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Les barrages : vers de nouveaux enjeux pour la montagne

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From hydroelectric power to artificial snow

Alain Marnezy

EDITOR'S NOTE

Translation: Brian Keogh

- 1 Although the primary aim of mountain dams is still to provide peak-period electrical energy, since their creation there has been a gradual diversification in the uses to which water resources are put: tourism development of mountain lakes, fishing, white-water sports, development of industrial heritage tourism, etc. In recent years, the making of artificial snow in winter sports areas has added yet another use for water resources. Resort managers are not short of arguments, climatic as well as commercial, to develop this type of facility; for the majority of professionals and elected officials in municipalities with winter resorts, this appears as indispensable for ensuring skiing in mountain areas.
- 2 This new need concerns the ski season, which is the low-water period for surface water and springs. As with the production of peak-period energy, the problem is one of storing and building up reserves of water during periods when there is a surplus, periods of heavy snow melt, for use during the winter. Small headwater reservoirs are designed for this purpose and their number has recently grown. But they have a number of critics because of their numerous alleged impacts and the lack of regulations concerning their construction and management. When hydropower developments and ski resorts are found in the same geographical area, resort managers turn towards these developments to meet their water requirements. This change in the use of water resources thus appears as a technical solution with less impact, destined to help sustain the model of alpine tourism focussed on skiing. It may be seen as a new form of support for local communities, with on-site reinvestment of the area's hydraulic heritage in skiing and local activities resulting from economic knock-on effects.

Functions of Alpine dams: increasing diversification

- 3 Although the principal role of major mountain hydro-power projects has always been to produce peak-period energy, over the decades there has nevertheless been a certain number of other functions added to this initial role.

Continuing search for peak-period energy

- 4 The construction of large mountain dams in the Alps dates back to the inter-war period. The Bissorte dam in the Maurienne valley (1935) and the Girotte dam (1945) in the Beaufortain region marked the beginning of a generation of large mountain dams that provided sufficient high-altitude water resources to alleviate the problems of the low-water winter period, while at the same time strengthening the regional electricity distribution networks (Messiez, 1993). In the post Second World War period, dams were built at Aussois (Plan d'Aval, 1950; Plan d'Amont, 1956), Roselend (1956), Mont Cenis (1968) and Grand'Maison (1985).
- 5 These dams had a number of common technical characteristics: during periods of snow and ice melt, in the spring and summer, the dams enable storage of large volumes of water at altitude, which can then be used to drive turbines during the low-water winter period (Fig. 1). To fill them and to ensure an optimal collection of water, it was necessary to divert as many mountain tributaries as possible, sometimes even in distant catchment basins. This required the excavation of kilometres of high-altitude tunnels (at around 2000m for Mont Cenis) and the construction of branching networks of intake points and delivery pipes. The flexibility of the hydraulics of mountain reservoirs enabled peak-period consumer needs to met almost instantaneously (daily, weekly, seasonally). Coupled with the production from nuclear plants, the most recent constructions, known as STEP (Stations for the transfer of energy by pumping), carried this type of development to its extreme, satisfying not only national but also international needs. For example, to optimise the power potential of the upper valley of the Arc, a connection was made between the development projects of Mont Cenis and Plan d'Aval. This enabled the melt water of the upper Maurienne valley (150 km³ harnessed) to be stored in the Mt Cenis reservoir and then sent to the Plan d'Aval reservoir to be used to meet peak winter demand in the power plants of Aussois and Combe d'Avrieux (Marnezy, 2003). The basin of the upper Arc was thus the subject of a comprehensive development project where the aim was to maximise the exploitation of local water resources for power production, at a time when using water resources in this way was the major concern.

Figure 1. Monthly flow rates for the Arc downstream of the La Soussaz plant (St Michel de Maurienne). Data from EDF

Stockage dans les barrages réservoirs de montagne = Storage in mountain impoundment reservoirs.
 Turbinage des barrages = Turbining of dams. Débit réel = Real flow rate. Débit naturel = Natural flow rate.

Significant spatial impacts

- 6 Compared with the pioneer period of hydropower development, electricity produced in the Alps is no longer used solely to meet local industrial needs as was the case for that provided by the private facilities of the pre-war period (plants along the thalwegs of the Arc, Isère and Romanche rivers). The spatial impact of large dams was nevertheless far from negligible for local communities. Local taxes on EDF equipment (property taxes on buildings and business taxes related to the dams, power plants and all installations) made a substantial contribution to local finances. EDF is the largest taxpayer in most municipalities in the upper Maurienne (Avrieux, Bonneval-sur-Arc, Termignon, Aussois, Orelle...). Another source of revenue are the municipal electricity companies set up after the construction of the dams. These were based on specific agreements and established on a case-by-case basis; they benefited from electricity supplies from EDF at reduced rates. When winter sports became more generalised at the beginning of the 1970s, the municipalities of the upper valleys turned resolutely towards tourism development and, thanks to EDF taxes, benefited from a borrowing capacity that was far greater than that possible for rural communities of the same size (around 300 to 700 inhabitants). With their guaranteed incomes, municipalities and inter-municipal groups thus developed village resorts with varying structures (owned by local municipality, inter-municipal associations, districts, semipublic companies, etc.), where the “manna from EDF” played a decisive role in initial investments for the

major facilities (cable cars, chairlifts, etc.). Revenues from hydroelectricity production still make a substantial contribution to the local finances of certain resorts in the Vanoise, Beaufortain and Oisans regions (La Norma, Orelle, Bonneval-sur-Arc, Saint-Colomban-des-Villards, Vaujany).

- 7 Local energy resources have thus often played a decisive role in the start-up of certain alpine winter resorts. Unquestionably, there has been a close link between hydropower developments and tourism development. In a somewhat compartmentalised geographical landscape, where the modest size of potential ski areas had discouraged private developers, the self-development of these resorts would probably not have taken place without EDF revenues.

But the link between hydraulic resources and tourism development is today undergoing important changes.

Multifunctional dams

- 8 Although hydropower production to satisfy peak consumer needs remains the principal aim of the large mountain reservoirs for EDF, complementary functions have also gradually appeared over recent decades together with a diversification in the uses of water.
- 9 The interest from a very early stage in EDF lakes for fishing (Bissorte, Plan d'Amont, Mont Cenis) has been maintained and even increased, as reflected in the enthusiasm of local fishing associations. Mountain reservoirs have become attractive destinations. Mt Cenis, for example, with its lake, mountain pass, alpine pastures and historical heritage, has become one of the most visited sites in the department of Savoie. To develop an image of the mountains that is compatible with summer tourism, a considerable effort has been made to improve the landscape by removing the foundations of former electricity pylons, restoring abandoned worksites, burying power lines, replanting damaged surfaces and even rehabilitating quarries. Consultations were set up between EDF and its different partners, with a focus on public safety. For example, in the field of white-water sports, the Ecot dam (municipality of Bonneval-sur-Arc) is used to divert the large summer flows of the Arc river towards the Tignes reservoir and to ensure that the stretch used for canyoning, downstream of the structure, is made safe in the morning.
- 10 Local development and heritage tourism go hand in hand. Numerous facilities have been provided to encourage visits by the public: Hydrelec museum at the Grand' Maison power station complex, EDF showroom and belvedere at Mont Cenis, panoramic viewpoint and showroom at Avrieux. In the Beaufortain region, a visit to the EDF dams is included in the "four-lakes tour". Regular Open Days are held at the hydropower installations and a series of talks has become increasingly popular. This is a good illustration of EDF's desire to adopt, where economically possible, a new role, seeking a compromise between the use of water for power production and other uses.

Today, however, a new stage has been reached with the production of artificial snow.

Production of artificial snow: new demands for water

- 11 Faced with the random nature of natural snowfall and the demands of a new clientele, winter resort managers, since the 1980s, have gradually turned towards the production

of artificial snow. The reasons put forward are related to both climate and business concerns. It is important to limit the problems of fluctuations in natural snowfall from one year to the next, to guarantee the dates for opening and closing resorts, to ensure good skiing conditions in strategic sections of the resort from a business point of view (relatively flat beginners' areas, kindergarten areas, runs to return to the resort from the main ski areas, link sections, etc.) or those with a naturally unfavourable exposition (in relation to wind or sun). Similarly, a sufficiently thick permanent cover of snow is required for grooming and maintaining the runs as well as for the safety of skiers. The handicap of insufficient or random snowfall is felt more in mid-altitude resorts than elsewhere. But this change in climatic conditions has led to new water requirements in the winter season. The arguments put forward are therefore in line with a clearly-stated policy of maintaining suitable mountain skiing conditions, as far as is possible, in which the diversification of tourist activities is seen, for the moment, more as something to reflect on rather than a real solution.

Water requirements at "the wrong time"

- 12 Artificial snow requirements are estimated at 3500 – 4000 m³ of snow per hectare of marked ski runs, an amount that would enable an initial layer about 30 cm thick to be created and maintained throughout the entire winter (Denarie, 2005). Obviously, this amount would be less if there were substantial natural snowfalls in the season. Based on an estimate of 500 litres of water per m³ of snow produced, the volume of water required to obtain a satisfactory snow cover for a hectare of ski runs is around 3000 m³. However, these figures, which vary depending on the meteorological conditions, the practices used in the resort and the sectors to be covered, are only an approximation.
- 13 The production of artificial snow thus requires access to water at the appropriate time, meaning from the beginning of November for the first layer, then during the winter for maintenance, until March or April. However, this period of snow production corresponds to the winter low-water period of mountain hydrological systems, not only for surface water (rivers and torrents) but also springs. In addition, it also corresponds to peak visitor rates in the resorts, or in other words to the period of greatest demand for drinking water in the municipalities and resorts (Fig. 2). It is therefore the most difficult period for water availability; water only becomes readily available again from April until July (snow melt). The small headwater reservoirs help to solve this problem, at least in part.

Figure 2. Water availability and requirements in the Alpine massif (according to documents of Conseil Général de Savoie, modified).

Production de neige de culture = Production of artificial snow. Consommation d'eau potable = Consumption of drinking water. Régime des eaux de surface = Surface water characteristics.

Increase in small headwater reservoirs

- 14 The managers of winter sports resorts have sought to overcome this seasonal difficulty by constructing small headwater reservoirs that act as storage basins to provide them with water when they need it.
- 15 These reservoirs are built, when possible, in the section upstream of the snow-production system so that gravity distribution can be used to supply the network of snow canons, thereby economising on energy. They must be located so as to take into account the conditions governing basin filling, also by gravity if possible, and the local conditions of the sites (topography, geology, exposure to risks, etc.), and to ensure that impacts are kept to a minimum. Their distribution by volume reveals a wide range of sizes, varying between 3000 m³ and 100 000 m³, for an average volume of about 40 000 m³. The current trend is toward the construction of large capacity reservoirs, for example, Maroly at Grand-Bornand (300 000 m³), a project at Les Deux-Alpes for a reservoir of 200 000 m³ at 2800 m altitude, and one at the Les Arcs resort (Adret des Tuffes, 400 000 m³).
- 16 The methods of filling these reservoirs vary considerably, involving either a single or a combined system: supply by directly tapping into the hydrographical network or groundwater supplies (capturing or diverting streams and torrents, drainage of nearby slopes, pumping from a natural lake or the groundwater) or supply through existing networks, drinking water supply networks in the tourist low season or overflow basins and, more rarely, agricultural irrigation networks.
- 17 The hydrological regimes of the reservoirs also vary considerably depending on the periods of filling, the number of storage and emptying cycles, and the relationship between useful volume and operating volume. Spring is the period of high water availability with supplies from torrents, springs (AEP overflow) and diffused slope runoff. Depending on the year, this abundance carries on, to a greater or lesser extent, into the summer. In autumn, the return of precipitation may also prove favourable. Depending on local weather (winter thaw) and hydrological conditions, some reservoirs

may enjoy a year-round supply of water. Depending on their volume and supply possibilities, reservoirs may be filled once or several times during a season or year.

- 18 These reservoirs provide real advantages for resort managers (availability of water in lowwater periods, relative flexibility of filling periods, large volumes). For this reason they have increased over recent years in parallel with the development of snowmaking equipment. The first such reservoirs appeared at the end of the 1980s, with a sharp increase in the second half of the 1990s and the beginning of the 2000s. In 2006, for example, there were 70 in the four departments of the northern Alps, added to which there were also some 20 projects (Fig. n° 3). In the current economic context of skiing, they represent a logical solution, one that is both suitable and profitable from a business standpoint.

Figure 3. Changes in snow cover (artificial snow) in France and creation of high-altitude reservoirs (Haute-Savoie, Savoie, Isère, Hautes-Alpes).

Facilities that have their critics

- 19 Despite their advantages, these reservoirs have often been the subject of criticism. They are relatively costly for small and medium-sized resorts, in terms of both initial investment and operating expenses. By way of example, the cost of work for the new Maroly reservoir (resort of Grand Bornand) in 2007, amounted to 4.5 million Euros (Montagne Leaders n°204). The sites that meet the desired conditions are few and far between, given the number of parameters to be taken into account. Useful capacities are sometimes insufficient to meet resort needs and there is no guarantee that the resorts can be re-supplied during the season should the need arise. The construction and operation of reservoirs also raises questions of environmental impact. In December 2006, a group of nature preservation associations denounced a number of negative consequences, in particular: visual impacts, with the reshaping of the terrain and

earthworks; loss of biodiversity and degradation of mountain ecosystems (destruction of wetlands and peat bogs); increased competition for water in the catchment areas (off-takes, ever-decreasing flows in mountain torrents, problem of respecting in-stream flow requirements, consequences for fishing); risks generated by the reservoirs themselves for downstream areas (danger of dam bursting or overflowing, transfer of pollution, etc.). In short, mountain reservoirs are blamed for contributing to an ever-increasing artificialisation of the mountain environment, especially as regulations governing this type of equipment are still very limited. Some of these criticisms are undoubtedly excessive. It is true, for example, that local conflicts can occur over the use of water for the production of artificial snow and the supply of drinking water. But as a general rule, reservoir filling only takes place in the period when consumption by tourists is low and when there is more stored water than is actually needed.

- 20 All these difficulties, whether real or supposed, have encouraged some resort managers, whenever possible, to turn towards the dams and EDF facilities to avoid adopting the solution of small headwater reservoirs.

A new vocation for Alpine dams and hydropower equipment?

- 21 EDF has taken up the baton in some Alpine regions by agreeing to help supply the resorts with water for artificial snow. Some installations are already in operation, others are at the project stage.

Alpine dams to the rescue of artificial snow production

- 22 In those municipalities that include both winter resorts and hydropower installations, an agreement had to be found with EDF as the agreements signed when the dams were constructed obviously did not provide for this type of use. Under the supervision of the DRIRE (Regional Directorate for Industry and Research), EDF – whose objectives were first and foremost to do with power production – had no specific mandate to help produce artificial snow. However, the supply of water was finally agreed on for this purpose, based either on a transformation of flows reserved for other uses or on a purchase price per m³. Thus at Aussois, in the upper Maurienne valley, the basis for agreement was a transfer of flows that had formerly been reserved for the irrigation of meadows but were no longer needed for this purpose. The water intake point, at the foot of the dam of Plan d'Amont that stored the discharge from the St Benoît torrent, is used to deliver water by gravity flow to the snowmaking plant. From there, water is distributed to the network of snow canons downstream, and by pumping/reverse flow to the upper ski area.
- 23 The resorts of Val Cenis, Bessans and La Norma are all located within the area that supplies the hydropower complex of Mont Cenis (Fig. 4). The dam is supplied by harnessing water from torrents at about 2000 m altitude and diverting flow through a tunnel from Bonneval-sur-Arc, on the left bank of the Arc river. The hydroelectric plants are grouped together in the Avrieux basin. Throughout the network of diversion tunnels, numerous “windows” were put in, perpendicularly to the slope, for digging tunnels (access, evacuation of rubble) and providing access for maintenance and other work. These areas can be used for the delivery of water supplies to the snowmaking

plants. Thus the diversion pipe for artificial snow at the resort of La Norma was installed on the penstock supplying the turbines of the Villarodin power plant, while that of Val Cenis was on the Châtel “window”, and that of Bessans on the penstock of Goulaz (Avérole valley), for laying snow on the cross-country ski trails. In the upper Maurienne, other projects are still under study, such as that for the resort of Val Fréjus, near the Bissorte reservoir.

Figure 4. Hydroelectric installations and winter sports resorts: Haute-Maurienne.

- 24 In another sector, in the Beaufortain massif, the reservoir created by the Girotte dam has supplied water to the snowmaking equipment on the Savoie side of the Col du Joly since the winter of 2002/3. The equipment is managed by SECMH in the resort of Contamines-Montjoie. This installation must be completed for the winter of 2007 / 2008 by a system to fill the small reservoir built in 2006 at the Col du Joly (Haute Savoie side). The municipality of Beaufort and SEMAB (resort of Arêche-Beaufort) are in the process of finalising a project with EDF that will supply the resort with water from the tunnel constructed between the Roselend dam and the La Bathie power plant (Fig. 5).

Figure 5. Hydroelectric installations and winter sports resorts: Beaufortain.

- 25 Thus, technically, water for snowmaking equipment can be “harnessed” from several sources: in delivery tunnels, on water intakes and on penstocks. Supply by direct pumping from the impounding dam is not yet possible in the Alps, unlike in the Pyrenees where the Castillon dam, for example, provides water for the resort of La MongieSuper-Barèges through the inter-municipal company of Tourmalet. While the actual number of installations completed in the Alps is still limited, several projects are well advanced and there are distinct possibilities for extensions in this field, both for downhill and cross-country skiing. In Italy (Val d’Aoste) and Switzerland, this change is also well underway and there are already a number of agreements between ski resorts and hydroelectricity companies.

Numerous advantages for resort managers

- 26 Taking water directly from hydroelectricity installations has a number of advantages for the manufacturers of artificial snow and for resort managers. The availability of water, related to storage that is essentially intended to meet peak-period power needs, fortunately coincides with those periods when snow requirements are greatest. The volume of water theoretically available in the reservoirs are unlimited in relation to the needs for artificial snow. The latter represent no more than a few per cent of the volumes that pass through the reservoirs. Artificial snow production in the Alps in 2007 required an estimated volume of 11 to 12 million m³ of water, while the figure was 15 million m³ for France as a whole and 95 million m³ for the entire Alpine arc. In the case of Mont Cenis alone, the useful capacity of the EDF reservoir there is 320 million m³ and its operational volume around 600 million m³, while the quantities abstracted for artificial snow production in the upper Maurienne amount to no more than a few hundred thousand m³ (that is, less than 0.1 %). In the departments of Savoie and Isère alone, there are 6 EDF dams with useful capacities of between 100 and 400 million m³, and 14 dams of between 5 and 100 million m³.

- 27 Other advantages: the water in these mountain lakes is relatively cold in winter (between 4 and 7°) and the supply points (dams and tunnels) are located at high altitudes (often around 2000 m), which means significant energy savings since it considerably reduces the need for pumping or reverse flows. There are also considerable savings in terms of investment costs since less heavy equipment will be needed (supply networks, different intakes). Furthermore, since the dams have taken over from the small headwater reservoirs, taking supplies directly from EDF facilities obviously eliminates the need to construct these reservoirs, with their associated disadvantages as mentioned above: the scattered distribution of many small reservoirs, the sequence of impacts that can result from their creation, the problem of limited regulations governing such developments, all the consequences of additional abstractions of water from the natural milieu.
- 28 Also worth noting, this time in favour of EDF, is that water used for making artificial snow returns to the hydrographic network in the spring, even though it is staggered over time and involves very small losses through evaporation and/or sublimation.

Interesting prospects

- 29 Not all the mountain regions are concerned to the same degree. This would take a fortunate geographical coincidence between the spatial distribution of resorts and that of hydroelectrical equipment. A few areas like the Beaufortain massif or the Maurienne valley have distinct potential, given the particularly high density of both their hydropower equipment and their network of resorts. As seen earlier, the process is already well underway in the upper Maurienne valley, but the middle valley area could also be concerned (domaine des Sybelles, for example) as well as the upper Tarentaise (Val d'Isère, Tignes), the Val d'Arly, the St-Gervais valley and several sectors of the Pyrenees (Tourmalet region) and the Massif Central.
- 30 Using water from EDF reservoirs appears to be a distinct advantage, particularly for any small and medium-sized resorts able to benefit from this. In an increasingly competitive environment, it represents a way of providing support, at little cost, for skiing, still without question the main economic activity in these regions, and for the moment difficult to replace. In the case of resorts managed by municipal, inter-municipal or semi-private companies, the economic spin-offs are direct and significant. Thus, local populations are able to find, to a certain extent, what they consider to be their heritage.
- 31 This new practice will have to be integrated into future agreements between EDF and local municipalities: a lot of agreements will be coming to an end in the next few years and will have to be renewed. Water supplies for artificial snowmaking will be a new consideration to take into account in negotiations. By way of example, when the concession for the Avrieux falls in the upper Maurienne was renewed in 2001, the issue of water supplies for making artificial snow had already been integrated into the discussions. Snowmaking needs (downhill and cross-country skiing) had been estimated and were added to forecasts of agricultural irrigation needs in the communities of the upper Maurienne valley and the needs of population centres (drinking water supply and for livestock).

Conclusion

- 32 Hydroelectrical equipment in some high alpine valleys has taken on an increased interest: wherever possible it provides an abundant source of clean water, at low temperatures, sometimes under pressure, and may also provide the most economic solution for supplying water to be used in snow-making equipment.
- 33 This new development may also help to enhance the management of certain mountain areas. By diverting a very modest volume of water from the production of hydraulic energy, this solution should slow the recent trend towards an increasing number of high-level reservoirs and has no additional impact on the natural environment. Admittedly, its development remains geographically limited to those sectors with both hydroelectrical equipment and winter resorts, but the phenomenon may nevertheless be significant by providing support for winter tourism in regions such as the Maurienne valley or Beaufortain massif which offer a dense network of small and medium-sized resorts.
- 34 Since the creation of EDF, the production of hydro-electrical power for the national and even international market has in some ways distanced the state authority from local concerns (compared with the pioneering era of hydropower development). With the use of water for making artificial snow, local alpine communities are now witnessing a new form of assistance to their local economy, a new territorial integration of water resources, and a re-appropriation of their heritage.

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ABSTRACTS

Mountain reservoirs were initially built in the Alps to meet energy needs in the winter. A certain diversification in the uses of water then gradually developed, related to tourism development in the local communities. Today, the use of facilities belonging to EDF (French Electricity Authority) to provide water for winter resorts to make artificial snow represents a new phase. By taking water from EDF resources to supply snow-making equipment, resort managers are thus able to avoid the problems related to the construction and management of small headwater dams. This new orientation in the use of mountain water resources already affects a number of alpine regions such as the Upper Maurienne valley and Beaufortain massif and represents a renewed form of the territorial integration of water resources.

Les barrages-réservoirs de montagne ont été réalisés initialement dans les Alpes pour répondre à la demande d'énergie en période hivernale. Une certaine diversification des usages de l'eau s'est ensuite progressivement développée, en relation avec le développement touristique des collectivités locales. Aujourd'hui, la participation des ouvrages d'Électricité De France à la production de neige de culture représente une nouvelle étape. Dans les régions où les aménagements hydroélectriques sont nombreux, les besoins en eau pour la production de neige peuvent être résolus par prélèvements à partir des adductions EDF. Les gestionnaires de stations échappent ainsi aux inconvénients liés à la construction et à la gestion des « retenues collinaires ». Cette évolution, qui concerne déjà quelques régions alpines comme la haute Maurienne ou le Beaufortin, apparaît comme une forme renouvelée d'intégration territoriale de la ressource en eau.

INDEX

Mots-clés: barrages alpins, énergie hydroélectrique, impacts territoriaux, multifonctionnalité, neige de culture, ressource hydraulique

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