Cents and Sustainability

Securing Our Common Future by Decoupling Economic Growth from Environmental Pressures

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Decoupling Economic Growth from Freshwater Extraction

The Complex Challenge of Freshwater Extraction and Use

> *We have in the past been concerned about the impacts of economic growth upon the environment. We are now forced to concern ourselves with the impacts of ecological stress – degradation of soils, water regimes, atmosphere, and forests – upon our economic prospects.*
>
> *Our Common Future*, 1987, p5

Fresh water is essential for life on our planet and is a critical component of most forms of economic development – ranging from primary sector activities to industrial production, energy generation and service sector development. The critical nature of water to human survival and economic activity explains why, historically, civilizations, cities and towns have grown and prospered next to, or with access to, plentiful sources of fresh water. However, history has shown that the manner in which water is used can be a significant factor in the long-term success or failure of a society, with the legacy of the world's first recorded civilization, Sumeria, being that of an environmental disaster.[1] The demise of Sumaria was largely due to irrigation practices that caused the increased salinity of agricultural land – with a Sumerian clay tablet recording that 'the earth turned white'. Despite the growing levels of soil salinity, the Sumer rulers had based their wealth and power on having a food surplus, and thus they required the farmers to continue irrigating and farming the salty land, inevitably leading to food shortages. Without enough food to feed and pay for large armies, their civilization was vulnerable and finally fell in 2370 BC to the Akkadian Empire from the north.

Just as the survival of past ancient civilizations has been threatened by poor water management, so is the long-term survival and sustainability of many rural and urban settlements in many parts of the world. In the 21st century, climate change threatens to significantly reduce water availability and lead to greater frequency of droughts in many countries and regions of the world. Studies by the International Water Management Institute have estimated that by the year 2025, one-third of the world's population will face absolute water scarcity.[2] According to the OECD this number could rise to two-thirds by around 2050 unless serious efforts are made to decouple economic growth from freshwater extraction.[3]

Climate change is set to exacerbate freshwater shortages significantly. It is already changing the water cycle and affecting water availability. Rising temperatures are boosting evaporation rates, altering rainfall patterns and melting glaciers that feed rivers during the dry season. In fact, the effects of climate change on these parts of the water cycle are so significant that the IPCC in 2008 released a new technical report on *Climate Change and Water* which concluded that:[4]

- *Globally, the area of land classified as very dry has more than doubled since the 1970s. There have been significant decreases in water storage in mountain glaciers and northern hemisphere snow cover. Shifts in the amplitude and timing of run-off in glacier- and snowmelt-fed rivers, and in ice-related phenomena in rivers and lakes, have been observed.*
- *By the middle of the 21st century, many semi-arid and arid areas (e.g. the Mediterranean Basin, western US, southern Africa, northeastern Brazil and Murray Darling Basin, Australia) are particularly exposed to the impacts of climate change and are projected to suffer a decrease of water resources due to climate change.*
- *Globally, the negative impacts of future climate change on freshwater systems are expected to outweigh the benefits. By the 2050s, the area of land subject to increasing water stress due to climate change is projected to be more than double that with decreasing water stress.*
- *Water supplies stored in glaciers and snow cover are projected to decline in the course of the century, thus reducing water availability during warm and dry seasons in regions supplied by melt water from major mountain ranges, where more than one-sixth of the world's population currently lives.*

Furthermore, climate change that leads to increasing average global temperatures will also directly reduce agricultural yields in many countries and areas, including southern Europe, the US and Australia.[5] For instance, an Australian study found that over the next 100 years, unmitigated climate change is forecast to devastate the Murray Darling Basin, which is the major food bowl for Australia. In one unmitigated scenario put forward by the Garnaut Climate Change Review, irrigation will continue in the Basin in the immediate term, but by 2030, economic production will fall by 12 per cent. By 2050 this loss will increase to 49 per cent and, by 2100, 92 per cent will be lost due to climate change.[6] The reality is that drought conditions have prevailed in many parts of rural Australia since 2000 and most of the 50,000 farmers in the Murray Darling Basin are already operating on less than 20 per cent of their normal water allocations.[7] Such impacts from climate change will add significant pressure to the economies of the world and this, combined with the fact that in many parts of the world – such as West Asia, the Indo-Gangetic Plain in South Asia, the North China Plain and the High Plains in North America – freshwater extraction rates are exceeding the natural water replenishment rates, means that decoupling water extraction from economic growth will prove to be a crucial component of economic development this century.

To date, in order to achieve the steady increases in food production required by the growing world population, countries have not only relied on irrigation from rivers but also from groundwater supplies. However, almost all of the world's wells now have falling water levels and declining yield, and many have run dry. Today in the US, groundwater provides drinking water for over half the population. The same applies in much of Europe, India, China and many other countries.[8] Together with the massive volumes of water used for agriculture, this means that many countries are in a classic overshoot-and-decline mode, with the potential risk only becoming clear when wells run dry. Developing nation economies are particularly sensitive to the surface-water impacts of climate change and subsequent overuse of groundwater because their economies and society are heavily dependent on the agriculture sector, which contributes 20–60 per cent of their nations' GDP. For example, the groundwater overdraft rate exceeds 25 per cent in China and 56 per cent in parts of northwest India.[9]

The issue of water availability and climate change will not just impact upon farmers and agriculture. Supplying fresh water is now a critical issue for many cities. Traditionally, many cities have relied largely on a network of dams to collect and store fresh water to meet urban demand. In the 21st century, when climate change is forecast to reduce and alter rainfall patterns in many parts of the world, this highly centralized approach cannot guarantee adequate future water supplies for rising populations as it is heavily reliant on rainfall falling in small geographical areas where there are dammed water catchments. This is a major challenge facing water supply authorities and utilities in the 21st century. Even without factoring in the risks from long-term climate change, some water supply authorities are struggling to keep pace with demand. According to a 2003 report by the US government's General Accounting Office, *Freshwater Supply: States' Views of How Federal Agencies Could Help Them Meet the Challenges of Expected Shortages*,[9A] current trends in rising water demand mean that at least 36 US states are anticipating local, regional, or state-wide water shortages by 2013 under 'normal conditions', with 46 US states anticipating water shortages under 'drought conditions' by 2013. Longer term, this report noted that 'Water supply conditions in all regions of the United States are likely to be affected by climate change in the future, either through increased demand for water associated with higher temperatures or changes in supply because of changes in precipitation and runoff patterns.' Already, some cities in the US are having to rely on piping water from other regions to meet their needs. In the US, cities such as San Diego, Los Angeles, Las Vegas, Denver and El Paso, are increasingly meeting their needs by taking a percentage of the irrigation water previously allocated for farming.[10] Hence, with rural and city implications in mind, this chapter focuses on how to decouple economic growth from freshwater extraction, both for agriculture and city supplies.

Economic Benefits Associated with Reducing Freshwater Consumption

Investments in water efficiency, demand management, rainwater and storm water harvesting and reuse to decouple freshwater extraction from economic growth have strong economic multipliers because they lead to multiple cost benefits, as well as creating local jobs and boosting the local economy. An economic impact study of the Malaysian Muda irrigation project reported that not only was water use reduced, but substantial indirect economic benefits were found in a range of other associated sectors of the regional economy. The study found that for every dollar of direct benefits, another 83 cents were generated in the form of downstream or indirect effects.[11] A study of a number of water-efficient irrigation investment projects in India found economic multipliers of as much as three times.[12] Such initiatives that deliver associated multiplier effects are a key part of the decoupling process. For example, water efficiency savings in business, industry and residential supply can also result in reduced wastewater treatment costs and energy savings from reduced water distribution and from reducing the amount of water needing to be heated. The amount of energy needed for pumping water for agriculture, and to distribute and heat water for use in businesses, commercial buildings and homes, is significant. The Californian Energy Commission 2005 report, *California's Water–Energy Relationship*,[12A] showed that water-related electricity use makes up 19 per cent of all energy used in California. Thus once the return on investment from water efficiency initiatives are achieved, usually within one to four years, business, industry and households do not just have lower annual water and water treatment costs but also lower energy costs too. If they then choose to invest this money in additional cost-effective water and energy saving opportunities, still more funds can be generated over time, further stimulating economic activity. Water efficiency and recycling investments have a high economic multiplier because they reduce demand for water resources and can thus delay, and even in some cases prevent, the need to build new water supply infrastructure such as dams, desalination plants and water treatment plants. Dr Peter Gleick, director of the Pacific Institute, showed in 2003, in his *Science* journal paper 'Global freshwater resources: Soft-path solutions for the 21st century',[12B] that the annual cost of ensuring all globally have access to clean water through investing in more large-scale centralized dams and treatment plants would cost around US$180 billion per annum to at least 2025. However, this figure can be reduced to an annual cost of US$10–25 billion, if the emphasis is on investing in water efficiency, demand management, rain and stormwater harvesting and water recycling at appropriate scale.

As Wolff and Gleick explain, 'water efficiency reduces the size, duration and frequency of peak water system loads. Peak loads determine the size of capital facilities required, hence capital costs. Lower peak loads mean that existing capital facilities can serve more customers, avoiding or reducing the expense of these facilities. Lowering peak water demand and usage also reduces peak energy usage by water utilities to pump, treat and handle water, providing further cost savings.'[13]

Research led by Professor White at the Institute for Sustainable Futures (Australia), indicates that for cities and towns facing the need to build more water supply infrastructure, investing in water efficiency can result in water savings of greater than 30 per cent, and can yield net present value economic benefits in excess of AU$100 million for some capital cities.[14] Research by the Pacific Institute has come to a similar conclusion for California, finding that despite progress already made in water efficiency, a further one-third of California's current urban water use can be saved through conservation and efficiency in the residential, commercial, institutional and industrial sectors.[15] Its report also showed that once the potential energy efficiency saving co-benefits were taken into account from water efficiency initiatives, virtually all water efficiency investments were financially worthwhile. In particular, the report found that at least 85 per cent of the savings can be achieved at costs below what it would cost to tap into new sources of supply and without the negative social, environmental and economic impacts that any new major dam project would bring. In a separate 2005 report that investigated the wider Californian economy including agriculture, the Pacific Institute found that water efficiency measures could reduce overall water usage to 20 per cent below 2000 levels by 2030, even with a growing population and a strong economy.[16]

With this type of research under way, water efficiency programmes are becoming better understood and this experience is leading to the development of robust and cost-effective long-term strategies. As more programmes come to fruition, short-term economic benefits are also being identified, by studies such as the 2009 US study by the Alliance for Water Efficiency, which showed that for the US economy:[17]

Table 9.1 *Example of the true cost of ambient water and hot water (US$/kL)*

Purchase cost	1.13†
Wastewater treatment costs*	0.75
Wastewater pumping costs	0.05
Wastewater discharge costs (volume charge)	0.40
True cost for ambient water	2.33
Heating to 80°C**	2.80
True cost of hot water	5.13

Note: * Based on assumption of typical treatment costs of an anaerobic digester
** Costs for heating to 80°C using steam produced by a gas boiler
† Based on Brisbane Water supply costs
Source: UNEP Working Group for Cleaner Production in Food (2004)[18]

- *The economic output benefits of investments in water efficiency range between US$2.5 and 2.8 million per million dollars of direct investment.*
- *GDP benefits range between US$1.3 and 1.5 million per million dollars of direct investment.*
- *Employment potential ranges between 15 and 22 jobs per million dollars of direct investment.*
- *Direct investment in the order of US$10 billion in water/energy efficiency could save between 20 and 40 trillion litres of water, with resulting energy reductions as well.*

For businesses, water efficiency saves money directly through reduced water costs, and indirectly by reducing wastewater treatment requirements (including energy requirements and the cost of chemicals) and trade waste disposal. These hidden costs of water usage are rarely properly evaluated and so potential cost savings from water-efficiency improvements tend to be underestimated. For example, in the food processing industry, some of the hidden components include the purchase price, treatment of incoming water, heating or cooling, treatment of wastewater, disposal of wastewater, pumping, maintenance (e.g. pumps and corrosion of pipe-work and equipment) and capital depreciation.[19] Table 9.1 provides an example of evaluating the full costs of water at ambient temperature, and of hot water, to businesses in the food processing industry. The results show that while the nominal purchase cost of the water is US$1.13, the true cost is actually US$2.33 for water at ambient temperature, and US$5.13 for water heated to 80°C.

Despite such a strong economic and financial case, little effort has been made by most businesses, farmers and most cities on the whole to improve the efficiency of water use, leading to high levels of wastage, even though significant opportunities have been shown to still exist to increase productivity, as shown in *Factor Five*.[20] This is particularly true in the agricultural sector where the true cost of water has been heavily subsidized, with farmers in many parts of the world paying very little to nothing at all for water, as shown in Figure

9.1. Thus OECD households or industries are potentially paying as much as 100 times more for water compared to the prices paid by farmers.[21] However, even with this comparative cost discrepancy, water usage by industry and urban businesses is still very cheap, where water costs typically, in OECD countries, represent less than 2 per cent of the total operating costs of most businesses and households. Hence, as for energy, the lack of a strong price signal for industry and residential consumers has resulted in most water efficiency opportunities in many countries being largely ignored.

A range of studies now show that increasing water prices can induce conservation. For instance, in Bogor, Indonesia, an increase in the water tariff from US$0.15 to US$0.42 per cubic metre resulted in a 30 per cent decrease in household demand for water. In Goa, India, increased water tariffs induced a 50 per cent reduction in water use over a five-year period by a fertilizer factory, and in Sao Paulo, three industries reduced water consumption by 40–60 per cent in response to the establishment of effluent charges.[22] The structures of water-pricing tariffs for households and commercial buildings vary considerably among OECD countries, but there is a trend away from fixed charges (e.g. based on dwelling size or number of occupants) and toward two-part tariffs which include both a small fixed component (to reflect fixed costs such as connection or metering costs) and a volumetric component to reflect the levels of water consumed. By charging consumers based on the actual volume of water used, volumetric pricing systems provide incentives for efficient water use. Some countries have also been experimenting with 'peak pricing' arrangements, especially seasonal pricing, in order to better manage demand.[23]

Another reason why large water efficiency opportunities exist globally is that urban water utilities have not had incentives to encourage their customers

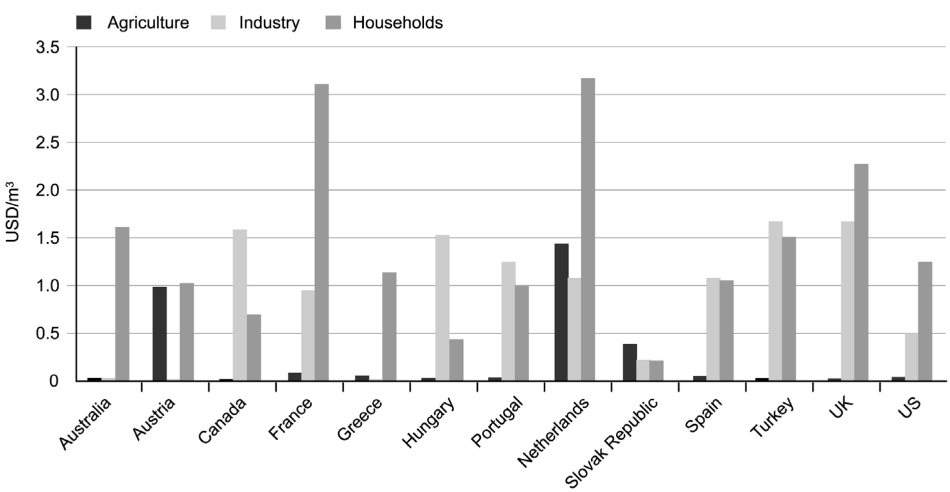

Figure 9.1 *Comparison of household, industrial and agricultural water prices for a selection of OECD countries*

Source: Adapted from OECD (2001)[24]

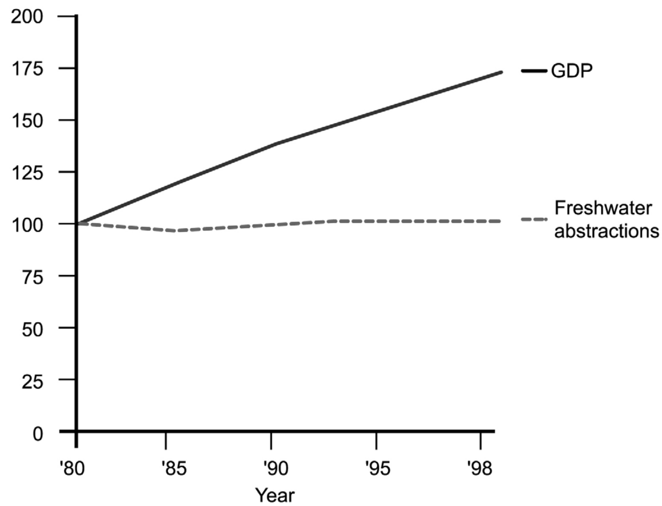

Figure 9.2 *Freshwater extraction per unit of GDP in OECD countries, 1980–1998*

Note: Not including Australia, Belgium, France, Greece, Ireland, Italy, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Portugal and the UK.
Source: OECD (2002)[25]

to use water more efficiently. Rather, they have simply been required to ensure supply and to keep selling more water to customers, much like energy utilities. Governments and the water supply industry have also historically addressed increasing demand for water by building more dams or more desalination plants, rather than encouraging greater water efficiency.[26] However, a range of market-based strategies, policies and demand management programmes can be used to encourage consumers to value water efficiency, rain and stormwater harvesting and water recycling, reducing overall freshwater demand on the limited resource, and reducing and delaying the need to invest in new dams and storage and treatment works.

To support this there have been numerous technical innovations that now enable 50–90 per cent water efficiency savings, most of which have a short return-on-investment period, as shown in Tables 9.2 and 9.3.[27] However, despite the significant potential for decoupling through water efficiency, reuse and recycling opportunities, most countries have only achieved relative decoupling of economic growth from freshwater extraction (see Figure 9.2), with only a few examples of absolute decoupling.

With this theory and reality in mind, we now explore a portfolio of options that can assist nations to achieve absolute decoupling of economic growth from freshwater extraction across the major areas of global freshwater usage in agriculture, industry, cities and buildings. According to the UN, the major global uses of freshwater include agriculture (69 per cent, mostly for irrigation), followed by urban, which includes industry (23 per cent) and buildings

(8 per cent, for drinking water and sanitation).[28] Hence we focus first on agriculture (grazing and cropping), followed by cities (industry and buildings).

Decoupling Economic Growth from Freshwater Extraction for Grazing

Decoupling economic growth from freshwater extraction on farms can be achieved through a combination of technology, policy and management actions. In *The Natural Advantage of Nations* we discussed the necessary policy and water-trading market mechanisms needed to underpin efforts to decouple economic growth from freshwater extraction in the agricultural sector, featuring pioneering work in this field by Dr Mike Young and Dr Jim McColl.[29] Here we focus on farming practices, and considering that of the total land used by agriculture, most is for livestock grazing (69 per cent, 3488Mha) followed by cropland (28 per cent, 1405Mha),[30] we will first look at ways to reduce freshwater extraction and irrigation by maintaining healthy pastures, followed by the potential to reduce freshwater extraction for crops.

Grazing pastures have tended to lose productivity over time, leading farmers to invest in more irrigated water, chemicals, fertilizers and the machinery to undertake traditional pasture improvement techniques to maintain pasture productivity. In the late 1980s, Allan Savory published *Holistic Management*[31] which explored a new way to restore pasture health and productivity while reducing artificial inputs and required irrigation levels. Savory helped to change the understanding of the underlying causes of grazing land productivity loss, and his methods have now been applied to 30 million hectares of grazing land globally with remarkable and economically attractive

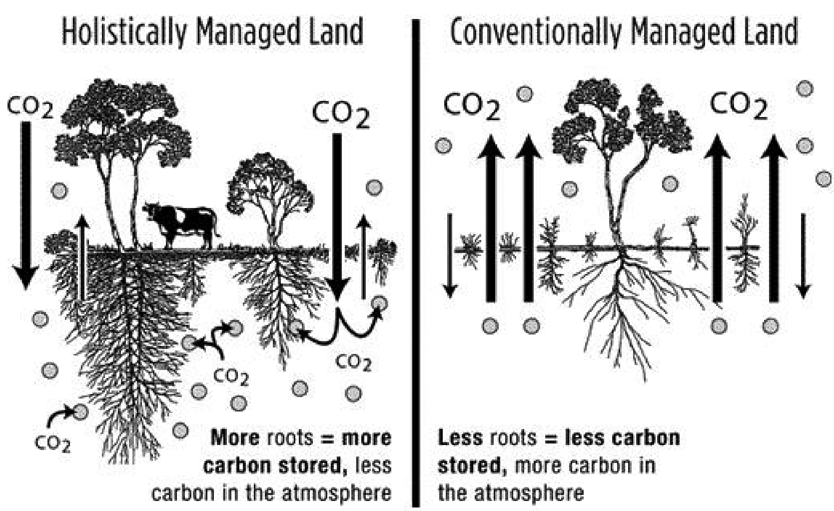

Figure 9.3 *Holistically versus conventionally managed grazing land*

Source: Holistic Resource Management[32] results. Furthermore, as the IPCC has concluded that the majority of the mitigation potential for the agriculture sector arises from soil carbon storage,[33] Savory's methods have shown that there is significant potential to enable greater levels of carbon to be stored in the plants and soil, as shown in Figure 9.3 and explained in the following paragraphs.

Up until the end of the 20th century, 'set stocking', also known as continuous grazing, was the standard agricultural practice, involving livestock browsing on one piece of land for an extended period of time. 'Conservative' stocking rates allowed the livestock to graze selectively, preferring some species while leaving others untouched.[34] With this practice, the extent of defoliation is largely determined by which species the livestock find most palatable.[35] Over many months in the same paddock, continuous grazing tends to reduce the amount of vegetation and the height of the preferred species as there is minimal time for regrowth and recovery. As the grasses and plants lose their height they also have less surface area to undertake photosynthesis and subsequently less capacity to grow large root systems or rapidly regrow. Set stocking also reduces the resilience of grasses and plants that are not grazed which can become 'rank' or 'tired'.[36] Furthermore, in set stocking livestock tend to form sprawling 'camps' where they rest and these areas can become bare due to frequent trampling, leading to soil erosion and land degradation issues. And once land degradation occurs on one part of the landscape over time it tends to spread.[37] In contrast, historically, as the plants and the animals were evolving together, herds of closely packed livestock roamed the landscape, regularly moving to new areas to miminize risk of attack from predators. Savory realized that the problem was one of concentration, where domesticated grazers – with stock-people guarding them and killing their predators – have no reason to clump together. Their impact on the land is therefore scattered and erratic.

Acknowledging these differences, Savory proposes a new grazing method called 'holistic resource management', which promotes 'time control grazing', 'a grazing management method where stock are moved through a number of paddocks at high stock density ... Stock moves are based on growth rate of pasture and its consequent physiological requirement for rest'.[38] Under this method large groups of stock graze for up to 14 days in a comparatively small paddock, before the paddock is then left to rest and recover for 30–100 days.[39] The short-duration and high-density grazing forces livestock to eat whatever grasses and vegetation are available, and not just those species it prefers. The short duration that the stock spend in each paddock prevents them from forming habitual camps, and with the regular movement of the dense herd, plants and grasses are 'mulched' (pushed back into the soil) through hoof action. Livestock manure is also more evenly spread out across the landscape reducing the potential for local over-fertilizing, and the need to add artificial fertilizers in other areas. Savory also recommends a return to natural native grasses and perennial plants as these tend to have greater resilience as they have co-evolved to thrive with only natural levels of rainfall. The combination of these changes leads to more soil biota activity, improved soil structure and hydraulic properties, and increased and more active root systems of plants, enabling soils to become more porous and stable. This also leads to higher infiltration of water into the soils and reduced surface water run-off and evaporation. Organic matter in the topsoil helps it hold a greater amount of water, which can lessen the need for irrigation dramatically. This means plants and grasses are able to grow longer in dry periods because more of the natural rainfall is stored in the soil. Furthermore, more active and extensive root systems, higher soil organic matter, and greater soil biota activity all means that grazing pastures have the capacity to store significantly more carbon than they currently do using the set stocking method.

Decoupling Economic Growth from Freshwater Extraction for Cropping

In *Factor Five*[40] our team worked with Professor von Weizsäcker to compile world-leading examples of water productivity improvements in agriculture. The research showed that through a whole system approach, using a combination of the following five strategies, up to 80 per cent reductions in freshwater extraction can be achieved:

1 appropriate selection and rotation of crop species;
2 sub-surface drip irrigation and irrigation scheduling;
3 advanced deficit irrigation strategies;
4 rainwater harvesting;
5 reusing urban stormwater and recycled water for peri-urban agriculture.

Here we summarize each strategy, updating the work in *Factor Five*, and incorporating leading findings from research undertaken by the Pacific Institute, based on interviews with Dr Peter Gleick.[41]

1 Appropriate selection and rotation of crop species

Selecting crops that are well suited to the intended biophysical and climatic conditions can deliver in the order of 50 per cent water savings. Furthermore, due to the foreseeable impacts of altered climatic conditions, not only is it important to choose appropriate crops, the variety of the crop, referred to as the varietal, is also important, with some offering lower water requirements, heat shock resistance, drought tolerance, higher protein levels, and resistance to new pests and diseases. For instance, researchers have developed drought-tolerant 'Tuxpeño' corn that can increase harvests by 40 per cent under drought conditions.[42] Additionally, researchers have been able to modify wheat varieties through intensive plant breeding to increase production even in hot climates and provide strong built-in resistance to major diseases.[43] Once appropriate crop species and varietals have been selected, water productivity can be further increased using crop rotation. Investigations of innovative crop rotation by leading farmers by the Australian National University (ANU) have verified that rotating rice and wheat crops can lead to significantly less water consumption overall. The trial grew wheat as a winter crop in rotation with a summer 'temperate Japonica' rice crop, and found that through precise and efficient use of flood irrigation for the rice crop the soil moisture levels were maintained during winter to allow a wheat crop to use little or no further irrigation, meaning that on average both crops can be harvested over the year for around the same level of irrigation as the most water-efficient wheat crop.[44]

2 Sub-surface drip irrigation and irrigation scheduling

Significant potential exists to reduce water consumption in agriculture as, in many countries, over 90 per cent of irrigated land surface receives water by flooding or through open channels. Water efficiency savings through sub-surface drip irrigation can be as high as 50–80 per cent, and can be made more affordable for use in the developing world.[45] However, currently only a few countries, namely Cyprus, Israel and Jordan, are fully utilizing the potential of drip irrigation, with the method used on only 1–3 per cent of irrigated land in India and China, and on roughly 4 per cent of agricultural land in the US.[46] Furthermore, by combining drip irrigation with appropriate watering schedules, informed by water sensors, water usage has been shown to reduce by 17 per cent, and crop yields to increase by as much as 8 per cent.[47]

3 Advanced deficit irrigation strategies

A growing body of international work shows that water consumption can be significantly reduced in orchards and vineyards using advanced 'deficit irrigation'. This method sees the application of water at below the full requirement for the particular crop, causing it to be more efficient with its water and reducing evapo-transpiration.[48] For instance, in Turkey, deficit irrigation strategies were shown to increase the yield of a winter wheat crop by 65 per cent.[49] Similar positive results have been described for cotton.[50] As documented in *Factor Five*:

> *One exciting area of research and development in this field has been that of the partial dry zone irrigation technique that is allowing farmers to achieve still more significant reductions in water application. It is called 'partial root-zone drying' because at any one time only half the root-zone is in a drying state. Using two rows of drip-line irrigation, instead of the usual one, one part of the root system side of the plant is kept wet while the other side is dried. The grower irrigates through one line at a time, two or three times a week for a couple of weeks (whatever local conditions dictate), then the same on the other line – that pattern continues throughout the season. The drying roots send a hormonal message to the rest of the plant that it is deprived of*

> *water, so the leaf stomata close, preventing excess moisture loss and reducing excessive shoot growth. In other words the plant is 'tricked' into believing it's stressed and the end result is a plant which uses the water it has, far more efficiently than it otherwise would use. This allows up to 50 per cent reductions in the total amount of water needed to irrigate many crops on top of traditional drip irrigation.*[51]

4 Rainwater harvesting

A wide variety of small-scale innovations are available which can catch and store rainfall for agriculture as well as aquifer and groundwater replenishment – collectively referred to as 'rainwater harvesting' technology.[52] In addition to storage containers (rainwater tanks and bladders), rainwater harvesting can include micro-dams, and channels and stream diversions that direct rainfall and river flow out over flood plains to rehydrate them, boosting productivity. Rainwater harvesting techniques are particularly important in those parts of the tropics where there is a long dry period after the wet season or in dry temperate climates where rainfall is infrequent and light. A grazing and fruit farm in the coastal tropics of Australia demonstrates this well. Owner Adrian Pozzebon had a choice in the mid-1990s to either address the water shortage or close the farm, reflecting:

> *This farm, being in the dry tropics, received rain for only a few months a year, from December through to February, which quickly flowed through the streams and rivers out to sea. So for the rest of the year the property relied on extracting bore water in large volumes, at about 75,000 gallons [284,000 litres] an hour. Over time the quality of the bore water decreased and the salinity levels in it increased significantly. We had no choice. We had to change practices or we would have had to close the farm. We figured that the key was learning how to restore the natural hydrology and slow down the flow of water through the landscape. We invested in natural structures across our creeks so that when the rains came these structures spread the water out over the floodplain effectively.*[53]

The results of this rainwater harvesting have been remarkable and were quickly achieved, including a near complete halt to the use of bore water pumping, significantly reducing salinity and improving productive land capacity. According to Pozzebon, 'The results have been so impressive that there are now at least six other farms that I am aware of trying aspects of this strategy in the dry tropics of Far North Queensland.'[54]

5 Reusing urban stormwater and recycled water for peri-urban agriculture

The FAO estimates that across 50 countries, 20 million hectares are already directly or indirectly irrigated with wastewater[55] – close to 10 per cent of the total irrigated area of the world.[56] 70 per cent of Israeli municipal wastewater is treated and reused, mainly for agricultural irrigation of non-food crops. Yet in virtually all other cities, most of the water which falls on that city is running out to sea as stormwater. Recycling stormwater and treated water from sewerage and reusing it for non-potable water applications therefore offers a significant way to assist peri-urban agriculture or replenish and store water in underground aquifers under or near cities in preparation for future droughts due to climate change.

Decoupling Urban Economic Growth from Freshwater Use in Industry

Globally, industry is the second largest user of fresh water in the world after agriculture. The potential to achieve significant reductions in net water usage and freshwater usage in a number of sectors and industries is significant because many industrial processes do not need fresh potable water. Many companies are finding that water efficiency and onsite water recycling measures are an effective way to reduce operating costs. Similarly, companies and organizations in the services sectors (for example in tourism, research, education and health) are finding that they too can achieve large water savings cost effectively. The examples shown in Table 9.2 demonstrate that across most sectors 60–95 per cent reductions in freshwater use can be achieved (further details are available in the online resource, *Water Transformed: Sustainable Water Solutions for Climate Change Adaptation*).[57]

Decoupling Economic Growth from Freshwater Use in Cities

Significant potential exists to reduce water consumption in cites through a range of mechanisms as shown in Table 9.3 (see also *Factor Five*). A number of cities have achieved significant per capita freshwater use reductions through implementing a suite of progressive water conservation programmes as part of a broad demand management programme. These cities include Jerusalem, Israel; Mexico City, Mexico; Los Angeles, California; Seattle, Washington State; Beijing, China; Singapore; Boston, Massachusetts; Waterloo, Canada; Bogor, Indonesia; and Melbourne, Sydney, and Brisbane, Australia. Sydney has been able to reduce its 2010 per capita water usage levels to 1970 levels largely through its water efficiency and demand management programmes. This is also true of Seattle, which started implementing demand management programmes in the 1990s, and by 2007 had reduced per capita water usage by 35 per cent. There is also significant potential to reduce the need for freshwater and

Table 9.2 *Best practice case studies demonstrating the potential for decoupling*

Sectors	*Best of sector case studies*
Steel manufacture	In the steel sector, water is used primarily for cooling and environmental treatment in the steelmaking process. There are two main methods for making steel: oxygen blast furnace (OBF) and electric arc furnace (EAF). Compared to OBF methods, EAF methods use 85% less water, and 70% less energy per tonne of steel.[58] BlueScope Steel's Port Kembla Steelworks in Australia has shown that a fivefold improvement in water efficiency can also be achieved in OBF steel making, reducing water use from 55 to 9 million litres per day.[59]
Aluminium manufacture	In the aluminium sector, water is largely used for cooling and environmental treatment in the aluminium smelting process. Alcoa, in their European Mill Products business, which includes casthouse and rolling mills, has achieved a 95% reduction in water consumption through installing a closed-loop system that recirculates process water, and has committed to 70% reductions in potable water use throughout all global operations.
Paper manufacture	Visy, through its Australian paper and pulp mill in Tumut, New South Wales has achieved an 80% reduction in the average water consumed by pulp and paper mills compared to elsewhere in the world. In accordance with its site-based ISO14001 certified environmental management system, no water is discharged off the site, and treated wastewater is used for the irrigation of pastures.[60]
Information and communication technology manufacture	With manufacturing plants all over the world, and many in very dry places, Intel has invested US$100 million on water efficiency measures, saving more than enough water to supply 180,000 homes for a year. Intel's 1000 acre (405 hectare) operation in Arizona includes processing equipment that uses 75% less water than the industry average (from 25 to 8 million litres per day). Additionally, Intel constructed a system that treats wastewater and then injects it into the local aquifer, treating and injecting more than 3.5 billion gallons (13.2 billion litres) of drinking-quality water into the aquifer since its inception in 2000.[61]
Chemical manufacture	Since 2002, Qenos, a leading chemicals and plastics company, has reduced its annual freshwater consumption by over 30%, saving 1.2 billion litres of water per year.[62]
Food processing	Oberti Olives olive processing plant in Madera, California processes in the order of 128 tonnes of olives per day, involving washing, curing, storing and packaging. Through installing a best practice membrane filtration system to enable water reuse, the company has reduced its freshwater use by 91%, equating to more than 3.5 million litres per day.[63]
Beverage industry	Breweries, on average, use about 6–8 litres of water per litre of product. Fosters Brewery at Yalata, Queensland has achieved a 75% improvement in water efficiency since 1993,[64] using only around 2 litres of water per litre of product.[65] Pacific Coca-Cola has also reduced its can line's need for rinse-water by 79%, using air instead of water to clean the insides of cans.[66]
Tourism and hospitality	The Hyatt Regency Sanctuary Cove resort, Queensland, Australia has reduced water use by more than 65%, from 140 million litres in 1996 to 54 million litres in 2000, saving AU$85,372 per year.[67]
Medical and health	Saint Petersburg hospital in Florida, US has saved 50% of its water,[68] while St Andrew's War Memorial Hospital in Brisbane, Australia has reduced its water use by 68%, from 105 to 33 million litres per year, in just four years.[69]
University campuses	The Queensland University of Technology in Brisbane, Australia reduced water consumption by 50% between 2004 and 2007, equating to 200 million litres per year, and has since reduced its consumption by a further 5–10% across its campuses.[70] The University of Queensland, Brisbane, Australia has reduced water usage by 48% since 2003.[71] The University of California's Santa Barbara campus reduced water usage by nearly 50% between 1987 and 1994, saving US$3.7 million, excluding energy and maintenance savings.[72]

Source: Compiled by The Natural Edge Project, based on Smith et al (2010),[73] with references added.

groundwater extraction through rainwater and stormwater harvesting, especially those cities situated on or near the coast. Currently, in most coastal cities, significant amounts of water is either used once, or falls on roads and roofs as rain, and then flows directly out to sea. However, as an example of what is possible, in two very different parts of the world, Singapore (population 3.5 million)[74] and Orange County[75] in southern California (2.3 million) have both made commitments to maximize the use of available fresh water through aggressive water-recycling schemes. Singapore and Orange County have also developed schemes that will use a dual membrane process to recycle domestic wastewater (sewage) to levels that approach the quality of distilled water. The basic cost to treat and recycle water using the dual membrane process is about 55 cents a kilolitre on top of the cost of treatment to secondary effluent standards. To compare, seawater desalination techniques cost about US$1.40 a kilolitre. While Singapore built four plants that recycle 20 per cent of water that is currently discharged into the ocean, Orange County commissioned one large recycling plant to treat the municipal wastewater before its use in recharging natural groundwater supplies. The recycled water mixes with existing groundwater supplies for six months to a year before it is pumped to the surface, treated and delivered through the water distribution system. Another area of significant opportunity for cities is from addressing water leakages. Most urban areas throughout the world are losing 30–50 per cent of their water supply through leakage. For instance, Mexico City found that its water system was losing 1.9 billion m^3 of water every year due to leakage. Jerusalem reduced its annual consumption of water by 14 per cent from 1989 to 1991 just by instituting a leak detection and repair system.[76]

Addressing leaks in buildings, residential and commercial, is important because the building sector is the third highest user of fresh water globally after agriculture and industry. Leakage of water in commercial buildings can be as much as 30 per cent of the overall building's consumption,[77] with roughly a third of this water wasted in leaking pipes, another third used in amenities (toilets, showers, etc.) and the final third in cooling towers. In the last 10–20 years a wide range of enabling technologies have been invented which, used together, can enable residential and commercial buildings to reduce their water use significantly. For example, technologies now exist to enable 80 per cent or better efficiency improvements in amenities and cooling towers. Through utilizing such technologies Melbourne University's new Faculty of Economics and Commerce building has achieved 90 per cent reductions in mains-supplied freshwater usage. The building achieves this through utilizing all the water-efficient amenities, reducing cooling demand by utilizing natural ventilation, using chilled beam cooling technology, and by the installation of highly efficient dry hybrid water coolers,[78] combined with rainwater harvesting and greywater reuse. Enabling technologies now also exist to help different commercial buildings – commercial laundromats, restaurants, hospitals – to achieve large cost-effective freshwater savings.

Residential buildings can also reduce their freshwater usage significantly through the use of efficient showerheads and water-efficient appliances, toilets and taps. Combining these can improve the water efficiency for an average home by over 60 per cent.[79] Rainwater tanks and greywater recycling systems can further significantly reduce demand for potable water, as can designing gardens to be drought tolerant.[80] For example, the Currumbin Ecovillage, in Australia, has shown that through using these strategies it is also possible to achieve self-sufficiency in water supply for a residential estate.[81] As Table 9.3 shows, many of these water-efficient technologies also achieve significant

Table 9.3 *Enabling technologies in water efficiency and potential for decoupling*

Sector	*Enabling technologies*
Buildings	• Various low-flow showerhead designs exist to reduce water consumption by 50–75%,[82] resulting in sizable reductions in water consumption along with the requirement for water heating. • Low-flow aerators reduce tap water flow by 30–50% and can also reduce the energy costs of heating water by up to 50%. • Water-efficient appliances such as front-loading domestic washing machines are 40–75% more efficient than top loading options. • Toilets using 6/3 litre dual flush systems are capable of reducing water usage by 67% compared with conventional models.[83]
Commercial buildings	• Waterless urinals use liquid-repellent coatings and a lighter-than-urine biodegradable liquid to trap odours, and can save between 150,000 and 230,000 litres per year.[84] • Ultra-efficient water urinals can flush with as little as a half a litre. • Hybrid dry air/water cooling systems for large buildings have been optimized to reduce typical consumption of water by as much as 75%.[85]
Commercial laundromats	• Highly efficient washers can reduce water consumption by 35–50% and achieve energy savings of up to 50%, with highly efficient washers requiring 50% less detergent.
Restaurants	• Boiler-less compartment food steamers have been developed that use 90% less water. • Water-efficient commercial dishwashers can save 25% of water usage. Payback periods for installing small efficient commercial dishwashers range between one and four years. • Pre-rinse spray valves account for 14% of water consumption in commercial kitchens. Replacing a traditional pre-rinse spray valve can save 25–80% of this water.
Medical and health	• Steam sterilizers are utilized widely in hospitals, pharmaceutical manufacturing, and research institutions to disinfect surgical instruments in hospitals, research and development laboratories and in the manufacture of products where sterilization is essential. Among many strategies, most sterilizers can be retrofitted with heat exchangers to cool condensate without the need to dilute the hot condensate water with tap water thus enabling the water to be reused. • Traditional X-Ray film processing generally uses a constant flow of potable water to cool the machine and develop the film, and 98% saving of water use can be achieved by recycling this water for use in the equipment.

Source: NDRC (2009)[86] unless otherwise noted energy savings as well. For further detail on how these enabling technologies can be used to improve the water efficiency of commercial buildings see the online textbook , *Water Transformed: Sustainable Water Solutions for Climate Change Adaptation*.[87]

There is significant potential to decouple economic growth from fresh water extraction by outlining how to reduce freshwater usage in the major areas of agriculture, industry and buildings (residential and commercial) (for a further detailed explanation on how to achieve decoupling economic growth from freshwater extraction, see the online textbook *Water Transformed: Sustainable Water Solutions for Climate Change Adaptation*).[88]

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