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# Applying Behavioral Economics to Energy Efficiency in Production

Sven Asmus

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| Vorsitzende: | Univ.-Prof. Dr. Isabell M. Welpe |
| Prüfer der Dissertation: | 1. Univ.-Prof. Dr. Alwine Mohnen |
| | 2. Jun.-Prof. Dr. Brooke Shaughnessy (Ludwig-Maximilians-Universität München) |

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"Okay, a PhD is pretty impressive, too"

(Unknown Author, n.d.)

I have read this phrase next to a thrilling yellow BMW M3 E46 on a poster two years ago for the very first time. That particular poster was pinned on a wall in front of a professor's office. To a certain extent this phrase fits perfectly to the last nearly six years in which I worked on my PhD thesis.

During that time, I had the chance to be involved in challenging research and teaching projects, working together with some smart people who helped me to improve on a daily basis and who kept me motivated. Besides that I was lucky enough to have time to do some other things, working on my own, travelling around, spending time with special people who greatly inspired me. Now it is the right time to say thank you!

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# 1 Introduction

The efficient use of energy in production processes is one of the key challenges the industrial sector faces in the 21st century (Abele & Reinhart, 2011). The underlying reasons are multifaceted with rising energy costs determined by the permanently growing scarcity of resources, the noticeably increasing awareness for environmental issues, as well as intensified governmental policies and regulations as being identified as some of the most discussed ones (Belz & Peattie, 2009; Bunse, Vodicka, Schönsleben, Brülhart, & Ernst, 2011; Jovane et al., 2008; Reinhart, Graßl, & Greitemann, 2012). Taking into account that manufacturing companies are responsible for 31% of global primary energy use and furthermore cause 36% of worldwide $CO_2$ emissions (International Energy Agency (IEA), 2007), the necessity of means to foster energy efficient manufacturing is an indisputable fact and therefore a prominent target (Tanaka, 2011).[1]

## 1.1 Energy Consumption by Sector

In most industrialized countries, both developing and developed, the industrial sector is the major consumer of energy. In Germany the energy consumption share of industry is at 28.9% nearly similar to the demand of the transportation sector (28.6%) and the private household expenditures at 27.0% (Bundesministerium für Wirtschaft und Energie (BMWi), 2014)[2]. In contrast to Germany, the consumption distribution in the United States between the three mentioned sectors emphasizes the relevance of the industrial sector especially compared to the private household energy use. Industrial companies in the United States are responsible

[1] In this thesis the terms production processes and manufacturing processes are used interchangeably, since the presented context refers solely to the industrial sector and no other kind of production.

[2] The English translation for 'Bundesministerium für Wirtschaft und Energie' (BMWi) is Federal Ministry for Economic Affairs and Energy. In this context it refers to the German Federal Ministry for Economic Affairs and Energy.

for 30.6% of total energy consumption compared to 27.1% for the transportation sector and 21.6% residential use (United States Energy Information Administration (EIA), 2012).[3] Even though numbers for newly industrialized economies are often neither precise nor fully reliable, regarding the context of the industrial share of energy consumption in a specific country, they shed a new light into the discussion. Estimations for China are between 50% (Tang, Li, & Du, 2006) and 70% industry share in nationwide energy consumption (China Information Office, 2012) and underline therefore the relevance of the discussed topic. Worldwide, the industrial sector counts for about one third of global energy use (IEA, 2007, 2008).

## 1.2 Energy Policies

Analyzing the intense efforts in the field of energy policies, both on an EU-level as well as on a national level specifically in Germany, it becomes obvious that next to the topic of renewable energies, the expediting of energy efficiency is of major relevance. While the member states of the European Union agreed on a 20% energy efficiency increase by 2020 compared to 1990 as one of the three primary goals in the '20/20/20 by 2020' concept (European Commission (EC), 2015), the German government identified energy efficiency as one of the key pillars in the 2010 released energy concept (Bundesregierung, 2010)[4]. German energy efficiency-specific goals include the increase of energy productivity by 2.1% on average per year in relation to the total energy consumption (BMWi & Bundesministerium für

[3] The commercial sector, as the fourth end use sector in energy consumption analysis, counts in Germany for 15.5% of the total energy consumption, while its share is 18.0% in the United States.

[4] The English translation for 'Bundesregierung' is Federal Government. In this context it refers to the German Federal Government.

Umwelt, Naturschutz und Reaktorsicherheit (BMU), 2012)[5]. The increase of the industry-related energy efficiency is therein determined at about 1.3% per year. The monetary saving potential, solely based on efficiency measures in the industrial sector, is estimated at 10 billion euro annually by the German government (Bundesregierung, 2010).

## 1.3 Energy Efficiency Measures in Industry

The commonly used definition by Patterson (1996, p. 377) "…energy efficiency refers to using less energy to produce the same amount of services or useful output…" only defines the term itself, without referring to applicable measures and approaches to ensure energy efficiency. In the current literature on the Energy Value Stream (EVS) method, three system elements are taken into account when it comes to measuring, visualizing, and analyzing energy consumption to reach energy efficiency: technology & system, organization & management, and human & behaviour[6] (Bullinger, Spath, Warnecke, & Westkämper, 2009; Reinhart et al., 2011). So far, most existing approaches to increase energy efficiency in industrial production processes are merely related to the technology & system as well as to the organization & management dimensions, while a human & behaviour perspective is seldom integrated (e.g., Asmus, Gries, Holtermann, Mohnen, & Schenuit, 2010; Duflou et al., 2012).

Due to the rising importance of an efficient energy use and the awareness of enormous energy saving potentials in companies (Neugebauer et al., 2008), nowadays there is a constantly increasing number of both, scientific and practical approaches, to measure, monitor, control,

[5] The English translation for 'Bundesministerium für Umwelt, Umweltschutz und Reaktorsicherheit' (BMU) is Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety. In this context it refers to the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety.

[6] In the following the term behavioral economics is written in American English spelling since its origin respectively its roots seem to be more in the United States than in any other part of the world. The word behaviour as well as the whole thesis is written in British English spelling.

and evaluate energy efficiency by the introduction and implementation of specific indicators (e.g., Bunse, Sachs, & Vodicka, 2010; Institut für Energieeffizienz in der Produktion (EEP), 2015)[7]. Other studies examine the financial outcomes of investments into energy efficiency in industrial processes (e.g., Pehnt et al., 2011) or analyze the energy efficiency gap between the actual and the optimal energy use (Gillingham & Palmer, 2013; Jaffe & Stavins, 1994). Even though there is already a common understanding about the existence of employee potential to reduce energy consumption in production, this chance is often either underestimated or not at all taken into account (McKinsey, 2009). This is reflected by the small number of studies on that particular measure to increase energy efficiency in production.

## 1.4 Employee Energy Use in the Workplace

To the best of the authors' knowledge, so far only the study by Siero, Bakker, Dekker, and van den Burg (1996) examined the influence of employee behaviour on energy efficiency in a production setting. In that particular study different forms of feedback as one approach from the field of behavioral economics were applied to employees working for a metallurgical company at two sites in the Netherlands. The results indicate that comparative feedback leads to higher energy savings compared to feedback on one's own consumption. Besides that, no other studies have been conducted in the field of energy efficient employee behaviour in any blue-collar context. In contrast, there is a continuously rising number of scientific publications and practical initiatives with the primarily focus on employee energy use in office buildings. Most of those studies were conducted in the United Kingdom or the Netherlands. Their main emphasis is either on the influence of individual, contextual, and organizational determinants on employee energy use in offices (Littleford, 2013; Lo, Peters, & Kok, 2012), or on the

[7] The English translation for 'Institut für Energieeffizienz in der Produktion' (EEP) is Institute for Energy Efficiency in Production.

impact of different feedback measures on employee consumption patterns (Carrico & Riemer, 2011; Murtagh et al., 2013). Besides the study of Lo et al. (2012), who recruited study participants partly from commercial companies, the other studies integrated merely office workers employed at universities (Carrico & Riemer, 2011; Murtagh et al., 2013) or employees of the local government (Littleford, 2013). The results of the feedback studies clearly indicate diminishing engagement with the feedback provided over time (Murtagh et al., 2013). Moreover, they raise the question, in what manner employees could be motivated to behave energy efficiently in the workplace, even when no financial incentives to behave pro-environmentally are provided (Carrico & Riemer, 2011).

Especially when comparing the amount and quality of studies on employee energy use in the workplace with the extensively examined field of household studies on energy efficiency (e.g., Abrahamse, Steg, Vlek, & Rothengatter, 2005; Bamberg & Möser, 2007), it is obvious that a systematic and differentiated analysis and discussion of energy use in the workplace is still pending (Lutzenhiser, 1993). This holds true especially for industrial production processes as the specific field of application as well as for behavioral economics approaches such as the induced methodology.

# 2 Subject and Approach

## 2.1 Research Subject

As already discussed in the previous chapter, industrial companies nowadays face the need to increase energy efficiency in their manufacturing processes. Since most technical approaches and measures to cope with this particular challenge only lead to marginal efficiency improvements, the investigation of employee potential to tackle that issue is undoubtedly necessary. Nevertheless, the number of scientific studies incorporating employee behaviour to decrease companies' energy consumption is comparatively small. This especially applies to the field of production.

Knowing about the substantive 21st-century-challenge to increase energy efficiency on the one hand and the described research gap on the other hand, this thesis examines empirically selected strategies and approaches to incorporate worker potential to increase energy efficiency in production processes. Therefore, the overall research question of this thesis is the following:

**WHAT ARE THE APPROPRIATE MEASURES TO INCORPORATE WORKER POTENTIAL TO SUBSTANTIALLY INCREASE ENERGY EFFICIENCY IN PRODUCTION PROCESSES?**

## 2.2 Methodical Approach

In order to be able to deal with the posed research question, certain requirements need to be fulfilled. One potential reason why the number of empirical studies in that respective research field is relatively small might be the difficulty of finding an adequate methodology and suitable setting to examine the given question. Facing the challenge described, all experimental studies in this thesis were conducted at the Learning Factory for Energy Productivity (LEP) at the Institute for Machine Tools and Industrial Management at the

Technische Universitaet Muenchen.[8] The LEP provides a realistic learning and research environment with the focus on energy productivity in production (Karl, Schmidt, & Reinhart, 2013; Reinhart & Karl, 2011).

The concept of learning factories started in 1994 as part of the Manufacturing Engineering Education Partnership (MEEP) of the Penn State University, University of Puerto-Rico Mayaguez, and the University of Washington (Lamancusa, Jorgensen, & Zayas-Castro, 1997). The introduction of those first three physical facilities was part of an initiative to redesign and to modernize engineering education, providing students with both technical knowledge and competencies as well as professional and practical skills. Nowadays, about 20 years later, numerous learning factories are established at universities and companies worldwide, providing learning and research environments and following an action- and competency-based approach (Tisch et al., 2013; Wagner, AlGeddawy, ElMaraghy, & Müller, 2012). Currently, at least 15 active learning factories exist at German universities, covering a wide diversity of application areas, e.g., lean production, continuous improvement processes, changeability, or energy efficiency (Cachay & Abele, 2012; Gossmann & Nyhuis, 2012; Kreimeier et al., 2014; Tisch et al., 2013). However, learning factories are conceptualized to provide an environment for learning and research, the clear orientation of scientific publications on learning factories relies on different learning and teaching approaches instead of applied engineering research. Especially the focus on the development of student competencies in the field of manufacturing is highlighted extensively (Abel, Czajkowski, Faatz, Metternich, & Tenberg, 2013; Tisch et al., 2013). Besides one experimental study on

[8] The German translation for Learning Factory for Energy Productivity (LEP) at the Institute for Machine Tools and Industrial Management at the Technische Universitaet Muenchen is ‘Lernfabrik für Energieproduktivität (LEP) am Institut für Werkzeugmaschinen und Betriebswissenschaften an der Technischen Universität München’. In the following, the terms Learning Factory for Energy Productivity, Model Factory for Energy Productivity, and Training Factory for Energy Productivity are used interchangeably for the LEP.

the effectiveness of the action-oriented learning approach at the Technische Universitaet Darmstadt (Cachay, Wennemer, Abele, & Tenberg, 2012), the effectiveness of the measures trained in the application fields of the different learning factories have not yet been evaluated sufficiently in empirical studies.

For the examination of employee influence on energy efficiency in production processes, the LEP offers a highly suitable setting providing a combination of economic laboratory and field experiment setting by simulating a real industrial production process including several manual as well as automated production steps (Karl et al., 2013). Following the distinction of field experiments by Harrison and List (2004), the LEP can be described as a framed field experimental setting. Points of criticism related to field experiments are, that certain background conditions are difficult to control and often not predictable (Nikiforakis, 2010). In order to ensure the highest possible controllability of external factors and to realize best comparability of the participants' performance, the final step of the production chain was chosen as the specific experimental setting. Here the task is to assemble gearboxes by using a pneumatic screwdriver to insert six bolts per gearbox. Based on the study of Falk and Fehr (2003), assembling a gearbox can be clearly defined as a real-effort task. Energy use is measured as the consumed compressed air of the pneumatic screwdriver per bolt inserted respectively per gearbox assembled.

Most participants of all the experimental studies were students of the two major Munich-based universities.[9] Choosing students as participants in experiments comes with several advantages, e.g., the simple availability at universities, the comparatively low costs, as well as

[9] Ludwig-Maximilians-Universitaet Muenchen & Technische Universitaet Muenchen

their steep learning curve (Abdel-Khalik, 1974; Friedman & Sunder, 1994).[10] With regard to the described measures and adjustments, the experimental setting shows clearly comparable conditions to experimental studies in behavioral economics laboratories.

## 2.3 Substantive and Structural Approach

Chapters 3 to 6 are based on three different experiments, which were all conducted at the LEP between November 2012 and November 2014. With reference to the overall research question on the impact of certain measures to incorporate worker potential to substantially increase energy efficiency in production processes, this thesis incorporates different approaches related to the broader field of behavioral economics, namely feedback (chapter 3), training and education (chapter 3), goal setting (chapters 4 and 5), and social incentives (chapter 6). Therefore, the title of this dissertation is the following:

**APPLYING BEHAVIORAL ECONOMICS TO ENERGY EFFICIENCY IN PRODUCTION**

In chapter 3 - ENERGY EFFICIENCY IN PRODUCTION PROCESSES – THE INFLUENCE OF CONSUMPTION VISUALIZATION AND STAFF TRAINING - the first focus is on the effect of consumption visualization on one's own energy use as a specific form of feedback. The study by Siero et al. (1996) in a real production setting as well as several studies on household energy consumption (e.g., Brandon & Lewis, 1999; Gleerup, Larsen, Leth-Petersen, & Togeby, 2010; Nilsson et al., 2014; van Houwelingen & van Raaij, 1989) had already provided empirical evidence on the effectiveness of feedback to decrease energy use. As the second field of interest, the impact of staff training and education on energy efficient

[10]Nonetheless, the adequacy of students being participants in experiments to draw conclusions about employee behaviour is controversially discussed in social sciences without establishing a common agreement (Peterson, 2001). Most studies thereby compare students' and managers' behaviour in decision making (e.g., Carlsrud, Brännback, Nordberg, & Renko, 2009; Montmarquette, Rullière, Villeval, & Zeiliger, 2004; Waichman, Requate, & Siang, 2008), while no study examined the transferability of students' behaviour on blue-collar workers so far.

behaviour in production processes was investigated. Both, feedback as well as training and education as factors to influence energy consumption patterns were examined by Carrico and Riemer (2011) regarding the use of energy in university buildings. However, so far no study about the effect of training and education has been conducted in the field of production.

In order to cover both areas of interest, feedback as well as training and education, four experimental groups were built, each consisting of 40 participants. Three of the experimental groups, all but the control group, were provided with an air flow meter to measure and display participants' energy consumption to test whether feedback in terms of consumption visualization has an effect on energy use. In order to measure the impact of training and education on consumption patterns, one of the experimental groups watched a video on how to save energy related to certain production tasks. The performance of that particular group was compared to the other groups which did not receive the additional energy saving information but were either provided with a non-energy related movie or a video sequence designated to increase environmental awareness by showing nature scenes.

Chapter 4 - THE IMPACT OF GOAL SETTING ON WORKER PERFORMANCE – EMPIRICAL EVIDENCE FROM A REAL-EFFORT PRODUCTION EXPERIMENT - examines the role of goal setting related to worker performance. The number of studies in the field of goal setting is enormous (e.g., Locke & Latham, 1984, 1990, 2002, 2013). Results clearly indicate a positive impact of goal setting on motivation and performance (e.g., Latham & Kinne, 1974; Locke, 1996; Locke, Shaw, Saari, & Latham, 1981; Mento, Steel, & Karren, 1987). Most of the studies either use typical behavioral economics laboratory tasks such as reading exercises (LaPorte & Nath, 1976) or mathematical calculations (Bryan & Locke, 1967), or measure participants' reactions on an appearing signal light (Locke, Chah, Harrison, & Lustgarten, 1989). Other experimental studies apply regular office tasks such as typewriting (Latham & Yukl, 1976) or predefined telephone services (Kim & Hamner, 1976) to examine the impact of goal setting on

performance. Moreover, some research projects already examined the impact of goal setting on energy efficiency in households (e.g., Abrahamse, Steg, Vlek, & Rothengatter, 2007; Becker, 1978; van Houwelingen & van Raaij, 1989) but to the best of the authors' knowledge no study has investigated the effect of goal setting in a real production setting so far. This holds true especially for the goal of energy efficiency in production processes.

In this experimental study on the impact of goal setting in an industrial process the performance of four different treatment groups, each consisting of 30 participants with either no goal or one goal to concentrate on, was compared. The control group had no defined goal, one group had to maximize the output quantity, one group had to ensure highest possible output quality and the fourth group had to minimize energy consumption. Hereby, the key question is whether goal setting leads to improved task performance, and furthermore if goal setting might intensify learning effects when performing repeated tasks. Both questions are examined related to the classical production goals of output quantity and output quality as well as for energy efficiency as one key driver of sustainable manufacturing.

Chapter 5 - GENDER DIFFERENCES IN PERCEIVED GOAL CONFLICT AND OVERCONFIDENCE - EVIDENCE FROM A REAL-EFFORT EXPERIMENT - is based on the same experiment as chapter 4. It concentrates on the perception of goal conflict which may occur due to the natural restrictions of human cognitive capacity when several goals are set simultaneously (Cheng, Luckett, & Mahama, 2007; Halford, Baker, McCredden, & Bain, 2005). Deviating from the previous chapter, chapter 5 incorporates only the experimental groups which were confronted either with two or three goals. In parallel to research on the subject of goal setting, substantial literature can be found in the field of goal conflict (e.g., Emmons & King, 1988; Kehr, 2003; Locke, Smith, Erez, Chah, & Schaffer, 1994). Nonetheless, based on the design, the study fills several research gaps in that particular field. The first focus is on the question of whether a growing number of goals lead to an increased self-perceived goal conflict. Integrating the goal

dimension energy efficiency next to output quantity and output quality, the study is the first of its kind incorporating three goal dimensions in an experimental setting. So far, most of the experimental studies in that specific area examined the occurring goal conflict resulting from the goal dimensions output quantity and output quality (e.g., Audia, Kristof-Brown, Brown, & Locke, 1996; Locke et al., 1994; Slocum, Cron, & Brown, 2002). Besides the integration of a third goal dimension, chapter 5 discusses gender differences in goal conflict. Even though the work of Levy and Baumgardner (1991) already provided first insights about the effect of gender on goal choice, no clear empirical evidence on potential differences of goal conflict perception between male and female exists. Chapter 5 tries to close that gap by integrating research on the 'self-attribution bias' (Deaux & Farris, 1977) and the extensive overconfidence literature (e.g., Bhandari & Deaves, 2006; Moore & Healy, 2008). Furthermore, chapter 5 gives valuable insights whether or not the classical production goals quantity and quality outperform the goal of energy efficiency in perceived goal importance.

Chapter 6 - SOCIAL REWARDS AND SOCIAL PUNISHMENTS TO FOSTER PRO-ENVIRONMENTAL BEHAVIOUR – EVIDENCE FROM A REAL-EFFORT EXPERIMENT - is based on the third experiment. While substantial literature exists on the effects of monetary and non-monetary incentives on employee motivation and performance related to output quantity and output quality in a broader sense (e.g., Fehr & Falk, 2002; Gneezy & Rustichini, 2000; Lazear, 2000; Prendergast, 1999), research on the impact of incentives on pro-environmental behaviour and energy efficiency is still lacking in quantity and quality (see for exceptions, e.g., Handgraaf, van Lidth de Jeude, & Appelt, 2013; Schultz, Nolan, Cialdini, Goldstein, & Griskevicius, 2007). In order to expand findings in that particular field, the focus of this chapter relies on the effect of social incentives on pro-environmental employee behaviour using the Goal Framing Theory by Lindenberg & Steg (2007) as a scientific fundament. The literature on factors influencing pro-environmental behaviour (e.g., De Young, 1985-1986; Polonsky,

Vocino, Grimmer, & Miles, 2014; Steg & Vlek, 2009) as well as on social incentives (e.g., Brüggen & Moers, 2007; Masclet, Noussair, Tucker, & Villeval, 2003; Stajkovic & Luthans, 2001) is extensive. However, the combination of the two fields demonstrates that a clear research gap exists.

In total 95 participants were distributed to three experimental groups. Contrary to the other two experiments, the task of the participants was not the assembling but the disassembling of gearboxes. Based on participants' energy consumption and their respective treatment group, people received a social reward (green button with a happy face emoticon), a social punishment (red button with an unhappy face emoticon), or no social incentive at all. Based on that experimental design the study aims to examine two potential effects of social incentives on energy related behaviour: first, the immediate impact of the announcement of social incentives, and second the sustainable effect of social incentives on energy efficient behaviour, once the incentives were already distributed. Similar effects have already been found for the influence of rewards and punishments on performance in general (e.g., Driscoll, 2005; Gershoff, 2002; Skinner, 2014), but neither for social incentives nor for the application to pro-environmental behaviour.

Taking into account the overall research question **WHAT ARE APPROPRIATE MEASURES TO INCORPORATE WORKER POTENTIAL TO SUBSTANTIALLY INCREASE ENERGY EFFICIENCY IN PRODUCTION PROCESSES?** and the thesis' title **APPLYING BEHAVIORAL ECONOMICS TO ENERGY EFFICIENCY IN PRODUCTION**, chapters 3 to 6 examine different measures to incorporate employee potential to decrease energy consumption in production. While chapter 3 focuses on the impact of feedback and training, chapters 4 and 5 relate to goal setting, and chapter 6 deals with the influence of social incentives on energy efficient employee behaviour.

# 3 Energy Efficiency in Production Processes – The Influence of Consumption Visualization and Staff Training

**Authors:** Asmus, Sven; Karl, Florian; Graßl, Markus; Mohnen, Alwine; Reinhart, Gunther

**First Author:** Asmus, Sven

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**Individual Contribution:** In the creation process of this paper which builds the basis for chapter 3 of this doctoral thesis, I did the supervision of the experimental design construction and the execution of the experimental study. Moreover, I conducted the data analysis almost exclusively and wrote most sections of the paper independently. Furthermore, I presented the paper at several international conferences and workshops and integrated the received feedback. Finally, I was in charge of the whole submission process until the final publication of the paper in the Proceedings of the 11th Global Conference on Sustainable Manufacturing – Innovative Solutions.

**Note:** The published edition of this chapter is attached in the appendix for the examiners of this dissertation. In order to avoid any kind of plagiarism or dual publication, it is not included in the freely accessible version of this doctoral thesis.

**Abstract**

This paper examines the influence of the visualization of consumed compressed air and staff training on the consumption behavior of employees in a real production process. To measure potential changes in consumption behavior a real-effort experiment at the Training Factory for Energy Productivity, a real production setting at iwb of TUM, had been designed. Therefore, four groups were defined, each group in a different experimental setting. This experiment is the first one ever conducted in a real-life setting and thus adds valuable results to academia and practitioners. Compared to the group without any information about the amount of consumed compressed air the participants provided with a display showing this information saved on average 7-8%. The group provided with a movie about general measures to save compressed air in production consumed around 24% less compressed air than all other groups of participants. Generally, no significant differences between male and female participants had been found.

# 4 The Impact of Goal-Setting on Worker Performance – Empirical Evidence from a Real-Effort Production Experiment

**Authors:** Asmus, Sven; Karl, Florian; Mohnen, Alwine; Reinhart, Gunther

**First Author:** Asmus, Sven

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**Note:** The published edition of this chapter is attached in the appendix for the examiners of this dissertation. In order to avoid any kind of plagiarism or dual publication, it is not included in the freely accessible version of this doctoral thesis.

**Abstract**

This paper examines the influence of goal-setting on worker performance in an industrial production process. For empirical examination, we conducted a real-effort experiment at the Training Factory for Energy Productivity at the Technische Universitaet Muenchen. The participants' performance was measured by checking for quantity and quality of the assembled products and furthermore by recording the consumed compressed air per finished good. In total four groups were defined, each group in a different experimental setting. This experiment is the first one ever conducted related to goal-setting in an industrial production setting and thus adds valuable results to academia and practitioners in the field of sustainable manufacturing. The major results are that even without financial incentives goal-setting improves worker performance by 12 to 15% compared to the situation where no goals were defined. This holds true for the groups which had to maximize either output quantity or output quality, as well as for the group which was obliged to be as energy efficient as possible.

# 5 Gender Differences in Perceived Goal Conflict and Overconfidence – Evidence from a Real-Effort Experiment

**Authors:** Asmus, Sven; Dietrich, Daniel; Hausler, Saskia; Mohnen, Alwine

**First Author:** Asmus, Sven

**Current Status:** Under review for publication

**Individual Contribution:** In the creation process of this paper which builds the basis for chapter 5 of this doctoral thesis, I did the supervision of the experimental design construction and the execution of the experimental study. Moreover, I conducted parts of the data analysis and wrote sections of the paper. Furthermore, I coordinated the dissemination of the paper at international conferences and workshops.

**Note:** A revised version of the submitted edition of this chapter is entirely presented in the copy for the examiners of this dissertation. In order to avoid any kind of plagiarism or dual publication, it is not included in the freely accessible version of this doctoral thesis.

**Abstract**

The present research examines gender-specific differences on the perception of goal conflict. In order to test the effects of multiple goal-setting-combinations on perceived goal conflict empirically, a real-effort experiment was conducted within an industrial production environment. Eight experimental groups with 240 participants in total have been set up, differentiated by the number and types of goals. Three goal dimensions, commonly set as objectives in production settings, were applied: energy efficiency, output quantity, and output quality. Findings indicate that a higher number of goals increase the perceived level of goal conflict. Moreover, men experience significantly less goal conflict than women under the same conditions. This gender gap rises with the number of requested targets. A possible explanation for this gender inconstancy may be drawn from overconfidence research, which provides evidence that men tend to overestimate their personal abilities due to a higher level of self-esteem and overconfidence. Nevertheless, irrespective of the number and types of goals, the actual goal achievements indicate only a few significant performance differences between men and women.

# 6 Social Rewards and Social Punishments to Foster Pro-Environmental Behaviour – Evidence from a Real-Effort Experiment

**Authors:** Hausler, Saskia; Asmus, Sven; Mohnen, Alwine

**First Author:** Hausler, Saskia

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**Individual Contribution:** In the creation process of this paper which builds the basis for chapter 6 of this doctoral thesis, I did the supervision of the experimental design construction and the execution of the experimental study. Moreover, I conducted parts of the data analysis and wrote sections of the paper. Furthermore, I coordinated the dissemination of the paper at international conferences and workshops.

**Note:** A revised version of the submitted edition of this chapter is entirely presented in the copy for the examiners of this dissertation. In order to avoid any kind of plagiarism or dual publication, it is not included in the freely accessible version of this doctoral thesis.

**Abstract**

The research presented examines social incentives as a means of fostering pro-environmental behaviour of production employees. For this purpose, a real-effort experiment has been conducted within an industrial production setting, with a combination of normative goal setting, feedback, and social incentives serving as interventions. The goal communicated to the participants was to minimize energy consumption during the production process, which is considered as pro-environmental behaviour. Social incentives included positively or negatively valenced emoticons, conveying social approval or social disapproval, respectively. Three experimental groups have been tested over a period of three rounds, differing by the social incentives received. The results indicate a positive effect of both social rewards and social punishments on energy conservation. Nevertheless, the level of energy consumption is strongly dependent on goal achievement in previous rounds. Participants under reward condition strived to realize energy savings over all three rounds. In contrast, motivation to furthermore decrease air consumption for subjects under punishment treatment dropped once the preset level of savings was reached. No such effect could be observed for neither the reward nor the control treatment. The performance of both treatment groups utilizing social incentives differed significantly from the control group. A possible explanation why social incentives act as an potential accelerator of pro-environmental behaviour may be drawn from the Goal Framing Theory of Lindenberg and Steg (2007), which underlines the importance of the salient goal frame. Social incentives activate the normative and the hedonic goal frame simultaneously, qualifying them for being a promising tool to foster pro-environmental behaviour.

# 7 Conclusion

## 7.1 Findings and Managerial Implications

Mounting energy costs, a growing public consciousness for environmental affairs, as well as new political regulations are key factors for industrial companies to place the topic of energy efficiency in operations at the top of their strategic agenda. Thus, the question arises which appropriate measures producing companies can initiate to tackle this 21st-century-challenge.

Since technical solutions to manage the described challenge often obtain only marginal improvements, this doctoral thesis applied different approaches from the field of behavioral economics in order to increase energy efficiency in production. Thereby, the effectiveness of several human-related measures resulting in lower energy consumption in production processes was inspected in order to deduce concrete managerial implications and recommendations for industrial companies.

As an introduction to the overall topic, chapter 1 motivated the theme by showing the impact of industrial companies on overall energy consumption, current developments in energy policies, as well as recent trends in energy efficiency measures. Furthermore, the current stage of research in the field of employee energy use in the workplace was outlined and an existing research gap especially in the field of employee behaviour incorporation related to energy efficiency in production processes could be disclosed. Chapter 2 presented the research subject of this dissertation and explained the applied methodology and the experimental setting serving as the basis for the empirical studies presented in chapters 3 to 6. Moreover, chapter 2 provided an initial overview on the following contents. All experimental studies were conducted at the Learning Factory for Energy Productivity at the Institute for Machine Tools and Industrial Management at the Technische Universitaet Muenchen. Feedback (chapter 3), training and education (chapter 3), goal setting (chapters 4 and 5), and social

incentives (chapter 6) were applied as means of fostering pro-environmental employee behaviour in order to provide empirical evidence on the effectiveness of behavioral economics' approaches to increase energy efficiency in production processes.

The focus of the first experimental study presented in chapter 3 - ENERGY EFFICIENCY IN PRODUCTION PROCESSES – THE INFLUENCE OF CONSUMPTION VISUALIZATION AND STAFF TRAINING – was both on the influence of feedback on energy consumption and on the impact of staff training on individuals' energy efficiency. The results clearly indicate a prominent impact of consumption transparency in the form of visualized feedback on one's own energy use. Savings only due to consumption feedback account on average for 7.4%. Therefore, it can be noticed that significant energy savings can already be reached without the inducement of incentives or comparative feedback, but with the provision of feedback on one's own energy use.

**Finding 1:** *Feedback on one's own energy consumption leads to a significantly lower energy use in production processes.*

Furthermore, the results of the first experiment show that explicit training and education on how to save energy in the particular field of application lead to energy savings of nearly one quarter. Moreover, results indicate that addressing the environmental awareness by solely showing nature scenes is not sufficient to reduce employee energy consumption. Therefore, industrial companies should provide detailed information to their employees on how to behave energy efficiently and additionally should invest thoroughly into specific employee training and education.

**Finding 2:** *While the sole addressing of one's own environmental awareness without the provision of additional information leads to no change in consumption patterns, specific energy efficiency related staff training and education leads to a highly significant lowered energy use.*

Chapter 4 - THE IMPACT OF GOAL SETTING ON WORKER PERFORMANCE – EMPIRICAL EVIDENCE FROM A REAL-EFFORT PRODUCTION EXPERIMENT – dealt with the influence of defined objectives on worker performance. Therein, the effects on the goal dimensions output quantity, output quality, and energy efficiency were examined in detail. The data analysis indicates that goal setting leads to improved worker performance for all tested goal dimensions. Participants with the goal to minimize energy consumption show a significantly reduced energy use compared to the control group with no goal given. Subjects with the goal to maximize output quantity produce significantly more than the control group. The results related to output quality do not differ noticeably between the group with the quality maximization goal and the control group, even though goal setting leads to a slightly improved quality. Therefore, by simply setting goals for its employees, companies are able to increase output quantity and output quality as well as energy efficiency in production processes, at least in the short run. Thereby, no further incentives are necessary for motivating employees to improve their performance as shown by the results. Moreover, the data prove, that goal setting works as an intensifier of learning effects when performing repeated tasks. This holds true for all goal dimensions. Hence, goal setting can also be used by companies to increase employee performance not only short term but in the long term. These conclusions are valid both for the conventional goal dimensions in production management being output quantity and output quality, and for the emerging goal of energy efficient production processes.

**Finding 3:** *Goal setting leads to improved worker performance related to output quantity, output quality, and energy efficiency in the short term as well as in the long term.*

The study presented in chapter 5 - GENDER DIFFERENCES IN PERCEIVED GOAL CONFLICT AND OVERCONFIDENCE - EVIDENCE FROM A REAL-EFFORT EXPERIMENT – examined, among other things, goal conflict differences between male and female. To measure possible disparities between both genders related to this topic, the four experimental groups either confronted with two or three different conflicting goals were taken into account for analysis. Results clearly confirm that women perceive a higher level of goal conflict than men. This holds true for all possible goal dimension combinations. Highest differences between male and female participants in perceived goal conflict exist in the experimental group which was imposed to fulfill all three goal dimensions output quantity, output quality, and energy efficiency, simultaneously. For both male and female participants the goal conflict perception is more intense in the three-goal-condition compared to the two-goal-groups, but with only the increase for women being significant. One possible explanation for this difference might be based on male overconfidence. Interestingly, only a few significant performance gaps between men and women can be observed in the analyzed experimental groups. Since the data clearly indicate that people perceive an increased level of goal conflict when confronted with a higher number of goals to achieve simultaneously, companies might use the results to avoid overstrained and stressed workforce. Because especially women indicate a higher level of perceived goal conflict compared to men, independent of the number of goals set, the communication of goals should be well thought through. Besides that, women should be encouraged to be confident about their proficiency, since their performance is comparable to their male counterparts.

**Finding 4:** *Women perceive significantly higher goal conflict than men particularly when confronted with a growing number of simultaneous goals, even though there are nearly no significant performance differences comparing male and female.*

The final experimental study was introduced in chapter 6 - SOCIAL REWARDS AND SOCIAL PUNISHMENTS TO FOSTER PRO-ENVIRONMENTAL BEHAVIOUR – EVIDENCE FROM A REAL-EFFORT EXPERIMENT - focusing on social incentives as one potential measure to influence pro-environmental behaviour at the production site. Depending on participants' performance and the particular treatment group subjects were distributed to, either positively or negatively valenced emoticons transmitting social approval or social disapproval were induced. Data analysis indicates that the effects of both social rewards and social punishments on energy efficient employee behaviour are predominantly positive. These findings imply that the provision of social incentives is one potential approach to decrease energy use in production which might result in cost savings for industrial companies. Since the introduction of social rewards and social punishments in the form of positively or negatively valenced emoticons bears almost no cost, the savings due to improved energy efficiency in production would directly increase the operating margin. Nevertheless, participants' performance related to energy use is strongly dependent on their goal achievement and the resulting implementation of social incentives in the previous round. This holds true especially if social punishments are induced. While the effect of social rewards is more sustainable and less dependent on goal achievement, the impact of social punishments on pro-environmental behaviour is strongly influenced by previous performance. Knowing about these varying effects of social rewards and punishments, companies should adapt the provision of social incentives to the specific situation and the particular goals.

**Finding 5:** *The effect of both social rewards and social punishments on employee energy use is generally positive but strongly dependent on goal achievement and incentive implementation in the past.*

Conflating the results and findings of the different experimental studies presented in this dissertation with the overall research focus on appropriate measures to incorporate worker potential in order to substantially increase energy efficiency in production processes, the following managerial implications and recommendations can be drawn: By applying behavioral economics and incorporating employee potential to reach increased energy efficiency in production, significant energy savings are realizable. The employment of feedback, training and education, goal setting, and social incentives as means of fostering pro-environmental behaviour leads to significantly decreased employee energy consumption. Even though there were already presumptions regarding employees' enormous potential to decrease energy use in production processes, the extent is both astonishing and encouraging. The application of these induced measures in producing companies not only helps to decrease energy costs immensely, but enables companies to appear more environmentally-friendly to its stakeholders, to successfully deal with governmental policies and regulations about energy efficiency, and to actively incorporate its employees into companies' sustainable well-being. Interestingly, all applied measures from the field of behavioral economics bear almost no cost in that context. Companies using these means are therefore able to increase their operating margin directly.

Although it can be confirmed that goal setting leads to increased worker performance comparing no-goal-situations with one-goal-situations, a mounting number of simultaneous goals yields in increased goal conflict, more stress, and declining performance as seen in chapter 5. Since more and more employees value a healthy work-life balance as one of the most important motivational factors, companies should review continuously their

requirements towards their workforce regarding the fulfillment of conflicting goals. While the applied measures from the field of behavioral economics could increase energy efficiency in the workplace significantly, a high level of perceived goal conflict might offset those positive achievements.

## 7.2 Limitations

However, the presented findings are limited due to several factors. Even though the Learning Factory for Energy Productivity provides an environment which is highly comparable to a real production process, several necessary adjustments have been made to provide an appropriate platform for teaching and research activities. Furthermore, it needs to be mentioned, that all participants of the experimental studies were students and not real production workers. Despite the fact that a control group was set up to test for learning and other effects in all experimental studies, it might hold true that the behaviour and therefore the results differ in comparison to experienced blue-collar workers. Moreover, the number of involved participants in the experiments was too small to draw any resilient conclusions about the impact of demographics on consumption pattern changes due to feedback, training and education, goal setting, and social incentives.

## 7.3 Scientific Contribution and Outlook

Regardless of these limitations, this dissertation sheds some bright light into the discussion in how far employees can be incorporated in order to save energy in the workplace, applied to the field of energy efficient behaviour in production. The findings of this doctoral thesis may contribute to the current literature in the fields of sustainable manufacturing, environmental psychology, and behavioral economics applied to energy and climate issues. Employing the

presented measures, industrial companies are enabled to decrease their costs of production significantly and furthermore to generate greater overall welfare!

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