The Myth of Hydroelectricity as "Green" Energy

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Proponents of hydroelectric development invariably emphasise that hydroelectricity is a clean source of energy, mainly because there are no polluting "greenhouse gases" emitted, and that therefore hydropower is harmless to the environment. Other advantages put forth are, that hydroelectric facilities are relatively cheap to build, the technology is standard, the source of the fuel costs nothing and is renewable, the facilities can be run by remote control, so that after construction costs labour is cheap, and the facilities run smoothly for many years with relatively little maintenance costs. Also, since many hydroelectric facilities are in remote areas away from communities, and therefore "out of sight, out of mind", most people believe that hydropower is "green". For example, political leaders in Manitoba and Québec presently are pushing to sell their hydroelectricity (Manitoba Hydro and Hydro-Québec) as "green energy" in the United States. Bernard Landry, prime minister of Québec, has been quoted as saying "build hydropower as much as you can", supporting 36 new dam sites, including ones on salmon rivers (World Rivers Review, February 2002, p.4).

In fact, hydroelectric development world wide has done more environmental damage and caused more human misery than any other method of power generation. Hydroelectric development may be compatible with the environment at some locations, such as "run of the river" type at the site of an impassable falls, for example at Niagra Falls, and mini-turbines using part of a river for local consumption may be relatively harmless. Also hydroelectricity has the advantage that it can be brought on stream to supplement demand faster than thermal plants. The reservoir in some cases is useful for flood control, or for irrigation purposes. Nevertheless I present a discussion as to why hydroelectric projects, including "small hydroelectric" projects, are in general damaging, and why there must be public awareness of the consequences.

Each hydroelectric facility is unique, in that effects vary with different ecosystems. However, generally a dam and reservoir are created, both of which disrupt river processes. The dam -a discontinuity - creates a break in line, an obstacle not only to water, but also to plants and animals that evolved to benefit from the river's original continuity. Much more than the inundated reach of a river is lost - upstream, downstream, and laterally. My experiences have been mainly in Newfoundland and Ireland, so I emphasise the problems caused in those two countries, both of which have important stocks of diadromous (using both sea and freshwater) fishes, although parallel effects occur in other countries, some of which I will refer to. A dam is a direct barrier to fish attempting to migrate upriver, e.g. salmon, sea-trout, eels, sturgeon, some species of whitefish, shad, striped bass, river flounder etc. All countries have their own migratory fish species, e.g. the Mekong giant catfish of the Mun river in Thailand, galaxiids in the southern hemisphere, or invertebrates, e.g. some species of commercially valuable crayfish in Chile migrate from the estuary to headwaters of some rivers. The reservoir, depending on its size, also disrupts downstream migrants. Depending on the fish community, lake dwelling fish replace river dwelling fish, and some previously migrating fish become resident. For example trout, which live in rivers and may migrate to sea, but thrive in lakes, become dominant over young salmon, whose preferred habitat is shallow fast water, and piscivorous fish, for example in Ireland, pike, thrive and prey on a proportion of the smolt (young salmon migrating to sea) in spring and early summer. A way has not yet been found to divert all smolt from turbine intakes, and less than 60% survive passing through the turbines (e.g. Williams et al. 2001), and others are killed or damaged by changes in water and gas pressures, which may attract fish eating birds below the dam (Rosell 2001). If the facility is a "run of the river" type, as most are in Ireland, the impoundment may provide fishing and other recreational facilities. Many hydroelectric facilities in Newfoundland are created by inundating originally natural lakes and surrounding terrain in a river system. However, the climate in Newfoundland is such that there is considerable drawdown over winter, as much of the precipitation is locked up in ice and snow, with storage of flood water in early spring with snow melt, causing fluctuations greater than would occur in a natural lake, which reduce productivity, so that such reservoirs are relatively barren. The reduction in productivity is caused primarily by loss of the littoral region, the shallow land-water perimeter in the euphotic zone, in which light penetrates enough to provide plant growth, going from shallow areas with macrophytes, down to moss and algae covered substratum. This littoral depth varies with clarity of the particular lake, but greatest productivity, highest invertebrate biodiversity, and refugia for small fish are usually within the first two metres or so. Lake fluctuations destroy this productive area, so that trout for example decrease drastically in such reservoirs. With water fluctuations there is slumping of the new shoreline, which becomes a mess, and the fluctuations eliminate nesting water birds, such as loon, and some mammals, such as beaver. The outlets of natural lakes are very productive, since the output of "seston" (plankton etc.), provides food for filter feeding insects, which are eaten by trout and young salmon. However, below hydroelectric dams the biotic diversity of the zoobenthos, mainly insect larvae, is depressed, and density and biomass are reduced, so that fish production is also reduced due to less food (e.g. Moog 1993; Odinetz-Collart et al. 2001; Ward and Stanford 1979). Also in acid waters, as are most in Newfoundland, methyl mercury, a neurotoxin, is leached from the newly inundated land, and passes up the food chain, making fish at the top of the food chain unsafe to eat, and causing mortalities in some fish eating birds. Mercury levels peak after 3-5 years, and remain high for at least 60 years after flooding (Anderson et al., 1995). Rotting peatlands emit methane, a greenhouse gas. With inundation, organic matter is leached from the soils and from rotting vegetation, enhancing planktonic production, a stage called "trophic upsurge". This may last for four to five years, after which production declines, and after about eight years the impoundment eventually becomes less productive than the original lake (Stockner et al. 2000). During the trophic upsurge planktivorous fish, such as some forms of arctic char, planktivorous whitefish, etc., may increase, if recruitment is satisfactory, and spring or summer spawning fish, such as pike, perch, suckers and cyprinids, may not be affected by winter drawdowns. However, many commercially valuable fish, such as arctic char, lake trout, whitefish, and some races of brook trout and ouananiche or landlocked salmon, spawn in the littoral regions, and since they spawn in late autumn or early winter, the developing eggs are killed as the reservoir level drops. Some populations of these species may spawn in inlet rivers, or in deep areas, but in general these species are eliminated from fluctuating reservoirs. It is cheaper to have one power house than several, so frequently adjacent river basins are combined into the one system. This mixes fish communities, which may or may not be changed, depending on whether the introduced species compete or prey on stages of the original species. Hydroelectric developments change the natural hydrological and nutrient fluxes in estuaries, with negative effects on the plant and animal communities adapted to them (e.g. Tolmazin 1985), such as salmon smolt and sea trout, which feed in estuaries before moving off shore, or bird life which use adjacent marshy areas. Further problems can be: increased access due to additional roads, which may not be desirable for wildlife or where areas are already heavily fished; and additional siltation may occur from new roads and construction activities.

A river is a living system, with gradual changes moving downstream, in sources of production, invertebrate taxa, fish population structure and communities, "spiralling" of nutrients, type of substratum and riparian vegetation etc., described as the "river continuum" by Vannote et al. (1980), and explained beautifully by Waters (2000).These natural river processes to which the instream and riparian fauna have evolved are disrupted by dams. Dams result in changes in temperature and water chemistry, conversion of riverine to lacustrine environments, and alterations in the frequency and duration of daily and seasonal downstream flow regimes. Terrestrial animal migrations along or across the river may be blocked. Salmon spawn in shallow fast water, usually at the downstream end of pools, depositing their eggs in nests, or "redds", in a substratum of coarse gravel, pebble and rubble, and juvenile salmon primarily rear in shallow fast water habitats. Therefore the potential effects on salmon habitat downstream include dewatering of spawning beds and rearing habitats, both low-flow and high-flow interference with spawning, changes in daily and seasonal water temperature regimes, detrimental alteration of downstream channel morphology and decreased productivity or diversity of invertebrates. Upstream of the dam inundation destroys spawning habitat and rearing habitat of young salmon. In natural rivers there is a constant movement of the substrate downstream. When this is disrupted the bed gets eroded, but not replaced, becoming "armoured". Since the type of substrate is the most important influence on bottom invertebrates and fish such as salmonids, the productivity of the river is reduced, and may not recover for several miles downstream, depending on tributary streams. In some cases of low gradient, where the dam prevents flushing, fine sediments are deposited instead, and terrestrial vegetation blocks the channel (Collier et al. 1996). Modern hydroelectric stations use computers to control water passage through the turbines to closely match power generation to demand. This results in the fish facing highly unpredictable discharges, and many can be stranded, flushed and/or killed over large distances downstream of the tailrace release. The release of relatively warm water from below the hypolimnion through the turbines in winter can speed up development of developing salmonid eggs, so that they emerge at an inappropriate time for finding suitable food. Low water levels in winter are a major cause of mortality of developing eggs, so that if water levels are reduced at critical times high mortalities will result. Cooler hypolimnetic release during the summer slows growth, leading to higher mortalities (Saltveit 1990). The assimilative capacity of a river for organic wastes is reduced by the formation of headponds, and anaerobic conditions may develop. Another frequent problem is supersaturation of the water below a dam by nitrogen gas, and consequent mortalities of fish by "gas-bubble disease" (Dominy 1973).

Invariably the mitigation suggested is a fishway and a hatchery. Not all returning salmon will use a fishway. For example on the Mersey River in Nova Scotia three consecutively built dams, with fishways, gradually eliminated the salmon. Hatcheries have repeatedly failed in conserving or restoring wild stocks. Hatcheries intuitively would seem to be the answer to declining fish stocks, and can be useful for initiating lost runs, and are useful for "put and take" fisheries and in aquaculture. However, natural stocks have evolved over thousands of years for their own unique ecosystem, and salmon migrate to their own stream in the system, so that in large river systems there are frequently unique genotypes for each tributary stream, which have migratory strategies, feeding strategies, growth rates, etc., selected for their own system (Verspoor 1997). A race may be unique, so considered as an "Evolutionary Significant Unit", and treated as a separate species. Introduction of hatchery fish invariably leads to decrease in the wild stocks, since they hybridise and reduce fitness of the wild fish. For example there are several studies showing that the hybrids are not as successful as coping with the environment as the indigenous stock (Reisenbichler 1997). In other instances the hybrids grew better than the natural stock juveniles, survived better (as juveniles, but not as adults) and displaced the wild fish, reducing population fitness and productivity (McGinnity et al. 1997). It is impossible to select for the behavioural and ecological diversity of the wild genotypes in hatcheries, where fish suitable for hatchery life are selected. The sad history of decimation of Atlantic salmon stocks in Europe and N. America, mainly by dams, has been recorded by Netboy (1974), and the loss of many Pacific salmon stocks by Lichatowich (1999), the latter an excellent book on the destruction caused by dams and hatcheries. For many years scientists have conducted studies which show that hatchery fish invariably lead to the decline, and sometimes extinction, of wild stocks, yet politicians and some administrators still use this smoke screen as a panacea for compensating for loss of fish habitat. As an example, hatchery advocates in the Columbia basin note that artificially propagated salmon make up 80% or more of salmon on the Columbia, but they fail to mention that the total run has crashed to less than 5% of its historical abundance. Wild steelhead trout are in great trouble all along the Pacific coast, and are now blocked by dams and can no longer ascend many of their previous natal streams. Smolts migrating downstream more often than not are ground to bits in the dam's turbines or diverted to agricultural crop fields to dessicate and die. In the U.S. nuclear power, popularly considered environmentally bad, provides 20% of energy production, compared to 2.8% by hydropower, which latter has wiped out numerous previously magnificent salmon runs. The American Fisheries Society has published a partial list of 106 major stocks of Pacific salmon and steelhead that are known to be extinct. An interesting recent finding is that Pacific salmon are a keystone species, not only beneficial but actually essential to the well-being of many other forms of plant and animal life in the forests of the Pacific rim (Cederholm 2001), since they provide food directly, and nutrients from marine sources by their rotting carcasses, in an ecosystem which otherwise would be nutrient poor.

In Ireland stocks of salmon and sea trout have decreased alarmingly over the last few decades. This is not entirely due to dams, and more recently damage has been caused by dredging, and by pollution and enrichment of water courses from runoff of sediments, fertilisers, insecticides, herbicides and fungicides from agricultural activities, which interfere with habitat and the food chain (EPA 2000; Reynolds 1998). Unfortunately there is not specifically fish habitat protection as is enforced under the Fisheries Act in Canada, so that many rearing streams are dredged to drain wetlands. Also riparian buffer strips of natural vegetation, which would do much to control harmful runoff, are not preserved, as they are in Canada. Nevertheless dams have in addition had significant negative effects on salmon stocks, despite mitigation with fishways and hatcheries. Hydroelectric generating stations presently produce 6% of the State's electric requirements. The Shannon, Erne, Lee and Liffey, which were among the principal salmon producing rivers at the turn of the century, were dammed for the generation of hydroelectric power between 1924 and 1957.There have been other dams in recent years, such as the headwaters of the Feale and the Crana in Donegal, with the consequent loss of habitat. The flagship of the hydropower development programme was the large dam built between 1925 and

1929 at Ardnacrusha, at the tidal head of the Shannon. Migration problems, loss of habitat and predation by pike on smolt reduced the salmon runs. The River Shannon was renowned as a producer of large multi-sea-winter salmon to commercial and recreational fisheries, but this component of the stock has been lost (O'Farrel et al. 1996). The remaining salmon fishery went into decline following the construction of the dam at Parteen, which posed a considerable obstacle to the fish reaching their spawning grounds (Twomey 1963). The impact of the Lee hydroelectric scheme was immediate, the salmon stock collapsing within five years of construction, and related to impaired water quality discharging to the lower river from newly impounded reservoirs. Twomey (1991) attributed the collapse to de-oxygenation of tailrace water due to large quantities of decomposing vegetation in the reservoirs during filling in the latter half of 1957. Predation on descending smolt initially by pike and subsequently by brown trout was associated with the failure of descending smolt to pass downstream and their consequent accumulation in reservoirs. Before hydroelectric development salmon were abundant in the Erne system, with over 100 tons being taken by nets in a fishing season. Stocks gradually declined after the construction of two generating stations. Recent counts indicate that the annual run of salmon fell from a peak of 10,000 in 1966 to an all time low of under 300 in 1978. This decline has been variously attributed to the combined effects of the salmon disease, ulcerative dermal necrosis, high rates of marine exploitation, pollution and drainage of nursery tributaries and the impact of the hydroelectric development at Ballyshannon. Salmon hatcheries were constructed on these rivers as a mitigation measure, but have been unsuccessful.

In Newfoundland loss of salmonid habitat due to hydroelectric development has not been quantified, but is considerable. Over 55% of the island's watersheds have been diverted for hydroelectric development. About 60% of the island's electricity use is presently from hydroelectric generation, from 35 stations. Fourteen of these are on the Avalon Peninsula, destroying their salmon runs. Salmon River on the south coast and most of the watersheds in the Wilderness Area have been diverted into the hydroelectric station at St. Albans. Salmon runs have been eliminated from Rattling Brook, and a large proportion of the Humber River watershed on the west coast is devoted to hydro-electric generation, through Grand Lake, Birchy Lake, Sandy Lake and their tributaries. Also the most productive areas of Indian River (the upper 25% of the watershed) have been diverted to supplement the discharge. Unfortunately no fishways were incorporated in any of these. Until recently all proposals for hydro-electric development in the province were granted. The first one rejected was for Northwest River on the east coast, running through Terra Nova National Park (mitigation proposed was a fishway and a hatchery). A well organised public campaign, with four years of intense public pressure, led by the Salmonid Association of Eastern Newfoundland (SAEN), resulted in cancellation of the project. A number of other projects at the same time were cancelled, mainly because SAEN had led an informative campaign about the effects of hydroelectric developments. The Premier at the time, the Hon. Brian Tobin, made a commitment that all hydroelectric projects on the island would be put on hold. This example illustrates very well that public awareness and participation are essential for conserving our environment. Under the Canadian federal Fisheries Act, it is stated plainly that there must be no net loss of fisheries habitat. However, political and economic pressures surround the conservation of any natural resource, and where there is sufficient political pressure from developers the authorities will cheat. It is therefore essential that we demonstrate that conserving our natural environment has economic benefits, and by public participation show that we know and care. A recent unfortunate example of the failure of the Act was the destruction of Star Lake in central Newfoundland in 1998. The public backlash from this mistake may have been a factor in the present lull in hydroelectric projects. Star Lake was a large (15.7 km^2) lake isolated from further colonisation of fish from Red Indian Lake by impassable falls on the outlet river. Only two fish species were present, brook trout and arctic char. The arctic char were small, but one of the strains of brook trout grew large, probably the largest on the island, and provided a trophy trout fishery. The system was unusual, and possibly unique, in that the large trout matured late, lived a relatively long time, and fed on the dwarf arctic char and small trout. The lake was valuable, scientifically, aesthetically, and for angling. However, an international company, Abitibi-Consolidated Inc., proposed a 15 MW hydroelectric project, by damming the outlet river, and turning the lake into a fluctuating reservoir, with water levels fluctuating 8 metres over the winter, and diverting an adjacent lake into the system. This was a classic example of where the system would be profoundly degraded, and considerable pressure was put on authorities to cancel the project, by internationally renowned limnologists, one of whom had conducted research in Star Lake, by conservation groups, and by individuals (Gibson et al., 1999). Nevertheless, the authorities accepted an inadequate and misleading Environmental Impact Study (EIS), and the project proceeded, with "mitigation" by annual stocking of hatchery trout. No spawning areas were identified, but no inlet tributaries were suitable, so the trout probably were littoral and lake outlet spawners, and the arctic char littoral spawners (both species spawn in the fall), so that the winter drawdown after spawning and the loss of the river would preclude recruitment. The dam was constructed during the spawning period and thousands of large trout were stranded below the dam, indicating that the outlet river had been a major spawning site. The trophy trout fishery has already collapsed. "By mistake" an additional 600 hectares were flooded. In fact the whole story was one of deceit and dishonesty, showing in this case the priority of political pressures over environmental concerns. Ironically, despite creating this environmental disaster, Abitibi were able to sell green energy points from this project to Ontario Hydro.

An EIS is conducted and financed by the proponent, which appears fair, but may not be the best solution, since frequently the science is poor, and biased in favour of the project proceeding, often claiming, falsely, that in fact the resource would be improved (Gibson et al. 1999; Campbell and Parnrong 2000). In response to the frequent inadequacies of such studies it has been suggested several times that the EIS be conducted "at arm's length" and that there be an independent committee to oversee the planning and interpretation of the EIS (e.g. Colbo and Ryan 1999). The Canadian Government has never responded to these suggestions, possibly because, as with the Star Lake example, authorities may want to have the excuse to proceed with the political decision. It is therefore essential that the public be well informed and make their views known, especially where the people are still able to cherish and enjoy their outdoor natural amenities, such as in Ireland and Newfoundland. The Northwest River example shows that despite big business pressures, sufficient public interest can save a resource. Boon et al. (In Press) emphasise that it is more cost-effective to manage rivers with care now rather than try to restore them later, and that the broader vision of the values of rivers to society and the 'ecosystem services' that they provide must be matched by a wide geographical perspective.

The Government of Newfoundland and Labrador recently (March 25th, 2002) released an Electricity Policy Review document, and is asking for public consultation. The present moratorium on small scale hydroelectric is to be reviewed, "with a focus on the policy approach towards small-scale hydroelectric projects". It is claimed that, "In many jurisdictions in Canada, the US and Europe, small-scale hydro is generally considered environmentally acceptable and to be beneficial overall." The present moratorium resulted from, "vocal opposition from a number of special-interest groups". It is likely these "special-interest groups" will again voice their opposition to proposed destruction of their rivers, reinforced by the recent collapse of the Star Lake system, predicted by credible scientists, but contrary to predictions of the proponents!

More than 400,000 square kilometres - the area of California - have been inundated by reservoirs worldwide. The 0.3 % of the global land surface which has been submerged represents a much greater loss than the raw statistic implies - the floodplain soils which reservoirs inundate provide the world's most fertile farmlands; their marshes and forests the most diverse wildlife habitats. Nearly four-fifths of the total discharge of the largest rivers in the US, Canada, Europe and the former USSR is 'strongly or moderately affected' by flow regulation, diversions and the fragmentation of river channels by dams. Dams are the main reason why fully one-fifth of the world's freshwater fish are now either endangered or extinct. Over 60 million people have been flooded off their traditional lands, usually poorer people who are inadequately compensated, and who lose their major protein source and traditional way of life. In tropical regions dam related diseases are created (e.g. schistosomiasis, malaria). Dams can be lethal too, because they may break. In Newfoundland there is only one example, a dam on Flat Bay Brook a few years ago, in which one person drowned. However, more than 13,500 people have been swept to their deaths by the roughly 200 dams outside China which have collapsed or been overtopped during the twentieth century. A calamitous series of dam bursts in the Chinese province of Henan in August 1975 left perhaps 230,000 dead. Hundreds have also died because they resisted eviction to make way for dams. In Guatemala in 1982, 378 Mayan Indians, mainly women and children, were tortured, shot, stabbed, garrotted and bludgeoned to death in punishment for their community demanding they be properly compensated for the loss of their homes to the Chixoy Dam. In Columbia a number of natives have been killed for opposing the construction of Urrá Dam, and last year Kimy Pernia Domicó, a leader of the Embera-Katío indigenous people from Colombia was kidnapped for the same reason. In Brazil last year Ademir Alfeu Federicci was murdered for leading the fight to stop Belo Monte Dam on the Xingu River in the Brazilian Amazon. Harassment of dam opponents is common in developing countries, and the projects have often been unprofitable and dogged by corruption. Many of these projects are promoted and constructed by agencies or companies from developed countries who would no longer be allowed to construct similar projects in their home countries, sometimes with the home government's support. For example, Fortis Inc., a billion-dollar Canadian corporation, partnering with the Belize government, and based in St. John's, Newfoundland, plans to build a dam (Chalillo project) in Belize, which would flood out one of the last undisturbed wildlife habitats in Central America, and threaten endangered species. Scientists from the Natural History Museum in London hired as part of the project's EIA team "highly recommend" in their final report that the scheme be dropped. Their report says that the dam would irreparably harm one of the most biologically diverse regions left in Central America. In addition, the dam could exacerbate water quality problems for downstream communities. However, a Canadian federal Agency, the Canadian International Development Agency (CIDA), whose mandate is to help poor countries (and Canadian corporations), gave US$314,000 to a Canadian engineering company, Toronto-based AMEC, (who incidentally also are generous contributors to the incumbent Canadian Liberal party) to conduct the dam's environmental assessment. Their report dismissed the recommendations of the British research team. Their dam-supportive EIA paid off, as they were recently awarded the contract to design and build the dam.

The earlier ambitions of wealth through boundless energy and improved irrigation projects, by building dams, have been dashed by the resulting ecological disasters and the displacement of millions of people (McCully 1996). For example the High Aswan Dam in Egypt was expected to pay for itself in two years and double national income in ten, industrialise the state in the same decade, and turn a vast, empty desert green. However, so far it has cost at least double the original outlay in damage to the country's soil, riverbed, coastline, and people. Today more than 98% of the Nile's sediment drops to the bottom of the reservoir, which has had a serious effect on Egyptian agriculture, partly through lack of depositions in the delta. Fisheries in the estuary relying on nutrients from the annual flood have collapsed, and river borne diseases mediated through snails and mosquitoes have increased. Productivity and fisheries have declined in the Black Sea due to changes in hydrography caused by hydroelectric projects on the Northwestern coast (Tolmazin 1985). The Three Gorges Dam in China, which will drown a 400 mile long stretch of the Yangtze River, will displace 1.9 million people. In India the Sardar Sarovar Dam is being built on the Narmada River, and around one million people will be directly affected. Over 200,000 people will lose land to the reservoir. Many more will be affected by other aspects of the project, including its canals, the town built for the construction workers, and the reduced flow of water downstream. Opponents of Sardar Sarovar say that the project will cost far more and produce far fewer benefits than claimed by dam supporters, and that more equitable, less destructive and cheaper alternatives exist. Similarly in Thailand, as a direct result of the 136 MW Pak Mun Dam, more than 20,000 people have been affected by drastic reductions in a once rich and productive fishery. The dam has blocked the migration of fish, and a $1 million fish ladder has proved useless. The villagers are now experiencing intestinal and liver flukes and the disease schistosomiasis. The International Rivers Network (1847 Berkeley Way, Berkeley, CA 94703, USA) documents many such projects, planned or under construction. The World Commission on Dams has concluded that, "it is not possible to mitigate many of the impacts of reservoir creation on terrestrial ecosystems and biodiversity, and efforts to 'rescue' wildlife have met with little sustainable success".

Alternate electricity generating methods are required. Natural gas is a cheap, safe and relatively environmentally benign transition fuel. Solar and windpower are becoming economically feasible. According to a report by the European Photovoltaic Industry and Greenpeace in Berlin last October solar power could provide 26% of global energy needs by 2040. Wood biomass, energy from municipal waste and geothermal energy are sources in some locations. In Portland, Oregon, methane collected from decomposing sewage waste provides hydrogen to power a commercial fuel cell, although fuel cell technology is still under development. In Ireland energy projections to 2010 include more than doubling of natural gas input to electricity generation, which follows an international trend, due largely to the current wide availability of cheap natural gas coupled with its lower emissions level relative to other fossil fuels. According to the Washington, DC research group Earth Policy, world wind electric-generating capacity grew from 17,800 megawatts in 2000 to an estimated 23,300 megawatts in 2001 - a one year gain of 31%. The prospects for the wind energy sector in Ireland in the medium term indicate that it can exceed the output level obtained by hydropower stations by 2005 (EPA 2000). Wind power can now compete with the price of fossil fuel based electricity in many countries and the proportion of wind power is increasing in Europe. About 18% of Denmark's electricity consumption is now met by wind power, targeted to be 29% by 2010. A wind farm in the coastal North Sea is to be built. It is rated at 1,200 megawatts and is scheduled to be completed by 2005.

In general hydro cannot be considered a clean source of energy. Hydro can seriously contaminate river water and it emits green-house gases due to the rotting of submerged vegetation and soils, which equal or even exceed the reductions claimed by not having to burn fossil fuel to generate the same amount of energy. The fragmentation and eradication of riverine ecosystems is also a form of pollution. If the collateral environmental damage, loss of valuable archaeological sites and cultural and social costs are included it is anything but cheap and the benefits (electricity, flood control, irrigation) are generally lost to the system overall. There are movements to restore dammed rivers. The Edwards Dam on Maine's Kennebec River was removed recently. There are plans to remove a dam on Marsh river, in Maine. Three dams have been breached on the Columbia river, and in Oregon there are plans to remove two dams on the Sandy river, a tributary of the Columbia, and there are plans to rip out two dams on Washington state's Elwha River. A dam was recently removed on the East River, at Sheet Harbour, in Nova Scotia. In British Columbia several dams are slated for removal, including the Kitsault Dam in the Skeena region. The Thai government has opened the gates of the Pak Mun Dam on a trial basis for a year, and an estimated 130 fish species of fish, previously eliminated by the dam, have returned, allowing a fishery and other beneficial results. In France 70% of electricity is generated by nuclear power plants, yet two dams have been demolished on the Loire, and other removals are planned. Salmon have disappeared from most of the large rivers of France because of dams (Thibault 1994). Both in Ireland and in Newfoundland there are good reasons to remove many hydroelectric dams, and replace them with other sources of energy generation. No more should be built. Now that we know the detrimental effects of hydroelectric dams, which technology will not repair, we realise they were of a different age, and their time has gone.

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