

Annex 1: Emissions scenarios used in UKCP09

Each of the SRES emissions scenarios used in UKCP09 suggests a different pathway of economic and social change over the course of the 21st Century. Changes in population, economic growth, technologies, energy intensity, and land use are considered in the emissions scenarios. They do not assume any planned mitigation measures and cannot currently be assigned probabilities.

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A1.1 Background

We need to make some assumptions about future emissions of greenhouse gases (and other pollutants) from human activities in order to make projections of UK climate change over the next century. Because we cannot know how emissions will change, we use instead a number of possible scenarios of these, selected from the IPCC Special Report on Emissions Scenarios (SRES) (Nakićenović and Swart, 2000). These correspond to a set of comprehensive global narratives, or storylines, that define local, regional and global socio-economic driving forces of change such as economy, population, technology, energy and agriculture — key determinants of the future emissions pathway. The scenarios are alternative conceptual futures to which no probabilities can be attached.

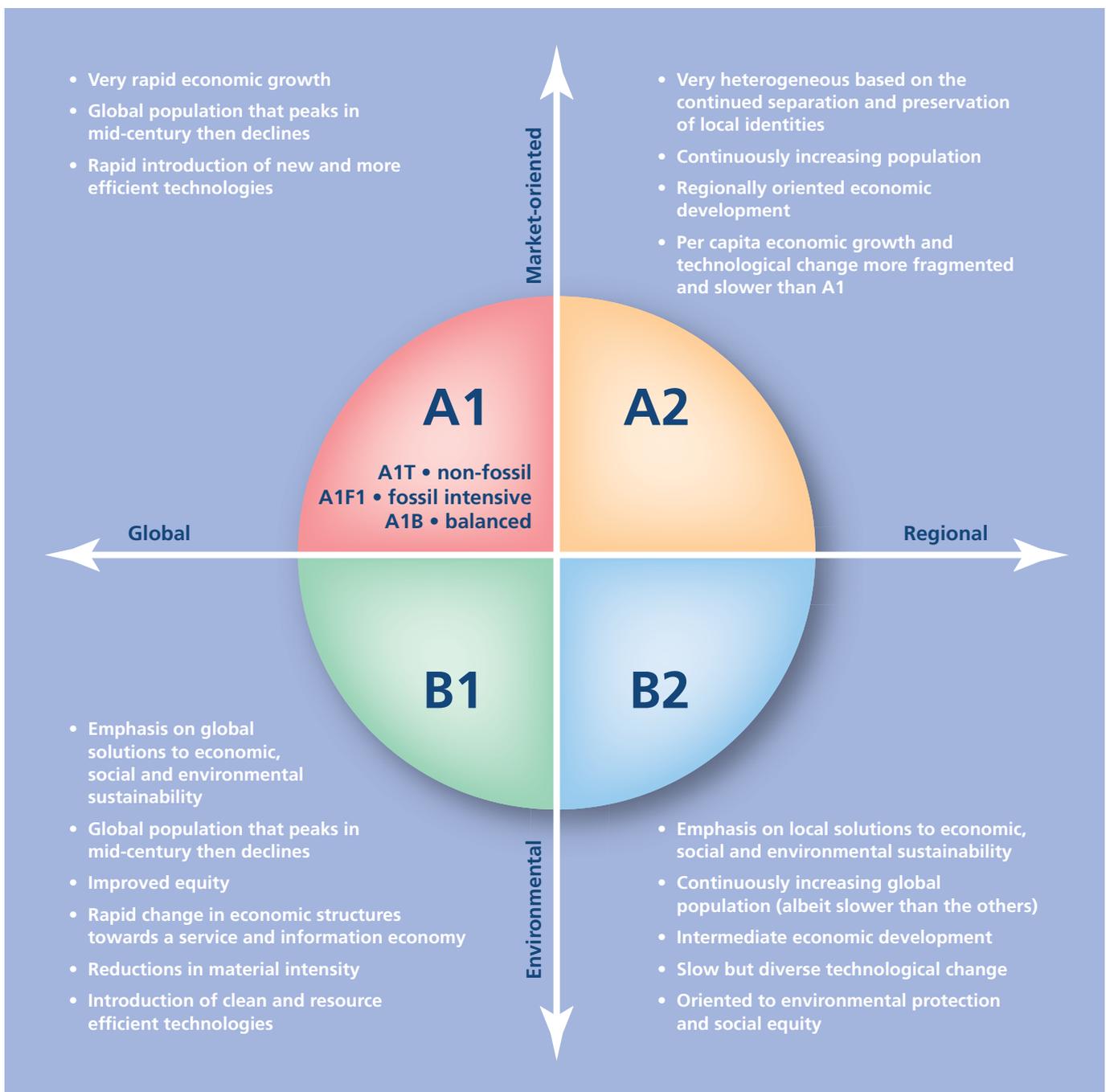
SRES emissions scenarios are structured in four major *families* labelled A1, A2, B1 and B2, each of which represents a different storyline. They are commonly shown as in Figure A1.1, in which the vertical axis represents the degree to which society is economically or environmentally oriented in the future, whilst the horizontal axis refers to the degree of globalisation. All scenarios are *non-interventionist*, that is, they assume that emissions will not be changed in response to concerns over climate change.

The A1 storyline describes a future world of very rapid economic growth, and a population that increases from 5.3 billion in 1990 to peak in 2050 at 8.7 billion and then declines to 7.1 billion in 2100. Rapid introduction of new and efficient technologies is assumed, as is convergence among regions, including large reductions in regional differences in Gross Domestic Product (GDP). Within the A1 family are three subgroups, referring to high use of fossil fuels (A1F1), high use of non-fossil energy sources (A1T) or an intermediate case (A1B).

The B1 storyline also describes a convergent, more equitable world, and has the same population scenario as the A1 storyline: however, rapid changes in economic structures towards a service and information economy are assumed, with reductions in material intensity, and the introduction of clean and resource-efficient technologies. Global solutions are found to economic, social and environmental sustainability.

The *High, Medium, and Low* emission scenarios in the UKCP09 report correspond to the A1F1, A1B and B1 SRES scenarios. The High and Low emission scenarios are the same as those of the same name used in UKCIP02. They span almost the full range of SRES scenarios, with cumulative (2000–2100) CO₂ emissions of 2189 GtC and 983 GtC respectively. SRES A2 and B2 storylines, with higher, continuously increasing population scenarios (to 15.1 and 10.4 billion in 2100 respectively), are

Figure A1.1: The SRES storylines/emissions families.



not used in UKCP09, as the population assumed in the A2 storyline is significantly higher than the high end of current projections.

Extreme high or low emissions scenarios, for example very high rates of fossil fuel combustion or strong mitigation in response to concerns over climate change, are also not considered in the projections available from UKCP09. The UKCP09 Low emissions scenario (SRES B1) does, according to some models, result in approximate stabilisation of CO₂ concentrations between about 500 and 600 ppm. However, when the full (ocean and land) climate–carbon cycle feedback is included, as is done in UKCP09, then the CO₂ concentrations will vary over a wide range.

A1.2 Relevant work since the publication of SRES

The IPCC AR4 (2007) assessment, Working Group 1 Chapter 10 and Working Group 3 Chapter 3, reviewed the new data on demographics, economic trends and energy use and concluded that the emission ranges from scenarios that do not include climate policy that were reported before and after the SRES study in 2000 have not changed appreciably: hence they are still used as the basis for the 2007 IPCC assessment and for the UKCP09 projections. However, population scenarios produced by some major institutions (van Vurren and O’Neill, 2006) are now lower than they were in 2000, specifically for Asia, Africa, Latin America and the Middle East, which more than compensates for the slightly higher population projections for OECD countries. As a result, the population projections that are considered within the emission scenarios assumed as the basis of the UKCP09 projections, with a population of 7.1 billion in 2100, are some 1.3–1.9 billion below the current central estimates of 8.4–9.0 billion (Lutz *et al.* 2004; UN, 2004; Fisher *et al.* 2006). However, van Vurren and O’Neill (2006) also note that the projection of global GDP growth for the A1 family is higher (3.1% per yr) than the ranges (1.2–2.5%/yr) of current projections (USDoe, 2003; IEA, 2004).

The full SRES range of emission projections is actually still considered to be representative of the range of likely outcomes, because in studies which have incorporated the revised lower population estimates, emissions have not decreased because the reduction has been partly compensated for by changes in other drivers such as energy intensity (which has declined slower than anticipated) and the rate of technological change (which has also been slower than expected). These in turn are due to less rapid turn-over of capital stock in the energy sector, and slow penetration of new and advanced technologies due to lack of investments (Grubler *et al.* 2004). Other studies have not yet been revised to take account of these lower projections.

In the SRES scenarios used here, as well as in subsequent studies of future emission pathways, baseline land-related greenhouse gas emissions remain important throughout the 21st century. They include continued, although slowing, land use change (e.g. deforestation) and also increased use of high-emitting agricultural intensification practices due to the anticipated rising global food demand and shifts in dietary preferences towards meat consumption. More recent scenarios (e.g. Soares-Filho *et al.* 2006) suggest significantly more rapid rates of deforestation than those in the SRES scenarios, which would act to enhance the climate forcing and potentially make climate change more rapid.

There has been a debate on the form of exchange rates, market exchange rates or purchasing power parities, used in the SRES (2000) simulations. However, evidence from the limited number of new studies indicates that the choice of metric for

GDP does not appreciably affect the projected emissions, when metrics are used consistently, with the differences being small compared to other uncertainties such as rates of technological change. This is because when the exchange rate type is changed, the emission intensities change in a compensating manner when the GDP numbers change (van Vurren and O'Neill, 2006; Fisher *et al.* 2007).

Raupach *et al.* (2007) have compared recent global carbon dioxide emissions, estimated by two US government groups, EIA (Energy Information Administration) and CDIAC (Carbon Dioxide Information Analysis Center), with those assumed in the SRES scenarios. They find that CO₂ emissions increased by more than 3%/yr between 2000 and 2004, compared to 1.1%/yr for 1990–1999. This rate of 3%/yr is faster than that in any of the SRES scenarios, and it might be inferred from this that the latter underestimate future emissions, and this would mean that the UKCP09 projections are also an underestimate. However, there are obvious dangers in using comparisons over such a short period to draw conclusions about emissions over the next decades and century.

Some guidance on using the uncertainty associated with the three UKCP09 emissions scenarios is provided in the UKCP09 User Guidance.

A1.3 References

- Fisher, B. S., Jakeman, G., Pant, H. M., Schwoon, M. & Tol, R. S. J. (2006). CHIMP: A simple population model for use in integrated assessment of global environmental change. *The Integrated Assessment Journal*, **6**(3), 1–33.
- Fisher, B., Nakićenović, N., *et al.* (2007). Issues related to mitigation in the long term context. In: *Climate change 2007: Mitigation Of Climate Change. Contribution Of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel of Climate Change (IPCC)*. Metz, B. *et al.* (Eds) Cambridge University Press, Cambridge, UK, 169–250.
- Grübler, A., Nakićenović, N., Alcamo, J., Davis, G., Fenhann, J., Hare, B., Mori, S., Pepper, B., Pitcher, H., Riahi, K., Rogner, H. H., La Rovere, E. L., Sankovski, A., Schlesinger, M., Shukla, R. P., Swart, R., Victor, N. & Jung, T. Y. (2004). Emissions scenarios: a final response. *Energy and Environment*, **15**(1), 11–24.
- IEA (2004). *World Energy Outlook 2004*. International Energy Agency, Paris.
- Lutz, W., Sanderson, W. C. & Scherbov, S. (2004). The end of world population growth. In: *The End of World Population Growth in the 21st Century: New Challenges for Human Capital Formation and Sustainable Development*. Lutz, W. & Sanderson, W. (Eds) Earthscan Publications, London, 17–83.
- Nakićenović, N. & Swart, R. (Eds) (2000). Special Report on Emissions Scenarios. A Special Report of Working Group III of the Intergovernmental Panel on Climate Change. Cambridge University Press: Cambridge, UK and New York. 570 pp. <http://www.ipcc.ch/ipccreports/sres/emission/index.htm>.
- Raupach, M. R., Marland, G., Ciais, P., Le Quere, C., Canadell, J. G., Klepper, G. & Field, C. B. (2007). Global and regional drivers of accelerating CO₂ emissions. *Proceedings of the National Academy of Sciences*, **104**, 10288–10293 (doi/10.1073/pnas.0700609104).
- Soares-Filho, B. S., Nepstad, D. C., Curran, L. M., Cerqueira, C. G., Garcia, R. A., Ramos, C. A., Voll, E., McDonald, A., Lefebvre, P. & Schlesinger, P. (2006). Modelling conservation in the Amazon basin. *Nature*, **440**, 520–523. (doi:10.1038/nature04389).
- UN (2004). World population to 2300. Dept of Economic and Social Affairs, Population Division, UN, New York pp 254. <http://www.un.org/esa/population/publications/longrange2/WorldPop2300final.pdf>
- USDoE (2003). International Energy Outlook US Department of Energy — Energy Information Administration, Washington DC.
- Van Vuuren, D. & O’Neill, B. (2006). The consistency of IPCC’s SRES scenarios to recent literature and recent projections. *Climatic Change*, **75**, 9–46 (doi:10.1007/s10584-005-9031-0).
- World Bank (2004). *World Economic Prospects 2004*. World Bank, Washington DC.