A look at technological and technical tower extraction trends

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Blick auf technologische und technische Trends bei der Turmextraktion

Tower extraction has become the state-of-the-art technology for extracting sugar from cossettes. Sugar yield and plant economy are factors that have made this technology prevail over other extraction methods. In particular for high throughput rates per extraction line, tower extraction plants are unrivalled. The possibilities to reduce the energy consumption during extraction are shown using the example of a technologically leading European sugar producer. Thanks to the installation of large extraction plants in the sugar factories of Schweizer Zucker AG at Frauenfeld and Aarberg, the extraction losses and also the raw juice draft could be reduced significantly. Based on the records of the campaigns from 2000 to 2014, the paper reports on results of the operation of a modern tower extraction plant. In the more recent past, there has been a trend towards longer beet campaigns, and sugar factories are increasing their capacities due to economic reasons. Depending on the project conditions, various extension concepts are coming into effect. Special emphasis has to be placed on future-oriented material selection.

Key words: tower extraction, energy consumption, material selection

Die Extraktion von Zucker aus Zuckerrübenschnitzeln in Turmextraktionsanlagen ist heutzutage der technische Standard. Gegenüber anderen Extraktionsverfahren hat sich diese Technologie in Hinsicht auf Zuckerausbeute und die energiewirtschaftlichen Vorteile durchgesetzt. Speziell für eine hohe Durchsatzleistung je Extraktionslinie ist die Turmextraktion unangefochten. Die Möglichkeiten, den Energiebedarf im Prozessschritt der Saftgewinnung zu senken, werden am Beispiel eines technologisch führenden europäischen Zuckerherstellers dargestellt. Durch die Installation großer Extraktionsanlagen in den Zuckerfabriken Frauenfeld und Aarberg der Schweizer Zucker AG konnten sowohl die Extraktionsverluste als auch der Rohsaftabzug entscheidend reduziert werden. Anhand der Aufzeichnungen der Kampagnen 2000 bis 2014 wird über Ergebnisse zum Betrieb einer modernen Turmextraktionsanlage berichtet. Generell verlängern Zuckerfabriken in den letzten Jahren ihre Rübenkampagnen und erweitern die Kapazitäten aus wirtschaftlichen Gründen. Abhängig von den Vorhabenbedingungen kommen unterschiedliche Konzepte zur Erweiterung zum Tragen. Ebenso rückt die vorausschauende Materialauswahl in den Fokus.

Schlagwörter: Turmextraktion, Energiebedarf, Materialauswahl

1 Introduction

Extraction is one of the most important stations of a beet sugar factory, in terms of energy requirements and also with regard to sugar losses. The energy consumption of the extraction plant itself is directly determined via the effective cooling of the raw juice. The necessary water evaporation to obtain thick juice from thin juice in the evaporator station is decisively influenced by the raw juice draft. A reduced raw juice draft results in a higher dry substance content of the raw juice, which in turn reduces the need for water evaporation and the juice mass flows in the juice purification. In many cases, this directly helps realise energy savings.

A study performed by the German Association of Sugar Technologists (VDZ) [1] shows that in 2006/07 the energy demand of 65 selected European sugar factories amounted to approximately 1350 kWh/t of sugar (Fig. 1). Factories with only one beet campaign consume less energy (an average of 1300 kWh/t of sugar) than factories with a beet campaign and a thick juice campaign (an average of 1400 kWh/t of sugar). The deviations around these average values vary from less than 1000 kWh/t of sugar up to more than 1700 kWh/t [2]. Figure 1 also shows that the two Swiss sugar factories are top-ranking compared to other European factories with regard to an efficient use of energy.

The examples of the Schweizer Zucker AG sugar factories at Frauenfeld and Aarberg show that the energy consumption is significantly reduced in the process stage of juice production thanks to the installation of large extraction towers. Since their construction in 1899 (Aarberg) and 1963 (Frauenfeld), the two sugar factories have repeatedly invested in new technologies and increased their efficiency continuously.

Since 2003, a new extraction tower has been running at Frauenfeld factory with a daily processing rate of 10,000 t of beet (ø 9.6 m, extraction length: 22.7 m); at Aarberg, a new tower has been in operation since 2010 for 12,000 t/d (ø 10.6 m, extraction length: 22.8 m). The example of these two factories describes how investments in extraction equipment helped to reduce sugar losses and energy requirements.

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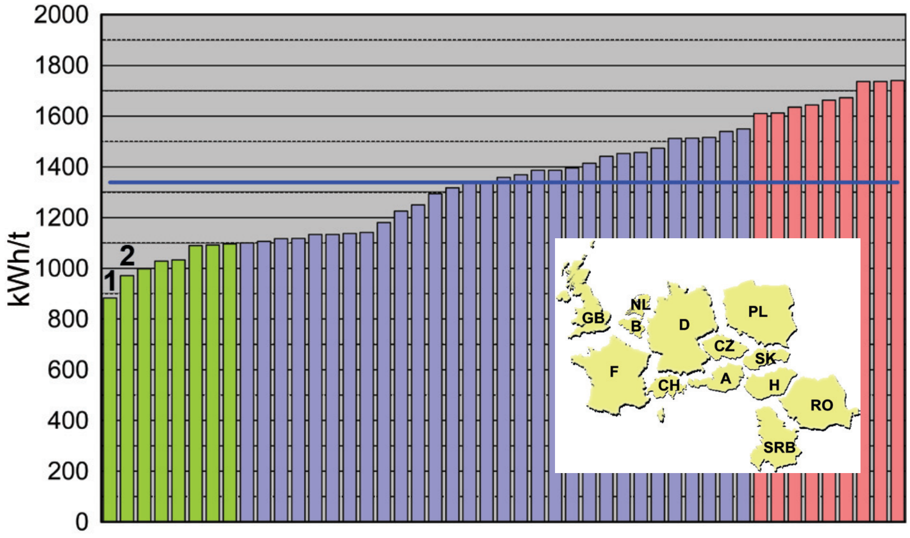

Fig. 1: Specific fuel consumption in kWh/t of sugar of selected European factories in 2006/07 [1] (modified). 1 Aarberg sugar factory. 2 Frauenfeld sugar factory.

2 Swiss sugar factories: A good example of energy efficiency

2.1 Frauenfeld sugar factory

The Frauenfeld sugar factory is a beet sugar factory where no thick juice campaigns are run. As a special feature at Frauenfeld since 2001, a organic (bio) campaign is performed once per year before the beet campaign (with the exceptions of 2005 and 2010, when no organic sugar was produced). The processing rate of an average campaign is therefore lower by about 200 t/d than without considering the organic campaign. During an organic campaign, a maximum of 6000 t/d of beet is processed to produce organic sugar, with limited addition of processing aids. To increase the organic sugar yield, production is finally interrupted for approximately two shifts. Taken as a whole, the organic campaign thus raises the energy consumption compared to conventional beet sugar manufacture.
In the years 2000–2002, the factory processed on average 7600 t/d of beet using an extraction tower that had become clearly too small over the years, since it was designed for a nominal rate of 6000 t/d (ø 7.2 m, extraction length: 21.6 m, year of construction: 1976). With 17.0% of sugar contained in fresh cossettes, the resulting extraction losses amounted to about 0.43% on beet with a raw juice draft of approximately 112% on beet.
The aim of modernisation of the extraction plant in 2003 was to reduce not only the factory's energy consumption considerably but also the sugar losses, with a more or less constant beet processing rate. For the 2003 campaign, a modern and larger BMA extraction tower was installed (ø 9.6 m, extraction length: 22.7 m, BMA-type: Tower 2000) with a nominal capacity of 10,000 t/d. The appropriate countercurrent cossette mixer (ø 6.0 m, length: 8.0 m) for nominally 8000 t/d has been in operation for an optimum raw juice cooling since 1995. Figure 2 shows the operating data of extraction before and after installation of the extraction tower.
The results after the first campaign of the new extraction tower confirmed the design calculations. Not only the extraction sugar losses decreased from 0.48% in 2002 to 0.28% on beet in 2003; the raw juice draft, too, could be considerably reduced from 110% (2002) to 102% on beet (2003). The lower raw juice draft reduced, as expected, the raw juice temperature by approx. 8 K. For the energy consumption, there was only a negligible change from 1143 kWh/t of crystal sugar in 2002 to 1123 kWh/t in 2003, because the sugar content of the beet was low in 2003 (16.8%) and the 2003 campaign, which was difficult as a whole, required additional energy.
The long-term comparison, however, showed that the specific energy consumption clearly sank by 12.2% from 1135 kWh/t of sugar (2000–2002) to 996 kWh/t of sugar (2003–2014). Meanwhile, the Frauenfeld sugar factory managed to reduce the specific energy consumption permanently to less than 1000 kWh/t of sugar. Given that beet processing rate has been continuously increased since 2003 from 7600 t/d to 9650 t/d (2014), another tower extension has become technologically necessary from today's point of view.

2.2 Aarberg sugar factory

The sugar factory at Aarberg is a beet sugar factory applying mechanical vapour compression in the evaporator plant and the sugar house. In addition to the beet campaign, stored thick juice is processed in a thick juice campaign.
Before the extraction plant was modernised in 2010, the factory's average processing rate amounted to 8700 t/d of beet with one extraction tower which was designed for a nominal rate of

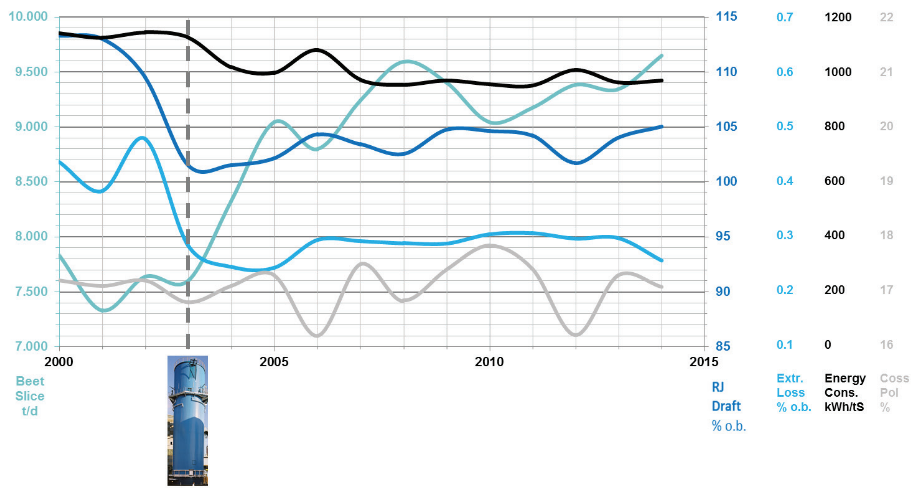

Fig. 2: Frauenfeld sugar factory: Selected operating data (annual average values) of extraction from 2000 to 2014 with installation of a new extraction tower in 2003

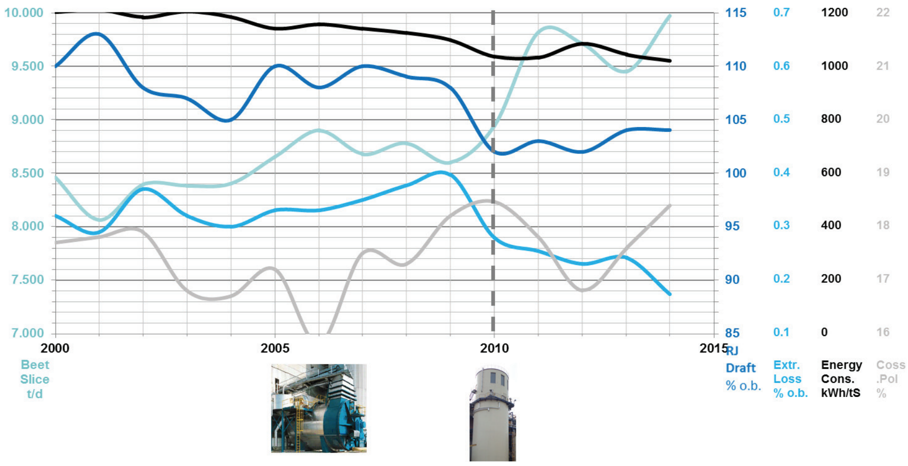

Fig. 3: Aarberg sugar factory: Selected operating data (annual average values) of extraction from 2000 to 2014 with installation of new counter-current cossette mixer in 2006 and a new extraction tower in 2010

8000 t/d of beet (ø 9.2 m, extraction length: 19.1 m; year of construction: 1985). The fresh cossettes contained 17.2% of sugar and the resulting extraction losses amounted to about 0.36% on beet with a raw juice draft of approx. 109% on beet. Like the Frauenfeld factory, also the Aarberg sugar factory aimed at reducing the factory's energy consumption and sugar losses considerably by modernising the extraction plant. For the 2010 campaign, a larger BMA extraction tower of the Tower 2000 type was installed, too, with a nominal capacity of 12,400 t/d of beet (ø 10.6 m, extraction length: 22.8 m). The countercurrent cossette mixer for nominally 8000 t/d (ø 6.0 m, length: 8.0 m) has been in operation there since 2006.
The operating data of extraction in Figure 3 show the results obtained after installation of the new extraction tower for the 2010 campaign. When comparing the 2010 campaign (after modernisation) to the 2009 campaign (before modernisation), the extraction losses sank (2009: 0.40% on beet; 2010: 0.28% on beet) with a similar beet processing rate but reduced raw juice draft, as did the specific energy consumption (2009: 1098 kWh/t of sugar; 2010: 1036 kWh/t of sugar).
In the long-term, the specific energy consumption of the Aarberg factory clearly decreased. Referred to the periods examined before and after modernisation, this means a reduction of the specific energy consumption by 7.9% (2005–2009: 1132 kWh/t of sugar on average; 2010–2014: 1043 kWh/t of sugar on average).

2.3 Extraction losses

The aim to reduce the sugar losses without increasing the specific energy consumption can only be reached by increasing the extraction time, as implemented at Frauenfeld and Aarberg. As from the first campaign after modernisation, each of the two factories has been working with a raw juice draft of 102% on beet and could limit the sugar losses to 0.28% on beet. As expected, the vectors of the changes in the diagram of sugar losses against the raw juice draft run from top right to bottom left and cut the iso-lines for the "extraction time" parameter in the direction of the increasing extraction time (Fig. 4). Both ways, however, do not run exactly in parallel, which is to be attributed to the slightly changed sugar content in the campaigns compared. At Aarberg, the sugar content increased from 2009 to 2010 by 0.3%, whereas at Frauenfeld, the sugar content sank by 0.4% from 2002 to 2003.
Limits are set for further prolongation of the extraction time, since also the extraction of nonsugars would increase. Practical experience with plants installed show that it is possible to reduce the raw juice draft down to 100% on beet with still acceptable extraction losses and without a noticeable increase of the nonsugar content in the dry substance of the raw juice [3].

2.4 Specific energy consumption

The specific energy consumption of the sugar factory is decisively determined by the raw juice draft. A lower draft results in a higher dry substance content of the raw juice and thus leads to a lower water evaporation and also to smaller juice mass flows in the juice purification stage.
The practical evidence is given in Figure 5. It represents the specific energy consumption of the Frauenfeld and Aarberg factories against the raw juice draft, and shows the difference between operation with a small old extraction tower and a large new tower. The small tower before modernisation did not allow a reduction of the raw juice draft with regard to the sugar losses, whereas with the large towers, the raw juice draft amounts to 103% on beet on average for the campaigns compared. At Frauenfeld the energy savings due to the reduced raw juice draft are higher than at Aarberg. Both change arrows

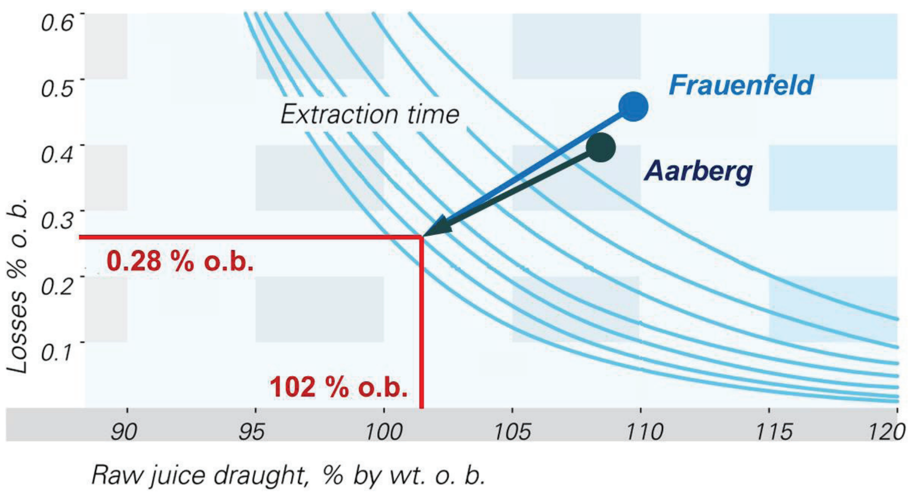

Fig. 4: Raw juice draft and sugar losses of the Frauenfeld and Aarberg sugar factories before and after modernisation of the extraction plant (campaign average)

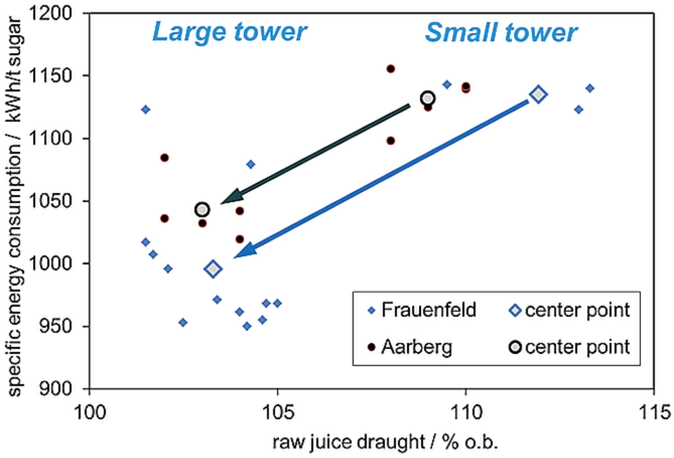

Fig. 5: Raw juice draft and specific energy consumption (campaign average) of the sugar factories at Frauenfeld (2000 to 2014) and Aarberg (2005 to 2014)

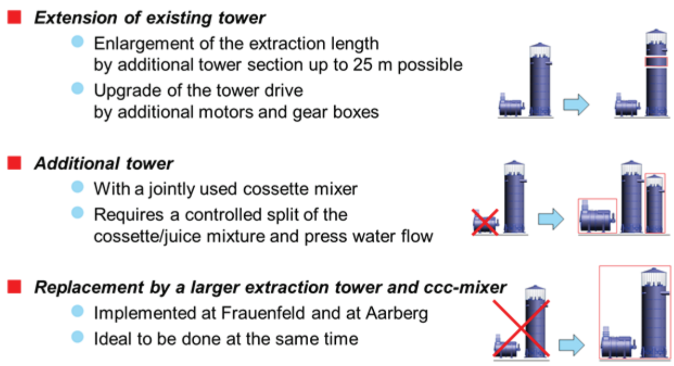

Fig. 6: Concepts for the extension of extraction plants

run in parallel, so that all in all, a reduction of the specific energy consumption of about 15 kWh/t of sugar per 1% of reduced raw juice draft is found.

The different levels of the specific energy consumption of Frauenfeld and Aarberg are due to the difference in the respective factory concepts, such as thick juice storage and vapour compression. The broad distribution of the operating results for the individual campaigns is mainly to be attributed to the varying sugar contents of the fresh cossettes.

3 Upgrade possibilities of an extraction plant

3.1 Concepts for extension of extraction plants

Existing equipment items of the extraction plants at Frauenfeld and Aarberg were replaced by new ones, which allowed for a higher processing rate, a reduction of the energy consumption and an improvement of the sugar yield. Prior to these replacements, various possibilities for the extension of extraction plants had been examined.

The decision-making process does not only consider the desired operating data, such as processing rate, raw juice draft or sugar losses, but also the local conditions, such as the available footprint, age and condition of existing equipment, and the budget available. It is discussed in principle, whether an extension of the extraction tower, the combination of existing and additional equipment, or the replacement of existing equipment items by new ones is reasonable.

The most cost-efficient variant is the extension of the extraction length of an existing extraction tower (Fig. 6 at the top). The maximum extraction length realised is approx. 25 m, which means the extension of the extraction volume is limited and to be applied only to moderate processing rate increases. In addition, it has to be considered that the diameter of the extraction tower limits the processing rate hydraulically. Together with a tower extension, the drives are also upgraded in most cases to be able to deliver the necessary torque at the extraction tower. Repair measures are often combined with tower extension, such as the complete modernisation of the drive unit.

In case of substantial processing rate extensions, the combination of existing and additional equipment is possible (Fig. 6 in the middle). In historically grown factories, several processing lines that work in parallel can often be found, such as the combination of several extraction apparatuses with one joint cossette mixer. The advantage of flexibility in processing has to cope with the disadvantageous extra efforts for operation and maintenance. The solution that is often preferred for reasons of space is the operation of two extraction towers with one joint large-size countercurrent cossette mixer.

A radical solution is shown in Figure 6 at the bottom: the replacement of small equipment items by large ones. Currently, nominal processing rates of up to 16,000 t/d can be implemented in one line. Although initial and replacement installations require high investment costs, they ensure a long-lasting optimal and failure-free beet processing with the lowest operating and maintenance costs.

The comparison of all possibilities for the extension of the extraction plant has to be tailored to each project with its individual requirements and conditions. In such cases, a conceptual study may help find a decision.

3.2 Material selection

The use of new equipment for the extraction plant implies the question whether the new equipment can cope with future technological developments. Given that the service life of an extraction tower easily amounts to several decades, the effects and how to face them should be analysed, especially in case of innovations that are to be expected relatively in the short term.

The discussion about the optimal pH value for extraction can be used as a relevant example for a possible technological development in the field of extraction. The currently applied, slightly acidic mode of operation for extraction (pH value in the tower centre: 5.0–5.6) could be followed by an increasingly acidic extraction. Such a modified mode of operation can contribute to an increase in the dry substance content of pressed pulp [4]. An increased level of sucrose inversion has also to be taken into consideration.

With a more acidic mode of operation, the pH value in the tower centre ranges permanently between 4 and 5, in the top part of the tower very close to pH = 4 (Fig. 7). The low pH value increases the danger of pitting corrosion at the equipment surfaces that are in contact with acidic media.

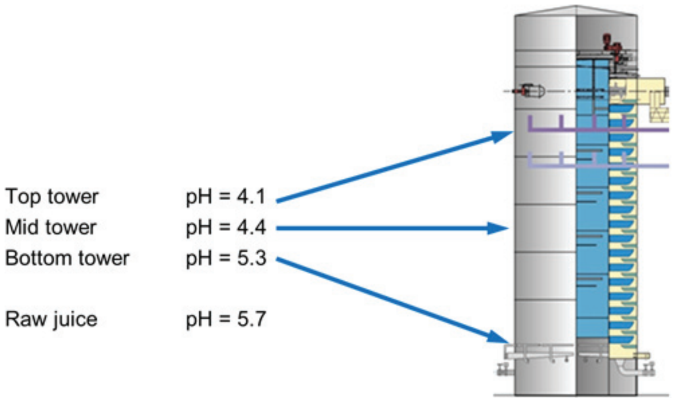

Fig. 7: pH value profile at an extraction tower with an increasingly acidic mode of operation

For the selection of the suitable material, the resistance to corrosion and abrasion has priority from the technical point of view (Table 1). Materials with a very high resistance are 1.4404, 1.4462 and 1.4571; they are suited for cladding but also as solid material. Further criteria are investment costs, maintenance costs, service life and the use of disinfectants, which have an influence on the decision for the appropriate solution.

Table 1: Resistance to corrosion and abrasion of various steel grades for the use in extraction plants

Material	Corrosion resistance	Abrasion resistance	Comment
Mild steel	–	–	Not for parts in contact with product
Usual stainless steel at pH = 5–6	++	++	For parts in contact with product Cladding or solid
Enhanced resistance stainless steel at pH = 4–5	+++	+++	For parts in contact with product Cladding or solid

4 Conclusion

The replacement of the originally existing extraction plants by new larger extraction towers in the sugar factories of Frauenfeld and Aarberg led to a clear reduction of the specific energy requirements of the factories and to a lower sugar loss in the pressed pulp. For selection of the size of the extraction plant, the intended raw juice draft was of highest importance, which could be clearly reduced by modernisation.
The basis for the correct selection of the steps to be performed for such an extension and modernisation of the extraction plant is the examination of different ways that accomplish the goal. There are different solutions for a capacity extension, with differently strong advantages and disadvantages depending on the local conditions. With regard to the future mode of operation, also the material selection may be a factor for the definition of a new extraction tower.

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