Business Plan for Strategical Enlargement of the Biomass Business Area

Diplomarbeit von
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O. Univ.-Prof. Dipl.-Ing. Dr. techn. Ulrich Bauer

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Statutory Declaration

I declare that I have authored this thesis independently, that I have not used other than the declared sources/resources, and that I have explicitly marked all material which has been quoted either literally or by content from the used sources.

I certify that I have not presented this thesis to a judge as an examination paper in any way, neither at home nor abroad.

Graz, 31-05-2010 Hans Peter Schnöll

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Abstract

The Department Thermal Processes of Andritz AG deals with drying of sludge and biomass. Within this thesis, potential future markets in the field of biomass drying are analyzed and assessed. Based on these assessments, one can identify strategically attractive markets and derive a corresponding action plan to achieve the set goals for the future target markets.

This process is conducted through a business plan project, which was adapted to the specific requirements. The theoretical considerations are discussed in chapter 2, and Chapter 3 deals in detail with the field of information search. Afterwards, the implementation of theoretical knowledge into the practical application is described. The results of examinations, which are structured into four main elements, namely product analysis/description of existing drying methods, analysis of selected industry sectors, evaluation of industries, and derivation of targets and measures are presented in sections 5-8.

Kurzfassung

Die Abteilung Thermal Processes der Andritz AG beschäftigt sich mit der Trocknung von Schlämmen und Biomasse. Im Rahmen dieser Arbeit werden potentielle zukünftige Märkte im Bereich der Trocknung von Biomasse analysiert und bewertet. Aufgrund dieser Bewertung können strategisch interessante Märkte identifiziert und ein entsprechender Maßnahmenkatalog zur Erreichung der gesetzten Ziele für die zukünftigen Zielmärkte abgeleitet werden.

Dieser Prozess wird in Form eines Businessplan-Projektes, welches an die speziellen Erfordernisse angepasst wurde, durchgeführt. Die theoretischen Grundlagen werden in Kapitel 2 behandelt und in Kapitel 3 wird speziell auf den Bereich der Informationsbeschaffung eingegangen. Im Anschluss erfolgt die Beschreibung der Umsetzung der theoretischen Erkenntnisse in die praktische Anwendung. Die Ergebnisse der Untersuchungen, welche in die vier Hauptelemente Produktanalyse/Beschreibung existierender Trocknungsverfahren, Analyse ausgewählter Industriebereiche, Bewertung der Industrien und die Ableitung von Maßnahmen für gewählte Industrien gegliedert sind, werden in den Kapiteln 5 -8 behandelt und dargestellt.

Table of content

1. Introduction

This thesis was prepared in collaboration with Andritz AG (AAG), department "Thermal Processes" (ET). Following sections should give a short overview of AAG, the fields of business activity of ET, the objective target and the structure of the diploma thesis.

1.1. Andritz AG

The headquarters of AAG is located in Graz, Austria. AAG employs approximately 13,000 employees worldwide (as of end of December 2009) and has more than 120 production sites, service- and sales organizations around the world.[1]

The Andritz Group is a global leading supplier of customized plants, systems and services for hydropower, pulp and paper industry, steel industry and other specialized industries like solid/liquid separation, feed and biomass.[2]

Figure 1 shows the organizational chart of Andritz group.

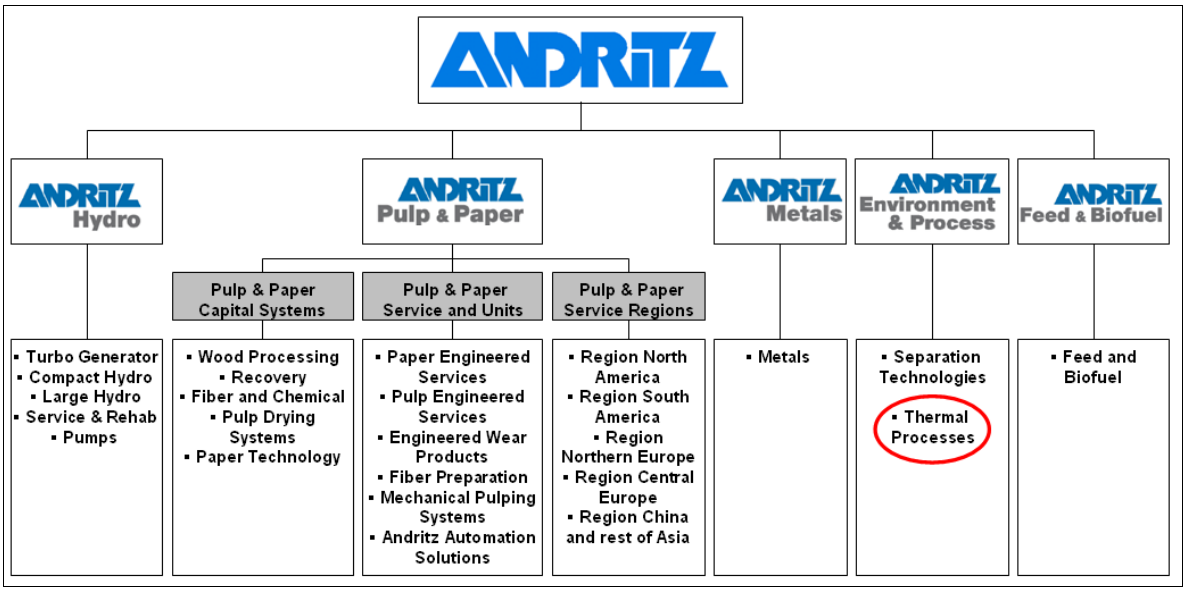

Figure 1: Organizational chart of AAG[3]

[1] Cf. N.N. (2010), page 2

[2] Cf. http://www.andritz.com (25.03.2010)

[3] Own presentation, Cf. AAG

As illustrated in Figure 1, AAG is divided into 5 main business areas:[4]

The Division HYDRO is a provider of electromechanical solutions and services for hydro, the product range further includes the manufacture of pumps for the pulp and paper industry and components for space technology, including components for the European ariane space program.

PULP & PAPER develops and manufactures equipment and systems for the production of virtually all types of wood pulp for making paper, cardboard and fibreboard, as well as special machinery for the manufacture of tissue paper.

The division METALS plans, develops and builds plants for the production of cold-rolled and hot-rolled carbon steel, stainless steel and nonferrous metals, including regeneration and oxide plants. In addition, equipment for punching and forming is generated.

ENVIRONMENT & PROCESS covers a broad spectrum of technologies, products and services for mechanical and thermal solid / liquid separation for municipalities and major industries (mining, steel industry).

FEED & BIOFUEL supplies systems and machinery for the industrial production of conventional animal feed and special high-quality animal feed. In addition, the division is taking a leading position in plants for wood pellet production.

1.2. Department Thermal Processes

The division “Thermal Processes” is the world’s leading provider of thermal sludge treatment solutions as part of the “Environment & Process” business area (see Figure 1).[5]

The scope activities of the division are focused on the design, construction, erection, and start up, of:[6]

- Drum drying systems for sludge from 1 to 12 tons water evaporation per line.
- Granulate incineration systems (EcoDry) which can be added to each drying system to heat the drying process with its waste heat from the incineration process. EcoDry is the combination of drying and incineration in a cyclone furnace or in a bubbling fluidized bed (BFB) furnace.

[4] Cf. http://www.andritz.com (25.03.2010)

[5] Cf. AAG

[6] ibidem

- Fluidized bed drying systems from 0,5 to 15 tons water evaporation for sewage sludge and fluid bed drying, cooling and spray granulation systems for industrial applications.
- Belt drying systems from 0,5 to 10 tons water evaporation for sewage sludge direct heated or indirect heated by using waste heat.
- Belt drying systems (once through or closed cycle system, direct or indirect heated) from 2 to 25 tons water evaporation for biomass.

The division is divided into 2 centres of competence, Graz and Ravensburg (Germany). The foci of the competence centre in Graz are drum drying systems (DDS), belt drying systems (BDS), granulate incineration systems (EcoDry - cyclone and BFB-furnace) and biomass dryers (BDS). The centre in Ravensburg is focused on fluidized bed drying systems (FDS).[7]

1.3. Objective Target of the Diploma Thesis

The target is the elaboration of a business plan (BP) to identify potential future markets in biomass drying, to derivate strategic goals and to define measures to reach the strategic goals. The superior targets are the increase of sales volume and achievement of the market leadership in biomass drying business.[8]

1.4. Structure of Diploma Thesis

Section 2 and 3 deals with the theoretical background of a BP and information search. Section 4 describes the practical implementation according to the theoretical considerations in previous sections. The results of the BP are divided into 4 main parts, namely product analysis, analysis of selected industries, the assessment of selected industries and the definition of measures and actions, which are described in detail in sections 5 to 8. The last point includes a personal conclusion and impressions in section 9.

[7] Cf. AAG

[8] ibidem

2. Business Plan

The business opportunities of a company are recognized in the future and not in the past. Thus, planning the future is absolutely important for successful business development for any company. A business plan is an appropriate tool to do this in a structured and meaningful way to demonstrate how to obtain the future targets and proceedings.[9]

2.1. What is a Business Plan?

According to Nagl, a BP is a written document representing the implementation strategy of the company's goals with all the essential requirements, plans and measures usually within a time horizon of 3-5 years. The BP comprises an important basis for decisions made by management, shareholders and potential business partners.[10]

2.2. Purpose of a Business Plan

A BP will usually be applied when decision makers are faced with decisions of enormous importance and need to show up the chances and risks of a business venture. Based upon the information obtained from the BP it is possible to come to the right decisions.[11]

A BP can be used internally as a planning instrument, or externally as an instrument for negotiations or acquisitions (Figure 2).

[9] Cf. Stocker/Dorizzi (2005), page 36

[10] Cf. Nagl (2009), page 13

[11] Cf. Stocker/Dorizzi (2005), page 36 f.

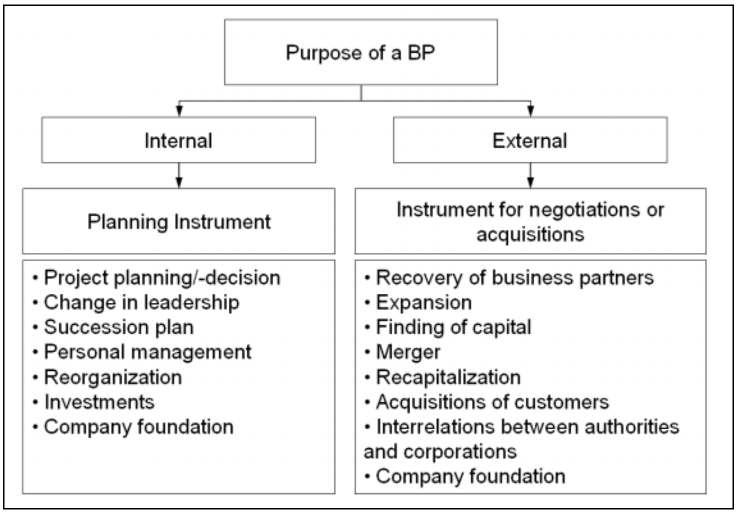

Figure 2: Purpose of a businessplan[12]

The most important intra-corporate functions of a BP are strategic planning and assessment of internal initiatives and projects.[13]

In case of a company establishment a BP is used as an acquisition instrument towards investors and creditor institutes (external) and entrepreneurs ensuring that business idea, business model, and other relevant aspects are comprehensively proven (internal). In the field of debt capital procurement, the BP is the main instrument to give creditor institutes the opportunity to get an idea of the economic prospects of success, in addition to the balance sheet and income statement. While searching for investors and venture capitalists, the main task of the BP is to provide complete and accurate information for potential partners.[14]

The following sections mainly describe the internal use of business plans within the meaning of a strategic planning tool.

2.3. Workflow of a Business Plan Project

Each future project starts off with a crude idea or intention. This idea has to be further developed and analyzed to gain knowledge about its future prospects. If the result of this preliminary analysis turns out to be positive, the next step will be the preparation of the project - defining the target group, approach, project organisation, schedule, and the contents the BP. Afterwards, the actual creation of the business plan can begin. The final document merges the individual results by eliminating interfaces and

[12] Own presentation, Stocker/Dorizzi (2005), page 36

[13] Cf. Nagl (2009), page 14

[14] ibidem

the verification of data consistency. After the presentation of the results and the acceptance of the decision-making body, the BP is implemented. [15]

In case of a declined BP, the project will be stopped and additional improvements are required for further decisions or the project will be delayed.[16]

Figure 3 illustrates the work flow and main steps of a BP project.

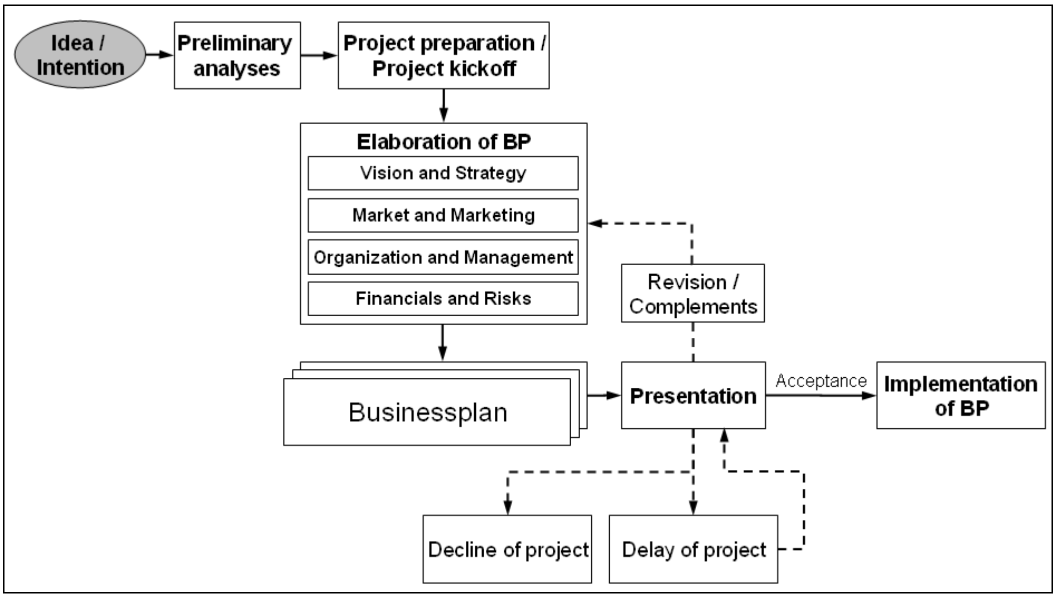

Figure 3: Work flow of a BP-project[17]

The following sections describe these main steps of a BP project.

2.3.1. Idea and Intention

To describe the idea and intention of a business plan project, the following questions should be answered:[18]

- What shall be achieved?
- Why should the objective be achieved?
- How can the objective be achieved?
- Which resources are required?

This description is of essential importance for the further course of the project. It is the primary basis of decision whether the business plan project will be realized or not.[19]

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[15] Cf. Stocker/Dorizzi (2005), page 37

[16] Cf. Paxmann/Fuchs (2005), page 28

[17] Own presentation, Cf. Stocker/Dorizzi (2005), page 37, Cf. Paxmann/Fuchs (2005), page 28

[18] Cf. Paxmann/Fuchs (2005), page 38

[19] Cf. Paxmann/Fuchs (2005), page 34

2.3.2. Preliminary Analysis and Acceptance

The idea should be submitted to co-workers and supervisors who have relevant professional background and key contacts within and outside the company to get a first feedback ensuring that possible errors and problems are identified and fixed early and that similar projects have not been done or cancelled in the past. If the idea is considered to be good, a positive decision will be made regarding the elaboration of the BP.[20]

2.3.3. Project Preparation

Project preparation includes defining the focus (What should be achieved with the BP?), the target group (Who is the recipient of the BP?), the framework of the BP (What is the content and how is the structure?), and the definition of organizational and chronological order.[21]

2.3.3.1. **Focussing**

According to Paxmann and Fuchs the focus of a BP can be subdivided into four different types:[22]

- Strategic focus

The main contents of a strategic focus provide the description of the strategic importance, the positioning within the company (or division), the long-and medium-term target planning, the risks, possible alternative scenarios, financial key data, and the description of the market and competitors.

- Internal start-up or establishment of a new company

This focus of the BP is probably the most complex and most expensive type, due to being presented to the management, employees and other groups as well (e.g. the works council). It is therefore advisable to prepare the BP in various elaborations, adapted to the needs of the different recipients. In this case the BP should include a task description of the new department, the organizational structure including management, organizational and strategic dissociation from other departments, a detailed statement of costs and revenue planning, the desired portfolio of clients, a marketing and sales plan, risk planning, and alternative scenarios.

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[20] Cf. Paxmann/Fuchs (2005), page 22

[21] Cf. Stocker/Dorizzi (2005), page 37; Cf. Paxmann/Fuchs (2005), page 46 ff.;

[22] Cf. Paxmann/Fuchs (2005), page 48 ff.

- Financing

In general, a business plan will always be connected to the financing of a project, but the described specific case of targeted procurement of capital from lenders or investors must be distinguished from other types of focus. The addressees are in particular interested in being informed on the thematic approach, short-medium and long term goals, investment requirements, a revenue and expenditure statement, financial ratios such as return on investment (ROI) or break even, the liquidity planning, and the detailed business case.

- Professional elaboration

Here the BP is used to analyze a particular project in detail. In daily project business, this form of a BP is a good opportunity to initiate new projects. The BP should include detailed thematic descriptions, technical descriptions (processes, flow charts), activity and time planning, the strategic positioning, and the description of possible alternatives. The financial analysis is a minor aspect of a functional preparation.

2.3.3.2. **Target Group**

The BP aims for a goal, which has to be set in advance. To achieve this goal, the business plan must be adapted to fit the needs of the target group(s) exactly. Only by means of a targeted approach and coordinated information, the desired effect can be achieved.[23]

There is no all-in-one business plan for all described foci, therefore, the following questions have to be clarified:[24]

- Which people will read the BP in technical and organizational terms?
- Who will make the decisions?
- At which level of responsibility are the key persons?

By answering these questions, the content and structure of the BP can be adjusted accurately to the specific needs of the target group(s) in order to increase the success rate of the businessplan project.[25]

[23] Cf. Stocker/Dorizzi (2005), page 37

[24] Cf. Paxmann/Fuchs (2005), page 24

[25] ibidem

Paxmann and Fuchs identify four different target groups:[26]

- Corporate management and executives

This target group is mostly responsible for the strategic direction of a company. To support such decisions with facts, such as information on sales opportunities, cost saving potentials, an increase in production efficiency, financial key facts (ROI, breakeven), the required investments of the project, and any strategic competitive advantages, is of enormous importance.

- Banks and other external financiers

In case future entrepreneurial projects are not financed from own resources, it is necessary to obtain the required capital from external sources. In addition to basic considerations of the issue, information regarding the related revenue and cost planning and the potential of sales and profit are of particular interest. The consideration should also deal with issues such as minimizing the risk for the investor and the possible return on investments. Investors often perform a due diligence review to analyse and evaluate the project professionally.

- Intra-corporate sponsors

Sponsors within the company can be understood as "internal donors." This target group, like external investors, is also interested in financial protection and risk assessment, in addition to the basic considerations of the project. Thus, the answers to following questions should be given in the BP:

    - Could an improved position be reached in comparison to competitors?
    - Could the customers' loyalty be increased?
    - Could the intra-corporate position of the internal sponsor be strengthened?
    - Is additional revenue generated or is it just a shift in sales?
    - What strategic and political implications may be involved in the business sector in case of project implementation?

- Project teams

In this context, a BP is a basic document for further analyses and assessments of future intents. Addressees are mostly technically savvy colleagues and supervisors, who are able to assess the project accordingly. The BP is used as the basis for further specifications and future planning.

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[26] Cf. Paxmann/Fuchs (2005), page 53

2.3.3.3. **Framework**

The framework defines the structure and the contents of the business plan which have to be adapted to the requirements of addressees.[27]

In literature, the following modules are referred to as the main components of a business plan:[28]

- Executive summary
- Business model / corporate concept
- Target markets
- Targets and strategy
- Products and services
- Marketing and distribution
- Management, personnel and organization
- Opportunities and risks
- Financial planning

This list represents a starting point for the possible contents and structure of a business plan only. This modules need to be adapted in content and precedence to the individual company -related situation and the targets of the BP.[29]

Executive summary

The executive summary (ES) is a compressed summary (not an introduction) of the results of the BP. No more than two pages should present the most important facts to rouse the readers' interest. While reading, the reader usually comes to a preliminary decision. Therefore, the ES is essential, providing the first impressions about the planned entrepreneurial ventures.[30]

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[27] Cf. Paxmann/Fuchs (2005), page 102 f.

[28] Cf. Stocker/Dorizzi (2005), page 38; Cf. Nagl (2009), page 17;

[29] Cf. Nagl (2009), page 17

[30] Cf. Nagl (2009), page 19, Cf. Schwetje/Vaseghi (2006); page 23

According to Paxmann and Fuchs 5 key-messages should be considered:[31]

- The title

The title should be self-describing and should arouse the readers' expectations and interests.

- The reason

The reason of the BP-project must be clear due to demonstrated traceable arguments. It must be clear why this project is worth to be realized.

- The target customers

This fact should be described by future markets, market segments and target customers to know who will be addressed with the product or service

- The benefit

The addressee should be convinced of its own advantage (monetary or qualitative value for the customer or the company itself) of the realization of the project.

- The decision

The decision should not be prejudged, but it is important to specify required future decisions at the very beginning of the BP, to inform the reader in which context the BP should be read and assessed.

Business model / corporate concept

The main issues which should be answered in this chapter are:[32]

- What business is the company or department operating in?
- What are the objectives (mission and vision)?
- How can these goals be achieved?
- What is the company's offer (product portfolio)? How does the product fit into the existing businesses?
- By what can the company/the product be silhouetted against competitors or other products? (What is the unique selling proposition (USP), what are the core competencies)?
- What is the potential of success of the project (earnings before interest and taxes (EBIT), ROI)?

[31] Cf. Paxmann/Fuchs (2005), page 117 ff.

[32] Cf. Nagl (2009), page 21

A business model will only succeed if a unique customer value meets a sufficiently large market, while offering a satisfactory profitability.[33]

Target markets

Knowledge regarding the market environment and the target customers are very important for the future success of a BP-project. Only to this information the product or service can be placed in the market appropriately, and the market potential can be estimated realistically.[34]

Important aspects are:

- Facts and figures about the needs of actual and potential customers: [35]

Corresponding information (current market situation and trends, specific characteristics of the market, trends of the environment, etc.) can be levied only by a thorough market research. General information regarding particular sectors and their development can be achieved in a fast and cheap way by statistic agencies, industrial unions, special interest groups (chamber of commerce, industrialists' association) or an internet research. [36]

Information search will be discussed in more detail in section 3.

- Market potential, market volume, market share and market growth:[37]

The market potential is defined as the totality of consumers who have a specific interest in a particular market offer. The market volume is the realized or projected sales or revenues in a defined target market, and the market share is the part of the market which is or will be covered by a company. [38]

[33] Cf. Nagl (2009), page 21 f.

[34] Cf. Paxmann/Fuchs, page 136. f.

[35] Cf. Nagl (2009), page 24

[36] Cf. Paxmann/Fuchs (2005), page 136 f.; Cf. Nagl (2009), page 24

[37] Cf. Nagl (2009), page 24

[38] Cf. Kotler/Keller/Bliemel (2007), page 195; Cf. Nagl (2009), page 23

The relationship between potential market, market volumes and market share is illustrated in Figure 4.

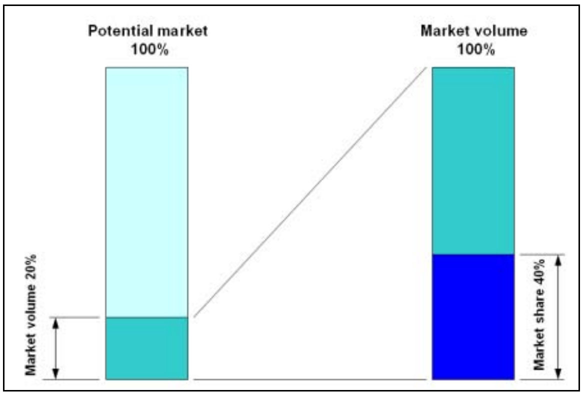

Figure 4: Potential market, market volume and market share[39]

- Competitors:

To clarify the situation regarding potential competitors, the following questions should be answered: [40]

- Which competitors are already active in the market?
- What are their strengths and weaknesses?
- Which products are in direct competition?
- What is the competitors' position in the market?

Competitors should be determined by geographical, product-specific, customer-and industry-specific factors, but also the distinction between real and potential competitors should be made.[41]

Targets and strategy

Business targets are more specific than the mission and vision. They reflect the desired conditions and outcomes in terms of measurable indicators (e.g. profit, sales volume, contribution margin), which should be achieved through entrepreneurial employments.[42]

[39] Own presentation, Cf. Nagl (2009), page 23

[40] Cf. Paxmann/Fuchs (2005), page 106

[41] Cf. Paxmann/Fuchs (2005), page 172

[42] Cf. Meyer/Davidson (2001), page 305

The corporate strategies of multi-stage companies are described by Aaker by six dimensions:[43]

- The product market the company competes in

The scope of a company is determined by products offered, markets served, competitors and the level of vertical integration.

- The level of investment

A company may invest in order to grow (or even to enter new markets) or to keep the current position. Another possibility is the confiscation of a particular product or market constellation (milking of the "cash-cow") by minimization of investments or the liquidation or sale of the company.

- The business strategies which are necessary to compete in the selected product market

Specific types of competition can be characterized, e.g. by the following business strategies:

  - Product strategy
  - Price strategy
  - Strategy of positioning
  - Distribution strategy
  - Logistic strategy, etc.

- The strategic advantages or capabilities that are underlying the strategy, to create a lasting competitive advantage

A strategic capability describes specific skills and resources of a company, which distinguishes it from its competitors in a positive way and creates advantages.

- The distribution of resources in the business units

Financial resources and non-financial resources (buildings, staff, etc.) must be generated and distributed. These facts can influence the strategic decisions substantially.

- The development of synergies within the company

Synergies within a company are a possibility to create a competitive advantage.

[43] Cf. Aaker (1989), page 4 f.

Products and services

The description of the product or service is carried out primarily through the depiction of its (special) values.[44]

The "benefit" can be defined in corporate terms in many ways:[45]

- Strategic benefit:

The strategic benefit is determined by the company or product strategy. A strategic benefit can be the expanding of the product portfolio, the strengthening of customer relationships, the strengthening of the competitive situation, the expansion of market share, etc. .

- Commercial benefit:

A commercial benefit is identified either by the reduction of incurred costs or investments, or by the increase of commercial parameters. Examples of commercial benefits are an increase of orders, an increase in turnover and profit, a reduction of production and development costs or a reduction of administrative costs.

- Organizational benefit:

The organizational benefit concerns the internal structure of a company and is characterized by simplifying procedures and / or improved organizational processes. Typical examples are the creation of an efficient organizational structure and flatter hierarchies, the shortening of reporting lines, or an increase in IT (Information Technology) security.

- Indirect benefit:

This benefit (often called „soft-factors“) does not appears directly. It can not be detected and quantified easily. The reputation of a company, the company's reputation in the market, or the satisfaction of employees, customers and suppliers are a typical "benefit" in this category.

In addition to previously described corporate benefits (internal), the customers benefit should also be considered. The customer buys and utilizes the product - therefore the benefit of the potential customer should be examined. This review of benefit is

[44] Cf. Nagl (2009), page 40

[45] Cf. Paxmann/Fuchs (2009), page 173 ff.

particularly important in customer orientated businesses, because relevant information for marketing and sales messages can be derived. [46]

Marketing and distribution

Marketing is the planning, coordination and monitoring of activities of a company which are focused on current and potential markets, with the aim to delight customers.[47]

For marketing planning, exact knowledge of the needs and characteristics of potential customers is required. These data have been identified in the previously described modules (target markets, products and services) of the business plan and are basic data for further explanations. Especially information regarding market requirements, trends and possible developments, customer needs, competitors, as well as the added value for the customers and the benefits of the product compared to competition are required. [48]

Marketing planning can be divided into operational and strategic marketing planning. Strategic planning deals with the basic knowledge of markets and products as well as with appropriate strategies. It defines the marketing objectives for the next five years and the required resources to achieve the objectives and measures. The operational marketing planning is focused on the intermediate future, and plans the active influence of the market by using the marketing instruments (four "P"s, see Figure 5).[49]

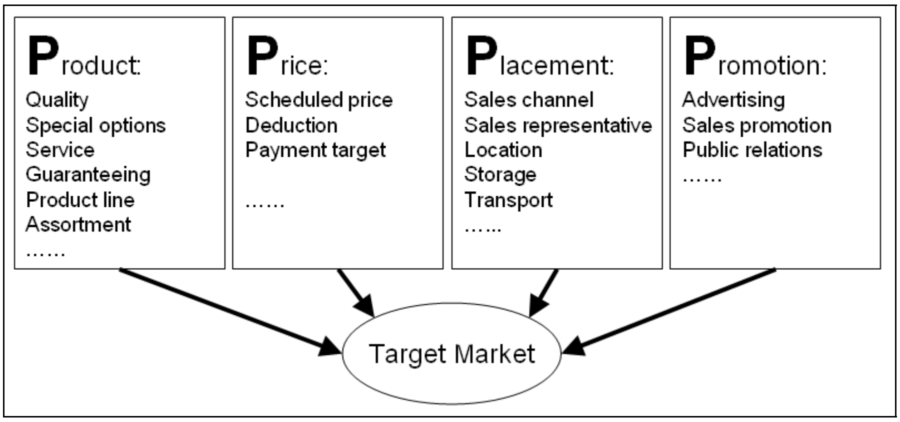

Figure 5: Marketing instruments[50]

[46] Cf. Paxmann/Fuchs (2005), page 180 f.

[47] Cf. Nagl (2009), page 47

[48] Cf. Paxmann/Fuchs (2005), page 200 f.

[49] Cf. Nagl (2009), page 47 f.

[50] Own presentation, Cf. Nagl (2009), page 48

Management, personal and organisation

The potential of the management team and employees is a critical success factor in entrepreneurship. To get the financial resources for a business venture, an appropriate quality of the leading team is required. Important features of a high quality management and employees are:[51]

- Professional and business know-how (entrepreneurial experience)
- Social competence (capacity for teamwork)
- Communication and leadership skills (willingness to delegation)
- Industry and market knowledge (understanding of industry)
- Flexibility
- Vision force
- Networking skills

Even the best ideas can not be successfully implemented in the absence of "human quality". Therefore, it is important to demonstrate the skills of the individuals involved in the businessplan, to win the confidence of potential internal or external investors.[52]

The term “organization” can be understood in the sense of process organization or organizational structure. Efficient process organization ensures appropriate capacity utilization, minimized cycle -times, continuous quality assurance, and the clarification of potential partnerships and possible outsourcing of products or services. Through an analysis of the value chain, like illustrated in Figure 6, cost reductions can be investigated and the depth of added value can be verified.[53]

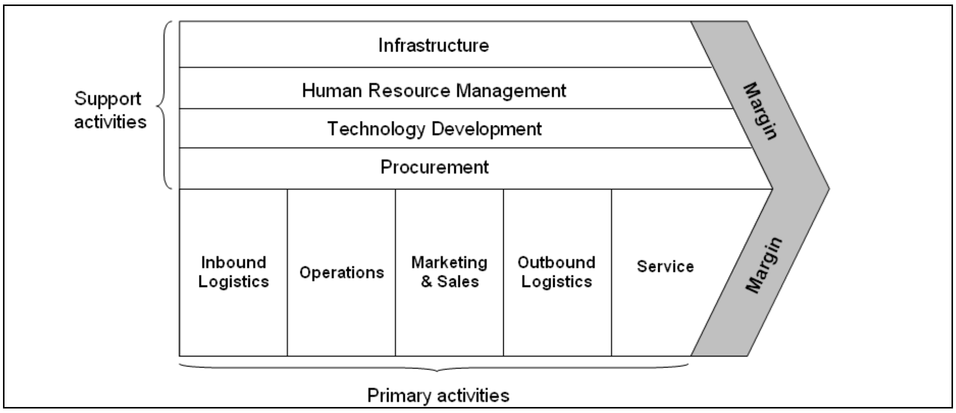

Figure 6: Value chain of a company[54]

[51] Cf. Nagl (2009), page 62 f.

[52] Cf. Singler (2008), page 46

[53] Cf. Nagl (2008), page 64

[54] Own presentation; Cf. Porter (2000), page 66

The organizational structure should be shown by an organizational chart to fix the responsibilities and the allocation of rights and duties.[55]
An example for an organigram is illustrated in Figure 7.

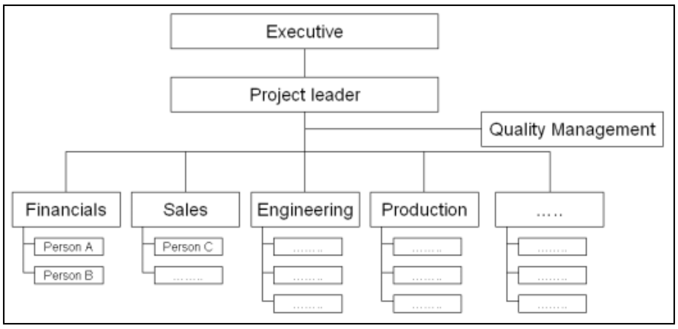

Figure 7: Example of an organisational structure of a company[56]

Opportunities and risks

All business initiatives are linked to opportunities and risks. These can be found both within the company itself and in the business environment.[57]

Opportunities describe the potential for success of entrepreneurship, such as future growth opportunities or an exceptional, new business opportunity.[58]

Risks are uncertain future developments which are not predictable. A new situation may have a negative influence on the project. Therefore, risks have to be identified and evaluated previously, to be able to handle possible problems properly.[59]
According to Paxmann and Fuchs, risks can be subdivided into several types:[60]

- Operational risks
  (Risks regarding internal operations of processes, operations and organizational measures)
- Financial risks
  (Budget exceeding, penalties by missed deadlines, taxes, export duties, etc.)
- Technological risks
  (Infrastructural problems, emergence of new technologies or new standards, etc.)

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55 Cf. Singler (2008), page 51; Cf. Nagl (2008), page 65

56 Own presentation

57 Cf. Nagl (2008), page 68

58 ibidem

59 Cf. Paxmann/Fuchs (2005), page 251

60 Cf. Paxmann/Fuchs (2005), page 253 f.

- Risks regarding resources
  (Loss of staff, decreasing productivity and motivation of employees, etc.)
- Legal risks and compliance
  (Non-compliance of statutory regulations or requirements of occupational unions, infringement of patents, copyrights or trademarks)
- Risks regarding reputation
  (Bad reputation of the company as a result of bad press)
- Risks of time
  (Time delays result in additional risks such as financial risks or risks concerning reputation)
- Market risks
  (Emergence of new competitors, sudden lack of customers, negative trend of total economic activity, etc.)
- Risks regarding partners
  (Bankruptcy of a partner, responsibilities that can not be covered by the partner, change of assortment, etc.)
- Political risks
  (Changes in society or own company, influence of trade unions, etc.)

Financial planning

The goal of financial planning is the information of addressees of the business plan through an effective overview of assets, liabilities, financial position, and results of a company from its current and future perspective. Financial planning is part of the quantitative business planning (illustrated in Figure 8). It is based on the sales and price plan, production plan, procurement plan, personnel plan and investment plan, and includes the profit and loss account, budgeted balance sheet and liquidity plan. To get a quick overview of the results, final key indicators (equity ratio, return on investment, sales per employee, break even, cash flow, et al.) should be derived.[61]

[61] Cf. Nagl (2009), page 72 ff; Cf. Paxmann/Fuchs (2005), page 308

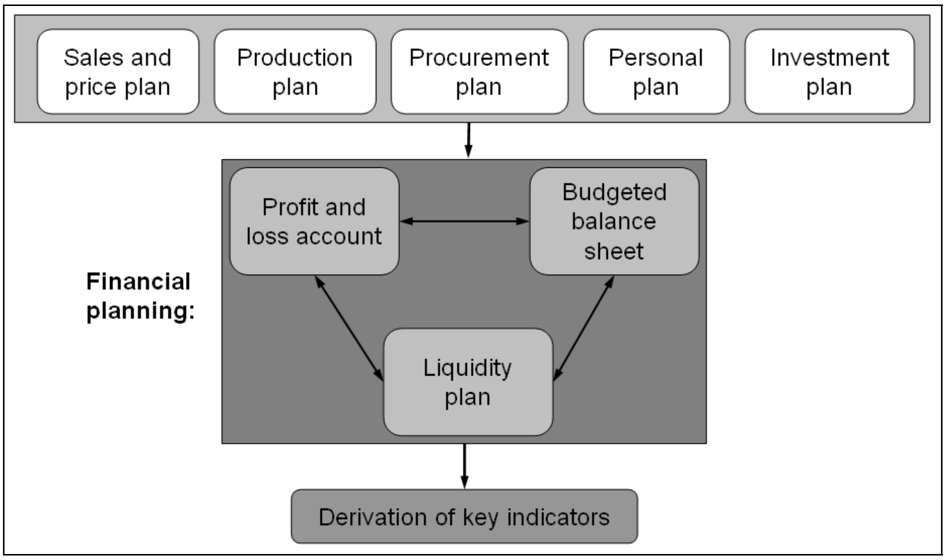

Figure 8: Components of quantitative corporate planning[62]

2.3.4. Elaboration of BP

The elaboration includes the information search, analysis and the assessments of results. More information is declared in section 3.

2.3.5. Presentation

Quality Check:[63]

Prior to submission and presentation of the BP a final quality check is advisable. The quality check should include following aspects:

- Correct information

The BP should be based on facts and verifiable data. If possible, sources and references for statements should be given.

- Sufficient information

The BP must provide sufficient information to enable an understanding of the business plan. There must be enough substance to suggest a thorough analysis and evaluation.

- Intelligibility

The texts should be drafted clear and simple. If it can be assumed that terms are not known, they have to be explained (e.g. by footnotes). Charts and graphs should promote the understanding of the text and should always be associated with the text.

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[62] Own presentation; Cf. Nagl (2009), page 73

[63] Cf. Paxmann/Fuchs (2005), page 320 ff.

The graphical representation is designed to support the statements in the text and should not raise new issues.

- Meaningfulness

The logic of the arguments must yield a meaning. If the need of the businessplan can not be recognized, it will be difficult to reach a positive decision.

- Authenticity

It should be apparent that the BP is penned by you. It makes sense to be supported by experts, but it should be apparent that the document is not only based on "copy and paste" of other documents.

- Originality

Thru originality, the reader may get excited of the topic. If a plan had already been submitted, it is doomed to fail in advance as a result of missing meaningfulness.

- Structure

The order of sections should be consistent to avoid scrolling while reading.

Presentation:

Based on the professional quality of the BP, the quality of preparation and presentation is a very important aspect of success. The layout should be fixed and applied consistently throughout the business plan. It is also advisable to use existing intra-corporate templates to achieve an identification of the projects related to the company. [64]

[64] Cf. Paxmann/Fuchs (2005), page 323

3. Information Search and Analyses

The process of a businessplan project is quite similar to the marketing research process according to Kotler.

Kotler splits the marketing research process into six main parts:

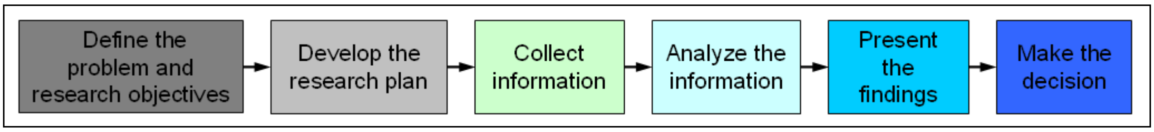

Figure 9: The marketing research process[65]

The first phase of marketing research requires a precisely specified research and development problem to get the appropriate answers for all questions posed.[66]

The problem and the research objectives are defined during the first steps of the BP project as a result of fixing the idea and intention, preliminary analysis and especially the project preparation (definition of focus, target group and framework). Information research in context of a businessplan project consists of the development of the research plan and the collection of information. The analysis of the information gathered is part of the BP's elaboration. The last two parts of Kotler's marketing research process are equal to the last two steps of the BP-process as illustrated in Figure 3, section 2.3.

The development of the research plan, the collection of information and the analyses of information are considered in the following sections.

3.1. Marketing Research Plan

To design a research plan, decisions regarding data sources, data acquisition methods, acquisitions instruments, sampling plan and contact methods are required, as listed in Table 1.[67]

[65] Own presentation, Kotler/Keller/Brady/Goodman/Hansen (2009), page 193

[66] Cf. Kotler/Keller/Bliemel (2007), page 164

[67] Cf. Kotler/Keller/Brady/Goodman/Hansen (2009), page 192

Data sources:	Data acquisition methods	Acquisition instruments	Sampling plan	Contact methods
Primary data	Observation	Questionnaire	Main unit	written
Secondary data	Interview	Technical equipment	Sample size	by phone
	Experiment		Sample selection procedure	personal
	Group discussion			

Table 1: Required decisions regarding the marketing research plan[68]

The following sections describe these main facts which have to be considered in marketing research planning.

3.1.1. Data Sources

Data sources can be divided into primary and secondary sources. Secondary data are already existing information, whereas primary data need to be collected first-time. The collection of primary data is in most cases more expensive compared to secondary data, but the quality of information is more detailed. [69]

Primary data sources

"*Primary data are data freshly gathered for a specific purpose or for a specific research project, […]"*[70]

The main possibilities to collect primary data are observations, focus groups, surveys, behavioural data and experiments.[71]

Secondary data sources

"Secondary data are data that were collected for another purpose and already exists somewhere, such as in surveys or market reports from research organisations or government agencies. Secondary data may also take the form of internal company information, such as sales records or financial data."[72]

[68] Own presentation, Cf. Kotler/Keller/Bliemel (2007), page 166

[69] Cf. Kotler/Keller/Bliemel (2007), page 166

[70] Kotler/Keller/Brady/Goodmann/Hansen (2009), page 193

[71] Cf. Kotler/Keller/Brady/Goodmann/Hansen (2009), page 193

[72] Kotler/Keller/Brady/Goodmann/Hansen (2009), page 193

Intra-corporate secondary data sources are the income and loss statement, sales statistics, customer lists, reports of previous researches of primary and secondary data, etc. .[73]

External data sources are:[74]

- Reports by public agencies and business associations:
    - Statistic agencies
    - Industrialists' associations, boards of trade
    - Professional associations
- Reports of special institutes and research services
- Business press, professional journals, books
- Corporate publications (annual balance sheet, reports to shareholders, PR reports, advertising folders, announcements of new products, etc.)
- Electronic databases, information -broker, internet

3.1.2. Data Acquisition Methods

Observation

Observation can be detailed in four principle types, namely field tests, laboratory tests, personal observations and observations by assistive technologies. Field observations are conducted under real-life conditions. In contrast, laboratory tests create artificial conditions under which the observation takes place. Observations which are supported by assistive technologies use those to measure the behaviour and responses of the proband.[75]

Interview

The prerequisite for an interview is always the personal relationship between interviewer and respondent. In an interview, the interviewee can wander from the subject to reflect his own opinions and attitudes. This way, the results of the research are closer to reality in comparison to e.g. pre-prepared answers to a multiple choice questionnaire - but of course the required efforts are much higher.[76]

[73] Cf. Kotler/Keller/Bliemel (2007), page 167

[74] Cf. Kotler/Keller/Bliemel (2007), page 167 f.

[75] Cf. Bruhn (1995), page 97 f.

[76] Cf. Paxmann/Fuchs (2005), page 79 f.

Experiment

"The most scientifically valid research is experimental research, designed to capture cause-and-effect relationships by eliminating competing explanations of the observed findings."[77]

Workshops

A workshop presents a practice -related meeting to discuss and structure projects and intents in a major group. Within a workshop problems and challenges can be addressed specifically.[78]

There are a few rules for planning a workshop:[79]

- The goals and tasks of the workshop must be defined clearly.
- The estimated time shall be designed to allow the achievement of defined targets.
- Prior to the start of the workshop information concerning the objectives and tasks should be sent out to the parties. This will enable participants to be prepared for the topic.
- The optimal number of participants is 5 to 15 persons. Too many participants are working inefficiently
- The workshop should be led a facilitator who is responsible for ensuring that the focus of the workshop will not be forgotten.

3.1.3. Acquisition Instruments

Questionnaire

An interview or survey is a key element of market research. Questionnaires give a list of questions to be answered by the respondents. The answer can be given in freely available text fields, the selection of predetermined answers, or numerical rating scales. Statements in a questionnaire must be defined and described carefully to ensure that the respondent is aware of the issue and the answers.[80]

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[77] Kotler/Keller/Brady/Goodmann/Hansen (2009), page 197

[78] Cf. Paxmann/Fuchs (2005), page 77

[79] Cf. Paxmann/Fuchs (2005), page 77 f.

[80] Cf. Paxmann/Fuchs (2005), page 71

Important aspects in the development of a questionnaire are:

- Order of questions

The first questions should be ice breakers, followed by factual issues. Personal questions (about the person and the company) should be asked at the end.[81]

- Wording of questions

Questions can be provided directly (Do you drink alcohol daily?) or indirectly (Which drink do you prefer to your daily meals?).[82]

- Type of questions

"*Closed questions specify all the possible answers and provide answers that are easier to interpret and tabulate. Open-ended questions allow respondents to answer in their own words and often reveal more about how people think*"[83]

- Type of survey

The survey by a questionnaire can be done written or verbal. In case of a written questionnaire additional information regarding the topic should be given. In case of a verbally answered questionnaire, questions of the respondent can be answered directly by the interviewer. If a questionnaire is sent electronically, it must be ensured that the used file format can be read and used by the addressee (the use of a pdf -file is recommended). It is advisable to offer several different ways of returning (e.g. e-mail, postal service, internal mail, fax) to achieve a higher response rate.[84]

3.1.4. Sampling Scheme

Generally, decisions on the main unit, the sample size and the selection procedure must be made. The main unit indicates who or what will be included in the considerations. The sample size determines how many people are respected in the investigation and the selection procedure determines how the sample is drawn.[85]

[81] Cf. Bruhn (1995), page 96 f.

[82] ibidem

[83] Kotler/Keller/Brady/Goodmann/Hansen (2009), page 198

[84] Cf. Paxmann/Fuchs (2005), page

[85] Cf. Kotler/Keller/Bliemel (2007), page 178 f.

3.1.5. Contact methods

There are several ways to get in touch with the desired informants:

- Written contact

A written survey is particularly advantageous in case of an expected rejection of a personal interview, or to avoid a personal influence of the interviewer on the answers. Simple and clearly worded questions are essential to ensure that the respondent is able to understand the questions correctly. Written surveys sent by postal service or mail are usually characterized by low response rates and long return rates.[86]

- Telephone contact

A Telephone survey is an excellent method to get information extremely fast. One advantage of this type of survey is the possibility to answer questions of the respondent immediately. The disadvantage is the fact that the questions must be brief and may not be personal. The response rate is higher compared to a written survey.[87]

- Personal contact

The interviewer can ask more questions than in the written or telephone survey and is able to provide additional questions. Another positive aspect is the possibility to record additional observations regarding the appearance and body language. The personal questioning is the most expensive option and may cause troubles by the interviewer's influence on the questions by suggestion or bias.[88]

3.2. Information Collection

The collection of data causes the highest costs of marketing research and highest number of failures. In surveys following problems may occur:[89]

- Contact persons can not be reached
- Others refuse to provide information
- Some deliberately give false or biased answers
- Interviewers may be biased or dishonest

[86] Cf. Kotler/Keller/Bliemel (2007), page 180; Cf. Kotler/Keller/Brady/Goodman/Hansen (2009), page 204

[87] Cf. Kotler/Keller/Bliemel (2007), page 180

[88] ibidem

[89] Cf. Kotler/Keller/Brady/Goodman/Hansen (2009), page 205

3.3. Information Analysis

Following sections describes three of the most common used analysis tools, namely PEST Analysis, SWOT Analysis and the Portfolio analysis.

3.3.1. PEST Analysis

The acronym PEST describes an analytical method to scan and illustrate the environmental factors of influence. PEST comprises the following factors:[90]

- **P**olitical
- **E**conomical
- **S**ocial
- **T**echnological

This analysis is also called STEP- or PESTLE analysis. PESTLE means the addition of two more factors:[91]

- **L**egislative
- **E**cological

These additional factors are in principle already contained in "PEST", but it may make sense in case of a special focus, e.g. on ecological parameters. [92]

Examples of potential factors are listed in Table 2:

Political	**E**conomic	**S**ocial	**T**echnological
- tax policy - employment laws - enviromental regulations - trade restriction and tariffs - political stability	- economic growth - interest rates - exchange rates - inflation rate	- health consciousness - population growth rate - age distribution - career attitudes - emphasis on safety	- R&D activity - automation - technological incentives - rate of technological change

Table 2: PEST analysis, examples of factors of influence[93]

[90] Cf. Paxmann/Fuchs (2005), page 82

[91] Cf. www.quickmba.com (11.03.2010); Cf. Paxmann/Fuchs (2005), page 82 f.

[92] Cf. Paxmann/Fuchs (2005), page 83

[93] Own presentation; Cf. www.quickmba.com (11.03.2010)

Codes of practice:[94]

- Factors of a PEST analysis are only external and can not be influenced by the company or the project.
- The “market” has to be defined prior to performing the analyses. The consideration of the market may be done in context to a product, a company, a department, a customer, or an idea.
- To evaluate different factors in relation to each other weighing of the factors may be added.

Preferred approach:[95]

- Creation of a list on a sheet of paper, a flipchart, or whiteboard
- Entering of actual or potential external factors by the determination of specific statements
- Sorting of the identified factors in order of importance within each category
- Arrangement of different groups of factors in order of importance, to reach an emphasis of groups of factors

3.3.2. SWOT Analysis

The abbreviation “SWOT” stands for strengths, weaknesses, opportunities, and threats. The SWOT analysis associates the external opportunities and threats of a company with its internal strengths and weaknesses.[96]

Internal factors: [97]

The internal analysis of strengths and weaknesses identifies the scope of the company in relation to its main competitors. Strengths have to be utilized and weaknesses must be removed.

- Strengths:
  - What are the causes of past successes?
  - What are the chances of their own company in the future?
  - What synergies which can further be exploited with new strategies are available?
- Weaknesses:
  - What weaknesses exist (regarding products, production processes, etc.)?

[94] Cf. Paxmann/Fuchs (2005), page 83

[95] Cf. Paxmann/Fuchs (2005), page 83 f.

[96] Cf. Bruhn (1995), page 44

[97] Cf. Nagl (2009), page 30

External factors:[98]

The scope of the external analysis regarding opportunities and threats is the identification of the development and resulting chances or risks of the market.

- Opportunities:
    - What options are available?
    - What trends could be prosecuted?
    - Is there untapped potential? If so, what?
- Threats:
    - What is to be observed about the economy overall?
    - What are competitors doing?
    - What trends are expected?
    - Do laws or other regulations change?
    - Is there probably a change of technology?

The results of a SWOT analysis can be demonstrated by a matrix like illustrated in Figure 10.

	Opportunities	**T**hreats
Strengths	→ develop	→ assure
Weaknesses	→ gain up	→ cut

Figure 10: SWOT-analysis[99]

The combination of strengths and opportunities opens options which should be developed and expanded. If internal strengths meet external threats, the company has to be assured against the risks as much as possible. In case of own weaknesses connected to opportunities, the company has to catch up the leeway to utilize possible chances. The worst combination is the combination of internal weaknesses and external threats. The best procedure in this case is to cut activities to defend the company from threats. [100]

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[98] Cf. Nagl (2009), page 30

[99] Own presentation; Cf. Pepels (1999), page 91

[100] Cf. Pepels (1999), page 92

3.3.3. Portfolio Analysis

The origin of portfolio techniques is the financial industry. A portfolio of various financial assets should be composed in balance regarding expected returns and risks. Striving for balance in portfolio selection is transmitted to strategic business planning within the scope of a product portfolio.[101]

Portfolio techniques are tools which allow a multi-dimensional assessment of products or business segments to achieve a visualization of strategic market positions.[102]

The portfolio analysis was originally developed by the Boston Consulting Group (BCG). This matrix is also referred to as "Boston-I-portfolio" or "market share – market growth portfolio". The "market attractiveness- competitive advantage portfolio analysis" (MA-CA-Analysis) is an advancement developed by McKinsey/GE (General Electric).[103]

According to Bruhn, a portfolio analysis includes the following general steps:[104]

- Step 1:
  - Definition of dimensions
  - The abscissa describes a corporate influenced parameter
  - The ordinate describes a market influenced parameter
- Step 2:
  - Generation of Information regarding each strategic business unit (SBU)
  - Positioning of the SBU in the matrix
  - The size of positioned points can describe additional information e.g. sales volume, etc.
  - The result of step two is an actual portfolio
- Step 3:
  - Analysis of actual portfolio and finding of possible strategies to strengthen the position of the SBU
- Step 4:
  - Definition of target positions for each SBU for a defined planning period

[101] Cf. Nagl (2009), page 242

[102] Cf. Pepels (1999), page 97

[103] Cf. Meyer/Davidson (2001), page 314 f.

[104] Cf. Bruhn (1995), page 70

- Step 5:
    - Concretion of strategies and target positions by defining strategies regarding products, instruments, sales and competition

BCG-Portfolio

The abscissa of BCG portfolio is defined by the relative market share of products/SBU, with the ordinate describing the market growth. The relative market share is the ratio of the own market share to the share of the largest competitor. The market growth describes the growth of the overall market or of a market segment.[105]

Products/SBU in good market position in growing markets are known as STARS. Through the implementation of volume effects in production and marketing there is potential for cost reductions, but high resource requirements come along with strong investments. CASH-COWS are products/SBU in good market position in markets with low growth rates. Here, the focus should be on the potential of cost reduction. Investments should only be done to ensure the market position. POOR DOGS are in the worst position with a low market growth and a relative market share with the generic strategy of divestment. QUESTION MARKS are characterized by high market growth in context to a low relative market share and require high investments to improve the position in the market. The generic strategies for question marks are market development or exit strategies. [106]

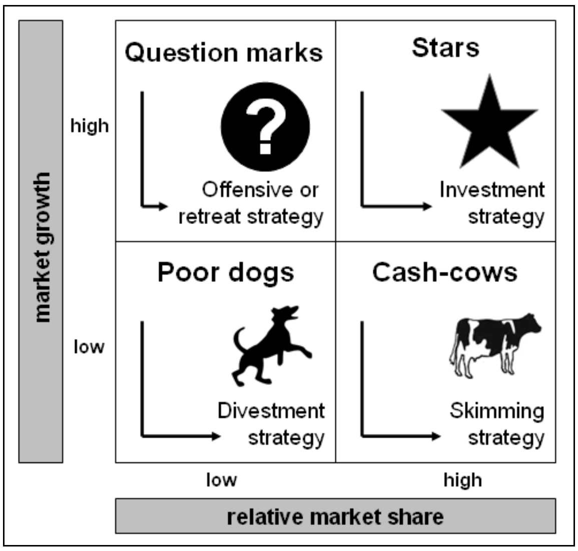

Figure 11: BCG portfolio[107]

[105] Cf. Meyer/Davidson (2001), page 315; Cf. Bruhn (1995), page 71
[106] Cf. Bruhn (1995), page 72
[107] Own presentation; Cf. Bruhn (1995), page 71

Advantages:[108]

- The BCG Portfolio is a simple tool to use.
- The required data are relatively easy to collect.
- It is a useful graphical tool to visualize the strategic position and to assist decision- making.

Disadvantages:[109]

- The assessment is only based on two high-density factors, market growth and relative market share.
- A high relative market share describes only one among many criteria of a strong position in the market.
- A fast-growing market is not necessarily an attractive market. Growing markets can attract new competitors with the possible result of lower margins because of overcapacities.
- Due to the dichotomous division of factors in "high" and "low", it is often difficult to classify occurring middle-positions.

McKinsey/GE portfolio:

This portfolio analysis corrects some disadvantages of the BCG-Matrix. In this case more qualitative and quantitative factors for success are considered for positioning of products/SBU in the matrix. [110]

The abscissa is defined by the competitive advantage of products/SBUs, and the ordinate describes the market attractiveness. The description of these two main factors is determined by a variety of individual factors:[111]

- Competitive advantages:
    - Market position
      (e.g.: market share, size of enterprise, growth rates, profitability, marketing potential)
    - Production potential
      (e.g.: innovation, know-how, licensing relationships, location advantages, cost advantages in production)
    - Research and development potential
      (e.g.: basic and Applied Research, innovative potential of researchers)

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[108] Cf. Meyer/Davidson (2001), page 317

[109] ibidem

[110] Cf. Meyer/Davidson (2001) , page 318

[111] Cf. Bruhn (1995), page 72

- Qualification of employees and managers
  (e.g.: quality of management systems, professionalism and motivation of employees)

- Market attractiveness:
  - Market size and market growth
  - Market quality
    (e.g.: profitability of industry, intense of competition, possibility of substitution)
  - Supply of energy and raw materials
    (e.g.: vulnerability of supply, existence of alternative raw materials and energy sources)
  - Situation of environment
    (e.g.: cyclicality, legislation, environmental pressures)

To determine these two main factors, the individual factors have to be weighted according to their importance.[112]

An example for such weighting of factors can be seen in Table 3:

Driver:	Weighting	Points [1-10]	Weighted points:
Market Volume	30%	10	3
Market Maturity	20%	1	0,2
Market Trend	30%	6	1,8
Competitiveness of market	10%	2	0,2
Margin	10%	1	0,1
	100%		5,3

Table 3: Weighting of factors of market attractiveness[113]

The MA-CA portfolio analysis also enables the derivation of recommendations for further procedure, namely expanding, skimming and selecting, as illustrated in Figure 12.[114]

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[112] Cf. Kotler/Keller/Bliemel (2007), page 101

[113] Own presentation

[114] Cf. Meyer/Davidson (2001), page 319

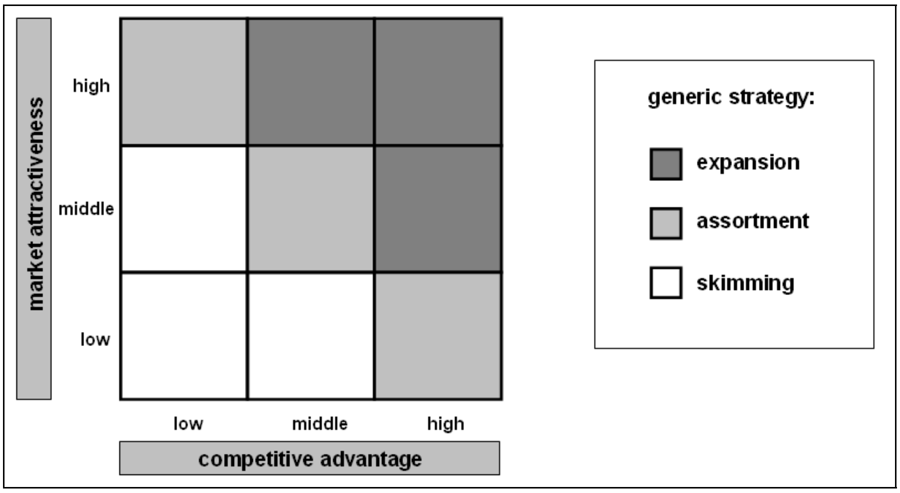

Figure 12: McKinsey/GE portfolio[115]

Advantages:[116]

- The reception of information is very extensive.
- Due to the variety of influences, one is forced to deal systematically with the own market position and the market factors.
- The influences of competition are of more importance in observations in comparison to the BCG portfolio analysis.

Disadvantages:[117]

- High effort due to extensive information search.
- The weighting of the factors may be subjective.

[115] Own presentation; Cf. Meyer/Davidson (2001), page 319

[116] Cf. Bruhn, page 74

[117] ibidem

4. Practical Implementation of the Business Plan

The following sections describe the workflow of the businessplan project according to the theoretical considerations stated in the previous sections.

4.1. Idea and Intention

The idea and intention of the business plan is the identification of potential future markets in the field of biomass drying to increase the sales volume in this business. Main components of the BP should be an analysis of existing drying technologies, an analysis of potential future markets, the derivation of strategic goals and the definition of measures to achieve them. This should happen, regardless whether the relevant market may already be served by AAG, or the relevant know-how must be procured, either through self-development, joint ventures, or acquisitions.

The industries to be considered were selected ET internally ahead of the thesis:

- Wood processing industry
    - Pellet Production
    - Panel board production
- Pulp and paper industry (rejects, deinking sludge)
- Food industry
    - Sugar industry
        - Bagasse
        - Sugar beet pulp
    - Brewery industry
- Edible oil industry
    - Palm oil residues
    - Olive oil residues
- Biogene waste industry (biogas plants – digestion residues)
- Energy industry
    - Liquid fuel production
        - Gasification, 2nd generation biodiesel
        - 1st generation bioethanol
        - 2nd generation bioethanol
    - Torrefaction

4.2. Preliminary Analysis and Acceptance

The preliminary analysis was conducted by division managers of department ET (sales, commercial management, technology, and engineering) within a meeting. The project was found to be good and agreed upon by the head of department.

4.3. Focussing

The focus of the BP-project is the professional elaboration to analyse previous stated industries regarding their potential for further considerations. The businessplan is an initiative to find new market fields in biomass drying.

4.4. Target group

The first addressees of this BP are project teams as a basic document for further analysis and assessments of possible future intents. In case of positive decisions regarding the results of the BP also management and executives are possible members of the target group.

4.5. Framework

The framework of the business plan has been divided in consultation with division managers of the department into four main parts:

- Product analysis / description of existing drying technologies
- Analysis of selected industries
- Assessment of selected industries / deflection of priorities
- Definition of measures and actions for selected industries

The four main parts are illustrated and described by their inputs and outputs in Figure 13.

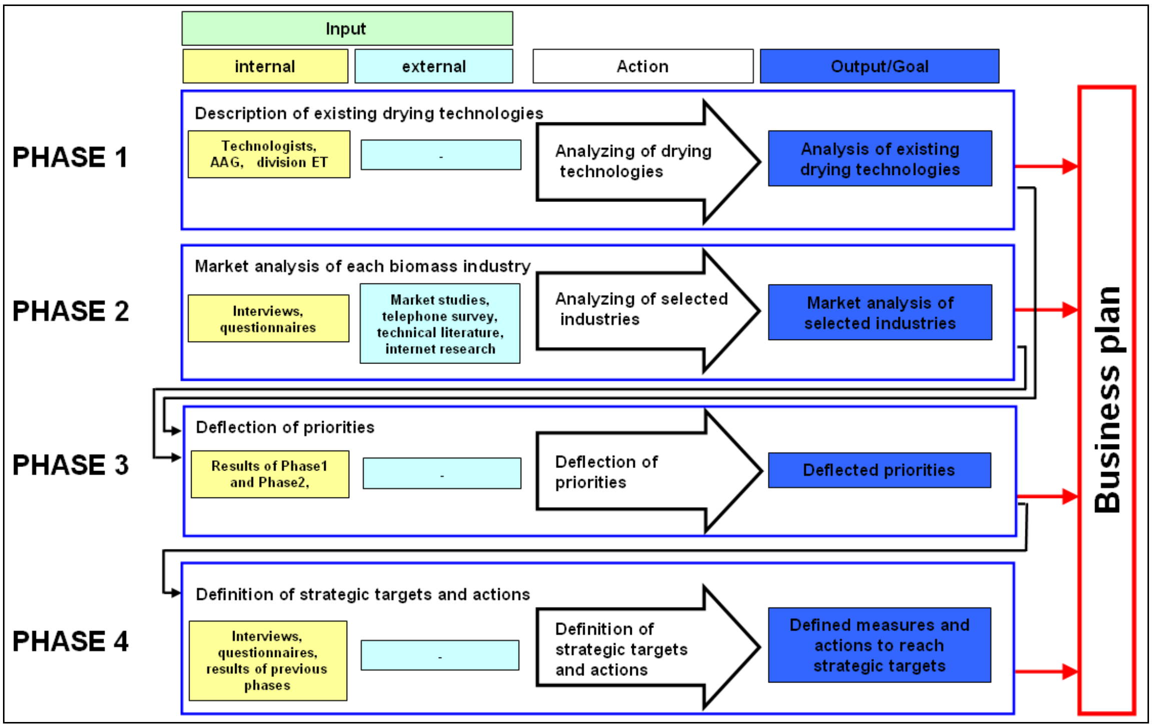

Figure 13: Framework of the business plan project[118]

4.5.1. Product Analysis / Description of Existing Drying Technologies

Existing technologies are described by the following facts, which were defined within a workshop with division managers (commercial management, sales, and technology) of ET in order to get a technological overview of currently used dryers:

- process description (including schematic diagram)
- advantages
- disadvantages
- typical applications in biomass drying
- current know -how of AAG
- main competitors

4.5.2. Analysis of Selected Industries

The analysis of industries is divided into a technological analysis and a market analysis. The facts which should be stated for every selected industry, both in technological and market analyses, were defined within a workshop with division managers (commercial management, sales, and technology) of ET.

[118] Own presentation

Technological analysis:

- Description of overall process

It is essential to know the basic principles of the main process to understand in which context drying applications can possibly be applied.

- Purpose and position of drying application (DA)

Depending on the overall processes, the purpose and position of the DA has to be defined to know whether the DA is part of the main process or a separate one, e.g. for utilization of residues, etc. .

- Feed product of drying application

Knowledge of the feed product for the DA is a prediction to apply suitable technology to the dedicated market. Important factors are the typical moisture content and the lumpiness.

- Dried product after DA and overall process

Applying the most suitable technology is dependent on specification of information of the dried product.

- Possible heat sources for drying applications

Depending on available heat sources, the range of applicable technology can further be restricted.

- Typical throughput of implemented drying applications

Information about the typical throughput of possible applications is important regarding deployable technologies.

- Currently applied drying technologies

Information regarding currently applied technologies is useful to identify possible competitors.

Market analysis:

- Customers

Potential customers for a DA (small/big companies, background of companies, public enterprises, etc.) have to be investigated to set the appropriate marketing actions.

- Market volume and allocation

Information regarding the market potential and its geographic distribution is needed to assess further entrance to the market and use of existing sales networks.

Assumptions for the quantification of possible future market volumes are based on previous results of analysis of industries and were defined within a workshop of the heads of technology, commercial management and sales.

The market volume is measured in tons water evaporation per hour.

- Market trend.

The market trend is described by potential drivers and barriers and existing facts relating to each industry.

- Competition in drying business in relevant industry

The determination of the competitors is the basis for optional further analysis of competition.

4.5.3. Assessment of Selected Industries

Selected industries are assessed based on information of the previous analysis by implementation of a McKinsey/GE portfolio considering market attractiveness and the competitive advantage as described in section 3.3.3, page 31.

Due to a meeting of the heads of sales, technology, and commercial of ET the factors of influence of market attractiveness and competitive advantage were fixed and weighted. Table 4 shows the fixed factors and weighting percentages.

Points: 1 -10
1.....very bad
10...very good

	Factor of influence	Weighting	Comment:
Market attractivness:	Market volume	30%	
	Market trend	30%	
	Market maturity	20%	stability or volatility of market, quality of market data, maturity of market
	Low competitiveness of market	10%	high competition = low score and vice versa
	Margin	10%	
		100%	

	Factor of influence	Weighting	Comment:
Competive advantage:	Market access	20%	advantage due to existing sales representive networks
	Dryer part of AAG-package	20%	AAG as process supplier (ET as subsupplier)
	Sales price	15%	
	Dryer size > 3 t/h	15%	
	Technology	10%	technology advantage and availability of AAG dryers
	Image/Publicity	10%	
	Customer responsiveness	10%	ability to offer taylor made solutions
		100%	

Table 4: Definition of factors of influence of market attractiveness and competitive advantage[119]

[119] Own presentation

4.5.4. Definition of measures and actions for selected industries

After presenting the results of the first three phases, measures and actions were defined and planned on the basis of findings from a workshop of the divisional heads of commercial, sales and technology.

In particular the targeted medium term market position and sales volumes which should be achieved and the corresponding actions (including responsibility) to reach the targets were defined.

4.6. Information search

Primary data:

Information on the wood pellet industry was collected via a telephone survey. Prior to the survey, a questionnaire was developed and finally processed via telephone with the contact persons.

To get the appropriate facts for the technological and market analysis (see section 4.5.2, page 38) the following questions were asked:

- Is drying applied in the process?
- How many dryers are applied?
- Which types of dryers are installed?
- Who is the supplier of the dryer?
- How old is the dryer?
- What heat sources are used for drying applications?
- What is the temperature of the heat sources?
- What is the throughput of the dryer(s)?
- Which material is to be dried?
- What is the dryness content of the feed product?
- What is the dryness content of the dried product?
- What is the operating time per year?
- Are there any special operation experiences?
- Are new investments in planning?
- What is the future prospective of the industry (points from 1 to 10; 1=bad, 10= very good)?

In sum 45 (Austria, Germany, Finland, Sweden, UK USA, Canada) pellet producers were interviewed. The answers to the questions were in part very incomplete. The main reason given for non-responses was the fear of disclosure of technological advantages. However, due to the survey it was possible to get useful information regarding proven industries.

Secondary data:

To generate secondary data followed data sources were used:

- world wide web
  (e.g. homepages of potential customers, homepages of competitors, etc.)
- statistic agencies
  (e.g. United Nations Statistics Division, Static Division of Food and Agricultural Organization of the United Nations (FAOSTAT), etc.)
- industrial associations
  (e.g. Comitee European des Fabricants de Sucre, Pro Pellets Austria, etc.)
- reports of special institutes and research services
  (e.g. market studies in wood processing industries, results of Pellet Atlas Projects, etc,)
- professional journals
  (e.g. “Brauindustrie”, “Forrest Energy Monitor”, etc.)
- books

5. Product Analysis / Description of Existing Drying Technologies

In the following sections, the most common used technologies in the field of biomass drying are characterized by below mentioned features, both in technical terms as well as in terms of AAG:

- Process description (incl. schematic diagram)
- Advantages
- Disadvantages
- Typical applications in biomass drying
- Current know-how of AAG
- Main competitors

5.1. Basics of Drying Technology

To get an overview in drying technology, the following chapter describes some characteristic features of dryers.

Type of heat transfer:

- Convection:

Convective heat transfer takes place between two thermodynamic systems, which are moving relative to each other, e.g. the heat transfer from a fluid (i.e. a liquid or a gas) to a wall. If the flow of the fluid is only caused by buoyancy forces (caused by a density gradient) in the fluid, that heat transfer is referred as free convection. The forced convection is a forced flow under the influence of external forces, such as the driving forces of pumps or fans.[120]

- Conduction:

Conduction is heat transfer in matter but in comparison to convection it does not require any motion of matter. In case of conduction, kinetic energy of molecules, viz. heat, is transferred to the neighbored molecules. In gases the thermal conductivity is small compared to solids, because of the lower density and the big distances between the molecules.[121]

[120] Cf. Ekbert/Rolf/Stohrer (2007), page 208

[121] Cf. Eichler (2007), page 103

- Radiation:

In matter, atoms, ions and electrons are moving due to their thermal energy. This is a reason for emission of electromagnetic waves, called radiation. Thermal radiation depends on the temperature and the size and structure of the surface. If this process takes place in the other direction, called absorption, radiation contacts matter and is converted into thermal energy.[122]

Type of heating:

- Direct heated:

In direct heated dryers, the feed product is in direct contact with the hot furnace gas, the main type of heat transfer is convection. [123]

- Indirect heated:

In indirect heated dryers, the heat is transferred by heat exchangers and the drying product is not in contact with furnace gases. All types of heat transfer are possible depending on the type of dryer. Big advantages of indirect heated dryers are low offgas emissions and low level of noise exposure. Through direct heating, specific emissions (per ton drying product) and quantity of offgas are lower in comparison with direct heated systems but on the other side the throughput rate is lower and the specific demand of energy is higher.[124]

Type of product transportation:

- Mechanical transport

The advantage of mechanical transport of the drying product is a low level of dust emission. Negative aspects are wear and the possibility of blockages.[125]

- Pneumatic transport

The positive aspect of pneumatic systems in case of convective heat transfer is a high percentage of free surfaces of the product which are in contact with drying air. Pneumatic product transportation causes a higher demand of energy in comparison to mechanical transport and higher abrasion of the dryer.[126]

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[122] Cf. Ekbert/Rolf/Stohrer (2007), page 214; Cf. Eichler (2007), page 105

[123] Cf. Kutschera/Winter (2006), page 54; Cf. AAG, ET, Technologists

[124] ibidem

[125] Cf. AAG, ET, Technologists

[126] ibidem

Table 5 shows a categorization of selected drying technologies regarding heat transfer, type of heating and type of transport.

	Heat transfer			Heating		Transport	
	Convection	Conduction	Radiation	direct	indirect	mechanical	pneumatic
Drum dryer	X		X	X	X		X
Belt dryer	X			X	X	X	
Fluidized bed dryer	X				X		X
Rotating (steam-) tube dryer		X	X		X	X	
Flash Dryer	X			X	X		X
Contact dryer		X	X		X	X	
Solar dryer			X		X	X	
Feed and turn dryer	X				X	X	

Table 5: Categorization of different types of dryers[127]

5.2. Drum Dryer

Process description:

The feed-material is introduced into a hot air stream and is pneumatically conveyed through the rotation drum which is designed either as a single or triple pass. Within the drum the air is cooled down by evaporation of water. Subsequently the dried material gets separated from air. After dedusting drying air can be recycled or discharged to ambient. [128]

A schematic diagram of a drum dryer is illustrated in Figure 14.

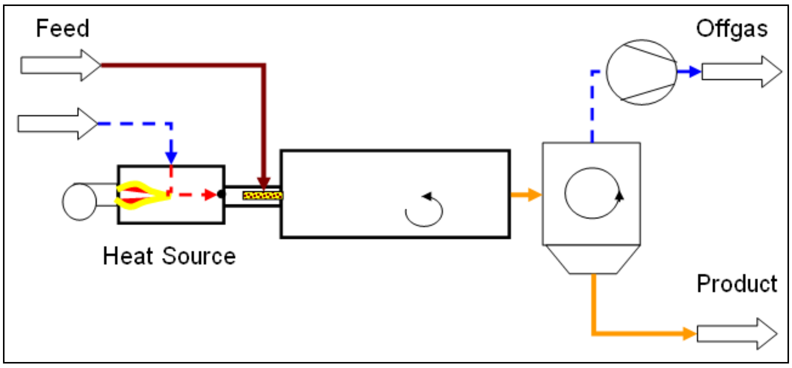

Figure 14: Schematic diagram of a drum dryer[129]

Advantages: [130]

In comparison to other drying concepts, drum dryers are characterised by little specific thermal consumption (especially in case of a recycle loop process) and a good heat transfer between drying air and the feed material. Another positive aspect is a small footprint of drum drying facilities.

[127] Own presentation; Cf. AAG, ET, Technologists

[128] Cf. AAG, ET, Technologists

[129] AAG, ET

[130] Cf. AAG, ET, Technologists

Disadvantages: [131]

The necessity of a high temperature heat source is one of the biggest negative aspects. In most cases drum dryers are heated by direct firing of primary energy like fuel oil or natural gas but there is also the possibility of indirect heating by steam. Another point is a high solid temperature which causes a high risk of fire and "blue haze".

Typical applications in biomass-drying:[132]

- Wooden materials: sawdust, woodchips, wood waste, bark
- Sewage sludge
- Sugar beet chips

Current Andritz know-how:[133]

- > 120 lines for sewage sludge
- one reference for sawdust

Main competitors:[134]

Stela, Vandenbroek, Büttner, Swiss-Combi, MEC

5.3. Belt Dryer

Process description: [135]

The feed material is distributed on a belt, moves slowly through the chamber, ambient air heated by heat-exchanger is drawn through a layer and the belt (top-down) by fans and the material is finally discharged. One possibility to reduce emissions is recycling offgas and operating in a closed loop system.

A schematic diagram of a belt dryer is illustrated in Figure 15.

[131] Cf. AAG, ET, Technologists

[132] ibidem

[133] ibidem

[134] Cf. AAG, ET, Sales representatives

[135] Cf. AAG, ET, Technologists

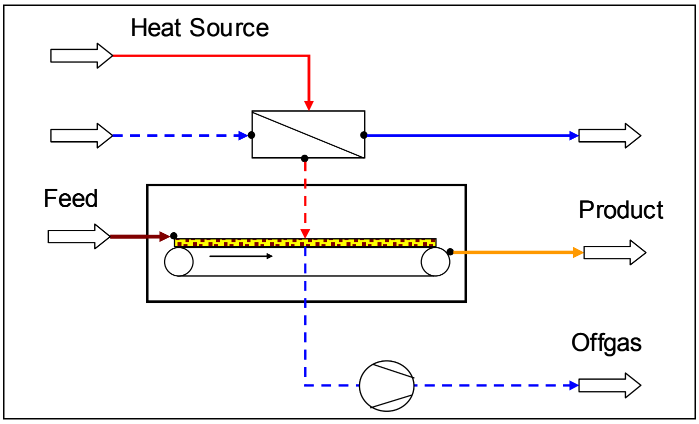

Figure 15: Schematic diagram of a belt dryer[136]

Advantages: [137]

One of the biggest advantages of belt drying systems is the possibility to use low temperature heat sources, e.g. waste heat from other processes. Other positive characteristic traits are simple operation, gentle mechanical material handling (good product quality, low dust emissions) and low emission level due to low drying temperature.

Disadvantages: [138]

Belt dryers are characterized by a high specific energy demand (especially for once through systems), high offgas-volume and high required fan power. A negative point is also the big footprint in comparison to other drying systems, e.g. drum dryers.

Typical applications in biomass-drying:[139]

- Wooden materials: saw dust, wood chips, bark
- Sewage sludge
- Various biomass products: grass, leaves, herbs, etc.

Current Andritz know-how:[140]

- 3 lines for saw-dust in operation (once through systems)
- 25 lines for sewage sludge

Main Competitors:[141]

Stela, Swiss-Combi, many small scale competitors[142]

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[136] AAG

[137] Cf. AAG, ET, Technologists

[138] ibidem

[139] ibidem

[140] ibidem

[141] ibidem

5.4. Fluidized Bed Dryer

Process description: [143]

As illustrated in Figure 16, the feed material is introduced into the fluidized bed, which consists of the feed material itself and the heat is introduced by heat-exchanger in the fluidized bed where the drying air is circulated. Condensation may be applied in the dryer air loop (air system) or not (vapour system). Dust is separated from the air loop by a filter or a cyclone and re-introduced into the fluidized bed.

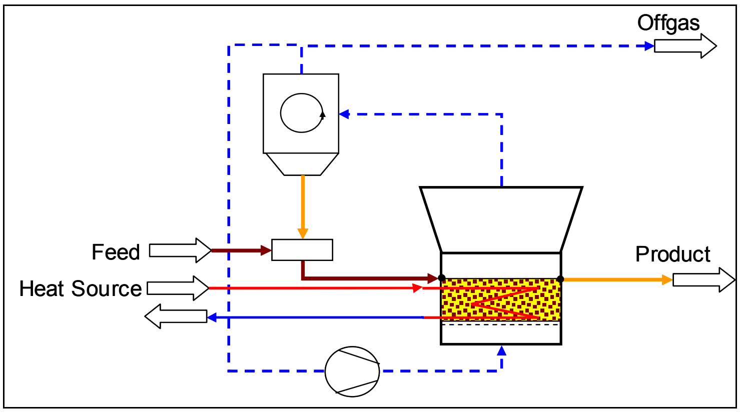

Figure 16: Schematic diagram of a fluidized bed dryer[144]

Advantages: [145]

Positive aspects of fluidized bed drying systems (FDS) are excellent heat transfer from feed-material to fluidized bed, low exhaust gas volume, small footprint and short retention time of the feed material.

Disadvantages: [146]

To dry biomass with FDS feed material in well defined, homogeneous structure is required. FDS represents an "advanced technology" with high technological standards and causes a high demand of electrical power for fans.

Typical applications in biomass-drying: [147]

- DDGS (Dried Distiller Grains with Solubles)
- Food (soybeans, etc.)
- Starch

[142] Cf. AAG, ET, Sales representives

[143] Cf. AAG, ET, Technologists

[144] AAG

[145] Cf. AAG, ET, Technologists

[146] ibidem

[147] ibidem

Current Andritz know-how: [148]

- 1 DDGS drying plant in operation
- 30 lines FDS for various feed materials (sewages sludge, minerals, plastics, etc.) in operation

Main Competitors:[149]

Ammag, Ventilex, Anhydro

5.5. Tube Dryer

Process description: [150]

The feed material is introduced into a rotating, inclined drum. The thermal energy is provided by a heat exchanger bundle inside the drum. Possible heat sources are steam, thermal oil or flue gas. Offgas (consisting vapour and leakage air) is drawn off from the dryer.

A schematic diagram of a tube dryer is illustrated in Figure 17.

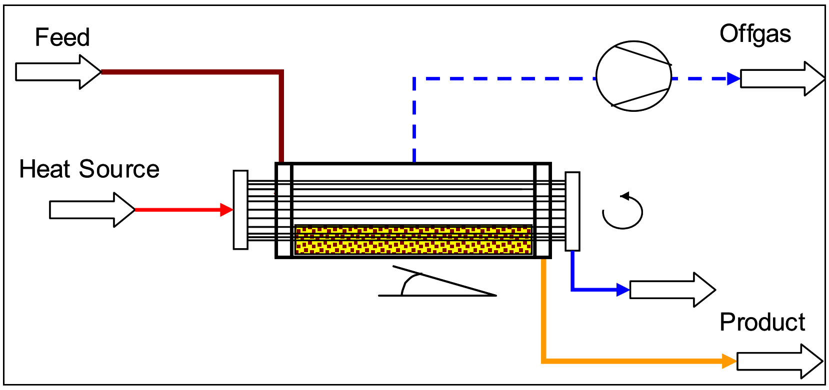

Figure 17: Schematic diagram of a tube dryer[151]

Advantages: [152]

Positive aspects are compact design and low exhaust gas volume.

Disadvantages: [153]

The product is in contact with a hot surface tending to fouling.

[148] Cf. AAG, ET, Technologists

[149] Cf. AAG, ET, Sales representives

[150] Cf. AAG, ET, Technologists

[151] AAG

[152] Cf. AAG, ET, Technologists

[153] ibidem

Typical applications in biomass drying: [154]

- Saw dust
- DDGS
- Starch

Current Andritz know-how: [155]

Currently there is no know-how available within Andritz AG.

Main competitors: [156]

Torkapparater, Ponndorf, Anhydro

5.6. Flash Dryer

Process description: [157]

As illustrated in Figure 18, the feed-material is introduced into a flash duct where it is pneumatically transported through the drying zone. The thermal energy is provided directly by burners (fuel, natural gas) or indirect by a heat exchanger. After the drying zone the product is separated from the drying gas.

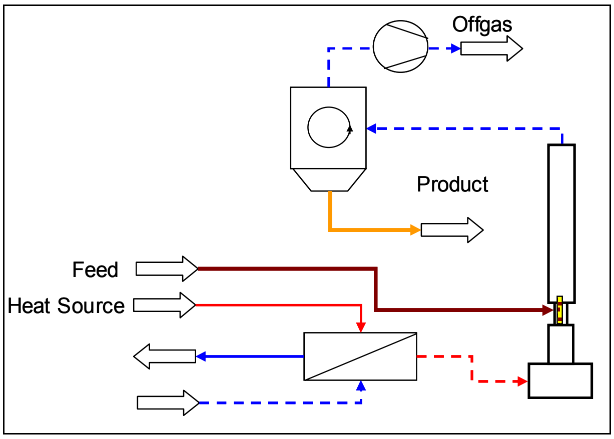

Figure 18: Schematic diagram of a flash dryer[158]

Advantages: [159]

Flash dryers are available with high evaporation capacities and can reach short retention times.

[154] Cf. AAG, ET, Technologists

[155] ibidem

[156] Cf. AAG, ET, Sales representives

[157] Cf. AAG, ET, Technologists

[158] AAG

[159] Cf. AAG, ET, Technologists

Disadvantages: [160]

Flash drying is a high temperature process, thus primary energy like fuel or natural gas is required in most cases.

Typical applications in biomass drying: [161]

- MDF industry
- Starch

Current Andritz know-how: [162]

Pneumatic dryer with integrated mill and sifter within department "Pulp drying systems"

Main competitors:[163]

- GEA, Anhydro, Münstermann

5.7. Contact Dryer

Process description: [164]

The product is introduced into the dryer and is brought into contact with a hot surface to increase the temperature of the material to remove the moisture. There are different types of contact dryers, e.g. paddle dryer, disc dryer, etc.

Figure 19 shows a schematic diagram of a contact dryer.

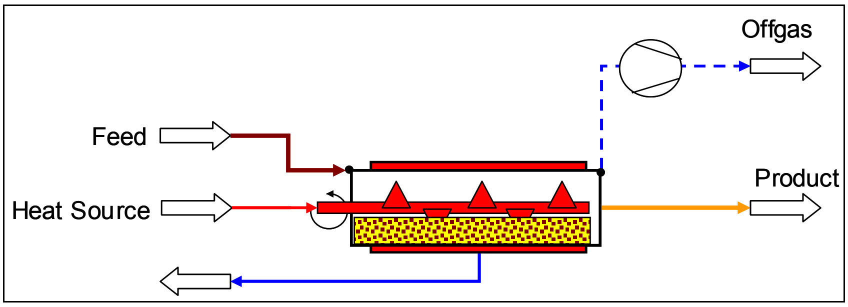

Figure 19: Schematic diagram of a contact dryer[165]

Advantages: [166]

One positive aspect is a low exhaust gas volume.

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[160] Cf. AAG, ET, Technologists

[161] ibidem

[162] ibidem

[163] Cf. AAG, ET, Sales representives

[164] Cf. AAG, ET, Technologists

[165] AAG

[166] Cf. AAG, ET, Technologists

Disadvantages: [167]

The product is in contact with a hot surface tending to fouling.

Typical applications in biomass drying: [168]

- Food
- Starch

Current Andritz know-how: [169]

Currently there is no know-how available within Andritz AG.

Main competitors: [170]

GMF Gouda, Theiss Engineering, Anhydro, Buss

5.8. Solar Dryer

Process description: [171]

One side of the cabinet is glazed to admit solar radiation, which is converted into low grade thermal heat thus raising the temperature of the air, the drying chamber and the product. The material is placed in shallow layers on trays inside the drying cabinet. The sun light shines directly to the material which is being dried and the moisture evaporated by solar heat is removed by air circulation with fans.

A schematic diagram of a solar dryer is illustrated in Figure 20.

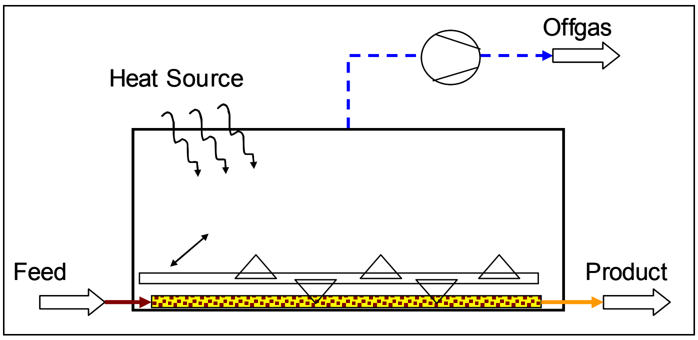

Figure 20: Schematic diagram of a solar dryer[172]

[167] Cf. AAG, ET, Technologists

[168] ibidem

[169] ibidem

[170] Cf. AAG, ET, Sales representives

[171] Cf. AAG, ET, Technologists

[172] AAG

Advantages: [173]

The biggest advantage is the heat source for free – the sun.

Disadvantages: [174]

The biggest disadvantages are low capacities and throughputs, large footprint and the dependence from the sun as heat source.

Typical applications in biomass drying: [175]

- Food (fruit, herbs, etc.)

Current Andritz know-how: [176]

Currently there is no know how available within Andritz AG.

Main competitors: [177]

In general, all companies active in plant engineering are possible competitors.

5.9. Feed and Turn Dryer

Process description: [178]

Hot air is blown through the product. A mobile paddle mechanism mixes and conveys the product during the whole drying time and the paddle wheel is moved across the dryer during the whole drying duration. This dryer type can be operated either continuously or discontinuously.

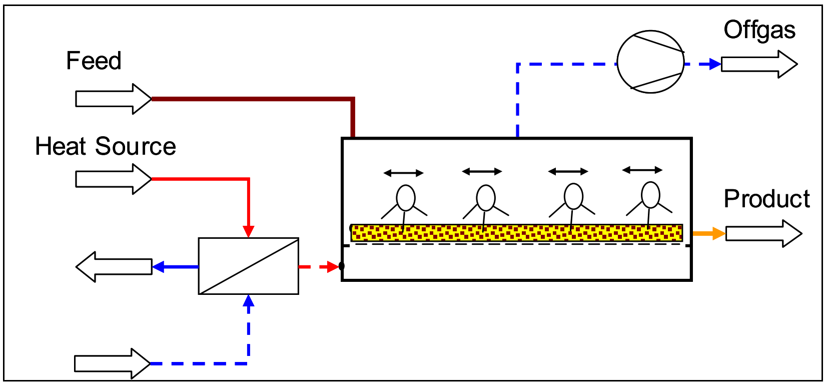

Figure 21: Schematic diagram of a feed and turn dryer[179]

[173] Cf. AAG, ET, Technologists

[174] Cf. AAG, ET, Technologists

[175] ibidem

[176] ibidem

[177] Cf. AAG, ET, Sales representives

[178] Cf. AAG, ET, Technologists

[179] AAG

Advantages: [180]

With feed and turn dryers a well mixed material with a homogeneous dryness can be achieved.

Disadvantages: [181]

Handicaps are a high number of moving parts and high offgas volume.

Typical applications in biomass drying: [182]

- Food
- Agricultural products

Current Andritz know-how: [183]

Currently there is no know-how available within Andritz.

Main competitors: [184]

Stela, Riela, Rosoma

[180] Cf. AAG, ET, Technologists

[181] Cf. AAG, ET, Technologists

[182] ibidem

[183] ibidem

[184] Cf. AAG, ET, Sales representives

6. Analyses of Selected Industries

In following sections each selected industry is analysed and characterized by facts which where defined in collaboration with technologists and sales managers within ET (see section 4.5.2, page 38).

6.1. Wood Pellet Industry

Wood pellets are standardized, cylindrical briquettes made of dried, natural saw dust or wood chips with a calorific heating value of about 5 [kWh/kg] which means that the energy content of approximately 2 kg pellets equates to 1 liter heating oil.[185]

6.1.1. Technological Analysis

- **Description of overall-process:**

The basic principle of wood pellet production is illustrated in Figure 22. After delivering raw materials, they are moved by a transport device (e.g. push floor (1)) to a strainer (2) where impurities like stones and metals are separated. After milling of raw material to a common size of approximately 4mm (3), the material is dried to a certain moisture level (4). To homogenize the moisture, an intermediate storage (5) is installed before prior entering the conditioner (6) where water or/and starch are added if necessary to allow an appropriate bond. After maturation of the conditioned material (7), it is led to the pellet press (8) where pellets are extruded and cut to the appropriate length. Pellets are passing a cooling unit (9) for hardening, strained to separate broken pellets and dust and are finally stored (11).[186]

[185] Cf. N.N. (2007), page 3; Cf. Egger/Öhlinger, page 3

[186] Cf. http://www.unendlich-viel-energie.de (31.08.2009)

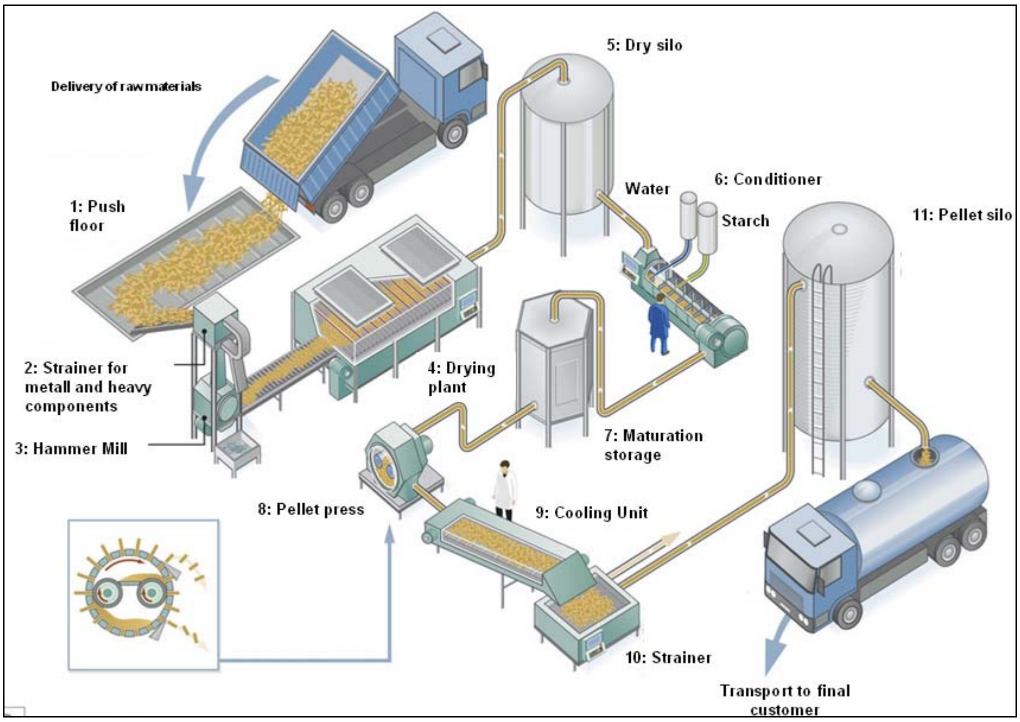

Figure 22: Basic principle of wood pellet production[187]

- **Purpose and position of drying applications:**

There are several reasons for drying in a pellet production process.

In general drying biomass decreases the moisture content and increases the energy density. It improves combustion efficiency and boiler operation and reduces air emissions.[188]

Drying is important regarding storage of dried product (pellets) because of reduced volume, increased energy density and increased shelf life.[189]

Drying applications are implemented before pelletizing to reach the right moisture levels to allow the process itself.[190]

- **Feed product:**

The main feed products for wood pellets are woodchips, sawdust, shavings, splinters and bark. Depending on energy prices and availability of raw material, also round timber is used as raw material. The typical moisture content is 35-75%.[191]

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[187] http://www.unendlich-viel-energie.de (31.08.2009), translated

[188] Cf. Golser/Pichler/Hader (2005), page 3

[189] Cf. Golser/Pichler/Hader (2005), page 3; Cf. van Loo/Koppejan (2009), page 79

[190] Cf. http://www.unendlich-viel-energie.de (31.08.2009)

[191] Results of telephone survey in pellet industry

It is possible to add fractions of other biomasses like grains, various types of grass, etc.. Pellets including other fractions are called MBP (mixed biomass pellet).[192]

- **Dried product:**

The moisture content of the dried material should be at approximately 10% to meet the requirements of finished pellets.[193]

Nowadays there are several legal requirements for woodpellets, like "ÖNORM M 7135: Compressed wood or compressed bark in natural state – Pellets and briquettes – Requirements and test specifications" in Austria, DIN 51731 and DIN plus in Germany. These requirements are not only executed in these two countries, but throughout Europe.[194]

From 2010 onwards wood pellets will be the first type of biomass-fuel which is determined by an EU-standard (EN 14961-2). This new standard will replace existing national standards. The new EU-standard determines 3 different quality-categories, A1, A2 and B.[195]

Category A1 is the most important for end-consumers and offers the highest restrictions regarding maximum ash content (0,5% for softwood, 0,7% for other wood types). Instead of density, the bulk density has to be stated.[196]

Category A2 determines pellets with higher ash contents (1%) to allow pellets with a wider spectrum of raw material.[197]

Category B determines pellets for industrial applications, e.g. for combustion in power plants with higher ash contents in comparison to A2 pellets. So there's an enlarged potential of raw materials for category B pellets (e.g. addition of bark).[198]

- **Possible heat sources:**

To get an idea of the currently used heat sources, corresponding data were collected via a telephone survey.

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[192] Cf. http://www.pelletcentre.info (12.01.2010)

[193] Result of telephone survey

[194] Cf. Steiner/Pichler (2009), page 8

[195] Cf. N.N. (2009) page 1 f.

[196] Cf. N.N. (2009), page 2

[197] ibidem

[198] ibidem

As illustrated in Figure 23, the most common heat sources are biomass (wood, wood waste, etc.), waste heat from CHP (Combined Heat and Power) process, waste heat of several industrial processes, natural gas, steam and oil.[199]

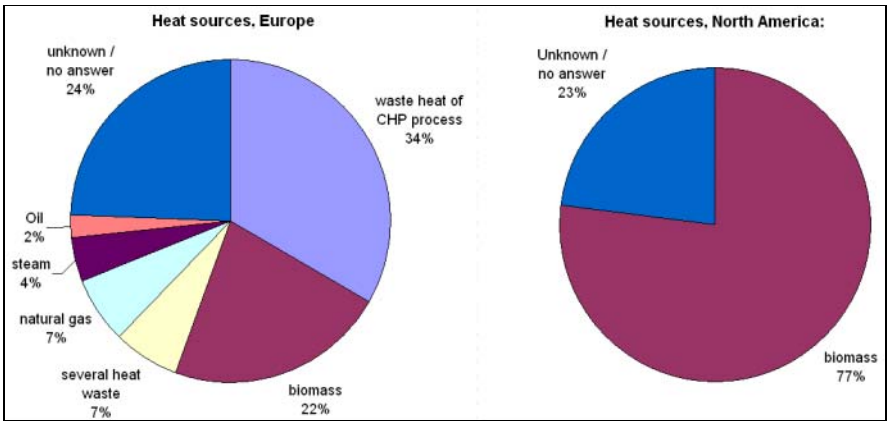

Figure 23: Most common used heat sources, Europe and North America[200]

- **Typical throughput:**

In Austria about 80% and in Germany about 75% of pellet production capacity is installed in medium- or large-scale plants (production capacities > 30.000 tons pellets per year).[201]

It can be assumed that these relations can also be adapted to other pellet-markets. In future there is a tendency towards big scale solutions.[202]

Table 6 shows the estimation of the required drying capacity as a function of pellet production capacity per plant.

estimations:				small scale	medium scale	large scale
dry content of raw product:	50	[%]				
dry content of end product:	90	[%]	pellets production capacity [tons/year]	10.000	30.000	100.000
operating time:	8.000	[hours]	evaporation capacity [tons H_2O/hour]	1	3	10

Table 6: Estimation of evaporation capacity per pellet plant production capacity[203]

- **Currently applied technologies:**

Figure 24 shows the share of individual types of dryers for the markets of Europe and North America.

[199] Results of telephone survey in pellet industry

[200] Own presentation, results of telephone survey in pellet industry

[201] Cf. Steiner/Pichler (2009), page 7; Cf. Hiegl/Jansen (2009), page 8

[202] Appreciation of sales reps, AAG, ET/FB

[203] Own Presentation and calculation

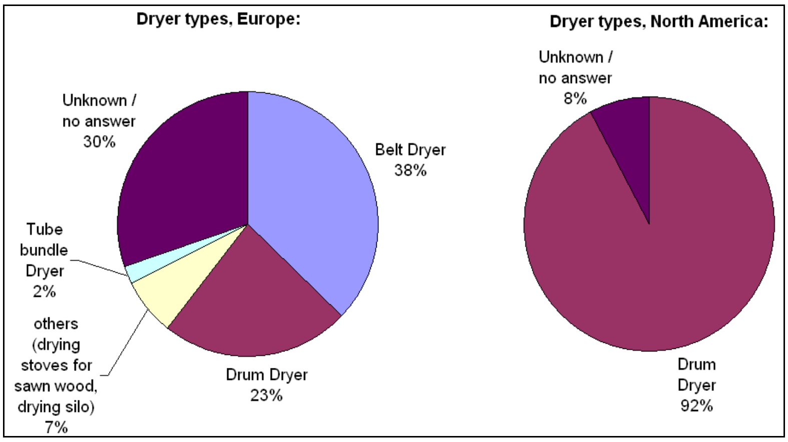

Figure 24: Applied drying technologies, Europe and North America[204]

In Europe belt dryers and drum dryers are used in most cases. Other technologies like tube bundle dryers, drying stoves or drying silos are of little significance. In North America (NA) the most applied drying technology are direct heated drum dryers.[205]

6.1.2. Market Analysis

- **Customers:**

In general, the customers of drying applications in pellet-industry are the pellet-manufacturers. There are different types of manufacturing companies. On one hand there are big sawmills and other wood processing industries which convert their own sawdust and other wooden residues into pellets, and on the other hand specialized companies focusing mainly on pellet production.[206]

- **Market Volume and allocation:**

Current market volume:

Wood pellet production, 2008, global:[207]	12.520.000 [tons]
Installed production capacity, 2008, global:[208]	18.130.000 [tons]
Installed evaporation capacity, 2008, global:[209]	1.813 [tons H2O/hour]

[204] Own presentation, results of telephone survey in pellet industry

[205] Result of telephone survey in pellet industry

[206] Appreciation of sales rep., AAG, ET

[207] Own calculations, data can be found in appendix

[208] ibidem

[209] ibidem

Allocation:

As shown in Figure 25, Europe, followed by North America is by far the largest market. The four most important producers Canada, Germany, Sweden and USA are covering more than 50 % of installed pellet production capacity in 2008.[210]

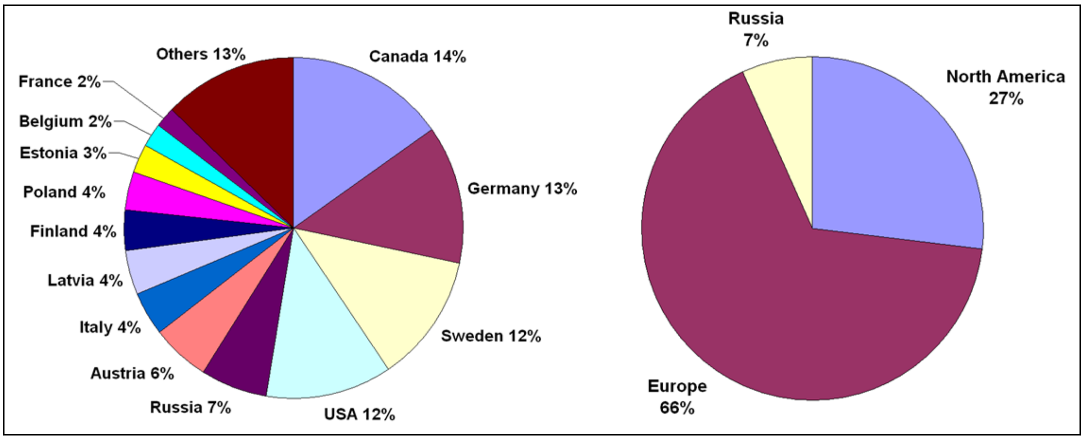

Figure 25: Regional allocation of installed pellet production capacity, 2008[211]

Possible future market volume:

Based on the results of the market analysis, following estimations were formed to appraise the expected future market volume as can be seen in Figure 26:

- MC feed product: 50%
- MC dried product: 10%
- Operating time: 8000 [hours]
- Production data: see appendix
- Future annual growth of industry: 15%
- 2009: slow down of economy – market consolidation, no growth
- All new facilities are implementing drying applications
- 3% of existing facilities are renewing drying applications

The MC of the feed product and the dried product and the operating time of the facility define the evaporation capacity for each application.

[210] Own calculation, data can be found in appendix

[211] Own presentation and calculation, data can be found in appendix

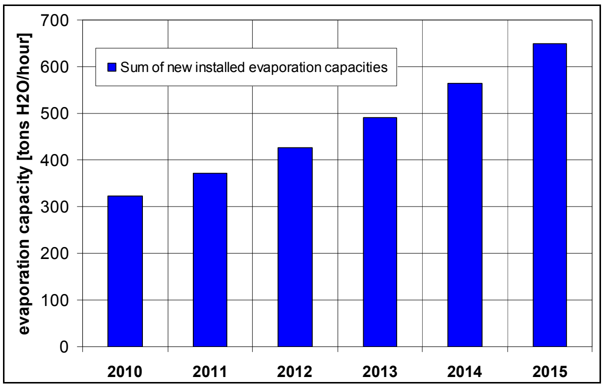

Figure 26: Estimation of market volume for drying applications in pellet industry, 2010-2015[212]

- **Market Trend:**

As indicated Figure 27, the global pellet production was growing rapidly from 2,01 million tons in 2001 up to 12,52 million tons in 2008 which means an CAGR (Compound Annual Growth Rate) of 30% from 2001-2008.[213]

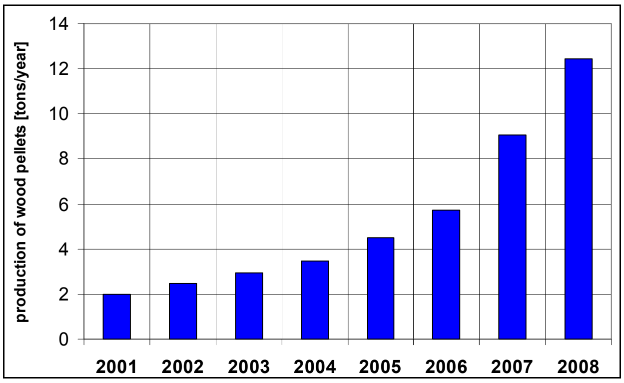

Figure 27: Pellet production, global, 2001-2008[214]

Contacts of the telephone survey (Europe and North America) were asked to pre-estimate future development of wood pellet business by a number between 1 (very bad) and 10 (very good). The averaged result is 7.6, which is a predominantly positive mood reflecting the market.[215]

[212] Own presentation, data can be found in appendix

[213] Own calculations, data can be found in appendix

[214] Own presentation, data can be found in appendix

[215] Result of telephone survey

North America:

[…] *the success of the Canadian wood pellet industry in particular is largely linked to the growing demand for wood pellets in Europe, initially in Sweden, later also in other European countries such as the Netherlands and Belgium. Lately, it looks like the USA is taking giant steps to become a second large exporter of wood pellets to Europe*.[216]

The accuracy of future trend depends largely on following factors: [217]

- Pellet prices in Europe and change on market due to the increasing supply from other regions like Eastern Europe and Latin America
- Stimulation of biomass fuels due to climate change mitigation policies in USA
- Development of low ocean freight rates

Europe:

A common characteristic of all pellet markets is the ongoing growth on the demand and supply sides that even occurs in mature markets. On the other hand, the availability of raw materials becomes more and more limited due to the competition with other industries. This effect is currently intensified following the low activity of the construction sector and other wood processing industries and, as a consequence, decreased timber sales.[218]

One important step to increase pellet production in Europe is the utilization of a broader raw material basis. Further research and development efforts are necessary to facilitate the use and to demonstrate the ecological and economic viability of alternative wood and non wood feedstock (forest thinning, wood chips, short rotation coppice, agricultural residues, herbaceous energy crops, etc.).[219]

General:

Drivers:

- Increased efforts regarding CO_2 reduction (Kyoto protocol, emissions trading regulations, etc.) and increasing CO_2 prices[220]
- Policy support in many countries[221]

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[216] Junginger/Sikkema/Faaij (2009), page 24

[217] Cf. Junginger/Sikkema/Faaij (2009), page 24

[218] Hiegl/Jansen (2009), page 30

[219] Vgl. Hiegl/Jansen (2009), S.30, Pellet market overview report Europe

[220] Cf. von Weizsäcker/Breyer/Schnitzer (2008), Cf. Junginger/Sikkema/ Faaij (2009), page 27

- Oil/Gas/Coal prices rising further due to shortages both in oil and natural gas supply ahead[222]
- *Constant increase of global power demand*[223]
- *More developed trading mechanisms*[224]
- *Increased security of supply by diversification of resources*[225]

Barriers:

- Handling and transport problems because of lack of logistical infrastructure[226]
- Absent development of a global market[227]
- Rising costs for feedstocks[228]

Facts:

- *Pellets are on way to become a mainstream fuel*[229]
- Markets are growing worldwide:[230]
    - production: Europe, CAGR: 32% (2001-2007)
      NA, CAGR: 24% (2000-2007)
- *Europe will continue to import pellets*[231]
- Canada and Brazil will be important players in the international pellet market because of their big resources of raw materials[232]
- *In some countries, the current slowdown of economy has had positive effect on the biomass industry because politicians have often favored bio energy projects in governmentally funded stimulus packages*.[233]

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221 Cf. Junginger/Sikkema/ Faaij (2009), page 26

222 Cf. Wild (2008)

223 Wild (2008)

224 ibidem

225 ibidem

226 Cf. Wild (2008)

227 ibidem

228 Cf. Junginger/Sikkema/ Faaij (2009), page 26

229 Wild (2008)

230 Own calculation, data can be found in appendix

231 Wild (2008)

232 Cf. Wild (2008)

233 http://www.pelletinfo.com (18.02.2010)

- **Competition:**[234]
  - Stela Laxhuber
  - Swiss Combi
  - Metso (Swiss Combi license)
  - Bruks
  - Urbas
  - Büttner
  - MEC
  - TSI
  - DUPPS
  - Recalor

6.2. Panel Board Industry

In the following sections two special areas of panel board industry - wood panel and MDF (Middle Density Fibreboard) production - are considered.

6.2.1. Technological Analysis

- **Description of overall-process:**

As illustrated in Figure 28, the process can be split into 3 main parts:[235]

- Raw material preparation including debarking, chopping, cutting and drying
- Production of boards including gluing, strewing and pressing
- Finishing including trimming and grinding

[234] Result of telephone survey

[235] Cf. Klammroth/Hackel (1971), page 449

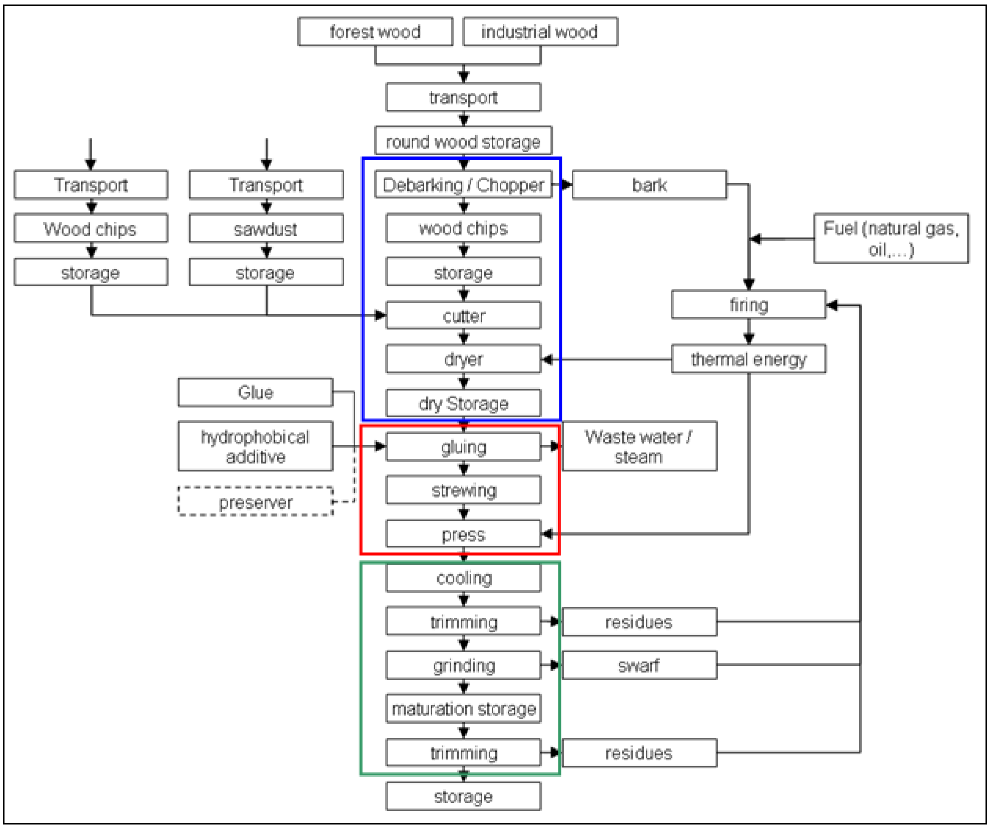


Figure 28: Schematic diagram of panel board production[236]

- **Purpose and position of drying applications:**

The purpose of drying in the production process is the provision of wood particles with certain moisture content for further utilization. Drying is the last step of raw material preparation prior to the main process of board production. [237]

- **Feed product:**

Raw materials for panel board production are wood chips, sawdust, smallwood, lumber, used wood and annual plants (sisal, straw, bagasse). Depending on the type of raw material moisture contents 20-150% are possible (based on absolutely dry wood).[238]

- **Dried product:**

The typical moisture content of the dried product is 2-3%.[239]

236 Own presentation; http://wecobis.iai.fzk.de (14.09.2009)

237 Cf. Klammroth/Hackel (1971), page 449; Cf. http://wecobis.iai.fzk.de (14.09.2009)

238 Cf. Kutschera/Winter (2006), page 45 ff; Cf. Klammroth/Hackel (1971), page 449

239 Cf. Kutschera/Winter (2006), page 51

- **Possible heat sources:**

The most common heat sources are primary energies like natural gas, oil or exhaust gases e.g. from combustion turbines. Also firing and co-firing of wooden residues, other biomass or waste is applied. [240]

- **Typical throughput:**

As illustrated in Table 7, there is a big range of typical throughputs from small capacities less than three tons up to more than 72 tons of water evaporation per plant.

capacity/year [m³]	evaporation [tons H2O/hour]	number of plants
>1050000	>72	1
950.000 - 1.050.000	65-72	4
850.000 - 950.000	58-65	1
750.000 - 850.000	52-58	6
650.000 - 750.000	45-52	13
550.000 - 650.000	38-45	26
450.000 - 550.000	31-38	37
350.000 - 450.000	24-31	65
250.000 - 350.000	17-24	80
150.000 - 250.000	10-17	148
50000 - 150.000	3-10	314
0 - 50.000	0-3	271

Table 7: Typical throughput, panel board industry, global[241]

- **Currently applied technologies:**

Table 8 shows the most common used drying technologies in panel board industry.

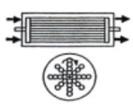
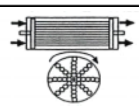
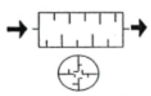
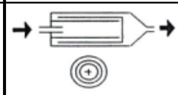
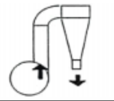
Type of dryer	schema	range of temperature	dwell period	evaporative capacity
tube bundle dryer		up to 200°C	up to 30 min	1-9 t/h
tube drum dryer		up to 160°C	k.A.	10-18 t/h
one-pass drum dryer		up to 400°C	20-30 min	up to 40 t/h
tripple-pass drum dryer		up to 400°C	5-7 min	up to 25 t/h
flash dryer		up to 500°C	approx. 20 s	2-14 t/h

Table 8: Currently applied technologies, panel board industry[242]

[240] Cf. Klammroth/Hackel (1971), page 450; Cf. AAG, technologists, ET

[241] Own presentation and calculation, data can be found in appendix

[242] Own presentation (schemata of dryers are taken over); Deppe/Ernst (2000), page 185

Most applied dryers in panel board production are direct heated and the most commonly used type is the one-pass drum dryer due to its high evaporation capacity.[243]

Indirect heated dryers like tube bundle dryer or tube drum dryers are used too, but there are disadvantages like smaller throughput and higher demand of energy. Advantages of indirect heated systems in comparison to direct heated dryers are low emissions and low noise exposure.[244]

6.2.2. Market Analysis

- **Customers:**

Customers for drying applications in panel board industry are huge companies specialized in producing derived timber products. [245]

- **Market Volume and allocation:**

Market volume, wood panels + MDF, global, 2007:[246] 310.170.000 [m³]

Installed evaporation capacity, 2007, global:[247] 21.235 [tons H2O/hour]

Allocation:

As shown in Figure 29, Asia is by far the largest market covering 41%, followed by Europe and America. Shares of Oceania and Africa are insignificant. The top 4 countries China, USA, Germany and Canada are covering 56% of the market.[248]

[243] Cf. Kutschera/Winter (2006), page 54

[244] ibidem

[245] Appreciation of sales representatives, AAG, ET

[246] Own calculation, data can be found in appendix

[247] ibidem

[248] ibidem

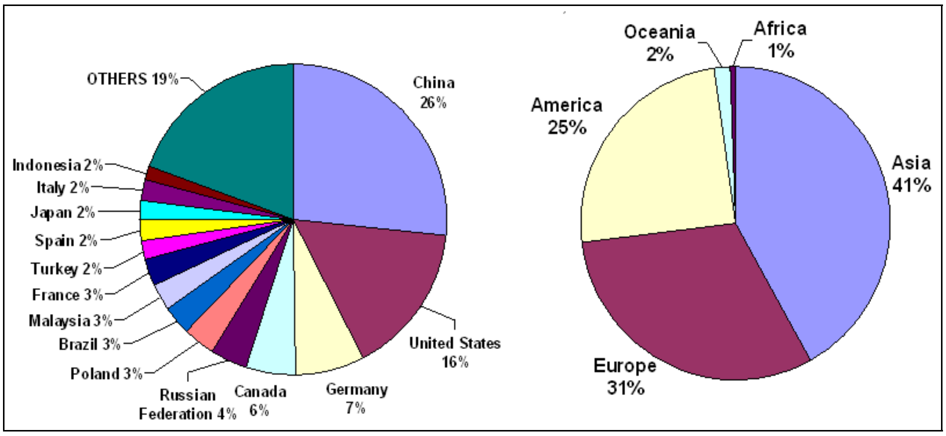


Figure 29: Allocation of panel board production, 2007[249]

Possible future market volume:

Assumption for expected future market volume as stated in Figure 30:

- potential of new installed capacities:
  - 100% of new facilities are implementing drying applications
  - 5% of existing facilities are implementing new drying applications
- assumed initial development:
  - 2009/2010: negative influence of economic crisis (EC), no growth, no investment.
  - 2011: upturn to 25% of growth before EC, 2012: 50%, 2013: 75%, following years: 100% of growth before EC

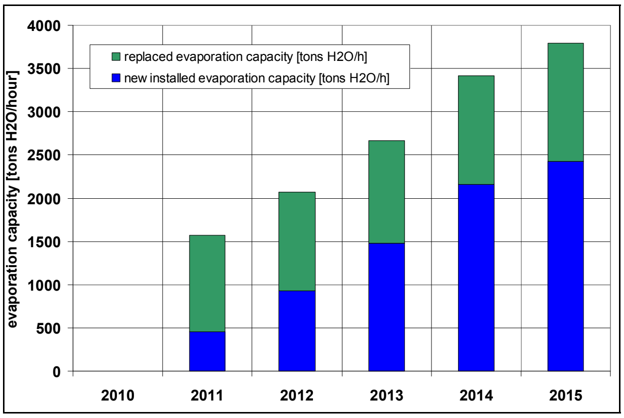


Figure 30: Estimation of market volume for drying applications in panel board industry, 2010-2015[250]

- **Market Trend:**

As shown in Figure 31, the Asian panel-board production was growing rapidly with a CAGR of 15% from 2000 to 2007. The CAGR for Europe in the same period amounts

[249] Own presentation, data can be found in appendix

[250] ibidem

to 5 % and for America to 1% (with falling tendency). In total a global compound annual growth of 7% between 2000 and 2008 occurred.[251]

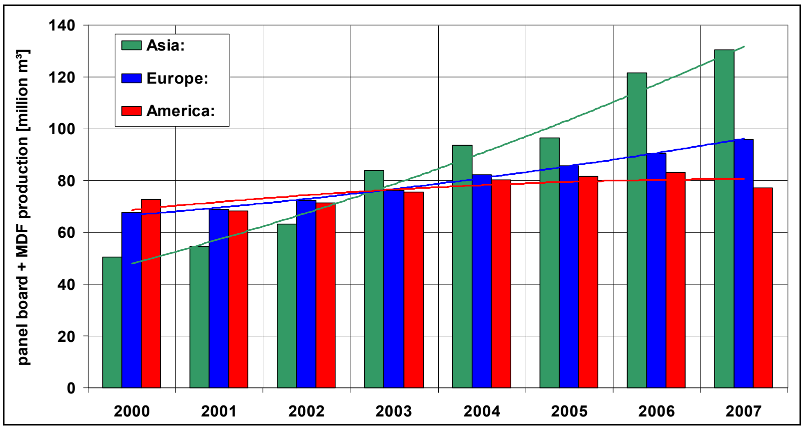


Figure 31: Panel board + MDF production, Asia, Europe, America, 2000-2007[252]

Drivers:

- Possibility to replace direct fired dryers by indirect heated belt dryers to utilize waste heat out of process and replace fossil fuels.[253]
- Continuous growing demand on wooden construction materials depending on development of population and overall economic conditions.[254]

Barriers:

- Ongoing downturn of building industry[255]

- **Competition:**

- Büttner[256]
- Swiss-Combi[257]
- MEC[258]
- Dieffenbacher / Schenkmann & Piel[259]
- In general all competitors in biomass drying (in particular drum dryers and flash dryers)

[251] Own calculations, data can be found in appendix

[252] Own presentation, data can be found in appendix

[253] Appreciation of technologists, AAG, ET

[254] Appreciation of sales representatives, AAG, ET

[255] Cf. http://www.timber-online.net (27.02.2010)

[256] Cf. http://www.buettner-dryer.com (18.01.2010)

[257] Cf. http://www.swisscombi.ch (18.01.2010)

[258] Cf. http://www.m-e-c.com (18.01.1010)

[259] Cf. http://www.dieffenbacher.de (18.01.2010)

6.3. Pulp and Paper Industry

The following sections consider the part of pulp and paper industry that uses recovered paper as raw material for paper production.

6.3.1. Technological Analysis

- **Description of overall-process:**

The paper production process is divided into the main production steps fibre production and treatment, paper making and paper processing, whereas different types of waste are generated.[260]

Figure 32 shows the main production areas depending on used raw materials with typical wastes. Wastes from paper production out of recovered paper are rejects and deinking sludge and wastes of paper production out of primary raw materials (wood) are bark and wood waste.

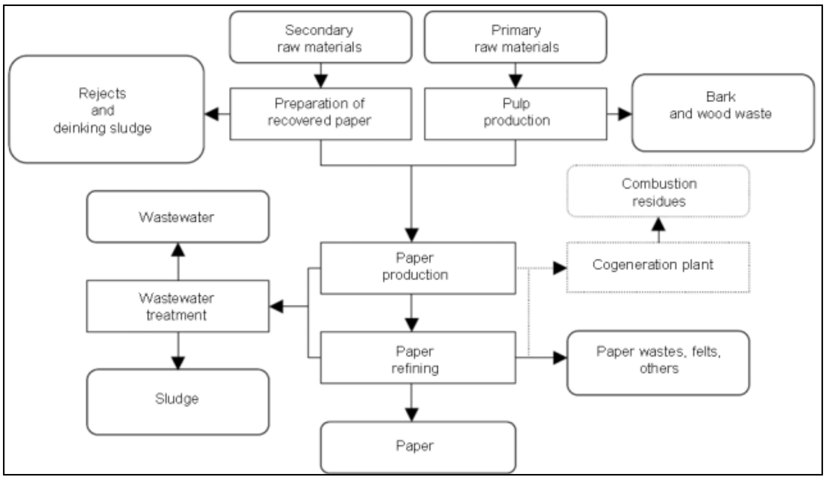


Figure 32: Schematic diagram of paper production[261]

- **Purpose and position of drying applications:[262]**

There are several possibilities for drying applications to prepare residues in paper processing industries for following utilization, e.g. combustion, pelletizing or gasification.

Flowcharts of possible utilization processes are indicated in Figure 33.

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[260] Cf. Chryssos/Maeck/Geller (1995), page 465 ff

[261] Chryssos/Maeck/Geller (1995), page 465, translated

[262] Cf. AAG, PP

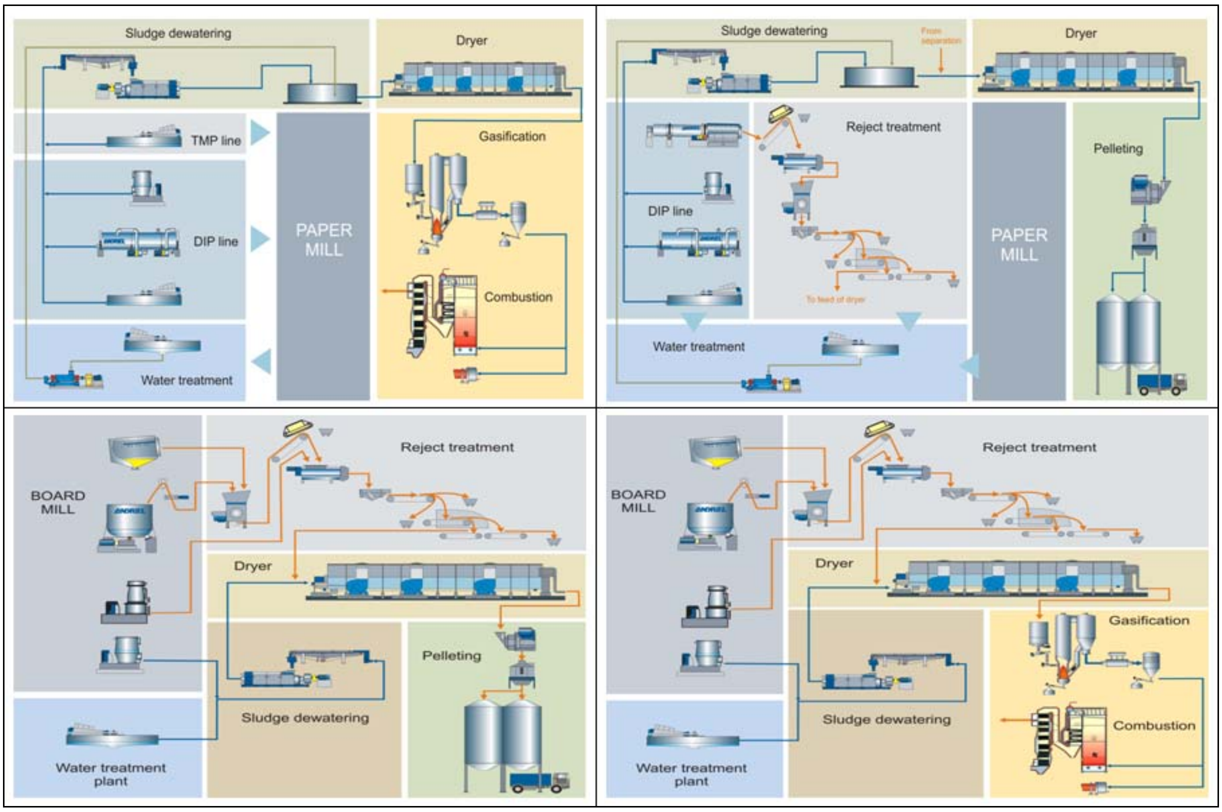

Figure 33: Flowcharts of possible processes for utilization of residues out of paper production[263]

- **Feed product:**[264]

Rejects and paper sludge are production-specific residues from paper industry. Sludge is generated in each production step of a paper mill, whereas either paper or wood is used as raw material. Rejects and deinking sludge are characteristic wastes from recycled waste paper.

Rejects:

Rejects are non-fibre materials which can be separated due to the recycling-process of recovered paper. The moisture content of this material is about 14-62 %.

Typical contents of rejects are staples, plastics, polystyrene, textile, sand, composites, etc.

Deinking Sludge:

Deinking sludge is a byproduct in the deinking-process of recovered paper and consists of printing ink, pigments and fillers. The moisture content is about 43-75 %.

[263] AAG, PP

[264] Cf. http://www.lanuv.nrw.de (14.10.2009), page 1 f.

Sewage Sludge:

This sludge consists of short fibers, fillers, particles of color, pigments and glue.

The moisture content is about 31-97 %.

- **Dried product:**

The required quality of dried products depends on further processing, as follows:

Combustion:

Moisture content should be as low as possible, to increase calorific value, depending on available heat sources (costs).[265]

Pelletizing:

Moisture content should be approx. 10% to achieve biological stability if stored and a high calorific value.[266]

Gasification:

Raw materials require certain moisture content prior to gasification depending on the type of used gasifier. Fixed bed gasifiers are capable to use biomass with MC up to 60% thus, no dryers are required. Coflow gasifiers need biomass with a MC of at least 20%.[267]

- **Possible heat sources:**

There are various waste heat sources from pulp and paper mill:[268]

- flue gas from boilers
- exhaust air from infrared and hot air dryers
- exhaust paper mill (PM) air
- condensate / hot water from PM systems
- compressor heat loss (air and oil)
- in addition fossil fuels

[265] Cf. AAG, ET

[266] ibidem

[267] Cf. Kaltschmitt/Hartmann/Hofbauer (2009), page 605 f.

[268] Cf. AAG, ET; http://www.l-e.de, request of 15.10.2009

- **Typical throughput:**[269]

Following numbers describe the typical throughput of residues of an average mill size in Europe (evaporation capacity per hour per type of residue).

- Rejects: 1,5 [tons H2O/hour]
- Deinking sludge: 3,0 [tons H2O/hour]
- Sewage sludge: 3,0 [tons H2O/hour]

- **Currently applied technologies:**
  - Rack dryer (Lang & Engelbrecht)[270]
  - Drum dryer (Siemens, Vandenbroeck)[271]
  - Tube drum dryer (Torkapparater)[272]
  - Superheated steam dryer (GEA Barr-Rosin)[273]

6.3.2. Market Analysis

- **Customers:**

Typical customers for DA are paper mills or recycling companies to prepare residues for further utilization.[274]

- **Market Volume and allocation:**

Production, recovered paper, global, 2007:[275] 194.242.995 [tons]

Theoretical evaporation capacity, global, 2007:[276] 7.129 [tons H2O/hour]

The theoretical evaporation capacity describes the potential in case of drying 100% of residues out of paper-processing out of recovered paper.

[269] Own calculation, data can be found in appendix

[270] Cf. http://www.l-e.de (16.12.2009)

[271] Cf. http://www.industry.siemens.com (16.12.2009); http://www.vadeb.nl/ (16.12.2009)

[272] Cf. http://www.torkapparater.se (16.12.2009)

[273] Cf. http://www.barr-rosin.com (16.12.2009)

[274] AAG, ET, appreciation of sales reps.

[275] Own calculations, data can be found in appendix

[276] ibidem

Allocation:

As stated in Figure 34, Asia, Europe and North America are by far the most important producers of recovered paper covering 92% of global production.[277]

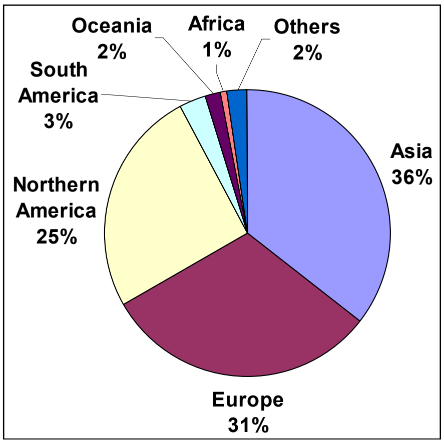

Figure 34: Allocation of production of recovered paper[278]

Possible future market volume:

Assumption for expected future market volume as shown in Figure 35:

- current installed capacity (2007): insignificant
- potential of new installed capacity p.a.:
    - 30% of new facilities are implementing drying applications
    - 5% of existing facilities are implementing drying applications
- assumed initial development:
    - 2010: 20% of potential capacity p.a. is implemented
    - 2011: 40%, 2012: 60%, 2013: 80%, following years: 100%

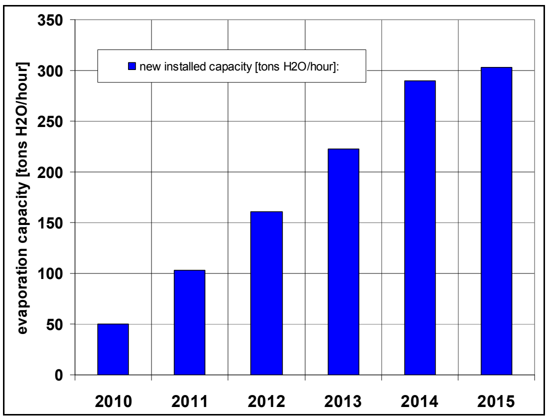

Figure 35: Estimation of market volume for drying applications in pulp and paper industry, 2010-2015[279]

[277] Own calculation, data can be found in appendix

[278] Own presentation, data can be found in appendix

[279] ibidem

- **Market Trend:**

Drivers:[280]

- No landfill for waste with organic content >5% from 2011 on in Europe and will be fined in addition to basic costs
- *Costs for deposits are steadily increasing in all countries*
- *Transport costs are high, due to very low specific weight and wet material*
- *Energy costs started to grow again and rejects are high valuable energy*
- *Recovery and usage of all internal mill waste leads to a more energy and cost independent company*
- *Usage of sludge and fibre containing residuals for the cement and brick industry leads to a seasonal dependency. Will become a critical factor after 2011(basically no possibility of land filling anymore).*
- *Incentives for investment & research in the usage of wastes in all of the European countries*
- *Investments in specific energy reduction and reduction of deposits are still funded*
- *CO2 balance for the mill can be partly changed (if fossil fuel is replaced by biomass or waste); additional financial benefit*

Barriers:

- High investment costs for equipment[281]

Facts:

CAGR, production of recovered paper, (2000-2007):[282]

- Asia: 7%
- Europe: 5%
- North America: 1%

[280] AAG, PP; Cf. AAG, PP

[281] Cf. appreciation, sales reps, AAG, department ET

[282] Own calculation, data can be found in appendix

- **Competition:**

System Competitors:[283]

Voith (VPES)- Meri:

- *Strongest in reject treatment, directly connected to the recycling fiber line). Supplied a lot of single units and complete systems for reject treatment.*
- *VPES is the only full system supplier within the paper mill for sludge/reject separation and dewatering.*
- *At the moment they are lacking of dryer, pelletizing, small boiler (10 to 20 MW) and gasification.*

Siemens SiPaper:

- *Siemens is able to offer and already has installed complete systems including reject & sludge, forest residuals, incineration and turbines.*
- *Currently there are more than 10 projects under preparation / negotiation (15 to 30 M€).*
- *Siemens and VPES connect the reject handling with water treatment (biogas production from an-aerobic process).*

Metso:

- *Metso seems to be in a pre - preparation mode and will be able to offer a complete system soon. Press releases clearly state, that Metso will focus on environmental issues during the next years.*

Bellmer:

- *Reject – sludge –water (membrane) seems to become a strategic item; Sold recently 6 screw presses to Global Renewable for the Urban Resource Process.*

Competitors in drying:[284]

- Langbein und Engelbrecht
- Siemens
- GEA Barr-Rosin
- Vanden Broeck
- In general equivalent to competitors in sludge and wooden biomass business

[283] AAG, PP

[284] Cf. AAG, PP; Cf. appreciation of sales representatives, AAG, ET

6.4. Sugar Industry – Sugarcane

White sugar, containing more than 97% of sucrose, is industrially obtained from two plants: sugar cane and sugar beet. The first plant grows in tropical and sub tropical zones and is normally processed in two steps. In the first step a granular yellow sugar is obtained, raw sugar, in Sugar Mills. In a second step, in a set of operations named refining, the final product, white sugar, is produced.[285]

6.4.1. Technological Analysis

- **Description of overall-process:**

The main steps in sugar cane processing, as illustrated in Figure 36, are washing, juice extraction, and juice treatment. The treated juice is the raw product for further utilization for sugar or alcohol production. Bagasse is the residue of juice extraction and is utilized for energy production or comprises raw materials for other products.[286]

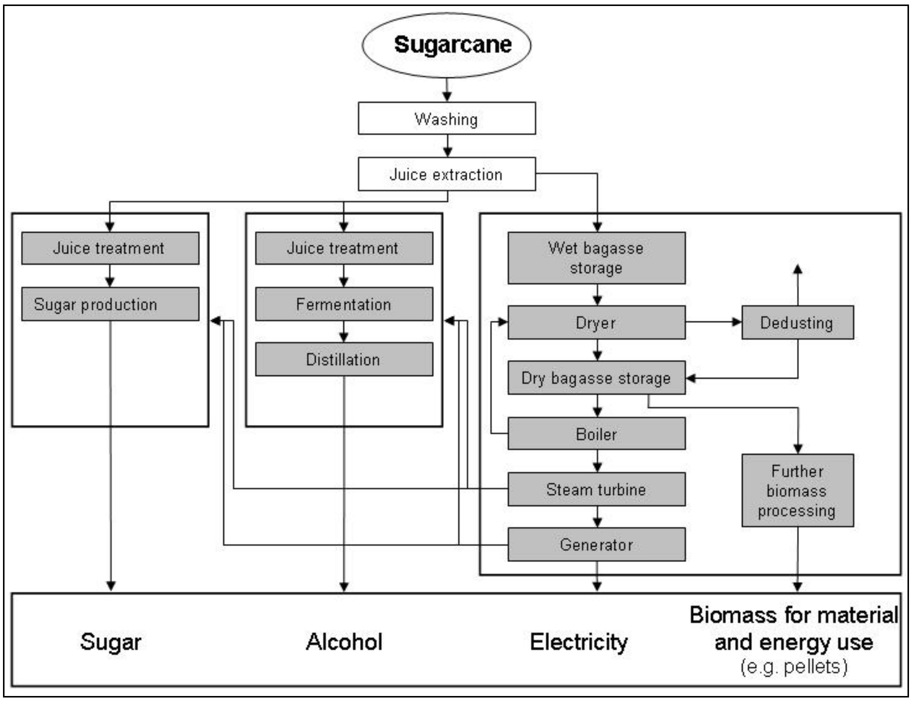

Figure 36: Schematic diagram of sugarcane processing[287]

- **Purpose and position of drying applications:**

As showed in Figure 36, drying is relevant in case of using bagasse as fuel or raw material for further utilization. Drying is part of a separate system.

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[285] http://www.sucropedia.com (12.04.2010)

[286] Cf. Belting/Semrau (2009), page 413

[287] Own presentation, Belting/Semrau (2009), page 413

By separating drying process from combustion, the following improvements can be achieved: [288]

- *Increase of the boiler efficiency factor*
- *Better operational availability*
- *Lower environmental pollution*
- *Better use of bagasse as a valuable bio fuel*
- *Better process control response*

The use of fibers as a substitute for plastics or as raw material for textile or fibreboards is an additional utilization opportunity for dried bagasse as well.[289]

- **Feed product:**

Bagasse is a fibrous material with a moisture content of about 45-50%.[290]

- **Dried product:**

In case of combustion it makes sense to decrease the moisture content to a lower level to increase the calorific heating value.[291]

Table 9 shows the net caloric value of bagasse as a function of water content. The caloric value of bagasse with a MC of 10% is more than two times higher in comparison to untreated bagasse with a MC of 50%.

Water	[%]	0	10	30	50
Carbon	[%]	47	42,3	32,9	23,5
Hydrogen	[%]	6	5,4	4,2	3,1
Oxygen	[%]	44	39,6	30,8	22
Net caloric value	[kJ/kg]	17724	15666	11592	7518

Table 9: Composition and heating value of bagasse at different water contents[292]

If bagasse is used as fuel, e.g. in pelletized form, residual moisture should be approximately 10% to allow pelletizing and fuel storage. If bagasse is used in industrial boilers, for example in sugar plants, requirements regarding moisture are less and depend on economic influences (energy prices) and legal requirements.[293]

[288] Belting/Semrau (2009), page 414 f.

[289] Cf. AAG, Technologists, ET

[290] Cf. AAG, Technologists, ET, results of pilot test; Belting/Semrau (2009), page 413

[291] Cf. Belting/Semrau (2009), page 414

[292] Own presentation, Belting/Semrau (2009), page 414, page 414, own presentation

[293] Cf. AAG, Technologists, ET

Bagasse can be used as raw material for panel boards as well requiring moisture contents of about 3-4%.[294]

- **Possible heat sources:**

It is reasonable to use heat wastes from sugar-production-process as heat sources for drying to increase efficiency of the overall process. In sugar processing possible waste heat sources are boiler flue gases, boiler blow down and hot condensate.[295]

- **Typical throughput:**

The range of typical evaporation capacities is from 4 to 22 tons H_2O per hour.[296]

- **Currently applied technologies:**[297]
  - Flash-dryer
  - Drum-dryer (direct heated)
  - Drum-dryer (indirect steam heated)
  - Combined bagasse steam generator

6.4.2. Market Analysis

- **Customers:**

The main customers are sugar and ethanol plants as well as surrounding industries. Additional large corporations consuming steam generated by fossil fuels need to partially replace fuel requirements by renewable fuel sources and large electric power companies are interested in utilization of sustainable energy sources for power generation.[298]

- **Market Volume and allocation:**

Production, bagasse, 2007:[299] 427.416.000 [tons]

Theoretical evaporation capacity, 2007:[300] 23.745 [tons H2O/hour]

Production of bagasse and the theoretical evaporation stated above includes data for sugar production and also for ethanol production (no difference of residues out of both processes).

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[294] Cf. Hse/Shupe (2002)

[295] Cf. http://www.ese.iitb.ac.in (01.10.2009)

[296] Cf. AAG, ET Brazil

[297] AAG, Technologists, ET; AAG, ET Brazil; Belting/Semrau (2009), page 415

[298] Cf. AAG, ET Brazil

[299] Own calculation, data can be found in appendix

[300] ibidem

Allocation:

The most important producers of sugarcane are Brazil and India, covering 57% of global production as indicated in Figure 37.[301]

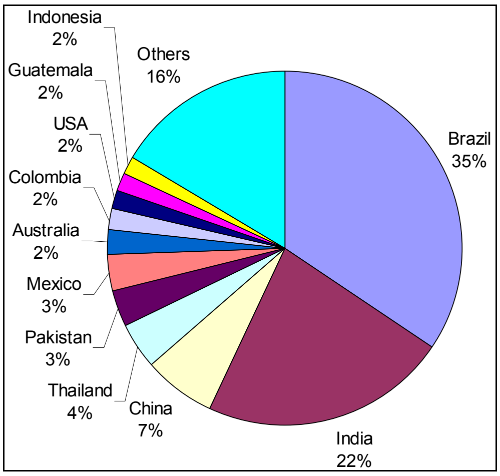

Figure 37: Allocation of sugar cane production, 2007[302]

Possible future market volume:

Assumption for expected future market volume as can be seen in Figure 38:

- Current installed capacity: insignificant
- Potential of new installed capacity p.a.:
  - 15% of new installed facilities are drying bagasse
  - 5% of existing facilities are implementing drying applications
- CAGR (2000-2007) projected into future
- Assumed initial development:
  - 2010: 10% of potential capacity p.a. is implemented
  - 2011: 20%, 2012: 30%, 2013: 40%, 2014: 50%, 2015: 60%;

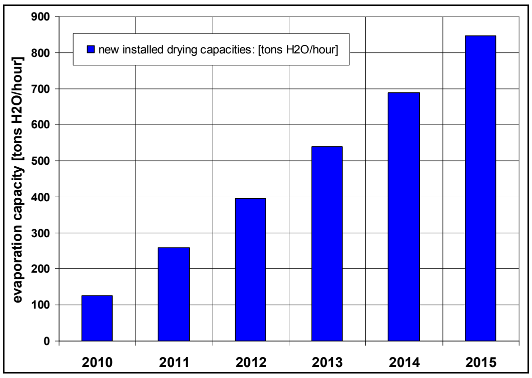

Figure 38: Estimation of market volume for drying applications in sugarcane industry, 2010-2015[303]

[301] Own calculation, data can be found in appendix

[302] Own presentation, data can be found in appendix

[303] ibidem

- **Market Trend:**

Drivers:[304]

- *Potential market growth in the next 10 years due to lack of power generation in a growing economy (Brazil] (water power plants take 5 to 10 years to be implemented and natural gas costs are increasing).*
- *Large inventory of sugar cane bagasse from sugar and ethanol industry, ready to sell or to be converted in a renewable fuel source.*
- *Environmental friendly solution to generate power and to replace fossil fuels, lowering CO2 emission.*
- *Highly political driven by the Kyoto-protocol and other agreements*

Barriers:[305]

- In Brazil imported equipment pays 14% duty and imported know how pays 49% duty. This may certainly change depending on political reasons.
- Existing experience of AAG could be good potential, but equipment prices are still too high.

Facts:

Figure 39 shows the development of sugar cane production of the top 4 producing countries, Brazil, China, India, and Thailand.

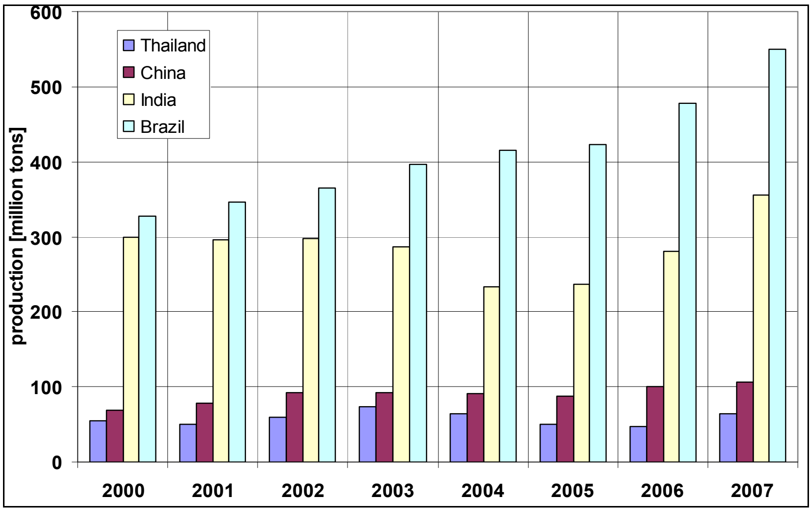

Figure 39: Sugar cane, production, top 4 producers, 2000-2007[306]

[304] AAG, ET Brazil

[305] Cf. AAG, ET Brazil

[306] Own presentation, data can be found in appendix

CAGR of sugarcane (bagasse) production (2000-2007), as stated in Figure 39:[307]

- Brazil: 8%
- China: 2%
- India: 6%
- Thailand: 3%

- **Competition:**

In Brazil small local companies offer rotary and flash dryers at a low price level. Local competition does not offer large systems with evaporation rate larger than 4 tons H_2O per hour. Situation can change, if market demand pushes new developments.[308]

6.5. Sugar Industry - Sugar beet

Additional to sugar production from sugar cane, sugar is also produced from sugar beet. Sugar beet grows preliminary in temperate climate zones.[309]

6.5.1. Technological Analysis

- **Description of overall-process:**

The basic sugar processes consists of slicing, diffusion, juice purification, evaporation, crystallization and recovery of sugar. […]Sugar beet is first cleaned and washed to remove soil, stones, and organic matter from the beet. Cleaned and sliced beet is delivered to the extraction unit where raw juice is extracted. The resulting pulp is dewatered by mechanical pressing, followed by drying to produce dried pulp. The dried pulp is pelletized for storage and transportation. [310]

A schematic diagram of sugar beet processing is illustrated in Figure 40.

307 Own calculation, data can be found in appendix

308 Cf. AAG, ET Brazil

309 Cf. http://www.sucropedia.com (12.04.2010)

310 Wang (2009), page 244

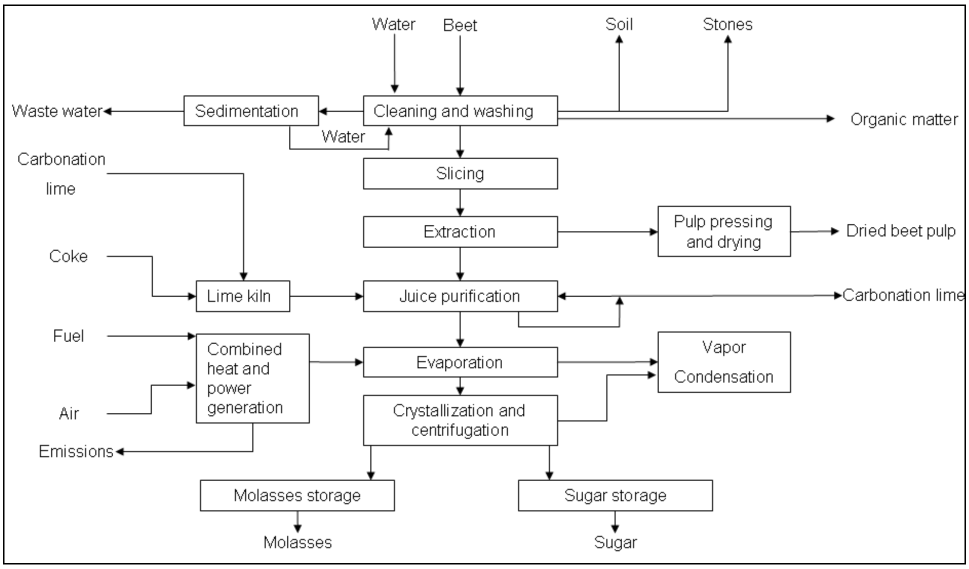

Figure 40: Schematic diagramm of sugar beet processing[311]

- **Purpose and position of drying applications:**

Drying is applied after extraction to reach the appropriate moisture level, for further utilization e.g. as pelletized animal feed.[312]

- **Feed product:**

Prior to drying beet pulp is pressed (e.g. in spindle presses) to remove as much water as possible mechanically. After mechanical pressing the moisture content of the pulp is decreased from 90 to 70-65%.[313]

- **Dried product:**

After pressing, the beet pulp requires drying to a level of 88-92% DS to allow pelletizing.[314]

These pellets are used as animal feed.[315]

- **Possible heat sources:**

Possible heat sources are heat wastes from sugar processing and primary energy like fossil fuels for direct heated dryers.[316]

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311 Own presentation, Cf. Kranjnc/Mele/Glavic (2007) cited in Wang (2009), page 244

312 Cf. Wang (2009), page 244, Cf. http://www.zuckerverbaende.de (18.01.2010)

313 Cf. http://www.vincentcorp.com (24.09.2009), Cf. Voß/Wieting (2004)

314 Cf. Mosen (2007), page 185

315 Cf. http://www.zuckerverbaende.de (18.01.2010)

316 Cf. http://www.swisscombi.ch (22.10.2009)

- **Typical throughput:**

The typical throughput for drying applications in sugar beet pulp processing industries is influenced by the moisture content of the feed material and the dried product and especially by the operating time.

The operating time of a German sugar plant is about 100 days a year and depends on the harvest of sugar beet.[317]

An estimation of the typical throughput for sugar plants in Germany is given in Table 10.

	[tons]	moisture [%]	DS [%]	DS [tons]	percent of sugar beet production
dried sugar beet pulp	1419020	10%	90%	1277118	5,6%
pressed beet pulp	3648909	65%	35%		14,5%
beet pulp	12771180	90%	10%		50,8%
evaporation	2229889				8,9%

evaporation per plant [tons H_20/hour]:	min	18
	max	68

Table 10: Estimation of evaporation capacities, sugar beet processing industry, Germany[318]

- **Currently applied technologies:**
  - Drum dryer[319]
  - Belt dryer[320]
  - Fluidized bed steam dryer[321]

6.5.2. Market Analysis

- **Customers:**

The customers for drying applications in sugar-production out of sugar beet are sugar producing companies preparing beet pulp in order to sell it as animal feed.[322]

- **Market Volume and allocation:**

Current Market Volume:

Current installed capacity, 2007:[323] 6.253 [tons H2O/hour]

Production, sugar beet pulp, 2007:[324] 124.885.519 [tons]

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[317] Cf. http://www.ble.de (12.04.2010)

[318] Own presentation, data can be found in appendix

[319] Cf. http://www.buettner-dryer.com (22.10.2009)

[320] Cf. http://www.nolte-gmbh.de (22.10.2009)

[321] Cf. http://www.bma-de.com (22.10.2009); http://www.niro.de (22.10.2009)

[322] Appreciation of sales representatives, AAG, ET

[323] Own calculation, data can be found in appendix

Allocation:

As illustrated in Figure 41, the top 5 of sugar beet producing countries (France, USA, Russian Federation, Germany and Ukraine) are covering 56% of sugar beet production in 2007.[325]

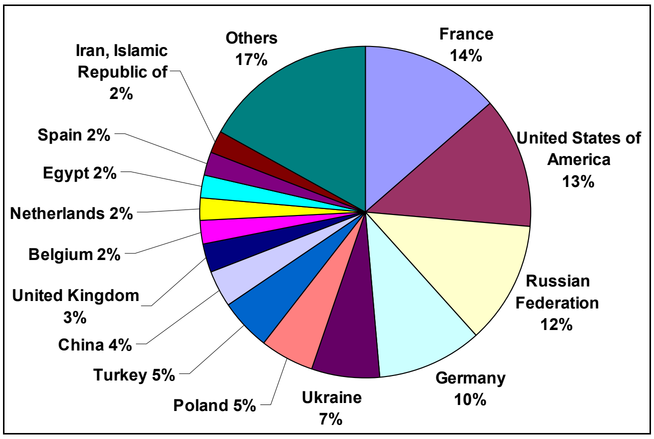

Figure 41: Allocation of sugar beet production global, 2007[326]

Possible future market volume:

Assumption for expected future market volume as can be seen in Figure 42:

- 80% of sugar beet pulp is dried[327]
- Potential of new installed capacity p.a.:
  - 100% of new installed facilities are implementing drying applications
  - 3% annual reinvestment of existing facilities
- CAGR (2000-2007) projected into future

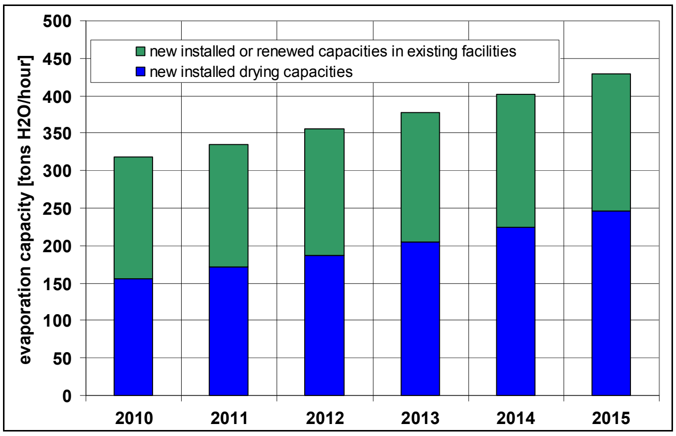

Figure 42: Estimation of market volume for drying applications sugar (beet) industry, 2010-2015[328]

[324] Own calculation, data can be found in appendix

[325] ibidem

[326] Own presentation, data can be found in appendix

[327] Cf. http://www.zuckerverbaende.de (18.01.2010)

[328] Own presentation, data can be found in appendix

- **Market Trend:**

The reform of the EU sugar regime caused a decline in sugar production in Europe from 17.4 million tons in 2005 to 6 million tons to 11.4 million tons in 2010. This led to a decline in the number of sugar factories in Europe. Some countries even dropped out of the sugar business completely.[329]

As a consequence thereof, there will be no capacity expansions in Europe in the near future.

- **Competition:**
  - GEA[330]
  - Büttner[331]
  - Nolte[332]
  - BMA[333]

6.6. Brewery Industry

Following sections describe the possible thermal treatment of spent grains out of beer production.

6.6.1. Technological Analysis

- **Description of overall-process:**

As shown in Figure 43, the main parts in beer production are malting, milling, mashing, brewing, cooling before fermentation, and filtration. Finally, the brewed beer is bottled in bottles or casks.[334]

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329 Cf. N.N. (27.02.2009), page 2 ff.; Cf. http://www.cefs.org/ (27.02.2010)

330 Cf. http://www.niro.com/niro (22.10.2009)

331 Cf. http://www.buettner-dryer.com (22.10.2009)

332 Cf. http://www.nolte-gmbh.de (18.012010)

333 Cf. http://www.bma-de.com (18.01.2010)

334 Cf. http://www.britannica.com (30.09.2009)

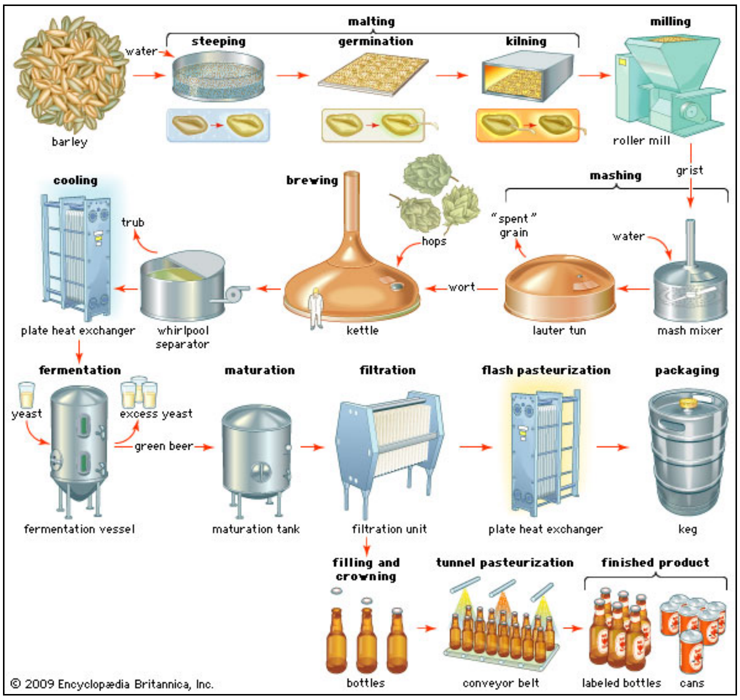

Figure 43: Schematic diagram of beer production process[335]

- **Purpose and position of drying applications:**

Drying is a separate step aside the beer manufacturing process to prepare spent grains for further utilization, like animal feed or reduction of moisture content prior to incineration in steam boiler, providing thermal energy and electrical energy for brewery.[336]

- **Feed Product:**

The typical moisture content of spent grains out of breweries is about 60-80%.[337]

There are also other residues from brewery, such as yeast, kieselgur, waste water sludge, malt dust.[338]

- **End Product:**

Utilization as animal feed:

Nowadays brewer grains are mostly used as animal feed. Brewer grains for animal feeding are available in wet or dried condition. Wet grains can be ensiled, ensuring durability of at least one year. Wet grains without ensiling should be used within 5

[335] http://www.britannica.com (30.09.2009)

[336] Cf. AAG, ET

[337] ibidem

[338] ibidem

days in summer and 30 days in winter (Austria). Drying spent grains is reasonable to increase the durability and decrease transporting costs.[339]

Energetic use:

A pilot plant for energetic utilization of spent grains is installed in Göss-Leoben (Austria). Wet grains are pressed in a continuous belt-press and the moisture level is decreased to about 42%. Biological activity of the material is decreased while storage time is increased. The pressed grains are fired (without drying as a separate step) in a special biomass-boiler covering 60% of the primary energy demand.[340]

As stated in the last paragraph, thermal drying prior to incineration is not essential, but if unused waste heat is available it may be feasible.[341]

- **Possible heat sources:** [342]
  - Steam
  - Natural gas/ biogas
- **Typical throughput:**

As stated in Table 11, in Germany 60,5% of beer production is produced in 27 breweries with capacities larger than 1 million hectolitre representing only 2% of existing plants.

capacity [hectolitre]		number of plants	% of plants	production [hectolitres]	% of total production
up to	1.000	623	46,9%	202.199	0,2%
up to	3.000	192	14,5%	329.483	0,3%
up to	5.000	72	5,4%	276.622	0,3%
up to	10.000	91	6,9%	676.034	0,7%
up to	50.000	171	12,9%	3.990.213	4,2%
up to	100.000	65	4,9%	4.429.005	4,7%
up to	200.000	36	2,7%	4.957.613	5,3%
up to	500.000	32	2,4%	9.691.408	10,3%
up to	1.000.000	18	1,4%	12.686.195	13,5%
>	1.000.000	27	2,0%	56.960.499	60,5%
	sum:	1.327	100%	94.199.271	100%

Table 11: Throughputs of German breweries, 2009[343]

A brewery with an output of 1 million hectolitres provides about 18.000 tons of spent grains.[344]

[339] Cf. http://www.brauunion.at (30.09.2009)

[340] Cf. Frisch (2005), page 26; Cf. http://www.holzfeuerung.ch (30.09.2009)

[341] Cf. AAG, ET, Technologists

[342] Cf. AAG, ET

[343] Own presentation and calculation, N.N. (2009)

[344] Cf. AAG, ET

That means, as shown in Table 12, an evaporation capacity, in case of drying from 70% to 10% DS and an operating time of 8000 hours per year, of about 1,5 tons H_2O per hour.[345]

Brewery for 1 mio hl:		
operating time:	8000	hours/year
moisture of spent grains:	70	%
moisture of dried spent grains:	10	%
spent grains:	18000,00	T/a
spent grains:	2,25	tons/hour
DS spent grains:	0,68	tons/hour
evaporation capacity	1,50	tons H2O/hour

Table 12: Estimation of evaporation capacity of brewery with an output of 1 million hectoliters[346]

- **Currently applied technologies:[347]**
  - Steam disk dryer
  - Steam tube dryer
  - Flash type dryer

6.6.2. Market Analysis

- **Customers:**

Customers are mainly large breweries and specialists in brewery processing. [348]

- **Market Volume and allocation:**

Current potential market volume:[349]

Production, beer, 2007: 174.359.441 [tons]

Production, spent grains, 2007: 31.230.094 [tons]

Theoretical evaporation capacity, 2007: 2.603 [tons H2O/hour]

[345] Own calculation

[346] Own presentation and calculation

[347] Cf. http://my.execpc.com (18.01.2010)

[348] Cf. AAG, ET

[349] Own calculation, data can be found in appendix

Allocation:

As illustrated in Figure 44, the top 5 beer producing countries China, USA, Russian Federation, Germany and Brazil are covering 54% of global market.[350]

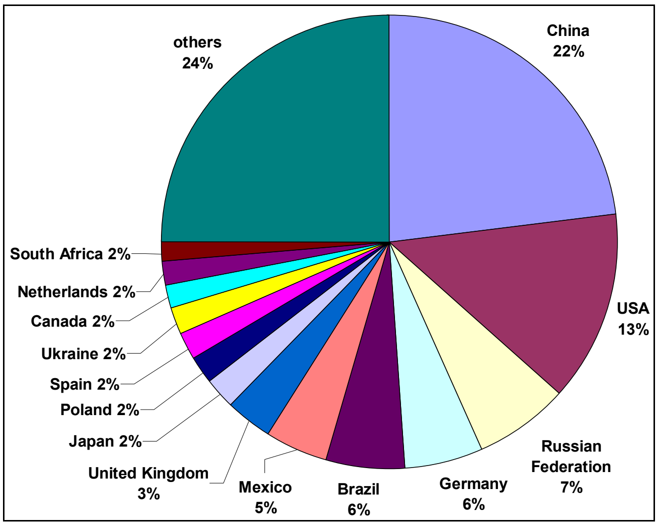

Figure 44: Allocation of beer production, global, 2007[351]

Possible future market volume:

Assumption for expected future market volume as can be seen in Figure 45:

- Potential of new installed drying capacities p.a.:
  - 60% of new installed facilities are implementing drying applications
  - 5 % of existing facilities are implementing drying applications
- CAGR (2000-2007) of bear production projected into future
- Assumed initial development:
  - 2010: 10% of potential capacity p.a. is implemented
  - 2011: 20%, 2012: 30%, 2013: 40%, 2014: 50%., 2015: 60%

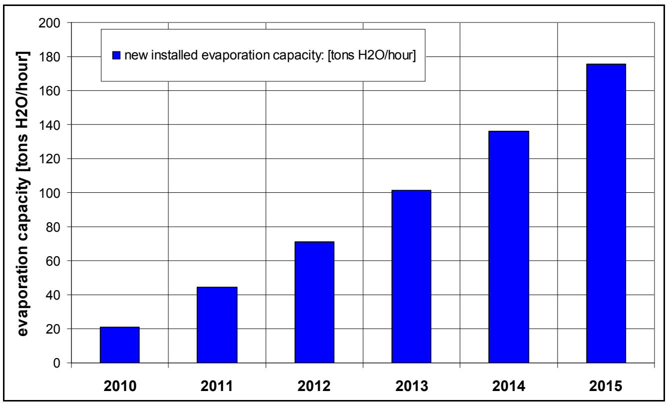

Figure 45: Estimation of market volume for drying applications in brewery industry. 2010-2015[352]

[350] Own calculation, data can be found in appendix

[351] Own presentation, data can be found in appendix

[352] ibidem

- **Market Trend:**

The world's beer production will grow by an average of 3% per year.[353]

Drivers:[354]

- Primary energy prices will continue to rise
- Increasing cost pressure on breweries
- Brewers' grains as animal feed are often substituted by soybeans, etc.
- Restrictions on landfill by landfill directive (only Europe)

Barriers:

- High investment costs for equipment[355]

- **Competition:**

- Anhydro[356]
- In general all competitors in biomass drying business

6.7. Palm oil industry

Palm oil is used as basic material for cooking oil and other household goods, but also as substitute for fossil oil fuels, e.g. bio diesel.[357]

6.7.1. Technological Analysis

- **Description of overall-process:**

The main steps of crude palm oil production are illustrated in Figure 46. After delivering FFB (Fresh Fruit Bunches), the first step is sterilization by steam injection. Thereafter FFB are threshed and the stripped bunches (EFB (Empty Fruit Bunches)) can be removed. The next steps are digestion and pressing of palm oil fruits. After clarification, the clear oil is refined and dried.[358]

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[353] Cf. Moser/Pelz/Zanker , page 2

[354] ibidem

[355] Appreciation of sales representatives, AAG, ET

[356] Cf. http://www.anhydro.com (01.02.2010)

[357] Cf. Lita (2009), page 1

[358] Cf. http://www.srijaroengroup.com, request of 29.11.2009

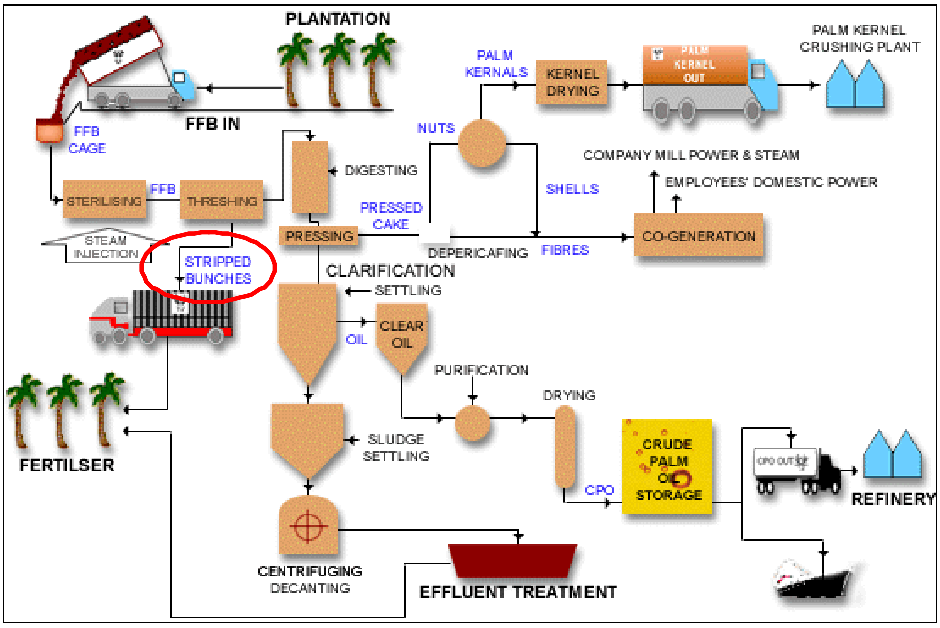

Figure 46: Basic principle of crude palm oil production[359]

- **Purpose and position of drying applications:**

Drying biomass in palm oil processing is a separated operation to prepare residues for following utilization.[360]

- **Feed product:**

There are different types of possible feed products for drying applications in palm oil processing as stated in Figure 47, e.g. shells, fibres, empty fruit bunches and palm oil mill effluent (POME).

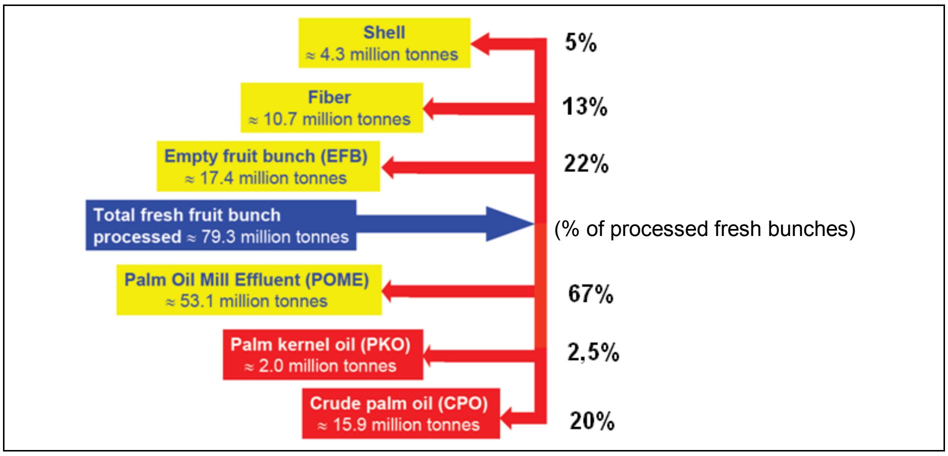

Figure 47: Palm biomass output, Malaysia, 2006[361]

[359] http://www.srijaroengroup.com, request of 29.11.2009

[360] Cf. http://www.srijaroengroup.com, request of 29.11.2009

[361] Cf. Shahrakbah (01.02.2010), supplemented

Table 13 shows a wide range of moisture contents of by-products from palm oil processing from 17% to over 70%.

	moisture content [%]
Empty fruit bunch (EFB)	58
Fibre	17
Shells	20
Palm Oil Mill Enfluent (POME)	>70
Palm Kernel cake	33

Table 13: Moisture contents of different residues from palm oil processing[362]

- **Dried product:**

Residues of palm oil production may be used in two general ways, namely energetic or as raw material for further utilization. In case of incineration of residues the MC should be as low as possible. In that case drying is reasonable depending on available unused waste heat sources out of palm oil processing. If residues are used as raw material for e.g. fibre board, the properties would be the same as stated already in section 6.2 regarding panel board production.[363]

No colour change during drying process is required in case of utilization as fibre-material.[364]

- **Possible heat sources:**

A possible heat source is waste heat of a palm oil mill[365]

- **Typical throughput:**

Typical large scale plants are processing 3 to 60 tonnes of FFB per hour resulting (as shown in Table 14) in typical evaporation capacities from about 1 to 18 tons H_2O per hour in case of drying of EFB and POME (mechanical dewatered prior drying) to a MC of 10%. [366]

[362] Cf. Van Dam/Elbersen (2004), page 2

[363] Cf. Van Dam/Elbersen (2004), page 3; Cf. Technologists, AAG, ET

[364] Cf. AAG, ET

[365] Cf. Lin (2009)

[366] Cf: Panapanaan/Helin/Kujanpää/Soukka/Heinimö/Linnanen (2009), page 18; own calculations

estimations:			
EFB content	22%	[% of FFB]	
POME content	67%	[% of FFB]	
EFB moisture content	58%		
POME moisture content	80%		
POME moisture content after mechanical dewatering	60%		
Moisture content of dried residues	10%		
typical Throughput:			
FFB	3	60	[tons/hour]
EFB	0,66	13,20	[tons/hour]
POME	2,01	40,20	[tons/hour]
POME dewatered	1,01	20,10	[tons/hour]
Evaporation capacity: EFB	0,35	7,04	[tons H_2O/hour]
Evaporation capacity: POME	0,56	11,17	[tons H_2O/hour]
Sum	0,91	18,21	[tons H_2O/hour]

Table 14: Typical throughput of palm oil plant[367]

- **Currently applied technologies:[368]**
  - Direct heated rotary drum dryers (Problems: over drying, browning and dust explosions)
  - Superheated steam dryer (Advantages: improved fibre quality by avoiding browning and dust explosions)
  - Belt dryer

6.7.2. Market Analysis

- **Customers:**

The main customers for drying applications are palm oil producing companies and in future possibly companies which are specialized in biomass treatment.[369]

- **Market Volume and allocation:**

Current potential market volume:

Production, palm oil fruits, 2007:[370] 193.210.334 [tons]

Production, EFB, 2007:[371] 42.506.274 [tons]

Production, POME (dewatered), 2007:[372] 64.725.462 [tons]

Theoretical evaporation capacity,

EFB+POME (dewatered), 2007:[373] 7.329 [tons H2O/hour]

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367 Own presentation and calculation

368 Cf. Hasibuan/Daud ((2004), page 2027 f.

369 Appreciation of sales representatives, AAG, ET

370 http://faostat.fao.org (28.11.2009), data can be found in appendix

371 Own calculation, data can be found in appendix

372 ibidem

373 ibidem

Allocation:

As shown in Figure 48, Malaysia and Indonesia are by far the most important producers of palm oil fruits covering 82% of the global market.[374]

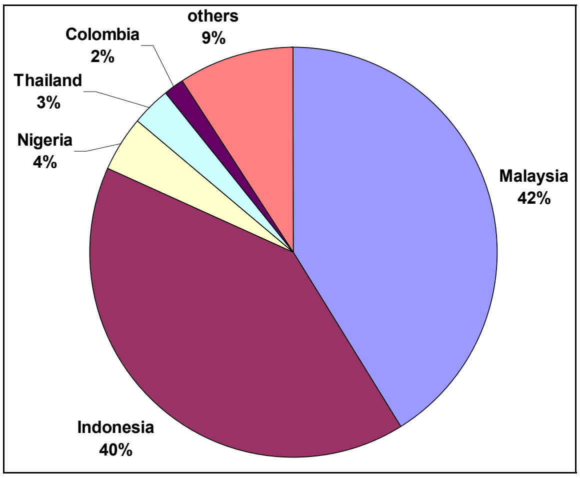

Figure 48: Allocation of global palm oil fruit production, 2007[375]

Possible future market volume:

Assumption for expected future market volume as can be seen in Figure 49:

- Drying of EFB and mechanically dried POME
- Potential of new installed drying capacities p.a.:
    - 15% of new installed facilities are implementing drying applications
    - 3 % of existing facilities are implementing drying applications
- CAGR of 2004-2007 projected into future
- Assumed initial development:
    - 2010: 10% of potential capacity p.a. is implemented
    - 2011: 20%, 2012: 30%, 2013: 40%, 2014: 50%., 2015: 60%

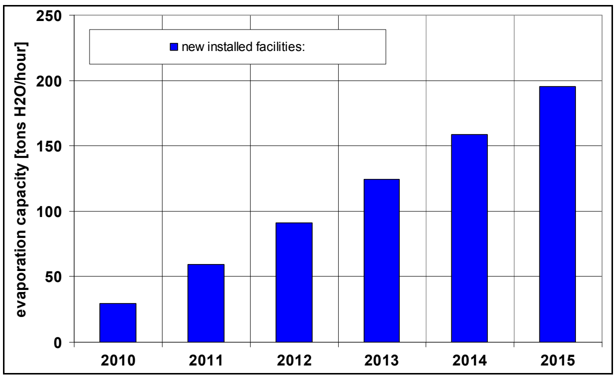

Figure 49: Estimation of potential market volume in palm oil industry, 2010-2015[376]

[374] Own calculation, data can be found in appendix

[375] Own presentation, data can be found in appendix

[376] ibidem

- **Market Trend:**

Up to now 10% of total palm biomass is commercially utilized only. There are increased efforts in R&D in Malaysia, led by Malaysian Palm Oil Board, universities and private R&D companies. The targets of these activities are the diversification of products from palm oil industry to ensure the sustainability of the industry.[377]

- **Competition:**

As part of an internet research no specialists in the field of drying in palm oil industry could be found, so it can therefore be assumed that all companies active in biomass drying are potential competitors.[378]

6.8. Olive Oil Industry

The following chapters describe the possible thermal treatment of residues out of olive oil production.

Olive oil industry is concentrated in the area around the Mediterranean Sea where more than 97% of global demand is produced.[379]

6.8.1. Technological Analysis

- **Description of overall-process:**

There are 3 different processes used in olive oil production, the traditional process, the 3-phase decanter process and the 2-phase decanter process. The schematic diagrams are illustrated in following figure.[380]

[377] Cf. Shahrakbah (01.02.2010)

[378] Appreciation of sales representives, AAG, ET

[379] Own calculation, Cf. http://faostat.fao.org (29.09.2009)

[380] Cf. http://www.biomatnet.org (23.02.2010)

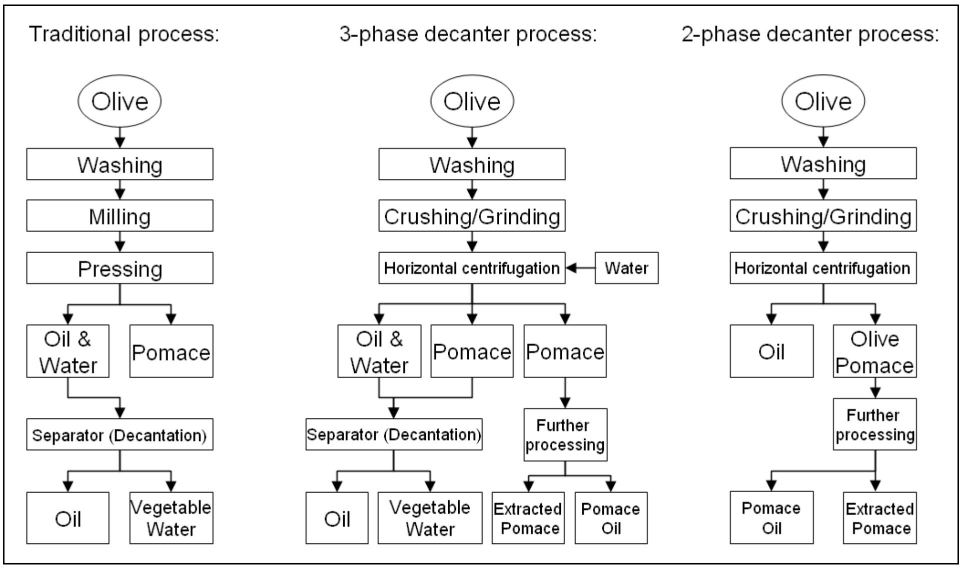

Figure 50: Schematic diagram of different olive oil production processes[381]

The 2-phase extraction was developed in the 1990s to minimize the volume of the waste produced and is widely used in Spain where approximately 90% of the country's olive mills use this technology. The philosophy is the same as the 3-phase centrifugation system but it uses no process water and delivers two streams only: olive oil and a single waste, a combination of olive husk and olive mill waste water (OMWW), i.e., a very wet olive cake, which is called "alperujo".[382]

Table 15 shows, that there are considerable differences of inputs and outputs depending on the type of production process.

PRODUCTION PROCESS	INPUT	AMOUNT OF INPUT	OUTPUT	AMOUNT OF OUTPUT
Traditional pressing process	Olives Washing water Energy	1000 kg 0.1 – 0.12 m³ 40 – 63 kWh	oil solid waste (c. 25 % water + 6 % oil) waste water (c. 88 % water)	c. 200 kg c. 400 kg c. 600 kg
Three-phase decanter	Olives Washing water Fresh water for decanter Water to polish the impure oil Energy	1000 kg 0.1– 0.12 m³ 0.5 – 1 m³ c. 10 kg 90 – 117 kWh	oil solid waste (c. 50 % water + 4 % oil) waste water (c. 94 % water + 1 % oil)	c. 200 kg c. 500 – 600 kg c. 1000- 1200 kg
Two-phase decanter	Olives Washing water Energy	1000 kg 0.1 – 0.12 m³ < 90 - 117 kWh	oil solid waste (c. 60 % water + 3 % oil)	200 kg 800 – 950 kg

Table 15: Inputs and outputs of different olive oil production processes[383]

[381] Own presentation; http://www.biomatnet.org (23.02.2010)

[382] Cf. Oreopoulou/Russ (2007), page 139

[383] Romero (2000), page 15

- **Purpose and position of drying applications:**

Drying is a separate operation to prepare residues of olive processing for following utilization, e.g. incineration, pelletizing and gasification.[384]

- **Feed product:**

The different types of residues depending on the type of production process can be seen in Table 15.

- **Dried product:**

The properties of dried products after drying depend on following utilization:

- Combustion: moisture content (MC) should be as low as possible[385]
- Pelletizing: MC should be approx. 10% to reach biological stability for storage[386]
- Gasification: Raw materials need to be dried to certain moisture content before gasification depending on the type of used gasifier. Fixed bed gasifiers are able to use biomass with MC up to 60%, not requiring a pre-drying process. Coflow gasifiers handle biomass with a MC of at least 20%.[387]

Figure 51 shows a possible process flow of incineration of olive oil residues.

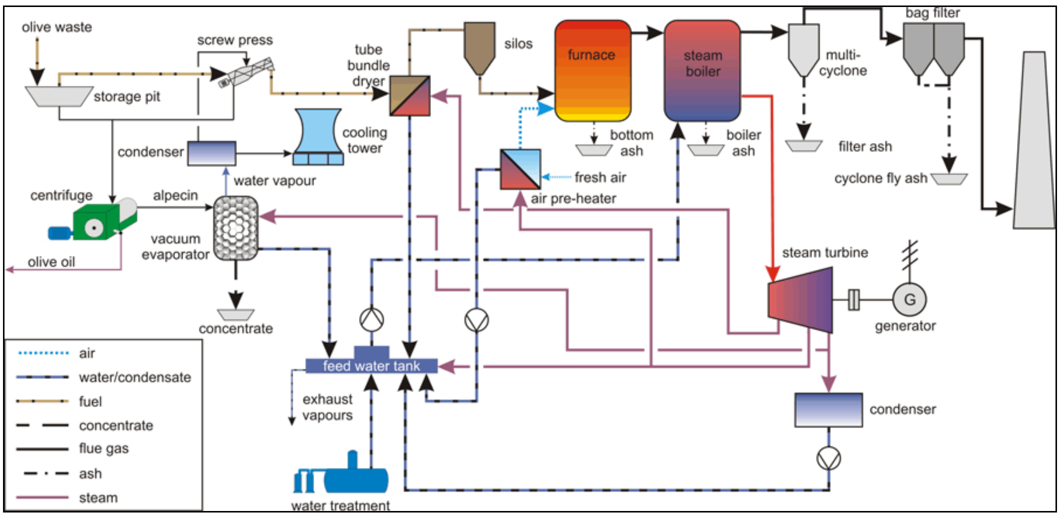

Figure 51: Schematic diagramm of "olive-power-plant"[388]

[384] Cf. Wang (2009), page 239

[385] Cf. Technologists, AAG, ET

[386] ibidem

[387] Cf. Kaltschmitt/Hartmann/Hofbauer (2009), page 605 f.

[388] http://www.bios-bioenergy.at (05.11.2009)

- **Possible heat sources:**

A possible heat source could be waste steam of steam turbine in case of incineration of residues.[389]

- **Typical throughput:**

The capacity of a typical oil mill is about 10 to 20 tons of olives per day and the season takes not more than 100 days per year.[390]

The evaporation capacity of a plant processing 10 tons olives per day is about 0,11 [tons H_2O/hour].[391]

- **Currently applied technologies:[392]**
  - Tube bundle dryer
  - Fluidized bed dryer
  - Ring dryer

6.8.2. Market Analysis

- **Customers:**

Customers are all olive processing industries like olive mills, olive kernel industries, refine units and, perhaps in the future companies specialized in biomass treatment.[393]

- **Market Volume and allocation:[394]**

Production, Olive oil, 2007:	2.965.434 [tons]
Production, Residues out of process, 2007:	8.896.302 [tons]
Theoretical evaporation capacity, 2007:	1.647 [tons H2O/hour]

The theoretical evaporation capacity is the capacity in case of drying of residues of olive oil production from a MC of 50% to a level 10% with an operating time of 2400 hours per year.

[389] Cf .http://www.bios-bioenergy.at (05.11.2009)

[390] Cf. Romero (2000), page 13

[391] Own calculation, data can be found in appendix

[392] http://www.bios-bioenergy.at (05.11.2009); Cf. Romero (2000), page 37 ff

[393] Appreciation of sales reps, department ET, AAG

[394] Own calculation, data can be found in appendix

Allocation:

As can be seen in Figure 52, Spain is by far the leading producer of olive oil, followed by Italy and Greece. These 3 countries are covering 71% of the global olive oil production.

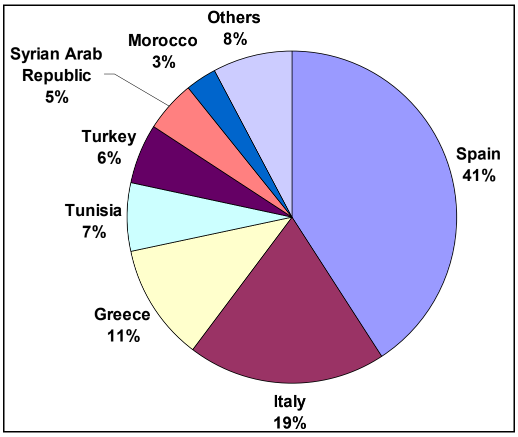

Figure 52: Regional allocation of olive oil production, 2007[395]

Possible future market volume:

Assumption for expected future market volume as can be seen in Figure 53:

- Current installed capacity: insignificant
- Potential of new installed capacity p.a.:
  - 15% of new installed facilities are implementing drying applications
  - 3% p.a. of existing facilities are implementing drying applications
- CAGR of 2004-2007 projected into future
- Assumed initial development:
  - 2010: 20% of potential capacity p.a. are implemented
  - 2011: 40%, 2012: 60%, 2013: 80%, following years: 100%

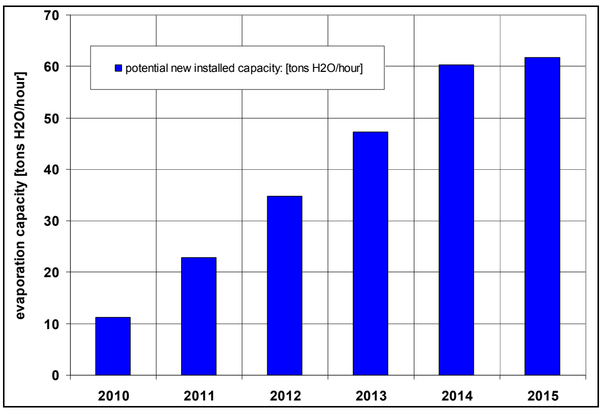

Figure 53: Estimation of potential market volume in olive oil industry, 2010-2015[396]

[395] Own presentation, data can be found in appendix

[396] ibidem

- **Market Trend:**

CAGR, olive oil production, Top 5 producers, 2000-2007:[397]

- Spain: 3%
- Italy: 2%
- Greece: -3%
- Tunisia: 8%
- Turkey: 4%

- **Competition:**

As part of an internet research no specialists in the field of olive residue drying could be found, thus it can be assumed that all companies active in biomass drying are potential competitors.

6.9. Biogene Waste Industry, Biogas Plants

The following sections consider the possible thermal treatment of residues out of biogas production.

6.9.1. Technological Analysis

- **Description of overall-process:**

The following figures illustrate two different types of biogas plants. Figure 54 shows a biogas plant which produces upgraded gas for utilization as a substitute for natural gas and Figure 55 shows a plant with integrated CHP.

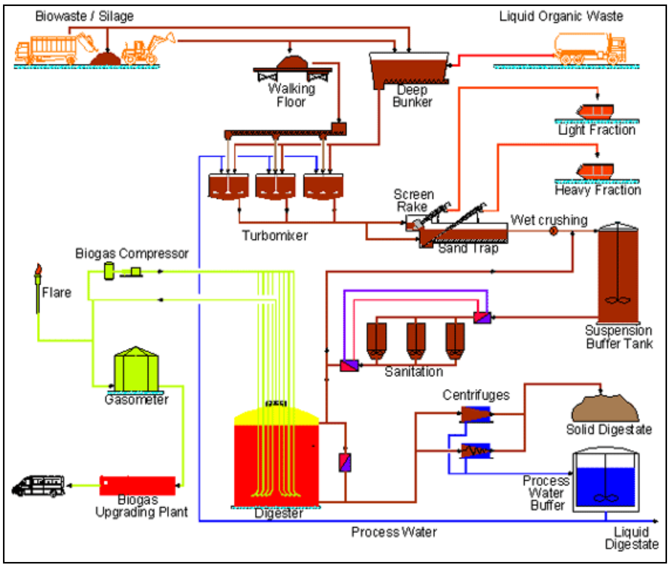

Figure 54: Process flowchart of biogas plant for biogas production as upgraded fuel[398]

[397] Own calculation, data can be found in appendix

[398] http://www.rosroca.com (02.10.2009)

The main steps are mixing of liquid and solid organic wastes, screening, crushing, sanitation and digestion. Afterwards, the digestion residues are dewatered in centrifuges.[399]

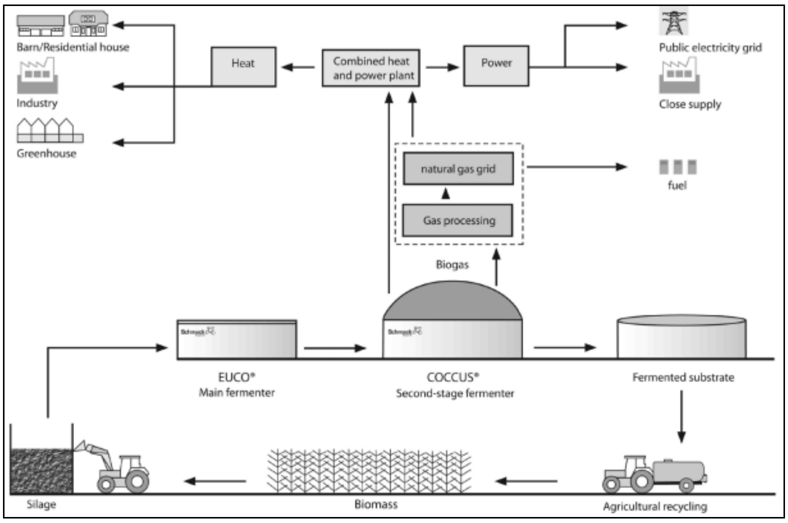

Figure 55: Process flowchart of biogas plant for CHP and fuel[400]

- **Purpose and position of drying applications:**

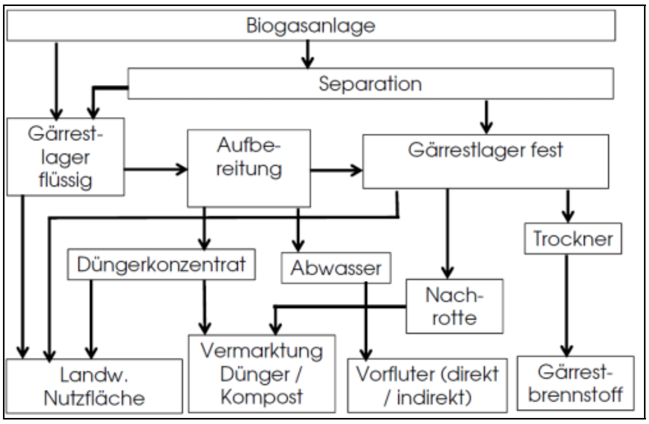

Figure 56: Possible digestion residue preparation[401]

Drying might be a separate step to prepare digestion residues for further utilization. Especially in large biogas plants it is important to prepare fermentation residues, because it is not possible to use all of them as fertilizer in surrounding agricultural holdings because a too large amount of residues and transportation over big distances is too expensive. It is also not possible to put out residues all year long, therefore it is necessary to prepare storage capacities for about 6 months with integrated reduction of climate-gases like methane or laughing gas also for plants

399 Cf. http://www.rosroca.com (02.10.2009)

400 http://www.schmack-biogas.com (02.02.2010)

401 Wagner (2008)

with small capacities. So there are big costs for storage which can be reduced by preparing digestion residues.[402]

Analyses in Bavaria identified that transportation costs are higher than the value as fertilizer if the distance is bigger than 5-10km.[403]

- **Feed Product:**

The properties of feed material for following preparation depends on the type of digestion and varies from 5% DS for continuous wet fermentation up to a maximum of 30% DS for discontinuous dry fermentation.[404]

The different digestion methods and their typical residues are illustrated in Figure 57.

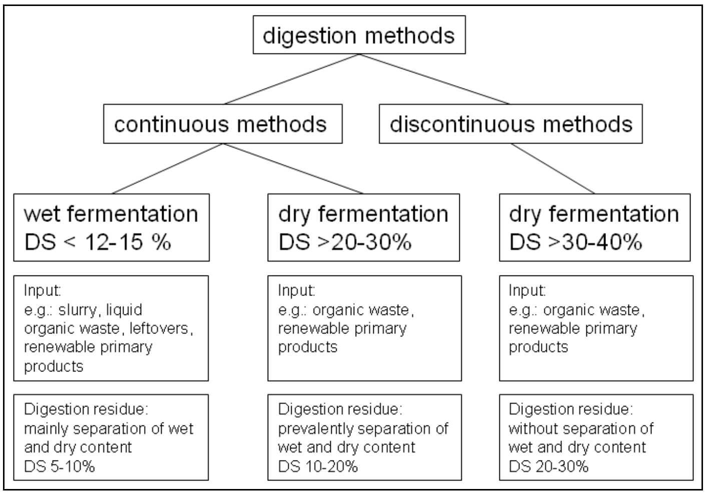

Figure 57: Different digestion methods and residues in biogas production[405]

Due to the high water content, a mechanical separation is usually the first step in treatment of fermentation residues to reduce moisture prior to drying. The mechanical separation can be waived if already dried digestate is remixed to undried residues prior to drying process.[406]

- **End Product:**

There is a differentiation between partly preparations (separation of solid components and production of a nutrient reduced liquid phase – both sold as fertilizer) and total preparation (separation of solids, production of nutrient-rich

[402] Cf. Lootsma / Rausen , page 559 (http://www.witzenhausen-institut.de (02.02.2010))

[403] Cf. Döhler / Schliebner (2006), page 199 ff.

[404] Cf. Lootsma/Rausen , page 561 f.

[405] Own presentation, Cf. Lootsma/Rausen , page 561 f. , http://www.witzenhausen-institut.de (02.02.2010)

[406] Cf. Lootsma/Rausen , page 564 , http://www.witzenhausen-institut.de (02.02.2010)

concentrate and cleaned water). Additionally, the utilization of dried residues as substitute solid fuels is achieved.[407]

In case of utilization as solid fuel, moisture contents of about 10% will be required to allow pelletizing and/or storage.[408]

- **Possible heat sources:**

In plants with integrated CHP waste heat is available.[409]

Applied drying technologies (stated below as “current applied technologies”) needs about 1,1 kWh of thermal energy to evaporate 1 kg water. In agricultural biogas plants it is possible to dry only the half of the digestion residue capacity with waste heat of the main process.[410]

- **Typical throughput:**

According to a report by a nationwide (Germany) biogas measuring program 60 representative biogas plants were examined. The investigations showed that only about a quarter of the existing plants showed an installed electric capacity of more than 250 kW.[411]

An installed electrical power of 150 kW needs, 3,100 tonnes fresh mass of maize and 2,800 m³ of manure per year as substrate in case of utilization of maize and manure. This data is based on an efficiency of the used engine of 36%.[412]

This means a substrate input of 5900 tons per year or approximately 0,7 tons per hour and the resulting substrate output after the biogas production process is much lower because of the mass loss during the process. Therefore it can be assumed that only big biogas plants are of interest for drying applications.[413]

[407] Cf. Lootsma/ Raussen, page 560 f.

[408] Appreciation, technologists, AAG, ET

[409] Cf. http://www.schmack-biogas.com (02.02.2010)

[410] Cf. Lootsma/Rausen, page 569

[411] Cf. VDI (2005), page 117 ff.

[412] Cf. Brettschuh (02.05.2010), page 9

[413] Own calculation, appreciation of sales representatives, AAG, ET

- **Currently applied technologies:**

Following types of dryers are currently used for drying of the solid content of digestion residues: [414]

- Belt dryer
- Drum dryer
- Feed and turn dryer
- Fluidized bed dryer
- Steam dryer
- Contact dryer
- Solar dryer

Waste air of stated dryers often contains a high amount of ammoniac. Usually wet scrubbing devices have to be applied. [415]

6.9.2. Market Analysis

- **Customers:**

Residues of local small and medium scale plants are used as agricultural fertilizers in surrounding areas without any treatment. The main customers for drying applications are centralized large-scale biogas plants, because the residues are too much to use it as fertilizer in surrounding agricultural areas. [416]

- **Market Volume and allocation:**

Production, biogas, 2006, global:[417]	400.078 [terrajoule]
Organic DM after digestion, 2006, global:[418]	13.891.598 [tons]
Theoretical evaporation capacity, 2006, global:[419]	5.016[tonsH2O/hour]

The theoretical evaporation capacity is the capacity in case of drying of all digestion residues in biogas production from a MC of 75% to a level 10% with an operating time of 8000 hours per year.

[414] Cf. Lootsma/Rausen (02.02.2010) page 567; Cf. http://www.rosoma.de (08.02.2010); Cf. http://www.acat.com (08.02.2010);

[415] Cf. Lootsma/Rausen (02.02.2010), page 567

[416] Cf. Lootsma/Rausen (02.02.2010) page 559

[417] Own calculation, data can be found in appendix

[418] ibidem

[419] ibidem

Allocation:

As illustrated in Figure 58, the top 3 of biogas producing countries, namely USA, Germany and United Kingdom are covering 73% of global production.

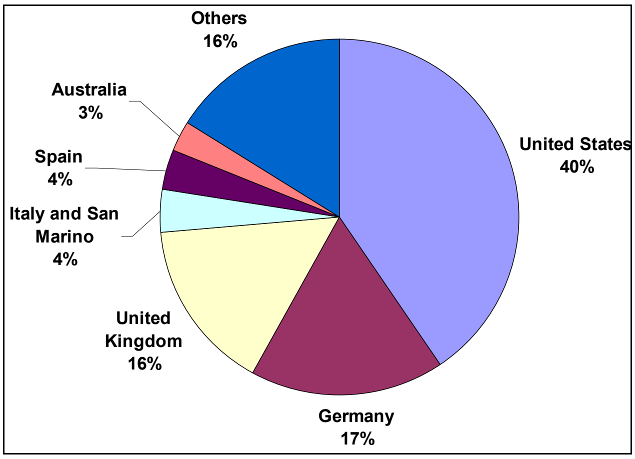

Figure 58: Allocation of global biogas production, 2006[420]

Possible future market volume:

Assumption for expected future market volume as can be seen in Figure 59:

- Current installed capacity: insignificant
- Potential of new installed capacity p.a.:
    - 15% of new installed facilities are implementing drying applications
    - 3% p.a. of existing facilities are implementing drying applications
- CAGR 2000-2006 projected into future
- Assumed initial development:
    - 2010: 20% of potential capacity p.a. are implemented
    - 2011: 40%, 2012: 60%, 2013: 80%, following years: 100%

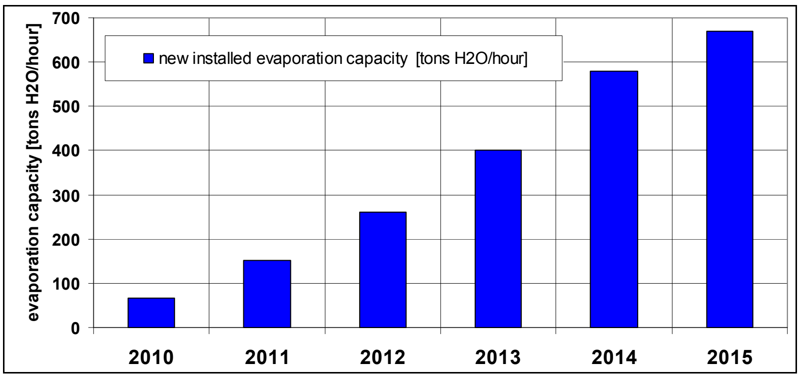

Figure 59: Estimation of market volume for drying applications in biogas industry, 2010-2015[421]

[420] Own presentation, data can be found in appendix

[421] ibidem

- **Market Trend:**

Biogas general:

The electrical power generation of German biogas plants in 2006 is about 1100 [MW] and will increase to about 4200 [MW] in 2020 indicating an average growth of 11% per year. The national German market is well developed in comparison to other high potential markets in Europe (France, Italy, Poland, Spain, Romania, Russia, Turkey, Ukraine, United Kingdom) and therefore growth rates in named states will be much higher than in Germany. This development depends strongly on general conditions, e.g. remuneration for feeding or available mass flows of biomass. The overall installed power in named countries including Germany is expected to extend from a level of 1200 [MW] in 2006 to 8600 [MW] in 2020 equal to a CAGR of about 16% per year.[422]

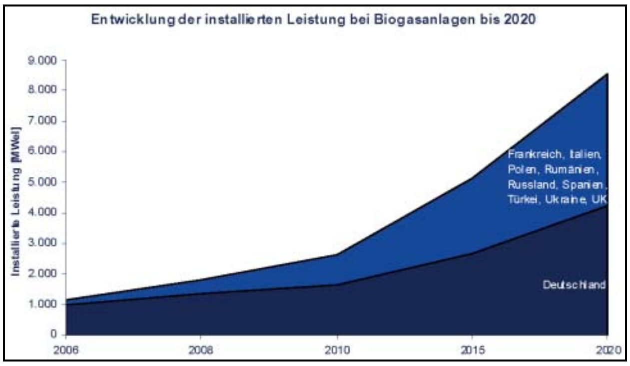

Figure 60: Development of installed capacity of biogas plants for selected European countries by 2020[423]

Figure 61 states the most important factors for biogas market entry in new countries, namely costs for input biomass, subsidies, the potential of farmland and the availability of industrial residues.

[422] Cf. http://www.ask-eu.de (5.10.2009)

[423] Trend research (2009)

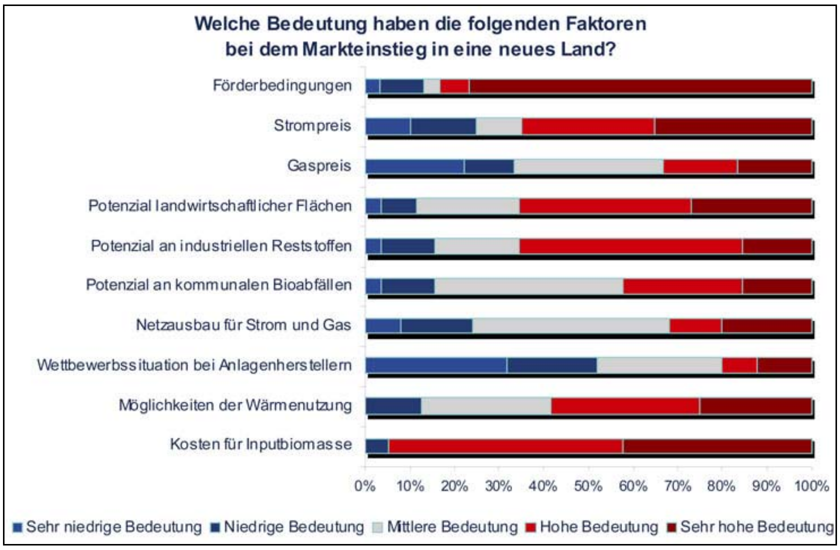

Figure 61: Factors influencing market entry in new countries in biogas business[424]

Drivers for DA:

- Low opportunities for large biogas plants to use all digestates in surrounding agricultural holdings as fertilizer[425]
- No landfill for waste with organic content >5% from 2011 on in Europe[426]
- Costs for deposits are steadily increasing in all countries[427]

Barriers for DA:

- High investment costs for related equipment[428]

Facts:

- CAGR of biogas production (2000-2006), Top 5:[429]
  - United States: 5%
  - Germany: 20%
  - United Kingdom: 11%
  - Italy and San Marino: 18%
  - Spain: 17%

[424] Trend research (2009)

[425] Cf. Lootsma/Rausen (02.02.2010), page 559

[426] AAG, PP

[427] ibidem

[428] Cf. AAG, ET, appreciation of sales representatives

[429] Own calculation, data can be found in appendix

- **Competition:**
  - Riela (Feed and Turn Dryer)[430]
  - Rosoma (Contact Dryer)[431]
  - Stela Laxhuber (Belt Dryer, Feed and Turn Dryer)[432]
  - Dorset (Belt Dryer)[433]
  - ACAT (Solar Dryer)[434]
  - In general all competitors in biomass and sludge drying business

6.10. Gasification / BtL (Biomass to Liquid)

Solid biomass is converted into a secondary energy source by a thermo-chemical conversation. This form of energy could have advantages regarding handling and later transformation into useful energy. In general, this process includes similar processes like incineration, but the processes are temporarily and spatially separated.[435]

6.10.1. Technological Analysis

- **Description of overall-process:**

The main steps in conversion of solid biomass, illustrated in Figure 62, are preparation of the solid fuel, gasification and gas cleaning. Purified gas may be utilized for power generation or for fuel production if already conditioned.

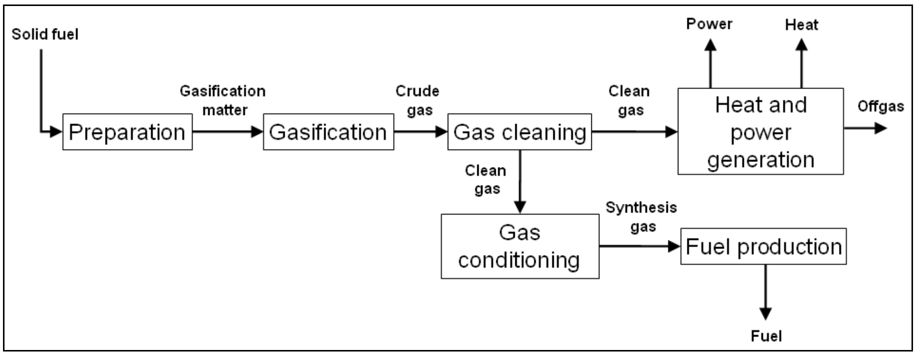

Figure 62: Schematic diagram of gasification of biogene solid fuels[436]

[430] Cf. http://www.riela.de (08.02.2010)

[431] Cf. http://www.rosoma.de (08.02.2010)

[432] Cf. Laxhuber (2009)

[433] Cf. http://www.dorset.nu (08.02.2010)

[434] Cf. http://www.acat.com (08.02.2010)

[435] Cf. Kaltschmitt/Hartmann/Hofbauer (2009), page 599

[436] Own presentation, Hofbauer (2007)

- **Purpose and position of drying applications:**

Drying is part of solid fuel preparation prior to gasification to reach the appropriate moisture level of used biomass. [437]

- **Feed product:**

Almost all types of biomass can be used for gasification.[438]

Several types of feed material might be suitable for DA. Of course, feed material has to be investigated in detail in later stage.

- **Dried product:**

Raw materials have to be dried to certain moisture content before gasification depending of the type of used gasifier. Fixed bed gasifiers are able to use biomass with MC up to 60% thus, not requiring any DA. Coflow gasifiers need biomass with a MC of at least 20%.[439]

In general the MC of biomass should be 10-15% before gasification, and particle sizes of 20-80 mm are typical.[440]

- **Possible heat sources:**

The hot gases after gasification have to be cooled prior to further processing. This waste energy can be used for DA.[441]

- **Typical throughput:**

No commercial production of second-generation biofuels is known so far.[442]

- **Currently applied technologies:**

Applied drying technologies will be the same like stated in other chapters, depending on used biomass.

[437] Cf. Technologists, department ET, AAG

[438] Cf. Eisentraut (2010), page 46

[439] Cf. Kaltschmitt/Hartmann/Hofbauer (2009), page 605 f.

[440] Cf. McKendry (2001) page 56

[441] Cf. AAG, Technologists, ET

[442] Cf. Eisentraut (2010), page 32, Cf. http://www.handelsblatt.com (27.05.2010)

6.10.2. Market Analysis

- **Customers:**

Customers will be fuel producing or power and heat generating companies to prepare raw materials before gasification.[443]

- **Market Volume and allocation:**

It is still very difficult to estimate future market volumes and its allocation because this market is still nascent.

- **Market Trend:**

As illustrated in Figure 68, the International Energy Agency assumes that the transition between first and second generation biofuels will change to a higher share for 2nd generation biofuels like Biodiesel – BtL and cellulosic ethanol in future.

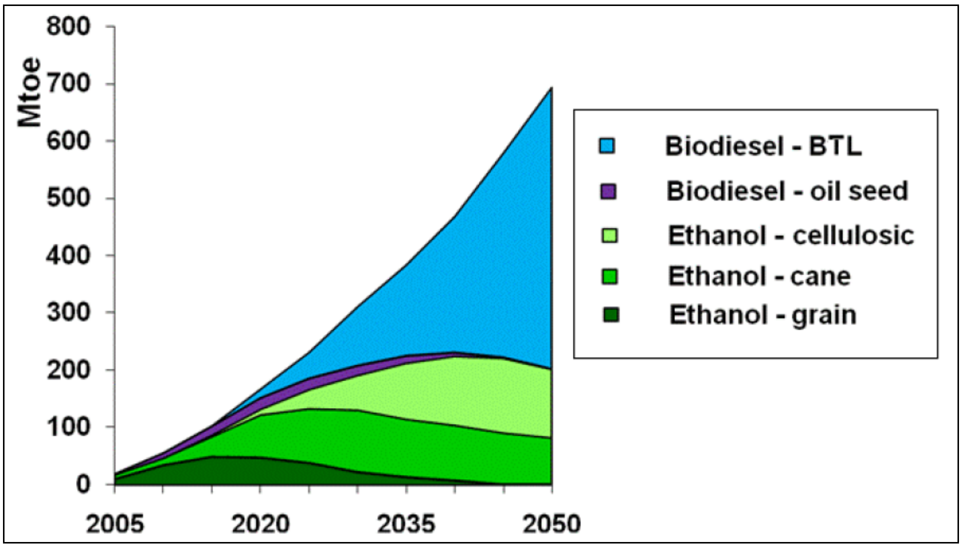

Figure 63: Projected transition between 1st and 2nd generation biofuels over time[444]

Innovative production technologies like biomass-to liquid synthesis are one of the most interesting opportunities for future biofuel production.[445]

Converting biomass into liquid fuels via Fischer Tropsch processes give higher yields per hectare than biodiesel based on oil seed crops. […] Small demonstration units exist, and other larger plants are planned, but there are currently no plans to intitiate large scale production.[446]

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[443] Appreciation of sales reps, AAG

[444] IEA (2008)

[445] Cf. OECD/IEA (2006), page 289

[446] OECD/IEA (2006), page 289

Up to now, fuel made by biomass-to-liquid synthesis is more expensive compared to other biofuel production technologies but will probably change in future if its technology is mature.[447]

Another very positive aspect of BtL- Fuel is its high CO_2 reduction potential of over 90% compared to fossil fuels and its high quality. BtL- Fuel can be used today and in foreseeable generations of engines (e.g. combined combustion systems).

- **Competition:**

As part of an internet research no specialists in the field of drying for this application could be found, so it can be assumed that all companies active in biomass drying are potential competitors.

6.11. Ethanol 1st Generation

Bioethanol 1st generation is currently the most used biofuel worldwide, covering more than 90% of the market.[448]

Following sections describe bioethanol production out of grains mainly. Bioethanol out of sugar cane (Brazil, etc.) is included in section 6.4 (Sugar industry – sugar cane).

6.11.1. Technological Analysis

- **Description of overall-process:**

Figure 64 shows the main steps in 1st generation ethanol production, namely milling of grains, saccharification, fermentation, rectification and dehydration of bioethanol. The main steps of DDGS production are evaporation, drying and pelletizing.

[447] Cf. OECD/IEA (2006), page 289

[448] Cf. N.N (January 2007), page 1

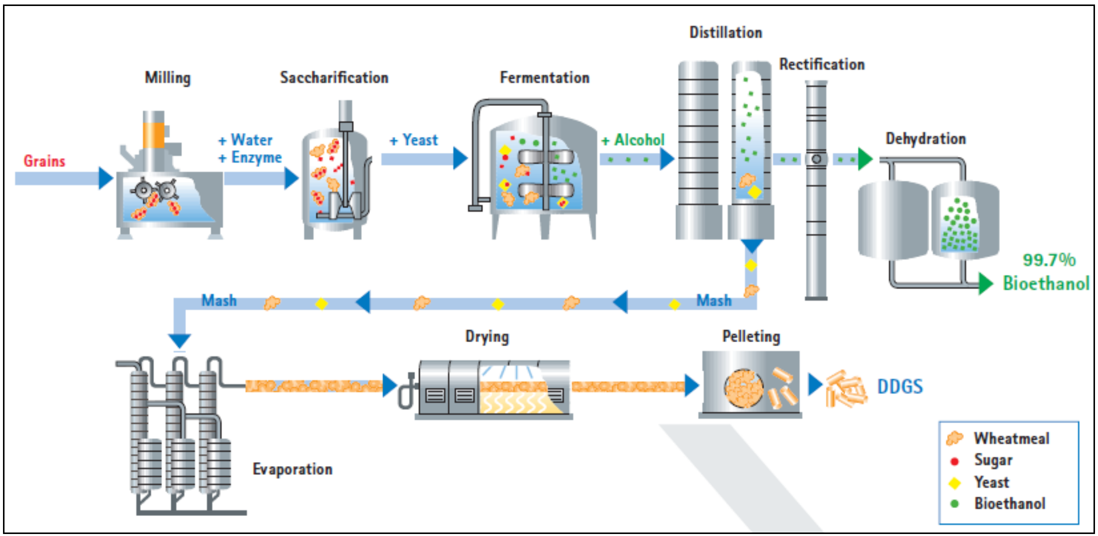

Figure 64: Schematic diagram of production process of bioethanol and DDGS from grains[449]

- **Purpose and position of drying applications:**

Drying is a separate step after the main process of ethanol production to prepare residues for following utilization.[450]

- **Feed product:**

There is a wide range of possible raw-materials for bioethanol production (which means many different residues out of process for further DA). In general, ethanol is able to be produced out of all starchy and sugary commodities. In Europe the most common materials are grains (wheat, barley, triticale, maize, rye) as well as sugar beet and potatoes. Other materials are sugar cane, rice or cassava.[451]

  - DG (Distiller grains):

Table 16 lists the typical DM of feed material.

	DM contents [%]	
	wheat	maize
draff	14	12
cake	25	25
thin draff	7	5
after 1st evaporation step	9	6,5
after 2nd evaporation step	13	10,5
syrup (after 3rd evaporation step)	30	29
syrup + cake	26	25,5
DDGS	90	90

Table 16: DM contents of material throughput in drying process of residues of ethanol production out of wheat and maize [452]

[449] http://www.cropenergies.com (06.10.2009), page 9

[450] Cf. http://www.cropenergies.com (06.10.2009), page 9

[451] Cf. http://www.cropenergies.com (06.10.2009), page 10

[452] Own presentation, Cf. Friedl et al. (2005), page 46

- Vinasse:

The residue of ethanol production out of sugar beet, called “Vinasse”, is mainly used as animal feed or fertilizer – no drying applications are essential.[453]

- Bagasse:

Treatment of bagasse is included in sections regarding sugar production out of sugar cane.

- **Dried product:**

The required dried product, DDGS, has a maximum moisture content of 10%. It is granular or pelletized and DDGS are preferred in light colour.[454]

- **Possible heat sources:**

Steam and natural gas are the usual heat source for drying DG. Typical drying temperatures are 120°C- 600°C.[455]

Drying turns out to be a very energy intensive process. About 30% of energy content of bioethanol production is required to dry the produced DG of a plant.[456]

- **Typical throughput:**[457]
  - Typical capacity of a Bioethanol (made of corn) facility in USA:
    - 300.000 [tons DDGS/year]
    - 98 [tons H2O/hour] evaporation

  - Typical capacity of Bioethanol (made of several cereals) facility in Germany:
    - 100.000 [tons DDGS/year]
    - 33 [tons H2O/hour] evaporation

[453] Cf. http://www.deutsche-melasse.de (08.02.2010)

[454] Cf. AAG, ET

[455] ibidem

[456] Cf. Hüttmann (08.02.2010)

[457] Own calculations, data can be found in appendix

- **Currently applied technologies:**
  - Drum dryer[458]
  - Belt dryer[459]
  - Ring dryer[460]
  - Tube bundle dryer [461]
  - Flash or ring dryers with natural gas firing[462]
  - Rotary dryers with natural gas firing[463]
  - Rotary steam tube dryers or disc dryers with steam heating[464]
  - Fluid bed dryer with steam or natural gas firing[465]

6.11.2. Market Analysis

- **Customers:**

The main customers for drying applications are bioethanol companies to prepare residues of the process for following utilization, but also technologists (such as Vogelbusch, Lurgi, Praj, Julius Montz, Katzen (USA), Delta-T) and EPC contractors (such as MAN Ferrostaal, Simon-Carves, Aker-Kvaerner, others).[466]

- **Market Volume and allocation:**

Current Market Volume:

Production Ethanol, 2007, US: 19.733.000 [tons][467]

Production DG, 2008, US: 25.000.000 [tons][468]

Installed evaporation capacity, 2008, US: 8.125 [tons H_2O/hour][469]

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458 Cf. http://www.aeroglide.com (06.10.2009)

459 ibidem

460 Cf. http://www.anhydro.com (28.10.2009)

461 ibidem

462 Cf. AAG, ET

463 ibidem

464 ibidem

465 ibidem

466 ibidem

467 http://data.un.org (15.02.2010), data can be found in appendix

468 http://www.biofuels-platform.ch (22.02.2010), page 24, data can be found in appendix

469 Own calculation, data can be found in appendix

Allocation:

As stated in Figure 65, USA and Brazil are the most important producers of alcohol covering 88% of the global market. Considering only those countries which produce alcohol mainly from corn, USA is by far the leading producer with a share of 81%.[470]

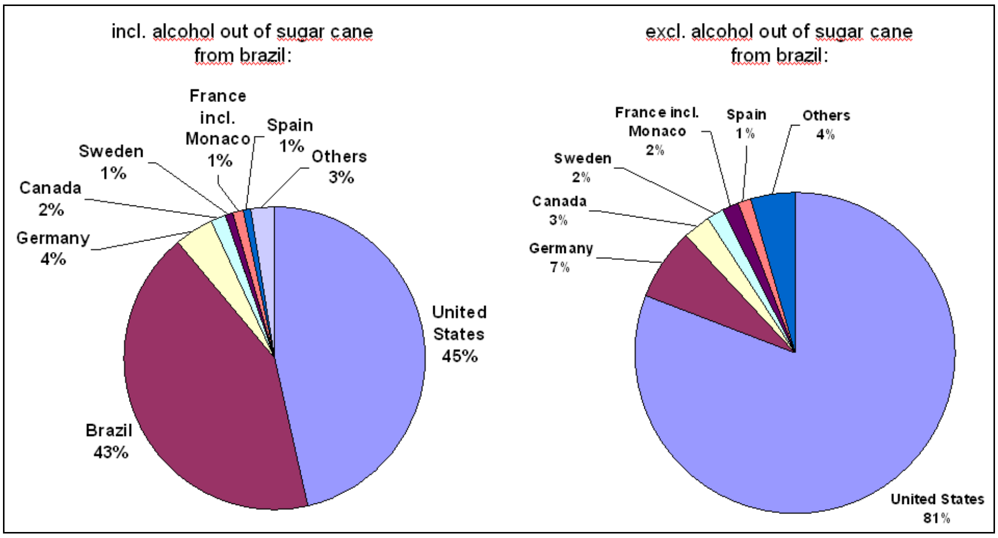
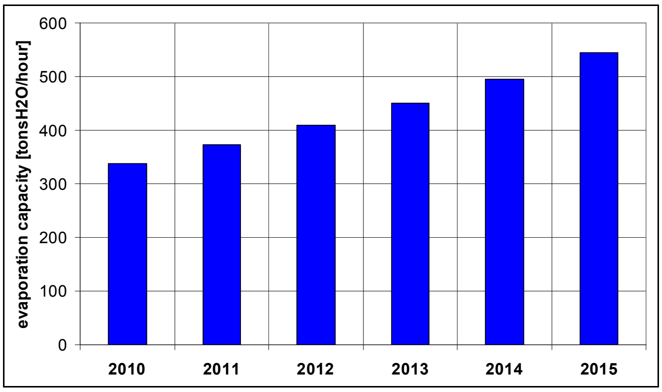


Figure 65: Regional allocation of alcohol production, 2007[471]

Possible future market volume:

Assumption for expected future market volume as can be seen in Picture 66:

- Potential of new installed capacity p.a.:
  - 100% of new installed facilities are implementing drying applications
  - 5% p.a. of existing facilities are implementing drying applications
- CAGR of 10% projected into future



Picture 66: Estimation of market volume of drying applications in bioethanol 1st generation business, 2010-2015[472]

[470] Own calculation, data can be found in appendix

[471] Own presentation, data can be found in appendix

[472] ibidem

- **Market Trend:**

Drivers:[473]

- Energy independence from fossil fuels
- Increased economic, environmental and national security

Barriers:[474]

- *The supply of grains is limited by the amount of available agricultural land and by competing uses.*
- Trade barriers in many countries
- Logistical barriers of biomass crops may limit the maximum size of conversation facilities, thereby limiting the potential for cost reductions due to economies of scale.
- The production of biofuels on massive scale may be a cause of deforestation and release of soil carbon, if pastureland or forest land is used for production.

Facts:

Table 17: shows the annual growth rates of alcohol production of the top 6 producers of alcohol made of cereals from 2001 to 2007 and, additionally the growth rates of the Brazil alcohol production which is mainly made out of sugar cane.

Growth of alcohol production: 2000-2007

	2001	2002	2003	2004	2005	2006	2007	CAGR (2000-2007)
United States	6%	32%	39%	23%	15%	23%	31%	24%
Brazil	7%	10%	15%	1%	10%	11%	27%	11%
Germany	-98%	50%	267%	295%	559%	52%	107%	33%
Canada	0%	0%	0%	0%	40%	-8%	251%	24%
Sweden	0%	142%	113%	112%	46%	15%	23%	56%
France incl. Monaco	-2%	0%	-15%	5%	44%	101%	76%	24%
Spain	0%	0%	38%	17%	-2%	1%	91%	17%

Table 17: Growth of alcohol production, 2000-2007, Top 6 producers[475]

473 Cf. http://europa.eu (02.05.2010)

474 Cf. OECD/IEA (2006), page 140

475 Own presentation and calculation, Cf. http://data.un.org (15.02.2010)

- **Competition:**
  - GEA Barr-Rosin[476]
  - Anhydro[477]
  - Ventilex [478]
  - Swiss-Combi[479]
  - Haarslev (Atlas-Stord)[480]
  - FEECO [481]
  - Aeroglide[482]
  - BMA[483]

6.12. Ethanol 2nd Generation

2nd generation ethanol (cellulosic ethanol) is chemically identical to first generation bioethanol, but it is produced from different raw materials via a more complex process (cellulose hydrolysis).[484]

6.12.1. Technological Analysis

- **Description of overall-process:**

Figure 67 shows the main steps of the 2nd generation ethanol production process, namely pre-treatment of raw materials, hydrolysis/liquefaction, fermentation, distillation and treatment of residues. [485]

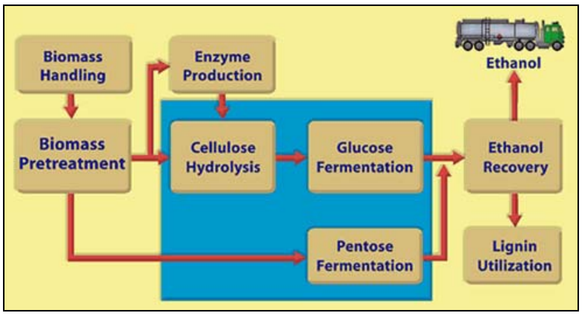


Figure 67: Schematic diagram of 2nd generation ethanol production process[486]

[476] Cf. http://www.barr-rosin.com (15.02.2010)
[477] Cf. http://www.anhydro.com (28.10.2009)
[478] Cf. http://www.ventilex.net (15.02.2010)
[479] Cf. http://www.swisscombi.ch (15.02.2010)
[480] Cf. http://www.haarslev.com (15.02.2010)
[481] Cf. http://ethanol.feeco.com (15.02.2010)
[482] Cf. http://www.aeroglide.com (15.02.2010)
[483] Cf. http://www.bma-de.com (15.02.2010)
[484] Cf. http://www.biofuelstp.eu (15.02.2010)
[485] Cf. http://www.ethanolrfa.org (15.02.2010)

- **Purpose and position of drying applications:**

Probably drying applications can be used to prepare lignin as solid biofuel for following utilization in power- and heat conversation in power plants or as raw material for following utilization.[487]

- **Feed Product:**

Feed products for drying applications are process residues of lignocellolosic materials (wood, straw, energy crops, etc.), mainly lignin with 20-40% DS.[488]

- **End Product:**

Up to now, it is difficult to estimate specifications of lignin after drying process due the lack of information concerning further utilization.[489]

- **Possible heat sources:**

Probably waste heat from CHP is available in case of incineration of lignin.[490]

- **Typical throughput:**

Today, only demo or pilot plants for 2nd generation bioethanol are in operation. Outputs of those plants vary from 10 to 4.500 tons ethanol per year. [491]

Up to now, there is no commercial 2nd generation bioethanol plant in operation, but a few are under construction or planned. Outputs of those future plants are 13.000-70.000 tons of ethanol per year.[492]

- **Currently applied technologies:**

Probably fluidized bed dryers and belt dryers are appropriate technologies for lignin drying.[493]

486 http://www.ethanolrfa.org (15.02.2010)

487 Cf. AAG, ET

488 ibidem

489 ibidem

490 ibidem

491 Cf. http://biofuels.abc-energy.at (15.12.2009)

492 ibidem

493 Cf. AAG, ET

6.12.2. Market Analysis:

- **Customers:**

Potential customers are ethanol producing companies or, possibly, companies specialized in lignin treatment.[494]

- **Market Volume and allocation:**

It is still very difficult to estimate future market volumes because this market is still nascent. Currently known projects can be seen in Table 18.

Company	Country	Product	Output [t/a[	Type	Status	Start-up
Abengoa Bioenergy Biomass of Kansas, LLC	US	ethanol	34.000	commercial	under construction	2011
Abengoa Bioenergy New Technologies	US	ethanol	75	pilot	operational	2007
Abengoa, Biocarburantes Castilla y Leon Ebro Puleva	Spain	ethanol	4.000	demo	under construction	2009
AE Biofuels	US	ethanol	500	pilot	operational	-
BBI BioVentures LLC	US	ethanol	13.000	commercial	planned	2010
BioGasol	Denmark	ethanol; biogas; lignin; hydrogen;	4	demo	planned	-
BioGasol / AAU	Denmark	ethanol/biogas/cellulose/hemicel./lignin;	10	pilot	planned	2009
Borregaard Industries LTD	Norway	ethanol	15.800	commercial	operational	1930
DDCE DuPont Danisco Cellulosic Ethanol	US	ethanol	750	pilot	under construction	2009
EtanolPiloten i Sverige AB	Sweden	ethanol	80	pilot	operational	2004
Frontier Renewable Resources	US	ethanol; lignin	60.000	commercial	announced	-
Inbicon (DONG Energy)	Denmark	ethanol; c5 molasses; solid biofuel;		pilot	operational	2003
Inbicon (DONG Energy)	Denmark	ethanol; c5 molasses; solid biofuel;		pilot	operational	2004
Inbicon (DONG Energy)	Denmark	ethanol; c5 molasses; solid biofuel	4.000	demo	operational	2009
Iogen Biorefinery Partners, LLC	US	ethanol	55.000	commercial	on hold	-
Iogen Corporation	Canada	ethanol	1.600	demo	operational	2004
Iogen Corporation	Canada	ethanol	70.000	commercial	planned	2011
KL Energy Corporation	US	ethanol	4.500	demo	operational	2007
Lignol Energy Corporation	Canada	ethanol, Lignin	80	pilot	commissioning	2009
Lignol Energy Corporation	US	ethanol; lignin	7.500	demo	on hold	2012
Mascoma Corporation	US	ethanol; lignin	500	demo	operational	-
Mossi & Ghisolfi - Chemtex Italia	Italy	ethanol	50	pilot	operational	2009

Table 18: Overview of 2nd generation ethanol plants[495]

Market Trend:

As illustrated in Figure 68, the International Energy Agency assumes that the transition between first and second generation biofuels will change in future to a higher share for 2nd generation biofuels like biodiesel – BtL and cellulosic ethanol.

[494] Appreciation of sales representatives., AAG, ET

[495] Own presentation; http://biofuels.abc-energy.at (15.12.2009)

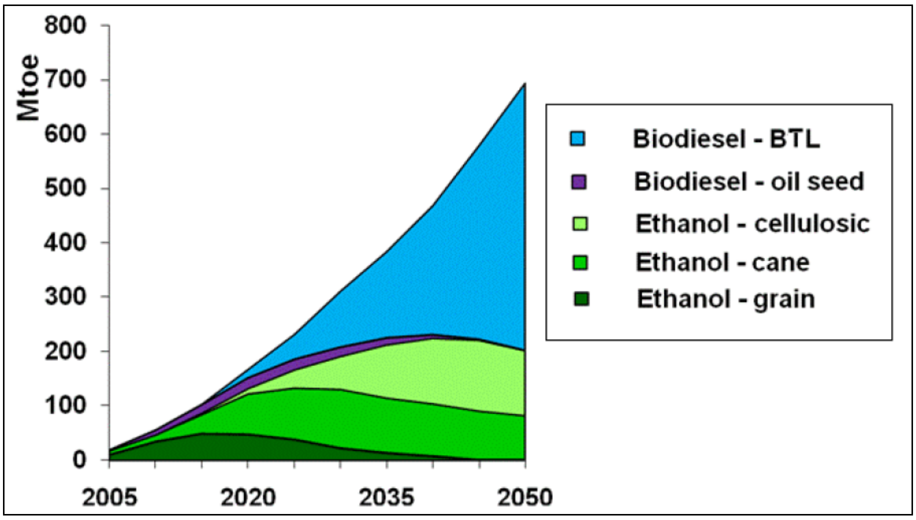


Figure 68: Projected transition between 1st and 2nd generation biofuels over time[496]

Drivers:[497]

- *Lignocellolosic ethanol has the potential to reduce CO_2 emissions by 70% or more compared to gasoline.*
- *Ethanol from cellulose [.] reduces the potential competition for the use of land between farmers and energy producers*
- *2nd generation ethanol can be produced from a wide variety of feedstocks.*

Barriers:[498]

- *Large scale plants will face some logistical challenges, as one of the disadvantages of the biomass feedstock is its dispersed nature*
- High costs of 2nd generation bioethanol up to now

- **Competition:**

As part of an internet research no specialists in the field of drying of residues out of the process could be found, therefore it can be assumed that all companies active in biomass drying are potential competitors.

[496] IEA (2008)

[497] OECD/IEA (2006), page 141

[498] ibidem

6.13. Torrefaction

Torrefaction is a mild pre-treatment of biomass at a temperature between 200-300°C. During torrefaction the biomass properties are changed to obtain a much better fuel quality for combustion and gasification applications. In combination with pelletisation, torrefaction also aids the logistic issues that exist for untreated biomass.[499]

6.13.1. Technological Analysis

- **Description of overall-process:**

As can be seen in Figure 69, the main steps of production of torrefied pellets are drying of biomass, torrefaction, cooling/ storage, size reduction and, finally pelletizing.

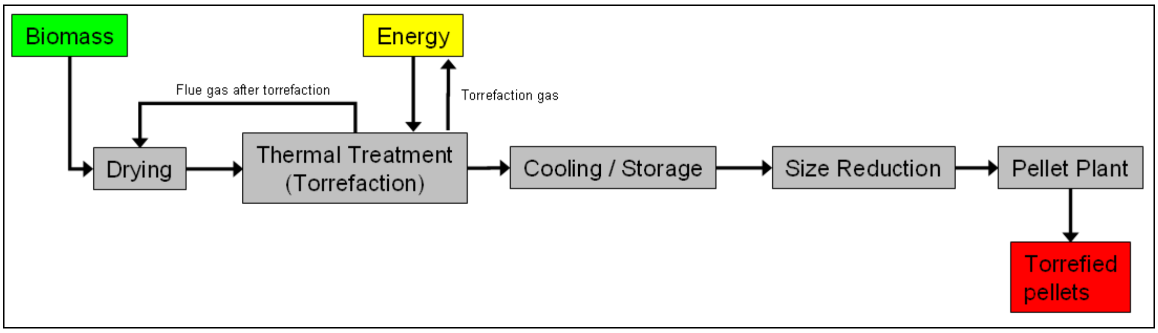


Figure 69: Schematic diagram of torrefaction process[500]

As illustrated in Figure 70, torrefaction improves the relation between energy and mass. The gas, which is produced during torrefaction, can be used in the sense of a loop process to produce energy for torrefaction.[501]

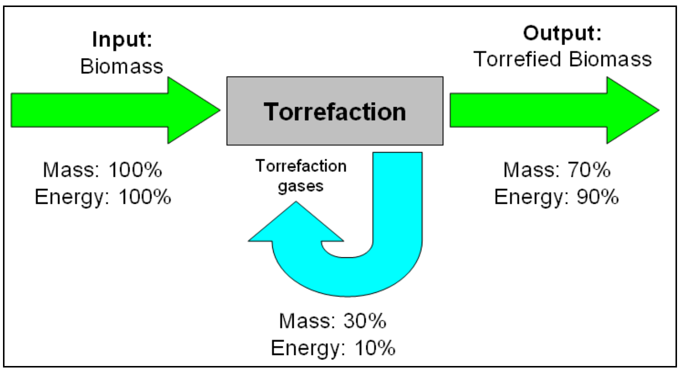


Figure 70: Mass and energy balance of torrefaction process[502]

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[499] Bergmann/Kiel (2005), page 3

[500] Own presentation, Cf. AAG, ET, Technologists

[501] Cf. AAG, ET, Technologists

[502] Own presentation, Cf. Bergman (2005), page 12

- **Purpose and position of drying applications:**

As shown in Figure 69, drying is a step before torrefaction to allow the following processes.

- **Feed Product:**

Torrefied biomass can be produced from many different kinds of lignocellolosic biomass, like wood, straw, etc. . [503]

So there is a big range of feed products for drying applications like stated in chapters above.

- **End Product:**[504]

Biomass needs to be dried to a moisture level of at least 5% or lower to allow torrefaction process.

Properties of torrefied biomass are:

- Uniform fuel produced from various biomass sources
- Improved grindability
- Hydrophobic fuel, no biological degradation
- High net calorific value of 19-23 MJ/kg
- High energy density of ~15 GJ/m³ (wood pellets: 10-10,5 GJ/m³)
- Low costs for transport and handling
- Combustion and co-firing in conventional coal-fired powerplants possible

- **Possible heat sources:**

Possible heat sources for DA are flue gas from incineration of torrefaction gas or of any utility fuel or a combination of both.[505]

- **Typical throughput:**

There are no commercial applications up to now, but capacities of 50.000 [tons/year] and more are expected.[506]

[503] Cf. Bergmann/Kiel (2005), page 5

[504] Cf. AAG, ET, Technologists

[505] Cf. Bergman/Boersma/Zwart/Kiel (2005), page 23 ff

[506] Appreciation of technologists, AAG, ET

- **Currently applied technologies:**

Applied technologies will be the same as in wood pellet industry - especially indirect heated technologies with low temperature levels to use waste heat from torrefaction process like belt dryers.[507]

6.13.2. Market Analysis

- **Customers:**

Customers for drying applications are biomass-solid-fuel producing companies to prepare raw materials before torrefaction.[508]

- **Market Volume and allocation:**

The market for torrefaction does still not exist but, as stated in Table 19, there are a few projects on the way to implementation.

Company	Location	Under construction	Planned	Future development	Start-Up	Note
		Capacity [tons/year]				
4Energy invest	Amel, Belgium	40.000			Q4 2009	Under construction
	Ham, Belgium		40.000		2010	Advanced development
	Reisbach, Germany		40.000		2011	Under development
	Flanders, Belgium		40.000		2011	Under Development
	Unknown			40000 +	2011 +	Plan for 200.000 tons p.a. of capacity in production by 2011
Strampoy Green	Steewijk, Netherlands	135.000			Q4 2009	Under construction. Long term supply contract with Essent
	Benelux		270.000		2011 +	Plans for 2 more plants
	Unknown			1.600.000	2014	Plan for 2 million tons capacity p.a. in production by 2014
Topell	Duiven, Netherlands	60.000			Q3 2009	Under construction
	Unknown			1.000.000	2012	Plan for 1 million tons capacity p.a. in production by 2012
Atmosclear SA (Airless Systems Ltd.)	Rezekne, Latvia	180.000	180.000		2010 +	Wood pellet and biocoal plant under construction . Start up Q1 2010, initially producing 40.000 tons p.a. biocoal, increasing to 180.000 tons p.a.. Plans to double capacity agreed
	USA, New Zealand, Brazil, Canada, Australia, Uruguay			4-5 million	by 2015	Exclusive agreements for 10 plants in USA to be rolled-out over next 2-3 years. Terms aggreed for 3 plants each in Brazil & New Zealand. Negotiation for others n Canada, Australia and Uruguay. 4-5 million tons p.a. by 2015
Integro Earth Fuels	Roxbro, NC, USA		68.000	159.000	H1 2010	Equipment ordered. Possible expansion to 227000 tons p.a.
	SE USA			??	2011 +	Integro is intending to built approximatelly ten plants in SE USA within the next five years
EBES	??		50.000		2011	80 plants with capacity of 50.000 tons p.a. are planed by 2016

Table 19: Torrefaction plants under construction or planned[509]

Essent Energy Trading BV and Stramproy Green Coal B.V. have signed [.] a multi-year contract in August 2009 for Stramproy to deliver 90,000 tons of bio-coal to Essent on an annual basis. The bio-coal, which will start to be delivered in late 2009 or early 2010, is to be produced in a […] facility in Steenwijk, the Netherlands.[510]

[507] Appreciation of technologists, AAG, ET

[508] Appreciation of sales reps, AAG, ET

[509] Own presentation; N.N. (2009), page 14; N.N. (2009a), page 18;

[510] http://www.essent.eu (16.10.2009)

If coal-fired power plants in EU-27 are starting co-firing of torrefied biomass at a level of 10%, 1.400 torrefaction plants with plant size of 50.000 [tons/year] will be necessary.[511]

A plant with an output of 50.000 [tons/year] of torrefied material needs a drying capacity of about 8 tons of water per hour which means a potential market volume for EU-27 of 11.200 [tons H_2O/hour] for 1.400 plants.[512]

The allocation will probably be the same as in wood-pellet industry. Future markets depend on resources of raw materials, so Canada, Russia and Brazil will probably become big players in torrefaction business.[513]

- **Market Trend:**

In case of co-firing of biomass in coal-fired power plants CO_2 emissions out of fossil fuels can be reduced significantly.[514]

In view of the efforts for CO_2 reduction all over the world (Kyoto Protocol), co-firing of biomass can be an important part to reach the set targets. Torrefied biomass can be fired in all coal fired power plants without big changes in equipment because properties of the material are similar to coal. One big advantage of co-firing of biomass is the saving of CO_2 certificates of operators of power plants.[515]

Other positive aspects of torrefied biomass are the high energy density and the fact that it is a hydrophobic material, especially in context with savings of costs for transportation and storage of biomass. So it is possible to produce torrefied biomass where biomass is cheap and plentiful. [516]

Possible barriers are high costs for torrefaction-process (at the moment – can change in future), and technological uncertainty because of missing technical maturity.[517]

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[511] Cf. AAG, ET, Technologists

[512] Own calculation, data can be found in appendix

[513] Appreciation of sales reps. , AAG, ET

[514] Cf. http://idw-online.de (17.02.2010)

[515] Cf. AAG, ET, Technologists

[516] ibidem

[517] ibidem

- **Competition:**

The competitors depend on used raw materials. Probably in most of the cases wooden biomass is used as raw material, so the competitors will be the same as in wood pellet industry (chapter 6.1.2) .[518]

[518] Cf. Technologists , AAG, ET

7. Assessment of Selected Industries

In this section each industry is evaluated and assessed based on the information of product analysis and analysis of industries (see section 6) to issue a recommendation for further consideration. The general procedure of assessment is described in section 4.5.3, page 40.

7.1. Wood Pellet Industry

Evaluation:

- There is a global trend to push primary energy made out of renewable energy sources especially in connection with the Kyoto-protocol to reduce CO2 emissions and so the pellet market will be a growing one in future
- Pellet market is "mature" and relatively large with a strongly positive trend
- Strengths: AAG is able to offer complete solutions for pellet industry (together with FB). ET-Drying technology (BDS) has been proven for large scale throughputs (Kopparfors, Lauterbach).
- Weakness: Sales price is too high due to insufficient standardization because of short term market presence
- Preferred technologies: drum dryer, belt dryer

Assessment:

MA:

Driver:	Weighting	Points [1-10]	Weighted points:
Market Volume	30%	5	1,5
Market Maturity	20%	9	1,8
Market Trend	30%	8	2,4
Low competitiveness of market	10%	3	0,3
Margin	10%	3	0,3
	100%		6,3

CA:

Driver:	Weighting	Points [1-10]	Weighted points:
Technology	10%	6	0,6
Sales price	15%	3	0,45
Image/Publicity	10%	5	0,5
Market access	20%	4	0,8
Dryer size > 3 t/h	15%	8	1,2
Dryer part of A-package	20%	10	2
Customer Responsiveness	10%	7	0,7
	100%		6,25

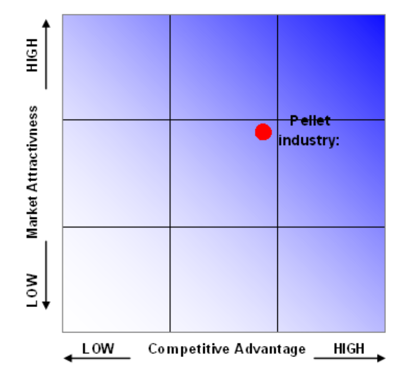

Figure 71: MACA-Analysis, wood pellet industry[519]

[519] Own presentation

7.2. Panelboard Industry

Evaluation:

- There is a possibility to replace direct fired dryers by indirect heated belt dryers to use waste heat out of process to replace fossil fuels.
- The panel board market is very mature and its growth is characterized by a continuous growing demand on wooden construction materials depending on development of population and overall economic conditions.
- Strength: large dryer capacities; reference plant Lauterbach (2% residual moisture!)
- Weakness: no market access so far; high sales price – equal to pellet market
- Prefered technologies: drum dryer, flash dryer, belt dryer

Assessment:

MA:

Driver:	Weighting	Points [1-10]	Weighted points:
Market Volume	30%	10	3
Market Maturity	20%	10	2
Market Trend	30%	6	1,8
Lowcompetitiveness of market	10%	4	0,4
Margin	10%	5	0,5
	100%		7,7

CA:

Driver:	Weighting	Points [1-10]	Weighted points:
Technology	10%	6	0,6
Sales price	15%	3	0,45
Image/Publicity	10%	5	0,5
Market access	20%	5	1
Dryer size > 3 t/h	15%	10	1,5
Dryer part of A-package	20%	6	1,2
Customer Responsiveness	10%	8	0,8
	100%		6,05

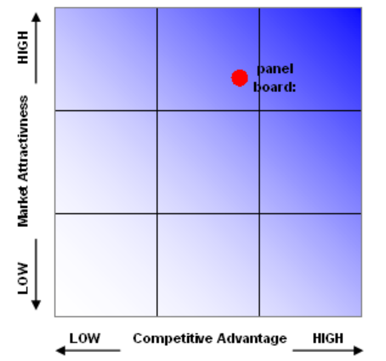

Figure 72: MACA- Analysis, panel board industry[520]

7.3. Pulp and Paper Industry

Evaluation:

- Especially big potential in Europe depending on prohibition of landfill for wastes with organic content >5% from 2011 on.
- CO2 balance for the mill can be partly changed (if fossil fuel is replaced by biomass or waste); additional financial benefit
- Strength: Andritz would be able to offer/introduce complete solutions for paper mill reject and sludge treatment.
- Weakness: high sales price; small dryer capacities; cooperation with other A-divisions not fully established yet.
- Preferred technologies: belt dryer, drum dryer

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[520] Own presentation

Assessment:

MA:	Driver:	Weighting	Points [1-10]	Weighted points
	Market Volume	30%	8	2,4
	Market Maturity	20%	3	0,6
	Market Trend	30%	7	2,1
	Lowcompetitiveness of market	10%	3	0,3
	Margin	10%	3	0,3
		100%		5,7

CA:	Driver:	Weighting	Points [1-10]	Weighted points
	Technology	10%	8	0,8
	Sales price	15%	3	0,45
	Image/Publicity	10%	8	0,8
	Market access	20%	9	1,8
	Dryer size > 3 t/h	15%	1	0,15
	Dryer part of A-package	20%	10	2
	Customer Responsiveness	10%	7	0,7
		100%		6,7

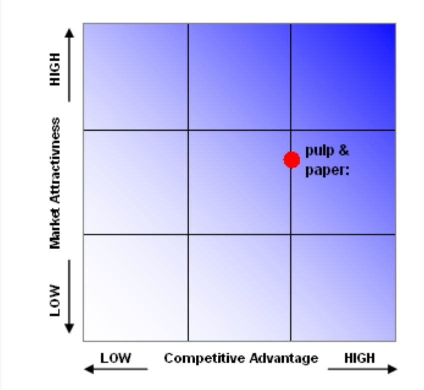


Figure 73: MACA- Analysis, pulp and paper industry[521]

7.4. Sugar Industry – Sugarcane

Evaluation:

- Bagasse is a big potential of central available biomass in the future.
- Market is very young but in development
- Strength: big dryer capacities
- Weakness: sales price (problematic because market in low cost countries - Brazil, India)
- Preferred technologies: drum dryer, flash dryer, belt dryer

Assessment:

MA:	Driver:	Weighting	Points [1-10]	Weighted points:
	Market Volume	30%	10	3
	Market Maturity	20%	1	0,2
	Market Trend	30%	6	1,8
	Lowcompetitiveness of market	10%	2	0,2
	Margin	10%	1	0,1
		100%		5,3

CA:	Driver:	Weighting	Points [1-10]	Weighted points:
	Technology	10%	5	0,5
	Sales price	15%	1	0,15
	Image/Publicity	10%	1	0,1
	Market access	20%	2	0,4
	Dryer size > 3 t/h	15%	9	1,35
	Dryer part of A-package	20%	6	1,2
	Customer Responsiveness	10%	5	0,5
		100%		4,2

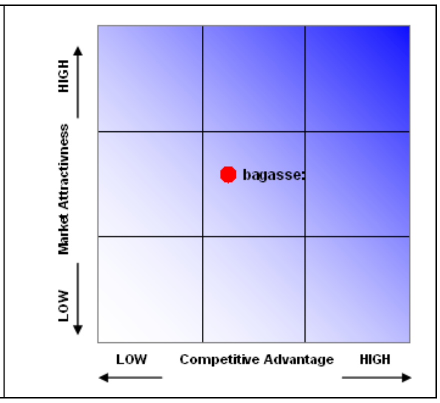


Figure 74: MACA-Analysis, sugar industry - sugar cane[522]

[521] Own presentation

[522] ibidem

7.5. Sugar Industry – Sugar Beet

Evaluation:

- Notable market volume and mature market, but with negative trend (out phasing sugar sector regulations in EU)
- Growth of sugar beet production only in Russia, all other markets are stagnating or shrinking.
- Strength: large dryer capacity
- Weakness: sales price; difficult market access
- Preferred drying technologies: drum dryer, tube bundle dryer, belt dryer

Assessment:

MA:

Driver:	Weighting	Points [1-10]	Weighted points:
Market Volume	30%	8	2,4
Market Maturity	20%	9	1,8
Market Trend	30%	4	1,2
Low competitiveness of market	10%	3	0,3
Margin	10%	3	0,3
	100%		6,0

CA:

Driver:	Weighting	Points [1-10]	Weighted points:
Technology	10%	5	0,5
Sales price	15%	3	0,5
Image/Publicity	10%	1	0,1
Market access	20%	3	0,6
Dryer size > 3 t/h	15%	8	1,2
Dryer part of A-package	20%	2	0,4
Customer Responsiveness	10%	5	0,5
	100%		3,8

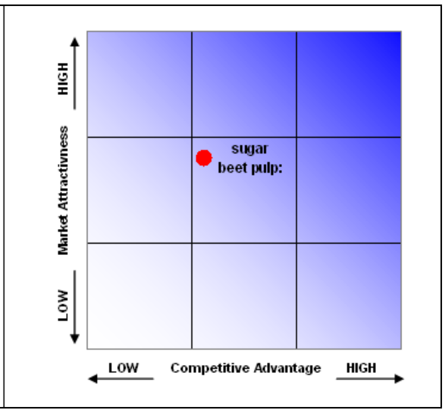


Figure 75: MACA-Analysis, sugar industry - sugar beet[523]

7.6. Brewery Industry

Evaluation:

- Notable theoretical market volume; high competitive market
- Strength: no significant
- Weakness: extremely small dryer capacities out of AAG range
- Preferred technologies: contact dryer, belt dryer

[523] Own presentation

Assessment:

MA:

Driver:	Weighting	Points [1-10]	Weighted points:
Market Volume	30%	6	1,8
Market Maturity	20%	1	0,2
Market Trend	30%	6	1,8
Lowcompetitiveness of market	10%	3	0,3
Margin	10%	3	0,3
	100%		4,4

CA:

Driver:	Weighting	Points [1-10]	Weighted points:
Technology	10%	6	0,6
Sales price	15%	3	0,5
Image/Publicity	10%	3	0,3
Market access	20%	2	0,4
Dryer size > 3 t/h	15%	1	0,2
Dryer part of A-package	20%	1	0,2
Customer Responsiveness	10%	6	0,6
	100%		2,7

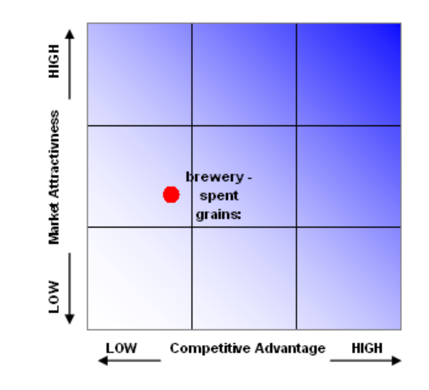


Figure 76: MACA- Analysis, brewery industry[524]

7.7. Palm Oil Industry

Evaluation:

- Notable theoretical market volume, very young market
- Low price levels in main markets (Indonesia, Malaysia)
- Strength: no significant
- Weakness: no market access up to now in main markets, low image and publicity

Assessment:

MA:

Driver:	Weighting	Points [1-10]	Weighted points:
Market Volume	30%	8	2,4
Market Maturity	20%	1	0,2
Market Trend	30%	6	1,8
Lowcompetitiveness of market	10%	2	0,2
Margin	10%	1	0,1
	100%		4,7

CA:

Driver:	Weighting	Points [1-10]	Weighted points:
Technology	10%	5	0,5
Sales price	15%	2	0,3
Image/Publicity	10%	1	0,1
Market access	20%	1	0,2
Dryer size > 3 t/h	15%	8	1,2
Dryer part of A-package	20%	4	0,8
Customer Responsiveness	10%	5	0,5
	100%		3,6

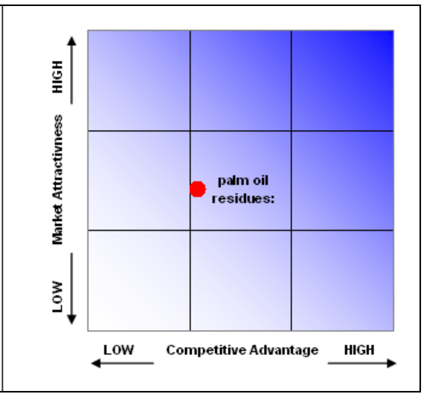


Figure 77: MACA- Analysis, palm oil industry[525]

[524] Own presentation

[525] ibidem

7.8. Olive Oil Industry

Evaluation:

- Small market volume and low developed market.
- Strength: Relatively good market access via department ES (Separation technologies)
- Weakness: Small scale drying applications out of range of AAG
- Preferred drying technologies: belt dryer, drum dryer

Assessment:

MA:

Driver:	Weighting	Points [1-10]	Weighted points:
Market Volume	30%	4	1,2
Market Maturity	20%	2	0,4
Market Trend	30%	6	1,8
Lowcompetitiveness of market	10%	3	0,3
Margin	10%	3	0,3
	100%		4,0

CA:

Driver:	Weighting	Points [1-10]	Weighted points:
Technology	10%	5	0,5
Sales price	15%	3	0,5
Image/Publicity	10%	6	0,6
Market access	20%	6	1,2
Dryer size > 3 t/h	15%	1	0,2
Dryer part of A-package	20%	4	0,8
Customer Responsiveness	10%	6	0,6
	100%		4,3

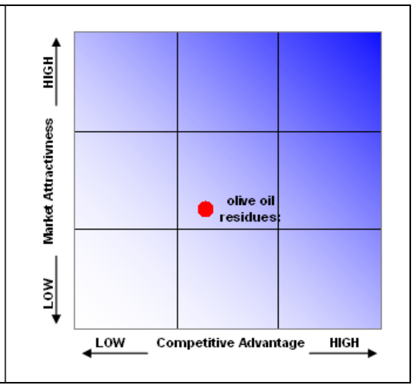


Figure 78: MACA-Analysis, olive oil industry[526]

7.9. Biogene Waste Industry – Biogas Plants

Evaluation:

- Notable market volume and low developed market.
- Strength: relatively good market access via department ES (Separation technologies)
- Weakness: Small scale drying applications are necessary.

Assessment:

MA:

Driver:	Weighting	Points [1-10]	Weighted points:
Market Volume	30%	7	2,1
Market Maturity	20%	2	0,4
Market Trend	30%	7	2,1
Lowcompetitiveness of market	10%	6	0,6
Margin	10%	6	0,6
	100%		5,8

CA:

Driver:	Weighting	Points [1-10]	Weighted points:
Technology	10%	5	0,5
Sales price	15%	5	0,8
Image/Publicity	10%	6	0,6
Market access	20%	5	1,0
Dryer size > 3 t/h	15%	1	0,2
Dryer part of A-package	20%	2	0,4
Customer Responsiveness	10%	5	0,5
	100%		3,9

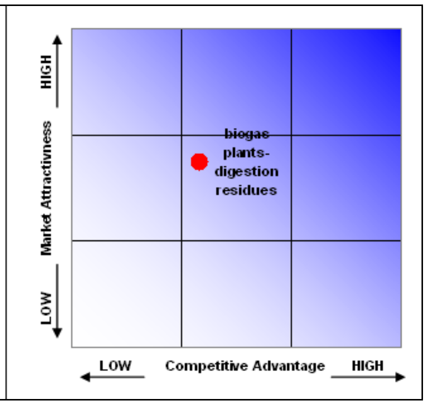


Figure 79: MACA-Analysis, biogas plants[527]

526 Own presentation

527 ibidem

7.10. Gasification / Biomass to Liquid

The assessment of this industrial area was renounced due to incomplete data.

7.11. Ethanol 1st Generation

Evaluation:

- Medium scale market volume and well developed market
- Strength: big drying applications necessary
- Weakness: limited applicability of AAG drying technology (Fluidized bed dryer)
- Preferred technologies: Fluidized bed dryer, flash dryer

Assessment:

MA:

Driver:	Weighting	Points [1-10]	Weighted points:
Market Volume	30%	7	2,1
Market Maturity	20%	8	1,6
Market Trend	30%	6	1,8
Lowcompetitiveness of market	10%	3	0,3
Margin	10%	3	0,3
	100%		6,1

CA:

Driver:	Weighting	Points [1-10]	Weighted points:
Technology	10%	5	0,5
Sales price	15%	5	0,8
Image/Publicity	10%	5	0,5
Market access	20%	6	1,2
Dryer size > 3 t/h	15%	10	1,5
Dryer part of A-package	20%	4	0,8
Customer Responsiveness	10%	5	0,5
	100%		5,8

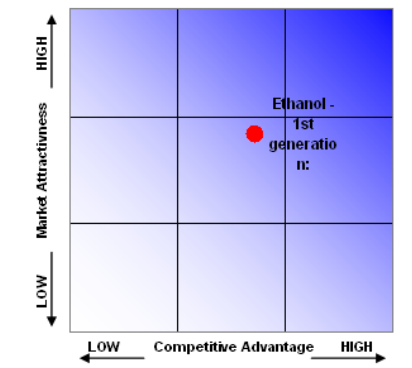


Figure 80: MACA-Analysis, bioethanol industry - 1st generation[528]

7.12. Ethanol 2nd Generation

Evaluation:

- Low developed market but with positive trend in future.
- Drying application as well as whole process not yet fully established.
- Strength: AAG will be able to offer complete systems for bioethanol business in 2nd generation.
- Weakness: not known yet
- Preferred technologies: Fluidized bed dryer, flash dryer

[528] Own presentation

Assessment:

MA:

Driver:	Weighting	Points [1-10]	Weighted points:
Market Volume	30%	7	2,1
Market Maturity	20%	1	0,2
Market Trend	30%	7	2,1
Lowcompetitiveness of market	10%	4	0,4
Margin	10%	4	0,4
	100%		5,2

CA:

Driver:	Weighting	Points [1-10]	Weighted points:
Technology	10%	5	0,5
Sales price	15%	4	0,6
Image/Publicity	10%	5	0,5
Market access	20%	6	1,2
Dryer size > 3 t/h	15%	8	1,2
Dryer part of A-package	20%	7	1,4
Customer Responsiveness	10%	5	0,5
	100%		5,9

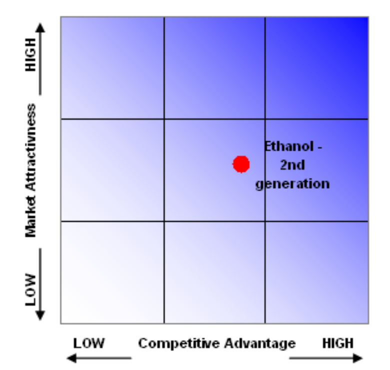


Figure 81: MACA- Analysis, bioethanol industry - 2nd generation[529]

7.13. Torrefaction

Evaluation:

- Big theoretical market potential but very low developed market
- Strength: Big scale drying applications necessary; AAG will probably be able to offer complete systems for torrefaction.
- Weakness: sales price

Assessment:

MA:

Driver:	Weighting	Points [1-10]	Weighted points:
Market Volume	30%	8	2,4
Market Maturity	20%	1	0,2
Market Trend	30%	6	1,8
Lowcompetitiveness of market	10%	3	0,3
Margin	10%	3	0,3
	100%		5,0

CA:

Driver:	Weighting	Points [1-10]	Weighted points:
Technology	10%	6	0,6
Sales price	15%	4	0,6
Image/Publicity	10%	6	0,6
Market access	20%	6	1,2
Dryer size > 3 t/h	15%	10	1,5
Dryer part of A-package	20%	8	1,6
Customer Responsiveness	10%	6	0,6
	100%		6,7

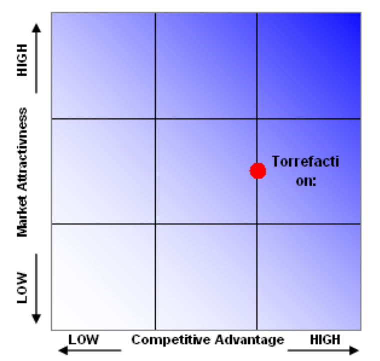


Figure 82: MACA-Analysis, torrefaction[530]

[529] Own presentation

[530] ibidem

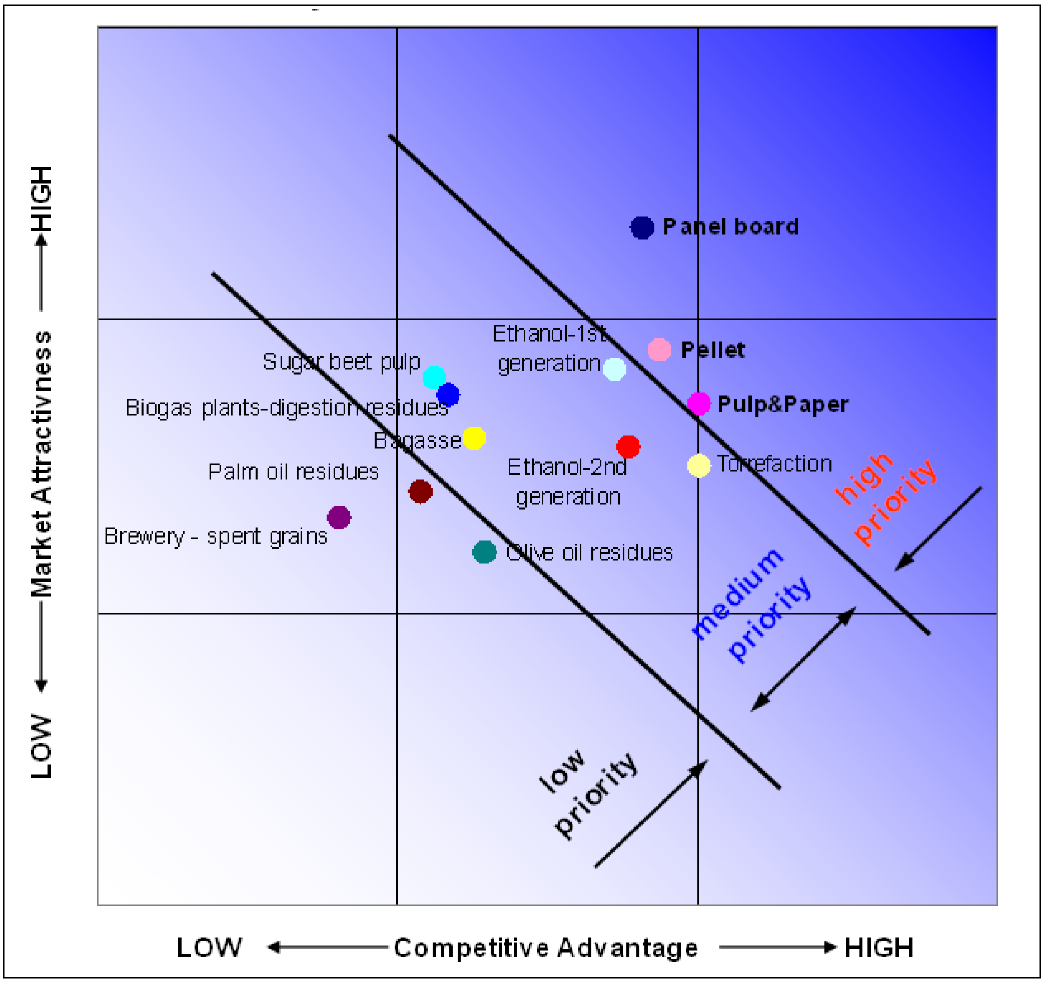
7.14. Summery and Recommendation

Based on the results of assessments for selected industries, they could be prioritized for further considerations to deflect further measures, actions and targets. As illustrated in Picture 83, different industries were categorized in 3 different levels, namely “high priority industry”, “medium priority industry”, and “low priority industry”.

- **High priority industries:**
  - Pellet industry
  - Panel board industry
  - Pulp and Paper industry

- **Medium priority industries:**
  - Torrefaction
  - 1^{st} generation ethanol
  - 2^{nd} generation ethanol
  - Sugar beet pulp
  - Biogas plants– digestion residues
  - Bagasse

- **Low priority industries:**
  - Palm oil residues
  - Brewery – spent grains
  - Olive oil residues



Picture 83: MACA- Analysis, summery[531]

[531] Own presentation

8. Definition of measures and actions for selected industries

Based on the results of the product analyses (section 5, page 43 ff.), the market analysis (section 6, page 55 ff.) and the assessment of selected industries (section 7, page 127), strategic targets and measures and actions to reach them were defined within a workshop of divisional managers (commercial management, sales, technology). The level of detail of set targets and actions depends on the priority of respective industry. The results of this last phase of the business plan will not be listed in detail because of confidentiality, but mentioned in its principles. Following targets and actions including responsibilities were defined:

- **General actions:**
  - Actions which are independent from the kind of application and suitable for all kind of industries.
- **High priority industries:**
  - Targeted sales volumes of next two years
  - Targeted medium term (5 years) market share
  - Actions regarding further analysis of technology and the market
  - Actions regarding technological development
  - Necessary marketing actions
- **Medium priority industries:**
  - Actions regarding further analysis of technology and the market
- **Low priority industries:**
  - Actions regarding further analysis of technology and the market (in a lower level of detail compared to medium priority industries)

9. Personal Experiences, Impressions, Conclusion

It was a great experience to get a view of a global company like AAG, which is active in many different business areas all over the world. There are advantages in a big global group like available networks in many different industries but also disadvantages like lower flexibility and long decision paths. Therefore, in my opinion it is very important to use the advantages to minimize the disadvantages.

This thesis was the first time I came into closer contact with the task of biomass and renewable energy. The buzzwords biomass and renewable energy are indispensable in view of the concern of sustainability of energy from daily life and the media reporting any more. This thesis offered the possibility for me to get a general glimpse at the big range of opportunities of biomass utilization. In my opinion, this business area is, up to now, at the very beginning of the utilization of its full potential. On one hand there are relatively mature businesses e.g. the pellet industry, but also very young businesses which are still in development. Especially the monitoring of these possible new fields of biomass business will be very important to be ready for the market, in case of the start-up of different businesses.

The results of the diploma thesis are an initial basis for the further approach, to be able to satisfy the needs of possible new business areas. As said, the results are only the basics of the knowledge of different industries to get a first view if it makes sense to consider the markets in future, but there are a few further steps which have to be done. These steps were defined at the end of the thesis and are on the way to implementation.

List of Figures:

List of Tables

List of Abbreviations

AAG	Andritz AG
BCG	Bosten Consulting Group
BDS	Belt Drying System
BFB	Bubbling Fluidized Bed
BP	Businessplan
BtL	Biomass to Liquid
CA	Competitive Advantage
CAGR	Compound Annual Growth Rate
CHP	Combined Heat and Power
DA	Drying Application
DDGS	Dried Distiller grains with solubles
DDS	Drum Drying System
DG	Distiller grains
DM	Dry Matter
DS	Dry Substance
EBES	European Biomass Energy Services AG
EBIT	Earnings before interest and tax
EC	Economic Crisis
EFB	Empty Fruit Bunches
ES	Executive Summary
ET	Department "Thermal Processes", AAG
EU	European Union
FB	Department "Feed and Biofuel", AAG
FDS	Fluidised bed drying system
FFB	Fresh Fruit Bunches
GE	General Electric
MA	Market Attractiveness
MBP	Mixed Biomass Pellets
MC	Moisture Content
MDF	Medium Density Fibreboard
NA	North America
OMWW	Olive Mill Waste Water
OSB	Orientated strand board
PD	Department „Pulp Drying Systems“, AAG
PM	Paper Mill
POME	Palm Oil Mill Effluent
PP	Department "Pulp&Paper capital systems"
ROI	Return on Investment
SBU	Strategic Business Unit
USP	Unique Selling Proposition

Bibliography

Aaker, D.A.: Strategisches Marktmanagement – Wettbewerbsvorteile erkennen, Märkte erschließen, Strategien entwickeln, Wiesbaden 1989

Belting, K.-W.;Semrau Paul-G.: Bagasse drying by flash-drier in Brazil and some theoretical considerations, in Sugar Industry 134, 2009 No.6

Bergman, P.C.A.: Combined torrefaction and pelletisation, The TOP Process, Utrecht, July 2005

Bergman, P.C.A.; Boersma, A.R.; Zwart, R.W.R; Kiel, J.H.A.: Torrefaction for biomass co-firing in existing coal-fired power stations – "Biocoal", Utrecht, July 2005

Bergman, P.C.A.; Kiel, Jacob H.A.: Torrefaction for biomass upgrading, published at 14th European Biomass Conference & Exhibition, Paris, October 17-21, 2005

Brettschuh, A.: Biogas Infomappe, Caussade Saaten, Hamburg; http://www.caussade-saaten.de/Pdf/Caussade%20Biogasinfomappe.pdf, request of 02-05- 2010

Bruhn, M.: Marketing - Grundlagen für Studium und Praxis, 2. Auflage, Wiesbaden 1995

Chryssos, G.; Maeck, K.; Geller, A.: Reststoffvermeidung und –Verwertung in der Papierindustrie, in AbfallwirtschaftsJournal 7, 1995, page 465-470, cited in: http://www.lanuv.nrw.de/abfall/bewertung/DBSpuckstoffe.pdf, Landesamt für Natur, Umwelt und Verbraucherschutz Nordrhein-Westfalen, Spuckstoffe und Papierschlämme aus der Papierindustrie, request of 14-10-2009

Deppe H.-J. & Ernst K.: Taschenbuch der Spanplattentechnik, 4. überarbeitete und erweiterte Auflage, Leinfeld-Echterdingen 2000

Döhler, H.; Schliebner, P.: Verfahren und Wirtschaftlichkeit der Gärrestaufbereitung, in: KTBL (Hrsg.): Verwertung von Wirtschafts- und Sekundärrohstoffdüngern in der Landwirtschaft – Nutzen und Risiken, page 199-212, KTBL, Darmstadt 2006

Eder, B.; Eder, J.; Gronauer, A.; Kaiser, F.; Papst, C.: Mehr Gas als aus der Gülle, in: Bayerischen Landwirtschaftlichen Wochenblatt 47, 20-11-2004, http://www.lfl.bayern.de/arbeitsschwerpunkte/as_biogas/10904/linkurl_0_2_0_2.pdf

Egger, C.; Öhlinger, C.: Key issues for wood pellet market development, OÖ Energiesparverband, Linz

Eichler, J.: Physik – Grundlagen für das Ingenieurstudium – kurz und prägnant, 3. überarbeitete und ergänzte Auflage, Wiesbaden, 2007

Eisentraut, A.: Sustainable production of second-generation biofuels – Potential and perspectives in major economies and developing countries, International Energy Agency, Paris, February 2010

Ekbert, H.; Rolf, M.; Stohrer, M.: Physik für Ingenieure, 9. Aufl., Heidelberg 2007

Fokaides, P.; Tsiftes, K.: Utilization of Olive Husk in energy sector Cyprus, Renewable Energy Sources & Energy Efficiency, September 28-30, 2007, Nicosia, Cyprus

Friedl, A.; et al.: Polygeneration Bruck/Leitha, Produktion alternativer Treibstoffe, Wärme, Strom und nichtenergetischer Produkte unter Berücksichtigung der Optimierung der Gesamtenergiebilanz sowie der Materialflüsse, Bundesministerium für Verkehr, Innovation und Technologie, Berichte aus Energie- und Umweltforschung 77/2006, Wien, September 2005

Frisch, J.: „Die kannst du echt verbrennen“ – Thermische Verwertung von Biertrebern, in Brauindustrie 10/2005, page 26-28

Führer, A; Züger, R.-M.: Projektmanagement - Management-Basiskompetenz – Theoretische Grundlagen und Methoden mit Beispielen, Repititionsfragen und Antworten, 2. und überarbeitete Auflage, Zürich 2007

Golser, M.; Pichler, W.; Hader, F.: Energieholztrocknung – Zusammenfassung des Endberichts, Forschungsbericht Holzforschung Austria, Wien, March 2005

Hasibuan, R./Daud W.R.W.: Through drying of oil palm empty fruit bunches (EFB) fibre using superheated steam, Drying 2004 – Proceedings of the 14th international drying symposium (IDS) 2004, Sao Paulo, Brazil, August 22-25, 2004

Hiegl, W.; Jansen, R.: Pellet market overview report Europe, Pellets Atlas, München 2009

Hiegl, W.; Jansen, R.: WIP Renewable Energies, Pellets Atlas, Country Report Germany, München 2009

Hofbauer, H.: Conversation technologies: Gasification overview 15th European Biomass Conference & Exhibition, 7-11 May 2007, Berlin, Germany, cited in: Kaltschmitt, M.; Hartmann, H.; Hofbauer, H.: Energie aus Biomasse – Grundlagen, Techniken und Verfahren, 2. neu bearbeitete und erweiterte Auflage, Heidelberg 2009

Hse, C.Y.; Shupe, T.F.: Presentation: Utilization of Agricultural Waste for Composite Panel, at: 6th Pacific Rim Bio-Based Composites Symposium Portland, Oregon, November 10-13, 2002

http://biofuels.abc-energy.at/demoplants/projects/mapindex, IEA Bioenergy Task 39, Commercialising 1st and 2nd generation liquid biofuels from biomass, request of 15-12-2009

http://data.un.org/Data.aspx?d=EDATA&f=cmID%3aAL%3btrID%3a01, United Nations Statistics Division, request of 15-02-2010

http://data.un.org/Data.aspx?d=EDATA&f=cmID%3aAL%3btrID%3a01, United Nations Statistics Division, request of 15-02-2010

http://data.un.org/Data.aspx?d=FAO&f=itemCode%3a1669, UN Data – United Nations statistics division/ Department of Economic and Social Affairs, request of 14-10-2009

http://data.un.org/Data.aspx?d=FAO&f=itemCode%3a1669, United Nations Statistics Division, request of 14-10-2009

http://data.un.org/Data.aspx?q=biogas&d=EDATA&f=cmID%3aBI, United Nations Statistics Division, request of 02-10-2009

http://de.wikipedia.org/wiki/Zuckerfabrik, request of 28-09-2009

http://ec.europa.eu/research/energy/pdf/biofuels_vision_2030_en.pdf, Biofuels in the European Union – A vision for 2030 and beyond, Final Report of the Biofuels Research Advisory Council, EUR 22066, European Commission, request of 08-02-2010

http://ethanol.feeco.com/Portals/0/FEECO-ethanol-brochure.pdf, Feeco International Inc., request of 15-02-2010

http://europa.eu/legislation_summaries/internal_market/single_market_for_goods/motor_vehicles/interactions_industry_policies/l28175_de.htm, request of 02-05-2010

http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor, Food and Agriculture Organisation of the United Nations, request of 28-11-2009

http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor, Food and Agricultural Organization of the United Nations, request of 23-09-2009 http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor, Food and Agricultural Organization of the United Nations, request of 24-09-2009

http://faostat.fao.org/site/636/DesktopDefault.aspx?PageID=636#ancor, Food and Agriculture Organisation of the United Nations, request of 29-09-2009

http://faostat.fao.org/site/636/DesktopDefault.aspx?PageID=636#ancor, Food and Agricultural Organization of the United Nations, request of 30-09-2009

http://idw-online.de/pages/de/news219409, Informationsdienst Wissenschaft e. V., request of 17-02-2010)

http://my.execpc.com/~drer/sgd.htm, Dr. E.A. Richards, P.E.,Energy Costs and Spent Grains Drying, request of 18-01-2010

http://wecobis.iai.fzk.de/cms/content/site/wecobis/lang/de/Spanplatte, Bundesministerium für Verkehr, Bau und Stadtentwicklung, ökologisches Baustoffinformationssystem, request of 14-09-2009

http://www.acat.com/_files/datasheets/813/SolareGaerresttrocknung.pdf, Applied chemicals International Group, request of 08-02-2010

http://www.aeroglide.com/_German/biofuels-dryers-coolers-ge.php, Aeroglide Corporation, request of 06-10-2010

http://www.aeroglide.com/_German/biofuels-dryers-coolers-ge.php, Aeroglide Corporation, request of 15-02-2010

http://www.andritz.com/de/ANONID05C8EF5F67F43E/about-us/about-company-profile.htm, Andritz AG, request of 25-03-2010

http://www.anhydro.com/content/us/industries/brewery, Andydro A/S, request of 01-02-2010

http://www.anhydro.com/media(104,1033)/Solutions_for_Bioethanol.pdf, Andydro A/S, request of 28-10-2009

http://www.barr-rosin.com/gr/index.asp, Barr Rosin Ltd / Barr Rosin Inc., request of 15-02-2010

http://www.barr-rosin.com/gr/produkte, Barr Rosin Ltd / Barr Rosin Inc., request of 16-12-2009

http://www.bio-energie.de/biogas/was-ist-biogas.html, Fachagentur Nachwachsende Rohstoffe e.V, request of 22-02-2010 http://www.biofuels-platform.ch/en/media/index.php?cat=7&id=240, 2009 Ethanol Industry Outlook, Renewable fuel association, request of 22-02-2010

http://www.biofuelstp.eu/cell_ethanol.html, European Biofuels Technology Plattform, request of 15-02-2010

http://www.biomatnet.org/publications/1859bp.pdf, TDC Olive – By-Product Resuing from olive and olive oil production, TDC-OLIVE project, FOOD-CT-2004-505524 , 2005, request of 23-02-2010

http://www.bios-bioenergy.at/de/referenzen/alle-projekte/meligalas.html, BIOS Bioenergiesysteme GmbH, request of 05-11-2009

http://www.ble.de/nn_454424/DE/01__Marktangelegenheiten/08__Marktbeobachtung/01__Zucker/Zucker__node.html?__nnn=true, Bundesanstalt für Landwirtschaft und Ernährung, request of 12-04-2010

http://www.bma-de.com/fileadmin/Templates/BMA/pdf/d/Prospekte/CSD_de_en.pdf, Braunschweigische Maschinenbauanstalt AG, request of 18-01-2010

http://www.bma-de.com/fileadmin/Templates/BMA/pdf/d/Prospekte/CSD_de_en.pdf, Braunschweigische Maschinenbauanstalt AG, request of 15-02-2010

http://www.brauunion.at/ASP/ContentScripts/htmlPage.asp?COID=6843150&CVER=DE&MOID=300224&MVER=DE&UID=182759172124112007#Haltbarmachung, Brauunion Österreich, request of 30-09-2009

http://www.britannica.com/EBchecked/topic-art/58378/70929/The-process-of-beer-production, request of 30-09-2009

http://www.buettner-dryer.com/buettner/de/, Büttner – Gesellschaft für Trocknungs- und Umwelttechnik mbH, request of 18-01-2010

http://www.buettner-dryer.com/buettner/de/, Büttner – Gesellschaft für Trocknungs- und Umwelttechnik mbH, request of 22-10-2009

http://www.cefs.org/, Comitee Europeen des Fabricants de Sucre, CEFS sugar statistics 2009, request of 27-02-2010

http://www.cropenergies.com/en/Downloads/Broschueren/RZ_CE_Magazin-0507_E.pdf, Bioethanol Report, Crop Energies AG, request of 06-10-2009

http://www.deutsche-melasse.de/Vinasse.73.0.html, Deutsche Melasse Handelsgesellschaft mbH, request of 08-02-2010 http://www.dieffenbacher.de/fileadmin/bilder/Sonstiges/Broschueren_PDFs/Holzplattentechnik/PDFs_alte_Homepage/Trommeltrockner_dt.pdf, Dieffenbacher GmbH + Co. KG, request of 18-01-2010

http://www.dorset.nu/upload/File/dorset-gm/in-de-media/Artikel_Bandtrockner_Varrel_Joule_12_07.pdf, Dorset Agrar- und Umwelttechnik GmbH, request of 08-02-2010

http://www.enplus-pellets.de/downloads/DEPI_Flyer_ENplus.pdf, Deutsches Pellet Institut, request of 03-12-2009

http://www.essent.eu/content/about_essent/news/archive/essent_trading_and_stramproy_agree_unique_bio_coal_deal.jsp, Essent EV, request of 16-10-2009

http://www.ethanolrfa.org/resource/made/, Renewable fuel association, request of 15-02-2010

http://www.haarslev.com/page473.aspx, Haarslev Industries A/S, request of 15-02-2010

http://www.handelsblatt.com/unternehmen/industrie/foerderung-die-debatte-um-biosprit-spitzt-sich-zu;2571865;2, request of 27-05-2010

http://www.holzfeuerung.ch/d/include.php?file=410, Schmid AG, request of 30-09-2009

http://www.industry.siemens.com/broschueren/pdf/paper/en/dont_throw_SIPAPER_rej_pow_en.pdf, Siemens AG, request of 16-12-2009

http://www.iwr.de/bioethanol/kapazitaeten.html, Internationales Wirtschaftsforum Regenerative Energien, request of 24-02-2010

http://www.lanuv.nrw.de/abfall/bewertung/DBSpuckstoffe.pdf, Landesamt für Natur, Umwelt und Verbraucherschutz Nordrhein-Westfalen, Spuckstoffe und Papierschlämme aus der Papierindustrie, request of 14-10-2009

http://www.l-e.de/engl_07/e_pap_neuetechno2.htm, Lang & Engelbrecht, request of 16-12-2009

http://www.niro.com/niro/CMSDoc.nsf/webdoc/ndkk5hvee2PressurizedSteamFluidBedDryer, GEA Niro, request of 18-01-2010

http://www.nolte-gmbh.de/html/roester.html, Nolte GmbH – Luft- und Umwelttechnik, request of 22-10-2009 http://www.pelletcentre.info/pelletsatlas_docs/showdoc.asp?id=090325212745&type=doc&pdf=true, Pelletatlas, Mixed Biomass Pellets Market in Europe – MBP Data Collection – results, request of 12-01-2009

http://www.pelletinfo.com/General/sweden-consumes-20-of-world-wood-pellet-production.html, request of 18-02-2010

http://www.pelletsatlas.info/cms/site.aspx?p=9138, Pelletsatlas, request of 25-02-2010

http://www.quickmba.com/strategy/pest/, Internet Center for Management and Business Administration, inc., request of 11-03-2010

http://www.riela.de/html/produkte/trocknung_schubwende.html, Riela - Karl-Heinz Knoop e. K., request of 08-02-2010

http://www.rosoma.de/de/produkte/trocknungsanlagen/haupt.html, Rosoma GmbH, request of 08-02-2010

http://www.rosroca.com/en/detalle, request of 02-10-2009

http://www.schmack-biogas.com/wDeutsch/img/gasaufbereitung_de_g.jpg, Schmack Biogas GmbH, request of 02-02-2010

http://www.srijaroengroup.com/images/cpo_pic.gif, Srijaroen Group, request of 29-11-2009

http://www.sucropedia.com/?p=entries&a=read&id=E0012, Sucropedia, Sugar Industry Enzeclopedia, request of 12-04-2010

http://www.swisscombi.ch/de/marktsegmente/holzindustrie/holzwerkstoff/, SWISS COMBI - W. Kunz dryTec AG, request of 18-01-2010

http://www.swisscombi.ch/en/marktsegmente/ethanolindustrie/, SWISS COMBI - W. Kunz dryTec AG, request of 15-02-2010

http://www.swisscombi.ch/files/downloads/de/w_kunz_drytec_ag_prospekt.pdf, COMBI - W. Kunz dryTec AG, request of 22-10-2009

http://www.timber-online.net/?id=20000,4356296,,,#popup, request of 27-02-2010, “Interview mit Dir. Werner Bechtold und Dr. Leonhard Schitter von DI (FH) Birgit Fingerlos“

http://www.torkapparater.se/pdf/ABT_5cases_060601_eng.pdf, AB Torkapparater, request of 16-12-2009 http://www.unendlich-viel-energie.de/de/biomasse/detailansicht/browse/1/article/103/die-herstellung-von-holzpellets.html, Agentur für Erneuerbare Energien e. V., request of 31-08-2009

http://www.vadeb.nl/, Vandenbroeck International, request of 16-12-2009

http://www.ventilex.net/Applications/ddgs_drying.html, Ventilex USA Inc., request of 15-02-2010

http://www.vincentcorp.com/applications/issue23.html, Vincent Corporation, request of 24-09-2009

http://www.zuckerverbaende.de/2_1_5.html, Wirtschaftliche Vereinigung Zucker / Verein der Zuckerindustrie, request of 28-10-2009

http://www.zuckerverbaende.de/2_1_6.html, Wirtschaftliche Vereinigung Zucker – Verein der Zuckerindustrie, request of 18-01-2010

http://www.zuckerverbaende.de/2_1_6.html, Wirtschaftliche Vereinigung Zucker / Verein der Zuckerindustrie, request of 28-10-2009

http://www.zuckerverbaende.de/2_3.html, Wirtschafliche Vereinigung Zucker, Verein der Zuckerindustrie, request of 13-01-2010

Hüttmann, A.: Presentation, Futterrationen und Fütterungsstrategien der Zukunft – Geflügelhaltung, Getreide AG, Vollkraft Mischfutterwerke GmbH, http://www.dlg.org/uploads/media/huetmann.pdf, Deutsche Landwirtschafts-Gesellschaft e.V., request of 08-02-2010

IEA: Energy technology perspectives to 2050, International Energy Agency, OECD/IEA, Paris; cited in: Sims, R.; Taylor, M.; Saddler, J.; Mabee, W.:, From 1st – to 2nd- Generation Biofuel Technologies – An overview of current industry and RD&D activities, International Energy Agency, Paris 2008

Junginger, M; Sikkema, R.; Faaij, A.: Analysis of the global pellet market – Including major driving forces and possible technical and non technical barriers, Pellet Atlas, Copernicus Institut, Utrecht University, February 2009

Kaltschmitt, M.; Hartmann, H.; Hofbauer, H.: Energie aus Biomasse – Grundlagen, Techniken und Verfahren,2. neu bearbeitete und erweiterte Auflage, Heidelberg, 2009

Klamroth,K.; Hackel, J.: Trockungsanlagen für die Spanplattenindustrie, Büttner-Schilde-Haas AG, Krefeld-Uerdingen 1971

Kotler, P.; Keller, K.L.; Brady, M.; Goodmann, M.; Hansen, T.: Marketing Management, London 2009

Kotler,P.; Keller,K.L.; Bliemel, F.: Marketing-Management – Strategien für wertschaffendes Handeln, 12. aktualisierte Auflage, München 2007

Kutschera, U.; Winter, B.: Stand der Technik zur Span- und Faserplattenherstellung – Beschreibung von Anlagen in Österreich und Luxemburg, Umweltbundesamt, Wien 2006

Laxhuber, T.: Professionelle Trocknung von Gärsubstrat, presentation at “Fachgespräche anlässlich der Biomasse 2009“, http://www.carmen-ev.de/dt/hintergrund/vortraege/fg_biomasse09/03_Laxhuber.pdf, request of 08-02-2010

Lin, C.Y.: Study on Effective Utilization of Palm Oil Waste (Empty Fruit Bunch) System in Malaysia, 2009

Lita, M.: Marketing Report, Biomass Processing/ Drying of Palm Oil Waste, PT Grazindo Asia Perkasa, 09-10-2009

Lootsma, A; Raussen, T.: Aktuelle Verfahren zur Aufbereitung und Verwertung von Gärresten, http://www.witzenhausen-institut.de/downloads/ks_20_lootsma.pdf, request of 02-02-2010

McKendry, P.: Energy production from biomass (part 3): Gasification technologies, Applied Environmental Research Centre, Colchester 2001

Melin, S.: Personal written communication with Martin Junginger, June 2008, Research director, Wood pellet association of Canada, cited in: Junginger, M.; Sikkema, R.; Faaj, A.: Analysis of the global pellet market,Pellets-Atlas, Utrecht, February 2009

Meyer, A.; Davidson, J.H.: Offensives Marketing: Gewinnen mit P.O.I.S.E, Märkte gestalten – Potentiale nutzen, Freiburg im Breisgau 2001

Mosen, A.: Beet-Sugar handbook, New Jersey, 2007

Moser, G. ;Pelz, D.; Zanker, G.: Präsentation: Thermische Treberverwertung, Brau-Union Österreich

N.N.: Die Andritz-Gruppe – Unternehmenspräsentation März 2010, http://www.andritz.com/de/andritz_unternehmenspraesentation_maerz_2010.pdf, request of 25-03-2010

N.N.: Finanzen und Steuern, Brauwirtschaft, 2009, Fachserie 14 Reihe 9.2.2, 10-02-2010, Wiesbaden, 2010, http://www.zoll.de/b0_zoll_und_steuern/b0_verbrauchsteuern/a0_allgemeines/e0_statistik/q_2009/biersteuer_jahresstatistik_2009.pdf, request of 18-02-2010

N.N.: IEA Energy Technology essential: Biofuel Production, International Energy Agency, January 2007

N.N.: Pellet market data 2008, Pelletsatlas, December 2009

N.N.: Pellets for small scale domestic heating systems, European Biomass Association, May 2007

N.N.: Press Release – for immediate release, wood recourses International LLC, Seattle, September 2009

N.N.: Pressemitteilung, 9. Industrieforum Pellets, Pforzheim/Stuttgart, 23.06.2009

N.N.: Torrefaction – The race to bring torrefied biomass to the market, in: Forest Energy Monitor, Volume 1, Issue 3, September, 2009

N.N.: Torrefaction – Torrefaction update – EBES AG develops its “accelerated carbonised biomass (ACB)” Technology, in: Forest Energy Monitor, Volume 1, Issue 4, November, 2009a

Nagl, A.: Der Businessplan – Geschäftsfälle professionell erstellen – Mit Checklisten und Fallbeispielen, 4. überarbeitete und erweiterte Auflage, Wiesbaden 2009

OECD/IEA: Energy Technology Perspectives 2006 – Scenarios & Strategies to 2050, Paris, 2006

Oreopoulou, V.; Russ W.: Utilization of By-Products and Treatment of Waste in the Food Industry, 3. reprint, 2007

Paxmann, A.; Fuchs, G.: Der unternehmensinterne Businessplan – Neue Geschäftsmöglichkeiten entdecken, präsentieren, durchsetzen, Frankfurt/Main 2005

Pepels, W.: Business to Business Marketing - Handbuch für Vertrieb, Technik, Service, Neuwied/Kriftel 1999

Porter, M.: Wettbewerbsvorteile, Spitzenleistungen erreichen und behaupten, Frankfurt/New York 2000

Romero, J.M.A.: Project IMPROLIVE (FAIR CT96-1420), final report, annex A2, February 2000

Scarmucci, J.A.;Perin, C.;Pulino, P.; Bordoni, O.F.J.G.; da Cunha, M.P.: Energy from sugarcane bagasse under electricity rationing in brazil: A computable general equilibrium model

Schmitt, J.-P.: Global Market Report – Wood panels, Innomis – Market Intelligence Solutions, 27-07-2009

Schwetje, G.; Vaseghi, S.: Der Businessplan – Wie Sie Kapitalgeber überzeugen, Heidelberg 2006

Shahrakbah, Y.: Presentation: Progress & challenges in utilization of palm biomass, Advanced agriecological research SDN. BHD, http://www.jst.go.jp/asts/asts_j/files/ppt/15_ppt.pdf, request of 01-02-2010

Singler, A.: Businessplan, 2. Auflage, München 2008

Steiner, M.; Pichler, W.: Holzforschung Austria, Pellets Atlas, Country Report Austria, Wien 2009

Stocker, A.O.; Dorizzi,F.: Der Businessplan – Nur wer sein Ziel kennt, findet den Weg, in KMU-Magazin, Nr. 4, May 2005

Stölken, B.; Michel, V.; Pienz, G.: Bioenergie aus der Landwirtschaft – eine neue Herausforderung für das regionale Sortenwesen – III. Getreide für die Ethanolproduktion, Gülzow, 15. December 2006; http://www.info-agrarportal.de/var/plain_site/storage/original/application/38cd54f2027414ce7702c0cd74eaf62a.pdf, request of 25-05-2010

Trend research: Markt für Biogasanlagen in Europa bis 2020, cited in: http://www.ask-eu.de/default.asp?SHOWNEWS=3403&LANG=SPA&lang=DEU, “Access to sustainable knowledge”, request of 05-10-2009

van Dam,J.; Elbersen,W.: Palm oil production for oil and biomass: the solution for sustainable oil production and certifiably sustainable biomass production?, November 2004, http://www.riaed.net/IMG/pdf/Palmoil_byproducts_wastes.pdf, request of 01-02-2010

van Loo,S.; Koppejan,J.: The handbook of biomass combustion & co-firing, Stirling, 2009

VDI, Biogas – Energieträger der Zukunft, VDI-Bericht 1872, Düsseldorf, 2005

von Weizsäcker,D.G.; Breyer, F.; Schnitzer, M.: Brief an den Bundesminister für Wirtschaft und Technologie, Berlin, 05-12-2008

Voß, C.;Wieting, J.:, Presentation at “Energy Efficiency in IPPC installations”: Innovative examples of energy efficiency in the German sugar industry -dewatering and drying process for sugar beet pulp, Vienna, October 21-22, 2004

Wagner,R.: Allgemeine Möglichkeiten der Gärresteverwertung – Technik und Recht, presentation at: Fachkongress Alternative Rohstoffe für Bioenergie, http://www.carmen-ev.de/dt/portrait/sonstiges/biokraftstoffkongress08/08_Wagner_CARMEN.pdf, Rosenheim, 07-11-2008

Wang, L.: Energy Efficiency and Management in Food Processing Facilities, Boca Raton 2009

Wild, M.: The pellets market in Europe status 2008, targets for the future, new approaches, presentation at “European pellets roadmap up to 2020” Workshop”, Vienna, 26-06-2008

Appendix 1: Wood Pellet Industry

The following calculations are based on the data stated in chapter 6.1.

Installed capacity, production and consumption of wood pellets, Europe, 2001-2008:

Table 20 shows data regarding consumption, production and installed production capacity for wood pellets in Europe. Data are given in million tons pellets per year.

Consumption: million [tons/year]

	Austria	Belgium	Bulgaria	Czech Republic	Denmark	Estonia	Finland	France	Germany	Greece	Hungary	Ireland	Italy	Latvia	Lithuania	Nether-lands	Norway	Poland	Romania	Slovakia	Slovenia	Spain	Sweden	Switzer-land	United Kingdom	sum
2001	0,085				0,408		0,011		0,024				0,150										0,906			1,58
2002	0,122				0,451		0,240		0,067				0,160			0,150							0,902			2,09
2003	0,166				0,562		0,033		0,120				0,210			0,200	0,015	0,001					1,129	0,015		2,45
2004	0,220				0,731		0,047		0,180				0,230			0,225	0,022	0,006					1,256	0,024		2,94
2005	0,303				0,818		0,059		0,330				0,290			0,487	0,019	0,025					1,490	0,041		3,86
2006	0,400				0,892		0,100	0,090	0,480				0,380			0,486	0,030	0,035					1,685	0,085		4,66
2007	0,330	0,730			0,993		0,118	0,130	0,550	0,001		0,005	0,630			0,705	0,032					0,004	1,715	0,090		6,03
2008	0,513	0,920	0,003	0,017	1,060	0,003	0,150	0,200	0,900	0,001	0,001	0,030	0,850	0,039	0,020	0,914	0,040	0,120	0,025	0,018	0,112	0,010	1,850	0,090	0,176	8,06

Production: million [tons/year]

	Austria	Belgium	Bulgaria	Czech Republic	Denmark	Estonia	Finland	France	Germany	Greece	Hungary	Ireland	Italy	Latvia	Lithuania	Nether-lands	Norway	Poland	Romania	Slovakia	Slovenia	Spain	Sweden	Switzer-land	United Kingdom	sum
2001	0,1000				0,1730				0,0060														0,7800			1,06
2002	0,1640				0,1680				0,0210														0,7650			1,12
2003	0,2250				0,1770				0,0730				0,1600				0,0200	0,0200					0,8700			1,55
2004	0,3240				0,1870			0,0230	0,1270				0,1980				0,0340	0,1200					0,9500			1,96
2005	0,4430				0,1870			0,0710	0,2550				0,2400			0,1100	0,0420	0,2000					1,1000			2,65
2006	0,6170				0,1370			0,1210	0,4700				0,3000			0,1100	0,0510	0,2800				0,0300	1,4580			3,57
2007	0,6950			0,0270	0,1490	0,3830		0,1900	1,1000	0,0790	0,0120	0,0150	0,5220	0,1300		0,1080	0,0450	0,3290	0,1080	0,1000	0,1150	0,0950	1,4000	0,0390	0,1300	5,77
2008	0,6260	0,3250	0,0270	0,1700	0,1340	0,3380	0,3730	0,2400	1,4600	0,0280	0,0050	0,0170	0,6500	0,3790	0,1200	0,1200	0,0350	0,3400	0,1150	0,1170	0,1540	0,1000	1,4050	0,0700	0,1250	7,47

Production capacity: million [tons/year]

	Austria	Belgium	Bulgaria	Czech Republic	Denmark	Estonia	Finland	France	Germany	Greece	Hungary	Ireland	Italy	Latvia	Lithuania	Nether-lands	Norway	Poland	Romania	Slovakia	Slovenia	Spain	Sweden	Switzer-land	United Kingdom	sum
2001					0,3000				0,0230							0,1000										0,42
2002			0,0010		0,3000				0,0720							0,1000										0,47
2003					0,3000				0,1230				0,1600			0,1000										0,68
2004			0,0030		0,3000	0,2700	0,4500		0,1750				0,2000			0,1000	0,0950	0,2550	0,0300				1,2520	0,0400		3,17
2005	0,4900	0,0150	0,0040		0,4000	0,3000	0,4500		0,3850				0,2000			0,1100	0,0990	0,3000					1,4000	0,0500		4,20
2006	0,6170	0,0600			0,3700	0,3800	0,5600		0,9000				0,3000		0,1200	0,1250	0,1210	0,4160		0,0800		0,0750	1,7160	0,0800		5,92
2007	0,9000	0,2150		0,1180	0,3700	0,4380			2,0000	0,0770	0,0150	0,0700	0,7000	0,5400	0,1200	0,1250	0,1350	0,5450	0,2140		0,1650	0,1600	2,0320	0,1090	0,1760	9,22
2008	1,0060	0,4500	0,0620	0,2600	0,1310	0,4850	0,6800	0,3500	2,4000	0,0870	0,0050	0,0780	0,7500	0,7440	0,1520	0,1300	0,1640	0,6740	0,2600	0,1420	0,1850	0,2500	2,2000	0,1710	0,2180	12,03

Table 20: Installed capacity, production and consumption of wood pellets, Europe, 2001-2008[532]

Installed capacity, production and consumption of wood pellets, North America 2000-2010:

Table 21 shows data regarding consumption, production and installed production capacity for wood pellets in North America which are illustrated in Figure 84, 84 and 85. Data are given in million tons of pellets per year.

[532] Own presentation and calculation; http://www.pelletsatlas.info (25.02.2010)

	CANADA			USA			SUM NA		
	Capacity	Production	Consumption	Capacity	Production	Consumption	Capacity	Production	Consumption
	million [tons/year]			million [tons/year]			million [tons/year]		
2000	0,48	0,25	0,05	0,60	0,55	0,75	1,08	0,80	0,80
2001	0,60	0,30	0,08	0,78	0,65	0,80	1,38	0,95	0,88
2002	0,70	0,60	0,10	0,78	0,75	0,85	1,48	1,35	0,95
2003	0,72	0,65	0,10	0,78	0,75	0,90	1,50	1,40	1,00
2004	0,75	0,70	0,10	0,90	0,80	1,00	1,65	1,50	1,10
2005	0,95	0,90	0,08	1,05	0,95	1,20	2,00	1,85	1,28
2006	1,20	1,10	0,20	1,25	1,05	1,40	2,45	2,15	1,60
2007	1,90	1,75	0,18	1,85	1,55	1,80	3,75	3,30	1,98
2008	2,75	2,40	0,30	2,15	2,00	2,10	4,90	4,40	2,40
2009	3,75	3,60	0,35	2,70	2,50	2,40	6,45	6,10	2,75
2010	5,00	4,70	0,35	3,30	3,00	2,80	8,30	7,70	3,15

Growth:	CANADA			USA			SUM NA		
	Capacity	Production	Consumption	Capacity	Production	Consumption	Capacity	Production	Consumption
2001	25%	20%	60%	30%	18%	7%	28%	19%	10%
2002	17%	100%	25%	0%	15%	6%	7%	42%	8%
2003	3%	8%	0%	0%	0%	6%	1%	4%	5%
2004	4%	8%	0%	15%	7%	11%	10%	7%	10%
2005	27%	29%	-20%	17%	19%	20%	21%	23%	16%
2006	26%	22%	150%	19%	11%	17%	23%	16%	25%
2007	58%	59%	-10%	48%	48%	29%	53%	53%	24%
2008	45%	37%	67%	16%	29%	17%	31%	33%	21%
2009	36%	50%	17%	26%	25%	14%	32%	39%	15%
2010	33%	31%	0%	22%	20%	17%	29%	26%	15%
CAGR 2000-2010:	26%	34%	21%	19%	18%	14%	23%	25%	15%

Prediction

Table 21: Installed capacity, production and consumption of wood pellets, North America 2000-2010[533]

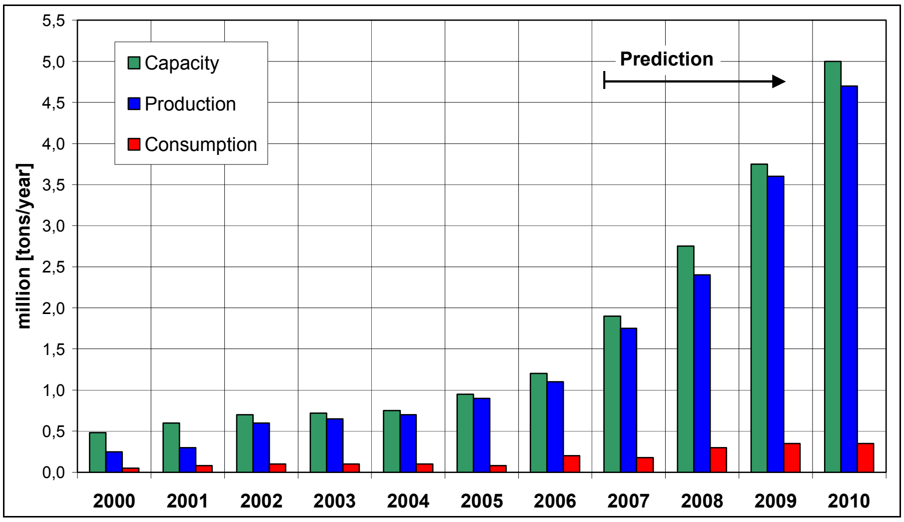


Figure 84: Pellet market Canada, 2000-2010[534]

[533] Own presentation and calculation; Melin (2008)

[534] Own presentation, Melin (2008)

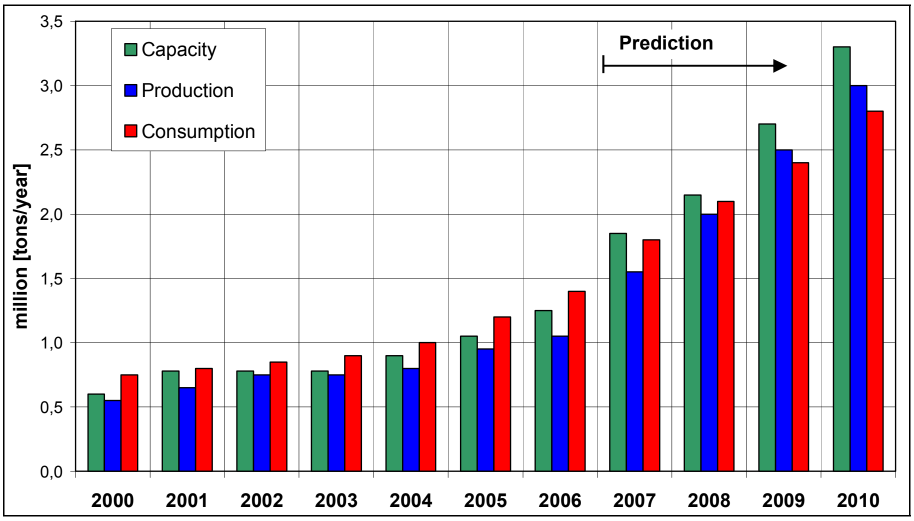


Figure 85: Pellet market USA, 2000-2010[535]

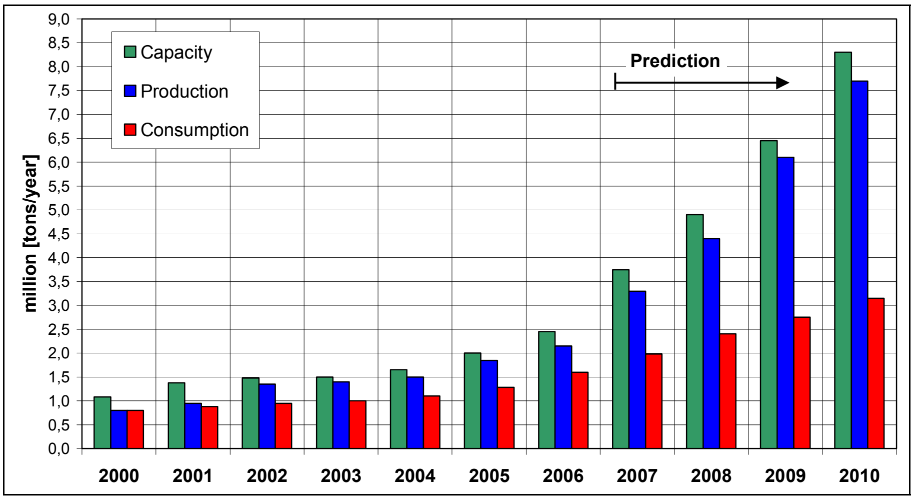


Figure 86: Pellet market North America, 2000-2010[536]

[535] Own presentation, Melin (2008)

[536] ibidem

Installed capacity, production and consumption of wood pellets, global, 2001-2008:

Table 22 gives an overview of global installed production capacity, production and consumption of pellets including Europe, North America and Russia (2008 only).

	Global					
	capacity million [tons/year]	growth	production million [tons/year]	growth	consumption million [tons/year]	growth
2001	1,80		2,01		2,46	
2002	1,95	8%	2,47	23%	3,04	23%
2003	2,18	12%	2,95	19%	3,45	13%
2004	4,82	121%	3,46	18%	4,04	17%
2005	6,20	29%	4,50	30%	5,14	27%
2006	8,37	35%	5,72	27%	6,26	22%
2007	14,17	69%	9,62	68%	8,10	29%
2008	18,13	28%	12,52	30%	10,59	31%
	CAGR: 2001-2008:	39%		30%		23%

Table 22: Global wood pellet production capacity, production and consumption, 2001-2008[537]

Estimation of installed evaporation capacity, global, 2008:

Table 23 show an estimation of the global installed evaporation capacity in the wood pellet industry in the year 2008.

Feed Product:	Moisture content:	50%	[%]
	production capacity:		[tons/year]
Endproduct:	Moisture content:	10%	[%]
	production capacity:	18.130.000	[tons/year]
	DS	16.317.000	[tons/year]
	Operating time:	8.000	[hours/year]
Evaporation capacity:	evaporation capacity per year	14.504.000	[tons H2O/year]
	evaporation capacity per hour	**1.813**	[tons H_2O/hour]

Table 23: Estimation of installed evaporation capacity, global 2008[538]

537 Own presentation and calculation; Junginger/Sikkema/Faaij (2009), page 4; N.N. (Dec. 2009), page 2

538 Own presentation and calculation

Estimation of possible future market volume, pellet industry, 2010-2015:

Table 24 shows the estimation of possible market volume for the next five years taking into account the following assumptions:

- MC feed product: 50%
- MC end product: 10%
- Operating time: 8000 [hours]
- Future annual growth of industry: 15%
- 2009: slow down of economy – market consolidation, no growth
- All new facilities are implementing drying applications
- 3% of existing facilities are renewing drying applications

	New installed evaporation capacities in new facilities:	Renewed evaporation capacities in existing facilities:	Sum of new installed evaporation capacities
2010	263	60	323
2011	302	69	372
2012	347	80	427
2013	399	92	491
2014	459	106	565
2015	528	122	650

Table 24: Estimation of possible future market volume, pellet industry, 2010-2015[539]

[539] Own presentation and calculation

Appendix 2: Panel Board Industry

The following calculations are based on the data stated in chapter 6.2.

Estimation of typical throughputs:

Table 25 shows the estimation for typical throughputs in panel board industry by taking into account following assumptions:

- MC raw material: 50%
- MC of dried material: 3%
- Operating time of facility: 8000 [hours]
- Density of panel board: 0,65 [tons/m³]
- Wood content of panel board: 90%

capacity/year [m³]	evaporation [tons H2O/hour]	number of plants
>1050000	>72	1
950.000 - 1.050.000	65-72	4
850.000 - 950.000	58-65	1
750.000 - 850.000	52-58	6
650.000 - 750.000	45-52	13
550.000 - 650.000	38-45	26
450.000 - 550.000	31-38	37
350.000 - 450.000	24-31	65
250.000 - 350.000	17-24	80
150.000 - 250.000	10-17	148
50000 - 150.000	3-10	314
0 - 50.000	0-3	271

Table 25: Estimation of typical throughput, panel board industry[540]

[540] Own presentation and calculation; Schmitt (2009)

Market data and market development of wooden materials, global:

Table 26 shows the global market data of wooden materials and its development from 2000 to 2007. Data are given in thousand [m³].

	1=6+12	2=3+4	3	4	5=6+12	6=7+8+11	7	8	9	10	11	12
	Primary wood products	**Sawn wood**	**Sawn wood NC**	**Sawn wood C**	**Panels and veneers**	**Wood panels**	**Particelboard**	**Fibreboard**	**MDF**	**oth. Fibreboard**	**Plywood**	**Veneers**
	production [1000 m³]	production [1000 m³]	production [1000 m³]	production [1000 m³]	production [1000 m³]	production [1000 m³]	production [1000 m³]	production [1000 m³]	production [1000 m³]	production [1000 m³]	production [1000 m³]	production [1000 m³]
2000	570.800	385.681	106.111	279.571	185.119	177.135	84.985	34.099	19.046	15.052	58.051	7.984
2001	561.703	379.494	101.894	277.601	182.209	173.950	83.893	35.596	23.617	11.978	54.461	8.259
2002	588.355	393.825	100.024	293.801	194.530	186.142	85.799	41.143	27.543	13.600	59.201	8.388
2003	618.007	440.443	100.266	300.177	217.564	208.774	92.069	48.010	33.828	14.182	68.695	8.790
2004	625.528	420.404	101.274	319.129	232.124	222.750	98.431	55.755	40.845	14.911	68.564	9.374
2005	663.610	425.209	101.192	324.017	238.401	228.166	101.304	57.858	42.481	15.376	69.004	10.235
2006	700.521	439.002	111.378	327.624	261.519	250.022	106.443	69.921	52.205	17.715	73.658	11.497
2007	696.427	430.447	112.235	318.212	265.980	254.597	106.132	72.394	55.573	16.822	76.070	11.383
	consumption [1000 m³]	consumption [1000 m³]	consumption [1000 m³]	consumption [1000 m³]	consumption [1000 m³]	consumption [1000 m³]	consumption [1000 m³]	consumption [1000 m³]	consumption [1000 m³]	consumption [1000 m³]	consumption [1000 m³]	consumption [1000 m³]
2000	575.352	387.887	109.728	278.159	187.465	179.464	83.748	36.943	19.310	17.633	58.773	8.001
2001	562.460	380.290	104.895	275.395	182.169	173.820	83.277	36.327	22.246	14.081	54.216	8.349
2002	586.443	391.862	103.008	288.855	194.581	186.149	85.530	41.511	25.631	15.880	59.108	8.432
2003	614.390	395.880	102.648	293.233	218.509	209.657	91.670	49.254	32.496	16.757	68.733	8.853
2004	653.306	419.979	103.894	316.085	233.326	223.963	98.226	57.338	39.996	17.342	68.298	9.464
2005	661.720	421.453	103.911	317.542	240.267	230.360	101.007	60.132	41.238	18.894	69.221	9.908
2006	687.993	431.568	112.921	318.646	256.425	245.326	105.003	69.771	52.227	17.544	70.553	11.099
2007	679.271	431.568	112.741	310.094	256.436	245.088	103.327	70.736	52.853	17.883	71.026	11.348
	growth production [%]	growth production [%]	growth production [%]	growth production [%]	growth production [%]	growth production [%]	growth production [%]	growth production [%]	growth production [%]	growth production [%]	growth production [%]	growth production [%]
2001	-1,6	-1,6	-4,0	-0,7	-1,6	-1,8	-1,3	4,4	24,0	-20,4	-6,2	3,4
2002	4,7	3,8	-1,8	5,8	6,8	7,0	2,3	15,6	16,6	13,5	8,7	1,6
2003	5,0	11,8	0,2	2,2	11,8	12,2	7,3	16,7	22,8	4,3	16,0	4,8
2004	1,2	-4,5	1,0	6,3	6,7	6,7	6,9	16,1	20,7	5,1	-0,2	6,6
2005	6,1	1,1	-0,1	1,5	2,7	2,4	2,9	3,8	4,0	3,1	0,6	9,2
2006	5,6	3,2	10,1	1,1	9,7	9,6	5,1	20,8	22,9	15,2	6,7	12,3
2007	-0,6	-1,9	0,8	-2,9	1,7	1,8	-0,3	3,5	6,5	-5,0	3,3	-1,0
CAGR	2,9	1,6	0,8	1,9	5,3	5,3	3,2	11,4	16,5	1,6	3,9	5,2
	growth consumption [%]	growth consumption [%]	growth consumption [%]	growth consumption [%]	growth consumption [%]	growth consumption [%]	growth consumption [%]	growth consumption [%]	growth consumption [%]	growth consumption [%]	growth consumption [%]	growth consumption [%]
2001	-2,2	-2,0	-4,4	-1,0	-2,8	-3,1	-0,6	-1,7	15,2	-20,1	-7,8	4,3
2002	4,3	3,0	-1,8	4,9	6,8	7,1	2,7	14,3	15,2	12,8	9,0	1,0
2003	4,8	1,0	-0,3	1,5	12,3	12,6	7,2	18,7	26,8	5,5	16,3	5,0
2004	6,3	6,1	1,2	7,8	6,8	6,8	7,2	16,4	23,1	3,5	-0,6	6,9
2005	1,3	0,4	0,0	0,5	3,0	2,9	2,8	4,9	3,1	8,9	1,4	4,7
2006	4,0	2,4	8,7	0,3	6,7	6,5	4,0	16,0	26,6	-7,1	1,9	12,0
2007	-1,3	0,0	-0,2	-2,7	0,0	-0,1	-1,6	1,4	1,2	1,9	0,7	2,2
CAGR	2,4	1,5	0,4	1,6	4,6	4,6	3,0	9,7	15,5	0,2	2,7	5,1

Table 26: Market data and market development, wooden materials, 2000-2007[541]

[541] Own presentation and calculation; Schmitt (2009)

Production of wood panels + MDF, 2000-2007:

Table 27 shows the production quantity of wood panels and MDF boards for Asia, America, Europe, Oceania, Africa, and global. Data are given thousand [m³].

	Asia:	America:	Europe:	Oceania:	Africa:	Global:
	Wood panels + MDF production [1000 m³]	Wood panels + MDF production [1000 m³]	Wood panels + MDF production [1000 m³]	Wood panels + MDF production [1000 m³]	Wood panels + MDF production [1000 m³]	Wood panels + MDF production [1000 m³]
2000	50465	72597	67495	4287	1336	196180
2001	54489	68126	68767	7392	1793	200567
2002	63318	71290	72484	7694	1899	216685
2003	83904	75629	76111	5092	1837	242573
2004	93803	80362	82291	5199	1940	263595
2005	96587	81596	85836	5075	1553	270647
2006	121690	83093	90416	5208	1820	302227
2007	130353	77295	95937	4782	1802	310169

Table 27: Production of wood panels + MDF, 2000-2007[542]

Estimation of installed evaporation capacity:

Table 28 shows an estimation of the installed evaporation capacity in panel board and MDF industry in the year 2007 by taking into account the following assumptions which are given in the table.

				source/comment:
Feed Product:	Moisture content:	[%]	50%	
Endproduct:	Moisture content:	[%]	3%	
	Production capacity: wood panels	[tm³/year]	254.597.000	density: 0,625 [tons/m³]
		[tons/year]	159.123.125	
	Production capacity: MDF	[tm³/year]	55.573.000	density: 0,75 [tons/m³]
		[tons/year]	41.679.750	
	Production capacity: wood panel + MDF	[tons/year]	200.802.875	
	Wood content of wood panels/MDF		90%	
	DS	[tons/year]	175.300.910	
Facility:	Operating time:	[hours/year]	8.000	
Evaporation:	Evaporation capacity per year	[tons H2O/year]	169.879.232	
	Evaporation capacity per hour	[tons H_2O/hour]	21.235	

Table 28: Estimation of installed evaporation capacity, wood panel and MDF industry, 2007[543]

542 Own presentation and calculation; Schmitt (2009)

543 Own presentation and calculation

Production of wood panels, 2000-2007:

Table 29 shows the production quantity of wood panels from 2000 to 2007 of the top 20 producing countries of the world. Data are given in [m³]. Table 30 shows the annual growth rates and the CAGR from 2000 to 2007 of wood panel production quantity of the top 20 producing countries.

	2000	2001	2002	2003	2004	2005	2006	2007	
Austria	2.341.500	2.996.000	3.397.000	3.396.000	3.396.000	3.430.000	3.584.000	3.693.000	
Belgium	2.771.000	2.595.000	2.860.000	2.650.000	2.601.000	2.765.000	2.545.000	2.510.000	
Brazil	5.183.000	5.537.524	6.053.986	7.006.005	7.893.159	7.929.000	7.838.000	8.060.000	
Canada	14.440.440	14.671.000	15.393.000	15.791.000	15.759.000	16.701.000	16.733.000	14.045.000	
Chile	1.090.000	1.255.000	1.479.000	1.678.000	1.848.000	2.041.000	2.462.000	2.426.000	
China	17.937.000	18.175.000	22.613.000	37.710.000	42.718.000	42.718.000	61.317.000	67.800.700	
France	5.387.000	5.348.000	5.334.000	5.505.000	6.085.000	6.325.000	6.581.000	6.629.000	
Germany	13.671.500	13.140.000	13.301.000	14.258.000	15.958.000	16.700.000	17.008.000	17.793.000	
India	334.000	590.000	1.734.800	1.900.000	2.082.600	2.283.200	2.283.200	2.283.200	
Indonesia	8.827.000	8.024.000	8.274.000	6.835.000	5.238.000	5.086.000	4.364.000	4.006.000	
Italy	4.975.000	4.988.000	5.120.000	4.861.000	5.196.000	5.071.000	5.270.000	5.231.000	
Japan	5.477.000	4.972.000	4.833.000	5.124.000	5.228.000	5.320.000	5.454.000	5.253.000	
Korea Republic	2.482.000	2.543.000	2.849.000	3.006.000	3.244.000	3.186.000	2.938.000	3.225.000	
Malaysia	4.671.000	6.076.000	6.088.000	7.137.000	7.457.000	8.241.000	8.275.000	7.097.000	
Poland	4.557.200	4.530.000	4.822.000	5.754.000	6.384.000	6.627.000	7.284.100	8.445.335	
Russian Federation	4.709.000	5.092.000	5.605.000	6.264.000	7.042.000	7.782.000	8.783.000	9.647.000	
Spain	4.598.000	4.763.000	4.950.000	4.730.000	4.866.000	4.978.000	5.082.000	5.330.000	
Turkey	2.353.000	2.085.000	2.654.000	3.131.000	3.763.000	4.696.000	4.905.000	5.364.000	
United Kingdom	3.275.000	3.255.000	3.217.000	3.361.000	3.533.000	3.398.000	3.498.000	3.549.000	
United States	45.423.000	39.895.607	40.649.713	42.338.260	44.114.255	44.389.051	43.958.721	40.691.104	
SUM								223.080.346	88% of global production
								254.596.597	100% of global production

Table 29: Production of wood panels, 2000-2007[544]

	2001	2002	2003	2004	2005	2006	2007	CAGR
Austria	28,0%	13,4%	0,0%	0,0%	1,0%	4,5%	3,0%	6,7%
Belgium	-6,4%	10,2%	-7,3%	-1,8%	6,3%	-8,0%	-1,4%	-1,4%
Brazil	6,8%	9,3%	15,7%	12,7%	0,5%	-1,1%	2,8%	6,5%
Canada	1,6%	4,9%	2,6%	-0,2%	6,0%	0,2%	-16,1%	-0,4%
Chile	15,1%	17,8%	13,5%	10,1%	10,4%	20,6%	-1,5%	12,1%
China	1,3%	24,4%	66,8%	13,3%	0,0%	43,5%	10,6%	20,9%
France	-0,7%	-0,3%	3,2%	10,5%	3,9%	4,0%	0,7%	3,0%
Germany	-3,9%	1,2%	7,2%	11,9%	4,6%	1,8%	4,6%	3,8%
India	76,6%	194,0%	9,5%	9,6%	9,6%	0,0%	0,0%	31,6%
Indonesia	-9,1%	3,1%	-17,4%	-23,4%	-2,9%	-14,2%	-8,2%	-10,7%
Italy	0,3%	2,6%	-5,1%	6,9%	-2,4%	3,9%	-0,7%	0,7%
Japan	-9,2%	-2,8%	6,0%	2,0%	1,8%	2,5%	-3,7%	-0,6%
Korea Republic	2,5%	12,0%	5,5%	7,9%	-1,8%	-7,8%	9,8%	3,8%
Malaysia	30,1%	0,2%	17,2%	4,5%	10,5%	0,4%	-14,2%	6,2%
Poland	-0,6%	6,4%	19,3%	10,9%	3,8%	9,9%	15,9%	9,2%
Russian Federation	8,1%	10,1%	11,8%	12,4%	10,5%	12,9%	9,8%	10,8%
Spain	3,6%	3,9%	-4,4%	2,9%	2,3%	2,1%	4,9%	2,1%
Turkey	-11,4%	27,3%	18,0%	20,2%	24,8%	4,5%	9,4%	12,5%
United Kingdom	-0,6%	-1,2%	4,5%	5,1%	-3,8%	2,9%	1,5%	1,2%
United States	-12,2%	1,9%	4,2%	4,2%	0,6%	-1,0%	-7,4%	-1,6%

Table 30: Growth of wood panel production, 2000-2007[545]

[544] Own presentation and calculation; Schmitt (2009)

[545] Own presentation and calculation

Estimation of future market volume, 2010-2015:

Table 31 shows the estimation of the possible market volume for the next five years taking into account the following assumptions:

- MC of raw material: 50%
- MC of dried material: 3%
- Operating time: 8.000 [hours]
- Potential of new installed capacities:
    - 100% of new facilities are implementing drying applications
    - 5% of existing facilities are implementing new drying applications
- Assumed initial development:
    - 2009/2010: negative influence of economic crisis, no growth, no investment
    - 2011: upturn to 25% of growth before EC, 2012: 50%, 2013: 75%, following years: 100% of growth before EC

	Asia:	America:	Europe:	Oceania:	Africa:	Global:
	new installed evaporation capacity [tons H2O/h]	new installed evaporation capacity [tons H2O/h]	new installed evaporation capacity [tons H2O/h]	new installed evaporation capacity [tons H2O/h]	new installed evaporation capacity [tons H2O/h]	new installed evaporation capacity [tons H2O/h]
2010	0	0	0	0	0	**0**
2011	347	12	90	1	1	**451**
2012	719	24	182	3	3	**930**
2013	1157	36	280	4	4	**1481**
2014	1710	48	388	5	6	**2157**
2015	1958	49	408	5	6	**2426**

	Asia:	America:	Europe:	Oceania:	Africa:	Global:
	replaced evaporation capacity [tons H2O/h]	replaced evaporation capacity [tons H2O/h]	replaced evaporation capacity [tons H2O/h]	replaced evaporation capacity [tons H2O/h]	replaced evaporation capacity [tons H2O/h]	replaced evaporation capacity [tons H2O/h]
2010	0	0	0	0	0	0
2011	478	266	349	16	6	1115
2012	495	266	353	16	6	1137
2013	531	267	362	17	6	1184
2014	589	269	376	17	7	1258
2015	674	272	396	17	7	1366

Table 31: Estimation of future market volume, wood panel industry, 2010-2015[546]

[546] Own presentation and calculation

Appendix 3: Pulp and Paper Industry

The following calculations are based on the data stated in chapter 6.3.

Estimation of typical throughput:

Table 32 shows an estimation of the typical throughput in pulp and paper industry by taking into account the following assumptions which are given in the table.

estimations:	Rejects (DM) of recovered paper:	6,7%	
	Deeiking sludge (DM) of recovered paper:	13%	
	Sewage sludge (DM) of recovered paper:	13%	
	MC of residues before drying:	50%	
	MC of dried residues:	10%	
	Operating time:	7.920	[hours]
	averaged mill size europe:	1.980	[tons/year]
calculations:	Rejects (DM)	4.045.944	[tons/year]
	Reject per year and mill	13.266	[tons/year]
	Reject per day and mill	40,20	[tons/day]
	Reject per hour and mill	1,68	[tons/hour]
	Evaporation	1,49	[tons H_2O/hour]
	Deinkingsludge (DeInkS)	8.091.887	[tons/year]
	DeInkS per year and mill	26.532	[tons/year]
	DeInkS per day and mill	80,40	[tons/day]
	DeInkS per hour and mill	3,35	[tons/hour]
	Evaporation	2,98	[tons H_2O/hour]
	Sewage sludge (SS)	8.091.887	[tons/year]
	SS per year and mill	26.532	[tons/year]
	SS per day and mill	80,40	[tons/day]
	SS per hour and mill	3,35	[tons/hour]
	Evaporation	2,98	[tons H_2O/hour]

Table 32: Estimation of typical throughput, pulp and paper industry, Europe[547]

Production of recovered paper, 2000-2007:

Table 33 shows data of production quantity of recovered paper from 2000 to 2007 - data are given in [tons].

Recovered Paper: Production Quantity [tons]	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Asia	43.236.152	46.632.198	48.964.559	51.781.823	54.739.300	57.550.016	63.551.168	69.202.603
Europe	43.991.709	44.809.515	46.841.330	48.375.651	51.950.471	55.131.906	58.358.075	60.387.219
Northern America	44.848.000	42.690.397	43.074.980	45.733.995	46.776.543	47.757.747	49.453.033	49.282.473
South America	4.455.000	4.446.000	4.489.000	4.703.000	4.772.700	5.496.700	5.919.000	6.103.000
Oceania	1.732.000	1.825.000	1.834.000	2.126.000	2.422.000	2.642.000	3.242.000	3.254.000
Africa	1.166.700	1.183.700	1.183.700	1.516.700	1.516.700	1.516.700	1.516.700	1.516.700
Others	1.097.000	1.097.000	1.097.000	1.097.000	1.097.000	1.097.000	4.497.000	4.497.000
Global	140.526.561	142.683.810	147.484.569	155.334.169	163.274.714	171.192.069	186.536.976	194.242.995

Table 33: Production of recovered paper [tons], 2000-2007[548]

547 Own presentation and calculation; http://www.lanuv.nrw.de (14.10.2009); AAG, PP

548 Own presentation and calculation; http://data.un.org (14.10.2009)

Table 34 shows the annual growth rates and the CAGR from 2000 to 2007 of the production of recovered paper.

Growth: recovered paper, production

	2001	2002	2003	2004	2005	2006	2007	CAGR 2000-2007
Asia	8%	5%	6%	6%	5%	10%	9%	7%
Europe	2%	5%	3%	7%	6%	6%	3%	5%
Northern America	-5%	1%	6%	2%	2%	4%	0%	1%
South America	0%	1%	5%	1%	15%	8%	3%	5%
Oceania	5%	0%	16%	14%	9%	23%	0%	9%
Africa	1%	0%	28%	0%	0%	0%	0%	4%
Others	0%	0%	0%	0%	0%	310%	0%	22%
World	2%	3%	5%	5%	5%	9%	4%	5%

Table 34: Growth of production of recovered paper, 2000-2007[549]

Estimation of theoretical evaporation capacity:

Table 35 shows the estimated theoretical evaporation capacity. The assumptions for calculation are the same as stated in Table 32. The theoretical evaporation capacity means the evaporation capacity in case of drying of all residues out of processing of recovered paper.

	2000	2001	2002	2003	2004	2005	2006	2007
Asia	1.587	1.711	1.797	1.900	2.009	2.112	2.332	2.540
Europe	1.615	1.645	1.719	1.775	1.907	2.023	2.142	2.216
Northern America	1.646	1.567	1.581	1.678	1.717	1.753	1.815	1.809
South America	164	163	165	173	175	202	217	224
Oceania	64	67	67	78	89	97	119	119
Africa	43	43	43	56	56	56	56	56
Others	40	40	40	40	40	40	165	165
World	5.157	5.237	5.413	5.701	5.992	6.283	6.846	7.129

Table 35: Estimation of theoretical evaporation capacity, pulp and paper industry, 2000-2007[550]

549 Own presentation and calculation

550 ibidem

Estimation of future market volume:

Table 36 shows the estimation of the possible market volume for the next five years taking into account the following assumptions:

- Content of rejects: 6,7% of recovered paper
- Content of deinking sludge: 13% of recovered paper
- Content of sewage sludge: 13% of recovered paper
- 100% of residues are dried
- Operation time: 7920 [hours]
- Moisture content feed product: 50%
- Moisture content end product: 10%
- 30% of new facilities are implementing drying applications
- 5% of existing facilities are implementing drying applications
- Linear market development over 5 years

new installed evaporation capacities:
[tons H2O/hour]

	2010	2011	2012	2013	2014	2015
Asia	30	32	35	37	40	42
Europe	17	18	18	19	20	21
Northern America	4	4	4	4	4	4
South America	2	2	2	2	2	2
Oceania	2	2	2	3	3	3
Africa	0	0	0	0	0	0
Others	8	10	12	15	19	23
World	63	68	74	80	88	96

installed capacities in existing facilities:
[tons H2O/hour]

	2010	2011	2012	2013	2014	2015
Asia	68	69	71	73	75	77
Europe	58	59	60	61	62	63
Northern America	46	46	46	46	47	47
South America	6	6	6	6	6	6
Oceania	3	3	3	4	4	4
Africa	1	1	1	1	2	2
Others	5	6	6	7	8	9
World	187	190	194	198	203	207

new installed capacity [tons H2O/hour]:

SUM	250	259	268	279	290	303
linear market development over 5 ye	20%	40%	60%	80%	100%	100%
estimated future market volume:	50	104	161	223	290	303

Table 36: Estimation of future market volume, pulp and paper industry, 2010-2015[551]

[551] Own presentation and calculation, Cf. AAG, PP

Appendix 4: Sugar Industry – Sugar Cane

The following calculations are based on the data stated in chapter 6.4.

Sugarcane production:

Table 37 shows data of sugar cane production of the top 11 producing countries - data are given in thousand [tons].

Sugar cane production: thousand [tons]

	2000	2001	2002	2003	2004	2005	2006	2007
Brazil	327.705	345.942	364.391	396.012	415.206	422.957	477.411	549.707
India	299.230	295.956	297.200	287.383	233.862	237.088	281.172	355.520
China	69.299	77.966	92.203	92.039	91.044	87.578	100.498	106.432
Thailand	54.052	49.563	60.013	74.259	64.996	49.586	47.658	64.365
Pakistan	46.333	43.606	48.042	52.056	53.820	47.244	44.666	54.742
Mexico	44.100	47.250	45.635	47.484	48.662	51.646	50.676	52.089
Australia	38.165	28.116	31.424	36.995	36.993	37.822	37.128	36.397
Colombia	33.400	33.000	36.950	39.000	40.100	39.849	31.000	32.000
USA	32.762	31.377	32.253	30.715	26.320	24.137	27.033	27.751
Guatemala	16.552	16.935	17.490	17.400	18.283	23.454	18.721	25.437
Indonesia	23.900	25.185	25.530	24.500	26.750	29.300	29.200	25.300
84% of global production								1.329.740
100% of global production								1.583.024

Table 37: Sugarcane production, 2000-2007[552]

Table 38 shows the annual growth rates and the CAGR from 2000-2007 of the top 11 producing countries.

Annual growth rate of sugar cane production:

	2001	2002	2003	2004	2005	2006	2007	CAGR 2000-2007
Brazil	6%	5%	9%	5%	2%	13%	15%	8%
India	-1%	0%	-3%	-19%	1%	19%	26%	2%
China	13%	18%	0%	-1%	-4%	15%	6%	6%
Thailand	-8%	21%	24%	-12%	-24%	-4%	35%	3%
Pakistan	-6%	10%	8%	3%	-12%	-5%	23%	2%
Mexico	7%	-3%	4%	2%	6%	-2%	3%	2%
Australia	-26%	12%	18%	0%	2%	-2%	-2%	-1%
Colombia	-1%	12%	6%	3%	-1%	-22%	3%	-1%
USA	-4%	3%	-5%	-14%	-8%	12%	3%	-2%
Guatemala	2%	3%	-1%	5%	28%	-20%	36%	6%
Indonesia	5%	1%	-4%	9%	10%	0%	-13%	1%

Table 38: Annual growth rate of sugar cane production, 2001-2007[553]

[552] Own presentation, http://faostat.fao.org (23.09.2009)

[553] Own presentation and calculation

Bagasse production:

Processing of one ton of sugar cane (whether into sugar or ethanol) yields 270 kg bagasse.[554]

Table 39 shows the production of bagasse of the top 11 producing countries, based on data from Table 37- data are given in thousand [tons].

Bagasse production: thousand [tons]

	2000	2001	2002	2003	2004	2005	2006	2007
Brazil	88.480	93.404	98.386	106.923	112.106	114.198	128.901	148.421
India	80.792	79.908	80.244	77.593	63.143	64.014	75.916	95.990
China	18.711	21.051	24.895	24.851	24.582	23.646	27.135	28.737
Thailand	14.594	13.382	16.204	20.050	17.549	13.388	12.868	17.379
Pakistan	12.510	11.774	12.971	14.055	14.531	12.756	12.060	14.780
Mexico	11.907	12.758	12.322	12.821	13.139	13.944	13.682	14.064
Australia	10.304	7.591	8.484	9.989	9.988	10.212	10.025	9.827
Colombia	9.018	8.910	9.977	10.530	10.827	10.759	8.370	8.640
USA	8.846	8.472	8.708	8.293	7.106	6.517	7.299	7.493
Guatemala	4.469	4.572	4.722	4.698	4.936	6.333	5.055	6.868
Indonesia	6.453	6.800	6.893	6.615	7.223	7.911	7.884	6.831
				84% of global production			→	359.030
				100 % or global production:			→	427.416

Table 39: Bagasse production, 2000-2007[555]

[554] Cf. Scarmucci/Perin/Pulino/Bordoni/da Cunha

[555] Own presentation and calculation

Theoretical evaporation capacity:

Table 40 shows the estimated theoretical evaporation capacity, by taking into account the following assumptions:

- Moisture content of raw material: 50%
- Moisture content of end product: 10%
- Operating time of facility: 8000 [hours]
- Complete bagasse production is dried

The theoretical evaporation capacity means the evaporation capacity in case of drying of all residues out of sugar cane processing.

Theoretical evaporation capacity [tons H_2O/hour]

	2000	2001	2002	2003	2004	2005	2006	2007
Brazil	4.916	5.189	5.466	5.940	6.228	6.344	7.161	8.246
India	4.488	4.439	4.458	4.311	3.508	3.556	4.218	5.333
China	1.039	1.169	1.383	1.381	1.366	1.314	1.507	1.596
Thailand	811	743	900	1.114	975	744	715	965
Pakistan	695	654	721	781	807	709	670	821
Mexico	662	709	685	712	730	775	760	781
Australia	572	422	471	555	555	567	557	546
Colombia	501	495	554	585	602	598	465	480
USA	491	471	484	461	395	362	405	416
Guatemala	248	254	262	261	274	352	281	382
Indonesia	359	378	383	368	401	440	438	380
				84% of global production			→	19.946
				100 % or global production:			→	23.745

Table 40: Theoretical evaporation capacity, bagasse[556]

[556] Own presentation and calculation

Estimation of future market volume:

Table 41 shows the estimation of the possible market volume for the next five years taking into account the following assumptions:

- Moisture content of raw material: 50%
- Moisture content of end product: 10%
- Operating time of facility: 8000 [hours]
- 15% of new facilities are implementing drying applications
- 5% of existing facilities install new or renew existing drying applications
- CAGR (2000-2007) projected into future
- Linear market development over 10 years

new installed drying capacities: [tons H2O/hour]

	2010	2011	2012	2013	2014	2015
Brazil	115	125	135	145	157	170
India	70	72	73	75	76	78
China	22	23	25	26	28	29
Thailand	13	13	14	14	15	15
others	26	27	28	29	30	31
sum	246	260	274	289	306	323

new installed capacities in existing facilities [tons H2O/hour]

	2010	2011	2012	2013	2014	2015
Brazil	423	428	435	441	449	456
India	273	277	280	284	288	292
China	82	83	84	85	87	88
Thailand	49	50	51	51	52	53
others	193	194	195	197	198	200
sum	1.020	1.032	1.045	1.059	1.073	1.089

SUM	1.266	1.292	1.319	1.348	1.379	1.411
Linear development over 10 years	10%	20%	30%	40%	50%	60%
Sum	127	258	396	539	689	847

averaged annual investment, 2010-2015:	476

Table 41: Estimation of future market volume, bagasse, 2010 -2015[557]

[557] Own presentation and calculation

Appendix 5: Sugar Industry – Sugar Beet

The following calculations are based on the data stated in chapter 6.5.

Relations between sugar beet production and production of several beet pulp types, Germany, 2007/2008:

Table 42 shows the relation between produced sugar beets, sugar beet pulp and the different types of sold beet pulps, namely wet sugar beet pulp, pressed sugar beet pulp and dried sugar beet pulp in the year 2007/2008 in Germany.

Germany:		2007/2008		
Production[tons]:	sugar beet:	25.139.137	100%	
		[tons "Trockenschnitzelwert"]	% of sugar beet production	
	sugar beet pulp	1.693.508	6,7%	100%
				% of sugar beet pulp
Sold as:	wet sugar beet pulp	4.857	insignificant	0,3%
	pressed sugar beet pulp	269.631	1,1%	15,9%
	dried sugar beet pulp	1.419.020	5,6%	83,8%

Table 42: Relations between sugar beet production and production of several beet pulp types, Germany, 2007/2008[558]

Averaged daily sugar beet processing, Germany:

Table 43 shows the averaged sugar beet processing quantity in German sugar plants from 2001/2002 to 2008/2009.

	[tons]	[tons / plant]
2001/02	306.335	10.211
2002/03	292.624	10.451
2003/04	290.054	10.743
2004/05	288.760	11.106
2005/06	289.322	11.128
2006/07	275.649	11.026
2007/08	261.877	11.386
2008/09	233.959	11.698

Table 43: Averaged daily sugar beet processing, Germany[559]

[558] Own presentation and calculation, http://www.zuckerverbaende.de (28.10.2009), , http://faostat.fao.org (24.09.2009)

[559] Own presentation and calculation, http://www.zuckerverbaende.de (25.09.2009)

Estimation of evaporation capacity for an average German sugar plant:

Table 44 show the estimation of the evaporation capacity for an average German sugar plant in case of drying all sugar beet pulp which is mechanical dewatered before drying.

	[tons]	moisture [%]	DS [%]	DS [tons]	% of sugar beet production
dried sugar beet pulp	1419020	10%	90%	1277118	5,6%
pressed beet pulp	3648909	65%	35%		14,5%
beet pulp	12771180	90%	10%		50,8%
evaporation	2229889				8,9%
evaporation per average plant [tons H_2O/hour]:	43				

	[tons]	moiture [%]	DS [%]	DS [tons]	
sugar beet	1				100,0%
beet pulp	0,51	90%	10%	0,051	50,8%
pressed beet pulp	0,15	65%	35%		14,5%
dried beet pulp	0,06	10%	90%		5,6%
evaporation	0,09				8,9%

Table 44: Estimation of evaporation capacity for an average German sugar plant[560]

Sugar beet production, global, 2000-2007:

Table 45 shows the production quantity of the top producing countries – data are given in [tons]. Table 46 shows the annual growth rates and the CAGR from 2001 to 2007.

Production, Sugar beet, [tons]

	2000	2001	2002	2003	2004	2005	2006	2007
France	31.121.000	26.841.000	33.463.756	29.358.296	30.788.266	31.149.552	29.878.767	33.212.700
United States of America	29.520.700	23.372.710	25.145.350	27.744.430	27.234.590	24.886.800	30.631.090	31.912.000
Russian Federation	14.053.490	14.555.730	15.664.750	19.383.650	21.848.320	21.420.110	30.861.230	28.961.320
Germany	27.870.100	24.729.920	26.794.334	23.756.000	27.159.000	25.284.700	20.646.600	25.139.137
Ukraine	13.198.800	15.574.600	14.452.500	13.391.900	16.600.400	15.467.800	22.420.700	16.977.700
Poland	13.134.383	11.363.907	13.433.900	11.739.509	12.730.366	11.912.444	11.474.820	12.681.555
Turkey	18.821.000	12.632.520	16.523.166	12.622.900	13.517.000	15.181.247	14.452.162	12.414.715
China	8.073.487	10.888.615	12.820.000	6.181.662	5.857.144	7.881.000	10.536.000	8.931.000
United Kingdom	9.079.000	8.335.000	9.557.000	9.168.000	9.042.000	8.687.000	7.150.000	6.500.000
Belgium	6.152.000	5.613.900	6.537.100	6.449.682	6.215.850	5.983.173	5.666.621	5.730.500
Netherlands	6.798.000	5.996.000	6.250.195	6.209.800	6.292.200	5.931.000	5.414.100	5.511.500
Egypt	2.890.360	2.857.730	3.168.311	2.691.515	2.860.547	3.429.535	3.904.970	5.458.210
Spain	7.929.700	6.755.103	8.197.289	6.365.142	7.174.942	7.291.092	5.827.031	5.314.900
Iran, Islamic Republic of	4.332.172	4.649.017	6.098.000	5.729.105	4.916.336	4.902.387	6.709.110	5.300.000
sum	192.974.192	174.165.752	198.105.651	180.791.591	192.236.961	189.407.840	205.573.201	204.045.237

83% of global production → 204.045.237

100% of global production → 245.837.635

Table 45: Sugar beet production, global, 2000-2007[561]

[560] Own presentation and calculation, http://www.zuckerverbaende.de (25.09.2009), , http://www.zuckerverbaende.de (28.10.2009)

[561] Own presentation, http://faostat.fao.org (24.09.2009)

Annual growth of sugar beet production:

	2001	2002	2003	2004	2005	2006	2007	CAGR 2000-2007
France	-14%	25%	-12%	5%	1%	-4%	11%	1%
United States of America	-21%	8%	10%	-2%	-9%	23%	4%	1%
Russian Federation	4%	8%	24%	13%	-2%	44%	-6%	11%
Germany	-11%	8%	-11%	14%	-7%	-18%	22%	-1%
Ukraine	18%	-7%	-7%	24%	-7%	45%	-24%	4%
Poland	-13%	18%	-13%	8%	-6%	-4%	11%	0%
Turkey	-33%	31%	-24%	7%	12%	-5%	-14%	-6%
China	35%	18%	-52%	-5%	35%	34%	-15%	1%
United Kingdom	-8%	15%	-4%	-1%	-4%	-18%	-9%	-5%
Belgium	-9%	16%	-1%	-4%	-4%	-5%	1%	-1%
Netherlands	-12%	4%	-1%	1%	-6%	-9%	2%	-3%
Egypt	-1%	11%	-15%	6%	20%	14%	40%	10%
Spain	-15%	21%	-22%	13%	2%	-20%	-9%	-6%
Iran, Islamic Republic of	7%	31%	-6%	-14%	0%	37%	-21%	3%
sum	-10%	14%	-9%	6%	-1%	9%	-1%	1%

Table 46: Annual growth of sugar beet production, 2001-2007[562]

Estimation of installed evaporation capacity:

Table 47 shows the estimation of the installed evaporation capacity in 2007 of the top of producing countries, taking into account following assumptions which are given in the table, data regarding moisture contents of the beet pulp from Table 44, and production data as stated in Table 45.

estimations:

80 % of sugar beet pulp are dried.

capacity per plant:		15000	[tons beet/day]
days per year:	Europe:	100	[days]
	UK:	140	[days]
	USA:	270	[days]
	others:	150	[days]

[tons H_2O/hour]	2007		
France	982		
United States of America	349		
Russian Federation	856		
Germany	743		
Ukraine	502		
Poland	375		
Turkey	367		
China	176		
United Kingdom	137		
Belgium	169		
Netherlands	163		
Egypt	108		
Spain	157		
Iran, Islamic Republic of	104		
sum	5.190	←	83 % of global capacity
	6.253	←	100% of global capacity

Table 47: Estimation of installed evaporation capacity, sugar industry, sugar beet, 2007[563]

[562] Own presentation and calculation

[563] Own presentation and calculation, http://de.wikipedia.org/wiki/Zuckerfabrik (28.09.2009)

Estimation of future market volume:

Table 48 show the estimation of the possible market volume for the next five years taking into account the following assumptions:

- 80% of sugar beet pulp is dried
- Potential of new installed capacity p.a.:
  - 100% of new installed facilities are implementing drying applications
  - 3% annual reinvestment of existing facilities
- CAGR (2000-2007) projected into future

New installed drying capacities: [tons H2O/hour]

	2010	2011	2012	2013	2014	2015
France	-	-	-	-	-	-
United States of America	4	4	4	4	4	4
Russian Federation	115	127	141	156	173	192
Germany	-	-	-	-	-	-
Ukraine	20	20	21	22	23	24
Poland	-	-	-	-	-	-
Turkey	-	-	-	-	-	-
China	3	3	3	3	3	3
United Kingdom	-	-	-	-	-	-
Belgium	-	-	-	-	-	-
Netherlands	-	-	-	-	-	-
Egypt	12	13	15	16	18	19
Spain	-	-	-	-	-	-
Iran, Islamic Republic of	3	3	3	4	4	4
sum	156	171	187	205	224	246

New installed or renewed capacities in existing facilities: [tons H2O/hour]

	2010	2011	2012	2013	2014	2015
France	30	30	31	31	31	31
United States of America	11	11	11	11	11	11
Russian Federation	32	35	39	43	48	53
Germany	22	21	21	21	20	20
Ukraine	16	17	17	18	19	19
Poland	11	11	11	11	11	11
Turkey	10	9	9	8	8	7
China	5	6	6	6	6	6
United Kingdom	4	4	3	3	3	3
Belgium	5	5	5	5	5	5
Netherlands	5	4	4	4	4	4
Egypt	4	4	5	5	6	6
Spain	4	4	4	4	3	3
Iran, Islamic Republic of	3	3	4	4	4	4
sum	161	165	169	173	178	184

Sum of new installed and renewed drying capacities: [tons H2O/hour]

2010	2011	2012	2013	2014	2015
318	336	356	378	402	430

Table 48: Estimation of future market volume, sugar industry, sugar beet, 2010-2015[564]

564 Own presentation and calculation

Appendix 6: Brewery Industry

The following calculations are based on the data stated in chapter 6.6.

Production capacity of beer of barley:

Table 49 show data of beer production of the top producing countries - data are given in [tons]. Table 50 show the annual growth rates and the CAGR from 2000 to 2007 of the brewery industry.

Beer of Barley: production [tons]

	2000	2001	2002	2003	2004	2005	2006	2007
China	22.737.878	23.331.018	24.427.396	25.801.177	29.902.369	31.672.033	35.891.519	39.997.700
United States of America	23.417.000	23.389.000	23.515.000	22.857.000	23.249.000	23.115.000	23.182.200	23.500.000
Russian Federation	5.160.000	6.380.000	7.003.000	7.554.040	8.378.690	9.098.570	10.005.140	11.463.910
Germany	10.687.700	10.637.200	10.213.600	9.893.300	9.761.453	9.480.625	9.921.118	9.718.811
Brazil	8.788.200	9.137.200	7.988.300	7.692.100	8.663.300	9.000.000	9.360.000	9.600.000
Mexico	5.985.100	6.163.200	6.370.000	6.642.000	6.848.200	7.255.800	7.816.200	8.100.000
United Kingdom	5.527.900	5.680.200	5.667.200	5.801.400	5.745.900	5.625.500	5.413.300	5.500.000
Japan	5.463.800	4.813.100	4.270.700	3.929.400	3.810.100	3.844.500	3.800.000	3.850.000
Poland	2.523.100	2.516.300	2.687.500	2.862.200	2.950.000	3.030.000	3.250.000	3.550.000
Spain	2.638.800	2.771.000	2.863.100	3.102.840	3.146.690	3.115.600	3.360.000	3.435.000
Ukraine	1.080.000	1.310.000	1.500.000	1.700.000	1.940.000	2.380.500	2.675.020	3.157.870
Canada	2.451.500	2.575.850	2.556.706	2.175.355	2.468.326	2.538.193	2.908.871	2.900.000
Netherlands	2.496.000	2.461.000	2.476.000	2.398.000	2.349.000	2.413.000	2.647.900	2.725.900
South Africa	2.000.000	2.250.000	2.440.000	2.520.000	2.500.000	2.590.000	2.700.000	2.653.000
Venezuela, Bolivarian Republic of	1.877.280	2.082.899	1.719.442	1.744.110	1.987.760	2.200.000	2.400.000	2.450.000
Thailand	1.165.367	1.238.000	1.275.000	1.602.000	1.613.500	1.703.000	2.020.900	2.100.000
Czech Republic	1.779.600	1.773.400	1.798.700	1.821.600	1.859.600	1.888.500	1.980.000	2.000.000
Belgium	1.550.900	1.506.800	1.506.000	1.592.000	1.704.200	1.727.400	1.838.300	1.856.500
Korea, Republic of	1.654.393	1.776.470	1.822.365	1.786.339	1.803.319	1.748.942	1.744.940	1.813.730
Australia	1.745.000	1.744.000	1.727.000	1.726.000	1.691.000	1.748.190	1.720.000	1.677.000
Colombia	640.000	1.345.200	1.200.000	1.507.400	1.600.000	1.650.000	1.660.000	1.675.000
France	1.599.400	1.571.800	1.534.500	1.543.700	1.471.900	1.413.100	1.603.000	1.509.600
Argentina	1.209.000	1.239.000	1.199.000	1.295.000	1.280.000	1.370.000	1.400.000	1.420.000
Romania	1.194.096	1.266.300	1.162.700	1.329.200	1.440.586	1.529.480	1.748.419	1.349.793
Nigeria	919.500	956.000	1.171.000	1.170.000	1.199.000	1.180.000	1.252.600	1.252.600
Viet Nam	514.000	495.800	563.200	711.700	883.800	922.300	1.036.600	1.236.300
Italy	1.117.300	1.137.300	1.120.600	1.367.200	1.312.500	1.226.900	1.205.500	1.200.000
Sum	117.922.814	121.548.037	121.778.009	124.125.061	131.560.193	135.467.133	144.541.527	151.692.714

87% of global production → 151.692.714

100% of global production → 173.500.520

Table 49: Beer of barley, production, [tons], 2000-2007[565]

[565] Own presentation and calculation, http://faostat.fao.org (30.09.2009)

Beer of Barley: annual growth of production

	2001	2002	2003	2004	2005	2006	2007	CAGR 2000-2007
China	3%	5%	6%	16%	6%	13%	11%	8%
United States of America	0%	1%	-3%	2%	-1%	0%	1%	0%
Russian Federation	24%	10%	8%	11%	9%	10%	15%	12%
Germany	0%	-4%	-3%	-1%	-3%	5%	-2%	-1%
Brazil	4%	-13%	-4%	13%	4%	4%	3%	1%
Mexico	3%	3%	4%	3%	6%	8%	4%	4%
United Kingdom	3%	0%	2%	-1%	-2%	-4%	2%	0%
Japan	-12%	-11%	-8%	-3%	1%	-1%	1%	-5%
Poland	0%	7%	7%	3%	3%	7%	9%	5%
Spain	5%	3%	8%	1%	-1%	8%	2%	4%
Ukraine	21%	15%	13%	14%	23%	12%	18%	17%
Canada	5%	-1%	-15%	13%	3%	15%	0%	2%
Netherlands	-1%	1%	-3%	-2%	3%	10%	3%	1%
South Africa	13%	8%	3%	-1%	4%	4%	-2%	4%
Venezuela, Bolivarian Republic of	11%	-17%	1%	14%	11%	9%	2%	4%
Thailand	6%	3%	26%	1%	6%	19%	4%	9%
Czech Republic	0%	1%	1%	2%	2%	5%	1%	2%
Belgium	-3%	0%	6%	7%	1%	6%	1%	3%
Korea, Republic of	7%	3%	-2%	1%	-3%	0%	4%	1%
Australia	0%	-1%	0%	-2%	3%	-2%	-3%	-1%
Colombia	110%	-11%	26%	6%	3%	1%	1%	15%
France	-2%	-2%	1%	-5%	-4%	13%	-6%	-1%
Argentina	2%	-3%	8%	-1%	7%	2%	1%	2%
Romania	6%	-8%	14%	8%	6%	14%	-23%	2%
Nigeria	4%	22%	0%	2%	-2%	6%	0%	5%
Viet Nam	-4%	14%	26%	24%	4%	12%	19%	13%
Italy	2%	-1%	22%	-4%	-7%	-2%	0%	1%
Sum	3%	0%	2%	6%	3%	7%	5%	4%

Table 50: Annual growth of production of beer and barley, 2000-2001[566]

Production of spent grains:

Table 51 show the production capacity of spent grains in brewery industry.

Production of spent grains out of beer of barley:
[tons]

	2000	2001	2002	2003	2004	2005	2006	2007
China	4.092.818	4.199.583	4.396.931	4.644.212	5.382.426	5.700.966	6.460.473	7.199.586
United States of America	4.215.060	4.210.020	4.232.700	4.114.260	4.184.820	4.160.700	4.172.796	4.230.000
Russian Federation	928.800	1.148.400	1.260.540	1.359.727	1.508.164	1.637.743	1.800.925	2.063.504
Germany	1.923.786	1.914.696	1.838.448	1.780.794	1.757.062	1.706.513	1.785.801	1.749.386
Brazil	1.581.876	1.644.696	1.437.894	1.384.578	1.559.394	1.620.000	1.684.800	1.728.000
Mexico	1.077.318	1.109.376	1.146.600	1.195.560	1.232.676	1.306.044	1.406.916	1.458.000
United Kingdom	995.022	1.022.436	1.020.096	1.044.252	1.034.262	1.012.590	974.394	990.000
Japan	983.484	866.358	768.726	707.292	685.818	692.010	684.000	693.000
Poland	454.158	452.934	483.750	515.196	531.000	545.400	585.000	639.000
Spain	474.984	498.780	515.358	558.511	566.404	560.808	604.800	618.300
Ukraine	194.400	235.800	270.000	306.000	349.200	428.490	481.504	568.417
Canada	441.270	463.653	460.207	391.564	444.299	456.875	523.597	522.000
Netherlands	449.280	442.980	445.680	431.640	422.820	434.340	476.622	490.662
South Africa	360.000	405.000	439.200	453.600	450.000	466.200	486.000	477.540
Venezuela, Bolivarian Republic of	337.910	374.922	309.500	313.940	357.797	396.000	432.000	441.000
Thailand	209.766	222.840	229.500	288.360	290.430	306.540	363.762	378.000
Czech Republic	320.328	319.212	323.766	327.888	334.728	339.930	356.400	360.000
Belgium	279.162	271.224	271.080	286.560	306.756	310.932	330.894	334.170
Korea, Republic of	297.791	319.765	328.026	321.541	324.597	314.810	314.089	326.471
Australia	314.100	313.920	310.860	310.680	304.380	314.674	309.600	301.860
Colombia	115.200	242.136	216.000	271.332	288.000	297.000	298.800	301.500
France	287.892	282.924	276.210	277.866	264.942	254.358	288.540	271.728
Argentina	217.620	223.020	215.820	233.100	230.400	246.600	252.000	255.600
Romania	214.937	227.934	209.286	239.256	259.305	275.306	314.715	242.963
Nigeria	165.510	172.080	210.780	210.600	215.820	212.400	225.468	225.468
Viet Nam	92.520	89.244	101.376	128.106	159.084	166.014	186.588	222.534
Italy	201.114	204.714	201.708	246.096	236.250	220.842	216.990	216.000
								27.304.689
				87% of global production				
				100% of global production				31.230.094

Table 51: Production of spent grains 2000-2007[567]

566 Own presentation and calculation

567 ibidem

Estimation of theoretical evaporation capacity:

Table 52 shows the theoretical installed evaporation capacity in beer industry in case of drying of 100% of produced spent grains.

Feed Product:	Moisture content:	[%]	70%
	production capacity:	[tons/year]	31.230.094
Endproduct:	Moisture content:	[%]	10%
	production capacity:	[tons/year]	10.305.931
	DS	[tons/year]	9.369.028
Facility:	averaged capacity (feedproduct)	[tons/year]	18.000
	Operating time:	[hours/year]	8.000
	evaporation capacity per hour	[tons H_2O/hour]	2.603

Table 52: Estimation of theoretical evaporation capacity, brewery industry, 2007[568]

Estimation of future market volume:

Table 53 show the estimation of the possible market volume for the next five years taking into account the following assumptions:

- CAGR (2000-2007) of beer production projected into future
- Operating time: 8000 [hours]
- MC feed product: 70%
- MC end product: 10%
- 5% of existing facilities are implementing DA p.a.
- 60% of new installed facilities are implementing DA
- Linear market development over 10 years

568 Own presentation and calculation

new installed evaporation capacity: [tons H2O/hour]

	2010	2011	2012	2013	2014	2015
China	36	39	42	45	49	53
United States of America	0	0	0	0	0	0
Russian Federation	16	18	20	22	25	28
Germany	0	0	0	0	0	0
Brazil	1	1	1	1	1	1
Mexico	4	4	4	4	4	4
United Kingdom	0	0	0	0	0	0
Japan	0	0	0	0	0	0
Poland	2	2	2	2	2	2
Spain	1	1	1	1	1	2
Ukraine	6	7	9	10	12	14
Canada	1	1	1	1	1	1
Netherlands	0	0	0	0	0	0
South Africa	1	1	1	1	1	1
Venezuela, Bolivarian Republic of	1	1	1	1	1	1
Thailand	2	2	2	3	3	3
Czech Republic	0	0	0	0	0	0
Belgium	0	0	0	0	1	1
Korea, Republic of	0	0	0	0	0	0
Australia	0	0	0	0	0	0
Colombia	3	3	4	4	5	6
France	0	0	0	0	0	0
Argentina	0	0	0	0	0	0
Romania	0	0	0	0	0	0
Nigeria	1	1	1	1	1	1
Viet Nam	2	2	2	3	3	4
Italy	0	0	0	0	0	0
Sum	77	84	92	101	111	122

new installed or renewed capacities in existing facilities: [tons H2O/hour]

	2010	2011	2012	2013	2014	2015
China	37	40	43	47	51	55
United States of America	19	19	19	19	19	19
Russian Federation	11	13	14	16	18	20
Germany	7	7	7	7	7	7
Brazil	8	8	8	8	8	8
Mexico	7	7	8	8	8	9
United Kingdom	4	4	4	4	4	4
Japan	3	3	2	2	2	2
Poland	3	3	3	4	4	4
Spain	3	3	3	3	3	4
Ukraine	3	4	5	5	6	7
Canada	2	2	3	3	3	3
Netherlands	2	2	2	2	2	2
South Africa	2	2	2	3	3	3
Venezuela, Bolivarian Republic of	2	2	2	2	2	3
Thailand	2	2	2	3	3	3
Czech Republic	2	2	2	2	2	2
Belgium	2	2	2	2	2	2
Korea, Republic of	1	1	2	2	2	2
Australia	1	1	1	1	1	1
Colombia	2	2	2	3	3	3
France	1	1	1	1	1	1
Argentina	1	1	1	1	1	1
Romania	1	1	1	1	1	1
Nigeria	1	1	1	1	1	1
Viet Nam	1	1	2	2	2	2
Italy	1	1	1	1	1	1
Sum	131	137	144	152	161	171

SUM	208	222	237	254	272	293
linear market development over 10 years	10%	20%	30%	40%	50%	60%

theoretical market volume	21	44	71	101	136	176

Table 53: Estimation of future market volume, brewery industry, 2010-2015[569]

[569] Own presentation and calculation

Appendix 7: Edible Oil Industry – Palm Oil Industry

The following calculations are based on the data stated in chapter 6.7.

Production of palm oil fruits, 2000-2007:

Table 54 show the production quantity of palm oil fruits of the top 12 producing countries – data are given in tons.

Production: oil palm fruits [tons]

	2000	2001	2002	2003	2004	2005	2006	2007
Malaysia	56.600.000	58.950.000	59.546.000	66.775.000	69.881.000	74.800.000	79.400.000	79.100.000
Indonesia	36.380.000	40.950.000	46.800.000	52.600.000	60.425.500	74.000.000	80.250.000	78.000.000
Nigeria	8.220.000	8.500.000	8.500.000	8.632.000	8.700.000	8.500.000	8.300.000	8.500.000
Thailand	3.343.000	4.096.562	4.001.376	4.902.383	5.181.797	5.002.670	6.715.036	6.389.983
Colombia	2.470.000	2.600.000	2.600.000	2.579.459	3.106.500	3.272.500	3.200.000	3.200.000
Ecuador	1.339.400	1.424.000	1.645.000	1.522.000	1.843.819	1.929.919	2.000.000	2.100.000
Ghana	1.066.426	1.102.087	1.100.000	1.600.000	1.955.300	2.024.600	2.097.400	1.900.000
Papua New Guinea	1.245.000	1.218.000	1.178.000	1.200.000	1.250.000	1.300.000	1.350.000	1.400.000
Côte d'Ivoire	1.133.606	993.438	1.160.122	1.029.141	1.311.035	1.231.754	1.328.443	1.359.470
Cameroon	1.100.000	1.150.000	1.150.000	1.250.000	1.300.000	1.300.000	1.300.000	1.300.000
Congo, Democratic Republic of	1.119.190	1.085.070	1.052.040	1.065.300	1.078.770	1.092.450	1.106.300	1.120.350
Honduras	618.600	668.794	709.734	805.552	928.418	1.092.270	1.040.722	1.112.118
sum								185.481.921
				96% of global production				185.481.921
				100% of global production				193.210.334

Table 54: Global production of palm oil fruit, 2000-2007[570]

Table 55 show the annual growth rates of palm oil fruit production and the CAGR from 2000 to 2007 and from 2004 to 2007.

Growth: oil palm fruit production

	2001	2002	2003	2004	2005	2006	2007	CAGR 2000-2007	CAGR 2004-2007
Malaysia	4%	1%	12%	5%	7%	6%	0%	5%	4%
Indonesia	13%	14%	12%	15%	22%	8%	-3%	12%	9%
Nigeria	3%	0%	2%	1%	-2%	-2%	2%	0%	-1%
Thailand	23%	-2%	23%	6%	-3%	34%	-5%	10%	7%
Colombia	5%	0%	-1%	20%	5%	-2%	0%	4%	1%
Ecuador	6%	16%	-7%	21%	5%	4%	5%	7%	4%
Ghana	3%	0%	45%	22%	4%	4%	-9%	9%	-1%
Papua New Guinea	-2%	-3%	2%	4%	4%	4%	4%	2%	4%
Côte d'Ivoire	-12%	17%	-11%	27%	-6%	8%	2%	3%	1%
Cameroon	5%	0%	9%	4%	0%	0%	0%	2%	0%
Congo, Democratic Republic of	-3%	-3%	1%	1%	1%	1%	1%	0%	1%
Honduras	8%	6%	14%	15%	18%	-5%	7%	9%	6%

Table 55: Growth of palm oil fruit production, 2000-2007[571]

[570] Own presentation and calculation; http://faostat.fao.org (28.11.2009)

[571] Own presentation and calculation

Production of residues out of palm oil processing:

Table 56 show the production quantity of empty fruit bunches based on production data as given in Table 54.

Production: EFB [tons]	content of palm oil fruit:	22%
	moisture content:	58%

	2000	2001	2002	2003	2004	2005	2006	2007
Malaysia	12.452.000	12.969.000	13.100.120	14.690.500	15.373.820	16.456.000	17.468.000	17.402.000
Indonesia	8.003.600	9.009.000	10.296.000	11.572.000	13.293.610	16.280.000	17.655.000	17.160.000
Nigeria	1.808.400	1.870.000	1.870.000	1.899.040	1.914.000	1.870.000	1.826.000	1.870.000
Thailand	735.460	901.244	880.303	1.078.524	1.139.995	1.100.587	1.477.308	1.405.796
Colombia	543.400	572.000	572.000	567.481	683.430	719.950	704.000	704.000
Ecuador	294.668	313.280	361.900	334.840	405.640	424.582	440.000	462.000
Ghana	234.614	242.459	242.000	352.000	430.166	445.412	461.428	418.000
Papua New Guinea	273.900	267.960	259.160	264.000	275.000	286.000	297.000	308.000
Côte d'Ivoire	249.393	218.556	255.227	226.411	288.428	270.986	292.257	299.083
Cameroon	242.000	253.000	253.000	275.000	286.000	286.000	286.000	286.000
Congo, Democratic Republic of	246.222	238.715	231.449	234.366	237.329	240.339	243.386	246.477
Honduras	136.092	147.135	156.141	177.221	204.252	240.299	228.959	244.666
sum	25.219.749	27.002.349	28.477.300	31.671.384	34.531.671	38.620.156	41.379.338	40.806.023

96% of global production → 40.806.023
100% of global production → 42.506.274

Table 56: Production of EFB, 2000-2007[572]

Table 58 show the production quantity of palm oil mill effluent which is mechanically dewatered to a moisture content of 60%.

Production: POME [tons]	contant of palm oil fruit:	67%	POME is mechanically dried
	moisture content:	60%	

	2000	2001	2002	2003	2004	2005	2006	2007
Malaysia	18.961.000	19.748.250	19.947.910	22.369.625	23.410.135	25.058.000	26.599.000	26.498.500
Indonesia	12.187.300	13.718.250	15.678.000	17.621.000	20.242.543	24.790.000	26.883.750	26.130.000
Nigeria	2.753.700	2.847.500	2.847.500	2.891.720	2.914.500	2.847.500	2.780.500	2.847.500
Thailand	1.119.905	1.372.348	1.340.461	1.642.298	1.735.902	1.675.894	2.249.537	2.140.644
Colombia	827.450	871.000	871.000	864.119	1.040.678	1.096.288	1.072.000	1.072.000
Ecuador	448.699	477.040	551.075	509.870	617.679	646.523	670.000	703.500
Ghana	357.253	369.199	368.500	536.000	655.026	678.241	702.629	636.500
Papua New Guinea	417.075	408.030	394.630	402.000	418.750	435.500	452.250	469.000
Côte d'Ivoire	379.758	332.802	388.641	344.762	439.197	412.638	445.028	455.422
Cameroon	368.500	385.250	385.250	418.750	435.500	435.500	435.500	435.500
Congo, Democratic Republic of	374.929	363.498	352.433	356.876	361.388	365.971	370.611	375.317
Honduras	207.231	224.046	237.761	269.860	311.020	365.910	348.642	372.560
sum	38.402.799	41.117.214	43.363.161	48.226.880	52.582.317	58.807.965	63.009.447	62.136.444

96% of global production → 62.136.444
100% of global production → 64.725.462

Table 57: Production of mechanical dewatered POME, 2000-2007[573]

[572] Own presentation and calculation

[573] ibidem

Estimation of theoretical evaporation capacity:

Table 58 shows the theoretical installed evaporation capacity in palm oil industry in case of drying of 100% of produced EFP and POME.

EFB:

Feed Product:	Moisture content:	[%]	58%
	production capacity:	[tons/year]	42.506.274
Endproduct:	Moisture content:	[%]	10%
	production capacity:	[tons/year]	19.637.898
	DS	[tons/year]	17.852.635
	Operating time:	[hours/year]	8.000
evaporation:	evaporation capacity per year	[tons H2O/year]	22.670.013
	evaporation capacity per hour	[tons H_2O/hour]	2.834

POME, dewatered:

Feed Product:	Moisture content:	[%]	60%
	production capacity:	[tons/year]	64.725.462
Endproduct:	Moisture content:	[%]	10%
	production capacity:	[tons/year]	28.479.203
	DS	[tons/year]	25.890.185
	Operating time:	[hours/year]	8.000
evaporation:	evaporation capacity per year	[tons H2O/year]	35.958.590
	evaporation capacity per hour	[tons H_2O/hour]	4.495
	SUM: EFB+POME:	[tons H_2O/hour]	7.329

Table 58: Estimation of theoretical evaporation capacity, EFB + POME, 2007[574]

[574] Own presentation and calculation

Estimation of future market volume:

Table 59 show the estimation of the possible market volume for the next five years taking into account the following assumptions:

- 15 % of new installed facilities are implementing DA
- 3% of existing facilities re-/install drying applications
- MC of EFB: 58%
- MC of POME (mechanically dewatered): 60%
- MC of end product: 10%
- Operating time: 8000 hours
- Linear market development over 10 years
- CAGR of 2004-2007 projected into future

new installed facilities:
[tons H2O/hour]

	2010	2011	2012	2013	2014	2015
Malaysia	20	21	22	23	24	25
Indonesia	46	50	54	59	64	70
Nigeria	0	0	0	0	0	0
Thailand	3	3	3	4	4	4
Colombia	0	0	0	0	0	0
Ecuador	1	1	1	1	1	1
Ghana	0	0	0	0	0	0
Papua New Guinea	0	0	0	0	0	0
Côte d'Ivoire	0	0	0	0	0	0
Cameroon	0	0	0	0	0	0
Congo, Democratic Republic of	0	0	0	0	0	0
Honduras	0	0	0	1	1	1
sum	70	75	81	87	93	100

re-/installing of existing facilities:
[tons H2O/hour]

	2010	2011	2012	2013	2014	2015
Malaysia	96	96	96	96	96	97
Indonesia	93	93	93	93	94	94
Nigeria	11	11	11	11	11	11
Thailand	7	7	7	7	7	8
Colombia	4	4	4	4	4	4
Ecuador	3	3	3	3	3	3
Ghana	2	2	2	2	2	2
Papua New Guinea	2	2	2	2	2	2
Côte d'Ivoire	2	2	2	2	2	2
Cameroon	2	2	2	2	2	2
Congo, Democratic Republic of	1	1	1	1	1	1
Honduras	1	1	1	1	1	1
sum	223	223	224	224	225	225

	2010	2011	2012	2013	2014	2015
SUM	293	299	305	311	318	325
linear market development over 10 years:	10%	20%	30%	40%	50%	60%
→	29	60	91	124	159	195

Table 59: Estimation of possible future market volume, palm oil industry, 2010-2015[575]

[575] Own presentation and calculation

Appendix 8: Edible Oil Industry – Olive Oil Industry

The following calculations are based on the data stated in chapter 6.8.

Estimation of evaporation capacity per plant:

Table 60 shows the estimation of the evaporation capacity of a olive oil plant which is processing 10 tons of olives a day.

estimations:	moisture content of feed product	50%	
	moisture content of end product	10%	
	operating time:	2400	[hours]
	mass of residues is 3 times higher than mass of produced oil		
	capacity per plant: olives	10	[tons/day]
	capacity per plant: olive oil	2	[tons/day]
	mass of residues:	6	[tons/day]
		0,25	[tons/hour]
	evaporation capacity:	0,11	[tons H2O/hour]

Table 60: Estimation of evaporation capacity per plant, olive industry[576]

Production of olive oil virgin:

Table 61 shows the production of olive oil virgin from the top 11 producing countries.

Olive oil, virgin Production (tonnes)	2000	2001	2002	2003	2004	2005	2006	2007
Spain	962.400	1.412.100	836.902	1.449.071	1.005.461	819.428	1.092.602	1.211.900
Italy	507.400	573.500	574.950	600.482	794.559	671.315	603.253	574.261
Greece	408.375	302.230	381.620	374.903	321.338	386.385	396.196	331.310
Tunisia	115.000	30.000	72.000	280.000	130.000	210.000	180.000	200.000
Turkey	185.000	65.000	160.000	80.000	145.000	115.000	137.000	172.000
Syrian Arab Republic	165.354	95.384	194.599	163.700	145.800	167.000	130.300	152.000
Morocco	40.000	35.000	60.000	45.000	100.000	50.000	75.000	84.500
Portugal	25.974	34.950	31.050	36.498	50.066	31.817	51.847	49.700
Algeria	30.488	26.200	22.500	24.300	55.000	34.694	32.017	40.000
Jordan	27.202	17.429	27.977	17.955	24.116	40.400	28.300	34.400
Libyan Arab Jamahiriya	6.000	5.000	6.800	13.000	15.800	7.900	13.000	26.400
97% of global production								2.876.471
100% of global production								2.965.434

Table 61: Production capacity, olive oil virgin, 2000-2007[577]

[576] Own presentation and calculation

[577] Own presentation and calculation, http://faostat.fao.org (29.09.2009)

Table 62 shows the annual growth rates of production of olive oil virgin and the CAGR from 2000 to 2007.

Growth of production, olive oil vergin, 2000-2007

	2001	2002	2003	2004	2005	2006	2007	CAGR 2000-2007
Spain	47%	-41%	73%	-31%	-19%	33%	11%	3%
Italy	13%	0%	4%	32%	-16%	-10%	-5%	2%
Greece	-26%	26%	-2%	-14%	20%	3%	-16%	-3%
Tunisia	-74%	140%	289%	-54%	62%	-14%	11%	8%
Turkey	-65%	146%	-50%	81%	-21%	19%	26%	-1%
Syrian Arab Republic	-42%	104%	-16%	-11%	15%	-22%	17%	-1%
Morocco	-13%	71%	-25%	122%	-50%	50%	13%	11%
Portugal	35%	-11%	18%	37%	-36%	63%	-4%	10%
Algeria	-14%	-14%	8%	126%	-37%	-8%	25%	4%
Jordan	-36%	61%	-36%	34%	68%	-30%	22%	3%
Libyan Arab Jamahiriya	-17%	36%	91%	22%	-50%	65%	103%	24%

Table 62: Growth of production of olive oil virgin, 2000-2007[578]

Estimation of theoretical evaporation capacity:

Table 63 shows the estimation of the theoretical evaporation capacity in olive oil industry based on production data as stated in Table 61.

Theoretical evaporation capacity [tons H2O/hour]

moisture content of feed product: 50%
moisture content of end product: 10%
operating time: 2400 [hours]
mass of residues is 3 times higher than mass of produced oil

	2007	
Spain	673	
Italy	319	
Greece	184	
Tunisia	111	
Turkey	96	
Syrian Arab Republic	84	
Morocco	47	
Portugal	28	
Algeria	22	
Jordan	19	
Libyan Arab Jamahiriya	15	
sum	1598	97% of global capacity
	1647	100 % of global capacity

Table 63: Estimation of theoretical evaporation capacity, olive oil industry, 2007[579]

[578] Own presentation and calculation

[579] ibidem

Estimation of future market Volume:

Table 64 shows the estimation of the possible market volume for the next five years taking into account the following assumptions:

- 15 % of new installed facilities are implementing DA
- 3% of existing facilities re-/install drying applications
- MC of feed product: 50%
- MC of end product: 10%
- Operating time: 2400 hours
- Linear market development over 5 years
- CAGR of 2000-2007 projected into future

potential of new installed capacity:
[tons H2O/hour]

	2010	2011	2012	2013	2014	2015
Spain	4	4	4	4	4	4
Italy	1	1	1	1	1	1
Greece	-1	-1	-1	-1	-1	-1
Tunisia	2	2	2	2	2	2
Turkey	0	0	0	0	0	0
Syrian Arab Republic	0	0	0	0	0	0
Morocco	1	1	1	1	2	2
Portugal	0	1	1	1	1	1
Algeria	0	0	0	0	0	0
Jordan	0	0	0	0	0	0
Libyan Arab Jamahiriya	1	1	1	1	2	2
sum	8	8	9	10	11	12

potential re-/install of capacities in existing facilities:
[tons H2O/hour]

	2010	2011	2012	2013	2014	2015
Spain	21	21	21	21	21	21
Italy	10	10	10	10	10	10
Greece	5	5	5	5	5	5
Tunisia	3	4	4	4	4	4
Turkey	3	3	3	3	3	3
Syrian Arab Republic	3	3	3	3	3	3
Morocco	1	2	2	2	2	2
Portugal	1	1	1	1	1	1
Algeria	1	1	1	1	1	1
Jordan	1	1	1	1	1	1
Libyan Arab Jamahiriya	1	1	1	1	1	1
sum	49	49	49	49	50	50

	2010	2011	2012	2013	2014	2015
SUM	56	57	58	59	60	62
Linear market development over 5 years	20%	40%	60%	80%	100%	100%
implemented evaporation capacity p.a. [tons H_2O/hour]	11	23	35	47	60	62

Table 64: Estimation of future market volume, Olive industry, 2010-2015[580]

[580] Own presentation and calculation

Appendix 9: Biogene Waste Industry – Biogas Plants

The following calculations are based on the data stated in chapter 6.9.

Production of biogas:

Table 65 shows the production of biogas of the top 10 of producing countries – data are given in [terrajoules]. This numbers include the production of landfill gas, sewage sludge gas and other biogas.

biogas - gross production: 2000-2006
[Terajoules]

	2000	2001	2002	2003	2004	2005	2006
United States	123.966	137.350	152.430	152.186	156.590	159.849	162.182
Germany	23.341	35.278	53.180	38.446	41.527	55.753	69.721
United Kingdom	33.912	37.842	40.540	47.253	56.672	60.302	62.740
Italy and San Marino	5.480	6.581	9.045	10.691	13.353	13.559	15.025
Spain	5.492	5.624	7.116	10.743	12.354	13.269	14.002
Australia	5.780	9.331	11.016	10.197	11.460	12.730	11.100
France incl. Monaco	6.133	6.764	8.422	8.507	8.686	9.214	9.498
Canada	7.787	7.787	8.005	8.005	8.038	8.038	8.038
Netherlands	5.212	5.360	5.561	5.392	5.285	5.095	5.909
Republic of Korea	1.380	1.614	2.735	3.469	3.860	3.406	5.856
sum	218.483	253.531	298.050	294.889	317.825	341.215	364.071

91% of global production → 364.071
100% of global production → 400.078

Table 65: Production of biogas, 2000-2006[581]

Table 66 shows the annual growth rates of biogas production and the CAGR from 2000-2006.

Growth of biogas production, 2000-2006:

	2001	2002	2003	2004	2005	2006	CAGR 2000-2006
United States	11%	11%	0%	3%	2%	1%	5%
Germany	51%	51%	-28%	8%	34%	25%	20%
United Kingdom	12%	7%	17%	20%	6%	4%	11%
Italy and San Marino	20%	37%	18%	25%	2%	11%	18%
Spain	2%	27%	51%	15%	7%	6%	17%
Australia	61%	18%	-7%	12%	11%	-13%	11%
France incl. Monaco	10%	25%	1%	2%	6%	3%	8%
Canada	0%	3%	0%	0%	0%	0%	1%
Netherlands	3%	4%	-3%	-2%	-4%	16%	2%
Republic of Korea	17%	69%	27%	11%	-12%	72%	27%
sum	16%	18%	-1%	8%	7%	7%	9%

Table 66: Growth of biogas production, 2000-2006[582]

581 Own presentation and calculation, http://data.un.org (02.10.2009)

582 Own presentation and calculation

Estimation of theoretical evaporation capacity:

Table 67 shows the necessary organic dry matter for biogas production and Table 68 shows the organic DM of substrate after digestion out of biogas production taking into account the following assumptions and calculations:

- Methane output: 0,3 [m³/kg organic DM][583]
- Methane content of biogas: 60%[584]
- Energy content of biogas: 6 [kWh/m³][585]
- Density of biogas: 1,25 [kg/m³][586]
- MC of digestion residue: 90%
- MC of digestion residue after mechanical dewatering 75%
- MC of dried product: 10%
- Operating time: 8000 [hours]

Calculations:

- Biogas output: 0,5 [m³/kg organic DM]
- Biogas output: 0,63 [kg/kg organic DM]
- Mass loss of organic DM: 60%
- Energy content of biogas: 21.600.000 [Joule/m³]
- Energy content per organic DM: 0,0000108 [Terrajoule/kg organic DM]

organic DM for biogas production
[tons]

	2000	2001	2002	2003	2004	2005	2006
United States	11.478.333	12.717.593	14.113.889	14.091.296	14.499.074	14.800.833	15.016.852
Germany	2.161.204	3.266.481	4.924.074	3.559.815	3.845.093	5.162.315	6.455.648
United Kingdom	3.140.000	3.503.889	3.753.704	4.375.278	5.247.407	5.583.519	5.809.259
Italy and San Marino	507.407	609.352	837.500	989.907	1.236.389	1.255.463	1.391.204
Spain	508.519	520.741	658.889	994.722	1.143.889	1.228.611	1.296.481
Australia	535.185	863.981	1.020.000	944.167	1.061.111	1.178.704	1.027.778
France incl. Monaco	567.870	626.296	779.815	787.685	804.259	853.148	879.444
Canada	721.019	721.019	741.204	741.204	744.259	744.259	744.259
Netherlands	482.593	496.296	514.907	499.259	489.352	471.759	547.130
Republic of Korea	127.778	149.444	253.241	321.204	357.407	315.370	542.222
sum							33.710.278
			91% of global production			→	33.710.278
			100% of global production			→	37.044.261

Table 67: Necessary organic DM for biogas production, [tons]. 2000-2006[587]

[583] Cf. Eder/Eder/Gronauer/Kaiser/Papst (2004), page 48

[584] http://www.bio-energie.de (22.02.2010)

[585] ibidem

[586] Reinhold (2005). page 6

[587] Own presentation and calculation

organic DM of substrate after digestion
[tons]

	2000	2001	2002	2003	2004	2005	2006
United States	4.304.375	4.769.097	5.292.708	5.284.236	5.437.153	5.550.313	5.631.319
Germany	810.451	1.224.931	1.846.528	1.334.931	1.441.910	1.935.868	2.420.868
United Kingdom	1.177.500	1.313.958	1.407.639	1.640.729	1.967.778	2.093.819	2.178.472
Italy and San Marino	190.278	228.507	314.063	371.215	463.646	470.799	521.701
Spain	190.694	195.278	247.083	373.021	428.958	460.729	486.181
Australia	200.694	323.993	382.500	354.063	397.917	442.014	385.417
France incl. Monaco	212.951	234.861	292.431	295.382	301.597	319.931	329.792
Canada	270.382	270.382	277.951	277.951	279.097	279.097	279.097
Netherlands	180.972	186.111	193.090	187.222	183.507	176.910	205.174
Republic of Korea	47.917	56.042	94.965	120.451	134.028	118.264	203.333
sum							12.641.354
			91% of global production			→	12.641.354
			100% of global production			→	13.891.598

Table 68: Organic DM of substrate after digestion, [tons], 2000-2006[588]

Table 69 shows the estimation of the theoretical installed evaporation capacity in biogas industry.

estimations:

	moisture content degestion residue:	90%
	after dewatering	75%
	moisture content end product	10%
	operating time	8000 [hours]

theoretical evaporation capacity
[tons H2O/hour]

	2000	2001	2002	2003	2004	2005	2006
United States	1.554	1.722	1.911	1.908	1.963	2.004	2.034
Germany	293	442	667	482	521	699	874
United Kingdom	425	474	508	592	711	756	787
Italy and San Marino	69	83	113	134	167	170	188
Spain	69	71	89	135	155	166	176
Australia	72	117	138	128	144	160	139
France incl. Monaco	77	85	106	107	109	116	119
Canada	98	98	100	100	101	101	101
Netherlands	65	67	70	68	66	64	74
Republic of Korea	17	20	34	43	48	43	73
sum							4.565
			91% of global capacity			→	4.565
			100% of global capacity				5.016

Table 69: Theoretical evaporation capacity, Biogas industry[589]

As stated above (Production of biogas), this numbers include landfill gas, sewage sludge gas and other biogas.

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[588] Own presentation and calculation

[589] ibidem

Estimation of possible future market volume:

Table 70 shows the estimation of the possible market volume for the next five years taking into account the following assumptions:

- CAGR (2000-2006) projected into future
- Potential of new installed capacity p.a.:
  - 15% of new installed facilities are implementing drying applications
  - 3% of existing facilities are implementing drying applications p.a.
- Assumed initial development:
  - 2010: 20% of potential capacity p.a. are implemented
  - 2011: 40%, 2012: 60%, 2013: 80%, following years: 100%

new installed evaporation capacity in new facilities:
[tons H_2O/hour]

	2010	2011	2012	2013	2014	2015
United States	16	17	18	19	19	20
Germany	54	65	78	94	113	135
United Kingdom	18	20	22	24	27	30
Italy and San Marino	9	11	13	16	18	22
Spain	7	9	10	12	14	16
Australia	3	3	4	4	4	5
France incl. Monaco	2	2	2	2	2	2
Canada	0	0	0	0	0	0
Netherlands	0	0	0	0	0	0
Republic of Korea	9	11	14	18	23	29
sum	119	139	162	189	222	261

new installed evaporation capacity in new facilities:
[tons H_2O/hour]

	2010	2011	2012	2013	2014	2015
United States	73	77	80	84	88	92
Germany	60	73	89	108	130	157
United Kingdom	36	40	44	49	55	61
Italy and San Marino	12	14	16	20	23	28
Spain	10	12	14	16	19	22
Australia	6	7	7	8	9	10
France incl. Monaco	5	5	6	6	6	7
Canada	3	3	3	3	3	3
Netherlands	2	3	3	3	3	3
Republic of Korea	7	9	12	16	21	26
sum	215	242	275	313	357	409

	2010	2011	2012	2013	2014	2015
SUM	334	381	436	502	579	670
linear market development over 5 years	20%	40%	60%	80%	100%	100%
potential market volume [tons H_2O/hour]	67	152	262	401	579	670

Table 70: Estimation of future market volume, biogas industry, 2010-2015[590]

[590] Own presentation and calculation

Appendix 10: Energy Industry – Bioethanol 1st Generation

The following calculations are based on the data stated in chapter 6.11.

Estimation of typical throughputs:

Table 71 shows the estimation of the typical throughput of a bioethanol plant for USA and Germany.

USA:	DDGS	300.000	[tons/year]
	moisture content	10	[%]
	DS DDGS	270000	[tons/year]
	moisture content DGS	75	[%]
	evaporation	780000	[tons/year]
	operating time	8000	[hours/year]
	evaporation capacity	98	[tons H2O/hour]
Germany:	DDGS	100.000	[tons/year]
	moisture content	10	[%]
	DS DDGS	90.000	[tons/year]
	moisture content DGS	75	[%]
	evaporation	260.000	[tons/year]
	operating time	8.000	[hours/year]
	evaporation capacity	33	[tons H2O/hour]

Table 71: Estimation of typical throughputs, USA and Germany[591]

Production of alcohol, 2000-2007:

Table 72 shows the production of alcohol from 2000 to 2007.

Alcohol - production
thousand [tons]

	2000	2001	2002	2003	2004	2005	2006	2007
United States	4.498	4.747	6.279	8.697	10.718	12.273	15.077	19.733
Brazil	8.555	9.159	10.056	11.547	11.709	12.829	14.229	18.100
Germany	250	4	6	22	87	573	870	1.803
Canada	144	144	144	144	144	201	184	646
Sweden	0	19	46	98	208	304	349	429
France incl. Monaco	93	91	91	77	81	117	235	413
Spain	0	0	112	154	180	177	179	342
Cuba	49	48	47	47	47	60	58	225
Colombia	0	0	0	0	0	22	196	220
Thailand	0	0	0	0	5	53	100	148
Poland	0	0	0	44	21	81	119	96
Austria	20	22	23	23	46	59	73	93
Netherlands	0	0	0	0	2	60	106	89
Australia	0	0	0	0	0	17	41	66
Belgium	0	0	0	0	0	19	33	38
Czech Republic	0	0	0	0	0	0	2	27
Slovakia	0	1	1	2	0	0	0	24
Lithuania	0	0	0	0	2	7	10	15
Hungary	0	0	0	0	0	8	19	14
Latvia	0	0	0	0	0	0	5	12
Paraguay	1	1	1	0	0	7	7	6
Bulgaria	0	0	0	0	0	0	9	4
Ireland	0	0	0	0	0	0	3	4
Switzerland-Liechtenstein	0	0	0	0	0	1	1	3
sum	13.610	14.236	16.806	20.855	23.250	26.868	31.905	44.557

Table 72: Production of alcohol, 2000-2007[592]

[591] Own presentation and calculation; Cf. http://www.iwr.de (24.02.2010); Stölken/Michel/Pienz (2006), page 1; AAG, ET; Cf. Kaltschmitt/Hartmann/Hofbauer, page 836

[592] Own presentation and calculation, http://data.un.org (15.02.2010)

Production of DDGS, US, 2000-2009:

Table 73 shows the production of DDGS in USA and its annual growth rates and CAGR from 2000 to 2009.

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	
DDGS: [tons]	2.000.000	2.250.000	3.000.000	5.000.000	6.000.000	7.500.000	9.000.000	12.500.000	20.000.000	25.000.000	CAGR (2000-2009)
Growth:		13%	33%	67%	20%	25%	20%	39%	60%	25%	32%

Table 73: Production of distiller grains, [tons], US, 2000-2009[593]

Estimation of current installed evaporation capacity, US, 2009:

Table 74 shows the estimation of current installed evaporation capacity in USA in 2009.

DDGS	25.000.000	[tons/year]
moisture content	10	[%]
DS DDGS	22500000	[tons/year]
moisture content DGS	75	[%]
evaporation	65000000	[tons/year]
operating time	8000	[hours/year]
evaporation capacity	8125	[tons H2O/hour]

Table 74: Estimation of installed evaporation capacity, ethanol industry, US, 2009[594]

[593] Own presentation and calculation; http://www.biofuels-platform.ch (22.02.2010), page 24

[594] Own presentation and calculation

Appendix 11: Energy Industry – Torrefaction

The following calculations are based on the data stated in chapter 6.13.

Estimation of evaporation capacity for a torrefaction plant with an output of 50.000 tons:

Table 75 shows the estimation of a torrefaction plant with an output of 50.000 tons per year.

Estimations:	Output of plant (torrefied material):	50.000	[tons/year]
	DM of torrefied material:	100%	
	Massflow during torrefaction process:	30%	
	DM raw material:	50%	
	DM dried material:	90%	
	Operation time:	8.000	[hours/year]
Results:	Necessary DS of biomass:	71.429	[tons/year]
	Evaporation capacity:	7,9	[tons H_2O/hour]

Table 75: Estimation of evaporation capacity for a torrefaction plant with an output of 50.000 tons[595]

[595] Own presentation and calculation