Reducing Uncertainties in CO2 Emission Forecasts

Using the time series properties of per capita emission levels

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Overview

- Range of CO2 emission projections remains wide (0-40 GtC by 2100)
- Yet global per capita emissions data occupy narrow range, as do population estimates
- Implies plausible forecast range should be narrow
- *Stationarity* supports constructing confidence interval
- Only 7 of 40 SRES scenarios appear plausible
- These occupy low end of emissions range (10.1 GtC)

CO2 emission scenarios

- Current data: 6.7 GtC (fossil fuel-based)
  - = ~1.1 tonnes/person globally per year
- Dean and Hoeller (1992): models range from 20-40 GtC by 2100
- Chakravorty et al. (1997): 0 GtC by 2100
- Schmalensee et al. (1998), Webster et al. (2002): 20-25 GtC by 2100
- SRES: 4-38 GtC by 2100
- SRES drives range of IPCC global warming forecasts

Critiques of SRES etc.

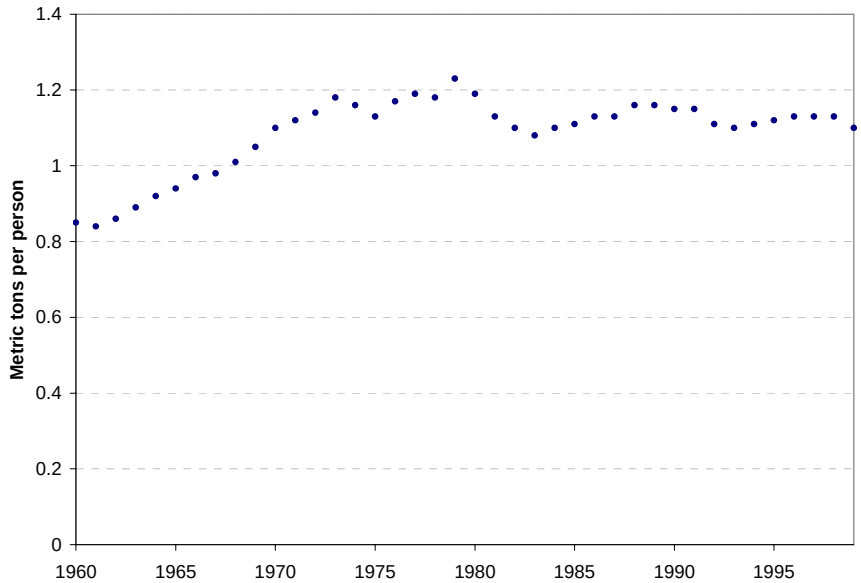
- Wide range with no guidance about probabilities
- Castles-Henderson (2003)
- Sensitivity to key parameters (e.g. AEEI)

Look at per capita data

- Highly variable at national level:
  - 0.02 to 5.5 tonnes/person
  - 1970 – 2000: some countries doubled or tripled; some fell by up to 75%
  - On average, per-cap emissions doubled within each country from 1970 to 2000
- Yet global average did not change

Global average constant after 1970

- ~1.1 tonnes



- Implication: national variability cancels out at global level

Using per capita data to establish probabilities

- If a scenario implies very high (or low) per capita emissions over next few decades it is less likely to be observed than one close to current mean

- Emissions/person x Global population = Total Emissions

Using per capita data to establish probabilities

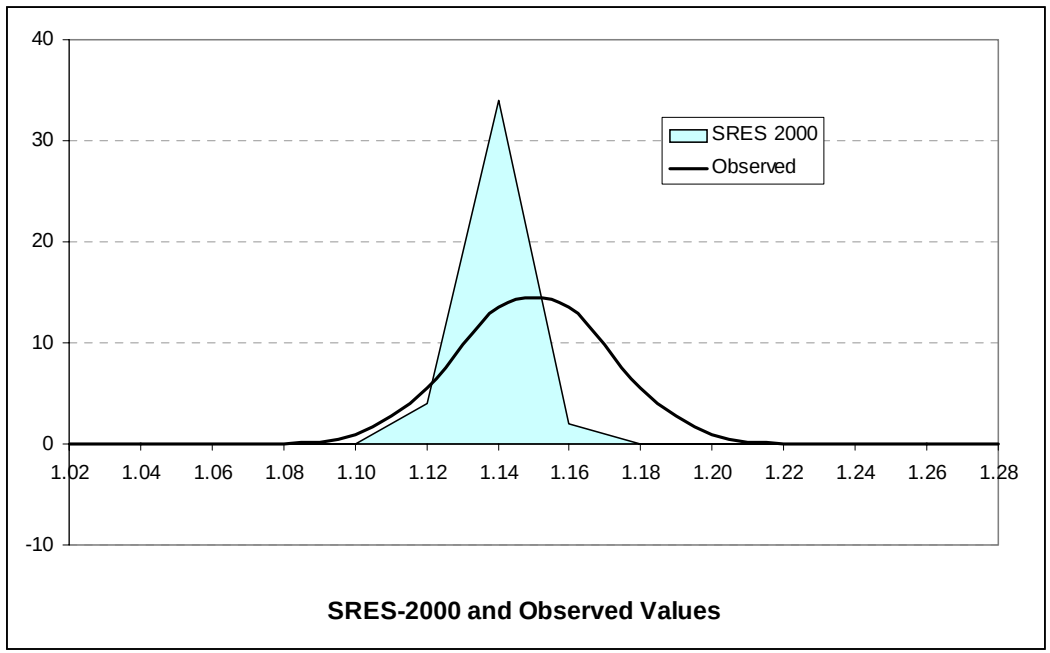
- This approach requires establishing:
  - Global emissions series is stationary and no trend
  - Any nonstationary national series are cointegrated
- Stationarity permits use of constant mean and variance to establish confidence interval

Data imply narrow distribution of per capita emissions

- Annual average emissions product of complex structure of global economy
- Yet for decades it has stayed roughly the same number: ~1.14

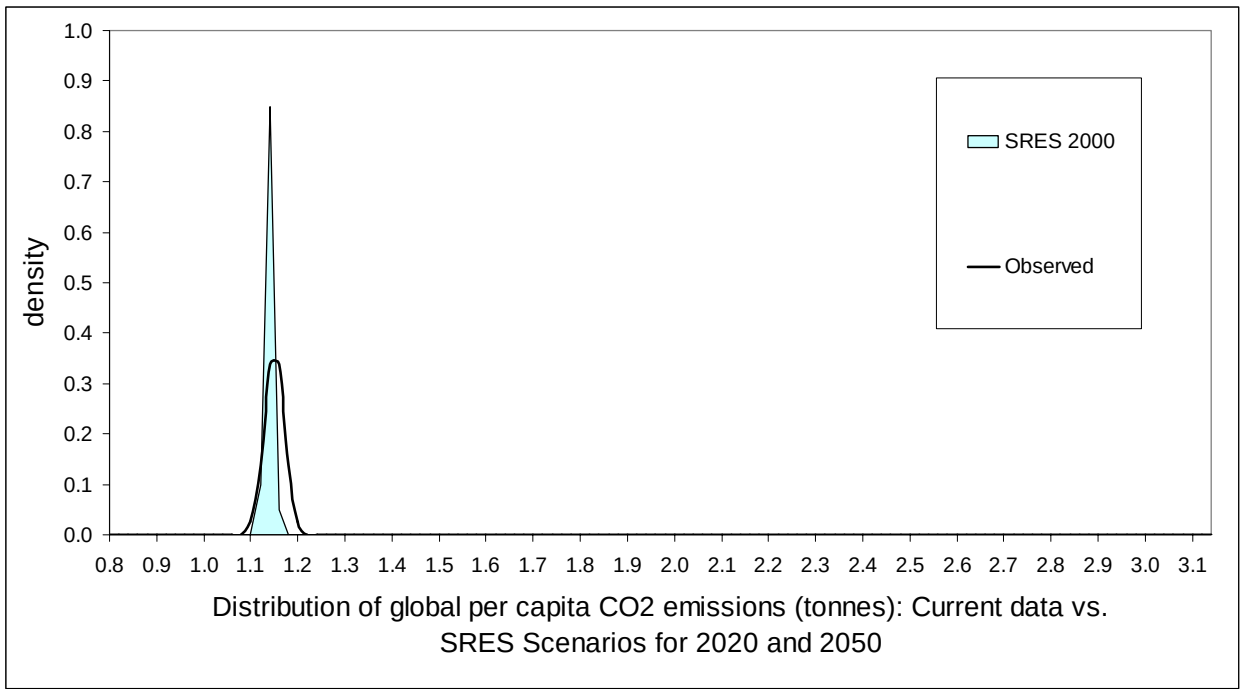
Data imply narrow distribution of per capita emissions

- Narrowness of distribution reflected in SRES distribution for 2000



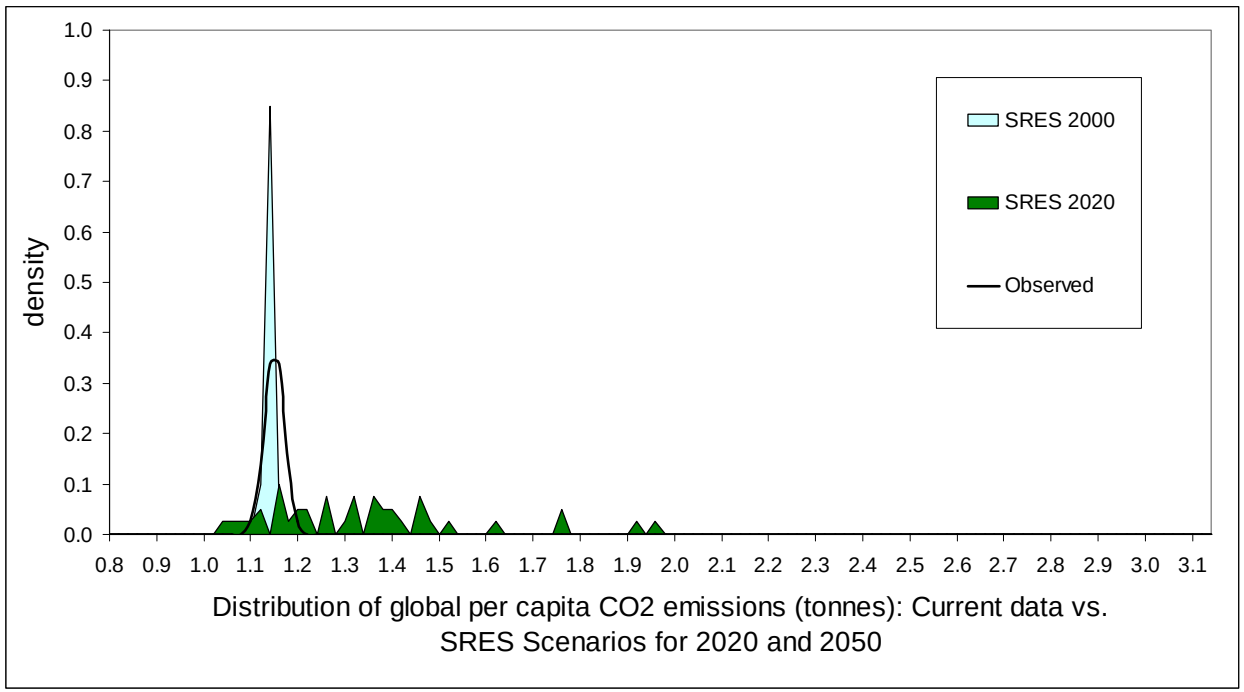
Data imply narrow distribution of per capita emissions

- SRES – 2000 projections



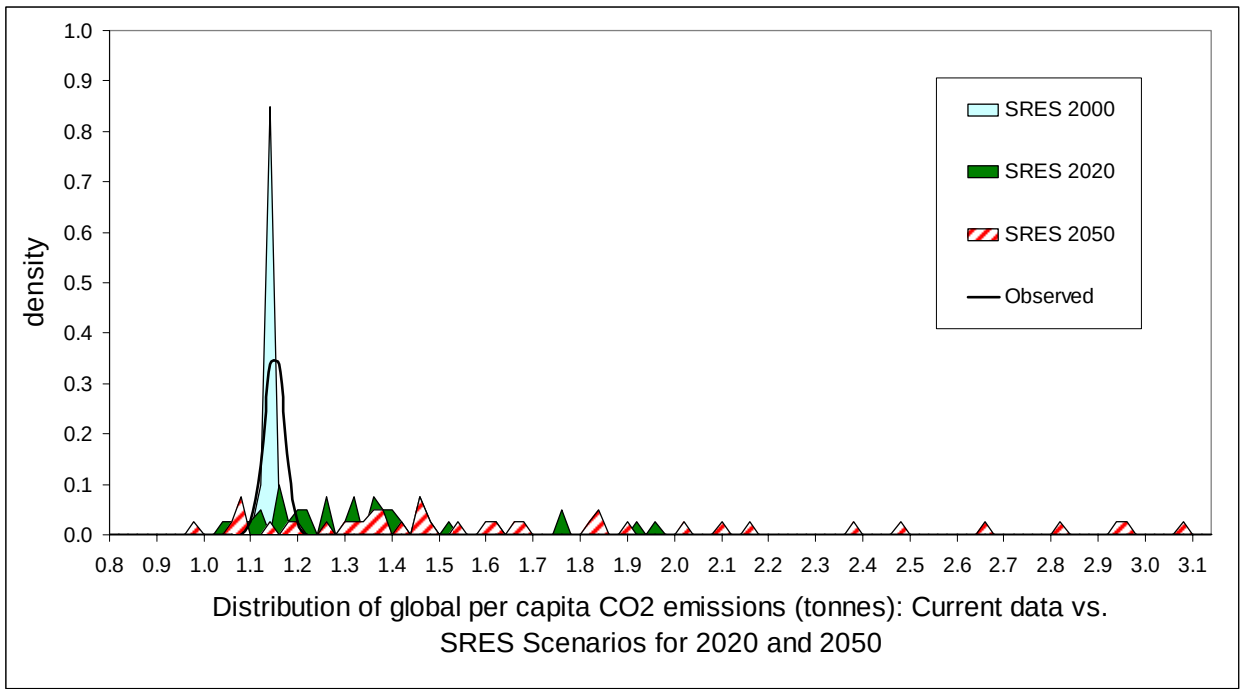
Data imply narrow distribution of per capita emissions

- SRES – 2020 projections



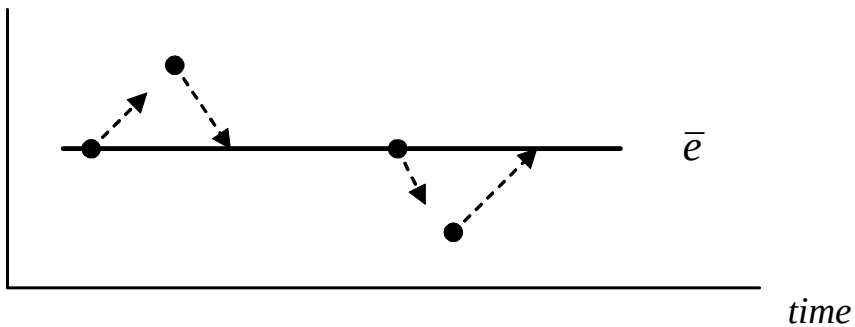
Data imply narrow distribution of per capita emissions

- SRES – 2050 projections



Stationarity

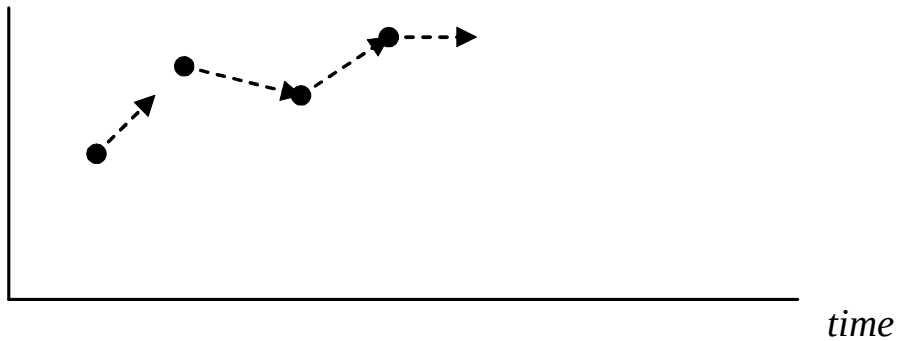
- Annual emissions/capita in country i: $e_i(t)$
- Global average: $\bar{e}$
- Global stationarity implies:
  - Annual levels tend to revert to stable mean (or trend)
  - (+) shock in one place implies (–) shock in another



  - Also implies mean and variance finite, well-defined

Nonstationarity (unit root)

- Annual levels do not revert to stable mean (or trend)
- Contemporaneous shocks do not necessarily cancel each other out



- No stable mean
- Variance of the forecast becomes infinite

Unit root tests

- Lee and Strazicich (2003) unit root test
- Allows up to two structural changes in mean and trend
- Break points are determined endogenously by the data
- Null hypothesis: unit root (with or without breaks)
  - Rejection of null (10% critical level) implies (trend) stationarity

Data: 1950-2000

- 131 countries available (CDIAC)
- Excluding colonies and territories we have 121 countries
- 95 of 121 individual countries exhibit trend stationarity

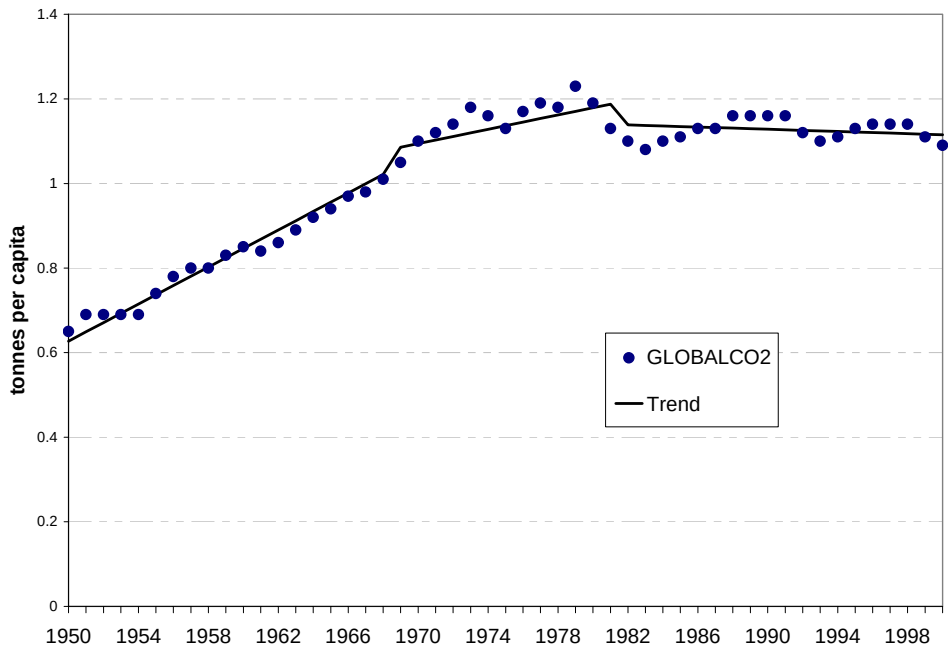
Data: 1950-2000

- Remaining 26 countries are cointegrated
  - Nonstationarity cancels out in global average
- Possible mechanism: energy prices
  - Positive shock in one country caused by jump in fossil fuel consumption
  - This leads to higher market prices
  - Reduces consumption and emissions in other countries
- Alternative explanation of remaining 26 countries
  - 22 of 26 countries nearly reject unit root
  - Unit root tests have low power to reject the null
  - As a practical matter, consider all countries stationary

Data: 1950-2000

- Global average per capita emissions: stationary around trend with break points at 1968, 1981

- Post-1981 trend line slopes down at -0.001 tonnes/year (t = 0.76)
  - i.e., no trend

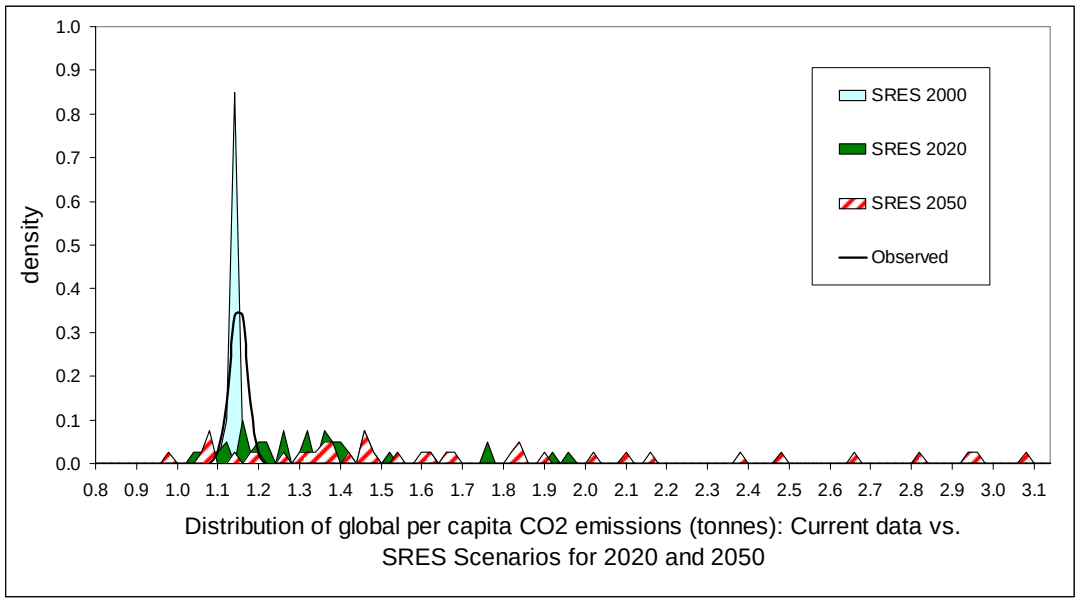


Evaluating scenario probabilities

- Post-1981 data (tonnes per capita):
  - Average 1.14
  - Std deviation 0.02
  - 95% CI [1.10 , 1.18]

Evaluating scenario probabilities

- SRES – 2020 and 2050 projections



Number outside 95%CI

2020	**2050**
33	38
82.5%	95.0%

Number >=10 sd's above mean

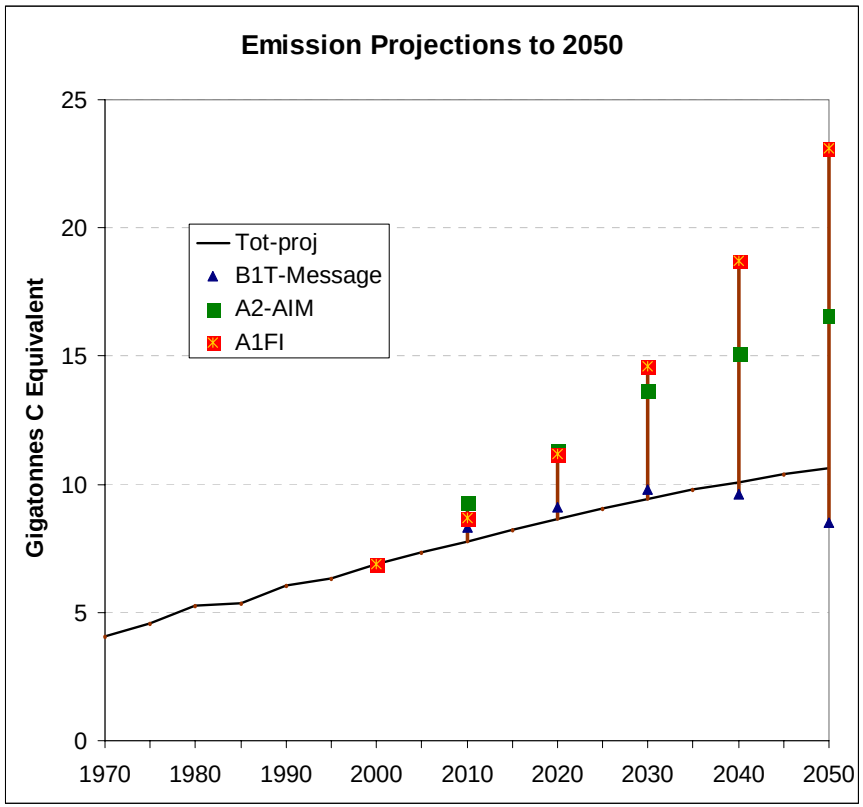
2020	**2050**
18	28
45.0%	70.0%

Evaluating scenario probabilities

- Using 5 standard deviations as cut-off
  - [1.04 – 1.24] tonnes annually as of 2050
- Allows 7 out of 40 SRES scenarios to be retained
- Average total emissions at 2050 = 10.1 GtC

Evaluating scenario probabilities

- On low end of SRES range



Evaluating scenario probabilities

- As of 2050: 9.1 to 11.2 GtC is range of plausible SRES scenario estimates
- Population declines thereafter, suggesting this could be emissions peak
- Outside this group the outcomes through 2050 are too improbable to make scenario worth using

Conclusion: Burden of proof

- To justify other 33 scenarios, IPCC must do 2 things:
  - Provide economic explanation
    - Explain mechanism that has kept historical average emissions constant
    - Prove that this mechanism will soon stop working
  - Provide time series model
    - Show that new mechanism yields nonstationary or strongly upward-trending series

Conclusion: Burden of proof

- Otherwise
  - only 7 out of 40 scenarios are statistically plausible
  - Imply likely emissions at low end of SRES range
  - ~10.1 GtC at 2050