Report

CASE STUDIES ON BIOMASS USE AND PRODUCTION IN NORWAY

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Introduction

This report contains three case studies on bioenergy focusing on biogas, unprocessed biomass, and processed biomass. Each case study focuses on one area and shows one example of a company or organization operating in the area.

Here is the original description of the task description:

> **Description of activity:** Based on the examination of the business profiles of relevant Norwegian companies and on the experience of Norwegian townships/ municipalities in using biomass and especially black pellets at municipal level, an international energy expert will create 3 case studies of sustainable biomass usage, some focusing on black pellets, showcasing the investment level mobilized, the CO_2 reductions achieved, the business case of the investment, etc.

Biomass is many things, as shown in Figure 1, and has different applications.

Figure 1 Examples of biomass

One use is energy production. It is possible to produce electricity from biomass, but this is not done in Norway. Biomass for energy is used for heating. Biochar and Biocarbon have other applications:

- Reduction in metallurgy
- Soil improvement
- Fodder additive

Case 1 Biogas

Biogas production has become mature. The latest statistics (2022) from **Biogass Norge**, an interest organization for companies and organizations concerned with developing the market for biogas, a total of 56 manufacturing plants produced biogas equivalent to 739 GWh. Municipalities and other public entities own most manufacturing plants, but the number of plants and production is also increasing in the private sector[1]. The main applications of biogas are transport and heating. Only a few plants generate electricity from biogas.

Biogas is produced through a biological process where biowaste is crushed to prepare it for anaerobic digestion. Often liquid is added to make biomass more fluid. The biomass is heated to around 37 degrees Celsius to create an ideal situation for microbes. The microbes decompose the biomass in an anaerobic process. CO_2 is separated from the biogas, and the residues are used as fertilizer. Biogas is normally compressed (CBG) but can be converted into liquid biogas (LBG) with higher energy density[2].

Greve Biogas

In 2008, environmental-conscious mayors in Vestfold County initiated a project to reduce their environmental footprint. A study trip to a biogas facility in Swedish city Trollhättan inspired the mayors. At that time, Trollhättan had a working biogas plant. The trip was organized by a 12K, a collaborative network of the Vestfold municipalities.

Greve Biogass was established on October 21, 2013, by 10 municipalities (Bamble, Færder, Holmestrand, Horten, Larvik, Porsgrunn, Sandefjord, Siljan, Skien, Tønsberg).
It is co-located with **Vesar**, the regional waste-handling company owned by six Vestfold municipalities**. Vesar** outsources waste collection and waste collection stations to an operator (private or public-owned) for a period after issuing a request for tender. The current operator is Lindum, a waste-handling company owned by Drammen municipality[3].

Greve Biogass aims to produce biogas and fertilizer from the owner municipalities' organic waste, livestock manure, and sludge. The value chain is shown in Figure 2. The production facility for biogas is organized as a subsidiary called the **Magic Factory.**

Figure 2 The Magic Factory value chain

[1] An interactive statistics web page from Biogass Norge (2022): https://app.powerbi.com/view?r=eyJrIjoiY2MzMjJkYTEtNGU1Ny00ZmIzLTkxYTktNTY0YjQ4MWZkNTk2IiwidCI6IjU2NjNkNmEyLWM2NGYtNGVhZi05YjhjLWVmM2Y5NTkwYWU2NyJ9&pageName=ReportSection
[2] https://biogassbransjen.no/hva-er-biogass/
[3] Interview with Kaia Ross Lind, Vesar

The biogas production facility is located on Taranrød in Tønsberg municipality. Figure 3 shows an aerial photograph of the facility showing the processing facility and storage tanks for biogas and fertilizer.

Figure 3 The Magic Factory – Aerial View

Production

In 2022 the **Magic Factory** processed 60,000 tons of food waste, 72,000 tons of livestock manure, and 28,000 tons of industrial liquid waste. The output was 153,000 biofertilizers and 9,4 million Nm^3 biogas (equivalent to 9,4-million-liter diesel). This equals almost 100 GWh, making the **Magic Factory** an important national production plant[4]. The production over time is shown in Figures 4a and 4b.

[4] Greve Biogass, Annual Report, 2022

Biofertilizer delivered to agriculture (tons)

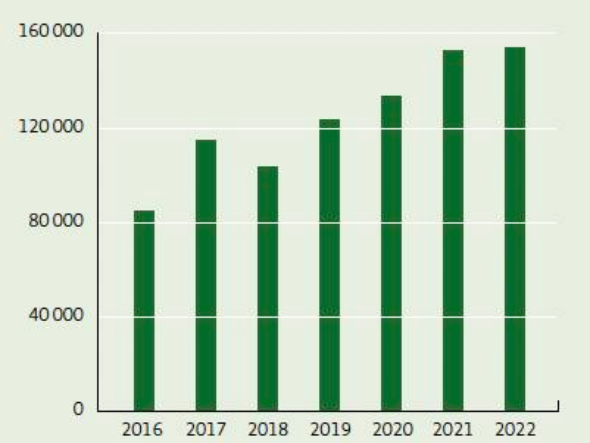

Figure 4a – Production 2016-2022

Biogas produced with fuel quality (millons Nm^3)

Figure 4b – Production 2016-2022

Organization

By the end of 2022, Lindum, the waste management company owned by Drammen municipality and current operator, became a co-owner of the **Magic Factory**, now owning 34% of the stock[5]. Lindum had already operated the plant for several years and saw this as a strategic investment[6]. The current ownership structure is shown in Figure 5.

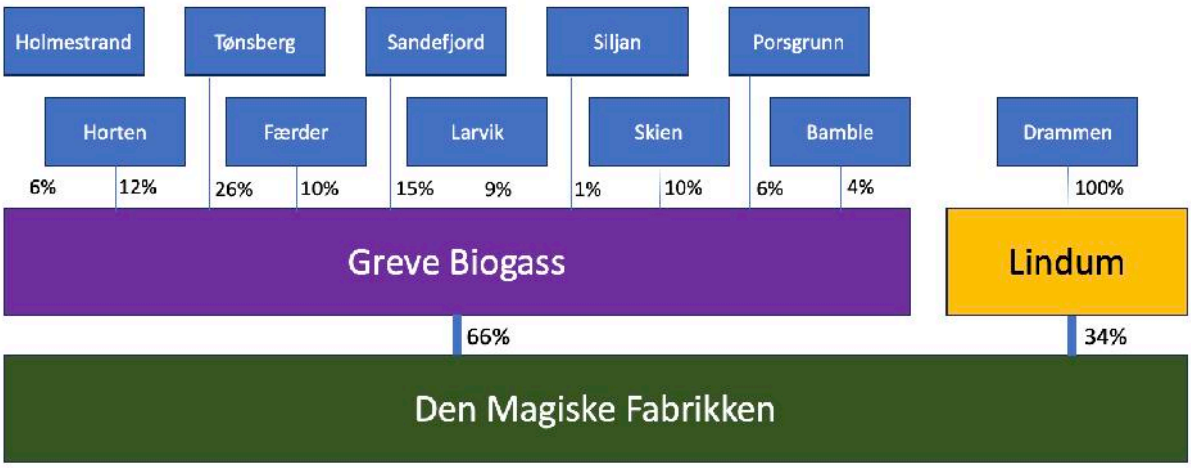

Figure 5 Ownership structure

[5] https://www.nfdr.no/om-oss-nyheter/lindum-blir-medeier-i-den-magiske-fabrikken
[6] Interview with Mariann Hegg, The Magic Factory

Financial statements

GREVE BIOGASS	**2018**	**2019**	**2020**	**2021**	**2022**
Income	112 312	118 052	128 408	135 161	141 951
Expenses	102 647	116 725	134 997	134 501	143 341
Result	**9 665**	**1 327**	**−6 589**	**659**	**−1 390**
Fixed Assets	151 377	145 109	233 312	223 006	223 827
Total Assets	198 043	223 544	382 213	271 750	288 26
Liabilities	179 469	186 762	277 231	170 670	195 806
Equity	18 574	36 782	104 982	101 080	92 459

DEN MAGISKE FABRIKKEN	**2018**	**2019**	**2020**	**2021**	**2022**
Income	0	0	0	13 644	18 140
Expenses	0	0	0	9 634	12 503
Profit/Loss	0	0	0	4 010	5 637
Result	**0**	**0**	**0**	**989**	**191**
Fixed Assets	0	0	0	216 482	205 715
Total Assets	0	0	0	221 108	218 696
Liabilities	0	0	0	140 090	137 486
Equity	0	0	0	81 019	81 209

Please note: *Greve Biogass and The Magic Factory are owned by municipalities. They deliver biogas and fertilizer to the local area. These companies have a wider mandate than to create profit. They should make an important contribution to green transition.*

Ecosystem

Figure 6 shows the ecosystem surrounding the **Magic Factory**. The **Magic Factory** is the production plant for biogas. "Magic" refers to transforming organic waste into biogas and fertilizer. There is, of course, no magic involved in this.

Figure 6 The Ecosystem

Additionality

The **Magic Factory** has a knowledge and experience center where school classes can see the process and learn about recirculation. So, the **Magic Factory** has become much more than a production facility, it has become an arena for creating citizen awareness about the circular economy.

A greenhouse co-located with the production facility uses CO_2 from the production to grow tomatoes. The CO_2 has potential for enhancing production for more than 7 million kg of vegetables.

As earlier mentioned, biogas is mainly used for transport. The garbage trucks and most of the county buses in run on biogas. This has been used to promote the sorting of organic waste. Both buses and garbage trucks have the slogan “Thank you for the food” painted on their bodies to remind that the waste food has been transformed into fuel. The buses and garbage trucks are shown in Figure 7.

Figure 7 Creating awareness

Case 2 Unprocessed biomass

This case focuses on unprocessed biomass from forests. The biomass can be divided into two fractions, the first is trees not useful for sawmills, and the second is branches and treetops. Sawdust and wood chips is also residues from the sawmills.

Unprocessed refers to chemical or biological processes, not mechanical. The creation of pellets is therefore regarded as unprocessed since the structural properties of the material is not changed.

Unprocessed biomass is mostly used for heating and not for electricity generation. Typical applications for heating is:

- Agriculture (greenhouses and livestock)
- Public buildings (schools, nursing homes, culture, etc.)
- Industry and commerce (logistics/storage)
- Housing complexes

Pellets are biomass (wood chips or sawdust) pressed together. The process makes them more dense and less moist. The pellets also have a uniform shape. Pellets can be used for the same purposes as above but have also been popular in holiday homes. Households get subsidies when the electricity is expensive, but these subsidies are not valid for holiday homes. Due to the uniform size of the pellets, it is possible to make automatic feeding mechanisms for ovens. Pellets are more expensive but much more manageable.

Gjennestad

Gjennestad is a high school and a property management company. They are both organized as associations under Normisjon, a Christian congregation. A garden center, "Hageland", part of a national chain, is collocated with the facilities.

The property management company maintains 12,000 m^2 of greenhouses, producing mostly flowers and herbs. Students from the agriculture branch of the high school do practical training in the greenhouses. The area is shown in Figure 8. The greenhouses are on the right and in the back. The main school building is in the middle (brown, massive tree). The school dormitory is the large white building.

Gjennestad Drift has 217 employees and an annual income of NOK 147 million. **Gjennestad Videregående Skole** (high school) has 33 employees and an annual income of NOK 30 million.

Figure 8 Gjennestad

Gjennestad Drift uses biomass (wood chips) for heating greenhouses and buildings. A circular pipe distributes the heat around the facilities. The biomass is collected from trees that do not satisfy the requirements for building materials, e.g., because they are not straight.

The trees are cut during the winter and stockpiled for drying during the summer. The humidity is reduced from 50% to 35% during drying. The supplier cuts the trees into wood chips with a humidity of 40%.[7]

[7] Interview with Geir Fossnes, CEO, Gjennestad Drift

Gjennestad has total buildings of 38,000 m^2. 15.000-16000 m^2 is greenhouses.

The bioenergy production at Gjennestad is 4.5 GWh/year.

Using wood chips is not simple, competent staff is essential to get optimal production[7]. It is essential to have someone in place when things go wrong.

Gjennestad also uses solar panels for electricity production. Gjennestad has 2,000 m2 of solar panels and is experimenting with other renewable energy sources, e.g., a newly installed wind turbine[8], as shown in Figure 9.

Figure 9 Wind turbine

[8] https://gjennestaddrift.no/klimatiltak/

Investments and production

The bioenergy facility was built from 2009 to 2014. All values have been transformed into present values. Amounts are given in Norwegian crowns. (For simplicity, the conversion rate is around 10:1, ten Norwegian crowns equal one Euro). Geir Fossnes, CEO of Gjennestad Drift, kindly provided the numbers shown here.

Investments

Buildings		3,495,691
Circular pipe (part)	(70%)	2,666,459
Inventory (bio-ovens, feeding system, internal pipe system, etc.		3,756,334
Total investments		9,918,484

Production 4,553,740 kWh

Fixed costs

Depreciation buildings including circular pipe (40 years)		154,054
Depreciation inventory (20 years)		187,817
Interest rate	2,9%	287,636
Emission measurements (mandatory) every second year	55,000	27,500
Yearly maintenance (scheduled)	70,000	70,000
Administration		101,400
Total fixed costs		**828,407**

Variable costs

Wood chips		1,800,000
Electricity (supporting the process)		55,560
Repairs and maintenance (unscheduled)		150,000
Personnel costs		202,800
Ash (treated as special waste)		11,545
Total variable costs		**2,219,905**

Total costs		**3,048,313**

With a production of 4,554,540 kWh, the price for each kWh is **NOK 0,67**. In 2022 the electricity price was particularly high, with an average of NOK 2,13 per kWh.

Figure 10 The wood chips facility at Gjennestad

Case 3 Processed biomass

Processed biomass, particularly wood residues, is not used for electricity generation in Norway. The reason is quite simple. Processed biomass is used to substitute coal in energy plants. Energy production in Norway is mostly coming from hydropower. Norway does not have any coal power plants on the mainland. Figures 11 and 12 compare the electricity production by source in Norway and Romania.

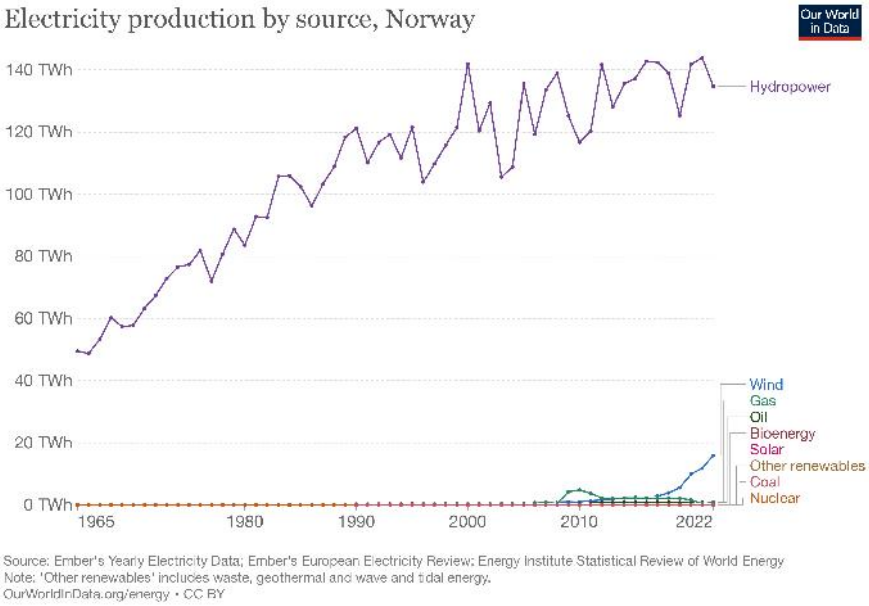

Figure 11 Electricity production by source, Norway

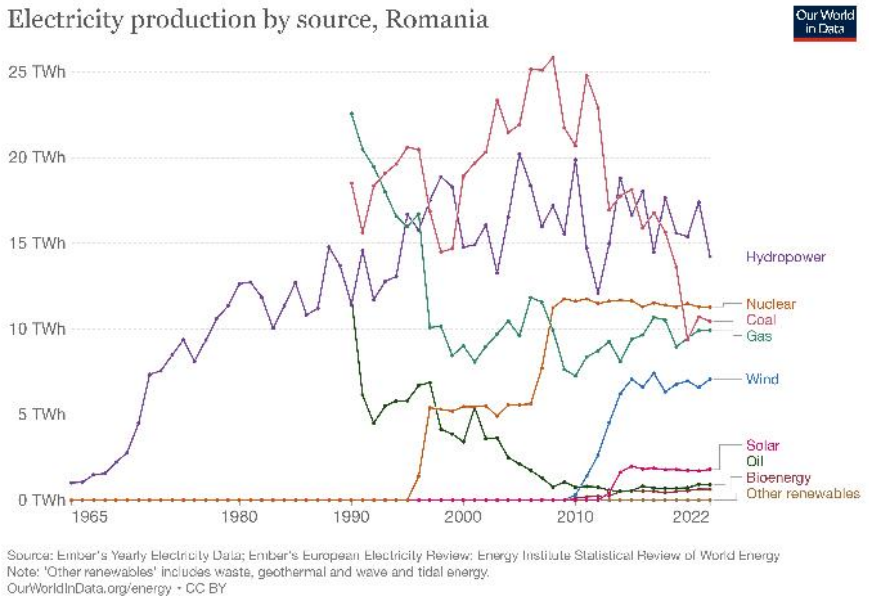

Figure 12 Electricity production by source, Norway

Even if processed biomass is not used for electricity generation in Norway, there are still a lot of ongoing activities. Some municipalities and private companies are planning or constructing biochar or biocarbon production facilities. Currently, at least two facilities are doing production:

- **Sandnes Municipality**, located in the country's southwestern part, has established its own biochar plant. Twigs, bushes, and other waste from gardens and parks go into the biochar plant, producing biochar and district heating for municipal buildings. The biochar is used for soil improvement in parks. The municipality reports an annual reduction of 3000 tons of CO_2 equivalents[9].

- **OBIO**, the largest Norwegian commercial biochar producer, has established a production facility on Rudshøgda, 140 km north of Oslo. Production started in 2021. OBIO produces 380 tons of high-quality biochar. The revenue per ton is NOK 11,000[10]. OBIO reports that 65% is used for soil improvement, and the rest is used as fodder additive (pigs).[11] The company is currently investigating the use of biochar in asphalt, concrete, composites, and industrial filters.

- **Standard Bio** is in Bø, 140 km southwest of Oslo. According to their website[12], they produce biochar for soil improvement and fodder additive but is also doing research on filter technologies.

Standard Bio	**2018**	**2019**	**2020**	**2021**	**2022**
Income	2 564	3 030	3 875	6 776	8 012
Expenses	12 486	12 859	13 701	14 968	14 577
Profit/Loss	−9 922	−9 829	−9 826	−8 192	−6 565
Result	**−10 421**	**−10 647**	**−11 055**	**−9 253**	**−7 427**
Fixed Assets	14 850	12 020	11 161	21 810	24 115
Total Assets	18 100	17 349	12 830	37 924	25 171
Liabilities	9 162	19 057	25 593	38 241	22 915

Recently, larger startups have been initiated to produce high-quality biochar for the metallurgical industry. One of the large metallurgy companies Elkem[13] reports a national demand for 250,000 tons of biocarbon to replace fossil carbon. The total demand may reach 1 million tons.

- **Vow Green Metals** is constructing a production plant to convert biomass into biocarbon on Follum, 60 km northwest of Oslo. **Vow Green Metals** aims to produce 7-8000

[9] https://cicero.oslo.no/no/artikler/Tre-kommuner-om-klimakutt
[10] https://norsk-skogbruk.no/industri/biokull-seiler-opp/
[11] Interview with Einar Stuve, CEO of OBIO
[12] https://www.standard.bio
[13] https://www.elkem.com

tons/year of biocarbon to replace coal in the metallurgic industry[14]. The half-year report - first half of 2023 - indicates a much higher volume in the future[15].

- **Carbonworks Haslestad AS** is a companionship between Bergene-Holm (the second largest sawmill corporation in Norway) and **Wei** (making pyrolysis reactors). The venture aims to produce industrial-grade charcoal for use in the metallurgic industry. Startup is planned Q1 2025[16]. Haslestad is in Holmestrand 80 km southwest of Oslo. The start capacity will be 9,000-10,000 tons biocarbon/year, with a second phase to increase production to 20,000-22,000 tons[17].

- **Ottem Carbonworks**, in Sunndal in western Norway, is under construction with a planned start in Q2 2024. **Wei** is also a partner in this project[18].

- Another company, **Phase Transition**, is working on Microwave Assisted Pyrolysis (MAP), but is still in the planning phase[19].

Norwegian bio coal network (**Norsk Biokullnettverk**[20]) is a network for all actors within the bioenergy value chain. The network has 34 members and functions as a hub for information sharing[21].

[14] https://fjernvarme.no/vil-bygge-biokull-fabrikk-pa-honefoss
[15] https://assets.ctfassets.net/7jb2xn8k4rjw/3Lz2oZCj4l4hahL1UDCyjY/7dc5b52882a6820334f98ef64029fa54/Vow_Green_Metals_-_Half-year_2023_presentation.pdf
[16] https://kobben.no/aktuelt/skal-produsere-22-000-tonn-biokarbon-arlig-pa-haslestad/
[17] https://norsk-skogbruk.no/aktuelt/konkurrerer-ikke-med-biozin-om-rastoff/
[18] https://www.tottem.no/informasjonocw
[19] Interview with Øyvind Trygstad, Advisor, Vestfold and Telemark County Municipality
[20] https://www.biokull.info
[21] Interview with Mia Rønningen Ulvin, Project manager, Norsk Biokullnettverk

Arbaflame

Arbaflame produces black pellets primarily as a substitute for fossil coal in power plants. The production is exported to European countries: The Netherlands, Germany, and France. The yearly production is around 40,000 tons (2023)[22], intending to reach 70,000 tons. The production facility is located at Grasmo, 70 km east of Oslo [23].

The company has at least two subsidiaries: **Arba One**, the first production plant, and **Arbaflame Technology**, working on innovation and process improvement. Figure 13 shows the ownership structure.

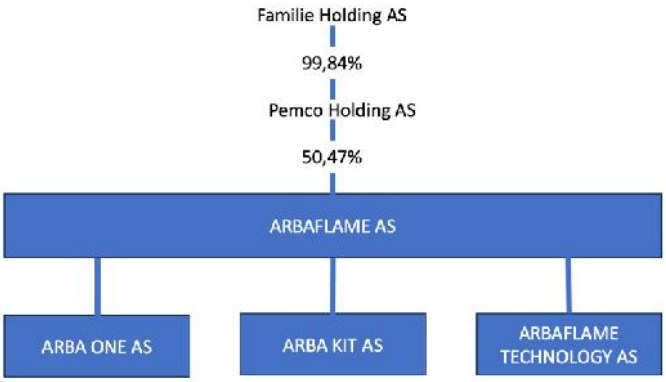

Figure 13 Arbaflame ownership structure

According to Dagens Næringsliv (newspaper) the commercial **Arbaflame** breakthrough was coal power plant in Rotterdam, owned by the French company Engie[24]. The first full-scale pellets factory was finished in 2020, with a total investment of NOK 200 million. The government, through its energy funding agency Enova contributed NOK 78 million. The expected capacity of the pellets factory is 70.000 tons.

Financial statements

Arbaflame	**2018**	**2019**	**2020**	**2021**	**2022**
Income	30 263	11 342	11 711	11 711	11 711
Expenses	36 119	19 088	38 200	38 200	38 200
Profit/Loss	−5 856	−7 746	−26 489	−26 489	−26 489
Result	**−6 151**	**−8 382**	**−27 852**	**−27 852**	**−27 852**
Fixed Assets	1 212	3 754	258 640	258 640	258 640
Total Assets	145 447	160 880	344 807	344 807	344 807
Liabilities	146 196	74 990	388 488	388 488	388 488
Equity	−749	85 889	−43 681	−43 681	−43 681

[22] Interview with Dag Helge Hermundsgard, Arbaflame
[23] Interview with Dag Helge Hermundsgard, Arbaflame
[24] https://www.dn.no/energi/arbaflame/gronn-energi/kull/norsk-pellets-danker-ut-kull-i-rotterdam/2-1-614251

Arbaflame Technology	**2018**	**2019**	**2020**	**2021**	**2022**
Income	0	0	0	0	0
Expenses	820	701	590	921	819
Profit/Loss	−820	−701	−590	−921	−819
Result	**−820**	**−701**	**−590**	**−922**	**−819**
Fixed Assets	0	0	0	0	0
Total Assets	5	2	2	5	1
Liabilities	2 179	2 878	3 468	4 394	5 209
Equity	−2 175	−2 876	−3 466	−4 388	−5 207

Arba One	**2018**	**2019**	**2020**	**2021**	**2022**
Income	14 899	16 563	4 040	477	35 467
Expenses	22 144	31 675	19 588	37 271	86 900
Profit/Loss	−7 245	−15 112	−15 548	−36 795	−51 433
Result	**−7 738**	**−15 605**	**−12 133**	**−37 154**	**−63 705**
Fixed Assets	2 012	1 872	258 567	316 726	340 451
Total Assets	8 522	5 859	282 033	354 940	381 947
Liabilities	88 518	101 460	211 602	321 664	412 376
Equity	−79 996	−95 601	70 431	33 276	−30 429

In 2021 **Arbaflame** signed a letter of intent to replace coal at the Paroșeni power plant in Romania[25]. According to the agreement, testing should have started in the first half of 2022[26], but the exact progress is unknown.

[25] https://bioenergyinternational.com/arbaflame-signs-loi-to-help-romania-phase-out-coal-with-arbacore-pellets/

[26] https://www.arbaflame.no/post/arbaflame-enters-into-an-agreement-that-will-help-romania-reach-its-climate-goals

The process and product

The most common way to produce black pellets is through torrefaction.

- Biomass is dried and then heated to 250-300 degrees Celcius without oxygen at atmospheric pressure.
- The properties of the biomass are changed.
- The biomass is made into pellets.

Arbaflame uses a patented technology. The underlying concept is steam explosion. The biomass is heated under pressure[27]. When the pressure is removed, the water in the biomass will be released into the air. Arbaflame says the energy efficiency is around 75% compared to 50% for normal pellets[28].

Arbaflame's black pellets, ArbaCore[29], share many of the properties of coal[30]. Basically, ArbaCore is hydrophobic, meaning it repels water. This is one of the reasons why it can be transported, stored, and handled in the same way as coal. Moreover, the same equipment, including that for pulverizing and combustion of the fuel, can still be used. The energy density of ArbaCore black pellets corresponds to 76 percent of the energy value of coal. For traditional white wood pellets, this value is typically close to half of the energy value of coal.

The business case of modifying existing coal energy plants to black pellets is excellent. CO_2 emission can be reduced by 90%. Changing a coal energy plant from coal to regular wood pellets costs 100 to 500 million euros. By using Arbacore (black pellets), the modification costs will be from 5 to 50 million. Transport costs for black pellets are much lower for black pellets than for wood pellets. The modification time is also much shorter for black pellets.

[27] https://www.uib.no/klimaenergi/121766/disse-kan-erstatte-forurensende-kull-i-store-kraftverk
[28] Interview with Dag Helge Hermundsgard, Arbaflame
[29] https://investinor.no/arbaflame-har-medvind-fra-alle-kanter/
[30] https://www.dn.no/energi/arbaflame/kullkraftverk/fornybar-energi/norske-arbaflame-far-180-millioner-av-eu/2-1-462696

Observations and Conclusions

This research was done by examining newspaper articles, articles in relevant trade journals, and interviews with key persons within the bioenergy field. Based on the research, I will make some observations and draw some conclusions.

Biogas is well developed with many production facilities. The **Magic Factory** is an important production facility in the national context. Part of the success was to establish a stable customer mass from buses and garbage trucks. Another success was to market the biogas efforts by using the slogan "Thank you for the food" on the vehicles. This puts the biogas production into a broader context – the transition to green economy.

Wood chips have been used for heating in both private companies and public institutions. **Gjennestad** is a good example of a community with different requirements for heating, including greenhouses, school, student dormitory, and other buildings.

The political interest in bioenergy is increasing. Several recent white papers mention bioenergy, mostly referring to existing or planned efforts, but with no real strategy from the government side.

Biocarbon is still early. Plans for production has been moved forward while the companies struggle with unknown problems. At the same time the metallurgic industry has opened their eyes to biocarbon to achieve their climate goals, which has led to substantial investments in companies like **Carbonworks** and **Vow Green Metals**[31].

Black pellets have only one commercial producer, **Arbaflame**. The had plans about setting up a production plant at Follum, but this was discarded. Instead, they decided to expand the existing plant, with somewhat lower capacity. They have ambitions about expanding internationally, but so far it has not materialized.

The financial statements show that the business of biocarbon and black pellets is still in its infancy (some of the companies like **OBIO**, **Carbonworks Haslestad** and **Vow Green Metals** are so young that they have still not submitted financial statements). Arbaflame is not profitable with the current production. Expansion will rely on external funding.

The NGO **Bellona** expresses worries about the supply of biomass.[32]. A possible shortage will lead to competition, and it seems that the most valuable use for biocarbon will be in the metallurgy industry.

[31] Interview with Thomas Dowling Næss, Energy analyst, Sparebank 1 Markets
[32] Interview with Olaf Brastad, Special Advisor, Bellona

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Financial statements were retrieved from Proff Forvaltning