FROM FOLLOWING TO IMPROVING TECHNOLOGY: THE CASE OF THE SWISS GAS INDUSTRY IN THE 19TH CENTURY

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1.- Introduction.

Our aim is to highlight the main characteristics of the Swiss gas industry in the 19th century. By adopting the new lighting technology during the 1840s and 1850s, Swiss cities belong to the second wave of diffusion, together with German, Austro-Hungarian, Italian and Spanish towns. This was mostly the result of a technological transfer from England and France, where gas lighting was invented[1].

We begin by showing the conditions of the initial circulation of basic know-how, from advanced cities to Swiss towns. In this context of followers, we consider municipal resistance to these new developments; the national implications of managing uncertainty when confronted with a new technology coming from foreign countries, and new problems caused by the dependency on imported coal. We then concentrate on a (re)orientation of the circulation of know-how from fertile Swiss towns to cities located in Southern Europe. What was the process involved in passing from the first stage of followers to the stage of "sustained improvements" and "experiences" accumulated at local scale by a strong convergence between science and technology, and subsequently valorised on international markets? Throughout this process, the circulation of techniques was backed up by a circulation of funds provided by bankers specialising in financial infrastructure. Geneva offered a particularly good example of those associations between the technical and financial worlds.

In the course of our exploration, we use concepts and notions drawn from the recent French and Anglo-American historiography in science and technology. We mainly base our analysis on the recent book published

1 PAQUIER, Serge ; WILLIOT, Jean-Pierre (dir.) (2005) *L'industrie du gaz en Europe aux XIXe et XXe siècles. L'innovation entre marchés privés et collectivités publiques*, Brussels, 26-30.

by François Caron, *La dynamique de l'innovation*, in which he develops some interesting ideas, such as "social request", "curve of experience", "interactivity between sectors", "circulation of know-how" and "implication of the Academic world in industry"[2]. In particular, we take from Joel Mokyr the seminal concepts of "useful knowledge" and "sustained improvements" drawn from *The Enlightened Economy*[3].

2.- Between French, German and local initiatives.

French technicians from Paris, Lyon, and Alsatian cities (Strasbourg and Mulhouse) were very active in searching for new markets in the largest Swiss cities. However, the French were successful only in the cities located in the west: Bern in 1843, Basel in 1852, and Neuchâtel in 1859. In Geneva (1844) and in Lausanne (1848), where the furnaces were supplied by coal or peat, gas infrastructure was the result of local initiatives. French ambitions encountered not only local rivalry but also met with German competition that was based on the carbonisation of wood. The German technician August Riedinger introduced this system in the Center and in the North-East of the country (Zürich in 1856, Sankt-Gallen in 1857, and Luzern in 1858). During his career, Riedinger set up more than eighty gasworks in South of Germany, as well as in the Austro-Hungarian and Russian Empires, where woodland was abundant. However, this wood-based system was first adopted in Basel, the city on the Rhine of particular international interest because of its location between Switzerland, France, and Germany. In fact, local authorities followed the textile lobby, which was intent on searching for a less damaging way of manufacturing clothes. The first uses of coal for the production of gas lighting contaminated the atmosphere with sulphur, a problem that was to be solved only in the 1860s thanks to progresses in purification provided by Chemistry.

2 CARON, François (2010) *La dynamique de l'innovation. Changement technique et changement social (XVIe-XXe siècle)*, Paris.

3 MOKYR, Joel (2009) *The Enlightened Economy. An Economic history of Britain (1700-1850)*, New Haven/London.

3.- The gas industry as the first mass user of coal, and its consequences.

Together with lake steamers gas lighting became the largest user of coal in Switzerland in the 1820s, prior to the construction of the railways in the early 1860s. Consequently, coal could only be imported by waterways and roads. Coal from the Loire, extracted from mines around Saint-Etienne, 200 km away from Geneva, was stored in Lyon. This fuel was transported from Lyon to Geneva by road. Transport costs accounted for two-thirds of the price of coal delivered in Geneva (at around 6 francs per quintal). Part of this coal was carried up to Lausanne by steamers on the Leman Lake. After testing local peat without success, the gas producers of Lausanne converted to the coal from the Loire.

Bern is a good example of the hopes founded on the use of national primary energy. This city used local coal extracted from the nearby Alps, then transported by waterway to the city. Nevertheless, it is necessary to stress the existence of Swiss coal, since its availability is barely known. However, the mining of this coal was limited because the seams were too thinly distributed[4]. It was therefore impossible to use coal on a large scale in the same way as in England or Belgium. Moreover, Swiss coal contained large amounts of sulphur and gave off a disagreeable odour[5]. This made it unsuitable for a mass technical system whose capacity to penetrate the markets largely depended on quality of service. Thus Switzerland was forced to import good quality coal, first from the Loire and the Saar areas, and later from Northern France and the Ruhr.

This dependency on imported coal was quickly perceived as a crucial factor in the Swiss process of industrialisation. Moreover, the urban revolts of the spring of 1848 destabilised the supply of coal. Although prices failed to rise as much as was feared, deliveries were discontinued. In 1848, awareness of Switzerland's economic dependence on foreign coal emerged in a turbulent political context. In autumn 1847, after the victory of the progressive forces during the Civil War of Sonderbund, Switzerland became a small democracy surrounded by powerful Royal or Imperial States. The govern-

4 PELET, Paul-Louis (2007) "Charbon (exploitation)". In: *Dictionnaire historique de la Suisse*, version électronique du 17/8/2007.

5 *Rapport fait au nom du comité de la Société genevoise pour l'éclairage au gaz*, Genève, 1845, 8. "L'odeur du gaz est tellement fétide (…)".

ments of these states argued that the Swiss Federal State should not serve as refuge for revolutionaries. After troubles in some Italian cities, no less than 20.000 revolutionaries were received in the Italian speaking Canton of Tessin. In the mid-1850s, the emerging kingdom of Prussia threatened the recently independent Canton of Neuchâtel. As a result, the Swiss army Chief, General Dufour, sent two Federal divisions to the Rhine border[6]. At that time, Dufour was to become a leading figure for gas in Geneva.

In order to limit economic dependency in a time of fear and uncertainty, the consulting engineer of the Geneva gas company, Daniel Colladon (1802-1893), obtained from the company board enough funds to build a special gasometer to carry out a number of tests[7]. This engineer thereby made the first demonstration of a scientific approach in the Swiss gas industry. In 1848, the first alternative to come under seriously consideration was that coal from Switzerland or from neighbouring Savoy, which was yet to form part of France, should substitute the French coal. The special gasometer was used for many experiments and tests in order to purify local coal. However, all such tests failed, and the use of national coal for manufacturing gas lighting remained an impossibility. A further motivation was the commercial opportunity to sell coke, a by-product of the distillation of coal, in a growing market for heating private and public buildings. In Geneva, the sale of coke represented not less than 20% of the total earnings for the gas company.

An illustration of the dependency on coal was that every Swiss gas company needed a daily supply of no less than five tons of coal. Moreover, the importation of coal increased rapidly to meet the needs of blasts furnaces, heating industries and buildings, as well as for the railways and steamers, not to mention the fact that the wood plants located in Swiss Germanic cities converted to coal because of their connexion with the railway. While in 1851 coal imports amounted to 11.000 tons compared with the national production of 38.000 tons, in 1860 they already exceeded 100.000 tons, a figure that had risen to one million tons in 1890 and were to grow to two millions during the "Belle époque". National production was then limited to 6%[8].

6 WALTER, François (2010) *Histoire de la Suisse, tome 4: La création de la Suisse moderne*, Neuchâtel, 41-42.

7 The special gasometer had been in place since 1848. See *Société genevoise pour l'éclairage par le gaz*, Geneva, 1848, 15.

8 MAREK, Daniel (1994) "Der Weg zum fossile Energiesystem. Ressourcengeschichte der Kohle am Beispiel der Schweiz 1850-1910". In: WERNER, Abelshauer (ed.) *Umweltvertragliches Wirtschaften in historischer Perspektive*, Göttingen, 56-75, 67.

Dependency on imported coal was therefore impossible to avoid. If Switzerland and many other European countries wished to follow the British model of industrialisation and export their manufactured products, they were obliged to abolish all economic and doctrinaire barriers. According to the future winner of the Nobel Peace Prize, Elie Ducommun (1833-1906), a proponent of Swiss industrialization, "l'activité et le progrès sont les seuls moyens pour les peuples de conquérir ou de conserver leur liberté"[9]. All in all, it was not in Switzerland's interest to pursue a path of isolation while industrializing its economy[10].

This point of view was certainly shared by Colladon. However, there was also another way to circumvent dependency on imported coal: the experience acquired in the gas industry represented a fundamental step towards an entirely new and large technical system capable of deriving its primary energy from the huge reserves provided by rivers. Colladon wrote a paper in which he advocated this idea as early as in 1858[11]. But now we must return to the first stages of gas lighting in Swiss cities.

4.- Municipal hesitation (from the 1820s to the 1840s).

As in the case of Scandinavian cities, the Swiss municipalities were exposed at an early stage to a macro-innovation, but for 20 years they hesitated to implement it. Just after the end of the Napoleonic Wars, in 1816, Geneva was approached by the English technician Richard Willcox, who promoted gas lighting[12]. Although annexed to France between 1798 and 1813, Geneva was still very British-oriented, as the title of its leading scientific magazine, the *Bibliothèque Britannique,* suggests. Furthermore, since the last third of the

9 *Bulletin de l'Institut national genevois*, 19 (1860), 142. See also our study: "Diversification d'un tissu industriel dans la longue durée. Le cas de Genève au XIX^e siècle". In: DURAND, Roger (with the cooperation of Serge PAQUIER) (2011) *Elie Ducommun Prix Nobel de la paix méconnu, famille, politique, économie, humanitaire, pacifisme*, Geneva, 91-108.

10 See DUC, Gérard (2010) *Les tarifs marchandises des chemins de fer suisses. Stratégies des compagnies ferroviaires, nécessités de l'économie nationale et évolution du rôle régulateur de l'Etat (1850-1913)*, Berne,15-17.

11 Bibliothèque de Genève (BG), salle des manuscrits, Ms fr 3758: COLLADON, Daniel (1858) *Notes et considérations générales sur l'utilisation de la puissance motrice des rivières et des fleuves*, Geneva.

12 MAYOR, Jean-Claude (1994) *Lumière-Chaleur-Energie. Les dons du gaz. 150 ans de gaz à Genève*, Geneva, 38-39.

18th century, Geneva scientists and technicians had developed close relations with the manufacturing area of Birmingham.

Although this approach from the English was received with scepticism by Geneva experts[13], local scientists and technicians took the matter up in 1824 by conducting some experiments. Among these who did so, there was one important personality in the Geneva world of science and technology in particular. Thanks to his studies at the Ecole Polytechnique, especially in the application school at Mézières (Génie militaire), Guillaume-Henri Dufour (1787-1875) had received some of the most advanced education in science for Applied Mechanics. Many professors distinguished themselves in this institution, such as Jean-Charles Borda in hydromechanics, and Gaspard Monge in descriptive geometry[14]. When he became interested in gas lighting, Dufour was an engineer in the Geneva Canton and a militia officer in the Federal Army. He was later appointed as the first General-in-Chief of the Swiss Army during the Civil War, which was also when Prussia put pressure on Switzerland, as outlined above. Although this first attempt to promote gas lighting led to nothing concrete, it nevertheless constituted a necessary stage in the preparation of the field for subsequent successful local initiatives. Besides technicians, financiers also became involved in gas lighting. Since the 1830s, private bankers in Geneva and in Basel had been active in setting up such projects in their cities.

Nevertheless, the Swiss municipalities were largely paralyzed by hesitation. Five reasons may be identified for this attitude: (1) The technology of gas lighting was too new when compared with the existing oil system already in use in most cities. Moreover, where local governments were directly involved in technology, as was the case with water adduction, they remained very traditional in their approach to urban infrastructure. For example, in Geneva the profits failed to cover the costs, and when it became necessary to replace the old pumping machine erected in 1708 on the Rhône to supply water to fountains, *hôtels particuliers* and the hospital located on the heights of the city[15], the re-elected government rejected many ambitious projects. (2) Entrusting a public service to a private company was a difficult decision.

13 See DUC, Gérard; FREI, Anita; PERROUX, Olivier (2008) *Eau, gaz, électricité. Histoire des énergies à Genève du XVIIIe siècle à nos jours*, Geneva, 46.

14 CARON (2010), 75.

15 BÉTANT, Alfred (1941) *Puits, fontaines et machines hydrauliques de l'ancienne Genève*, Geneva 54-58; 105-111.

According to the French Saint Simonian approach, which was then increasing in influence, private companies were to take over public services such as gas lighting, because while public administration could "manage people", the "management of things" had to be given to technicians and financial experts working in an industrial firm. These experts in the private sector not only possessed the necessary skills, but also the time to develop and install new infrastructures like gas lighting and railways. (3) The applications of the new technology by foreigners caused other problems. In the case of accidents, or conflicts between companies, the municipalities and consumers, company bosses would probably withdraw their business rather than face litigation in a Swiss court. (4) It was far from clear how long the city should grant a monopoly concession for ten, twenty, thirty years, or more? (5) Finally, how would it affect the general interest in Swiss cities for the conceding authority as well as for consumers?

Nevertheless, the "social request", the English translation of *demande sociale* (a term used by François Caron to determine the technical dynamic of societies)[16], put the municipalities under pressure. After the disasters of the French Wars in the late 18th and early 19th centuries, the progress in the converging fields of science and technology for the production of arms, uniforms and gunpowder, as was the case in Alpine region, was leading to the "building of new towns"[17]. Cities should be more pleasant places to live; public squares and gardens and wide streets were to improve air quality, and above all new towns should be planned more rationally. Inspired by the scientific progress, engineers believed themselves capable of solving numerous urban problems, particularly those caused by population growth. Urban engineers applied themselves to solutions for the evacuation of effluent, the large-scale supply of water through new infrastructures for public and private use, the distribution of power supply for the many craftsmen and tradesmen in the city, the creation of new transport systems for persons and merchandise, as well as providing heating and lighting systems for public and private spaces. These dynamics began to emerge in place after the more favourable decade of

16 CARON, François (1997) *Les deux révolutions industrielles du XXe siècle*, Paris, 24-25.

17 On new cities in the industrial era, see OSTERHAMMEL, Jürgen (2010) *Die Verwandlung der Welt. Eine Geschichte des 19. Jahrhunderts*, München, 355-484; BAYLY, Christopher (2007) *La naissance du monde moderne (1780-1914)*, Paris, 279-326; WALTER, François (1994) *La Suisse urbaine (1750-1950)*, Carouge/Geneva, 183-230; PINOL, Jean-Luc ; WALTER, François (2003) "La ville contemporaine jusqu'à la Seconde Guerre mondiale". In: PINOL, Jean-Luc (dir.) *Histoire de l'Europe urbaine*, t. II, Paris, 10-275.

the 1820s, which contrasted with the years immediately following the French wars, when at the same time Continental Europe was faced with a classical pre-industrial crisis due to bad weather and a new overproduction crisis caused by the liquidation of the Continental blockade. The role played by what Swiss historians call the Regeneration Movement, coming in the wake of the revolutionary days of June in Paris (1830), should also be taken into account. This liberal movement opened the door to technological and social progress.

Under Dufour's supervision, Geneva constructed the first cable suspension bridges on the European continent, and steamers had been sailing on Lake Leman since 1823[18]. Furthermore, the leading civil engineer Colladon started his public service career by writing a report on steamers and providing free utility services to the Hospital with a more rational heating of rooms and water. He also devised a plan for the rational distribution of power to urban artisans. But all in all, gas lighting was the prime mover in new urban infrastructures.

5.- From reducing incertitude to urban revenue.

Municipalities were thus obliged to go beyond the preliminary investigations carried out in those cities which had already adopted gas lighting. Swiss citizens in these pioneering cities were quizzed about their opinions[19], and surveys were conducted by special committees who visited adjacent towns such as the French cities of Lyon, Saint-Etienne, Vienne, Valence, Grenoble, and Chambéry[20]. The best solution for Swiss towns appeared to be the involvement of local technicians, investment and financiers. Financial capital itself was becoming increasingly Swiss, as well as the directors, technical solutions and managers. In fact, the best solution for protecting the common good and ensuring the safety of infrastructures was to appoint Swiss army

18 See PETER, Tom-F. (1987) *Transitions in Engineering. Guillaume-Henri Dufour and the Early 19th Century Cable Suspensions Bridges*, Bâle/Boston; and more recently DE LA CORBIÈRE, Matthieu (dir.); BRUNIER, Isabelle; FROMMEL, Bénédict; RIPOLL, David; SCHÄTTI, Nicolas; WINIGER-LABUDA, Anastazja (2010) *Genève, ville forte*, Geneva, 301-303.

19 See ULMI, Nicola (1991/92) "Les immenses avantages de la clarté ou comment la Ville de Genève décida de s'éclairer au gaz (1838-1843)", *Bulletin du Départment d'histoire économique*, 22, 33-56.

20 LAVARINO, Albert (1944) *Le centenaire de l'industrie du gaz à Genève*, Geneva, 18.

officers (who served on a volunteer and part-time basis) to the boards of administration or to management positions. General Dufour's involvement in the Geneva gas scheme was therefore not an isolated example.

Although it was a French technician whose solution was adopted in Bern, a local captain and a lieutenant were also involved[21]. Greater local control was established in 1860 when the Bern gas network was taken over by the city council[22]. In the town of Sion, the small capital of the Alpine canton of Valais, a former general in the service of the Naples Bourbons set up Gas Sion. Military officers had also been involved in large-scale water adduction since the 1860s, mostly in Zürich, and Luzern[23], and thirty years later they entered the hydro-electrical field, where numerous colonels took the leadership in Geneva, Bern and Zürich. This is the first example of interactivity between technical networks. The strategic objective was also to win public confidence, since such innovations were not without opponents. In Geneva, members of the patriotic adjacent shooting range did not hesitate to fire on gasometers[24]. The gas company had to build a wall in order to counter this dangerous situation. Later, fishermen on the Rhône accused the company of killing fish with waste poured into the river.

In spite of usual difficulties involved in the implementation of new infrastructures, the efforts of Swiss gas companies were crowned in main cities by a rapid conquest of markets. As our colleagues, Alain Beltran and Jean-Pierre Williot have shown in the French case, Swiss gas companies began to conquer markets at a horizontal level. This kind of market was an application of the water adduction model[25]. Water was delivered in butts at the entrance to buildings. This is another demonstration of the interaction between technical networks. The market was twofold: both public and private. When Daniel Colladon was prospecting markets for new water adduction in the mid 1820s in a small city like Geneva, with 25.000 inhabitants, he estimated a basic market composed of thirty public buildings and 800 private houses requiring modern conveniences. In the firsts years of the company, distribution of gas to the municipality for public lighting (streets, squares, monuments and

21 See WULLSCHLEGER, B. (1943) *Hundert Jahre Gaswerk Bern (1843-1943)*, Bern.

22 At this time, municipalisation of gas was an exception.

23 For the example of Luzern, see HODEL, Fabian (1997) *Versorgen und Gewinne. Die unternehmertätigen Stadt Luzern seit 1850*, Luzern.

24 *Rapport fait au nom du comité…* (1845), 5.

25 BELTRAN, Alain; WILLIOT, Jean-Pierre (2009) *Du gaz en France à Gaz de France, deux siècles de culture gazière*, Paris, 35.

public buildings) provided a basis of 40 percent of the total sales of gas. This public market evolved slowly until the introduction of new concessions. On the other hand, the private market (buildings courtyards, living and dining rooms in hotels, banks, shops, workshops and especially theatre) was growing rapidly. Before gas "à tous les étages", in 1860, the private market share reached 86,4 percent[26].

Thanks to "sustained improvements", most particularly those provided by Colladon[27], the conquest of indoor and vertical markets could then begin. The Geneva strategy was to attract the German company Mayence that specialised in cheap and simple equipment for the "appartements particuliers". The objective was simply to imitate what was already being done in "la plupart des autres villes"[28]. But the Geneva case also shows that vertical conquest was a difficult task. The company decided to accelerate the process with the installation of rising mains[29] at its own expense. The annual report for 1877 shows that the process of democratisation of gas lighting "à tous les étages" was already in place: "les nombreuses bâtisses, qui presque toutes profitent des facilités qui leur sont accordées par la compagnie pour l'établissement de colonnes montantes destinées à mettre le gaz à disposition de chaque étage, tendent à propager ce mode d'éclairage"[30]. At this time, gas sales generated one million francs, while some 90 percent was sold to private consumers.

By the late 19th century, when gas was municipalised in all Swiss cities[31], this utility service was so large-scale and wide-spread as to be really democratised. The first objective of the public firms, often called *Services industriels*, was the extension of their services by rebuilding the network and by providing subsidies for developing new markets, mostly for heating water and for cooking[32]. Since hydroelectricity had been controlled by the same municipal firms since the 1890s, the strategy was not to kill urban revenues generated by

26 *Compagnie genevoise pour l'éclairage et le chauffage par le gaz*, 1861 ; see tables at the end of the report.

27 *Ibid,* 1862, 16.

28 *Ibid*, 30 mars 1861, 13.

29 *Ibid*, 26 mars 1870, 15. The sum allocated each year for the «colonnes montantes» evaluated between 6.000 and 8.500 francs, until 1877; see tables at the end of the reports.

30 *Ibid*, 1877, 4.

31 For the process of municipalisation, see PAQUIER, Serge; PERROUX, Olivier (2005a) "Naissance et développement de l'industrie gazière en Suisse". In: PAQUIER, WILLIOT (dir.), 508-529, 519-526.

32 PAQUIER, Serge ; PERROUX, Olivier (2005b) "De la compagnie privée à l'entreprise municipale". In: PAQUIER, WILLIOT (dir.), 295-317, 314-316.

gas, but to develop them in accordance with the growing profits in electricity. Therefore, travelling through Swiss cities in 1904, the British Committee for the Study of Municipal Institutions was astonished to discover that municipal companies in charge of the large-scale utility services of water, gas and electricity were able to generate money[33].

Indeed, from the mid-19th century, the steadily rising market for gas generated large profits, as demonstrated by historical studies in Lausanne, Geneva and Luzern[34]. The same level of profit was observed in many other European cities[35]. However, there are cases, such as Malaga, analysed by Mercedes Arroyo, that reveal that huge profits were not always the rule[36]. In Sion, holes in pipes, default of an extended private market and under-investment caused important losses[37]. With only four thousand inhabitants and a pre-industrial economic structure, the famous leverage action of the private market could not work. A vicious circle then started: the larger the losses, the fewer were the investments, and the stationary state was set up.

6.- The Geneva case: from follower to "sustained improvements".

After analysed how the innovation was adapted from North-Western countries to Switzerland, we now enter the black box of cities which created a fertile field for "sustained improvements", following Mokyr's approach. Thus the circulation of techniques was redirected from Swiss cities to French and Italian towns. But how was local experience evaluated in external markets?

Constrained by circumstances to adapt to the wave of new infrastructures coming from the North-Western areas, followers were in fact confined to two options. One was to accept an infrastructure "à forfait" for a period deter-

33 HIETALA, Marjatta (1987) *Services and Urbaniation at the Turn of the Century*, Helsinki, 361-362.

34 See DIRLEWANGER, Dominique (1998) *Les services industriels de Lausanne*, Lausanne, 34.

35 See the analysis of English, French, German, Spanish and Italian cities in PAQUIER, WILLIOT (dir.) (2005).

36 ARROYO, Mercedes (2005) "Le développement contrasté de l'industrie gazière en Espagne. Les exemples de Barcelone et Malaga –Entrepreneurs, municipalités et marchés au XIXe siècle". In: PAQUIER, WILLIOT (dir.), 347-357.

37 DUC, Gérard (2003) *Les services industriels de la Ville de Sion (1867-1914). Reflet des mutations d'un chef-lieu rural*, Sierre, 53-96.

mined only by the duration of the concession, mostly 20 or 25 years. Another solution was to develop the first infrastructure for added value, and this option seemed to predominate in Swiss cities[38].

As suggested in the first part of this paper, the evolution of the Swiss gas industry demonstrates a rapid national control for adapting infrastructures to the new conditions prevailing in the early 1860s. From the supply side, the construction of railways forced the Central and North-Eastern Swiss towns to carbonise coal rather than wood for producing gas light. From the demand side, the initial infrastructure, built as precisely as before by the German entrepreneur Riedinger, had to be adapted to the constant extension of the markets. This meant building new gasometers and pipes.

In some cities, the process of *Swissification* went further than a simple adaptation of the infrastructures to a changing environment. In Basel, Geneva and Schaffhausen, local experiences were valorised on external markets. In Basel, Heinrich Gruner, Riedinger's German assistant who settled in Switzerland, obtained markets in neighbouring small German cities, in Lörrach and Schöpheim, Shaffhausen and Geneva, also had a role to play in the strategic field of creating hydro-mechanicals infrastructures, because these cities could benefit from rivers regulated by their passage through large lakes; the Rhine leaving the Bodensee upstream in Schaffhausen, and the Rhône leaving Lake Leman in Geneva, respectively. As a result of this experience in creating new infrastructures, these two towns became the seat of gas holdings with attractive positions in German and Italian cities[39]. Geneva went much farther in this process with the creation in 1861 of an important holding consisting of a shared capital of ten million francs. There is a clear inter-connexion between the gas business and the Brussels Financial centre, where an analogue holding was created at the same time[40]. If the financial capital of the "Belgian sister" was the largest (20 million Belgian francs), the two holdings were active in the same kind of markets, with important positions in German, French and Italian towns. We will return to this kind of transversal business when we analyse the case of Naples.

We do not intend to describe here the complete evolution local experience

38 *Rapport fait au nom du comité…* (1845), 12.
39 Pisa and Reggio d'Emilia.
40 On the Brussels Financial centre, see CASSIS, Youssef (2006) *Les capitales du capital. Histoire des places financières internationales* (1780-2005), Geneva, 54-56.

or the holdings. Other papers have been dedicated to this purpose[41]. We only mention the principal characteristics of gas in Geneva. The concession was acquired in 1843 following the liberal revolution of 1841, and inauguration took place in December 1844. The Geneva "haute banque protestante" (mostly Pictet, Bonna, Hentsch, Turrettini and Ador), with strong ramifications in the Parisian Financial Centre[42], was involved in the local experience, before playing the initial role in the holding. The first shared capital amounted to 500.000 francs, a sum that rose to one million after the new concession (1856)[43].

We can distinguish four principal steps in the development of the company. (1) The first was to choose who would build the basic infrastructure. The French technician Jean Rocher possessed a solid reputation, gained in the spread of the installation of gas in Venice, an ex-city-State like Geneva. While the board informed the shareholders that it was possible to begin without costly researches[44], it should be pointed out that the estimate for the work exceeded 100.000 francs[45]. One part of the strategy was to elect General Dufour as the president of the board. He provided a guarantee against opposition raised by this kind of new development coming from more advanced western countries. The annexation of Geneva to France (1798-1813), and even more the French Wars, had left bad memories in the Republic, which became a Swiss canton in 1815. (2) After a typical lack of business dividends from new infrastructures, the gas company encountered general difficulties as a result of the economical, political and social disorders of the mid-19th Century[46]. The Geneva gas company had to face the international consequences of the urban revolts of 1848. Coal supply was intermittent, as we pointed out at the beginning of this paper. (3) However, since 1848, markets and profits had been steadily growing. The annual report of July 1851 notes that "l'éclairage au gaz se substitue peu à peu à celui de l'huile dans la plupart des magasins"[47]. It was then possible to distribute dividends, which oscillated

41 See PAQUIER, Serge (1996) "Les Ador et l'industrie gazière 1843-1925". In: DURAND, Roger; BARBEY, Daniel; CANDAUX, Jean-Daniel (ed.) *Gustave Ador, 58 ans d'engagement politique et humanitaire*, Geneva, 139-179; PAQUIER, PERROUX (2005b).

42 For the *haute banque parisienne* and the financial place of Geneva, see CASSIS (2006), 46-51 ; 56-57; 85-87.

43 These are current Swiss francs, *Rapport fait au nom du Comité…* (1845), 4.

44 *Société genevoise d'éclairage* (1848), 18.

45 LAVARINO (1944), 26.

46 See BAYLY (2007), 255-264.

47 *Société genevoise pour l'éclairage…*(1851), 6.

between 6 and 10 percent. (4) The fourth step corresponded to a large rescaling of the infrastructure due to the necessity of delivering gas lighting to the new spaces opened up by the destruction of the voluminous Geneva Vauban style fortifications in[48].

Finally, a new concession was signed in 1856. These new conditions, lasting for at least 35 years, opened the door to enormous profits. In fact, a floor tariff was established at 40 centimes the cubic meter, which corresponded only to a fall of 8 percent, whereas the cost of coal was about to drop drastically : more than 60 percent, as a long term effect of the inauguration of the railway line between Lyon and Geneva. It is then possible to observe an asymmetrical information effect between the company expert and the common good of Geneva for which the municipality was responsible. Indeed, the principal negotiator, Daniel Colladon, was at the same time member of the municipal commission and leading engineer of the gas company[49].

Behind the common success story that was seen in many European cities, a precise analysis of gas in Geneva shows clear characteristics. Science and technology were converging. In this process Daniel Colladon played a leading role thanks to his early career in science and to his subsequent one as consulting engineer. In fact, "sustained improvement" was his religion, and according to Joel Mokyr the determining factor for explaining what the basis of the so called "sustained growth" was, as described by W.-W. Rostow in his classical work: The Stages of Economic Growth[50]. In Mokyr's view, the basis for "sustained growth" consisted in a flow of micro-inventions that followed immediately upon macro-inventions.

In his *Rapport de l'ingénieur* of 1852, Daniel Colladon wrote: "C'est en industrie surtout qu'il est vrai de dire que celui qui n'avance pas recule"[51]. For him, this was clearly the best means not only to deal with the "état stationnaire" feared by economists, but also to take on the competition directly. Because of the investments required by the new concession, Geneva gas was afraid of lighting systems such as those based on oil, and Colladon was responsible for speeding up the analysis of whatever competitors might provide in technical and economic terms[52]. Having study electricity thoroughly

48 See DE LA CORBIERE (dir) (2010), 231-249.
49 COLLADON (1858).
50 ROSTOW, W-W. (1960) *Les étapes de la croissance économique*, Paris.
51 *Compagnie genevoise pour l'éclairage…* (1857), 18.
52 *Ibid*, 17-18.

during his early career as pure scientist, Colladon considered this natural phenomenon as a technical solution for lighting. Before describing the role played by this leading engineer for gas in Geneva, we should first consider the reasons for his technical creativity.

7.- The role of the natural environment.

Daniel Colladon benefited from the best possibilities that the Geneva context could offer in terms of convergence between science and technology. Geneva is described by René Sigrist as the most important assimilated Swiss city in experimental research since the beginning of the Enlightenment[53]. Geneva scientists were active in many fields, such as mathematics, physics, astronomy, medicine, heat, electric current, meteorology and agronomy. In these subjects, however, the Geneva scientists were mostly followers rather than leaders. The proximity of the Alps as well as the largest European system of lakes provided Geneva with a natural environment with special features, which constituted a specific basis of study for geology and Alpine botany. Some Geneva scientists thereby became well known in these two specialities, particularly Horace-Benedict de Saussure (1740-1799) and the dynasty of de Candolle: Pyrame (1778-1841) and his son Alphonse (1806-1893). According to Mokyr, Geneva scientists accumulated "propositional knowledge", a concept used to define principles that govern natural phenomena. In Mokyr's view, such knowledge is useful because thanks to the declining cost of information it was transmitted to people involved in the production process, either as artisans or manufacturers[54].

In Geneva, the condition of this connexion was directly linked to pressure exerted by the powerful territorial-States on city-states like Geneva and Venice. The English historian Christopher Bayly offers an interpretation of the long-term roots. For him, in the 18th century, the territorial-States were facing a military-fiscal crisis due to costly colonial wars[55]. These states needed to increase their profits by absorbing cities whose independence was based on their capacity to generate wealth. During the Seven Year War, which between

53 SIGRIST, René (2003) *La République des Lettres et l'essor des sciences expérimentales: exemples genevois (1670-1820)*, thèse de l'université de Genève, Geneva, 55.
54 MOKYR (2009), 40.
55 BAYLY (2007), 155-162.

1756 and 1763 had embroiled the largest powerful states – Prussia, Russia, Spain, England, the Austro-Hungarian Empire and France – this latter country stepped up the pressure on opulent Geneva. The French objective was to create a city on the bank of Lake Leman. The entirely new town of Versoix was located in the French Pays de Gex. Equipped with water motive power, Versoix would provide competition for Geneva[56]. Voltaire and the minister of foreign affairs, de Choiseul, were at the root of this plan. Furthermore, in 1759, well before the war ended, a French decree put an end to the Swiss monopoly on printed calicoes[57]. In fact, the most interesting target was the Geneva clock industry. Not only France, but also the Realm of Sardaigne, which exerted its sovereignty over neighbouring Savoy, as well as the Austrian Emperor Joseph II, all attempted to hire Geneva clock-makers for setting up manufacturing in their own territory. The general and engineer Dufour was born in Constanz, where his father was a Geneva clock-maker who had settled temporarily in the German Empire.

In this context, the convergence between science and technology provided the means to fight competition by encouraging the arts and manufacturing. Thus in 1776, H-B de Saussure and the clock-maker Jacques Faizan created the Société des Arts. The London Society for the Encouragement of Art, Manufacturing and Commerce was certainly the best model. The objective in Geneva was also to set up new industries to enlarge the industrial sector. The means for connecting artisans to science were already in place. The French demonstrator Pierre-François Tingry (1743-1821) taught special chemistry to craftsmen, while scientists sought to implement new industries: earthenware on the Birmingham model, artificial mineral water and lamps[58].

The Geneva example also shows how difficult this process was in Continental Europe, where the end of the Old Regime took place in disruptive and violent circumstances when compared with the smoother evolution of institutions in England. In his seminal book, W.-W. Rostow remarked that

56 See FROMMEL, Bénédict (2005) *Versoix, patrimoine hydraulique*, Geneva.

57 For the Genevan printed calicoes industry, see the classical study by LEVY-LEBOYER, Maurice (1964) *Les banques européennes et l'industrialisation internationale dans la première moitié du XIXe siècle*, Paris, 51-53 ; and PIUZ, Anne-Marie (1983) "Notes sur l'industrie des indiennes". In: PUIZ, Anne-Marie (ed.) *A Genève et autour de Genève aux XVIIe et XVIIIe siècles,* Lausanne, 232-243.

58 See our study PAQUIER, Serge (2010) "D'un district industriel à l'autre. Histoire de la transition industrielle genevoise". In: TISSOT, Laurent ; GARUFO, Francesco ; DAUMAS, Jean-Claude ; LAMARD, Pierre (ed.) *Histoires de territoires*, Neuchâtel, 89-114, 90-94.

French elites lost the time and energy that might have been devoted to science by indulging in philosophy in an attempt to persuade the government to be more representative[59]. In Geneva, the Time of Revolution delayed the process of convergence between science and technology. After the serious social revolt of 1782, the Société des Arts, regarded by the Oligarchy as too liberal, was unable to carry on its activities and some scientific and liberal elites were forced to flee. During the Geneva revolution, the scientific and patrician elites had to defend their position, and finally integration with France between 1798 and 1813 delayed the activity of the Société des Arts. Science in Geneva was thus absorbed by the Parisian centre of gravity, as shown by the career of the physician Marc Auguste Pictet, who became General Inspector for imperial universities. At the end of the French annexation, Pyrame de Candolle could only state that the Société des Arts was an institution "qui mourrait de vieillesse"[60]. Its committees "ne s'assemblaient presque plus et les réunions générales se composaient de gens qui n'avaient presque pas de lien commun"[61]. The process of convergence between science and technology had to be renewed. Two members of the Société des Arts proved to be influential: the consulting engineer Daniel Colladon and his friend, the botanist Alphonse de Candolle, who were in charge of the Society for much of the 19th century.

Daniel Colladon belonged to a well known patrician family. Germain Colladon was hired from the Berry by Jean Calvin in order to create the juridical architecture of the *Rome protestante*[62]. Daniel, however, was only connected with the cadet branch of a merchant. One son was forced to leave Geneva in the 16th Century for preaching in the neighbouring territory of Vaud. Daniel's grandfather, a modest clock-maker, had re-established the family in Geneva in 1766. This branch of the Colladons therefore needed to climb the social ladder if it wished to attain the level of its Geneva collaterals who had distinguished themselves in law, theology and letters.

The future scientist and engineer Daniel Colladon had been steeped in the Republic of Letters since his childhood thanks to his father, who mod-

59 ROSTOW (1960), 58.

60 CANDAUX, Jean-Daniel ; DROIN, Jean-Marc (ed.) (2004) *Augustin Pyramus de Candolle, Mémoires et souvenirs (1778-1841)*, Geneva, 393.

61 *Ibid,* 392.

62 KADEN, Erich-Hans (1974) *Le jurisconsulte Germain Colladon, ami de Jean Calvin et de Théodore de Bèze*, Geneva.

estly taught classical letters at the Collège. His mother appreciated classical literature and was poet. It is necessary to emphasize that this background actually facilitated creation in science and industry, as underlined by the French thinker in industry, Claude-Henri de Saint-Simon (1760-1825). Indeed, this French reformer believed that his promised *Industrial Parliament* should in its *First Chamber of Creation* include not only two hundred civil engineers, but also sculptors, musicians, architects, poets and other creators in literature. On the hand, such people were able "de faire passer les passions", this essential ingredient for preparing societies for the new process of industrialisation, and on the other hand because the infrastructures thereby created should be agreeable and pleasant to use[63].

It is also interesting to mention Colladon's individual talents, such as a prodigious memory and a capacity for drawing. These were absolutely necessary skills for a leading engineer. In his youth, during a visit to his mother's cousins in Alsace, he expressed an interest in the mechanics used in textile manufacturing. Daniel's open spirit was also stimulated by interests outside the family, such as nature, theology and science. We may speak of a twofold sociability; the first made manifest mainly during the summer at the countryside homes belonging to his uncles, and later at the one owned by his father. In his autobiography, Daniel remembers with delight the periods of his childhood that he spent in the rural lands near Geneva[64].

There was also some degree of identification with Rousseau, since this branch of the Colladon family was active for the improvement of the Old Society, even if it was on the material point of view. When engineer Henri's father was searching the archives to ascertain the family genealogy, he was pleased to find that both families had taken the same road from the Berry at the same time, when they were received as refugees in Protestant Rome. Nevertheless, the engineer Daniel clearly dissociated himself from the pessimistic approach of the role played by Art and Science deployed in 1750 in the famous *Discours sur les arts et les sciences*[65]. In absolute opposition, the chief motivation for the leading Geneva engineers was to demonstrate the utility of science and technology in concrete fields.

Neighbours took turns in visiting each other in order to exchange experi-

63 YACINE, Jean-Luc (2001) *La question sociale chez Saint-Simon*, Paris, 252-256.
64 *Souvenirs et mémoires*, Genève, 1893, 4-35.
65 See COTTRET, Monique; COTTRET, Bertrand (2005) *Jean-Jacques Rousseau en son temps*, Paris, 132-147.

ences and ideas, to discuss all manner of subjects, and to play music or sing. The winter season was mainly organised around their building in the old town. These societies were dominated by *patres familias* who were regarded as playing a leading role in the restoration after the brutal Time of Revolution. They might be theologians, traders, scientists or agronomists, and later members of the emerging Protestant banks involved in new infrastructures, mostly in railways and gas lighting. Before assuming this role in a magnificent residence on the border of Lake Leman close to the city, Daniel Colladon was preceded by his father, who was the mayor of a distant rural municipality for 45 years.

Christopher Bayly has underlined the dynamic role played by this kind of little circle in the life of Protestant elites[66]. Daniel was inspired by the model of the Maurice family, which provides one of the best illustrations of the evolving Republic of Letters, moving from theology to letters and finally to sciences. Frédéric-Guillaume Maurice (1750-1826) was considered a hero when he accepted the post as the mayor of Geneva during the annexation of the city to France. Henri Colladon, Daniel's father, was a close friend of Frédéric-Guillaume's son, the Academician Jean-Frédéric Maurice (1775-1851), who at the Collège de France observatory was involved in the calculations of the *Mécanique Céleste,* published between 1799 and 1805 by the well-known scientists Lagrange, Laplace and Legendre.

After studying law at the Geneva Academy, at the age of 22 Daniel decided to become a scientist. Besides law, Daniel was educated in science by personalities like the physiologist Jean-Louis Prevost (1790-1850)[67]. He was also introduced to work in laboratories belonging to patrician families interested in science. However, the Geneva basis proved to be too limited and had to take its place on the Geneva-Parisian axis, which had arisen with the spread of the banking axis. The well-known Genevan Jacques Necker (1732-1804) was twice the head of French finances during the hard times of the military-fiscal crisis. His brother Louis (1730-1804) was not only a banker, but also a mathematician[68].

Daniel Colladon first embarked on a *stricto census* scientific career in the

66 BAYLY (2007), 124-125.

67 See SIGRIST (2003), 437-440.

68 See DE DIESBACH, Ghislain (2004) *Necker. La faillite de la vertu*, Paris; and for Louis: STELLING-MICHAUD, Suzanne (1976) *Le livre du recteur de l'académie de Genève (1599-1878)*, vol. 5, Geneva, 14.

Parisian centre of gravity, where he studied electricity with the well-known French scientist André Ampère. There he was able to work in the huge and costly laboratory at the Collège de France. After experiencing some early difficulties on joining this prestigious institution as an assistant, he turned to technology when he was elected assistant professor in physics at the newly created (1829) École Centrale des Arts et Manufactures. Three important consequences resulted from this move. First, Daniel was then closely linked to the French science of applied mechanics, which from the 1820s had a specific field of its own consisting of the Parisian mechanical industry[69]. This sector emerged from a fertile milieu composed of ex-apprentices from the clock industry and the manufacture of physical instruments. While this type of milieu could be found on a more modest scale in Geneva, the demand for mechanical machines did not really exist until the last quarter of the nineteenth century, when the American mechanised clock industry became a formidable competitor for the scattered collective of Genevan artisans. A second consequence was that his position as a professor at the Ecole Centrale provided Colladon with the opportunity to develop his teaching capacities by using models of machines created by specialists or by taking students to factories where steam engines were in use. Here, Daniel Colladon learned the scientific method which consisted in observing phenomena directly in their own context when he studied flora in his Alpine environment on excursions conducted by Pyrame de Candolle. These observations were followed up by intra-muros study with the help of books, collections and botanical gardens. Although it was difficult to transfer the principles governing natural phenomena to artificial systems, the transposition of the scientific method (precise observation and analysis) nevertheless offered many opportunities[70]. Thirdly, Daniel was able to develop his expertise, most particularly in steamers. While still a young man, he observed the first steamer on Lake Leman and wrote a report on the Geneva shore line. In France, he had to deal with numerous cases of boiler explosions. Daniel quite naturally sought to develop his expertise further by becoming a constructor of steamers, between Lyon and Geneva. However, he still lacked "shop culture", or experience gained while working in industrial firms, as recently noted by François Caron[71]. This

69 As remarked by CARON (2010), 86.
70 On the scientific method, see MOKYR, Joel (2002) *The Gifts of Athena*, Princeton/Oxford, 36-39.
71 CARON (2010), 120-121.

engineer mostly devoted himself to the science of applied mechanics on the Parisian model.

On his father's insistence, he eventually returned to Geneva in the mid-1830s, where he established himself as consulting engineer and professor in theoretical and practical mechanics at the Academy of Geneva. He extended his studies through the Société des Arts to the old pumping machine in the Rhône, beginning his career in Geneva with a project of large-scale water adduction[72]. Like most innovators, he inevitably found himself in a minority at first, meeting with a summary rejection from the government of the Restoration, which preferred to place its trust in French specialists in hydromechanics. Nevertheless, in this affair, Daniel found a back seat as an expert for the accounts of the Geneva government.

Colladon was eventually able to get his revenge through gas lighting. Thanks to his marriage with the daughter (Stéphanie Ador) of a new Genevan banker, he managed to bring the Protestant bank into the business. In agreement with the innovators, Saint-Simon regarded the new bankers as one of the mainstays of the future industrial world. Their function consisted in providing capital to entrepreneurs in charge of building the new infrastructures. Roads, waterways and later railways were at this time an appropriate field of activity for many reasons. Consulting history in the long term, Saint-Simon only took the power of economy and commerce into consideration. Arising in an inadequate "feudal" context, these dynamics were still able to create a more favourable context, a "bourgeois" one, in order to realize their full potential. Marx was to building on Saint-Simon's foundations when he coined the terms "infrastructure" and "superstructure".

For towns, regions and nations alike, the best way was to follow the trend of these dynamics. The question was how to do it, if not by building infrastructures which in the post-Napoleonic era provided the great advantage of linking the individual talents of engineers to the general interest. This was particularly important for societies that were searching for new values after the ineluctable destruction of the Old Regime.

72 See BG, Ms fr 3742, 3758/1 et 3758/2.

8.- A scientist in an industrial firm.

The gas industry provided Colladon, with his training in science, with a fine opportunity. Gas lighting was in fact a typically new industrial service with clear scientific roots. As Mokyr points out, gas was discovered through the search for what might be the fundamental components of nature. When burning wood and coal, scientists realized that it was capable of producing gas in great quantities. However, they did not know how to use all this gas[73]. But by following the Baconian program, backed up by the utilitarianism of Jeremy Bentham, scientists were also becoming more increasingly involved in industry. As François Caron notes, gas lighting was one of the first industrial sectors to establish close contacts with the academic world. Victor Regnault, professor at the Collège de France, headed the laboratory of the Parisian gas company during the Second empire of Napoléon III[74]. Interestingly enough, gas in Paris was linked with that in Geneva. In fact, the president of Parisian gas, Vincent Dubochet (1793-1877), was a native of Switzerland[75], and it is no surprise that Daniel Colladon used this contact not only for gas lighting, but also for numerous projects such as large-scale water adduction for Geneva and the Simplon Alpine railway tunnel. It should also be remembered that Colladon installed and developed a gas laboratory with the objective of improving the gas supply in Geneva. In the annual report of 1865 he wrote, "que peu d'industries en effet font plus d'essais d'améliorations que celle du gaz et, si souvent il convient d'admettre des changements dans la marche adoptée, il faut cependant le faire qu'après que l'expérience en a suffisamment sanctionné l'utilité"[76]. Moreover, Colladon came to regard the gas infrastructure globally as an "outside laboratory".

Heating systems were also a new industrial sector under investigation by scientists. According to Mokyr, one of the eminent "paradigmatic figures of the Industrial Enlightenment", Count Rumford[77], was among the fathers of

73 MOKYR (2009), 135-136.

74 CARON (2010), 102.

75 He was born without means in the Canton of Vaud at Chailly; see WILLIOT, Jean-Pierre (1999) *Naissance d'un service public: le gaz à Paris*, 288-293.

76 *Compagnie genevoise pour l'éclairage…* (1865), 19.

77 MOKYR (2009), 52-53. The works by Rumford are well known in Geneva. See *Correspondance sciences et techniques/Marc-Auguste Pictet (1752-1825)*, t 1 and 2, Genève, 1996, 1998. Texte établi et annoté par René Sigrist, préface de Jean-Claude Pont, introduction et prologue par Jean-Michel Pictet.

modern heating systems. Indeed, there existed a considerable social demand for heating, especially in a city like Geneva, located close to the Alps, where winters were harsh, particularly when a cold wind blew in the Lemanic region. Ever since the Restoration, public and private buildings had begun to proliferate, and scientists and technicians were searching for rational means of heating. Before the adoption of gas lighting in Geneva, Colladon had explored this particular field and had given lectures about it at the Parisian Ecole Centrale. Since 1838, and on the basis of the Perkins model in use in Zürich, he had trained in the speciality of heating systems a gifted student (Frederic Staib) of the Geneva Ecole Industrielle, a technical school created in 1830 on the initiative of the Société des Arts. Elementary chemistry, physics, mathematics and mechanics were taught in this school in the mornings and evenings to apprentices. The objective was to extend the social circle of those able to participate in "sustained improvements". Mokyr states that the English advancement was largely due to enlightened artisans[78]. The firm set up by Staib provided an important basis for the further development of the Geneva industry[79].

The link between heat and gas was made clearly evident in the coke sold as fuel to heating industries, buildings and households. Furthermore, as a result of the special attention given by the Society of Arts to the jewel in the crown, clock-making, a gas-powered furnace appropriate for gilding was designed by the Genevan chemist Alphonse Perrot-Turrettini[80]. As for stoves, the strategy was to start with an English technological product that could be improved for its adaptation to local conditions. For this industrial service, Perrot had the privilege of replacing General Dufour on the company board[81]. This enables us to understand better why after the new concession the firm was called the Compagnie Genevoise pour l'éclairage et le chauffage par le gaz. As was the case at the end of the 18th Century, when the Société des Arts gave science classes to clock-makers, this first stage was founded on many hopes. The annual report of 1848 mentions that «votre conseil d'administration a donné tout ses soins à l'établissement du gaz dans quelques ateliers d'horlogerie où

78 MOKYR (2009), 110-113.

79 For the trajectory of this firm in the 19th century, see WEIBEL, Luc (2008) *Jules Weibel. Un industriel au cœur de l'Europe*, Lausanne, disperse.

80 *Compagnie genevoise pour l'éclairage …*(1866), 17.

81 *Ibid*, 1876, 16.

ce mode d'éclairage à fort bien réussi»[82], although subsequently doubt was to dominate. In 1850, the board told the shareholders: "la prise de nouveaux abonnements a été satisfaisante; les ateliers de bijouterie et d'horlogerie restent néanmoins en arrière"[83]. In the main, clock-makers continued to resist the solutions proposed by scientists, as had already been the case in the infancy of the Société des Arts. Consequently, Perrot's furnace provided a new and useful opportunity for the clock-makers. New technological products should also bring solutions to the unproductive landscapes of Geneva. The gas company then attempted to sell another by-product, ammoniac, as an artificial fertiliser, but without great success.

Daniel Colladon's first task for Geneva gas was to draw in the republic of science and technology, and mostly on the Geneva-Parisian axis. As a former professor of physics at the Ecole Centrale des Arts et Manufactures, he chose one of his ex-students, Jean Rocher, to build the basic gas network in Geneva. Mindful of the development of the markets, Colladon went to Paris to select the best stove that could be adapted to the conditions in Geneva[84]. The objective was to develop the winter market with heat as well as light. In addition to social demand, François Caron considered the circulation of knowledge as another key factor in the development of technology. Previously we have seen how Daniel Colladon did not hesitate to move whenever necessary, in particular to the Parisian centre of gravity. He fully appreciated the direct observation of technologies within their own context. It is therefore hardly surprising that, obsessed by the improvement in Geneva gas, Colladon took advantage of his trip as a Federal representative at the first Universal Exhibition in London (1851). On his way there he visited all the French and English gas networks with similar characteristics to that in Geneva. Moreover, he waived his Federal salary to spend three more weeks studying recent improvements in the gas industry. In Paris, he contacted the professor of chemistry Persoz, who specialized in gas improvement, and together they devoted time to some experiments[85].

Daniel Colladon also conducted many experiments in his special gasometer. Previously we have mentioned the efforts made for the use of Swiss coal. Furthermore, and as noted by Caron, the principal gas companies car-

82 *Société genevoise pour l'éclairage…*(1848), 4.
83 *Ibid*, 1850, 4 ;1852, 4.
84 *Rapport fait au nom du comité…* (1845), 13.
85 *Société genevoise pour l'éclairage...* (1852), 16.

ried out many tests to analyse the quality of the coal from mines. In Caron's view, these test laboratories were an early version of the future Research and Development Departments in commercial firms, and were to constitute the main basis of the Mass Society in the 20th century[86]. The Geneva test gasometer was able to measure exactly the decline in quality of the coal extracted from around Saint-Etienne[87]. Despite putting pressure on the Saint-Etienne mining companies, Geneva gas had to wait until the mid-1870s before there was a satisfactory railway connexion with the Saar basin.

The board was relieved when activity was not disrupted by the weather[88]. Then the engineer's job was again to fight discontinuity and interruptions, a common feature of services and general activities in pre-industrial societies. For example, motive power furnished by water wheels was notoriously subject to climatic variations. More relevantly for our case, transport regularity was also affected by seasonal changes in the weather[89]. Thanks to the convergence between science and technology, a regular and reliable, large-scale service appeared as a realistic goal. In the Baconian program, useful knowledge is the master of nature! Research into continuity was also linked to the importance of the capital invested in the affair, investors demanded profits all throughout the year. Daniel Colladon and the company board members pooled their efforts to find the best solution for transporting coal from Lyon. They considered the Rhône as a waterway, but the annual report of 1847 mentions that this solution might only lead to more interruptions in transport[90]. In fact, navigation on the upper river is difficult because of the turbulent waters of the Alps. The company was therefore relieved when the railway between Lyon and Geneva was finally opened in 1858.

As regards the market, the main objective was also regular development. Marketing strategies were adopted; for example, material for lighting was exhibited in a magnificent new building located at the foot of the old town. Colladon took pains to find the right size for all the components: gasometers, epurators, stocks of coal, diameters of pipes and so on. This was a difficult task because of peaks of consumption during the long nights from December to

86 CARON (1997).

87 *Société genevoise pour l'éclairage…* (1855), 17.

88 *Ibid*, 1850, 3.

89 Daniel Roche states: «la tyrannie des saisons». ROCHE, Daniel (2008) *La culture équestre de l'Occident (XVIe-XIXe siècle), t.1 : Le cheval moteur*, Paris, 47.

90 *Société genevoise pour l'éclairage…* (1847), 18-19.

February. The company engineer believed that it was impossible to refuse this demand for increased supply, and in such circumstances all the equipment had to be capable of handling more than just average consumption. Consequently, the size of all the components had to be «prévu et monté sur une échelle qui dépasse de près du double celle qui suffirait à la consommation moyenne». In his *Rapport de l'ingénieur* (1853) Daniel Colladon wrote: «c'est on ne peut se le dissimuler un inconvénient majeur inhérent à notre genre d'industrie»[91]. We can call this process "learning by exploiting mass infrastructures". The lesson was to prove useful for the next more difficult stage, when the hydroelectric infrastructure was adapted from the supply side to important variations in river flows, and from the demand side to winter peak load[92].

Colladon saw the gas lighting network of Geneva as a "laboratory out of the wall"; not only for its improvements but also from a strictly scientific point of view. Just before its inauguration, he used the network to test physical principles on the resistance of fluids in tubs. One of his ambitions was to introduce corrections into existing textbooks as a result of accurate observations made on actual industrial infrastructure, something that was unsatisfactory and more costly in the laboratory. The Genevan engineer realized that resistance was less than that estimated by the science of his time when the diameter of the pipes was greater. To the existing macro-innovations, and the "sustained improvements" described by Mokyr as a key factor, we can add the creation of new macro-inventions. As a continuation of the studies of the French physician Antoine Parent, Colladon conceived of a compressed air system driven by hydromechanical power for boring tunnels under the Alps, even before the first engineers from to the Realm of Sardaigne used this technology at the Mont-Cenis (1861-1871). In the 1870s, with the help of another leading Genevan engineer, Théodore Turrettini (1845-1916), who was also the member of an old patrician family, Colladon participated in the boring of the 15 kilometres-long Saint-Gothard railway tunnel in the Alps.

91 *Ibid*, 1853, 18. See also the interesting analysis of the load factor in the classical study: PARKE HUGHES, Thomas (1983) *Networks of power. Electrification in Western Society (1880-1930)*, Baltimore/London, 217-219.

92 TURRETTINI, Théodore (1900) *Usine de Chèvres. Notice historique et descriptive*, Geneva, 52-53.

9.- Following "sustained improvements" on a local scale: evaluation on external markets.

The Geneva example also showed that local experience could be evaluated on external markets. This took the form of transnational business activities. This tendency may be regarded as a Swiss feedback in the scientific and technical republic, and was the result of a twofold process: first, the continuous drawing in of centres of gravity, and secondly the "sustained improvements" driven by adaptation to national conditions. The motivation was also to bring material progress to the culturally rich Mediterranean, an area regarded as the roots of Europe, but still backward in economic terms.

In the Geneva holding, Stuttgart served as an "outdoor laboratory" for German advancement in the organisation of a technical network. It was a school for Genevan engineers sent there by Colladon to improve their know-how[93]. In fact, the circulation of gas lighting followed the spread of the railways during the 1860s. Marseille gas, which was well situated on the main line linking Paris-Lyon-Marseille, often referred to as the PLM, was a huge technical complex consisting not only of gas but also of furnaces. Linked to Geneva by the Rhône waterway, Marseille held particular importance for Geneva merchants as a natural open door to Mediterranean markets. The other French towns on the Mediterranean, Antibes, Cannes and Menton, formed part of the development of winter tourism. Many Geneva citizens, whether patricians or radicals (the Republican Party opposed to the Liberal-Conservatives) were frequenting these towns more and more, sometimes for pleasure, sometimes to recover from ill-health, and sometimes they went there to die.

Italian locations were also very attractive for many reasons. Strictly from a business point of view, like its European counterparts, this new nation-state had to install new infrastructures, mostly railways and urban networks. At the same time, the cultural attraction exerted by Italy was strong. For the Genevan elite, who were well-educated in science as well as in classical culture, a Grand Tour through Italian cities had been almost a cultural obligation since the late 18th century[94]. On a larger scale, the *Italia* written in 1855 by the

93 *Compagnie genevoise pour l'éclairage…* (1862), 16; (1865), 19.

94 See VAJ, Daniela (ed) (1993) *Amélie Odier. Mon voyage en Italie (1811-1812)*, Geneva, 9-52.

Parisian Théophile Gautier, described these attractive cities with real talent[95]. It is not surprising that many young engineers wrote to Daniel Colladon requesting employment in industry in Italy. The Bologna location was important for Geneva gas because it was a central railway junction, and between 1862 and 1864 Colladon himself lived and worked in Naples, although he was more than sixty years old. A PhD thesis currently being written at Naples University clearly shows the international involvement of French, Belgian and Swiss financiers and technicians[96]. The old concession was in the hands of the Crédit Lyonnais, but in order to extend the gas supply in the city, the Naples City Council opened a new concession, which was finally awarded to Parent & Schaken, a Belgian railway company already well established in Paris.

Besides this international connexion, it is necessary to stress the role played by family relations. In fact, it was one Daniel Colladon's cousins, the banker Auguste Dassier (1790-1862), known as a financier of French and Swiss railways, who entrusted the task to him. At this time, the old consulting engineer was fighting against summer heat and new difficulties due to the death of his cousin. Things were not so easy because Dassier's son-in-law, the polytechnician Fernand Raoul Duval (1833-1892), was still a young man and was without sufficient power. As a result, from correspondence between Duval and Colladon we learn that Colladon was aware of everything that was going on in this important urban affair. Capital was rapidly declining and Duval suggested that everything should be noted down in case the affair went to court. Thanks to Daniel Colladon's efforts, the famous heir of the Colladon/Ador, Gustave Ador (1845-1928) dynasty, president of Geneva gas (1892), future president of the Red Cross (1910) and of the Swiss Confederation (1917), was able to write to his family from Naples in the Spring of 1902, "je retrouve Naples idéal –son golfe est une merveille- la mer bleue est sans une ride, on dirait un miroir (…), puis je me souviens qu'il faut aller voir des usines, implorer le syndic, et consulter nos avocats – Cela me ramène sur terre ferme"[97].

95 GAUTHIER, Théophile (1855) *Italia*, Paris.

96 CAIAZZO, Francesca [2011] *Reti di capitali e reti di servizi a Napoli: la Compagnie Napolitaine d'Éclairage et de Chauffage par le Gaz (1862-1920)*, under the direction of Maria Carmela Schisani, Università di Napoli Federico II, Facoltà di Economia.

97 Letter to his son-in-law, March 9th, 1902. In: BARBEY, Daniel; DURAND, Roger (dir.) (2009) *Gustave Ador. Lettres à sa fille Germaine et à son gendre Frédéric Barbey, t. 1 (1889-1913)*, Geneva, 155.

We have seen how the transfer of basic technology to Switzerland could open the door to "sustained improvement" valuated on external markets. This kind of feedback to the republic of science and technology was the result of a permanent connexion between local infrastructures and industrial centres of gravity, together with the accumulated experience acquired in the local "outdoor laboratory".

While stressing the key qualities of the technician Daniel Colladon, we should not overlook his faults. He was mistaken in his belief that electricity was only a natural phenomenon that would never be able to compete with the gas lighting. He was also mistaken in thinking that the public sphere could only manage "persons" and not "things". In the view of this consulting engineer, there was no place for Municipal, Cantonal or Federal firms in the world of mass services supported by new infrastructures. Most particularly in Switzerland, from the 1880s on, when the wave of Municipalisation in urban infrastructure and the process of Federalisation of the railways began, Daniel's thought was flying in the face of fact. In terms of the convergence between science and technology, Colladon gave too much importance to science and not enough to technology. His attempts at innovation therefore ended in failure. In Caron's view, he lacked "shop culture", an indispensable ingredient for innovation in the field of industry, thanks to which the English dynasty of the Browns who had settled around Zürich was able to play a leading role in the Swiss mechanical industry.