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BIOMASS EXPLOITATION FOR ENERGY SUPPLY AND QUALITY COMPOST
PRODUCTION. AN EXEMPLARY CASE OF CIRCULAR ECONOMY IN THE NORTH

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1. Introduction

The European Commission has adopted the revised Best Available Techniques (BAT) conclusions for waste treatment, published on August 17th, 2018, giving to the national authorities the guidelines for technical installation. The document contains BAT conclusions for the most common waste treatments, including mechanical, biological and physical-chemical treatments and treatment of water-based liquid waste (European Compost Network, 2018).

The Directive 2009/28/EC fixed the guidelines for waste management, recycling and recovery, in order to reach a separate waste collection (SWC) of 50% by 2020. According to the “Report on Municipal Solid Waste (MSW), 2017 Edition”, (ISPRA 2017), Italy is not so far from this target, even if the situation is different among the regions: separate collection of MSW per capita increased on average from 199 kg/year in 2011 to 261 kg/year in 2016, corresponding respectively to 37.7% and 52.5%.

In 2016, in the Friuli Venezia Giulia (FVG) region, in the North-East of Italy, SWC was on average 67.1%, with a peak of 83.5% for the province of Pordenone. In FVG the percentage change between 2016 and 2015 was +6.7%.

The EC Communication 2015/614/EC promoted SWC in order to decrease landfill disposal, by introducing economic incentives for technological solutions (EC Communication, 2015). In Italy, the Ministerial Decree No 23 of June 2016 fixed exact dispositions for plants fed by biomasses, biogas and sustainable bio-liquids production (Ministerial Decree, 2016). According to the Legislative Decree No 387/2003, with the term biomass we mean the biodegradable part of the residues of forest sector, agricultural and food industry sectors, zoo-technical sector, organic waste (residues of green and scraps of food) (Legislative Decree, 2003).

Every year, the report on the State of Green Economy intervenes on national and European debate on the sustainability of economic recovery and job occupation. In particular, the General States of the Green Economy 2012 organized a national strategy for the revival of biomass supply chain: “Biomass potential in Italy is very high, but there are many obstacles for its exploitation. It will be necessary to develop the second and third generation of biofuels, the biogas/bio-methane supply chain and the energetic valorisation of biodegradable fraction of waste, taking into account the respect for the European hierarchy” (General States of the Green Economy, 2012).

Organic waste recovery and recycling is a real example of Circular Economy. In Italy, this sector is living an expansion season: in fact, in the last 10 years it increased more than 10% on a yearly basis. The Italian operative plants treat about 9 million tons of bio-waste every year, with 1.9

66 million/year ton of compost production. The 33% of this compost has the Consorzio Italiano
67 Compostatori (CIC) (Italian Consortium of Composters) quality mark. To obtain the mark, thus
68 ensuring a high quality standard, compost is submitted to continuous checking (Italian Consortium
69 of Composters, 2018).

70 More than 80% of Italian compost is used in the agricultural sector as fertilizer for cereals,
71 foragers, grapevine, etc., while the other 20% as fertilizer for gardens and/or landscape scopes. The
72 medium price of loose compost is about 10 euro per ton. The difference of price is also due to the
73 transport. If compost is sold in bags, the price is higher, and can reach 120 euro per ton (Italian
74 Consortium of Composters, 2018).

75 Exploiting the bio-waste means many associated activities: the collecting services, the
76 technical effort for the plant project and realization, the activities for the valorisation and the use of
77 compost. The collecting sector and selection and exploitation sector are getting closer. The affair
78 volume of the supply chain for the collection-treatment of bio-waste is about 1.8 billion euro/year
79 (Althesys Strategic Consultant, 2017).

80 The integrated plants, born to control the odorous emissions and to stabilize the biomasses,
81 are constituted of sequential treatment lines to recover renewable energy under biogas/bio-methane
82 form, and to transform the digestate, plus other organic waste, by aerobic treatment, in quality
83 compost for use as fertilizer in the agricultural sector (ISPRA, 2017).

84 An integrated plant is a sustainable plant, from all the points of view, giving benefits to:

- 85 - the economy of the territory, by assuring work to the community and by producing
86 profits (economic and social support for the society);
- 87 - the community that is sure that the collected organic fraction is re-cycled (to produce
88 renewable forms of energy and compost);
- 89 - the environment from which less primary resources are taken, through the use of
90 renewable materials (organic waste); biogas burns polluting less the environment, in comparison with
91 fossil fuels (Arthur et al., 2011). Furthermore, the produced compost is suitable to fertilize fields,
92 when the results of the chemical analyses assure its qualification to be used in the agronomic sector
93 (Italian Consortium of Composters, 2018).

94 The composition of the substrate treated in the integrated plants is made up of 69% of wet
95 fraction, 10% of green fraction, 15% of sludge and the remaining 6% of other waste: the organic
96 fraction is 91% of the total waste managed by integrated plants (ISPRA, 2017).

97 Biogas composition mostly depends on the type of decomposed material and subsequent slight
98 differences in chemical compositions could result from that as well: 50–85% CH₄ (methane); 20–
99 35% CO₂; H₂, N₂ and H₂S form the rest (Pastorek et al., 2004; Salomon and Lora, 2009).

100 Biogas production can be considered an established sustainable process for simultaneous
101 treatment of organic wastes and generation of renewable energy (Angelidaki et al., 2018; Mateescu
102 et al., 2008), a clean fuel used for heat, electricity and transport (Scarlat et al., 2018). If biogas is used
103 as fuel, it is necessary to remove carbon dioxide to increase the percentage of methane and
104 subsequently its calorific power.

105 In Europe, biogas heat use presents many differences among the countries depending on their
106 policy targets for 2020. Germany, Italy and Denmark are the European leaders, while progresses are
107 expected in France, Poland, UK and The Netherlands (Scarlat et al., 2018).

108 In integrated plants, the digestate, which remains after anaerobic digestion, with addition of
109 other organic waste, is submitted to aerobic digestion under particular time and temperature
110 conditions, to produce quality compost.

111 In Italy, the Legislative Decree No 75/2010 fixed when organic waste, after composting, stop
112 the waste status and become qualified amender: composted green amender, composted mixed
113 amender and composted amender with sludge, depending on the typology of waste treated
114 (Legislative Decree, 2010a).

115 According to the Legislative Decree No 205/2010, quality compost is defined “product
116 obtained by organic waste composting under specific technic rules, to be adopted by the State,
117 finalized to define contents and use compatible with environmental and health protection and, in
118 particular, to define quality levels” (Legislative Decree, 2010b).

119 The aim of this study is to present a virtuous integrated plant, managed by Desag Ecologia,
120 located in Sedegliano, in the province of Udine, in the North-East of Italy, that contributes to circular
121 economy, by exploiting biomass (household organic and green waste) for the anaerobic production
122 of biogas, and subsequently aerobic production of quality compost.

123

124 **2. Materials and Methods**

125

126 An in-depth analysis of virtuous cases of waste management in the FVG region allowed to
127 find out a recent plant devoted to the treatment of the organic fraction of MSW and green waste on
128 the basis of anaerobic/aerobic digestion: Desag plant, located in Sedegliano, in the province of Udine.

129 To deepen the case study, we visited the plant and interviewed the Chief Executive Officer
130 (CEO) of the facility to collect data and information. Furthermore, some e-mails and calls were
131 necessary to improve information on the characteristics and production aspects of the plant. Data and
132 information collected are presented in Tables 3-7.

133

134 3. Case Study Presentation

135

136 Desag Ecologia S.c.a.r.l., born more than 10 years ago, is a special purpose entity set up with
137 100% private capital, of which leading private companies are part: De Vizia Trasfer S.p.A. and Sager
138 S.r.l.; De Vizia Trasfer S.p.A. is specialized in heavy lifting and industrial installations assembly
139 sectors, Sager S.r.l. is specialized in integrated waste management. In the case studied, Desag
140 Ecologia signed a concession contract with a grantor society (A&T 2000) for the building of a plant
141 for renewable energy and compost production, for a total period of 25 years in a project financing
142 operation where the public authorities require private capitals for the realization of work for public
143 use in accordance with current legislation (Italian Law, 1998). A&T 2000 is a public society born in
144 1998, as a natural evolution of an aggregation of municipalities of the province of Udine, with the
145 aim of implementing economic and operational strategies in the field of municipal waste
146 management. At present, it incorporates 50 municipalities and has a catchment area of 200,000
147 inhabitants. Within the project financing, A&T 2000 is the grantor subject, that is to say who shall
148 provide the good, in this case waste. A&T 2000 deals only with ensuring the commodity (waste) at a
149 specific tariff agreed with Desag Ecologia.

150 The construction and operation of an integrated plant of anaerobic digestion and composting
151 were charged to concession holder, Desag Ecologia.

152 The Desag Ecologia plant is located in Pannellia, in the municipality of Sedegliano, in the
153 province of Udine, in the North-East of Italy; its construction started in 2013 and the plant was put
154 into service in June 2016. A schematic representation of the stages of the production process is given
155 in the Results and Discussion section (Figure 1).

156 After a first phase of waste acceptance, aimed at selecting only compliant waste, a storage
157 phase follows, in specific inner paved areas, coated with anti-wear anti-acid lining and provided with
158 a liquid conveying system. During these phases, specific measures shall ensure the least pollutant or
159 odorous emissions leakage. Accepted waste is classified into four categories: organic fraction of
160 municipal solid waste and similar, mowing materials/small wood waste, large wood waste and sludge.
161 Purity of incoming materials is verified by random sample analysis, visual check and bulky waste
162 removal.

163 The production process provides for waste pre-treatments: initially waste pass through a
164 machine devoted to the bags opening (the machine is also equipped with a system aimed at detecting
165 foreign materials). Large wood waste shall be subjected to a possible volumetric reduction (chipping).

166 *Anaerobic digestion.* Anaerobic digestion is performed with dry batch modality, in a single
167 stage of fermentation. The duration of such process, performed at 37 °C, is 28 days. The plant is

168 constituted of 8 fermenters, that allow to treat indicatively 830 m³ of mixture. The fermenters are
169 equipped with a heating system of the fund and the walls, which is powered by the heat recovered by
170 the group of biogas cogeneration. This system allows to maintain the process temperature in
171 fermenters.

172 The fermenters are uploaded (and emptied after a fixed reaction time) in different days,
173 properly scheduled, in order to ensure continuity to the process and to properly distribute
174 downloading, mixture preparation and material uploading for the following cycle.

175 In order to ensure the conditions of constant moisture and controlled temperature, the leachate
176 generated from biomass is collected and sprayed once again on medium in a controlled way.

177 *Biogas Production.* Anaerobic digestion process enables to obtain biogas, which in Degas
178 Ecologia plant is conveyed into two co-generation groups (499 kWe each), for combined heat and
179 electricity production. Before combustion, biogas shall be submitted to pre-treatments: filtration (on
180 activated carbon), dehumidification (by means of a condenser) and compression at 80 mbar.

181 The Desag Ecologia plant is equipped with a safety torch, which shall be activated only in
182 case of servicing of failure of cogenerator, or in the event of biogas overproduction and in the start-
183 up phase. In order to ensure security, in the event that the torch is not sufficient, three emergency
184 chimneys have been set up to ensure immediate leakage of excess biogas.

185 Combustion cogenerative engines are provided both with a system that allows the removal
186 from biogas of sulphur compounds, before introduction in combustion chamber, and with a
187 containment system of nitrogen oxides production in exhausted gases resulting from combustion.

188 *Composting.* Composting of the mixture is carried out inside 8 independent bio-tunnels,
189 isolated from the external environment. The static heap technique is adopted. The bio-tunnels are
190 supplied with a floor aeration equipment, a system of suction of the exhausted air (conveyed to the
191 treatment section in order to eliminate odorous emissions), a device of collection of the process
192 liquids (stored in a devoted tank) and an automatized system of monitoring and control of the process
193 parameters (temperature, moisture, oxygen and carbon dioxide concentrations).

194 The composting process provides for the previous preparation of the mixture in a covered area
195 in front of the bio-tunnels and the subsequent loading of the mixture. The bio-tunnels are loaded in
196 sequence, at pre-defined time intervals, to assure the process continuity and the correct management
197 of the time for the steps of downloading, mixture preparation and material loading for the subsequent
198 cycle.

199 When the process ends, compost is sent to the step of primary ageing to degrade the most
200 complex compounds. Then the material is transferred to the area of secondary ageing, located under
201 a roofing.

202 The final step of refining has the aim of separating possible extraneous fractions which can
203 be present in compost, that is, plastics, iron components and materials with an unsuitable size (greater
204 than 10-15 mm).

205 At the end of the secondary ageing step, the material is transferred to the sieving step. On the
206 obtained compost, sampling and chemical-physical analyses are carried out to verify the end-of-waste
207 status. In particular, the employed criterion is the respect of the limits provided for by the enclosure
208 No 2 to the Legislative Decree No 75/2010 relative to the mixed composted amender (Legislative
209 Decree, 2010a). In case of not compliance with the aforesaid criterion, compost can either be managed
210 as waste and sent to authorized plants, or recycled in the production process for the preparation of the
211 mixture to be subjected to composting, or used as filtering bed during the bio-filtration process.

212 *Systems for shooting down of emissions into the environment and control systems.* The Desag
213 Ecologia plant uses systems under continuous improvement for reduction of diffuse and fugitive
214 emissions. All operations that can generate dust or odor are located inside buildings, in enclosed
215 spaces. The plant is endowed with a suction system, which conveys air to bio-filters which are filled
216 with a mixture of aged compost, bark and sawdust.

217 The facility is equipped with separate networks of collecting, treatment and discharge of
218 wastewater. The plant is fitted with an automation system, which allows monitoring of process
219 parameters and their dynamic setting, notification of operating faults, activation of correction or
220 emergency procedures, actuation of equipment, plant programming and control.

221

222 **4. Results and Discussion**

223

224 In 2016, Italian production of municipal solid waste (MSW) was 30.1 million t, with a 2%
225 increase, in respect of 2015, corresponding to 590,000 t. The percentage of separate waste collection
226 (SWC), calculated as the ratio between the amount of materials collected by separate waste collection
227 and the amount of materials collected as unseparated MSW x 100, was 52.5%, with an increase of 5
228 points if compared with 2015.

229 SWC per capita was 261 kg at the national level, 328 kg in the North of Italy (+38 kg more
230 than in 2015), 266 in the Centre (+28 kg more than in 2015) and 169 in the South (+20 kg more than
231 in 2015). From 2011 to 2016, SWC variation was 62 kg per capita (Table 1).

232 In 2016, SWC of organic fraction (kitchen scraps = wet fraction, and waste coming from the
233 management of gardens and parks and ornamental green = green) in Italy was 6.5 million t,
234 considering also the quantity destined to domestic composting, more than 220,000 t; an increase of
235 almost 450,000 t (+7.3 %) was observed compared with 2015.

236

237 **Table 1.** Separate waste collection (SWC) in t, in % and in kg/year per capita from 2011 to 2016 in
 238 Italy (ISPRA, 2017)

239

	Amount of SWC collected (x1000 t)				SWC %				SWC per capita (kg/year)			
	North	Centre	South	Italy	North	Centre	South	Italy	North	Centre	South	Italy
2011	7,327.0	2,122.5	2,398.5	11,848.0	51.1	30.2	23.9	37.7	269	183	116	199
2012	7,234.4	2,229.6	2,528.3	11,992.3	52.7	33.1	25.5	40.0	266	192	123	202
2013	7,400.4	2,414.8	2,693.2	12,508.5	54.4	36.4	28.8	42.3	266	200	129	206
2014	7,803.1	2,700.2	2,898.1	13,401.4	56.7	40.8	31.3	45.2	281	223	139	220
2015	8,043.4	2,868.2	3,109.3	14,020.9	58.6	43.8	33.6	47.5	290	238	149	231
2016	9,091.4	3,214.3	3,516.4	15,821.9	64.2	48.6	37.6	52.5	328	266	169	261

240

241

242 In 2016, in the FVG region MSW production was 582,052.2 t, SWC was 67.1%, with a
 243 variation of +6.75% if compared with 2015. The more virtuous province was Pordenone, with 82.3%
 (Table 2).

244

245 **Table 2.** Population, municipal solid waste (MSW) in t and in kg/year per capita, separate waste
 246 collection (SWC) in t and in % in 2016 in the Friuli Venezia Giulia region and $\Delta\%$ 2016-2015
 247 (ISPRA, 2017)

248

Territorial area	Population	MSW (t)	MSW per capita (kg/year)	SWC (t)	SWC %	$\Delta\%$ 2016-2015
Province of Udine	531,466	258,643.1	486.7	180,495.3	69.8	+ 5.1
Province of Gorizia	139,673	69,476.5	497.4	47,392.4	68.2	+ 10.2
Province of Trieste	234,682	110,801.2	472.1	44,961.8	40.6	+ 16.3
Province of Pordenone	312,051	143,131.3	458.7	117,825.6	82.3	+ 5.0
Friuli Venezia Giulia region	1,217,872	582,052.2	477.9	390,675.0	67.1	+ 6.7

249

250 In 2016, the plants of mechanical-biological treatment worked, in Italy, more than 10.8 million
 251 t of waste, with a 4.4% increase in respect of previous year. About 5.7 million t were recovered in
 252 these plants at the end of the process (+ 10% in respect of 2015). Almost 3.4 out of 5.7 million t were

253 addressed to composting plants, about 2 million t to integrated aerobic/anaerobic treatment plants and
 254 little more than 249,000 t were worked in anaerobic digestion plants.

255 In 2016, 326 plants (309 in 2015) were working in Italy. More in particular, 274 plants (263
 256 in 2015) were devoted only to aerobic treatment (composting), 31 plants (26 in 2015) to integrated
 257 aerobic/anaerobic treatment (ISPRA, 2017) and 21 plants (20 in 2015) to anaerobic digestion
 258 (Bacenetti et al., 2013; Bozano et al., 2012). 26 plants were located in the North, in particular 2 in the
 259 FVG region, 2 in the Centre and 3 in the South. In these plants, biogas is produced by anaerobic
 260 digestion and compost by aerobic degradation of digestate and other organic waste. The composition
 261 of the treated substrate is made up of 69% of wet fraction, 10% of green fraction, 15% of sludge and
 262 6% of other waste: the organic fraction is 91% of the total waste managed by integrated plants
 263 (ISPRA, 2017).

264 In this paper, the case of the plant located in the municipality of Sedegliano, in the province
 265 of Udine, in the North-East of Italy, is taken into account. The plant is devoted to recovery by
 266 anaerobic digestion both of the waste coming from separate collection of the organic fraction of MSW
 267 and of sludge, and to subsequent composting to produce quality compost. In the plant, anaerobic
 268 digestion of the raw materials is carried out to produce biogas, which is then transformed into both
 269 electric power by two cogeneration engines of the whole potential of 998 kW, and thermal power,
 270 which is used to heat the fermenters in order to keep the process temperature of about 37°C.

271 The potentials of the plant are 31,000 t/year of incoming waste, 3 million Nm³/year of biogas
 272 production and 10,300 t/year of compost production (Table 3).

273

274 **Table 3.** Plant potentials

275

Incoming waste	99 t/day
	31,000 t/year
Generative groups electric power	2 groups (499 kW each)
Biogas production	3,000,000 Nm ³ /year
Compost production	30 t/day
	10,300 t/year

276

277 *Anaerobic digestion.* Anaerobic digestion provides for previous preparation of the mixture,
 278 which is made up by:

279 - 50% of waste represented by the organic fraction of MSW and by green waste
280 (mowing and trimming materials, small wood pieces);

281 - 50% of digestate produced by the anaerobic fermenters and recycled into the process,
282 to allow the development of a suitable bacterial population.

283 Percent composition of the mixture for anaerobic digestion is shown in Table 4.

284

285 **Table 4.** Mixture composition for anaerobic digestion

286

Material type	Percentage
Recycled digestate	50.0
Organic fraction of MSW	42.9
Mowing and trimming materials/small wood pieces	7.1
Total	100.0

287

288 In Table 5 the biogas production characteristics are presented.

289

290 **Table 5.** Characteristics of biogas production

291

Biogas produced per year	3,000,000	Nm ³ /year
Production hours	8,760	hours/year
Biogas flow per hour	342	Nm ³ /hour

292

293 The cogeneration engines allow the production of electric and thermal power. About 10% of
294 the electric power obtained is employed for the needs of the plant itself, whereas the remaining
295 amount is distributed by the Enel network. The thermal power obtained is partly recovered by the use
296 of heat exchangers to produce hot water at the temperature of about 85°C. Hot water is employed to
297 heat the digesters, the tank of percolate collection and the technical rooms. The amounts of energy
298 involved in the management of the plant in 2017 are shown in Table 6.

299

300 **Table 6.** Plant energy amounts in 2017

301

	Thermal power (MWh/year)	Electric power (MWh/year)
Production	5792	5500

Own consumption	870	550
Amount sold to a third party	-	4950
External supply	-	3965

302

303

Composting. Composting provides for preliminary preparation of the mixture, which is made

304

up by:

305

- material digested following anaerobic fermentation (about 50% by weight),

306

- wood waste after chipping and sludge,

307

- material already subjected to composting and recycled,

308

- material subjected to primary ageing which is not yet aged,

309

- intermediate fraction obtained by compost refining, with size between 10-15 and 100

310

mm,

311

- possible compost which proved to be not compliant with the criteria established to

312

define the end-of-waste status, and for which the suitability to be recycled in the process has been

313

positively evaluated.

314

The percent composition of the composting mixture is shown in Table 7.

315

316

Table 7. Mixture composition for composting

317

Material type	Percentage
Digestate from the plant	58.5
Not aged compost	30.3
Big wood pieces/waste	6.7
In-between fraction from refining	4.5
Total	100.0

318

319

The composting step has the aim of metabolizing the most easily biodegradable materials; it

320

lasts 14 days and is carried out at the temperature of 55°C by employing the static heap technique. At

321

the end of the process, compost is transferred to the primary ageing step, during which the most

322

complex materials are degraded. The primary ageing step lasts 28 days. Then the secondary ageing

323

step follows, during which the material is periodically turned over. This step lasts 20 days. At the

324

end, compost is forwarded to the sieving section, that allows the separation of the following fractions:

325 - fraction with a size smaller than 10-15 mm, representing compost, on which plastic
326 suction and separation of iron materials are carried out. On this fraction, sampling and chemical-
327 physical analyses are carried out to check the end-of-waste status;

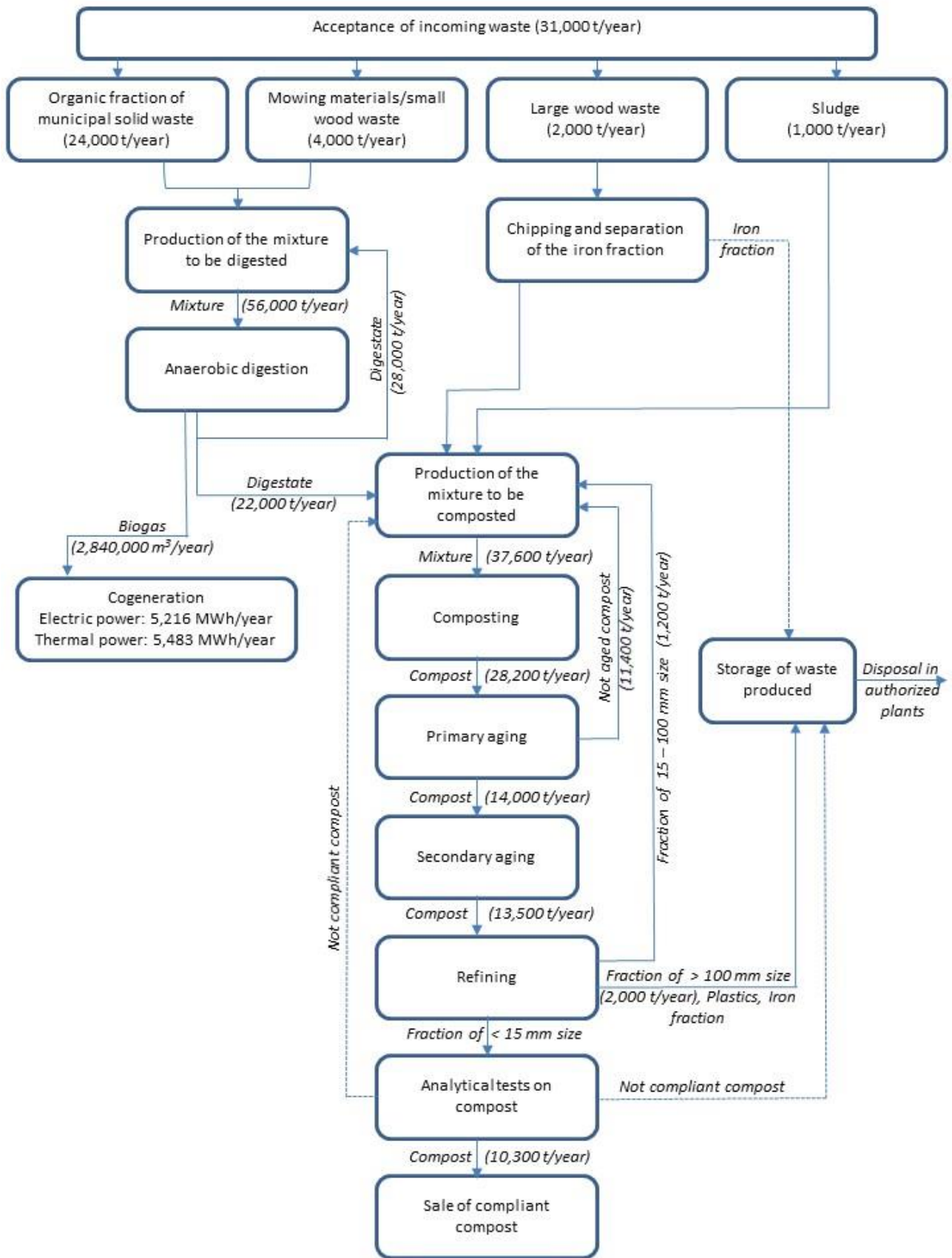
328 - fraction with a size between 10-15 and 100 mm, mainly made up by woodchips, which
329 can be recycled for the preparation of the mixture to be subjected to composting;

330 - fraction with a size larger than 100 mm, made up by rejected materials which are
331 managed as waste in authorized plants.

332 The quality compost obtained is certified by Italian Consortium of Composters for use in the
333 agricultural sector.

334 The matter balance foreseen is shown in Figure 1.

335



336

337

338

Fig. 1. Matter balance foreseen for Degas Ecologia plant

339

340 The output of materials obtained in 2017 was 3,408 m³ of biogas, 10,293 t of refined compost,
341 2,030 t of waste and 2,630 m³ of percolate.

342 At present, 75% of the raw materials treated by the plant comes from the FVG region, while
343 the rest from other basins, but in the future the plant manager will extend SWC to the whole region.
344 In fact, even if the plant started its activity in 2016, the management foresees to enlarge the plant
345 potential, by a new area of waste reception, already authorized by the Environmental Integrated
346 Authorization (EIA), and for which other building licences are required, starting works in 2019. EIA,
347 regulated by the II part of the Legislative Decree No 152/2006, authorizes the running of plants that
348 carry out activities cited in annex VIII, forcing measures to avoid or reduce air, water and soil
349 emissions (Legislative Decree, 2006).

350

351 **5. Conclusions**

352 The waste management EU policies act in order to reduce the environmental and health
353 impact. Waste production is increasing because population and consumes are growing, so their
354 production is unavoidable, but it is important to improve the technologies for recycling the materials
355 that can be transformed in renewable forms of energy and/or products to be used in different sectors.

356 To increase the SWC percentage at the national level, by reducing the differences among the
357 Italian regions, is a duty of national policies, by the reduction of the gap between the collected and
358 the recycled waste.

359 Desag Ecologia is able to operate in the perspective of Circular Economy through:

- 360 - the exploitation of the organic fraction of MSW and green waste;
- 361 - the production of a renewable form of energy, biogas, that can be used to produce
362 heat and electric energy;
- 363 - the production of quality compost for agricultural use.

364 The concept of sustainability, founded on the three main pilasters, economy, environment and
365 society, fits well with the activities of the plant taken into account.

366 The renewable sources sector, in particular the biogas sector, is living an important increase,
367 involving investments, new work places and several positive effects on the national economy.

368

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370 The authors contributed equally in idea conception, acquisition of information, data analysis
371 and comment, drafting of the manuscript.

372

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