Rutland in the Anglian Region of the EA and at Kielder in Northumberland, had been completed and interlinked with wider supply networks (NRA, 1994b). In Kent, but the end of 1992, river flow was reduced below that of the mid-1970s because of the long-term fall in groundwater levels to the lowest since records began (NRA, 1992a), due primarily to successive years of low winter recharge. Even in the British context, we see how the impact of prolonged low rainfall has variable results.

Low rainfall returned to England and Wales during 1995. Interestingly, this coincided with a meeting in Madrid of the Inter-Governmental Panel on Climatic Change (IPCC) in November of that year, where, for the first time, climate change attributable to the emission of 'greenhouse gases' was beginning to be identified. Individual droughts can never be attributed to global warming, but the water industry had started to take such opinion seriously. In the 1990s the NRA was already, in any case, concerned enough to commission research (Arnell *et al.,* 1994).

The Secretary of State did express concern that water companies (especially Yorkshire Water, North West Water and South West Water) experienced problems during 1995 (NRA, 1995c). This was in the face of widespread issuing of hosepipe bans and drought orders, restricting the use of water for non-essential purposes, and despite there being good surface and groundwater reserves during February of that year. The dry spell commenced in March, and by August rivers were commonly at 50% of their expected seasonal flow. Indeed, the period April to August 1995 was, in some areas, drier than the corresponding period in 1976, and it followed the dry period of 1988 to 1992. Drought orders were presented to the Secretary of State and aimed to widen options for water resource development (including new sources). These were supported by the NRA, provided adequate steps had been taken to mitigate the environmental impact and manage demand. As consumption rose throughout the first half of the twentieth century, *quantity* of supply (as distinct from water *quality)* was deemed not to be a problem for agriculture, industry or domestic supplies. Historically, there has been little perception that water could be in short supply until the dry years of the mid-1970s but following the 'droughts' after 1990, further legislation was required (Water Act, 2003; Box 2.1).

The present position is one by which climate change is part of the planning procedure for the water industry. The industry sees itself not only as a 'victim' of climate change (in reality this translates into growing uncertainty about resource availability) but it is also a contributor, for it is energy-intensive and contributes upwards of 1% of national Green House Gas (GHG) emissions. Carbon is a part of its business planning, and its uses if anything, is rising; already we can see it is becoming difficult to differentiate GHGs, carbon use (and abuse) resource availability and policy. The kinds of aims across the industry are listed in the Box 2.2.

The Environment Agency will be able to encourage transfer of water resources between water companies and recover costs associated with drought orders and permits. This has impact across all sectors and includes small abstractors, canals, harbours and agriculture, including irrigators and industries mentioned including the water industry.

The private water industry is, in reality highly regulated (Chapter 3), with its interests are represented by Water UK (Water UK, 2016a). This organisation calls for a more 'joined-up approach' by government and regulators in terms of policy issues around incentives and mechanisms for carbon reduction, renewable generation and green electricity.

Box 2.1 Summary of the Water Act 2003

It was found, following droughts after 1990, that 'existing legislation did not enable adequate management of water resources and protection of the environment'. A government review led to the publication in 1999 of 'Taking Water Responsibly'. This signalled important changes, including a move towards time limited licences and the development of Catchment Abstraction Management Strategies (CAMS). The Water Act 2003 and makes significant changes to the licensing system and key pints are that are summarised:

1) All small abstractions, generally under 20 cubic metres per day (m^3 day^{-1}), will not need a licence
2) A licence will be needed for dewatering of mines, quarries and engineering works, water transfers into canals and internal drainage districts, use of water for trickle irrigation and abstractions in some areas which are currently exempt will now need a licence to make sure that they are managed appropriately and that any impact on the environment can be dealt with
3) Administration for making applications, transferring and renewing licences will be made simpler
4) There will be an increased focus on water conservation
5) Water companies will have new duties to conserve water and all public bodies will need to consider how to conserve water supplied to premises
6) The Government has new responsibilities for monitoring and reporting progress in this area and water companies will need to develop and publish water resources management and drought plans

Box 2.2 Means towards reducing greenhouse gas emissions (Water UK, n.d.)

- Reducing energy use (electricity and other fuels) through efficiency measures
- Water efficiency and leakage control
- Research and development into alternative low-carbon technologies
- Embedded renewable power generation including anaerobic digestion
- Purchase of green power and good-quality Combined Heat and Power
- Investment plans that include whole-life carbon impacts and costs
- Work with the supply chain to encourage low-carbon behaviour
- Reduced water wastage; saving energy and carbon in the industry, homes and businesses
- Exploitation of least-cost solutions for waste disposal
- Insulation against energy price volatility and lower water charges
- Improved coordination of regulatory policies
- Enhance sustainability of land management
- Improve carbon accounting
- Support carbon sequestration initiatives
- Support Sustainable Urban Drainage Systems (SUDS)

2.1.4 The Climate of Britain

The climate of Britain is temperate, that is to say there is generally sufficient water to support the needs of the population and water supply, and measures have evolved to smooth out the supply where there is a risk of it becoming deficient. Rainfall, however, is not evenly distributed across the country. The position of the islands on the western seaboard of Europe, and the preponderance of westerly and southwesterly airflows, bring moist oceanic air.

Precipitation may be characterised by:

- *The amount falling in a given time period* (typically monthly or annual) and this may be averaged.
- *The frequency of 'rainfall events' in time* (e.g., magnitudes of daily rainfall events [called return levels]) for events with return periods of 1 in 5, 10, 20, 30, 50 and 100 years
- *The intensity of rainfall* (typically, mm hr^{-1})
- *Spatial variation in the above* (related to geographical concepts such as topography or region)

There are many accounts detailing the amount and occurrence of precipitation. The term 'precipitation' includes all water deposited from the atmosphere, including not only rain, but snowfall, hail, sleet, deposition from mist, and so on. The problem, however, is that precipitation patterns are changing (Osborn and Maraun, 2008). Throughout the twentieth century, intensity of UK precipitation has increased during winter and to a lesser extent also during spring and autumn. There were more frequent spells of very wet weather and an increase in total precipitation, at least during the second half of the century.

Table 2.2 shows that rainfall is fairly evenly distributed throughout the year, although proportionately more rain falls in the summer for the east than the west, attributable to convectional rainfall events.

Rainfall totals vary widely. The mountainous western highlands of Scotland is one of the wettest places in Europe with annual average rainfall capable of exceeding 4500 mm (Figure 2.2). Other wet areas include the Lake District, Snowdonia and Dartmoor. Across Britain, the interplay of climate and topography gives higher rainfall in the west. Mean annual rainfall here may be in the order of two and nine times that in the east; values can be as low as 500 and 600 mm along the coast of southeastern England. Typical values for lowland England and eastern Scotland range from 550 to 1000 mm.

In wetter, cooler climates potential evapotranspiration (PE) calculations are lower. The range is typically between 400 and 550 mm per year (Ward and Robinson, 2000, Ch. 4) with lowest values over upland areas. However, in very warm and dry years in south and eastern England, this figure can exceed 600 mm (NRFA n.d.). It is the net radiation available for evaporation which is dominant in controlling the evaporative loss, and this radiation is reduced due to cloudiness in upland areas. Other factors, such as increased humidity in regions of increased rainfall, and increased advectional losses in windier coastal regions, also increase regional variations. The slightly higher potential transpiration figures, linked with often dramatically lower rainfall figures result in regional supply problems through adverse catchment water balances.

Some water company supply areas are currently below their 'target 'headroom' (Figure 2.3), this is the difference between available supplies and demand. Each water company calculates its target headroom to ensure it can reliably meet customer demand