Nazi autarky policy and alumina without bauxite: The Séailles-Dyckerhoff Technology 1936-1945

Introduction

The economic policy of the Nazi regime was geared to autarky and rearmament practically from the outset. In view of the experience of the sea blockade of the Great War, the intention was to prepare for a situation where, in the event of war, Germany would again be cut off completely or largely from imports of raw materials and agricultural products. For this reason, among other things, substitute industries were built up on a large scale with government aid and generally on government initiative, and considerable funds were spent on R&D to develop new substitutes for goods for which one was dependent on imports. Aluminium played an important role in Nazi economic policy, as it was not only a central raw material for aircraft production, but also a very important substitute for non-ferrous metals, as will be shown in this article. As an input of aluminium alumina was of crucial importance for Nazi rearmament and autarky policy. However, bauxite had to be imported, which is why its substitution with German raw materials became the focus of the Nazi regime, especially from 1936 onward. In the first chapter, an overview about the structure of the aluminium sector, its expansion and the underlying driving forces in the Nazi economy will be given. Afterwards, I will show on the example of the Séailles-Dyckerhoff technology, the most promising of the various processes of replacing bauxite with German raw materials, how private business interests and the favourable conditions created by the Nazi regime interplayed from 1936 on resulting in the development of an innovative process for the production of alumina.

The role of the aluminium sector in the Third Reich

Before the Great Depression, Germany was one of the world's largest consumers of aluminium.[1] The production volumes of the German aluminium producers, the state-owned *Vereinigte Aluminiumwerke* (*VAW*) and the joint venture between *IG Farben AG* and *Metallgesellschaft* in Bitterfeld, were fixed by the international aluminium cartel. According

[1] Jonas Scherner, *Die Logik der Industriepolitik im Dritten Reich. Die Investitionen in die Autarkie- und Rüstungsindustrie und ihre staatliche Förderung*. Stuttgart: 2008. Generally on the aluminium industry, see Manfred Knauer, *Hundert Jahre Aluminiumindustrie in Deutschland (1886–1986): die Geschichte einer dynamischen Branche*, München 2014.

to this agreement, the German subsidiary of the Swiss producer *AIAG* did not belong to the German group.[2] By far the largest producer in Germany was *VAW*.[3] In the case of German alumina production, there was no quota system for producers.[4] There were three producers here, *VAW*, the *AIAG* subsidiary *Martinswerk* in Bergheim, and *Gebr. Giulini GmbH* in Ludwigshafen, a family-owned chemical company founded in 1823 that had been producing alumina in addition to basic chemical products since 1860. *Giulini* sold its alumina almost exclusively to *VAW*. The joint venture between *Metallgesellschaft* and *IG Farben AG* in Bitterfeld was completely dependent on the purchase of alumina from outside.

During the Third Reich, the aluminium sector, i.e. aluminium production and its upstream and downstream industries – alumina production and aluminium processing – became one of the fastest growing sectors of German industry, which was booming during these years.[5] Soon after Hitler had become chancellor, German consumption and production of aluminium increased rapidly. As early as 1934, the German aluminium industry was already producing 37,200 metric tons, about 10% more than in 1929, thus recovering faster than aluminium production abroad.[6] In spite of this increase German production could not meet domestic demand which stood at 48,000 tons and was almost 50% larger than in 1929. This implied that imports had to be increased and stocks depleted. The massive expansion of aluminium production and also its upstream alumina production continued in the following years. In 1939, German aluminium production was 199,500 tons, and then peaked at 250,100 tons in 1943. In accordance with a quota arrangement among German aluminium producers of January 1937, the combined share of *VAW* and the joint venture of *IG Farben AG* and *Metallgesellschaft* in Bitterfeld was to be 86 percent and that of *AIAG* 14 percent.[7] Given the capacity agreement between *IG Farben AG* and *VAW*, this meant that *VAW* accounted for the vast majority of German production (about 70 percent). In alumina production, in contrast to

[2] On AIAG, see Cornelia Rauh, *Schweizer Aluminium für Hitlers Krieg? Zur Geschichte der ‚Alusuisse' 1918-1950*, Munich 2009.
[3] E. Rauch, *Geschichte der Hüttenaluminiumindustrie in der westlichen Welt*, Düsseldorf 1962, p. 123.
[4] For Giulini, see. Gebr. Giulini (ed.), *150 Jahre Giulini-Chemie*, Ludwigshafen 1973.
[5] Generally on the expansion of the German aluminium sector, see Rauch, *Hüttenaluminiumindustrie*; Knauer, *Aluminiumindustrie*; Peter Josef Belli, *Das Lautawerk der Vereinigte Aluminium-Werke AG (VAW) von 1917 bis 1948. Ein Rüstungsbetrieb in regionalen, nationalen, internationalen und politischen Kontexten (zugleich ein Beitrag zur Industriegeschichte der Niederlausitz)*, Berlin 2012; Gottfried Plumpe, *Die IG-Farbenindustrie-AG, Wirtschaft, Technik und Politik 1904-1945*. Berlin 1990, 409-424; Scherner, *Industriepolitik*. On the expansion of the German industry during the Third Reich, see Jonas Scherner, Industrielle Entwicklung und Investitionen, in: Marcel Boldorf/Jonas Scherner (eds), *Wirtschaft im Nationalsozialismus,* (forthcoming, De Gruyter).
[6] Länderrat des Amerikanischen Besatzungsgebiets (ed.), *Statistisches Handbuch von Deutschland 1928-1944*, Munich, 1949, p. 293.
[7] For the following, see Scherner, *Industriepolitik.*

aluminium production, an increasing share of *VAW* in German capacity can be observed. It rose from about 32 percent in 1936 to about 60 percent in 1943. This was due to the fact that *Giulini* was not willing to expand its alumina production as much as its constant share of *VAW*'s alumina supply would have required. *Giulini* feared that in the case of decreased aluminium demand *VAW* would predominantly rely on its own alumina capacities. *Giulini* would have only increased its alumina production if it could have run its own aluminium plant. This, however, would have required a concession by the state, which the company was never successful in securing.

The growth in aluminium production and also in consumption (the latter requiring imports throughout the 1930s despite the massive expansion in production) was unusually high by international standards[8] and was favoured by a number of special conditions. First of all, the massive increase in German production was only made possible by the fact that, in view of the massive increase in demand in Germany, the international aluminium cartel had already lifted the production restrictions for Germany at the beginning of 1935.[9] Secondly, German demand was massively stimulated by the autarky policy that began quickly after Hitler came to power, and was deepened and accelerated in 1936 by the Four-Year Plan.[10] The background to the Nazi autarky policy was, on the one hand, Germany's balance-of-payments problems[11] and, on the other hand, Hitler's desire, in view of the imperialistic aims of Nazi foreign policy, to become as self-sufficient as possible and to be prepared for a possible blockade by the prospective opponents in a future conflict, i.e. France and Britain. Accordingly, from 1934, German authorities started to prohibit the use of many non-ferrous metals, for which Germany was predominantly dependent on imports from overseas, for specific purposes, which increased the demand for possible substitutes.[12] Aluminium in particular played an important role as a substitute material. It is true that bauxite, the usual raw material for aluminium production, had to be imported. However, the foreign exchange burden of bauxite accounted for only a relatively small (7%) percentage of the total production costs per one metric ton of aluminium, and was thus significantly lower than that

[8] O.E.E.C. (ed.), *Statistical Bulletins: Industrial Statistics 1900-1955*, Paris 1955, p. 89.
[9] Scherner, *Industriepolitik,* pp. 233-4.
[10] On the Nazi autarky policy and the Four-Year-Plan, see D. Petzina, *Autarkiepolitik im Dritten Reich: Der nationalsozialistische Vierjahresplan,* Stuttgart, 1968.
[11] On Germany’s balance of payments problems, see for example J.A. Tooze, *Wages of Destruction: The Making and Breaking of the Nazi Economy,* London, 2006, pp. 71–96.
[12] Jonas Scherner, Preparing for the Next Blockade: Non-ferrous Metals and the Strategic Economic Policy of the Third Reich, *English Historical Review* (2022) ceac063, https://doi.org/10.1093/ehr/ceac063

incurred in the supply of copper or tin, which aluminium was to replace as far as possible.[13] Because of the high proportion of German value added in aluminium production, Nazi propaganda considered aluminium a "German" metal.[14]

Copper in particular was to be replaced by aluminium. Germany was one of the largest consumers of copper worldwide and was highly dependent on imports from overseas. With RM 399 m. spent on imports of refined copper and copper ores, Germany spent far more than on mineral oil or iron ores; overall, it accounted for 7% of Germany's import volume of raw materials and semi-finished goods in 1928.[15] 50% of Germany's copper consumption went into the electrical industry.[16] Therefore, in 1934, as part of the above-mentioned prohibition of the use of nonferrous metals for some purposes, the Nazi government determined, among other things, that aluminium, and no longer copper had to be used in open wires. In this case, Germany simply adopted what had become the rule in other countries as in Canada or the USA where in 1932 80% of the power network consisted of open wires out of aluminium.[17] This plus numerous others prohibitions had the effect that by 1936/37 almost 8% of domestic copper consumption was already being saved by the increasing use of light metals.[18] Substituting copper with aluminium continued over the next few years: In the late 1930s, substitution with aluminium reduced Germany's domestic copper consumption by almost 25%.[19] In 1938, the German electrical industry alone consumed 40,000 tons of aluminium, more than 10 times as much as before the Great Depression.[20] Its share of German aluminium consumption was just under a quarter.[21] Other uses included the substitution of tin or the use

[13] Jonas Scherner, Staatliche Förderung, Industrieforschung und Verfahrensentwicklung: Die Tonerdeproduktion aus deutschen Rohstoffen im Dritten Reich, in Rüdiger Hachtmann/Florian Schmaltz/Sören Flachowsky (eds.), *Ressourcenmobilisierung. Wissenschaftspolitik und Forschungspraxis im NS-Herrschaftssystem*, Göttingen: Wallstein 2017, pp. 286-325

[14] Helmut Maier, *Forschung als Waffe. Rüstungsforschung in der Kaiser-Wilhelm-Gesellschaft und das Kaiser-Wilhelm-Institut für Metallforschung 1900 bis 1945/48*, Göttingen 2007, p. 371.

[15] *Statistisches Handbuch*, p. 398.

[16] Max Hessenland, *Deutschlands Kampf um seine Rohstoffe*, Munich, 1938, p. 82.

[17] Knauer, *Aluminiumindustrie*, p. 115.

[18] Calculated on the basis of Scherner, Preparing, table. 2.

[19] On German substitution of copper with aluminium, see BArch R 3112/13, note, 19 Dec. 1939; on German domestic consumption, see BArch R 3112/27, consumption, fol. 25.

[20] For consumption of the airforce in 1938, see BArch RW 19/3076, Rohstoffversorgung der Wehrmacht, 1937-30.6.1939, Übersicht über die Verteilung der Rohstoffkontingente. Aluminium, 23. June 1939; for consumption of the electrical industry, see Schwarz, 122; Knauer, *Aluminiumindustrie*, p. 218.

[21] For consumption, see United States Strategic Bombing Survey (USSBS), *The Effects of Strategic Bombing on the German War Economy,* Washington, DC, 1945, p. 263, table 83.

of aluminium for deoxidation of steel in order to substitute for manganese.[22] The increasing use of aluminium during this period was also favoured by massively improved processing technologies, which greatly increased its competitiveness during the 1930s.[23]

Not surprisingly, rearmament was also important for the massively increased demand for aluminium in Germany. However, compared to the autarky-induced demand, this occurred only somewhat delayed, since, given the restrictions of the Versailles Treaty, an air armament industry had to be created first, and aircraft types had to be developed.[24] Even after this was done in the late 1930s, the air force's share of German aluminium consumption was only about 25%, i.e. no higher than the electrical industry's share for copper substitution. [25] Overall, the share of total Wehrmacht demand in German aluminium consumption in the late 1930s was slightly less than 50%.[26] However, during the war when German production of aluminium and especially also of reclaimed aluminium expanded further[27], the Wehrmacht rapidly became the largest consumer of aluminium, but without crowding out the substitution-induced consumption of aluminium, which increased further in absolute terms.[28]

Yet, government-induced demand for aluminium was increasingly not enough for aluminium and alumina producers to offset the risks that companies saw in the very large capacities enlargements that the state wished for. They could not rule out that government-induced demand could only be of a temporary nature, i.e. before the investments in the new capacities had been amortized.[29] Given this risk perception, the government changed its aluminium price policy. After the Reich had initially decreed a reduction in the price of aluminium at the end of 1934 in order to create an incentive to substitute copper with the light metal, price policy in the following years aimed at cushioning the risks perceived by the companies, by

[22] Andreas Zilt, »Die Mangannot verlangt ganze Arbeit!«. Manganersatzverfahren und Sparstrategien der deutschen Stahlindustrie, in Elisabeth Vaupel (ed.), *Ersatzstoffe im Zeitalter der Weltkriege. Geschichte, Bedeutung, Perspektiven*, Munich 2021, pp. 135-166, here pp.155-6.
[23] Knauer, *Aluminiumindustrie*, p. 117.
[24] Generally on the Ggerman airforce industry, see Lutz Budraß, *Flugzeugindustrie und Luftrüstung in Deutschland 1918-1945*, Düsseldorf, 1998.
[25] For consumption of the airforce in 1938, see BArch RW 19/3076, Rohstoffversorgung der Wehrmacht, 1937-30.6.1939, Übersicht über die Verteilung der Rohstoffkontingente. Aluminium, 23. June 1939; for consumption of the electrical industry, see Schwarz, 122; Knauer, *Aluminiumindustrie*, p. 218,
[26] For consumption of the Wehrmacht in 1938 and the first half of 1939, see BArch RW 19/3076, Rohstoffversorgung der Wehrmacht, 1937- 30.6.1939, Übersicht über die Verteilung der Rohstoffkontingente. Aluminium, 23. June 1939; for German consumption, see *Statistisches Handbuch*, p. 293.
[27] BArch R 3/1797, Statistische Schnellberichte zur Kriegsproduktion, fol. 14.
[28] BArch RW 19/2336, fol. 10; Knauer, *Aluminiumindustrie*, p. 218
[29] For the following see Scherner, *Industriepolitik*; Jonas Scherner, Nichteisenmetalle: Bergbau und Verhüttung, in: Marcel Boldorf/Jonas Scherner (eds.), *Wirtschaft im Nationalsozialismus,* (forthcoming).

setting prices at a level, which was quite high when compared to production costs. While this method of price fixing solved one problem, it restricted the substitution of copper or tin via the price mechanism, which is why the above-mentioned negative instruments were also used, i.e. bans on the use of copper, for example, in order to steer consumers in the desired direction.

It should be clear by now that aluminium played a key role in the Nazi economic policy. This was also reflected in the level of investments in the aluminium and alumina industries, which among the autarky industries was surpassed only by those producing synthetic fuel and synthetic rubber, and which was about the same level as investment in the cellulose fibre industry.[30] Although in the 1930s some bauxite was still imported from countries from which no supplies could be expected in the event of war, either because they were potential adversaries in a conflict or because an anticipated blockade might cut off supplies, the German war planners saw bauxite supplies as secure at least in the medium term in the event of war.[31] First, they had very high bauxite stocks that could meet German needs for years, and second, they assumed that supplies from countries allied to Germany, i.e. predominately from Hungary and Italy could be increased in the case of war. Italian wartime supplies of bauxite were even fixed in a pre-war treaty between Germany and Italy which specified wartime supplies of many goods between both axis partners in the case of war. Nevertheless, in spite of this German perception, that bauxite supply would be secure at least in the medium-term, from the mid-1930s onward up to the end of the war, the state and German companies made extensive and costly attempts to develop an alternative to imported bauxite from German raw materials, as will be shown in more detail below. Why did they take on these costs and what was the role of the state and what the role of private companies? Were the attempts successful?

Attempts to produce alumina without bauxite: finding adequate technologies 1933/36-38

In view of Germany's balance of payments problems, research institutes and companies alike began shortly after Adolf Hitler had become chancellor to examine technologies which could

[30] For investment data, see J. Scherner, The Beginnings of Nazi Autarky Policy: “The National Pulp Programme” and the Origin of Regional Staple Fibre Plants, *Economic History Review*, (2008), pp. 867–95, here p. 870, table 1; Scherner, *Industriepolitik*, p. 234; Scherner, Staatliche Förderung, p. 384.
[31] Scherner, Preparing.

replace or reduce bauxite imports by using domestic alumina-containing.[32] As in some other fields, these considerations could build up and rely on technologies which had been developed during the Great War and its immediate aftermath.[33] German bauxite deposits were only small, and were also characterised by the fact that the alumina content was significantly lower than that of good bauxites. Thus, Imperial Germany's war administration decided to use these deposits only in extreme emergencies for aluminium production, and otherwise only for other purposes. At that time, only clays were known as substitutes for bauxite. German clays, however, had a much lower aluminium oxide content and significantly higher silica content than bauxite. Thus, an acidic process was needed. Even though a technology in principle was available, such plants were never built during the Great War (and in the 1920s).[34] First, production costs would have been very high because the use of acid was very expensive. Second, the use of German clays with their high silica content increased the use of coal and energy. Third, such alumina plants required bigger investments than plants processing good bauxites.[35] In addition, the construction of new plants required a longer construction period, and there was not enough experience with the acid processes to ensure with certainty that the aluminium produced from this alumina met the requirements of the army administration in terms of purity.[36] Finally, Imperial Germany soon had access to extensive bauxite deposits in Istria, Hungary, and Dalmatia via the ally Austria-Hungary.

In 1933, *VAW,* which had carried out trials with its sulphuric acid alumina (ST) process during the 1920s but had stopped it because it seemed clear that the process could not produce alumina at competitive costs, resumed its trials.[37] For the time being, however, the company did not receive any state funding for these trials, which used German clay as the raw material. Apparently, in 1933 the Nazi authorities were not very interested in such processes at first, which was probably due to their lack of economic viability.

[32] Maier, *Forschung*, p. 385f; BArch R 3112/150, Dr. Eberhard Neukirch, Die Entwicklung des Leichtmetallausbaues im Vierjahresplan mit besonderer Berücksichtigung des grossdeutschen Freiheitskampfes ab 1939, fol. 60

[33] For the following, see Albrecht Czimatis, *Rohstoffprobleme der deutschen Aluminium-Industrie im Rahmen ihrer wirtschaftlichen Entwicklung*, Diss., Dresden 1930, pp. 48-50. On technologies which were revitalized during the Nazi period, see for example for sulphuric acid production on the basis of gypsum, see Erik Reißmann, Schwefelsäure aus deutschem Rohstoff, 1235-7, Vierjahresplan, 3 Jg, November 1939.

[34] Czimatis, *Rohstoffprobleme*, pp. 99-100; 107-8; Belli, *Lautawerk*, pp. 185-6; 239.

[35] BArch R 3101/32162, Dr. E. Neukirch, Vortrag vor dem NSDAP-Führungsstab München am 21.9.1942, Thema: Leichtmetalle, fol. 34.

[36] Czimatis, *Rohstoffprobleme*, pp. 84-5.

[37] Scherner, Staatliche Förderung.

With the implementation of the Four-Year Plan in 1936 the authorities began to massively promote processes for alumina production from German raw materials. [38] The Four-Year Plan administration, for example, instructed *VAW* to carry out trials with various processes known in Germany at that time. In 1937, *VAW* decided to build a small ST pilot plant at the Lautawerk and began construction in 1938. Yet, the alumina produced in this pilot plant was five times more expensive than imported alumina.[39]

The most imported of these processes promoted by the state was the later so-called Séailles-Dyckerhoff process of the cement producer *Dyckerhoff Portland Zementwerke AG*, a medium-sized company that employed about 2,600 people in several production locations in 1938 and had its headquarters in Mainz-Amöneburg.[40] In the autumn of 1936, the Four-Year Plan administration put massive pressure on leading representatives of *Dyckerhoff* to become involved in the field of alumina production from German raw materials.[41] Cement producers were an obvious addressee in this respect for the Four-Year Plan administration, as they processed clay. At the same time, the German authorities tried to create incentives so that the company would be interested in such an engagement. The Reich Ministry of Economics (RWM) and the Four-Year Plan administration determined that no restrictions could be placed on the construction of plants for the utilisation of those raw materials for cement that resulted from the production of alumina. This meant, however, that *Dyckerhoff* could circumvent the quantitative restrictions imposed on cement producers by the area cartels and the ban on new construction imposed by the RWM in 1936 by taking up alumina production. In addition, the Four-Year Plan administration repeatedly pointed out to *Dyckerhoff's* managers that, despite the strong expansion of the German aluminium and alumina plants that had already taken place in the preceding years, a massive expansion of capacity was still planned by the state in the long term. According to the intention of the Four-Year Plan Administration, part of the corresponding alumina capacities to be expanded should be based on German raw materials.

[38] Scherner, Staatliche Förderung.
[39] Scherner, *Industriepolitik*
[40] On this company see, Manfred Pohl, *150 Jahre Dyckerhoff. Ein Unternehmen im Wandel der Zeit*, Frankfurt, 2014.
[41] For the following, see BArch R 2/154, Walter Dyckerhoff, Die Tonerdefabrik Stramberg. Ihre Entstehung und Entwicklung bis zum Jahresanfang 1943, 1943, fol. 29-51; Scherner, *Industriepolitik.*

Due to *Dyckerhoff*'s business contacts with the French cement producer *Société anonyme des Ciments Français*, the technical director of *Dyckerhoff*, learned of experiments that the French chemist Jean Charles Séailles had carried out on the production of alumina from highly siliceous bauxites.[42] In this process, this low-grade bauxite is mixed with lime and burned at about 1400 degrees to form a clinker. The ground clinker is leached out with water, and this solution is processed by precipitation with lime, similar to alkaline processes. Lime is again added to the residue from this process, and from this – a special feature of this process – a cement rich in iron oxide is obtained in a second step, which was more durable and cohesive than normal cement and could previously only be produced with the addition of chemicals. *Dyckerhoff*'s technical director, Walter Dyckerhoff, believed, based on his experience in the field of lime silicates and lime aluminates, that German raw materials could also be processed in a similar way. Therefore, after consultation with the RWM and the Four-Year-Plan administration, and equipped with extensive foreign exchange permits, he travelled to France at the end of 1936 to conclude a contract with Séailles. The successful negotiations resulted in *Dyckerhoff* receiving the rights for the Reich, among others, and Séailles for a number of Western European countries. Thereafter, *Dyckerhoff* began conducting extensive tests with different raw materials for which it spend a substantial amount in the following years.

Why was the company willing to cover at its own the substantial research expenditures for this process during the next years? Two incentives were already mentioned above – first, that it was expected to produce a high quality cement as a by-product, and second, that by taking up alumina production, *Dyckerhoff* could circumvent the quantitative restrictions imposed on cement producers by the regional cartels and the ban on new construction imposed by German authorities in 1936. Yet, two further incentives were added from 1938 on.

These additional incentives, from the management's point of view, were the result of the fact that in 1938, in the course of the tests carried out by *Dyckerhoff* with various raw materials, the prospects for the process improved dramatically. The chemists in *Dyckerhoff's* laboratory in Amöneburg discovered, that the process also worked with ash residues (which had an

[42] For the following, see Scherner, Staatliche Förderung.

alumina content of 20-30%)[43] and ash heaps resulting from the washing out of raw coal.[44] These residues were not only abundant, but could also not be used for any other purpose. The coal ash produced annually in the Ruhr region alone, for example, allowed the production of 1,350,000 tonnes of alumina per year, which would have been enough to produce more than 650,000 tonnes of aluminium – four times the amount produced in Germany in 1938. Especially important, from the point of view of the company, was that Walter Dyckerhoff expected that his process based on wash mountains or coal ash would be competitive with alumina produced out of bauxite.[45] He also expected that aluminium demand would increase worldwide, but that bauxite deposits would be exhausted in some time. In addition, *Dyckerhoff*'s Chairman of the Board, Fritz von Engelberg, saw alumina technology as promising because it could be assumed that in the future the extraction of cement from lime, clay and coal would be increasingly displaced by the extraction of cement from waste products of the chemical and metallurgical industries.[46] In other words, it was also hoped that research into alumina extraction would secure a competitive advantage in the company's core business.

The Four-Year Plan authority was also in summer 1938 enthusiastic about this discovery in *Dyckerhoff*'s trials.[47] From the point of view of the Four-Year Plan administration, the process was interesting not only because cement and alumina could be obtained from worthless coal ash, but also because ash disposal could also be carried out, a problem that was becoming more important in view of the fact that, due to the increased energy demand, there was an increasing need to resort to coals with a high ash content. Although it was subsequently agreed to attach a pilot plant to a cement factory near Bonn in which *Dyckerhoff* had a stake, with part of the investment risk to be borne by the state, the project was not implemented until the outbreak of war. On the one hand, strategic considerations seem to have played a role, since most German alumina plants were already massed near the western border of the Reich. In addition, the German government had to implement austerity measures due to the extremely critical budget situation at the end of 1938, so that only those projects of the Four-Year Plan were to be pursued that relieved the foreign exchange balance

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[43] Wilhelm Fulda/Hans Ginsberg, *Tonerde und Aluminium. Ergebnisse und Erfahrungen aus der Betriebspraxis 1920-1950, Vol. 1 Tonerde*, Berlin 1951, p. 178.
[44] For the following, see Scherner, Staatliche Förderung.
[45] StadtAWi WA5/949, Denkschrift über die zukünftige Entwicklung unseres Tonerdeverfahrens, 1938.
[46] StadtAWi WA5/870, Notiz, 25.8.1941.
[47] For the following, see Scherner, Staatliche Förderung

in the relatively short term or those that were considered particularly urgent.[48] The Reich Ministry of Finance (RFM) ruled out the former for the Séailles-Dyckerhoff process, as it was still in the experimental stage. Also for reasons of medium-term security of Germany's supply with bauxite, there was no absolute necessity to start the project as soon as possible, as discussed above.[49] However, the non-realisation of the large-scale test plant in the last year before the war did not mean that *Dyckerhoff* stopped the tests. On the contrary, the experimental plant in Amöneburg was massively expanded with company funds in the course of 1939 in order to better prepare for the large-scale development of the process.[50] This also shows that the company had a genuine interest in this technology.

Pilot plants: 1939-45

The fact that the pre-war plans to erect a pilot plant near Bonn were not realized, did not imply that the Four-Year-Plan administration had lost its interest in the Séailles-Dyckerhoff technology.[51] When after the start of the war, German authorities had far-reaching aluminium expansion plans that made it necessary to increase alumina capacities by 180,000 tonnes, plans to build up pilot plants based on the Séailles-Dyckerhoff process quickly re-emerged on the government side. Thanks to the RWM's intervention Walter Dyckerhoff like his chemists and other employees of the experimental plant, was able to return to Amöneburg from their draft call to the Wehrmacht to continue the alumina experiments as early as September 1939. In connection with these expansion plans, the RWM urged Walter Dyckerhoff to submit a concrete proposal for the construction of two alumina pilot plants. The plan to build alumina factories according to the Séailles-Dyckerhoff process was not primarily made in order to improve the supply of raw materials. This was seen, as mentioned above, as secure in the medium term. Nor were such factories intended to make a noticeable contribution to the planned expansion of alumina production; the total volume of 10,000 tons of the defined first expansion stage corresponded to only slightly more than five percent of the planned expansion of alumina capacity. Rather, it was based on long-term considerations. The Four-

[48] On the budget problems in late 1938, see Adam Tooze, Wages of Destruction. The Making and Breaking of the Nazi Economy, London 2006.
[49] See also BArch R 3112/14, Arbeitsbericht des Generalbevollmächtigten des Ministerpräsident Generalfeldmarschall Göring für Sonderfragender chemischen Erzeugung Dr. C. Krauch vor dem Generalrat, 20/21.4.1939, p. 38.
[50] Niederschrift über die 22. Sitzung des Arbeitsausschusses der DPAG am 23.1.1939, StadtAWi WA5/613, unfol.; Niederschrift über die 25. Sitzung des Arbeitsausschusses der DPAG am 22.1.1940, StadtAWi WA5/614, unfol..
[51] For the following, see Scherner, Staatliche Förderung.

Year plan authority did not consider it expedient to be permanently dependent on only one raw material for aluminium supply, especially since it remained unclear whether the bauxite supply based on imports from Axis countries and on the large German stocks would be sufficient for the gigantic expansion plans in the long term.

For security reasons, the pilot plants desired by the RWM were to be located east of the Elbe river and thus out of range of enemy aircrafts.[52] In addition, they were to be conveniently located with regard to the necessary raw materials and, in order to save on building materials, there was to be a cement factory at this location to which the plant components necessary for alumina production could be attached. Walter Dyckerhoff started looking for suitable locations, and quickly found what he was looking for. He suggested as locations Rüdersdorf near Berlin and Stramberg in the Sudetenland, the predominately German speaking part of the former Czechoslovakia, which had been annexed by Germany as a result of the Munich Agreement in 1938.

The cement plant in Rüdersdorf belonged to the state-owned *Preußische Bergwerks- und Hütten-Aktiengesellschaft* (*Preussag*), which was primarily active in mining various raw materials and smelting metal ores. [53] *Preussag*'s Rüdersdorf branch plant had pursued a diversification strategy since 1933 and successfully started cement and building materials production.[54] This strategy, the positive assessment of the Séailles-Dyckerhoff process with regard to its competitiveness by *Preussag*, and the fact that the RWM approved a renewed expansion of Rüdersdorf's cement production in the cartelized cement market in connection with the construction of the alumina plant, all contributed to why *Preussag* was interested in the project, apart from the fact that, as a state-owned company, it would hardly have been possible to evade the state's wishes anyway.[55] Moreover, there was no real investment risk for *Preussag* as the Reich guaranteed sales of the alumina for ten years at cost-covering prices. *Preussag* received a license for the patented Séailles-Dyckerhoff process and the promise that *Dyckerhoff* would provide technical advice.

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[52] For the following, see Scherner, Staatliche Förderung,
[53] Generally on the *Preussag*, see Bernhard Stier/Johannes Laufer, *Von der Preussag AG zur TUI. Wege und Wandlungen eines Unternehmens 1923 – 2003*, Essen, 2005.
[54] Stier/Laufer, *Preussag*, pp. 213-216.
[55] Scherner, Staatliche Förderung.

The second site, the cement factory in Stramberg originally had majority "Jewish" owners and had to be "aryanised". The newly founded bank *E. von Nicolai & Cie.* in Vienna acquired the majority of shares in *Stramberg-Witkowitzer AG* in the course of the Aryanisation. The company received a Reich-guaranteed loan of up to RM 8 million to finance the new plants and the start-up and trial costs. A newly founded alumina factory, *Stramberg GmbH*, whose Managing Director became Walter Dyckerhoff, leased the facilities of the cement plant in Stramberg from *Stramberg-Witkowitzer AG* for a period of five years. Of the *Stramberg GmbH* 's share capital of RM 100,000, two fifths each went to *Dyckerhoff* and *Stramberg-Witkowitzer AG*, and the rest to *Witkowitzer Eisenwerke AG*, an already "aryanised" subsidiary of the state-owned *Reichswerke Hermann Göring AG*.[56] *Dyckerhoff* had to make the licences available to the *Stramberg GmbH* free of charge for a period of five years. At the same time, the shareholders undertook to cover losses in the operation of *Stramberg GmbH* up to the amount of RM two million. The state granted the alumina factory in Stromberg a sales guarantee. To sum up, *Dyckerhoff* became the operator and leaseholder of the pilot plant to be built in Stramberg.

In addition to the construction of the two pilot plants, the state pursued a second strategy to advance the development of the Séailles-Dyckerhoff process. German authorities obliged at the beginning of 1940 *Dyckerhoff* and chemical giant *IG Farben AG*, which was also carrying out research since 1935 on a process that could process alumina-containing residues, to carry out technical exchange.[57] On the basis of this, a "best practice process" was to be developed. The two companies then concluded an agreement according to which patent applications for the further development of the processes were to be made jointly and a regular technical exchange was to be carried out. In addition, patents of the contract partner could be used free of charge in the contract area. This explicitly also applied to the plants in Rüdersdorf and Stramberg. In the following, *Dyckerhoff* and *IG Farben AG* had to repeatedly provide the German authorities with reports that included a comparative cost analysis and were intended to help identify weaknesses in the respective processes. Such a state-initiated technical exchange between companies was not something that only took place in this area, but an instrument that was also used in other areas that were of interest to the state as the

[56] On the *Reichswerke Hermann Göring*, see R.J. Overy, *War and Economy in the Third Reich* (Oxford, 1994), ch. 5.
[57] Scherner, Staatliche Förderung.

development of synthetic fatty acids[58], in order to conserve manganese[59], or in the field of loss reduction in the beneficiation and smelting processes of metal ores.[60] Yet, in contrast to some other cases, this cooperation between *Dyckerhoff* and *IG Farben AG* was not very successful. The technologies of both companies were too different, their interests differed too much, and the state in the end could not force the companies to successfully cooperate if they were rather unwilling.

In spite of this failure regarding technical exchange, around 1942/3, the Séailles-Dyckerhoff process was running smoothly in the pilot plants. They were able to produce high quality alumina.[61] Yet, the process did not manage to produce alumina at competitive costs as long as ash residues were used. Nevertheless, *Dyckerhoff*'s positive assessment of its alumina technology with its synergy effects for the core business did not change during the war in spite of the fact that its cement plants were under-utilised to a considerable extent due to the massive war-induced decline of German construction production[62], implying that the carrot - the exception to the ban on new construction of cement factories- no longer played a role in the company's interest in the new technology. *Dyckerhoff* even planned to finance and build a factory of their own after the war. Yet, this plan never materialized after the war was over. During the first post-war years, the aluminium sector in West Germany was subject to production prohibitions and dismantling [63] When West German aluminium production reassumed after all restrictions had been lifted in mid 1951, production of alumina could again use high quality bauxite which was imported especially from Yugoslavia, Greece, and France.[64] For the Séailles-Dyckerhoff process was no need.

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58 For a successful cooperation among companies, see Egbert Gritz, *Mersol: Entwicklung und Einsatz von Ersatzwaschrohstoffen aus Kohle 1936–1945. Ein Beitrag zur nationalsozialistischen Autarkiepolitik*, Stuttgart, 2013, pp. 72, 92-4.

59 Zilt, Mangannot, pp. 155-6.

60 BArch R 2/77, Abschrift aus dem Vortrag „Die Nichteisenmetallindustrie im Vierjahresplan“, Bl. 7.

61 Scherner, Staatliche Förderung. For post-war assessment sof this process, see also British Intelligence Objectives Sub-Committee, (ed.) *BIOS Final Report No.167*, *Seailles-Dyckerhoff Alumina Process Portlandzement Fabrik Dyckerhoff and Sohne at Amoneburg bei Biebrich*, London, 1945; Wilhelm Fulda/Hans Ginsberg, *Tonerde und Aluminium. Ergebnisse und Erfahrungen aus der Betriebspraxis 1920-1950, Vol. 1 Tonerde*, Berlin 1951, p. 178.

62 For data on the decline of German construction output during the war, see *Simon Gogl*, Laying the Foundations. Organisation Todt and the German Construction Industry in Occupied Norway (Jahrbuch für Wirtschaftsgeschichte. Beihefte 27), Berlin/Boston, 2020, p. 316 Table A.1.1. See also Jonas Scherner, Armament in the Depth or Armament in the Breadth? German Investments Pattern and Rearmament during the Nazi Period, *Economic History Review,* 66, 2 (2013), pp. 497–517, here p. 509, note g). On the massive reduction of *Dyckerhoff*'s cement production during the war, vgl. Pohl, *Dyckerhoff*, Tabelle 10, p. 98.

63 Knauer, *Aluminiumindustrie*, pp. 223-5, 281, 333.

64 Knauer, *Aluminiumindustrie*, pp. 261-2; *Statistisches Jahrbuch für die Bundesrepublik Deutschland 1957*, p. 292.

Due to the positive assessment of the technology, *Dyckerhoff* had invested considerable research costs in this technology from its own funds.[65] Between 1937 and 1944, total trial costs (i.e. excluding the costs of building up and running the pilot plants), amounted to RM 2.4 million, which was about two and a half times the balance sheet profit of the cement producer in the construction boom year 1937. However, the total R&D costs for the Séailles-Dyckerhoff process, at around just under RM 50 million, were considerably higher than the "pure" trial costs, and were largely borne by the state. These very high R&D costs were offset by only a very small production of alumina, which amounted to just about 5,000 tons between October 1943 and the end of the war in both pilot plants together. This extremely unfavourable cost/benefit ratio could now be seen as striking proof of a failed project. However, as shown above, the Nazi regime was ultimately concerned with having an alternative and thus contributing to supply security of the German aluminium industry in the long term. From this perspective, cost issues were secondary to the goal of developing a viable alternative technology - which was indeed achieved. In the end, the Nazi government did not act differently than the U.S. government: after the Séailles-Dyckerhoff process was granted a U.S. patent in July 1941[66], the U.S. government, which also wanted to protect itself against the risk of being dependent on foreign supplies, arranged for the construction of two pilot plants, in which processes which were a variation of the Séailles-Dyckerhoff technology were tested.[67] The conclusion drawn from these two pilot plants were the same as the ones in Nazi Germany: the processes were technologically viable, but – in terms of production costs – not competitive.

[65] For the following, see Scherner, Staatliche Förderung.
[66] https://patents.google.com/patent/US2248826A/en
[67] John J. Henn et al., Methods for producing alumina form clay. An evaluation of the two limes sinter process, U.S. Bureau of Mines, Report of Investigations 7299, 1969 retrieved on 28 June 2022: https://books.google.no/books?id=WMRhE9VUVjMC&pg=RA22-PA2&lpg=RA22-PA2&dq=Plant+Seailles+Dyckerhoff+tennessee&source=bl&ots=lOT_KX2ZtQ&sig=ACfU3U1DlyhQCC_3bVTeib3B1jk4OiXodA&hl=en&sa=X&ved=2ahUKEwiGttW0jND4AhX5X_EDHVoDA5kQ6AF6BAgDEAM#v=onepage&q=Plant%20Seailles%20Dyckerhoff%20tennessee&f=false; G. Baudet, A documentary study on alumina extraction processes, 1977, pp41-51; retrieved on 8 July 2022: http://infoterre.brgm.fr/rapports/77-SGN-061-MIN.pdf; Alan E. Comyns, *Encyclopedic Dictionary of Named Processes in Chemical Technology*, 4th ed, Boca Raton 2014, p. 308.

Conclusion

Between 1936 and the end of the war, German authorities fostered the development of processes to produce alumina from domestic raw materials, although Germany's bauxite supply was always assured in the medium term during this period. The background to this interest in processes to produce alumina from German raw materials was the fact that aluminium played a central role in the autarky and armaments policy of the Reich, and that in the long term domestic alternatives were wanted to replace bauxite imports. Thus, the state initiated and motivated companies to take up research, made efforts, not always with the desired success, to network companies, and created favourable conditions for successful process development by using considerable financial resources. Not only the state, but also companies were partially interested to pour resources in R&D efforts. The most important of these processes was the Séailles-Dyckerhoff technology, which was developed on the basis of a French patent by the *Dyckerhoff*, and which was able to produce good quality alumina in two pilot plants during the war. Even though recent scholarship has shown that not all innovations and autarky industries stemming from Nazi autarky policy were a commercial failure in the sense that they were not competitive under normal conditions[68], this was a technology which was not longer used after the end of the war.

[68] See for example A. Sudrow, *Der Schuh im Nationalsozialismus. Eine Produktgeschichte im deutsch-britisch-amerikanischen Vergleich*, Göttingen, 2010; Jonas Scherner/Mark Spoerer, Infant Company Protection in the German Semi-synthetic Fibre Industry: Market Power, Technology, the Nazi Government and the post-1945 World Market, *Business History* (2021) https://doi.org/10.1080/00076791.2021.1900118.