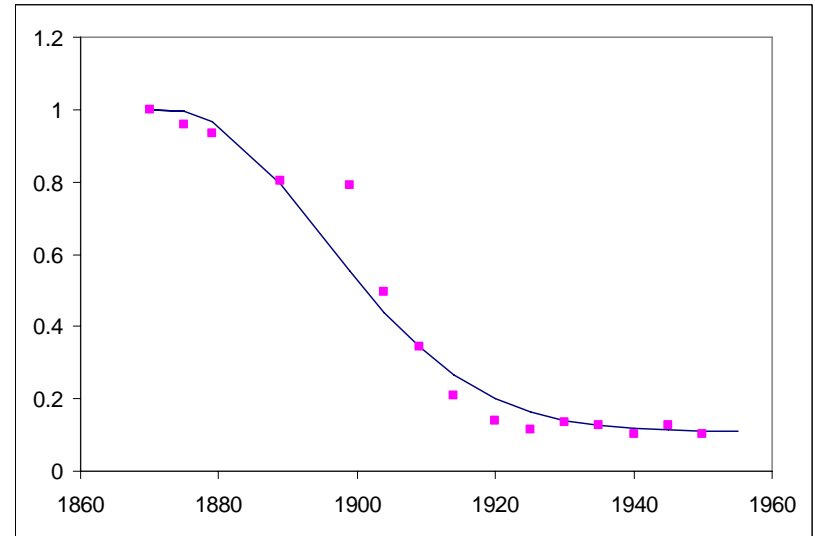
Fraction of coke (for steel) made in beehive ovens
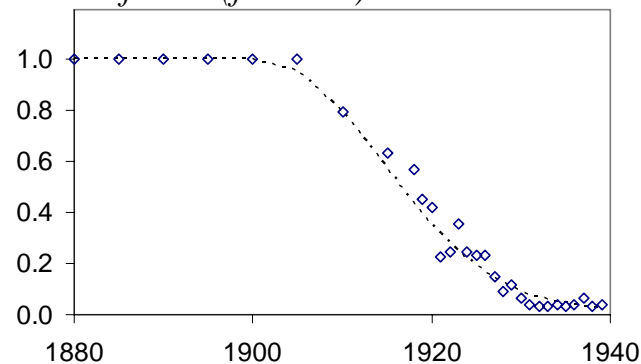
But they are not mechanistic enough.

Future modeling improvements

- Direct links between technology choice & SRES assumptions (population, GDP)
  - Slightly expanded dynamic model
- Lessons from the past
- Working sector by sector... *they are all different*
  - (1) Industry/utility; (2) vehicles (tough); (3) residential (tougher)
- Key question: What's the mechanism– the driver of change?
  - *Without this, no <u>feasible</u> scenario*
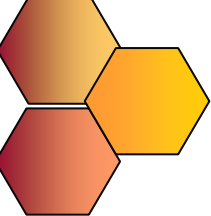
Mini-dynamic model

Soonkyu Jung, UIUC

U.S DOE Utility Survey

U.S. EPA Industrial Boiler Inventory

Simulate Distribution

Determine Age Based on U.S Historical Trend + IEA Historical Fuel data

Determine Distribution - Create 10 Capacity Groups

Determine model size of a country

Set unit number in each group

IEA Historical Fuel Data

Number of Units of Groups

Create Blank Cells

Bond et al 2004 Inventory

Initialize Unit properties (Sources)
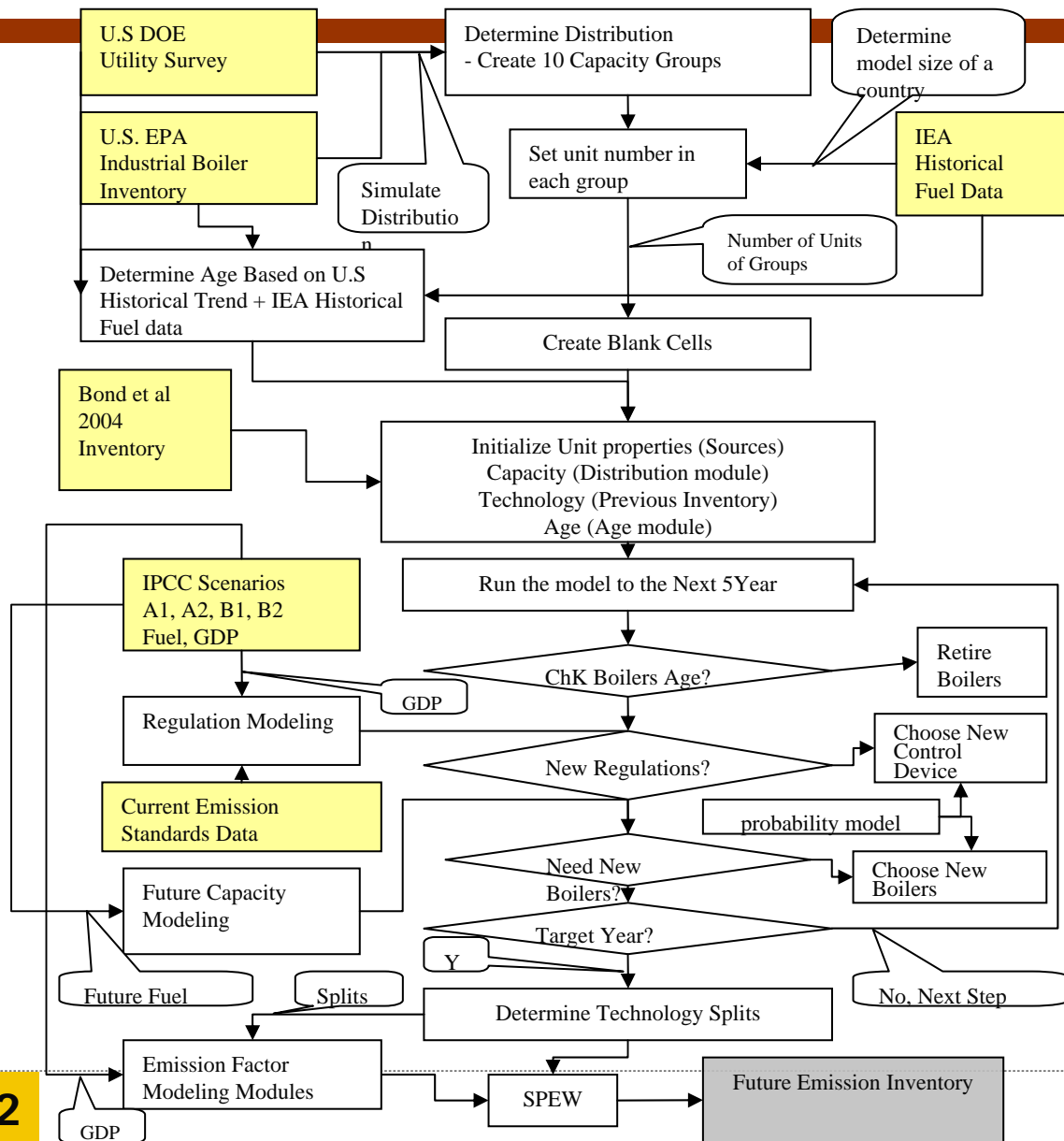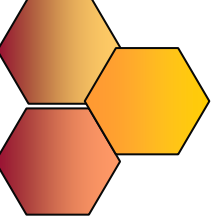Capacity (Distribution module)
Technology (Previous Inventory)
Age (Age module)

IPCC Scenarios A1, A2, B1, B2 Fuel, GDP

Run the model to the Next 5Year

ChK Boilers Age?

Retire Boilers

GDP

Regulation Modeling

New Regulations?

Choose New Control Device

probability model

Current Emission Standards Data

Need New Boilers?

Choose New Boilers

Future Capacity Modeling

Target Year?

Y

No, Next Step

Future Fuel

Splits

Determine Technology Splits

Emission Factor Modeling Modules

SPEW

Future Emission Inventory

GDP

Utility/industry preliminary results
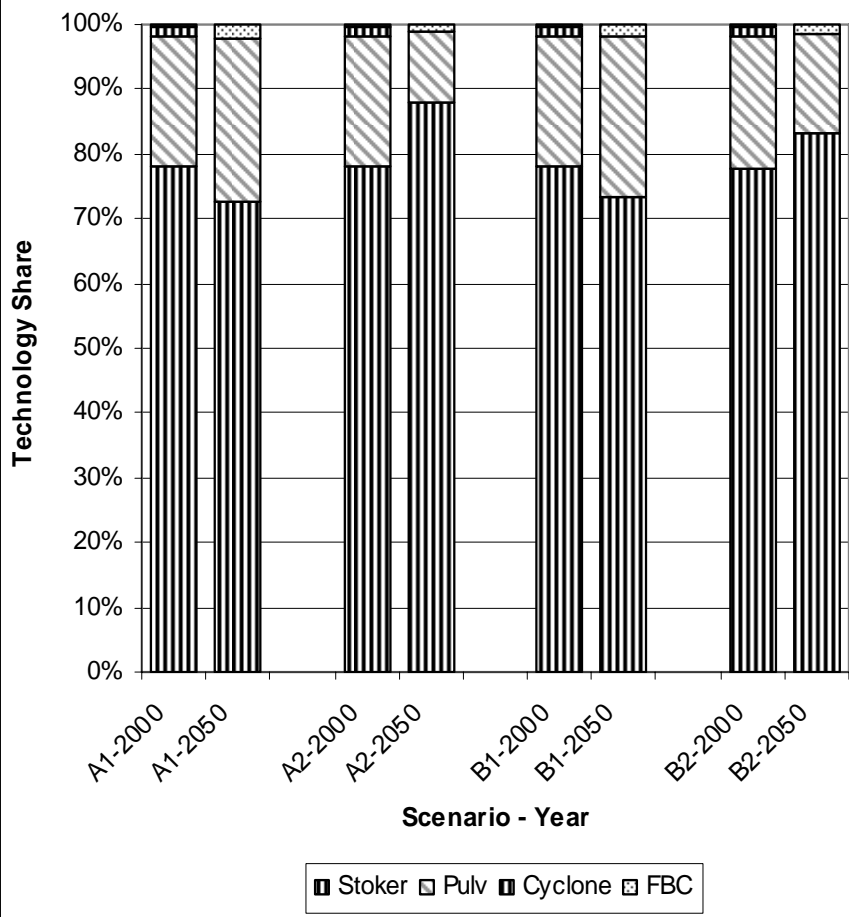
4. future emissions #2
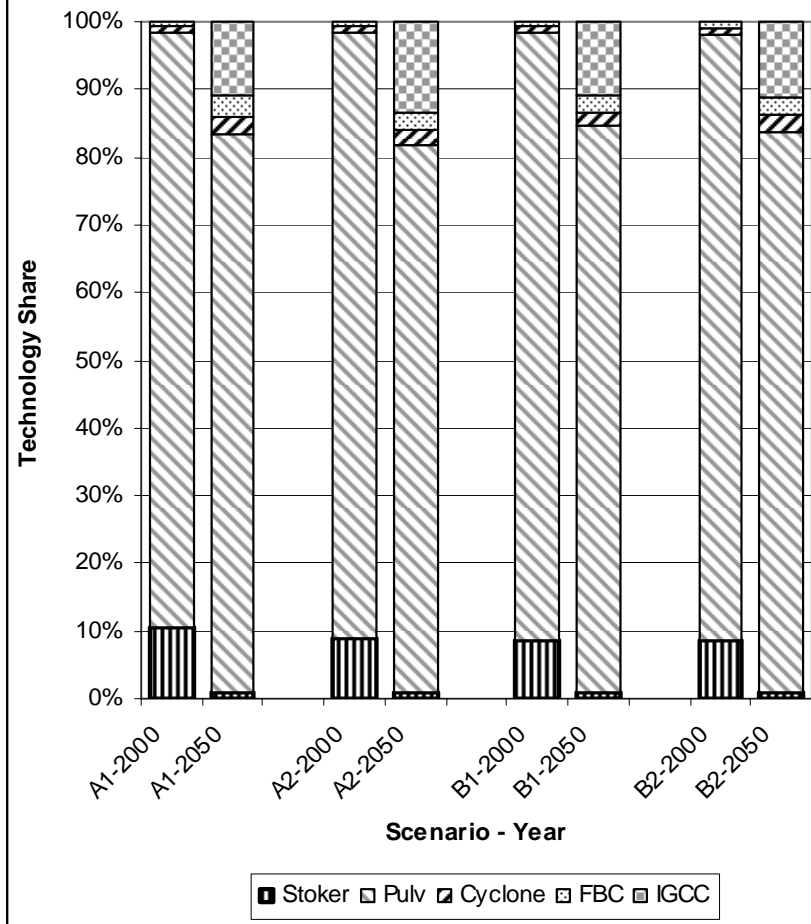
Bottom-up vs Top-down

- **Near future (to 2030, maybe 2050)**
  - Emissions driven by turnover of capital stock
  - For CO2 modeling, <u>new</u> technology is critical
  - For aerosol modeling, persistence of <u>old</u> technology is critical
- **Distant future (beyond 2030, definitely beyond 2050)**
  - Can't pretend to predict exact technology!
  - This is the place for "top-down" scenarios (next)

Summary

Bond/Streets emission house

- Future done once, needs more true linkage
  - Streets 2004
- Past done
  - Biofuel, BC/OC… sulfur coming
- Working on future again
  - IPCC scenarios; alternatives?
  - To 2050 only
  - Multiparticle: BC, OC, SO2 (…and multigas?)