VDI ZRE Brief Analysis No. 25: Resource efficiency in industry-related crafts

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VDI ZRE's brief analyses provide an overview of current developments in the field of resource efficiency in research and industrial practice. They contain a compilation of relevant research results, new technologies and processes as well as examples of good practice. The brief analyses thus provide a broad audience from industry, research and administration with an introduction to selected resource efficiency topics.

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Resource efficiency in industrial-related skilled crafts

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LIST OF ABBREVIATIONS

AR	Augmented reality
BIM	Building information modelling
BW	Baden-Württemberg
CO_2	Carbon dioxide
CAH (DHKW)	Compressed-air-and-heat unit (Druckluft-Heiz-Kraftwerk)
DIHK	Association of German Chambers of Industry and Commerce (Deutscher Industrie- und Handelskammertag)
DMS	Document management system
ERP	Enterprise resource planning
HWK	Chamber of skilled crafts (Handwerkskammer)
HwO	Trade and crafts code of Germany (Handwerksordnung)
IHK	Chamber of industry and commerce (Industrie- und Handelskammer)
ISO	International Organization for Standardization
IT	Information technology
SME	Small and medium-sized company
kWh	Kilowatt hours
NFC	Near field communication
NRW	North Rhine-Westphalia
PSS	Product-service system
QR code	Quick Response Code

RE	Resource efficiency
RFID	Radio-frequency identification
UVV	German accident prevention regulations (Unfallverhütungsvorschriften)
VDI	Association of German Engineers (Verein Deutscher Ingenieure e. V.)
VDI ZRE	VDI Competence Center for Resource Efficiency (VDI Zentrum Ressourceneffizienz GmbH)
VR	Virtual reality
3D	Three-dimensional
4M method	Manpower – Machine – Material – Method
5S method	Sort – Straighten – Shine – Standardise – Sustain
ZDH	Central Association of German Skilled Crafts (Zentralverband des Deutschen Handwerks e.V.)

1 INTRODUCTION

Skilled crafts are a key section of the German Mittelstand (SMEs) and form part of the bedrock of the German economy. The skilled craft sector consists of various trades, some of which are material-intensive. Here, the potential for resource efficiency can be tapped both within and across sectors – i.e., material and energy can be saved and costs reduced.

Skilled crafts are characterised by having resource-efficient production from the ground up. Traditionally, craft businesses employ qualified specialists, manufacture individualised products of high quality, carry out repairs and only travel short distances because of their regional client base.[1] This saves energy and materials. Nevertheless, it is estimated that many decision-makers in small and medium-sized craft businesses are not yet aware of the benefits of resource efficiency approaches, in particular the associated cost savings and competitive advantages.

The aim of this Brief Analysis is to provide industrial-related skilled crafts[2] with ideas and suggestions regarding the possibilities of resource-efficient production and to close any existing information gaps by presenting measures and providing references to further advice and support.

For these, after a short introduction (Chapter 2), resource efficiency measures in production infrastructure will first be presented (Chapter 3.1). These measures can be applied across all sectors and are not specifically tailored to one industry. In particular, the topics of compressed air (Chapter 3.1.1), tool management (Chapter 3.1.2) and the optimisation of storage and logistics (Chapter 3.1.3) will be examined in more detail.

Subsequently, the link between digitisation measures and resource efficiency will be set out (Chapter 3.2). A total of eleven measures and their resource efficiency potential will be presented here. Of these, the measures of particular interest to industrial-related skilled crafts, namely end-to-end data integration (Chapter 3.2.1), virtual product development (Chapter

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[1] Cf. ZDH (2012), p. 1.

[2] In the context of this Brief Analysis, "industrial-related skilled crafts" covers large companies with a high degree of mechanisation and automation that process or further process raw and intermediate products.

3.2.2), positioning and localisation systems (Chapter 3.2.3) and cloud computing (Chapter 3.2.4), will be illuminated in greater detail, with advice given on introducing these instruments within a company.

Finally, examples of good practices that have successfully implemented resource efficiency measures are presented for both areas - production infrastructure and digitisation (Chapter 4).

The resource efficiency potential identified in the Brief Analysis, achieved in particular through optimised operating procedures and the digitisation of business processes, could also be of interest to companies outside the industrial-related skilled craft sector and provide them some food for thought.

2 INDUSTRIAL-RELATED SKILLED CRAFTS

2.1 Classification of the industrial-related skilled craft

Skilled crafts are understood as a form of business that essentially carry out tasks “by hand”, thereby generating added value. The term “craft” (“Handwerk”) as such is not defined by law, but is subdivided into three groups in the trade and crafts code of Germany (HwO): crafts requiring a licence (Annex A with 41 trades, HwO), crafts not requiring a licence (Annex B, para. 1 with 53 trades, HwO) and craft-like trades (Annex B, para. 2 with 57 listed trades, HwO). For trades requiring a licence, the master craftsman qualification is mandatory; for trades not requiring a licence and craft-like trades, no such qualification is required. Increasingly, however, optional master craftsman examinations are also to be offered for these types of work [3]

Among other similar terms, “craft” must be distinguished from “industry”. Depending on the categorisation, registration is made either with the Chamber of Skilled Crafts (HWK) or the Chamber of Industry and Commerce (IHK) [4] The assessment of the respective categorisation is based on “the overall picture of the business in question based on the current state of evolution and the standards of the relevant industry” [5] and using the delimitation criteria:

- Degree of technical equipment,
- Degree of division of labour/specialisation,
- Degree of professional qualification of the employees,
- Degree of involvement of the company owner in the craft sector,
- Company size and type of production. [6]

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3 Cf. DIHK (2017), p. 3.

4 There are also “mixed operations” that belong both to the HWK and IWK. Such operations will not be separately examined below. However, the resource efficiency measures presented below could also apply to such mixed operations.

5 DIHK (2017), p. 4.

6 Cf. DIHK (2017), p. 5.

Industrial production is characterised by the extensive use of machinery in production to carry out the actual value-adding activities – supervised by the employee. In contrast to industrial production, in the craft sector, the master craftsman or journeyman usually follows the item to be manufactured along the entire process chain. Although there is division of labour, the degree is less pronounced in the skilled crafts than in industry. In industry, for example, people are deployed to handle individual process steps for which they have special qualifications, but they do not require in-depth knowledge of the entire process chain. The degree of involvement of the company owner in production also differs between craft and industry. In the skilled crafts, the company owner sometimes works in production and always has an overview of the entire process chain so that they can influence it and implement changes when necessary. This is possible due to the smaller size of the company (local sphere of activity, small number of employees e.g. up to 20, etc.[7]) and the type of production (small series production to one-off production).

This Brief Analysis sheds light on resource efficiency potential in industrial-related skilled crafts. A categorisation of the skilled crafts sector is provided by the Federal Statistical Office's Special Issue 4 Series 7.2 "Productive Industry – companies, active employees and turnover in the skilled crafts (Produzierendes Gewerbe – Unternehmen, tätige Personen und Umsatz im Handwerk"). It categorises the crafts into seven different industry groups.[8]

Industry groups according to the Federal Statistical Office

- I - Construction trades
- II - Finishing trades
- III - Crafts fulfilling industrial demand
- IV - Automotive trades
- V - Food industry trades
- VI - Healthcare trades
- VII – Crafts fulfilling private demand

[7] Cf. DIHK (2017), p. 5.
[8] Destatis (2018), p. 7.

In the context of this Brief Analysis, the industrial-related character of a craft trade is determined based on the processing or further processing of raw materials or intermediate products, a certain degree of mechanisation or automation and a higher number of employees. In Table 1, a number of trades are listed for each trade group that may fall under the definition of industrial-related crafts in the terms of this Brief Analysis.

Table 1: Trade groups and branches according to Destatis 2018[9]

Trade groups and branches			
Craft requiring a licence Annex A of the HwO		Craft not requiring a licence Annex B Section 2 of the HwO	
I - Construction			
• Bricklayers and concrete workers	• Heat, cold and sound insulation workers	• Producers of precast concrete and terrazzo	
II - Finishing trades			
• Furnace/air heater constructors • Electrical engineers	• Plumbers and heating engineers	• Roller shutter and sun protection technicians	
III – Crafts fulfilling industrial demand			
• Metalworkers • Surgical mechanics • Precision engineers	• Information technicians • Electrical engineers • Refrigeration plant constructors	• Tank and apparatus builders • Cutting tool mechanics • Galvanising workers	• Printers • Precision opticians • Decorative metalworkers
IV – Automotive trades			
• Coachbuilders and vehicle builders • Motorcycle/Bicycle mechanics • Vehicle technicians		-	
V – Food industry trades			
• Bakers • Butchers		• Millers • Brewers and maltsters	
VI – Healthcare trades			
• Dental technicians • Orthopaedic technicians		-	
VII – Crafts fulfilling private demand			
• Boat and shipbuilders		• Turners • Clock and watchmakers	

2.2 Economic developments in the skilled crafts sector

In 2017, the skilled crafts sector counted just under one million registered and non-registered businesses. Of these, around 57% were classified as trades requiring a licence, 25% as trades not requiring a licence and around

[9] Cf. Destatis (2018), p. 102.

18% as craft-like trades. In total, this corresponds to a share of around 27% of all businesses in Germany (Figure 1).[10]

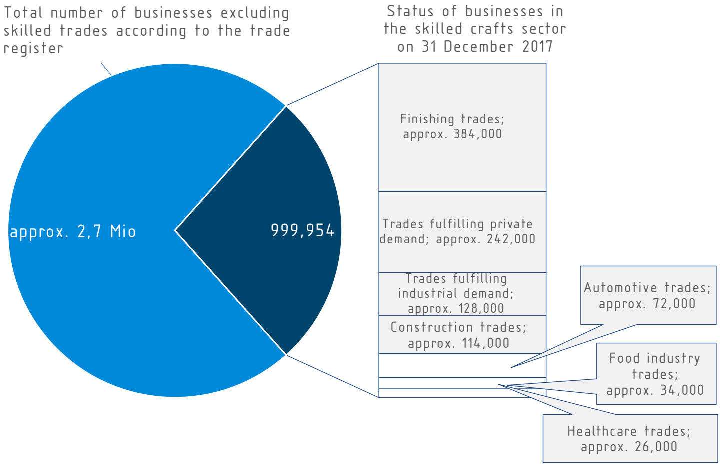

Figure 1: Percentage distribution of craft businesses in the total number of businesses as per the company register[11]

Around 38% of craft businesses are classified as finishing trades, while just under a quarter belong to the personal services sector, around 13% to the trades fulfilling commercial demand and around 11% to the construction trade. The remainder, totalling 13%, includes businesses in the automotive industry (7%), the food industry (3%) and the healthcare industry (3%).

Around 5.5 million people were employed in the skilled crafts sector as a whole in 2017 (Figure 2). This corresponds to a rate of around 12.4% of the total labour force in Germany. Compared to 2003, the number of employees had fallen by almost 350,000, but had risen by around 114,000 compared to the all-time low in 2010. Economic forecasts predicted that demand for personnel would continue to rise given the boom in orders in place at the time, and that competition for skilled labour would intensify.[12]

[10] Cf. ZDH (2018a).
[11] Taken from ZDH (2018a).
[12] Cf. Bretz (2018), p. 8 and ZDH (2018b), p. 14.

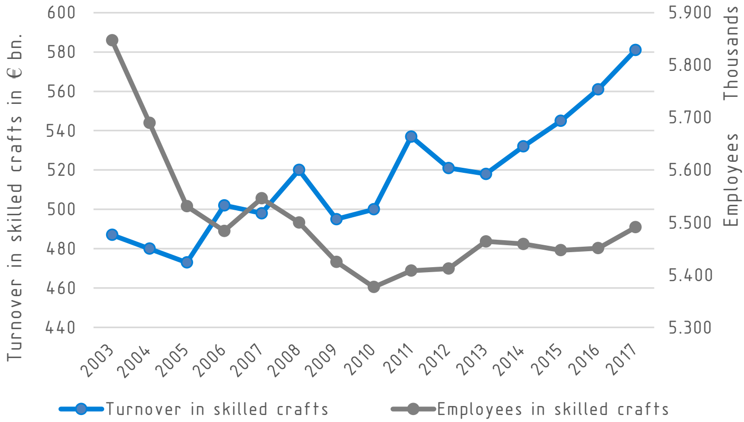

Figure 2: Turnover in billion euros and number of employees in the skilled crafts sector[13]

Turnover in the skilled crafts sector increased steadily from 2013 and totalled around 581 billion euros in 2017. This was an increase of 19 billion euros compared to 2016 (Figure 2).

The economic situation for 2018 was also considered to be very good. Almost all trade groups reported an increase in turnover compared to the previous year, 2017, while only one in ten respondents reported a drop in turnover (Table 2).[14]

[13] Taken from ZDH (2018a).

[14] Cf. Bretz (2018), p. 5.

Table 2: Turnover trends per trade group (figures from surveyed craft businesses in per cent)[15]

Trade/Craft	Increased turnover			Stable turnover			Decreased turnover		
	2017	2018	**Difference**	2017	2018	**Difference**	2017	2018	**Difference**
Construction	29.4	43.6	**+ 14.2**	58.6	49.8	- **8.8**	11.4	4.5	- **6.9**
Finishing	35.4	41.2	**+ 5.8**	55.2	52.9	- **2.3**	7.5	4.2	- **3.3**
Metalworking	34.6	32.8	- **1.8**	52.0	55.0	**+ 3.0**	12.6	8.4	- **4.2**
Automotive	29.5	31.1	**+ 1.6**	57.4	49.6	- **7.8**	12.4	14.3	**+ 1.9**
Food industry	41.2	37.5	- **3.7**	38.2	45.8	**+ 7.6**	20.6	14.6	- **6.0**
Personal services	42.3	44.9	**+ 2.6**	40.4	42.9	**+ 2.5**	17.3	10.2	- **7.1**
Other	34.3	50.0	**+ 15.7**	47.8	42.0	- **5.8**	14.9	8.0	- **6.9**

Turnover in per cent; difference in percentage points; other. crafts: including building cleaners, interior decorators, chimney sweeps, etc.

Rising turnover and the good economic situation have a positive effect on investment in the craft sector. In 2018, the highest willingness to invest was recorded at close to 60% of the companies surveyed.[16] Overall willingness to invest is broken down again into expansion investments, rationalisation investments and replacement investments (Table 3).

Table 3: Type of planned investments in the skilled crafts[17]

Type of investment	Investment climate		
	2017	2018	**Difference**
Expansion investment	51.3	49.3	- **2.0**
Rationalisation investment (cost reduction, productivity increase)	14.8	17.8	**+ 3.0**
Replacement investment	60.0	59.9	- **0.1**

Rationalisation investment in particular has risen by three percentage points. These include investments in measures to reduce costs or increase productivity. Resource efficiency measures aim to achieve this rationalisation within companies by reducing the use of resources and energy and, consequently, costs.

[15] Taken from Bretz (2018), p. 5.

[16] Cf. Bretz (2018), p. 16.

[17] Taken from Bretz (2018), p. 15.

3 RESOURCE EFFICIENCY POTENTIAL IN INDUSTRIAL-RELATED SKILLED CRAFTS

Resource efficiency can be achieved either by saving energy or materials. Studies have already analysed and demonstrated the efficiency potential of energy-saving measures in the skilled crafts sector.[18] Material savings, however, open up further potential for efficiency that should not be underestimated. In the manufacturing industry, material costs account for the largest share of total costs in small and medium-sized enterprises (SMEs) at around 40 to 45%. A similar cost distribution can be assumed for the industrial-related crafts. The implementation of resource efficiency measures makes it possible to achieve significant cost savings here.

Simple methods can be used without any additional assistance to determine the status quo of resource-efficient operation and discover the available potential for efficiency measures.

One tool for recognising resource efficiency potential in the company is the use of so-called resource checks. Questionnaires filled out by company employees/managers are used to determine the degree of resource efficiency in the company and provide an initial overview of possible savings potential in the company or in buildings. At the same time, appropriate measures and methods are presented that can be used to reduce resource consumption and increase material efficiency (including resource checks by the VDI ZRE).[19]

Another tool, for example, is the 4M checklist, which is based on the Japanese *Kaizen* method. *Kaizen* is a "Japanese concept of corporate management based on a philosophy of perpetual change, which consists of maintaining a continuous improvement process"[20]. The 4M checklist offers a simple tool for finding optimisation and resource efficiency potential in a company. It easily maps the current status of the operation and uncovers the current problems in its processes (Figure 3).

[18] Cf. Runst (2016).

[19] Cf. VDI ZRE resource checks: www.ressource-deutschland.de/instrumente/ressourcenchecks

[20] Duden (2018).

4M CHECKLIST

MANPOWER (employees of all genders)

- Do they follow the standards?
- Is their working efficiency acceptable?
- Are they problem-conscious?
- Do they have a sense of responsibility?
- Are they suitably qualified?
- Do they have enough experience?
- Is the workplace suitable for them?
- Are they open to self-improvement?
- Do they strive to maintain good interpersonal relationships?
- Are they healthy?

MACHINE (plant)

- Does it fulfil production requirements?
- Does it fulfil process requirements?
- Is it properly oiled (lubricated)?
- Is the inspection sufficient?
- Do mechanical problems often lead to machine downtimes?
- Does it make any unusual noises?
- Is the machine layout correct?
- Is the number of machines (plants) sufficient?
- Is everything in order?

MATERIAL

- Are there any deviations in volume?
- Are there any deviations in quality?
- Is it the right brand?
- Is the material contaminated?
- Is material circulation at the right level?
- Is material being wasted in any way?
- Is the material transport system correct?
- Is sufficient attention paid to material circulation?
- Is the material layout suitable?
- Is the quality standard sufficient?

(Working) METHOD

- Are there appropriate labour standards?
- Has the standard of work been raised?
- Is the method safe?
- Does the method guarantee a good product?
- Is the method efficient?
- Does the sequence of the individual work stepsmake sense?
- Was the installation properly carried out?
- Are the temperature and humidity acceptable?
- Are lighting and ventilation adequate?
- Is there sufficient contact with the upstream and downstream process?

Figure 3: 4M checklist[21]

Resource efficiency potential, however, can also be recognised by taking a more detailed look at the various sections of a business. A rough subdivision could be made, for example, into product design, production/assembly and operational management departments.[22] This allows the processes in each department to be analysed in more detail, with further resource efficiency measures then drawn up that are tailored to the various divisions of the company.

[21] Taken from Imai (1992), pp. 277 – 278 in Sonntag (2013), p. 3.

[22] Sonntag (2013), p. 4.

In Table 4, the resource efficiency measures and strategies compiled in VDI 4800, Sheet 1, et al., have been assigned to the business departments mentioned. This is a basic set of potential measures and should not be considered exhaustive.

Table 4: Selection of resource efficiency measures in companies[23]

Product design	Production and assembly	Operational management
• resource-efficient selection/replacement of materials • Application of miniaturisation and lightweight construction • economic design, e.g. through designing for production or recycling (e.g. with standardisation) • sustainable design, extending the technical product life cycle • ensuring reparability of the product • economical and resource-efficient design of packaging • integrating customers into the product development process	• optimising the production process and ensuring process reliability (including optimised use of machines, compressed air, piping and pump systems, etc.) • minimising the volume of initial material processed into a manufactured component • use of resource-efficient auxiliary materials and fuels • reduction of planned losses (e.g. from milling) and scrap (e.g. rejects produced during start-up processes) • reduction of losses causes by subsequent rework • recirculation of material through reuse or recycling/closed-loop production	• optimisation of warehouse inventories • Employee integration/qualification • use of key figures to document the process sequence • creation of unique and complete product documentation • creation of detailed work instructions • efficient cleaning • efficient transport • optimised heating/ cooling technology • efficient building envelope/ building infrastructure • implementing tool management

In addition to the listed resource efficiency measures, digitisation is another key enabler of resource efficiency in operations and will become an indispensable component for the skilled crafts. According to a survey, one in four craft businesses implemented digitisation measures in 2017 and more than a quarter of those surveyed planned to invest in digitisation measures in 2018.[24]

A study has investigated the connection between digitisation measures and operational resource efficiency. It established that these measures help save operational resources, especially through reduced error rates, rejects and waste, and by saving electrical energy. In most cases, these material savings

[23] Cf. Sonntag (2013), p. 4 and VDI 4800, Sheet 1, p. 17.
[24] Cf. Barthel (2018), p. 2.

are still perceived as a side effect of the use of digital technologies and are therefore rarely documented through data monitoring. However, the information which could be obtained or analysed in this regard would also offer opportunities for craft businesses to identify and realise further resource efficiency potential within their companies.[25]

Below, some of the resource efficiency measures (Chapter 3.1) listed in Table 4 and the effects on operational efficiency of digitisation measures (Chapter 3.2) are considered more closely.

3.1 Resource efficiency through optimised production infrastructure

As the crafts cover a wide range of different sectors and trades, the present Brief Analysis will treat those measures that roughly can be counted as relating to production infrastructure. Resource efficiency measures in the production infrastructure relate to the production periphery, which is found to the same extent in the majority of companies and is also responsible for a not inconsiderable proportion of operating costs.

In production infrastructure, we can draw a fundamental distinction between production-related and non-production-related infrastructure. Table 5 shows some examples of areas belonging to production infrastructure. The production-related areas directly support the production process, while the non-production-related areas are either indirectly involved in the production process or relate to the building infrastructure/building envelope or logistics, for example.

Table 5: production-related and non-production-related areas of production infrastructure

Production-related areas	Non-production related areas
• Pressurised air (Chapter 3.1.1) • Pumps/pipes • Tool management (Chapter 3.1.2) • Circulation system • Actuators • Electrical drive technology • Control technology	• Storage and transport (Chapter 3.1.3) • Lighting • Heating/cooling technology • Air conditioning • Building envelope/building infrastructure • Employee involvement • Water systems

[25] Cf. Schebek et al. (2017).

The resource efficiency aspects explained below for the areas marked with the respective chapter number in Table 5 can be used across all sectors and trades. For information on more specific resource efficiency measures (Table 4), please view the VDI ZRE webpages (and particularly the Brief Analysis “Resource efficiency through product development measures”[26]), further resource efficiency platforms and contacts in the Chambers of Skilled Crafts.[27]

3.1.1 Optimising compressed air

In industrial-related skilled crafts, pressurised air can account for up to 20 % of total energy consumption. It is estimated that efficiency measures can lead to savings in energy terms of around 30% to 50%.[28] Often, however, the optimisation of compressed air is not given sufficient consideration, with avoidable operational costs arising as a result. There are many reasons for high energy consumption. These include, among others[29]

- incorrect dimensioning of compressors,
- high idle times of the compressor (even when idling and unused, the compressor still has to run because of leaks),
- leaks,
- incorrect pressure level and pressure losses in the pipe due to unfavourable pipe layouts,
- lack of regular maintenance and servicing,
- lack of heat recovery.

Depending on the compressor running time, energy costs account for between 60% and 80% of the total costs for compressed air systems.[30] If a compressed air system is operated efficiently, high cost-saving potential can be

[26] VDI ZRE, Kurzanalyse Nr. 20 “Resource efficiency through product development measures”: www.ressource-deutschland.de/publikationen/kurzanalysen

[27] et al.: VDI ZRE: www.ressource-deutschland.de, Effizienzagentur NRW: www.ressourceneffizienz.de; Umwelttechnik BW: www.umwelttechnik-bw.de; Hessen Trade & Invest: www.technologieland-hessen.de/ressourceneffizienz; and Annex 8.4 of German Resource Efficiency Programme II.

[28] Cf. energieeffizienz-im-betrieb (2018).

[29] Cf. BayLfU (2004), p. 3 ff.

[30] Cf. BayLfU (2004), p. 2.

achieved. To draw up the initial operational status quo of the pressurised air system, the following exemplary checklist-style questions can be answered by operational employees.

Checklist of questions about the compressed air system[31]

1) Do you know the energy consumption of your compressed air system?
2) Do you know the pressure required by your compressed air system?
3) Do your compressed air systems have runtime counters?
4) Do you know the runtime of your compressors, and do you note it down as an annual or monthly figure?
5) Do you use technically optimised, state-of-the-art compressor technology?
6) Do you make use of the waste heat produced by compressed air generation?
7) When you use several compressors of varying power, do you use higher-level control systems to optimise the capacity of each compressor?
8) Do you use compressors of suitable size for plants with high fluctuation in consumption?
9) Do you understand the potential of ultrasound inspection to detect imperceptible leaks in the compressed air network?
10) Are cross-section reductions avoided, especially at couplings and valves?
11) Are deposits present in the pipework, e.g. from corrosion residue or oil deposits?
12) Does the difference between pressure at the consumer and the operating pressure correspond to approx. 1 bar?
13) Have you already carried out a system comparison/benchmarking process?
14) Have you ever checked possible alternatives to compressed air?

[31] Cf. VDI ZRE (2018a).

If the answers to the questions reveal initial potential for optimisation, various measures can be implemented to make compressed air system operation more economical.

Documentation and monitoring of the compressed air network

Determining resource efficiency potential in the compressed air network requires documentation of the distribution network. This includes the description of sections of the pipe routes, pipe lengths, pipe diameters, connection points, etc.[32]

Furthermore, the required pressure should be determined. This is the sum total pressure required for all consumers plus additional to account for losses in the system. The latter should normally not exceed 1 bar for machines and 1.5 bar for tools. If measurement reveals higher pressure losses, operation of the compressed air system is not efficient and should be subject to optimisation measures.[33]

Compressed air losses should be regularly determined based on the documentation of the compressed air network, the measurement of the required pressure and other parameters. This allows leaks between the pressure distribution network and consumers, e.g. at valves or couplings, to be detected and repaired directly at source. Measurement or localisation can be carried out, for example, using ultrasonic measuring devices, by acoustic detection of hissing sounds or using flow sensors (calorimetric flow sensors). The latter can be installed with little effort and enable automatic recording and analysis as well as IT-based visualisation of the results. These technologies can be used to reduce losses by finding the location of leakages.[34, 35]

Another opportunity resulting from monitoring the compressed air network is to identify areas that are only used periodically. Temporary disconnection from the compressed air network using zone valves is recommended here.[36]

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[32] Cf. VDI ZRE (2018a).
[33] Cf. VDI ZRE (2018a) and BayLfU (2004), p. 5.
[34] Cf. VDI ZRE (2014), p. 9 ff.
[35] Cf. VDI ZRE (2018b).
[36] Cf. VDI ZRE (2018a).

Recovery of generated heat

The compressor motor converts 90% of the electrical energy used to supply compressed air into heat. Depending on the type of cooling, the compressor design and the operating parameters such as output and temperature level, the heat generated can be decoupled and used, for example, to heat internal air, water or service water.[37] A simple way to use the heat is to open the compressor room so that neighbouring rooms can be warmed using the heat generated there.[38] The heat can be supplied to the relevant rooms via a duct system and regulated by temperature-controlled flaps in the ducts.[39]

Alternatives to the classic compressed air system

New business models ("using instead of owning") in the compressed air sector now make it possible to purchase compressed air by volume instead of installing a compressed air system. These so-called "result-oriented" product service systems (PSS) are based on a performance-based contract with the customer, whereby billing takes place per cubic metre of compressed air used. In this, the customer need not bear the cost of investment, operation nor maintenance, but can simply draw on and pay for compressed air as needed.[40]

Another product-related option is a compressed-air-and-heat unit (CAH). Here, the compressed air is not generated by electrical energy but by gas. Based on the operating principle of a combined heat and power plant, process heat is generated by a gas turbine. Compressed air (up to 13 bar) is generated as a by-product by a simultaneously operated (i.e. coupled) screw compressor. Compressed air can thus be generated without electrical energy, which can reduce operating costs by up to 60%.[41]

3.1.2 Introducing tool management

A large number of tools and other technical aids are used in the day-to-day skilled craft business. Failure to keep tools and technical aids organised and

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[37] Cf. VDI ZRE (2018a) and BayLfU (2004), p. 6.

[38] Cf. BayLfU (2004), p. 6.

[39] Cf. Mader GmbH & Co. KG (2018).

[40] Cf. VDI ZRE (2017a), p. 27 and Kaeser Kompressoren SE (2018).

[41] Cf. energiewerkstatt (2018) and altAIRnative GmbH (2018).

in order can lead to errors, and then to loss of productivity. The reasons for this include:[42]

- accumulation of irregularly used, worn out or duplicated tools and technical aids,
- mixing-up or shares storage of frequently and less frequently used tools and technical aids,
- unclean workplaces and
- lack of continuity in sorting and tidying activities.

Well-maintained, suitable tools and technical aids kept in good order help to reduce error rates, rejects and high levels of resource consumption, while at the same time extending the product service life (Table 4).[43] The implementation of a tool management system is ideal for achieving this. To determine the current integration of tool and resource management in the company, the following exemplary checklist-style questions can be answered by operational employees.

Checklist of questions on tool management[44]

1) Do you know how you can reduce your tool and production costs through tool management?
2) Are tools issued and collected at a central location?
3) Do you use technology to track tools?
4) Is your tool management networked with other operational areas?
5) Are there marked out areas for the respective tools at the workstations/storage locations?
6) Do you record tool use?

If the answers to the questions suggest potential for optimisation, various measures can be implemented to design tool management more efficiently.

[42] Cf. Sonntag (2013), p. 7.
[43] Cf. Sonntag (2013), p. 7.
[44] Cf. VDI ZRE (2018a).

Applying the 5S method

The 5S method is also a component of the Japanese *Kaizen* philosophy and should not be understood as a "silver bullet", but rather as a continuous improvement process. The 5S method is a five-stage process leading to systematic improvement[45], and standardising, tool organisation (Figure 4).[46]

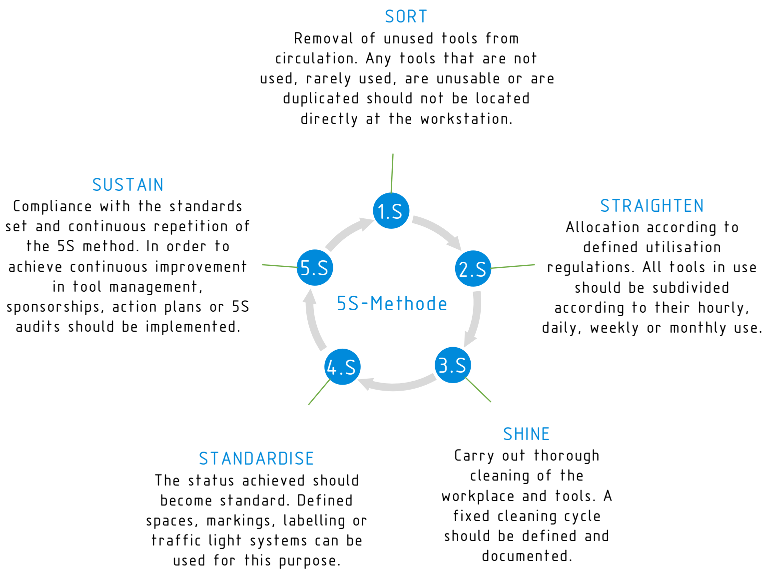

Figure 4: 5S method procedure[47]

The implementation of the 5S method offers various advantages. It leads to greater occupational safety, promotes transparency, integrates employees in the process or increases their quality awareness, reduces waste and improves productivity. The method can also be used across all sectors and trades.[48]

[45] The 5S method can also be used for the continuous improvement of workplace organisation. In this Brief Analysis, however, the focus is on the management of tools.

[46] Cf. Kaizen Institute (2018).

[47] Taken from Sonntag (2013), p. 7 and Kaizen Institute (2018).

[48] Cf. Kaizen Institute (2018).

Tool storage in a central location

Comprehensive tool control is made possible by storing tools at a central location in the company (shelving system, compartment system, etc.), ideally in a central hall/workshop, to ensure all employees travel the same distance to reach it. Each stored tool and its central storage location should be provided with a number to ensure quick searching and facilitate documentation of the inventory. Tracking systems can also be used for tool tracking (see next item).

Having employees take out and return tools avoids their storage at the workplace when unused, and provides an overview of the inventory. In this way, replacement can be requested automatically as the tools wear out and consumption statistics can be created to determine exact tool costs.[49]

The overview thus created also allows standard tools to be identified and defined. This can sometimes lead to discounts with tool suppliers, as it makes it possible to purchase higher quantities from a single supplier, thus saving transport costs at the same time.

Systems for tool tracking

Tracking systems can be used to improve the organisation of tools. The location, charging status and, in the case of machinery, the need for maintenance and availability can also be referred to. The use of such a tracking system can already be profitable for skilled craft businesses with eight to ten employees.[50] This target group includes, in particular, craft businesses that use machinery, electrical appliances, special tools, etc.[51]

Different systems are offered by the various providers. The differences lie in the tracking technology used, which ranges from barcodes and the more expensive RFID technology to the use of near-field communication (NFC) via smartphone (see also Chapter 3.2.3).[52]

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[49] Cf. Enßle (2010), p. 95.

[50] Cf. Klebig (2016).

[51] Cf. handwerk-magazin (2017).

[52] A comparison of various technologies from different providers can be found at the following link: www.handwerk-magazin.de/loesungen-zur-werkzeug-und-maschinenverwaltung/383/1518/download

3.1.3 Optimisation of storage and logistics

Optimised storage and efficient logistics can save losses, time and therefore operating costs. Storage damage to tools, auxiliary and operating materials and (intermediate) products in particular, as well as damage to them due to unnecessary transportation and intermediate storage, result in cost-intensive waste in the company. The reasons for these losses include:[53]

- poor storage conditions due to moisture, pests, heat, cold or rust,
- lack of warehouse organisation or lack of warehouse management (exceeding expiry dates of auxiliary and operating materials, overfilled and disorganised warehouses, damage to goods due to improper storage),
- lack of direct transport routes with the attendant intermediate storage,
- lack of optimised route planning for delivery to customers and
- lack of consistent maintenance and servicing of means of transport and storage facilities.

To reduce rejects caused by the named sources of loss, it is recommended to operate clean and tidy storage and ensure well-adjusted, unhindered material flows.[54] The following exemplary checklist-style questions can be used to show to what extent such optimisation can take place in a company.

Checklist of questions on optimised storage and logistics[55]

1) Do you sort stock by expiry date?
2) Is there a regular review of stock levels?
3) Do you use digitalised processes to manage the warehouse?
4) Do you avoid packaging where possible?
5) Do you limit the volume of packaging to the minimum appropriate to maintain the necessary safety and hygiene of the packaged product and its acceptability to the consumer?
6) Is packaging used multiple times? Do you use reusable systems such as box systems or Europool pallets?

[53] Cf. Sonntag (2013), p. 9.
[54] Cf. Sonntag (2013), p. 9.
[55] Cf. VDI ZRE (2018a).

7) Do you avoid unnecessary transport by optimising processes and routes?
8) Do you carry out regular maintenance to the vehicles used within the company (tyre pressure, lubrication, etc.)?
9) Is the braking energy of the transport technology (storage retrieval systems, forklift trucks, etc.) recuperated?
10) Do you utilise waste heat or process heat to regulate the temperature of storage areas?
11) Do you use dynamic storage?

If the answers to the questions suggest potential for optimisation, various measures can be implemented to design tool management more efficiently.

Warehouse optimisation and warehouse management

The 5S method already presented (Chapter 3.1.2) can be used to carry out warehouse optimisation. This allows the systematic development of basic organisational rules, to be maintained and further expanded through a continuous improvement process. For example, overstocking of production material can be counteracted, meaning stock levels and the level of tied up capital reduced.

Warehouse optimisation can also be carried out with the help of external companies. One company has developed a warehouse optimisation system, the basic element of which is the separation of standard and commission material along the entire operational process. Through further elements of optimisation (a small selection of which is shown in Table 6), capital commitment, search times and idle time can be reduced, operational processes smoothed out and activity made more productive.[56]

[56] Cf. Paulus-Lager (2018a).

Table 6: Measures for warehouse/storage optimisation[57]

Problem	Solution
Recently delivered material must be searched for by employees	Setting up defined areas for receiving materials, or a surface in the delivery area where the material can be stored until it can be brought to the set storage location.
Jumbling of materials, tools and machinery in storage causes long search times	Setting up a standardised item storage system with materials, tools and machines kept separately. An exception is made for materials linked to machines. These are stored next to the set location for the machine in question.
Shortages cause search costs and additional procurement rounds	Definition of the common material master and documentation of the stock using digital technologies or article lists, among other things, in order to initiate a timely ordering process.

Digitisation measures (see Chapter 3.2) essentially support warehouse optimisation. Digitisation simplifies operational processes in skilled craft businesses, especially when it comes to storing standard materials. One possibility is the use of QR codes attached to warehouse shelves. The link stored in the QR code refers to the corresponding product, which is stored in the supplier's database. The employee's smartphone can be used to read the QR codes and trigger an order from the supplier. Such ordering processes can also be automated by installing additional optical sensors.[58]

57 Cf. Paulus-Lager (2018b).

58 Cf. Guthardt (2018).

3.2 Resource efficiency through digitisation strategies and measures

Digitisation of various processes and technologies is progressing rapidly across many sectors. Even in the crafts sector, digital technologies are increasingly being used, e.g., to improve business processes, expand the customer base, ensure data protection and cybersecurity, optimise technologies as well as production processes and open up new areas of business. According to a survey, around 23% of skilled crafts businesses see digitisation as an opportunity, while only around 6% see it as a risk (Figure 5).[59]

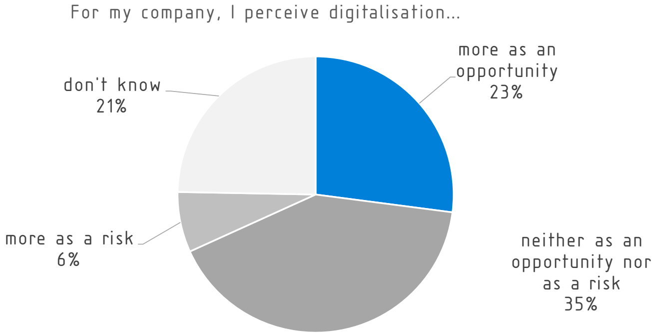

Figure 5: Opportunity and risk of digitisation for craft businesses[60]

The majority of skilled craft businesses see digitisation as neither an opportunity nor a risk or are unable to make an assessment regarding it (56%). This clearly shows that the opportunities arising from the digital transformation still need to be more widely communicated. But even if digitisation is seen more as an opportunity, there are other reasons why the skilled crafts sector does not want to engage with the topic or invest in digitisation measures. These include:[61]

- lack of personnel and time resources in the company,
- lack of benefit/added value for customers and operations,

[59] Cf. Barthel (2018), pp. 2 and 7.
[60] Taken from Barthel (2018), p. 8.
[61] Cf. Barthel (2018), p. 10.

- failure to guarantee IT security,
- patchy supply of broadband connection,
- lack of employee competence or
- lack of support programmes.

However, depending on the craft activity in question, the benefits of digitisation measures can contribute to the positive development of the business or business area. The areas already mentioned (improved business processes, development of new customer groups, etc.) can be optimised or expanded, for example, through:[62]

- time, resource and therefore cost savings,
- growing the range of services,
- opening up new markets and
- productivity increases.

Saving resources in particular can lead to a considerable reduction in operating costs. Digitisation measures that optimise technologies and production processes or integrate suppliers and customers more efficiently into the company's own operations, for example, can lead to material, energy and cost savings and thus increase competitiveness.[63] Resource efficiency is achieved through reduced error rates, scrap and waste, and savings in electrical energy, among other things.

In order to obtain an initial digital status quo, the following exemplary checklist-style questions can be answered by operational employees.

Checklist of questions about digitalised skilled craft businesses[64]

1) Is the IT infrastructure in your company continuously updated and adapted to the state of the art?

[62] Cf. Blank (2018), p. 5.

[63] Cf. VDI ZRE (2017b), p. 21 ff. and 37 ff.

[64] Cf. Bedarfsanalyse Handwerk (2019); (You can carry out the complete digitisation check on the website www.bedarfsanalyse-handwerk.de [in German].).

2) Do you use digital technologies to plan and coordinate work deployments?
3) Are processes in your operation documented using digital technologies?
4) Do you use technologies such as 3D printing, robotics or smart glasses in production?
5) Are your company's plants, machinery and devices networked together?
6) Have you used digital technologies to expand your range of services?
7) Do your employees use mobile devices such as smartphones or tablets?
8) Do you use cloud technologies in your company?
9) Do you use and analyse data from operational processes to optimise product manufacturing and service provision? Do you use real-time data to do this?
10) Do you use smartphones or tablets, for example, to record information flows, such as time recording, tool management or construction site diaries?
11) Are suppliers involved in service provision process via IT systems?

Depending on a company's range of products or services, various digitisation measures can help to tap into efficiency potential. A study that analysed the relationship between resource efficiency and Industry 4.0 identified eleven fundamental measures for digital transformation and derived the resource efficiency potential they presented (Table 7).[65]

[65] Cf. Schebek et al. (2017), p. 77.

Table 7: Eleven digitisation measures and their resource efficiency potential[66]

Measure	Description	RE potential
1) networking sensors and actuators	Sensors and actuators are used to continuously collect data in order to evaluate it for process/operation analysis and optimisation.	basic prerequisite for RE, recorded data generate process and operational transparency
2) use of digital object memory	Physical objects (machines) equipped with data memory that collect and store data that can be retrieved directly and in real time from the machine/product.	direct assignment of resource consumption to the product leads to process transparency
3) decentralised control	An intelligent workpiece has knowledge about its properties and contains retrievable information about its production method and the aim of production. It can thus control its own production process.	decentralised production reduces faults
4) worker support and assistance measures	Assistance systems, e.g. mobile devices, can support workers in their activities in production. Software systems can optimise the design of the production process on the basis of the networked infrastructure and the evaluation of the available sensor technology.	precise instructions avoid production errors and rejects and promote efficient material usage
5) dynamically co-operating systems and modularisation	The interaction of at least two systems can be achieved, changed or stopped with minimal effort. Independently operating system components can easily be supplemented with new/modified system components.	switching off unused plant components leads to better process utilisation
6) tracking and localisation systems (Chapter 3.2.3)	Localisation systems make it possible to track machines/tools through production facilities. Manufactured products can also be localised and tracked along the value chain.	Avoiding loss of products/tools/machinery, saving transport
7) status monitoring	Operating states of plants and processes are continuously analysed, with deviations marked and reported. Unexpected system failures can thus be avoided.	use of wear parts up to the limit of usability, rectification of atypical process errors
8) predictive maintenance	Machine errors (e.g. machine failures or malfunctions) can be detected before they occur. Maintenance or early repairs can thus prevent machine downtime or process failures.	identification of premature wear, rectification of atypical faults, avoidance of faults
9) end-to-end data integration (Chapter 3.2.1)	Standardised access to data structures throughout the company enables a holistic view of production and order planning. The prerequisite for this is vertical integration (from production to management) of Enterprise Resource Planning (ERP) systems.	recorded data generate transparency regarding processes and operations and serve to optimise them
10) virtual product development (Chapter 3.2.2)	A digital, three-dimensional product model is designed on the computer. It can be modified, tested and optimised through simulations as required. Prototypes of the design can be produced cost-effectively using 3D printing.	material-saving prototype optimisation and manufacturing
11) cloud computing (Chapter 3.2.4)	Some work areas (e.g. programs, software packages, storage space, computing capacity) are no longer provided on the hard drive, but via the internet or local networks (the cloud).	energy saved and bureaucracy reduced through relocation of computing activities

RE – resource efficiency; transparency regarding processes and operations can reveal inefficiencies that can lead to savings in materials and energy, among other things, through appropriate optimisation measures.

The integration of the measures presented into operational processes can lead to resource savings. Some companies have reported material and energy savings of up to 25%.[67]

Based on a study by the Thuringian Chamber of Skilled Crafts (Handwerkskammer Thüringen), which determined the degree of digitisation and its potential, the most common measures applied in the skilled crafts sector have been summarised and are listed below.[68] In conjunction with Table 7 this data can be used to derive a general idea of the potential for resource efficiency achieved in skilled craft businesses:

- Use of a document management system (DMS, database-supported filing and management of electronic documents in the company),
- Use of Building Information Modelling (BIM) for optimised digital planning of construction projects,
- Use of enterprise resource planning systems (ERP systems) via software for the needs-based planning, control and optimisation of operational processes (capital, personnel, operating resources, etc.),
- Use of systems for digital and mobile time recording that are linked to the ERP software,
- Use of industry-specific merchandise management systems that map the flow of goods and materials in the company's business processes,
- Use of digital workflow programs to optimise and automate work processes,
- Use of digital construction site diaries for construction site documentation.

➔ **listed applications belong to measure 9: End-to-end data integration** (Table 7)

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[66] Cf. Schebek et al. (2017), p. 77 and pp. 147 – 164.
[67] Cf. Schebek et al. (2017), p. 188.
[68] Cf. Mulatz (2017).

- Use of software for 3D technologies

➔ **listed application belongs to measure 10: Virtual product development** (Table 7)

- Use of cloud-based, secure data storage

➔ **listed application belongs to measure 11: cloud computing** (Table 7)

The majority of the measures already implemented in skilled crafts businesses can be assigned to "end-to-end data integration" (measure 9, Table 7). In this way, the value chain of the craft business, i.e. from the customer order through purchasing and operational delivery to sales and service, is made more transparent. Optimisation measures based on this can lead to resource savings. Cloud-based solutions and the use of virtual product development are also already being used in some craft sectors.[69]

The following chapters go into more detail on end-to-end data integration (Chapter 3.2.1), virtual product development (Chapter 3.2.2) and cloud computing (Chapter 3.2.4), as measures that can be applied across all sectors. Light is also cast on measure 6, Table 7 "tracking and localisation systems" (Chapter 3.2.3). Common practical solutions for the skilled crafts have also already become established here. For information on further sector-specific digitisation measures and future trends (incl. predictive maintenance, status monitoring and the networking of sensors and actuators), we direct you to the webpages of the Kompetenzzentrum Digitales Handwerk (Competence Centre for Digital Crafts) and other resource efficiency platforms, as well as to contacts in the Chambers of Skilled Crafts.[70]

3.2.1 End-to-end data integration

End-to-end data integration enables standardised data access to different data sources and formats during operation (Table 8). The analysis and

[69] Cf. Mulatz (2017).

[70] et al.: Kompetenzzentrum Digitales Handwerk (Competence Centre for Digital Crafts),VDI ZRE; Efficiency Agency NRW: www.ressourceneffizienz.de; Environmental Technology BW: www.umwelttechnik-bw.de; Hessen Trade & Invest: www.technologieland-hessen.de/ressourceneffizienz and Annex 8.4 of the German Resource Efficiency Programme II.

evaluation of these data can reveal inefficiencies in operation that can be eliminated through optimisation measures.

Table 8: opportunities of and barriers to end-to-end data integration[71]

Prerequisites	Challenges	Opportunities
• existence of interfaces with data exchange • data processing and gathering are purposeful • presence of data management structure • overview/information model on data origin for mapping and consolidation	• interface compatibility • complexity due to inconsistent data formats and structures • recording and processing of immense data quantities • data quality control • data collection from various departments requires high operational expenditure • the real-time requirement must be fulfilled • security requirements must be guaranteed • data silos must be dissolved and avoided • scalability of the system	• operational areas are networked, leading to unified (data) systems • information can be considered and evaluated uniformly • data traceability is guaranteed • processes become transparent • data-based decisions can be made • time savings • error reduction

So-called enterprise resource planning systems (ERP systems) use end-to-end data integration to ensure standardised access to data. This allows factors in operational production such as materials, capital, operating resources, labour and personnel to be efficiently planned, managed and controlled.[72] An ERP system is therefore made up of various modules. These include procurement/materials management, production, sales, research and development, plant management, human resources, finance and accounting, controlling, etc. The modules mentioned can be selected depending on the size of the company and the requirements of the business.[73] There are numerous manufacturer solutions for ERP systems on the market.[74] These can be categorised into more cost-effective open-source solutions, cloud solutions or on-premise solutions (Table 9).

[71] Cf. Schebek et al. (2017), p. 160.
[72] Cf. ERP-SYSTEM.online (2018a).
[73] Cf. Vahrenkamp and Siepermann (2018).
[74] Cf. ERP-SYSTEM.online (2018b) or handwerk-magazin (2017).

Table 9: Advantages and disadvantages of ERP systems[75]

Advantages	Disadvantages
OPEN-SOURCE SOLUTIONS:[76] Open-source solutions are freely accessible software programs for which no licence fees are charged. The source code can be modified by the user free of charge and can be customised to the needs of the company.	
• cost-effective, costs are incurred for maintenance, training, support, etc. • licence-free, customisable source code; scalability is guaranteed • all employees can access the software; no limitation through single-user licences • manageable functionality leads to simpler implementation	• manageable functionality, sometimes not all the needs of a business can be covered • performance and reliability may be lower compared to licensed ERP software solutions • IT specialists may be required for changes to the source code • no liability claim in the event of problems
CLOUD SOLUTIONS: The ERP system functions as an online or web-based solution. The provider makes the necessary hardware available to the customer and is responsible for maintenance work, repairs and updates. The company pays a monthly fee for these services and must have an internet connection and a web browser.	
• the web-based solution enables unrestricted data access from any location • costs are precisely calculable due to the flat rate to be paid • reduction in administration costs and energy savings achieved by relocating IT infrastructure and IT specialists • little effort required for commissioning	• no data access without an internet connection • the security of sensitive company data must be guaranteed • sufficient performance must be guaranteed for smooth processes • dependency on the ERP provider is established (see Chapter 3.2.2, Cloud Computing)
ON-PREMISE SOLUTIONS: The on-premise system is installed as software on the company's own server and requires a licence. The company requires its own hardware and its own data centre.	
• one-off costs from purchase of the software licence • own responsibility for the operation and data security of the ERP system • continuous scaling possible • independence from the ERP supplier guarantees	• high labour costs and expenditure when introducing the ERP system and setting up the necessary infrastructure • maintenance, repair etc. are the company's own responsibility • employees must be trained and qualified in-house • no liability claim in the event of problems

[75] Taken from ERP-SYSTEM.online (2018c) and ERP-SYSTEM.online (2018d).

[76] Note: open-source solutions tend not to be that pertinent to the crafts but are listed for the sake of completeness.

Before selection and commissioning, it must be checked whether all technical, legal, economic and security requirements are guaranteed by the ERP provider. Modern ERP systems should fulfil the following criteria:[77]

- Integrated systems - the ERP systems include as many functions (modules) as possible that are necessary for operations; data input, data storage and data output should be carried out from one database if possible.
- Scalability/modularisation - the functions required for operation can be flexibly expanded or reduced.
- Mobility - secure access to operating data is possible from any location and the graphical display of the ERP system is optimised for mobile devices.
- Web-based interface - company data can be accessed from any device via a page on the Internet.
- Security - ERP systems have secure infrastructures, such as highly individualised rights structures that prevent e.g. mass downloads of customer data (in the case of cloud services).
- Backup - with cloud services, data are backed up in real time and at different data centres (geo-redundancy), with data automatically backed up and archived; on-premise services have integrated backup solutions.
- Automation - the ERP system maps the company's workflows, which can be coordinated, streamlined and automated.
- Internationality - the ERP system can be used in several languages, at least in English.
- User-friendliness - the ERP system is intuitive to use.

[77] Cf. Esseling (2018).

3.2.2 Virtual product development

Virtual technologies (augmented reality (AR), virtual reality (VR) etc.) support skilled craft businesses in the field of planning, consultation, sales and everyday work (Figure 6).

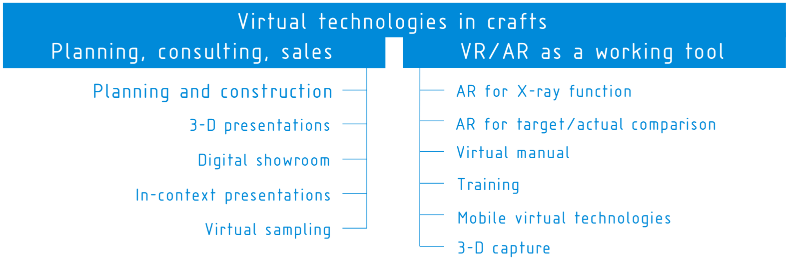

Figure 6: Virtual technologies in crafts[78]

Resource efficiency potential can be tapped in particular in planning and design and in virtual product development. Discrepancies or faulty designs can be detected and rectified using software-supported simulations, individual customer requirements can be fulfilled and higher product quality can be achieved. Thus, the need to rework faulty products and the associated increased materials purchasing are reduced.[79]

Table 10: Opportunities of and barriers to virtual product development[80]

Prerequisites	Challenges	Opportunities
• presence of adequate data infrastructure and data management • employee expertise • high computing power • process and project data must be accessible	• employees must be trained • production management is required • high software costs must be calculated	• few design changes in the subsequent product development and manufacturing process • high product quality • additive manufacturing instead of subtractive manufacturing • process optimisation for approval or changes

3D technologies are already being used in industrial-related skilled crafts, particularly in the hearing acoustics, orthopaedic technology and dental technology fields. The technology is also increasingly being used in precision

[78] Taken from Runde (2016).
[79] Cf. Schebek et al. (2017), p. 162.
[80] Cf. Schebek et al. (2017), p. 162.

mechanics and technical modelling.[81] Typical fields of application for 3D printing processes include:[82]

- the generation of prototypes from computer models for use in the design process (rapid prototyping),
- the manufacture of special tools, devices, moulds and customised production aids (rapid tooling),
- the production of one-offs or customised products based on digital computer models (rapid manufacturing),
- the production of very small series of workpieces with the option of individual modification (customising) and
- the production of spare parts on demand (on-demand production).

For craft businesses, 3D printing opens up new opportunities to tailor products to customer requirements, produce more quickly or manufacture spare parts on demand. This allows costs to be saved, for example for material and product storage, and competitive advantages to be gained by providing tailored responses to customer requirements.

Currently, skilled craft businesses are still faced with the challenges of high acquisition and operating costs, lower quantities produced or a lack of expertise in software-supported design with 3D data. Nevertheless, it is estimated that by 2030, almost half of all skilled crafts companies will have integrated 3D printing.[83] Existing qualification offers from the Chambers of Skilled Crafts and Competence Centres lend themselves particularly to this purpose.

3.2.3 Tracking and localisation systems

Tracking and localisation systems make it easier to organise and allocate products, tools or machines. Tracking systems can be used to locate finished or intermediate products along the entire value chain or to find tools if they are lost, e.g. on construction sites. When an order is received, it is also

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[81] Cf. Meyer-Veltrup (2018).
[82] Cf. VDI ZRE (2019).
[83] Cf. Meyer-Veltrup (2018).

possible to assign the vehicle with the shortest journey to it and to check if all the tools needed for the job are present in the vehicle. Material losses and unnecessary transport can thus be avoided through transparent transport and material flows (Table 11).[84]

Table 11: Opportunities and limitations of tracking systems[85]

Prerequisites	Challenges	Opportunities
• marking of the object to be tracked • transmitter and receiver units	• selection of a suitable tracking system • real-time capability must be provided by the tracking systems	• optimised processes along the entire operating sequence and supply chain/transparent material flows • reduction of errors and inefficient processes/operating procedures • tracking of components and machines • reduction of warehouse stocks • theft prevention • simplification of recalls

Tracking systems can save natural resources and be used in a variety of ways. This opens up numerous possibilities for crafts, such as:[86]

- the management and tracking of lost or forgotten tools on the construction site,
- the worldwide location of construction containers, e.g., as the network used is often the mobile network,
- the tracking of fleet vehicles to facilitate order management and checking the tool inventory in the vehicle or
- the installation of electronic fences that trigger an alarm if a tool leaves the premises outside operating hours (theft).

A number of solutions can already store data sheets for construction machinery and thus remind you in good time of inspection intervals listed online, such as the German accident prevention regulations inspection (UVV inspection).[87] Large companies are already trialling tools that can completely read the generated tool data. These data can be used to make judgments about

84 Cf. SBZ (2016).
85 Taken from Schebek et al. (2017), p. 156.
86 Cf. SBZ (2016).
87 Cf. Hansel (2017).

error messages and operating hours and thus provide information for predictive maintenance (Table 7, measure 8). Predictive maintenance in particular can reduce machine downtime by up to 70% and cut costs by around 30%. It is expected that such systems will also be used in smaller companies in the future.[88]

3.2.4 Cloud computing

Cloud computing relocates IT processes from the company's own computers to external servers using the respective software. The network typically used for these so-called cloud services is the Internet. The data and applications stored in the cloud can be accessed via an Internet-enabled device (e.g. tablet or smartphone) with a sufficient network connection. This simplifies data exchange and reduces administration cost and effort, e.g. costs of administering software products (Table 12).[89]

Table 12: Opportunities of and limitations of cloud computing[90]

Prerequisites	Challenges	Opportunities
• reliable broadband internet connection • data security • legal compliance • cloud services and IT infrastructure must work and interact with each other as seamlessly as possible	• ensuring the security of sensitive company data • sufficient performance for smooth (stable) processes • establishing reliability and fail-safe performance • sufficient network coverage, especially in rural areas •	• improved energy and resource efficiency through optimised utilisation of IT capacities • dynamic access to IT capacities • billing according to flexible payment models • low administration costs • mobile availability and availability guarantee from cloud provider • transfer of long-term investments to operational costs

There are already a large number of craft-specific cloud services. In order to fully utilise the advantages of cloud services, a technical, legal, economic and security-related review of the range available on the market is required in advance. To this end, a guide has been developed specifically for craft businesses to help them decide on a suitable cloud service (Figure 7).[91]

[88] Cf. Hansel (2017).
[89] Cf. Schebek et al. (2017), p. 163.
[90] Cf. Schebek et al. (2017), p. 163.
[91] Cf. Christmann et al. (2014), p. 9.

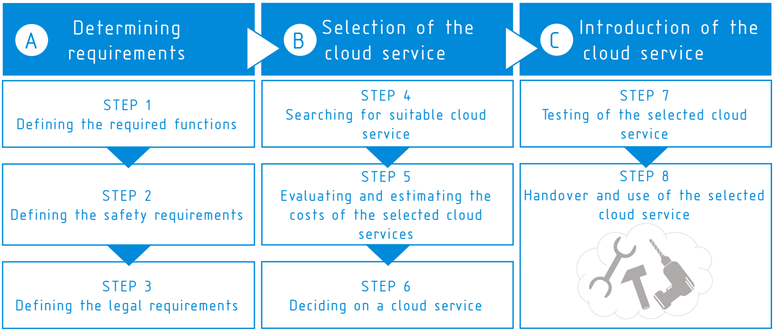

Figure 7: Selection of suitable cloud services for the skilled crafts[92]

Step 1 determines the functions and interfaces that need to be covered by the cloud application. The scope of the cloud computing service required for operation is checked accordingly. In step 2, the security requirements are used to determine which data are important for the success of the business and which must be continuously available and adequately protected by the cloud service (no system failures, no access by third parties, etc.). Step 3 determines which operational requirements are essential for the contract design (application of German law, protection of personal data within the EU, existence of a certification such as Trusted Cloud or ISO 27001, etc.). According to the definition from steps 1 to 3, suitable cloud services are searched for in step 4. This selection is subject to a structured cost analysis in step 5. In step 6, by comparing the investment costs and running costs of all alternatives and the current standard solution in operation, a decision is made in favour of a cloud service. This is then tested under realistic operating conditions in step 7. Once any problems have been resolved and the service has been assessed as positive by the company, acquisition takes place. This is where the cloud service is configured, all data are imported and all employees who use the cloud service are trained.[93]

After an extensive review and definition of "tasks, costs, procedures for availability, data processing, data storage, data protection, data security and data

[92] Taken from Christmann et al. (2014), p. 11.
[93] Cf. Christmann et al. (2014), pp. 11 – 27.

return at the end of the contract",[94] the use of cloud services thus enables a more flexible operational process and optimised utilisation of IT capacities.[95]

[94] Fischer (2018), p. 33.
[95] Cf. Schebek et al (2017), p. 163.

4 EXAMPLES OF GOOD PRACTICE IN INDUSTRIAL-RELATED SKILLED CRAFTS

The following chapter presents practical examples from the skilled craft sector that utilise resource efficiency measures to save materials, energy and CO_2 emissions. The practical examples cover all aspects of production infrastructure (Chapter 3.1) and digitisation (Chapter 3.2) and do not just focus on the topics presented in Chapters 3.1.1 to 3.1.3 and Chapters 3.2.1 to 3.2.4.

4.1 Practical examples from the field of production infrastructure

Good practice example 1: rabe Innenausbau GmbH

Sector:	finishing trades, Group II: interior finishing
Measure:	Installation of a wood chip briquetting machine and a wood pellet heating system
Result:	Reduction in heating oil consumption by around 90%

The company, rabe Innenausbau GmbH, plans, designs, manufactures and assembles interior fittings for private homes and commercial clients. The family-run company already uses resource-efficiency measures in planning and construction of its products. These include use of high-quality materials to ensure the product of the company's work is long-lived and durable. Alongside energy-efficient lighting and a modern, low-emissions vehicle fleet, there was potential to use the waste wood generated in production to heat the production halls and offices. To this end, a new wood briquette heating plant was installed to exploit the thermal energy potential of wood shavings. By heating the rooms and production halls in this way, the company was able to reduce its heating oil consumption by around 90%.[96]

[96] Cf. rabe Innenausbau (2018).

Good practice example 2: Orthopädie-Schuhtechnik-Schwarzenberg GmbH

Sector:	Crafts fulfilling private demand, Group VII: shoe technology
Measure:	Use of low-hazard materials, use of combined heat and power plants, utilisation of rainwater, use of photovoltaic systems, recycling of residual leather
Result:	Reduction in energy consumption, waste avoidance through reuse of materials

Orthopädie-Schuhtechnik-Schwarzenberg GmbH is a manufacturer of orthopaedic shoes. Because of its internal environmental measures, the company, based in Saxony, had already been accepted into the Saxony Environmental Alliance back in 2004. The measures carried out included:[97]

- use of two combined heat and power plants and a photovoltaic system to cover own energy demands, with any excess fed back into the grid,
- use of rainwater to irrigate outdoor areas,
- leftover leather from shoe production is used to manufacture smaller products and promotional items, including key cases and labels,
- use of less harmful materials such as non-toxic adhesives,
- the adhesives used are stored in hazardous materials cabinets to prevent any vapour generated from escaping unhindered into the work areas,
- Grinding machines are set up in a separate room so that the sanding dust can be removed immediately via a special extraction system.

[97] Cf. Orthopädie-Schuhtechnik-Schwarzenberg GmbH (2018).

Good practice example 3: Druckerei Vetters GmbH & Co. KG

Sector:	Crafts fulfilling industrial demand, Group III: printing
Measure:	Installation of a regenerative exhaust gas cleaning plant
Result:	savings of 101 tonnes of CO_2 per year, annual operational costs reduced by €26,520

Druckerei Vetters, located in Radeburg, Saxony, produces books, brochures, leaflets, magazines, etc. The printing process used by the company is heatset web offset printing. Natural gas provides the energy source for the process. It is used to dry the inks on the paper webs and was also used to fire the thermal incinerator. The latter took the pre-warmed exhaust from the drying process and, using additional natural gas, combusted it in a chamber. The lower the quantity of flammable pollutants in the air, the more gas was needed.[98]

The thermal incineration plant was replaced with a regenerative waste gas purification system as part of participation in the Ökoprofit project. This works by switching to autothermal mode when sufficient flammable pollutants have entered the chamber and doesn't need additional heat from natural gas.[99] This has helped the company save around 530,000 kWh per year. That amounts to around 100 tonnes of CO_2 emitted and €26,000.

Other measures implemented by the company to save materials and energy included:[100]

- use of an energy-saving, speed-controlled air compressor with VDS motor,
- use of an IT-based measurement and control system to regulate the operating technology.

[98] Cf. Umweltpakt Bayern (2003).
[99] Cf. Umweltallianz Sachsen (2019).
[100] Cf. Rilke et al. (2009).

4.2 Practical examples from the field of digitisation

Good practice example 4: Lungmetall OHG

Sector:	Crafts fulfilling industrial demand, Group III: metal processing
Measure:	Complete networking of production facilities (end-to-end data integration)
Result:	More flexible production, higher machine utilisation, less downtime and fewer production errors, condition monitoring of machines leading to the use of wear parts to the very limit of their service life

Lungmetall OHG manufactures standard and customised products for plant construction and mechanical engineering. The machines of various ages used in production were mostly from different manufacturers. This made it difficult to coordinate, analyse and optimise production processes and workflows, leaving them obscure.

The company, with 30 employees, aimed to introduce an integrated digital process platform enabling end-to-end data integration. Together with the Kompetenzzentrum Digitales Handwerk (Competence Centre for Digital Crafts), existing business processes were modelled and redesigned and then digitalised using suitable tools and existing solutions.

As a result, employees, machines and IT systems were networked with each other on the internal process platform. The company is now able to shape the production process transparently and reduce downtime by obtaining data in real time. Condition monitoring (measure 7, Table 7) via sensors (measure 1, Table 7) also takes place and is used indicate pending repair and maintenance work.[101]

101 Cf. Krause und Lung (2018).

Good practice example 5: LIGNEUS GmbH

Sector:	finishing trades, Group II: interior finishing
Measure:	Digitisation of operational processes, 3D design of components, barcode-marked components
Result:	lower production errors and error rates, continuous information flow creates transparency and reveals optimisation potential, high processing quality, shorter throughput times

LIGNEUS GmbH offers customised interior fittings for the retail trade and, in some cases, for trade fair presentations. Initial measures to make production more efficient were already implemented in 2008. These included tool and workplace management, which structured and streamlined process workflows (Chapter 3.1.2).

The processes were then digitalised step by step. Now, the company records customer requirements via a digital construction plan. The prerequisite for this is 3D construction of the components. This automatically generates the required machine programmes, which means that the subsequent process workflows are already perfectly adjusted to each other. Every component has a barcode containing information regarding the subsequent work steps (digital object memory, in part with decentralised control, measures 3 and 4, Table 7).

Digitalised production with a continuous flow of information results in a manufacturing process with a very low error rate and high transparency and processing quality. This avoids production errors and saves material and energy. In addition, process transparency enables further optimisation potential to be identified and exploited.[102]

[102] **Cf. Goedecke und Erhardt (2018).**

Good practice example 6: Rakowski Services GmbH

Sector:	Crafts fulfilling industrial and private demand, Groups III and VII: Disposal and cleaning services
Measure:	digitisation of operating processes (end-to-end data integration)
Result:	optimised route planning for the vehicle fleet, leaner and more efficient administrative processes, beginnings of a paperless office

Rakowski Dienstleistungen GmbH has a large fleet of vehicles, as the range of services extends from machine and plant cleaning to sewer cleaning and waste disposal. This results in a wide variety of operational processes that require extensive planning, coordination and administration.

In order to streamline its processes and make them more efficient, the company switched from paper-based process management to digital data capture. Together with the Kompetenzzentrum Digitales Handwerk (Competence Centre for Digital Crafts) and the Halle Chamber of Crafts, the management developed software adapted to the company which was able to digitalise operational processes step by step. The employees received mobile devices that enabled real-time data transfer between the driver and the accounting department. Care was taken to ensure that the input screens were similar to the former paper documents in order to make it easy for employees to switch to the programme. The company's customers can also use the software if they are interested. This means integrated data transmission can be carried out in just as lean and efficient a way beyond the limits of the company.

Alongside the paper savings achieved by leaner administration processes, the operation was also able to optimise route planning through digitisation measures. Thanks to the transparent processes, available drivers and quantities can be planned precisely, thereby reducing inefficient journeys.[103]

[103] **Cf. Goedecke (2018).**

5 CONCLUSION

The skilled crafts sector has recorded rising turnover since 2013. The order situation is currently considered to be very good, meaning that investment is increasing, and particularly in rationalisation measures. This includes investments to increase productivity, which can be realised through resource efficiency measures, for instance. The resulting material and energy savings can reduce costs in the skilled crafts and thus generate competitive advantages. To those working in industrial-related crafts, this Brief Analysis presents opportunities and measures for a more resource-efficient production process. It should serve as both stimulus and impetus for understanding material and energy savings not only as a sustainability measure, but also as an economic instrument.

A closer look at production infrastructure is recommended across all sectors as a starting point for the optimisation of material and energy costs. More efficient design of e.g. pressurised air systems, tool management or warehousing and logistics can already generate savings potential in the business. Energy consumption can be significantly reduced if the pressurised air network is continuously monitored or replaced by an alternative, such as a compressed-air-and-heat unit. Orderly tool handling, for example using the 5S method, reduces the accumulation of infrequently used, worn or duplicated tools, thus increasing tool service life.

Digitisation is currently a key focus of trade businesses. In 2017, one in four craft operations invested in digitisation measures. For the most part, measures are being implemented to network operational and process workflows to make them more transparent. This has a positive impact on resource efficiency. Transparency in operational and process workflows, e.g. the recording of resource-relevant data, uncovers inefficiencies that can be eliminated through resource efficiency measures. ERP systems in particular help to provide a comprehensive overview of operational processes, thereby opening up potential for optimisation based on it. This allows rejects and waste quantities to be reduced or electrical energy to be saved. In addition to tracking systems for localisation and monitoring in vehicle fleets and tool inventories, 3D printing, status monitoring and predictive maintenance in tools and machinery are the technologies set to play an ever-greater role in skilled craft businesses in the future. They allow material-saving prototypes and products to be manufactured, resource data to be collected and analysed in real time and machines and tools to be used up to their wear limits. At present, these technologies are still primarily found in large corporations, but technological developments will drive their penetration into the operating processes of smaller companies and businesses and reveal further opportunities for tapping resource efficiency potential.

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