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Livarski proizvodi in njihova dodana vrednost pri ovrednotenju njihovega življenjskega cikla

Foundry Products and Their Added Value in the Life Cycle Assessments

Povzetek

Naraščajoči stroški energije, novi okoljski predpisi in skrbi glede zanesljivosti energije so povzročili, da se industrija trudi zmanjšati rabo energije in povečati njeno izkoriščenost. Mednarodni in nacionalni zakonodajalci so razvili različne pravne okvirje za izvajanje strategij varčevanja z energijo. Zadnji prispevek k temu je začetek uveljavitve evropske direktive o energijski učinkovitosti, ki se na avstrijski nacionalni ravni uporablja kot zakon o energijski učinkovitosti. Predvsem energijsko intenzivne industrije, npr. livarska industrija, morajo zmanjšati svojo rabo energije, da se poveča energijska učinkovitost in izboljša odnos do okolja. Da bi se izpolnili načrti in cilji, ki jih je postavil zakonodajalec, se mora uporabiti integriran pristop k ukrepom za dosego energijske učinkovitosti s posebnim poudarkom na tehničnih, ekonomskih in ekoloških metodah in ocenah.

Za analiziranje potenciala učinkovitosti v livarski industriji so razvili modulni večnivojski pristop. Model/pristop je nastal s sodelovanjem nosilcev izkušenj in nosilcev znanja v okviru Avstrijske gospodarske zbornice – Združenja avstrijske livarske industrije in njihovih trgovinskih partnerjev na eni strani ter Montanistične univerze Leoben in Avstrijskega inštituta za livarske raziskave (ÖGI) na drugi strani. Pristop omogoča spoznati dejansko rabo energije za procese in izdelke, kar pripelje do boljšega razumevanja nastalih stroškov. Poleg tega ta metodologija razpoznava potenciale energijske učinkovitosti in jih združuje v model, ki sloni na pristopu načrtovanja, ocenjevanja in optimizacije rabe energije v livarski industriji. Te mere imajo lahko pozitivne učinke na faze življenjskega cikla izdelka.

Poleg tehničnih in ekonomskih ukrepov predstavlja ocenjevanje življenjskega cikla (LCA – life cycle assesment) pomemben del razvitja modela. LCA omogoča izdelati metodo za ocenjevanje vpliva materiala izdelka in energijskih tokov po vsej dobavni verigi od pridobivanja surovin do konca življenjske dobe uporabnosti izdelka. Metoda sloni na ISO-standardu 14040ff, ki opisuje osnove in okvir za ocenjevanje življenjskega cikla in vključuje: definicijo cilja in obseg LCA, analizo popisa življenjskega cikla (LCI – life cycle inventory), oceno vplivov življenjskega cikla (LCIA – life cycle impact analysis) in tolmačenje življenjskega cikla.

Glede na cilje projekta in interese raziskave se model osredotoča na tri kazalnike vplivov, ki so pomembni za livarsko industrijo: (1) potencial globalnega segrevanja (GWP – global warming potential), (2) celotna potreba po energiji (CED – cumulative energy demand) in (3) celotna potreba po materialih (CMD – cumulative material demand). Koristi

ocenjevanja življenjskega cikla za livarsko industrijo obsegajo identifikacijo potenciala izboljšav okoljskih značilnosti izdelkov, kako priti do informacije za strateško planiranje, postavitev prednosti, razvoj izdelka in procesa kot tudi utemeljitve pri prodaji izdelka.
Ključne besede: ocenjevanje življenjskega cikla, livarstvo, energijska učinkovitost

Abstract

Rising energy costs, new environmental regulations and concerns about energy security are causing industries to conduct efforts to reduce energy consumption and increase energy efficiency. The international and the national legislator are developing different legal framework conditions to support the implementation of energy saving strategies. A recent contribution to this issue is the commencement of the European Energy Efficiency Directive, which at Austrian national level finds its application in the form of the energy efficiency law. Particularly the energy-intensive industries (e.g. foundry industry) are faced to reduce their energy consumption, to increase energy efficiency and improve their environmental performance. In order to fulfill the plans and targets given by the legislator's an integrated approach on energy efficiency measures has to be used with special focus on the technical, economic and ecologic methods and assessments.

For the investigation of the efficiency potential in the foundry industry, the modular-based, multilevel approach was developed. The model/approach was generated through collaboration between the experience and know-how of the Austrian Economic Chamber - Association of Austrian foundry industry and their commercial partners, and science, i.e. the Montanuniversitaet Leoben and the Austrian Foundry Research Institute (ÖGI). The approach enables the derivation of actual energy consumption of processes and corresponding manufactured products, and leads therefore to a better understanding of cost generation. Moreover, the methodology identifies energy efficiency potentials and merges them to a model based approach for the planning, evaluation and optimization of energy consumption in the foundry industry. These measures can show positive effects on the phases of the product lifecycle.

Aside the technical and economic measures, the life cycle assessment (LCA) represents an important part of the model development. LCA provides a method of assessing the environmental impacts of a product material and energy flows across the whole supply chain, from raw material extraction to end of life recycling or disposal. The method is based on ISO Norm 14040ff which describes the principles and framework for life cycle assessment (LCA) including: definition of the goal and scope of the LCA, the life cycle inventory analysis (LCI), the life cycle impact assessment (LCIA) and the life cycle interpretation.

Regarding the aims of the project and research interests the model focuses on three impact indicators relevant for the foundry industry: (1) Global Warming Potential (GWP), (2) Cumulative Energy Demand (CED) and (3) Cumulative Material Demand (CMD). The benefits for the foundry industry from life cycle assessment include the identification of improvement potential of environmental characteristics of products, the purchase of information for strategic planning, priority setting, product and process development, as well as arguments for the marketing of products.
Keywords: Life cycle assessment, foundry, energy efficiency.

1. Uvod

Povečanje prebivalstva, hitra urbanizacija in višanje življenjskega standarda občutno povečuje rabo energije po vsem svetu. Kljub omejenim virom in naraščajočim cenam surovin ima dostop do virov energije in njena raba v Evropi vse večjo vlogo. Odvisnost držav EU od uvoza fosilnih goriv izjemno močno vpliva na njihove trgovske bilance, kar pomeni, da se s tem zmanjšuje njihova kupna moč. Zato je eden od bistvenih elementov vzdušja v EU in energijske politike potreba po izboljšanju energijske učinkovitosti. V okviru strategije Evropa 2020 za pametno, sonaravno in vseobsežno rast si je Evropska unija leta 2008 postavila cilje »20-20-20« za doseganje želenih učinkov glede podnebja in energije. Eden od ciljev je zmanjšati rabo primarne energije za do 20 % [1]. Za dosego tega cilja je Evropska komisija postavila energijsko učinkovitost v središče in začrtala novo strategijo energijske učinkovitosti, ki bo omogočila vsem članicam ločiti rabo energije od ekonomske rasti. V skladu s tem je EU izdala direktivo 2012/27/EU (EED) o energijski učinkovitosti, ki se navezuje na direktivi 2004/8 / EC in 2006/32 / EC 22. Glavni cilj nove direktive je vzpostaviti splošen okvir ukrepov za vzpodbujanje energijske učinkovitosti v EU. Določa tudi usmeritve za čim večje zmanjšanje ovir na energijskem trgu in obvladovanje nezmožnosti trga, da zavira učinkovitost pri dobavi in rabi energije [2]. Npr. EED vsebuje obveze, ki naj bi si jih vsaka članica EU postavila za svoj pomemben cilj pri nacionalni energijski učinkovitosti, ki sloni na primarni kot končni rabi energije. Izvajanje energijske učinkovitosti bo zmanjšala stroške za energijo, odliv kapitala v države izvoznice nafte in zemeljskega plina ter rešila pomembne investicije v domače gospodarstvo.

1. Introduction

Increasing population, rapid urbanization and the growth of living standards have significantly accelerated the energy consumption in countries around the world. Thorough the limited re- sources and raising raw material prices, access and use of energy resources is playing an increasingly important role in Europe. The dependence of EU countries on imports of fossil fuels strain the foreign trade balance extremely, making it that purchasing power and benefits from the countries flow out. Therefore, one of the essential elements of the European climate and energy policy is to improve the energy efficiency. With the Europe 2020 Strategy for smart, sustainable and inclusive growth, the European Union (EU) lanced in 2008 the "20-20-20" objectives" defining the climate/ energy targets. One of the targets is to reduce the primary energy consumption up to 20% [1]. In order to achieve the targets, the European Commission (EC) places energy efficiency in the focus and outlines the need for a new energy efficiency strategy that will enable all Member States to decouple energy use from economic growth. Furthermore, in this context the EC has launched the Directive on Energy Efficiency 2012/27/EU (EED) and repealing Directives 2004/8 / EC and 2006/32 / EC 22. The main goal of the new Directive is to establish a common framework of measures for the promotion of energy efficiency within the Union. Further, it defines the directions to minimize the obstacles in the energy market and overcome market failures that impede efficiency in the supply and use of energy [2]. For instance, the EED contains the obligations that each Member State shall set an indicative national energy efficiency target, based on either primary or final energy consumption, primary or final energy savings, or energy intensity.

Da bi se doseglo cilje, je Evropska komisija predlagala, da se cilji EU prenesejo v cilje in usmeritve posameznih držav. V Avstriji so to direktivo vpeljali kot Zvezni zakon BGBl I Nr. 72/2014 (EEG) o energijski učinkovitosti [3]. Glavni namen zakona je stabilizirati končno rabo energije v Avstriji (2020) pri 1 050 J/leto, preverjanje ukrepov za energijsko učinkovitost 310 PJ v letih 2014—2020 (ekvivalent 1,5 % avstrijskih končnih potreb po energiji; izboljšanje učinkovitosti dobaviteljev energije na področju energijske učinkovitosti; povečanje deleža obnovljive energije; zmanjšanje emisij toplogrednih plinov in izboljšanje razmerja med dovedeno in rabljeno energijo. Zakon podrobno določa zakonske obveze za velika podjetja, da razvijejo sistem upravljanja z energijo ali da izpeljejo preverjanje rabe energije, dobaviteljev energije za izboljšanje energijske učinkovitosti pri lastnih ali tretjih končnih uporabnikih, obvezo za zvezno vlado, da vodi tako politiko npr. z obnovo zveznih zgradb in da ponudi javnosti ukrepe za energijsko učinkovitost. Izvajanje zakona naj bi nadzorovale agencije za stalni nadzor, ki bi bile odgovorne za ocenjevanje ukrepov učinkovitosti in njihovo nadzorovanje. Trenutno to delo opravlja državna nadzorna agencija za energijsko učinkovitost.

EED in EEG pokrivata ne samo velike industrije ampak tudi elektrarne, javni sektor in transportna podjetja. A je energijska učinkovitost industrije bistvena. Posebno za energijsko intenzivne industrije (npr. livarsko industrijo) je to izziv, da občutno zmanjša rabo energije, poveča svojo energijsko učinkovitost in zmanjša vplive na okolje ter tako doseže postavljene cilje [4].

Pomembna vsebina in cilj EEG je zmanjšanje emisij toplogrednih plinov. V praksi in znanosti se vpliv industrije na okolje meri z znanstveno metodo ocenjevanja življenjskega cikla (LCA) [5]. V zadnjih letih je LCA postala vse bolj pomembna, ker se

The implementation of energy efficiency reduces energy costs, the capital outflow in exporting countries for oil and gas and solves significant investment for the domestic economy.

In order to ensure the achievement of the goals the EC proposed that the EU goals should be translated into national targets and trajectories. In Austria, the implementation of the Directive was carried out in form of the Federal Energy Efficiency Act BGBl I Nr. 72/2014 (EEG) [3]. The main objectives of the Act are stabilization of final energy consumption in Austria (2020) at 1,050 PJ / a; verification of energy efficiency measures between 2014-2020 of 310 PJ (equivalent to 1.5% of the Austrian final energy demand); improving the performance of energy sup- pliers in the field of energy efficiency; increasing the share of renewables in the energy mix; reduction of greenhouse gas emissions and improvement of input-output ratio. In detail the Act defines the legal obligation for big companies to develop an energy management system or to conduct energy audits, energy suppliers to improve energy efficiency via own or third party end-costumers, for the Federal Government to lead by example, e.g. in connection with the restructuring of federal buildings, and for public invitation to tender energy efficiency measures. The implementation of the law should be enforced by a monitoring agency that will be responsible for the evaluation of the efficiency measures, as well as monitoring. Currently the National Energy Efficiency monitoring agency performs this task.

This EED and EEG cover not only large industries, but also power generating companies, as well as the public sector and transport. However, the energy efficiency for the industries is essential. Especially energy intensive industries (e.g. foundry industry), are challenged to re- duce their energy jo lahko uporabi tako za izdelke kot procese. Na eni strani se jo lahko uporabi kot izjavo o izdelku in kot marketinško utemeljitev, na drugi strani pa za vrednotenje vplivov različnih variant na okolje, da se pride do strateških in obratovalnih odločitev na področju obdelanih informacij. Številne industrije, ki jih oskrbuje livarska industrija, kažejo zanimanje za okoljske vidike uporabljenih sestavin/izdelkov.

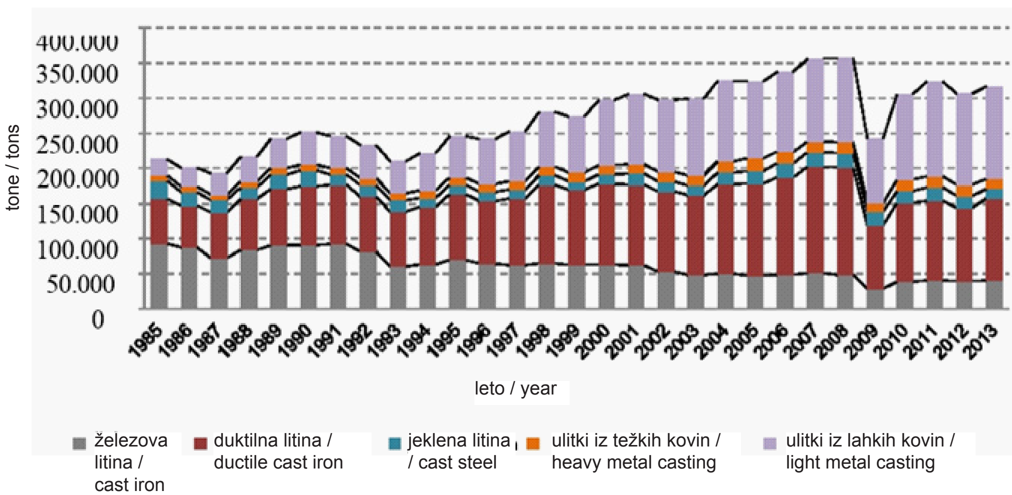
2. Zakon o energijski učinkovitosti – izziv za avstrijsko livarsko industrijo

Avstrijsko livarsko industrijo uradno predstavlja livarska zveza, v kateri je včlanjenih 43 industrijskih livarn (stanje 2013). Po strukturi izdelkov je 16 livarn železa, 23 livarn neželeznih kovin in štiri livarne, ki izdelujejo izdelke iz železove litine in neželeznih kovin. V vseh livarnah je zaposlenih 7 154 ljudi. Dve podjetji imata po več kot 500 zaposlenih, 10 po 200–500, 8 po 100–200 in 23 po manj kot 100 zaposlenih.

consumption noticeably, to increase their energy efficiency and their environmental performance in general to reach the given target values [4].

Important content and the goal of the EEG is the reduction of the greenhouse gas emissions. In praxis and science, the environmental impact from industry is measured through the scientific method Life Cycle Assessment (LCA) [5]. In the recent years LCA is becoming increasingly

important, whereby it can be carried out for both products, as well as processes. On the one hand, it is applied in the context of product declarations and as a marketing argument. On the other hand, it is used to evaluate the environmental impacts of different alternatives in order to provide strategic and operational decisions in the field of processed information. Numerous industries, which are supplied by the foundry industry, are showing interest in the environmental aspects of the used components/products.



Slika 1. Proizvodnja avstrijske livarske industrije (1985-2013) [6]

Figure 1. Production development of the foundry industry in Austria (1985-2013); source [6]

Celotna proizvodnja v letu 2013 je bila 316 795 ton in se je v primerjavi z letom 2012 povečala za 3,4 %. Od tega je bilo 42 % ulitkov iz lahkih kovin, 37 % iz duktilne litine, 13 % iz železove litine, 5 % ulitkov iz težkih kovin in 4 % iz jeklene litine (slika 1). Celoten prihodek sektorja, ki se je v letu 2012 povečal za 0,6 %, je bil 1,34 milijarde EUR. Okoli 80 % izdelkov je bilo izvoženih. Glavnina je bila za avtomobilsko industrijo. Ostali končni izdelki so cevi, cevni priključki in valji [6].

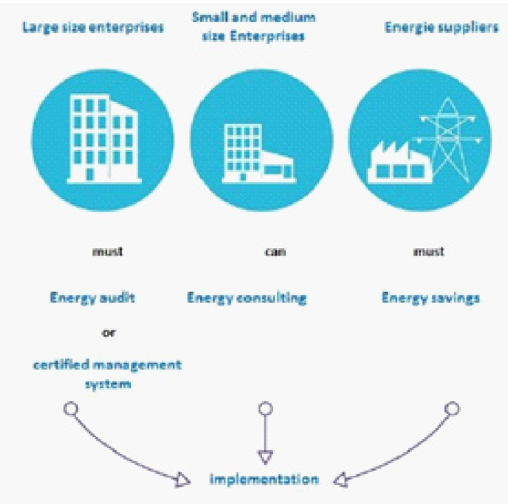
V Avstriji so se že desetletja trudili, da bi vpeljali ukrepe za varčevanje z energijo z namenom zmanjšati sorazmerno velike potrebe po energiji v livarski industriji [7,8,9]. Dichtl (2012) je zagovarjal dejstvo, da je enodimenzijski pogled na potrebe po energiji treba vzeti kot kritičen in negativen z ekološkega in ekonomskega vidika, sicer bo razvoj inovacij in izdelkov začel stagnirati. Poleg tega se morajo livarne osredotočiti na potenciale za varčevanje z energijo z izrabo odpadne toplote, optimizacijo procesov in izdelkov, optimizacijo toplotne obdelave itn. Na drugi strani je Bosse s sodelavci (2013) zagovarjal dejstvo, da raba obnovljive energije ni tehnični problem (npr. elektrika ali biomasa) v livarnah in da bi lahko bilo 97–98 % vse energije zelena energija [10]. Predlagali so, da bi bila v prihodnje raba zelene energije v livarnah odvisna od fleksibilnosti livarskih procesov in od zaposlenih v livarnah. Dejanska raba energije v livarnah je močno odvisna od materiala; pri dobri tehnologiji litja je raba 6 do 30GJ/t in zajema 2–10 % proizvodnih stroškov. Najpomembnejši kazalniki so masa ulitka, število ulitkov, kakovost materiala, talilni postopki, tehnologije toplotne obdelave in zapletenost ulitkov [7].

Izvajanje nedavnega zveznega zakona o energijski učinkovitosti vpliva tudi na livarsko industrijo. V splošnem so podjetja

2. Energy Efficiency Act - Challenge for the Austrian Foundry Industry

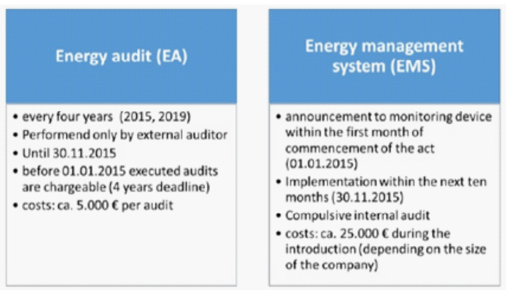
The Austrian foundry industry is officially represented by the Foundry Association, which supports 43 industrial foundries as member companies (status 2013). Structured into the various products, they encompass 16 pure iron foundries, 23 pure non-ferrous metal foundries and 4 foundries producing iron and metal castings. Employing the 7,154 people, the branch has 2 companies with more than 500 employees, 10 companies between 200 and 500 workers, 8 companies between 100 and 200 workers and 23 with less than 100 employees. Total production in 2013 amounts to approx. 316,795 t and compared to 2012 it increased by 3.4%. In the same year the composition of the production is divided into 42% light metal casting, 37% ductile cast iron, 13% cast iron 5% heavy metal casting and 4% cast steel (figure 1). The total turnover of the sector grew by 0.6% compared to 2012 and is approx. EUR 1.34 billion. The direct export quota of the member companies is about 80%. Apart from a few finished products, such as piping, fittings, and cylinders a majority of the products goes into the automotive sector [6].

For decades there have been efforts to implement energy saving measures in order to reduce relatively high energy demand in the foundry industry [7,8,9]. However, Dichtl [7] (2012) argues that though the one-dimensional view on primary energy requirements needs to be seen as critical and is considered negative in ecological and economical terms. Otherwise, innovation and product development would begin to stagnate. Nevertheless, the foundries should put focus on energy saving potentials in waste heat utilization, process and product optimization, optimization of heat treatment



Slika 2. Zahteve po evropski direktivi za podjetja, ki uporabljajo energijo [3]

Figure 2. Requirements for the energy-consuming enterprises in accordance EEG; Source [3]



Slika 3. Razlike med energijskim pregledom in sistemom upravljanja z energijo za podjetja, ki uporabljajo energijo, po evropski direktivi [3]

Figure 3. Differences between EA and EMS; Source [3]

glede na ta zakon obvezana izpeljati naslednje akcije:

- da se registrirajo kot podjetja, ki uporabljajo energijo,
- da prijavijo izvajanje energijskega pregleda ali certificiranega sistema upravljanja z energijo do 15.11.2015,

etc. On the other hand, Bosse et al. [10] (2013) argue that there is no technical problem using renewable energy (e.g. electricity or biogas) in foundries, and that 97-98 % of the total energy could be green energy [10]. They suggest that in the future the consumption of green energy in foundries will also depend on the flexibility of foundry processes and of foundry employees. The actual energy consumption in foundries is strongly dependent on the material; the range is between 6 and 30 GJ/t for good cast, and encompasses from 2-10% of the production cost. Dominant factors are cast weight and product numbers, material quality, melting processes, heat treatment technologies, and complexity of castings [7].

The implementation of the recent Federal Energy Efficiency Act (EEG) affects as well the foundry industry. In general, according to the EEG the companies are obliged to conduct the following actions:

(1) Registration as an energy-consuming enterprise,

(2) Notification of the implementation of an energy audit or a certified management system to 11/15/2015

(3) Continuous reduction of primary energy consumption by 0.6% per year (mandatory for energy suppliers)

(4) Implementation of indicators to represent the energy demand related to the economic performance

Furthermore, depending on the company size different requirements are have to be met. The grouping of the companies follows the classification given in the European Energy Efficiency Directive (EED), using the indicators such as number of employees, turnover and annual balance sheet. For instance, a medium size enterprise is a company with less than 250 employees, and has a turnover under 50 Mio. EUR or an annual balance sheet less than 43

- da zvezno zmanjšujejo rabo za 0,6 % (obvezno za dobavitelje energije),
- da vpeljejo indikatorje, ki kažejo potrebo po energiji glede na ekonomski učinek.

Poleg tega je treba izpolniti še določene zahteve v odvisnosti od velikosti podjetja. Razvrstitev podjetij je po klasifikaciji, ki je navedena v evropski direktivi o energijski učinkovitosti, v kateri so kazalniki kot število zaposlenih, prihodek in dobiček. Npr. srednje veliko podjetje ima manj kot 250 zaposlenih, prihodek pod 50 milijoni EUR in dobiček pod 43 milijoni EUR. Na drugi strani so majhna podjetja tista, ki imajo manj kot 50 delavcev, prihodek pod 10 milijoni EUR in dobiček pod 5 milijoni EUR [11]. Zahteve, ki najbolj vplivajo na velika podjetja, so, da se morajo registrirati in do 15.11.2015 obvestiti agencijo za nadzorovanje o izvajanju energijskega pregleda ali sistema za upravljanje z energijo (slika 2). V Avstriji zunanji energijski pregledi ali certificirani sistemi upravljanja z energijo ali okoljem vključujejo notranje in zunanje preglede, ki so se začeli januarja 2015 in se morajo narediti vsaka 4 leta. Osnovne razlike med energijskim pregledom in sistemom upravljanja z energijo so prikazane na sliki 3.

Cilj energijskega pregleda je sistematična analiza nosilcev energije ter rabe energije v podjetjih in se naredi s pregledom vseh sistemov v podjetju, povezanih z energijo. Rezultat je odkriti ukrepe za zmanjšanje rabe energije in optimizacijo energijske učinkovitosti [12]. Certificiran sistem upravljanja z energijo je na drugi strani sistem, ki je določen z ISO-standardom 50001, katerega cilj je zmanjšati stroške in emisije toplogrednih plinov z izboljšano energijsko učinkovitostjo [13]. Z izvajanjem evropske direktive in uvajanjem sistema upravljanja v podjetja je bilo opaziti številne prednosti kot so intenzivnejše izvajanje standardiziranih

Mio. EUR. On the other hand, small size enterprises are companies with less than 50 workers and have a turn- over under 10 Mio. EUR or an annual balance sheet less than 5 Mio. EUR [11]. The requirements affecting large size enterprises most, are that they had to register themselves, and until 11/15/2015 the monitoring agency had to be notified about implementation of an energy audit (EA) or a certified management system (EMS) (figure 2). In Austria an external energy audit or a certified energy or environmental management system including internal and external audits beginning with January 2015 needs to be executed every four years. Fundamental differences between EA and EMS (energy management system) are illustrated in the figure 3.

The aim of the energy audit is the systematic analysis of energy cariers and energy consumption in the enterprises, and is carried out by a review of all energy-related systems across the enterprise. As result it identifies measures for reducing energy consumption and optimizing energy efficiency [12]. A certified energy management system on the other hand has a defined system according to ISO Standard 50001, the aim of which is to reduce costs and greenhouse gas emissions by improving energy efficiency [13]. Through the implementation of the EEG and the energy management system in the enterprises several benefits can be noticed, such as increased implementation of standardized energy management systems (ISO 50001), establishing energy efficiency networks, implementation of energy indicators, performance measurement systems and benchmarks, advanced sensor, communication and analysis systems, sensible energy simulation and optimization approaches etc.

sistemov upravljanja z energijo (ISO 50001), vzpostavitev omrežij energijske učinkovitosti, izvajanje kazalnikov energije, delovanje sistemov in kriterijev merjenj, napredna zaznavala, sistemi analiziranja in komuniciranja, pametne energijskih simulacije, optimizacijski pristopi itn.

3. Pristop za ovrednotenje livarskih izdelkov, ki sloni na življenjskem ciklu

Da bi se obvladalo in čim bolj zmanjšalo zakonske izzive za livarsko industrijo, smo oktobra 2013 začeli s triletnim raziskovalnim projektom EnEffGieβ- razvoj pristopa za ovrednotenje energijsko učinkovitih, sonaravnih livarskih izdelkov, ki sloni na življenjskem ciklu. Projekt je financirala avstrijska agencija za spodbujanje raziskav (FFG) v okviru programa »skupne raziskave«. Nosilec izvajanja projekta je Zveza avstrijskih livarn ob sodelovanju raziskovalnih institutov: Avstrijski livarski institut, Montanistična univerza Leoben s katedro za ekonomsko in poslovno upravljanje (WBW) ter katedro za toplotno procesno tehnologijo (TPT), in industrije: Borbet Austria, Dynacast Austria, Georg Fischer Fittings, Nemak Linz, livarna Tirol Rohre and Voestalpine.

Cilj projekta je razviti model procesa in model vrednotenja, ki bo primeren za povečanje energijske učinkovitosti v livarnah. Model, ki sloni na tehničnih, ekonomskih in okoljskih metodah, bo omogočil ovrednotiti različne livarske izdelke s stališča rabe energije in ugotovil izvedljive ukrepe za povečanje energijske učinkovitosti. Inovacija projekta je v tem, da predstavlja celosten modulen pristop za nova opazovanja in vrednotenje heterogenih izdelkov livarske industrije, ki upošteva tudi posebnosti te industrije.

3. Life-Cycle-Based Approach for the Evaluation of Foundry Products

In order to overcome and to minimize the legal challenges for the foundry industry the three-year research project "EnEffGieß - development of a life-cycle-based approach to evaluation of energy-efficient, sustainable foundry products" was launched in October 2013. The Austrian Research Promotion Agency (FFG) finances the project within the programme „Collective Re- search". The project executing organization is the Association of the Austrian Foundry Industry with a broad consortium from research institutions: Austrian Foundry Institute, Montanuniversitaet Leoben with two chairs (Chair of Economic and Business Management WBW and Chair of Thermal Processing Technology - TPT) , as well from the industry: Borbet Austria, Dynacast Austria, Georg Fischer Fittings, Nemak Linz, Tirol Rohre and Voestalpine foundry.

The aim of the project is to develop a process and valuation model, which is suitable to increase the energy efficiency in foundries. Based on technical, economic and environmental methods, the model allows to evaluate different foundry products in terms of energy consumption and to identify derivable measures to increase energy efficiency. The innovation of the project is that by the holistic modular approach a new observation and evaluation of heterogeneous products of the foundry industry is generated, referring specifically to the particularities of this industry.

The special focus is placed on considering the product over all stages of their life cycle in order to evaluate the actual effectiveness of production comprehensively. The specific analyses are conducted using the methodology for assessment of environmental impacts. For that matter the indicators (1) cumulative primary energy

Poseben poudarek je bil dan obravnavanju izdelka v vsem njegovem življenjskem ciklu, da bi se podrobno ovrednotila dejanska učinkovitost izdelave. Narejene so bile posebne analize na osnovi metodologije ocenjevanja vplivov na okolje. Zato smo analizirali naslednje parametre: (1) celotna potreba po primarni energiji (CED – cumulative energy demand), (2) celotna potreba po materialih (CMD – cumulative material demand) (vstopna stran) in (3) potenciale globalnega segrevanja (GWP – global warming potential) (izstopna stran) z njihovimi kategorijami vplivov. Ta model posebej ustreza posebnostim livarske industrije in omogoča predstavitev ter vrednotenje energijskih izgub in energijske učinkovitosti glede na vire.

4. Analiza življenjskega cikla (LCA – life cycle analysis)

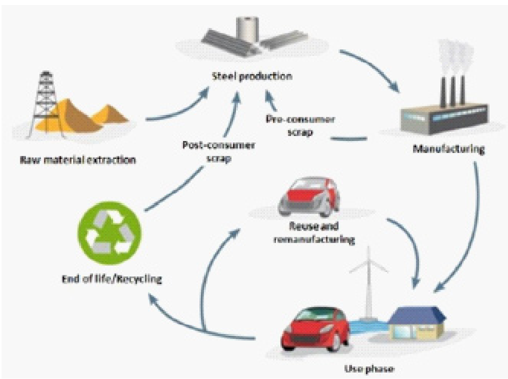
V zadnjih desetletjih so nastali številni standardi, vodila in navodila javnih ali internih skupin, da bi zadostili potrebam po zanesljivem in uporabni presoji vplivov na okolje na proizvodni in organizacijski ravni (npr. ISO 14 040; ISO 14 033; ISO 14 024, ISO 14 021). Večina njih zasleduje pristop življenjskega cikla. LCA je metoda za merjenje in vrednotenje vplivov proizvodnih sistemov na okolje v celotnem življenjskem ciklu, ki ga uporabljajo številne industrije (slika 4) [5]. Ta metoda postaja pomembna tudi za livarsko industrijo, kar se trenutno kaže v zvezi z upravljanjem sonaravne dobavne verige. Za to industrijo je zelo pomembno, da analizira celotno potrebo po energiji za posamezen izdelek v celotnem življenjskem ciklu. Npr. izdelek iz lahke zlitine potrebuje več energije, če se raba energije nanaša le na dejansko maso izdelka. Raba energije sloni v tem primeru na proizvodni fazi izdelka. Zato je

demand (CED) and (2) cumulative material demand (CMD) (input side) and (3) Global Warming Potential (GWP) (output side) with their impact categories are analyzed. This model will specifically respond to the specifics of the foundry industry and allows the source-related presentation and evaluation of energy losses and energy efficiency.

4. Life Cycle Analysis (LCA)

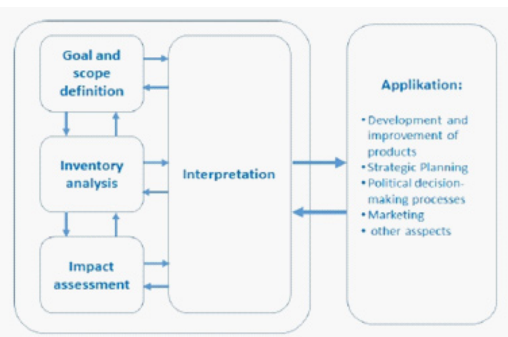
In recent decades' numerous standards, principles, and guidelines have been developed, either by public or by private groups, in order to meet the needs for dependable and usable environ- mental assessment at product and organization level (e.g ISO 14.040; ISO 14.033; ISO 14.024, ISO 14.021). Many of them follow the life cycle approach. LCA is a method for the measurement and evaluation of the environmental impacts of product systems throughout their entire life cycle, used by many industries (figure 4) [5]. As well for the foundry industry this method
gains on importance, which is currently reflected in the context of sustainable supply chain management. It is very important for this industry to analyze the cumulative energy demand for a product, analyzing the whole life cycle. For example, a light weight product needs way more energy if the energy consumption is related to the actual weight of the product. Energy consumption is in this case based on the production phase of the product. Therefore, it is necessary to evaluate products and the energy consumption for those on a life cycle basis starting with the raw material production and ending with the recycling phase of a certain product.
Conducting an LCA is very time consuming and requires specific methodological skills,

potrebno ovrednotiti izdelke in rabo energije za celoten življenjski cikel od proizvodnje surovin do faze recikliranja določenega izdelka. Izvedba LCA je dolgotrajna in zahteva posebne metodološke izkušnje, pri čemer je izvajanje v industrijski praksi še vedno pomanjkljivo. Na osnovi preglednih materialnih in energijskih tokov pomaga obravnavanje stroškov za celoten življenjski cikel, da se odkrijejo najbolj obetavni potenciali energijske učinkovitosti in sinergij med izdelovanjem [14].



Slika 4. Življenjski cikel jekla [15]

Figure 4. life cycle of steel; source [15]



Slika 5. Okvir ocenjevanja življenjskega cikla po ISO 14040 [16]

Figure 5. Life cycle assessment framework acccording to ISO 14040; source [16].

whereby the implementation in industrial practice is still deficient. Based on transparent material and energy flows the consideration of costs over the entire life cycle helps to uncover the most promising energy efficiency potentials and synergies in operation [14].

4.1 Methodological Framework for LCA

The methodological approach for conducting the life cycle assessment is presented by the intertional Standards ISO 14040 and ISO 14044 that describe the principles and framework for conducting and reporting LCA studies, and include certain minimal requirements [5]. According to the Standard 14040, LCA is defined as the "compilation and evaluation of the inputs, outputs and potential environmental impacts of a product system throughout its life cycle". Therefore, the LCA is a tool for assessing the environmental impacts of a product's material and energy flows across the whole supply chain, from raw material extraction to end of life recycling or disposal [16].

The method for the conduction of the LCA encompasses the inventory of relevant inputs and outputs of a product system, evaluates the potential environmental impacts associated with those inputs and outputs, and at the end interprets the result of the inventory analysis and impact assessment phases in relation to the objectives of the study [5]. In order to fulfill the consistent and uniformly use, the requirements and guidelines are detailed described in the Norm 14040.

The LCA study includes four stages (figure):

1) Definition of the goal and scope of the LCA (stage 1)
2) Life cycle inventory analysis (LCI) phase (stage 2)

4.1 Metodološki okvir za LCA

Metodološki pristop za ocenjevanje življenjskega cikla je predstavljen s standardoma ISO 14040 in 14044, ki opisujeta osnove in okvir za izvajanje LCA-študij, poročanje o njih ter vključujeta določene minimalne zahteve [5]. Po standardu ISO 14040 je LCA definiran kot »zbiranje in ocenjevanje vhodov, izhodov in potencialnih vplivov proizvodnega sistema na okolje v celotnem življenjskem ciklu«. Zato je LCA orodje za ocenitev vplivov materialnih in energijskih tokov izdelka po vsej dobavni verigi od pridobivanja surovin do končnega recikliranja ali odlaganja odpadkov [16].

Metoda za izvedbo LCA obsega popis bistvenih vhodov v proizvodni sistem, izhodov iz njega in na koncu razlago rezultatov analize popisa in faze ocenjevanja vplivov glede na cilje študije [5]. Da bi bila izpolnjena stalna in enakomerna raba, so zahteve in navodila podrobno opisana v standardu 14040. Študija LCA obsega štiri stopnje (slika):

1) določitev ciljev in obsega LCA,
2) analizo popisov življenjskega cikla (LCI),
3) oceno vpliva življenjskega cikla (LCIA),
4) fazo razlaganja.

Prvi korak pri izvedbi LCA je ugotoviti, opravičiti in razložiti cilje študije LCA, določiti ciljano uporabo rezultatov in na koncu ugotoviti izvajalce dejavnosti ter nosilce interesov, ki naj bi uporabljali rezultate študije (ciljna publika). Tu je potrebno določiti meje sistema, ki so odvisne od cilja študije in se lahko delijo na od zibelke do vrat, od vrat do vrat, od zibelke do groba in od zibelke do zibelke. Drugi korak je izpeljava analize popisa z ugotavljanjem vseh vhodnih in izhodnih elementov v sistemu. Pridobivanje podatkov je zelo dolgotrajen proces in obsega na vhodni strani surovine,

3) Life cycle impact assessment (LCIA) (stage 3)
4) Interpretation phase (stage 4)

The first step conducting the LCA is to state, justify and explain the goal of the LCA study, specify the intended use of the results (application), and at the end identify the practitioner and the stakeholders that are intended to use the study results (target audience). At this point, it is neccesery to define system boundaries that are dependent from the goal of the study, and can be divided into cradle to gate, gate to gate, cradle to grave and cradle to cradle. The second step is conducting the inventory analysis by identifying all input and output elements in the system. The acquisition of the data is very time consuming and encompasses from the input side the raw and operative materials, energy, and from the output side products, by product, waste and emissions to air, water and soil. The data collected should be calculated related to the functional unit. The third phase sets the results of the inventory analysis in connection with the impact categories and impact indicators. After this classification, all parameters are set to an equivalence factor within each impact category. For instance, by the impact category all emissions are calculated into the unit "kg CO_2 equivalent". This stage gives the crucial information for the interpretation phase. The main elements of this stage are the evaluation of results, the analysis of results, and the formulation of the conclusions and recommendations of the study [5,16].

4.2 Practical Implementation of the LCA in the Foundry Industry

Life cycle assessments for the foundry industry gain increasingly on importance. Numerous studies have been conducted in uporabljane materiale, energijo in na izhodni strani izdelke, stranske proizvode, odpadke in emisije v zrak, vodo, zemljo. Zbrani podatki morajo biti preračunani v ustrezno funkcionalno enoto. Tretja faza povezuje rezultate analize popisa s kategorijami in indikatorji vplivov. Po tej razvrstitvi so vsi parametri v vsaki kategoriji vplivov preračunani tako, da so med seboj enakovredni. Npr. v kategoriji vplivov so vse emisije preračunani na ekvivalent - kg CO_2. Ta stopnja daje odločilne informacije za fazo predstavitve rezultatov. Glavni elementi te stopnje so ovrednotenje rezultatov, analiza rezultatov in oblikovanje zaključkov ter priporočil študije [5,16].

4.2 Praktično izvajanje LCA v livarsko industrijo

Ocenjevanje življenjskega cikla postaja za livarsko industrijo vse pomembnejše. V zadnjih letih so bile narejene številne študije, ki analizirajo na eni strani končni izdelek, v katerem je livarski izdelek pomembna sestavina, in na drugi strani izdelek ali procese v samem livarstvu. Npr. v avtomobilski industriji različne študije prikazujejo vpliv vozil v vsej njihovi življenjski dobi na okolje (npr. Audi, BMW, Mercedez-Benz itn.) [17,18,19], da bi si zagotovili okoljske certifikate. Evropsko združenje avtomobilskih proizvajalcev (ACEA) je napovedalo poročilo o oceni življenjskega cikla v letu 2012, v katerem so priporočili, da bi vse študije LCA slonele na ISO 14040/44 in bi vključevale delničarje, da se zagotovi njihova podpora [20]. Avtomobilska industrija je uporabljala ocenjevanje življenjskega cikla in sorodna orodja interno, čeprav so bile neke ocene tudi objavljene. Trenutno so v avtomobilski industriji tri glavna področja uporabe ocenjevanja življenjskega cikla:

recent years that analyze, on one side the final product with the foundry product as important component, or on the other side the product or processes from the foundry itself. For instance, for the automotive industry several studies illustrate the environ- mental impact from vehicles across their whole life cycle (e.g Audi, BMW, Mercedes-Benz etc.) [17,18,19] in order to issue environmental certificates. The European Automobile Manufacturing Association (ACEA) announced the position paper on Life Cycle Assessment in 2012 and suggests that all LCA studies should be based on the ISO 14040/44, complemented on full stakeholder involvement to ensure acceptance [20]. The Automotive industry has used Life Cycle Assessments and related tools internally, although some have been published externally. Currently the automobile industry shows three major areas of application for life cycle assessments:

(1) internal use - LCA as an instrument for environmentally oriented product and process development and for decision-making processes
(2) publication of life cycle assessments to document product or process related environmental performance
(3) Joint automobile industry studies and/or (funded) LCA-projects about questions of general interest

The examples (found in literature) from the automotive sector illustrate assessments for the single automotive parts. Bonollo et al. (2006) have conducted a LCA comparison between aluminium and cast iron cylinder blocks. The results showed that while during the production stage the environmental load related to the aluminum block is higher than the one related to the cast iron block, during use and end-of-life treatment the gain of aluminum over cast iron makes the aluminum cylinder block more environment friendly than the cast iron one [21]. Similar

- interna uporaba LCA kot orodje za okoljsko usmerjen razvoj izdelkov in postopkov in za procese odločanja,
- objava ocenjevanja življenjskega cikla kot dokument, da je izdelek in postopek okolju prijazen,
- skupne študije avtomobilske industrije in/ali (financiranih) projektov LCA o vprašanjih splošnega interesa.

Primeri iz avtomobilskega sektorja (najdeni v literaturi) opisujejo ocenjevanje posameznih avtomobilskih delov. Bonollo in sodelavci (2006) so naredili LCA-primerjavo med aluminijastimi in litoželeznimi bloki motorjev. Rezultat je pokazal, da je v fazi proizvodnje vpliv aluminijastega bloka na okolje večji od litoželeznega, med uporabo in pri predelavi odpadkov na koncu uporabnosti izdelka pa je aluminij boljši od železove litine, tako da je aluminijast blok motorja bolj okolju prijazen kot litoželezni [21]. Podobno raziskavo je naredil Frische (2009), ko je primerjal energijsko učinkovitost in CO_2-emisije pri izdelavi karterjev, narejenih iz železove litine ali aluminijeve zlitine. On je trdil na osnovi energijske in CO_2-bilance, da bo izdelava motorja iz železove litine cenejša od aluminijastega.

Poleg tega motor iz železove litine prispeva k varovanju okolja in varčuje s fosilnimi gorivi [22]. Clegg (2013) je naredil študijo o uporabi ocenjevanja življenjskega cikla pri izdelavi in uporabi ulitkov [23]. On trdi, da je vrednost predpostavke, da je aluminij boljši od železove litine, vprašljiva, ker se zmanjšanje porabe goriva lahko doseže na račun drugih vplivov na okolje. Rezultati LCA jasno kažejo, da je celoten vpliv železove litine na okolje manjši od vpliva aluminija, kljub temu da ima železova litina med uporabo avtomobila večji vpliv na okolje.

LCA livarskih izdelkov se uporablja tudi v drugih industrijah/pri drugih izdelkih. Rittjoff je s sodelavci (2004) raziskal vpliv

re- search was conducted by Frische (2009), comparing the energy efficiency and CO_2 Emissions of the manufacturing of cylinder crankcases made of cast iron or aluminum alloy.

He argues that the energy and CO_2 balance for the future cast iron based motor manufacturing is cheaper. As well, cast iron contributes to further environmental protection and saves fossil fuels [22]. Clegg (2013) conducted a study about the application of a life-cycle assessment in the production and use of castings [23]. He argues, the validity of the assumption that aluminium is a better alternative to a ferrous alloy needed to be questioned because the reduction in fuel consumption may be achieved at the expense of other environmental impacts. The results of the LCA illustrates clearly that despite higher environmental impacts of iron cast in the auto use phase the total environmental impact is smaller than from aluminum.

The LCA from foundry products finds application also in other industries/products. Ritthoff et at. (2004) have examined the environmental impact of various materials in production of bicycle frames. Based on the four environmental indicators (Global Warming Potential (GWP), Cumulative Energy Demand (CED), Cumulative Material Demand (CMD) and Consumption of water), the authors have compared the frames manufactured from aluminum, steel and carbon fiber reinforced plastic. The outcomes have indicated that the frames made from steel have the best performances at all environmental indicators. However, the production of steel is at the same time energy and recourse intensive [24]. Another example of LCA research is the one from Saha (1996), developing a decision-making framework for foundry sand using life cycle assessment and costing techniques [25].

različnih materialov na okolje pri izdelavi koles. Na osnovi štirih okoljskih kazalnikov (potencial globalnega segrevanja, celotna potreba po energiji, celotna potreba po materialih in poraba vode) so avtorji primerjali aluminijaste in jeklene okvirje ter okvirje iz plastike, okrepljene z ogljikovimi vlakni. Rezultati so pokazali, da so jekleni okvirji boljši po vseh okoljskih kazalnikih. A je proizvodnja jekla istočasno energijsko intenzivna [24]. Drug primer raziskave LCA je naredil Saha (1996), ki je razvil okvir za odločanje o livarskih peskih z uporabo tehnike ocenjevanja življenjskega cikla in stroškov [25].

V okviru projekta „EnEffGieß“ se LCA uporablja na eni strani za računanje vplivov določenih/povprečnih izdelkov partnerskih podjetij na okolje, na drugi strani je metodika LCA vpeljana v Excelovo orodje „Quick Check tool“ (orodje za hitro kontrolo) za računanje ekološkega kazalnika GWP v obliki ekvivalentov CO_2. Na osnovi podatkov podjetij o rabi energije se je z orodjem Quick Check Tool izračunalo številne uporabne številske vrednosti na področju sistema upravljanja z energijo, potreb po energiji, porabe energije, stroškov za energijo in vplivov na okolje. Izračuni so bili narejeni na različnih ravneh, najprej za celotno podjetje, nato za procese in naprave ter končno za izdelke.

Da bi podčrtali motiv LCA in ponazorili računanje s tem orodjem, bomo predstavili izmišljen primer, ki sloni na dejanskih podatkih. Določitev mej sistema je usmerjeno na samo livarstvo (od vrat do vrat) s funkcionalno enoto za eno enoto primerjalnega izdelka (v kg ali t). Modelno podjetje je livarna železove litine s proizvodnjo 13 000 t izdelkov iz 15 000 t staljene železove litine, ki ima kupolko za talilno peč. Proizvodni postopek obsega taljenje, ulivanje, toplotno obdelavo, strojno obdelavo, končno kontrolo in

Within the project "EnEffGieß" the LCA is used, on one hand to calculate the environmental impact of specific/average products from partner companies, on the other hand the LCA methodic is implemented in the Excel-based "Quick Check tool" for the calculation of the ecological indicator GWP in form of CO_2 equivalents. Based on the energy consumption data from the companies, the Quick Check Tool calculates the different operating figures in the fields of energy management system, energy demand, energy consumption, energy costs, and environ- mental impact. The calculations are made for the different levels, starting with the whole com- pany, going further into the process and aggregate levels, and finishing at product level.

In order to underline the theme LCA and to illustrate the calculations within the tool, a fictitious example based on the realistic data will be presented. The definition of the system boundaries is orientated on the foundry itself (gate-to-gate) with the functional unit given as one piece of the reference product (in kg or tons). The model company is an iron foundry with a cupola melting furnace with production of 13,000 tons of products from 15,000 tons of melting iron. The production process includes the processes melting, casting, heat treatment, mechanical treatment, final control and numerous supporting processes (e.g. compressed air station, water station, buildings and other utilities etc.). The energy carriers are electricity, natural gas and coke.

The impact categories for this example concern the environmental category "climate change" and its indicator "Global Warming Potential" (GWP). In addition, the Cumulative Energy Demand (CED) is calculated. GWP or CO_2 equivalent is a measure of how much heat a green- house gas traps into the atmosphere. The comparative unit is številne podporne postopke (npr. postajo za stisnjen zrak, vodno postajo, zgradbe in gospodarska poslopja itn). Energenti so elektrika, zemeljski plin in koks.

Kategorije vplivov so v tem primeru okoljska kategorija »klimatske spremembe« in njen kazalnik potencial globalnega segrevanja (GWP). Dodatno je bila izračunana celotna potreba po energiji (CED) ali CO_2-ekvivalent. GWP ali CO_2-ekvivalent sta merilo, koliko toplote je ujete v toplotnogrednem plinu v atmosferi. Primerjalna enota je ogljikov dioksid. Pretvorba energije v emisije CO_2 je odvisna od različnih parametrov in je zelo zapletena, zato smo za računanje uporabili standardne vrednosti iz literature. Npr. emisijski faktorji v našem orodju in za ta primer so vzeti iz evropske referenčne baze podatkov za življenjski cikel [26] in iz baze podatkov Avstrijske zvezne agencije za okolje [27].

Razpredelnica 1 prikazuje neposredne emisije CO_2 iz livarskega procesa. Največji relativni prispevek h globalnemu segrevanju predstavlja koks, ki se uporablja za taljenje, sledi zemeljski plin pri toplotni obdelavi in elektrika za taljenje. V celoti je bil GWP ocenjen za vzorčno livarno na 10 252 t/leto. S spremembo posameznih parametrov, npr. s povečanjem ali zmanjšanjem porabe energenta v modulu, se lahko prikažejo različne proizvodne poti ali postopki. Ta postopek se navadno uporabi pod imenom »analiza občutljivosti« za primerjanje različic in/ali nadomestil v okviru ocenjevanja življenjskega cikla.

Drugi kazalnik je celotna potreba po energiji (CED). CED je izračunan na osnovi vhoda vse primarne energije za izdelavo izdelka ob upoštevanju ustreznih začetnih procesnih verig [28]. Celotna poraba v tej livarni je bila 31,24 GWh (slika 6).

Sankeyev diagram kaže, da sta glavna procesa, pri katerih se rabi energija, taljenje in toplotna obdelava, v okviru 92 % celotne

carbon dioxide. The conversion of energy in CO_2 emissions depends on various parameters and proves to be very complex, therefore standard values from literature are used for the calculation. For instance, the emission factors within the tool and for this example are used from the European reference Life-Cycle Database [26] and the Austrian Federal Environment Agency [27].

Table 1 shows the direct CO_2 emissions from the foundry process. The largest relative contribution to global warming is delivered by coke which is caused by the consumption within the melting process, followed by natural gas in the heat treatment, and electricity in the melting. Overall, the GWP of the sample foundry is estimated at 10,252 t/a. By changing individual parameters, for example, an increase or decrease in consumption of an energy carrier in a module, a comparison of different production routes or methods can be represented. This procedure is usually carried out as so-called "sensitivity analysis" for the comparison of alternatives and / or substitutes in the context of life cycle assessment.

The second indicator is the Cumulative Energy Demand (CED). CED calculated based on the total primary energy input for the generation of a product, taking into account the pertinent front-end process chains [28]. The total energy consumption in this foundry is 31.24 GWh (figure 6) .

The Sankey diagram illustrates, the major energy consumption processes are melting and heat treatment with 92% of the total energy consumption. Consumption of the energy carrier coke for melting iron and recycled material makes almost 60% of the total energy demand. Using this energy flow diagram, any changes for the optimization measures become immediately visible. These cumulative values may be supplemented by monetary data and

Razpredelnica 1. Neposredne emisije CO_2 iz livarskega procesa

Table 1. Direct CO_2 emissions from the foundry process

proces / process	energent / energy carrier	poraba / consumption	enota / unit	emisijski faktor / emissions factor	CO_2 ekvivalenti / equivalents (t/a)
taljenje / melting	elektrika / electricity	2 254,22	MWh/a	0,366 t CO_2/MWh	825
	zem. plin / natural gas	830,65	MWh/a	0,2 t CO_2/MWh	166
	koks / coke	18 299,42	MWh/a	0,38 t CO_2/MWh	6,954
litje / casting	elektrika / electricity	337,48	MWh/a	0.366 t CO_2/MWh	124
	zem. plin / natural gas	378.80	MWh/a	0,2 t CO_2/MWh	76
toplotna obdelava / heat treatment	elektrika / electricity	22.53	MWh/a	0.366 t CO_2/MWh	8
	zem. plin	7,234.88	MWh/a	0,2 t CO_2/MWh	1,447
strojna obdelava / mech. treatment	elektrika / electricity	4.55	MWh/a	0,366 t CO_2/MWh	2
končni nadzor / final control	elektrika / electricity	517.33	MWh/a	0,366 t CO_2/MWh	189
pomožni postopki / support processes	elektrika / electricity	1,144.84	MWh/a	0,366 t CO_2/MWh	419
	zem. plin / natural gas	212.45	MWh/a	0,2 t CO_2/MWh	42
				skupaj	10,252

rabe energije. Poraba energenta koksa za taljenje in recikliranje materiala predstavlja skoraj 60 % celotnih potreb po energiji. Iz uporabe tega diagrama za tok energije postane takoj jasno, kaj je treba storiti za optimizacijo. Te skupne vrednosti se lahko dopolnijo s podatki o denarnih sredstvih in dajejo koristno informacijo za ukrepe, ki jih je treba vpeljati, da se poveča energijska učinkovitost v livarni.

5. Sklepi

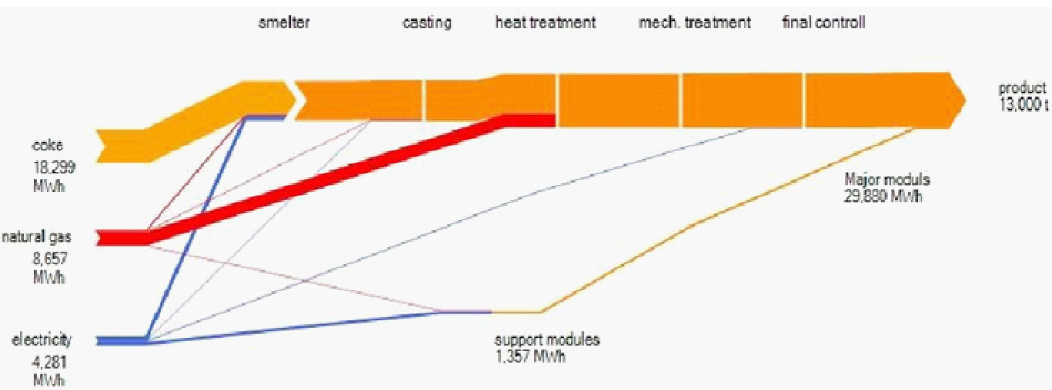
Izvajanje evropske direktive in avstrijskega zakona o energijski učinkovitosti je izziv za podjetja v Avstriji. Glavne ovire predstavlja pomanjkanje praktičnega izvajanja. Livarska industrija predstavlja kompleks energijsko intenzivnih procesov. Če se primerjajo samo livarski izdelki, je energijska bilanca v primerjavi z drugimi možnimi materiali negativna. Npr. izdelek iz lahke zlitine potrebuje mnogo več energije, če se pri

provide valuable information for measures implemented to increase energy efficiency in the foundry.

5. Conclusions

The implementation of the European Energy Efficiency Directive and the Austrian Energy Efficiency Act is a challenging process for companies in Austria. One of the major obstacles lies in a lack of practical implementation. The foundry industry includes complex, particularly energy-intensive processes. Considering only the production of the foundry products, the energy balance compared to alternative materials may be negative. For example, a lightweight product needs much more energy if the energy consumption is related to the actual weight of the product. Energy consumption is in this case based on the production phase of the product, which is one of many phases in the whole life rabi energije upošteva le dejansko maso izdelka. Raba energije v tem primeru sloni le na izdelovalni fazi izdelka, ki je le ena faza v celotnem življenjskem ciklu izdelka. Zato je potrebno ovrednotiti izdelke in rabo energije za celoten življenjski cikel, ki se začne z izdelavo materialov in konča z recikliranjem določenega izdelka. Razumen in pomemben rezultat za celotno energijo, ki je potrebna za nek izdelek, se dobi le z oceno življenjskega cikla izdelka. Zato mora predpostavka, da ima livarski izdelek prednost pred drugimi nadomestnimi izdelki, sloneti na oceni življenjskega cikla. Če se združijo napori za izboljšanje energijske učinkovitosti in ekonomski vidiki, so številne možnosti (ekonomske, tehnološke in ekološke), da se izboljša učinkovitost livarske industrije. Pozornost mora biti posvečena procesom s prepoznanim potencialom energijske uspešnosti. Če obravnavamo ulitke v celotnem življenjske ciklu izdelka, je to koristno, ker postanejo energijski in materialni tokovi prepoznavni in se lahko naredijo ekonomske ter ekološke ocene. Primerni kazalniki in značilnosti dajejo informacije, ki lahko dokažejo prednosti ulitkov (npr. v primerjavi z drugimi možnimi izdelki). Nadalje ta ocena daje osnovo za

cycle of the product only. Therefore, it is necessary to evaluate products and the energy consumption for those on a life cycle basis starting with the raw material production and ending with the recycling phase of a certain product. A reasonable and significant result for the whole energy consumption of a product can only be achieved if a life cycle assessment is made for such products. Consequential this results in the assumption that foundry products may be more advantageous than their substitution products, based on lifecycle considerations. Combined with efforts to improve energy efficiency and economic aspects there are numerous possibilities (economic, technological and ecological) to increase the performance of the foundry industry. The focus should be on processing the identified energy efficiency potential. Consideration of castings over the entire product life cycle is beneficial because actual energy and material flows are transparent, and ecological and economic assessments can be made. Appropriate indicators and characteristics provide information that can prove favorability of castings (e.g. comparison to alternatives). Further this assessment pro- vides a basis



Slika 6. Celotna potreba po energiji za modelno livarno

Figure 6. Cumulative energy demand for the model foundry

dokumentiranje novih zakonitih zahtev in za standardizirane, primerljive podatke za strateško-izvajalsko upravljanje z energijo in viri v livarni. Zato so prednosti ocenjevanja življenjskega cikla: (1) prepoznavanje možnosti za izboljšanje okoljskih značilnosti izdelkov v posameznih fazah življenjskega cikla, (2) osnovna informacija za strateško planiranje, postavljanje prioritet, razvoj izdelkov in procesov, (3) izbor bistvenih kazalnikov za vplive na okolje, (4) trditve, povezane z marketingom izdelkov (npr. izjave o izdelkih, oznake za okoljsko ustreznost). Projekt En-EffGieß ima za cilj, da z orodjem

„Quick Check Tool" ugotovi »vroča mesta« v livarski proizvodnji. Prispevek naj bi dal pregled energijske učinkovitosti in razmislek o življenjskem ciklu v livarski industriji kot tudi prikazal odzive na izvajanje izzivov.

for the documentation in the context of new legal requirements, and standardized, comparable processing data of the strategic-operational energy and resource management in the foundry. Therefore, the benefits of the Life cycle assessment are (1) identifying opportunities for improvement of environmental characteristics of products in the life cycle phases, (2) basis of information in the context of strategic planning, priority setting, product and process development, (3) selection of relevant indicators of environmental performance, (4) statements for the marketing of products (e.g. product declarations, environmental labeling). The project En- EffGieß aims to provide support with the "Quick Check Tool" within this process by identifying the "hot spots" in the foundry production.

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