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# Energy Transparency in Compound Feed Production

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**Abstract.** The finite nature of energy resources forces animal feed producers to minimize their energy consumption. As a first step towards energy conservation, more transparency over the energy usage in compound feed plants is required. However, current feed processing strategies do not consider the high dynamics in products and process conditions, nor do they augment the operator's energy awareness. Digital support tools, such as virtual and augmented reality, can close the gap between required information (e.g., actual operating conditions) and knowledge of operators. In this paper, first, a methodology for making energy values transparent is presented. Then the state of the art of digital tools and related requirements are discussed, followed by a description of the integration of a digital tool in a case study of a compound feed plant located in northern Germany.

**Keywords:** Energy · Animal Feed · Digital Tools

## 1 Introduction

The production of animal feed is associated with high dynamics and energy-intensive processes [2, 13]. Total feed production volumes are projected to expand substantially through 2050 to meet the needs of a growing and increasingly affluent population [6, 13]. Given the limited existence of energy resources along with the Co2-reduction plans, the implications for animal feed production merit closer consideration [6]. Yet, most animal feed producers produce on customers' demands and in small batch sizes, making energy protocols challenging. Electricity bills, on the other side, do not disclose how much energy on which product is mainly spent. Today, energy consumption in animal feed production is poorly explored, and energy conservation is still considered as a secondary effect with no specific urgency [12].

The traditionally hidden nature of energy has been observed as one barrier to energy awareness, and making energy information accessible is suggested to empower energy savings [9, 5]. Indeed, transparency of the energy usage of a process for creating the desired product (i.e., animal feed) lays the foundation for energy savings [9]. Many suppliers of energy metering equipment may provide

some visual solutions. Yet, their software systems do not address the visibility problem in an ideal way. Usually, the software is cost-intensive, which enlarges the restraint of feed producers to invest in such a system. Furthermore, this software mainly incorporates standards and basic guidelines (e.g., ISO 50001), as well as it mainly analyses the energy consumption of a plant with an emphasis on the technical aspect. In particular, a feed processing plant of northern Germany has limited process-specific solutions for assisting operative decisions across changing products and operator skills. At the moment, there is a lack of a support tool based on process data that does not intervene in the ongoing operations but provides appropriate (visual) feedback of the consumed energy of a process from a controlling perspective.

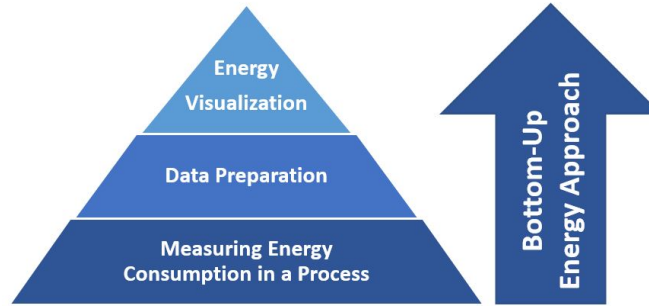
Digital support tools have the potential to make energy consumption visible. Then an operator gains a deeper understanding of the process, and related energy usage [9, 5]. When it comes to running operations, a digital tool can also help with operator engagement and memory retention, as well as boosting energy awareness [9]. In the following sections, this paper compiles a methodology for energy transparency in feed processing and includes the state of the art of digital support solutions and related requirements. Then, for a case study of an animal feed producer in northern Germany, the deployment of a digital tool is described.

## 2 Methodology to Energy Transparency in Compound Feed Production

Metering energy values in a systematic, regular and repetitive way, one speaks of energy monitoring. If the gained energy data are being augmented with output values, e.g., consumption per product produced, and this key figure is used in a controlling way, which represents a tool for generating transparency, energy improvements can be supported [7]. The controlling scope within the field of energy involves, according to [5, 7], (1) generation of energetic information related to a process, (2) processing of energy information via controlling instruments within the process, (3) provision of energy information in a comprehensible form to the process operators. Further, two fundamental ways of measuring energy consumption with the above controlling scope can be noted [7]:

- Top-down: Measuring the overall energy consumption (i.e., for a production site by the energy supplier) and subsequent derivation of information for the causative processes.
- Bottom-up: Metering every single consumer along with the derivation of information.

Because of higher and lower energy consumers and the high dynamics of the process conditions in feed processing, the bottom-up approach allows this study more flexibility, agility and consistency. Process parameters are conceived as controlling instruments inside a process, then the bottom-up approach (see



**Fig. 1.** Proposed approach to energy transparency in compound feed production

Fig. 1) evaluates the consumption of each process in feed production. A foundation of energy controlling in terms of improvements is energy monitoring. Hence, a systematic and regular capture of all relevant energy data of a process is required. Then data preparation is performed for the evaluation of the energy consumption. In this approach, data preparation basically means the generation of comparability and detailed information. The expressiveness and transparency of measured values can be raised by generating appropriate key indicators by associating energy values with the process outputs (product). The use of the specific energy consumption, as the energy consumption per tone of the product, builds a key indicator to the energy. Further, energy figures and resulting information are documented, such that new criteria or targets towards energy strategies can be better and faster understood and reconfigured.

Following the development of energy key figures, a detailed contemplation of the energy values of a product to the control parameters of the process and product specifications is required. Due to the several parameters affecting the energy, visualization instruments must be deployed in order to master the complexity. Energy-saving potentials can be revealed with the help of digital (visual) instruments. Better insights into the operating conditions and related consumed energy, as well as quality standards, enables fine-tuning process configurations without compromising the product quality. Then a fine-tune of process settings is an opportunity for energy savings.

### 3 Digital Support Tools

#### 3.1 State of the Art

Visualizations like 3D models of equipment, visual representations of key performance indicators, and simulations are some of the possibilities that digital support tools can provide for energy transparency [11]. Using virtual reality (VR) with the aim of visualizing energy-related data, key figures, and energy flows are the most practical applications shown by [11]. As an example, some

studies visualize key figures of a hydraulic pump through VR or investigate the energy analytic using VR within the context of digital twins [1].

Visualization methods of process data assisting operator decisions by augmented reality (AR) technology are studied in [8]. As a detailed analysis of data as well as the complexity of technical systems may pose great challenges to workforces, [8] presents different visualization approaches that show context-related information through AR. Some authors in the energy efficiency of buildings investigate visualizations for illustrating energy values. [10] studies visual representations in the form of AR for educating school students about energy consumption. The availability of actual measurements, such as energy usage, indoor and outdoor luminosity or temperature, facilitates the realization of energy-related strategies, as it engages users to save energy [10].

### 3.2 Requirements of Digital Support Tools for Energy Transparency

Against the existing challenges to energy conservation in feed processing plants, the following requirements for making the consumed energy more transparent and valuable should be considered:

**Availability of data.** Data of the process and related consumed energy need to be gathered through sensors, and interfaces to data collections and digital tools must be implemented.

**Mitigation of process complexity.** This paper suggests, first, the creation of energy indicators, linking them to relevant parameters affecting energy values, i.e., tons of product order. Second, other relevant parameters to energy usage, such as process conditions and product specifications, are well-known.

**Easy to use and mobile.** Workforces have to carry the tool easily. The tool should be ergonomic and have enough battery provision. Furthermore, the visualization should be user-friendly, simple to understand, and reachable without much setup.

## 4 Case Study

A compound feed plant refines agricultural raw materials such as corn, wheat, and soy. Feed mixtures can be up to 50 different components; also, vitamins and enzymes are added [3]. Only in Germany, the total amount of animal feed to be produced is about 23,1 million tons per year: 9.8 million tons for pigs, 6,9 million tons for cattle, and 6.4 million for broilers [4].

The entire feed production line of an animal feed producer was examined concerning energy demands. The compacting (pelleting) process showed the highest share in electrical and thermal energy consumption. Mainly, pelleting combined with short-term conditioning contains high energy values; about 60% of the total energy demand in the plant is used for pelleting. Further, 80% of the products are compacted, as pelleting generates an improved animal digestion performance. Conditioning is a process of converting mixed mash with heat, water, pressure,



**Fig. 2.** Pellets after compaction in a press machine (Source: DVT, p.2)

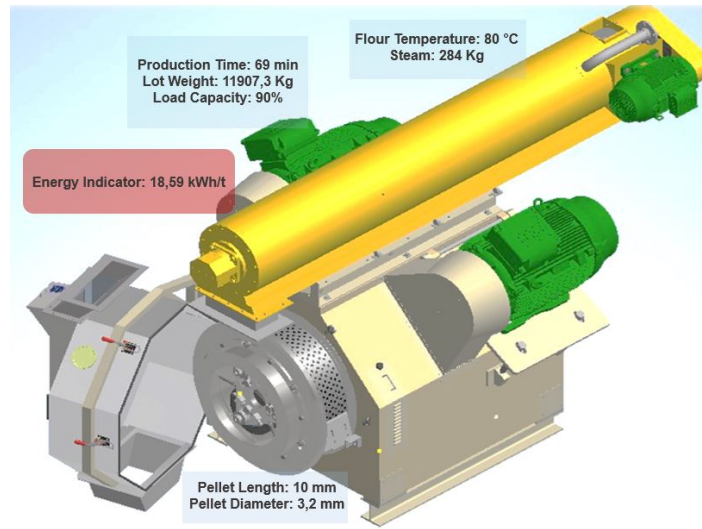
and time, to a physical state that is more suitable for compaction. Moreover, the integrated thermal process modifies starch content and improves tastiness. By adding steam, the moisture of mixed mash increases. Because of the gaseous state of the steam, the moisture is homogeneously dispersed in the mixture. Moreover, the steam condenses uniformly on the particle surfaces and provides better lubrication of the pellet, reducing the wear and increasing the production rate. Applying too much heat or water has a negative effect on the quality of the pellet and may lead to the plugging of the press die. In Fig. 2, the feed mixture goes through a die with specific dimensions, openings, and thickness for producing desired pellets as compact cylinders.

#### 4.1 Results and Discussion

The process-related data for the case study of a north Germany's feed producer were already available in electronic form. The data were extensive, including parameter values, energy usage, feed formulations, and quality requirements. First results show that the compound feed has a mean order of about 16 tones of product to be pelleted. Mainly, the energy consumption of pelleting varies from 10 to 15 kWh per tone of pellets. Mostly this consumption is about steam generation, compaction, and subsequent cooling.

The pelleting process is currently manually operated. Depending on the quality specifications, the parameters of the pelleting process are tuned by hand on the basis of operators' experience. Too much energy is generally consumed with this method of intuition and experience, as operators only control what they can see through their eyes, which is the product quality. Then operators are not aware of the effects of the process settings on the energy consumption, nor can they make critical decisions to conserve energy.

Figure 3 presents the implemented AR-based digital solution for the particular case study of pelleting. The model of the press machine was built with computer-aided designed software. The main components, such as motors, conditioner, dies, etc., are recreated. The digital tool can be overlaid on the press machine for showing actual parameter values of the process (e.g., temperature



**Fig. 3.** Digital support tool for a pelleting process

and steam). As the quality specifications guide the process, a provision of product characteristics, such as lot weight, length, and diameter of the pellets, are displayed in the AR solution. Further information as color energy labels (green, yellow, and red) add insights into the energy performances of each process activity - as conditioning and compacting- by, for instance, comparing actual to mean energy values or energy target values. Values of the pelleting process can be read from a database and visualized into the solution using interfaces. In the plant, the disposal of mobile devices (tablets, smartphones, or glasses) makes it possible to interact and provide visual feedback of the process conditions.

The definition and inclusion of energy figures and process characteristic data in visual form engage operators in interpreting the energy usage (in KWh) per product produced (in ton). As a result, the hidden impacts of manual settings on energy consumption become more visible and reveal energy-saving potentials. Then operators gain a better understanding of the process condition and its correlation to the consumed energy, as they can compare values between orders and quality characteristics using visual information (data). The operating parameters can thus be fine-tuned for energy conservation without affecting the pellet quality.

## 5 Conclusions

This paper presents an approach for gaining more visibility and control of energy consumption in animal feed production. Then a novel digital support tool for engaging operators in energy-conservation actions is implemented. For the process data visualization, a pelleting process, as the higher consumer of the



feed processing plant, is selected. The presented digital 3D model helps identify critical energy figures and related process parameters, as well as it highlights the energy consumption of process activities using color labels.

First discussions and evaluations indicate that the provision of actual process information (data) increases operator knowledge and skills. Then operators can better fine-tune the operating parameters for energy savings without altering the quality of the feed. However, the deployment of the AR solution can only be as good as the available data and their quality. Particularly for older equipment, reading and interpreting meter data and their metrics requires expert knowledge. In addition, massive unstructured data, e.g., product attributes, can make the selection and consistency of relevant data very challenging since feed mixtures have a wide range of components. Further research is required to investigate better the relationships of additional relevant parameters influencing the energy usage in pelleting, such as the fluctuating quality of the raw materials. As an alternative to energy indicators, data-mining methods could optimize and/or forecast process values for energy savings.

## Acknowledgments

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## References

1. Abdallah, A., Primas, M., Turcin, I., Traussnigg, U.: The potential of game development platforms for digital twins and virtual labs. In: IFIP International Conference on Advances in Production Management Systems. vol. 592, pp. 117–121. Springer, Cham (2020). [https://doi.org/10.1007/978-3-030-57997-5\\_14](https://doi.org/10.1007/978-3-030-57997-5_14)
2. Alvela Nieto, M.T., Nabati, E.G., Bode, D., Redecker, M.A., Decker, A., Thoben, K.D.: Enabling Energy Efficiency in Manufacturing Environments Through Deep Learning Approaches: Lessons Learned. In: IFIP International Conference on Advances in Production Management Systems, vol. 567, pp. 567–574. Springer, Cham (2019). [https://doi.org/10.1007/978-3-030-29996-5\\_65](https://doi.org/10.1007/978-3-030-29996-5_65)
3. DV-Tiernahrung(DVT): Pelletieren von mischfutter. p. 2 (2010), [https://www.dvtiernahrung.de/fileadmin/redaktion/redaktion/Aktuelles/2009/Einladung\\_Pelletieren\\_2010.pdf](https://www.dvtiernahrung.de/fileadmin/redaktion/redaktion/Aktuelles/2009/Einladung_Pelletieren_2010.pdf)
4. DV-Tiernahrung(DVT): Mischfutterproduktion 2020: Gutes ergebnis trotz steigender herausforderungen (2020), <https://www.dvtiernahrung.de/aktuelles-detail/mischfutterproduktion-2020-gutes-ergebnis-trotz-steigender-herausforderungen>

5. Grahl, A., Grohne, C., Ladiges, K., Peters, S. (eds.): *Handbuch für betriebliches Energiemanagement: Systematisch Energiekosten senken*. Deutsche Energie-Agentur, Berlin, stand: 12/2014 edn. (2014)
6. Haberl, H., Erb, K.H., Krausmann, F., Bondeau, A., Lauk, C., Müller, C., Plutzer, C., Steinberger, J.K.: Global bioenergy potentials from agricultural land in 2050: Sensitivity to climate change, diets and yields. *Biomass & bioenergy* **35**(12), 4753–4769 (2011). <https://doi.org/10.1016/j.biombioe.2011.04.035>
7. Hesselbach, J.: *Energie- und klimaeffiziente Produktion: Grundlagen, Leitlinien und Praxisbeispiele* (2012)
8. Kalkofen, D., Sandor, C., White, S., Schmalstieg, D.: Visualization Techniques for Augmented Reality. *Handbook of Augmented Reality* pp. 65–98 (2011). [https://doi.org/10.1007/978-1-4614-0064-6\\_3](https://doi.org/10.1007/978-1-4614-0064-6_3)
9. Karlin, B., Zinger, J.F., Ford, R.: The effects of feedback on energy conservation: A meta-analysis. In: *Psychological bulletin*. vol. 6, p. 1205–1227 (2015). <https://doi.org/10.1037/a0039650>
10. Mylonas, G., Triantafyllis, C., Amaxilatis, D.: An Augmented Reality Prototype for supporting IoT-based Educational Activities for Energy-efficient School Buildings. *Electronic Notes in Theoretical Computer Science* **343**, 89–101 (2019). <https://doi.org/10.1016/j.entcs.2019.04.012>
11. Nabati, E.G., Alvela Nieto, M.T., Decker, A., Thoben, K.D.: Application of Virtual Reality Technologies for Achieving Energy Efficient Manufacturing: Literature Analysis and Findings. In: *IFIP International Conference on Advances in Production Management Systems*. pp. 479–486. Springer, Cham (2020). [https://doi.org/10.1007/978-3-030-57993-7\\_54](https://doi.org/10.1007/978-3-030-57993-7_54)
12. Paul, M., Cerqueus, A., Schneider, D., Benderbal, H., Boucher, X., Lamy, D., Reinhart, G.: Reconfigurable digitalized and servitized production systems: Requirements and challenges. In: *IFIP International Conference on Advances in Production Management Systems*. vol. 592, p. 501–508. Springer, Cham (2020). [https://doi.org/10.1007/978-3-030-57997-5\\_58](https://doi.org/10.1007/978-3-030-57997-5_58)
13. Pelletier, N., Audsley, E., Brodt, S., Garnett, T., Henriksson, P., Kendall, A., Kramer, K.J., Murphy, D., Nemecek, T., Troell, M.: Energy Intensity of Agriculture and Food Systems. *Annual Review of Environment and Resources* **36**(1), 223–246 (2011). <https://doi.org/10.1146/annurev-environ-081710-161014>

## Reviews

"In this paper, first, the methodology and requirements for making energy values visible are presented, and then a digital support solution to energy transparency in a feed production scenario is presented".

1. "Try adding some newer references. Reference some APMS papers"

We have considered newer and APMS references. Please refer to references 1, 2, 11 and 12.

"This paper tackles the important issue of energy conservation and transparency over the energy usage in feed processing. The authors compiled a methodology for energy transparency and then propose a digital support tool as an instrument to better understand and control energy consumption in a compound feed plant case. The digital model of pelleting should help identify critical energy figures and highlight energy consumption of process activities using color labels. The writing and the structure of the paper are clear. I found the paper approachable and interesting. However, several issues require additional clarification". "2."In the State of the Art section, the usage of VR and AR technology for visualization of energy-related data is discussed, but in the Results and Discussion section, it is not made clear whether the VR and AR technology is proposed for the data visualization. It states: the tool is added to the pelleting process for assisting operators to better understand and control the energy consumption of the process using a mobile device (tablet, smartphone, or glasses). The proposed tool and its integration in the production process should be more clarified."

Further information was added in the section of results and discussion. Basically it describes an AR-solution built in CAD software as a 3D model.

"2.In the Results and Discussion section, it is revealed that the proposed tool is based on the application case and the data collection in the north Germany feed producer. I suggest that this should be further clarified in the introductory part in order to make the development of the methodology as clear as possible.

It was highlighted in the introduction part

"2.The authors have made suggestions for future research, but they did not discuss the possible limitations and alternatives to the proposed methodology.

Possible challenges, limitations and alternatives were added in the conclusion part as follows:

"However, the deployment of the AR solution can only be as good as the available data and their quality. Particularly for older equipment, reading and interpreting meter data and their metrics requires expert knowledge. In addition, massive unstructured data, e.g., product attributes, can make the selection and consistency of relevant data very challenging since feed mixtures have a wide range of components. Further research is required to investigate better the relationships

of additional relevant parameters influencing the energy usage in pelleting, such as the fluctuating quality of the raw materials. As an alternative to energy indicators, data-mining methods could optimize and/or forecast process values for energy savings ”.

”2.”Finally, authors should indicate the sources and copyright status of the figures included in the manuscript.”

Figure 1 and 3 are created by us (BIK Institute)

Source of Figure 2 was added

””The paper describes a solution to give factory operators visual feedback of the energy usage of the process. An animal feed production process has been as the case study. The proposed solution is interesting and sounds useful. However, the authors could describe better:” ”3.”Did they implement the solution or are they describing just the idea of the solution?”

Yes, we did and we described it in more detail. Test version is under evaluation at manufacturer side.

”3.”What would the operator do with the provided energy consumption information? The product requirements obviously guide the process, so what could the operator do to save energy?”

We described it in more detail. In summary, the operator learns about better adjusting process parameters manually, as the energy consumption and process related information provides the possibility of better process control. The aim is the conservation of energy through a fine-tune of process parameters without damaging the product quality.

”3.”Minor comments:

- page 2: ”as only a few standards..” The sentence seems to miss the main sentence: so what does the low amount of standards indicate?

- page 3: ”high dynamics of i.e. ..” Do you mean ”e.g.,”?”

Rewritten and changed.

Thank you for your feedback!