The time difference of printer cartridge production in the circular and linear economy in the context of climate change and employment policy

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Summary

The paper deals with the time difference of printer cartridges production using the basic principles of circular and linear economy in the context of climate change. The contribution determines the time difference in the production of an average toner cartridge originating from the circular economy as part of a national economy compared to the toner cartridge produced within the principles linear economy and imported into the national economy.

The paper further presents an example of the application of the primary research objective by providing an estimate of the number of domestic jobs created through the introduction of measures preventing the import of disposable toner cartridges that do not allow for the renovation process.

The refurbishment of one unit of an average toner cartridge was found to contribute an extra 37 minutes of labour to the local economy. This finding is of key importance for modelling the benefits yielded by the cartridge refurbishment industry with respect to domestic production and the generation of local jobs. The obtained results are key to facilitating the development of studies related to the cartridge refurbishment sector. The estimate of the number of domestic jobs created through the introduction of measures preventing the import of disposable toner cartridges to the Czech Republic was found to have the potential to generate more than 1,200 local jobs.

Keywords: *circular economy, climate, climate change, environmental protection, employment, greenhouse gases, import, linear economy, print cartridges, production, toner cartridges, vineyards, waste, waste reduction, unemployment, wine.*

Introduction

In 2016, 242 million tons of plastic waste was generated globally, corresponding to 12 percent of all municipal solid waste. If the current waste management trajectory continues unchecked, the volume of plastic waste production will exceed 400 million tonnes by 2050. (1)

Plastic production and plastic waste processing are associated with the emission of greenhouse gases, which contribute to the creation of the greenhouse effect. (2)

The vast majority of the world's scientists admit that the increase in the Earth's average surface temperature and global warming due to human activity are real and will have a catastrophic impact on the ecosystem and the environment unless there is a fundamental shift in consumption habits. (3) The greenhouse effect represents a significant factor with respect to global warming. (2)

The effects of global warming can be seen not only within the global ecosystem, but also in individual sub-sections and marginal parts of the ecosystem. (4)

The major impacts of climate change can be seen in Agricultural Systems. The impacts of climate change may not only be direct, but the impacts of climate change may be indirect, inter alia through changes in human land use. For example, the area suitable for viticulture decreases 25% to 73% in major wine producing regions by 2050. Human-induced climate change may cause establishment of vineyards at higher elevations. Establishment of vineyards at higher elevations will increase impacts on upland ecosystems. The establishment of vineyards at higher elevations thus can lead to a reduction in natural vegetation and a reduction in species diversity. (5) However, climate change, in the example of wine production, is not only the impact caused by changes in wine production, but climate change also has an impact on the quality of the wine itself. Climate change is altering the chemistry of wine. (6)

In September 2020, the European Commission introduced a plan to reduce greenhouse gas emissions in the European Union by at least 55% compared to 1990 by 2030. The overarching aim is to make Europe climate neutral by the year of 2050. A part of the plan is to identify the necessary legislative changes to be adopted over the course of 2021. (7)

Members of the European Parliament wish to increase this target further, effectively reducing greenhouse gas emissions within the European Union by at least 60% compared to 1990 by 2030, In keeping with this proposal, all EU member states would have to be climate-neutral by 2050, which will require negative emissions throughout the European Union thereafter. MEPs have called on the European Commission to submit a specific proposal by 31 May 2023 on how to achieve climate neutrality, including the setting of a 2040 checkpoint and the establishment of a new authority to address climate change issues, namely the European Climate Change Council. (8)

European Union industry produces approximately 20% of the EU's greenhouse gas emissions. The current EU industry is dependent on the consumption of new materials. Of the total consumption of European industry materials, only 12% of materials came from recycling. The European industry is linear in that it does not utilize the given resources repeatedly. (9) Resources in a linear economy are used for the production of products which are subsequently treated as waste. (10) Transition to a circular economy is an integral part of the transformation of the European Union's economy. (9)

The origin and main characteristics of a circular economy

A circular economy is based on the principle of circularity. There are a number of identifiable basic principles. Circularity is one of the fundamental components of nature. Natural resources essentially circulate in a continuous loop with a varying number of intermediate steps and fluctuating frequency of circulation.

The early form of circular economy was based on the reuse of manufactured articles and ongoing repair cycles of manufactured tools and various items. The high level of circularity was mainly due to the scarcity of different products, exclusively manual production and the related enormous complexity of production. (14).

Industrial manufacturing and automation brought about a rapid shift from circular to linear production. In a linear economy, raw materials are obtained, collected and moved through the production cycle to be subsequently transformed into final consumption products destined to be used and disposed of as waste. In the linear economy system, value is created by the production and consumption of the maximum amount of disposable products the market can utilize. (10)

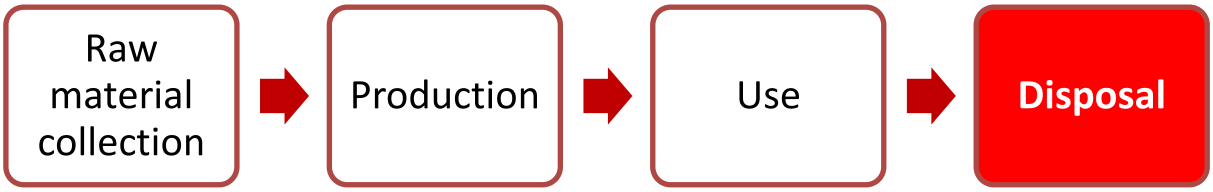

Chart 1: Basic principles of a linear economy

The first attempts to move away from the concept of a linear economy date back to the 1970s. This period sees the emergence of ecological movements that slowly gain in popularity and the advancement of the 3R (Reduce-Reuse-Recycle) Concept. This concept is based on the promotion of the principles of consumption reduction, product reuse and product recycling after use. (16) The theoretical approach is applied in practice, with particular emphasis on waste management rather than on waste prevention. This leads to a substantial increase in the volume of recycling. In this phase, no link between input requirements and output requirements can be said to exist. The emphasis is not placed on a closed cycle, but rather on the recycling of consumed products. (17) The use of salvage car components in various forms of construction is a good example of this. (18).

In the next phase, the concept of assessing the overall impact of consumption on the environment is introduced and developed, linking the input and output of production. At the same time, the model of prevention of negative impacts of production on the environment is being promoted. (19) The concept of linking inputs and outputs initiates a gradual paradigm shift in thinking – **elimination of the negative effects of production and consumption on the natural environment does not necessarily have to represent a threat to the economy. On the contrary, it may become an opportunity for economic development and long-term economic stability.** (20)

The current view of the circular economy regards it as a social and economic concept that is an integral part of sustainable development. As part of the circular economy concept, **the environmental and social perspectives merge into one whole,** bringing a solution to the sustainable concept of consumption. (12)

Basic principles of a circular economy

In a circular economy, the used materials are separated into two independent material cycles. The first flow cycle is represented by substances of organic origin. These materials are readily degradable and can be returned to the biosphere. The second cycle involves substances of synthetic origin. Within a circular economy, these materials are input in a way that allows for the complete separation and subsequent recycling of all products after their use. (1) The circular economy focuses on methods of industrial production that minimize negative environmental impacts and, at the same time, improve the quality of human life by increasing production efficiency. (11) The basic principle of a circular economy lies in the ability to reuse a product as a whole or its individual material components. (12)

Each product must be designed so that its individual components can be separated, dismantled and converted back into a source raw material from which a product of a quality comparable to the original can be produced. (13)

Such product design is part of ecodesign. Ecodesign can be defined as a process of product design and development that emphasizes the minimization of the product's negative impacts on the environment throughout the entire product life cycle while maintaining its required functionality, safety, ergonomic performance, quality, aesthetics and cost adequacy. The life cycle of each product includes all of its phases, namely processing, production, use and disposal. This entails all phases of raw material acquisition and processing, including logistics, all phases of production, distribution to customers, use of the product and the methods of its disposal after use. (21) (22)

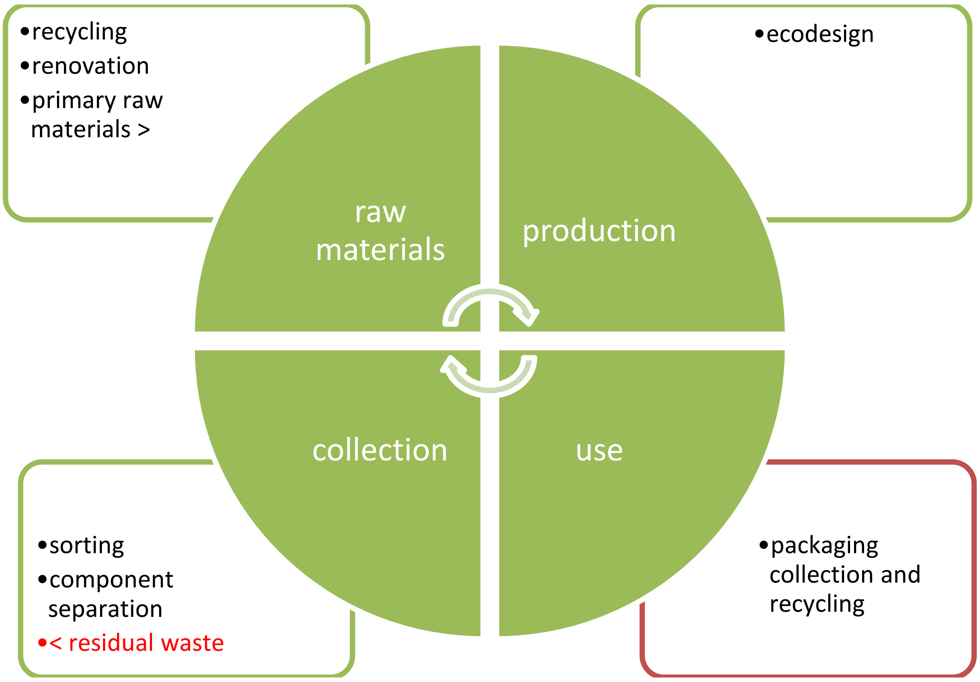

Chart 2: The basic principle of a circular economy

The macroeconomic and social impacts of an applied circular economy

The Cambridge Econometrics, Trinomics, and ICF study, aimed at identifying the macroeconomic and social impacts of circular economy policies in practice, divides the economy into a range of sectors. With respect to the electronics and electronic equipment sector, it forecasts that the introduction of the circular economy will have a positive impact on the total GDP of individual EU countries, projecting a growth between 0.03% and 0.11% by 2030 compared to the initial level in 2017. The study also anticipates a corresponding increase in employment within the sector, ranging from 0.01% to 0.03% by 2030. The impacts of the growth in the level of employment have not been forecast for the entire economy. An increase in the number of jobs is expected in segments related to recycling, renovation and repairs, while jobs in the area of primary material acquisition are expected to decrease. The overall impact is expected to increase slightly, with 700,000 new jobs created in all sectors. Cambridge Econometrics expects a decline in the volume of imports to EU countries and a marginal decrease in consumer prices in connection with the introduction of the circular economy. [(23)] The Meyer B. et al. describes structural changes related to the introduction of the circular economy. The importance of the electronics, electronic and optical devices sector will gradually decline. While in 2009 the proportion of all time worked in EU countries in the electronics, electronic and optical equipment sector was 1.6%, this number is expected to decrease to 1.4% by 2030, with a further decline down to 1.2% thereafter. And whereas the share of GDP of EU countries in 2009 amounted to 2.6%, it is projected to increase to 3.4% by 2030 and, subsequently, up to 20 % by 2050. The average time of the actual use of consumer electronics in households is expected to increase as the related demand for these goods will fall by around 5% to 15%. At the same time, however, there is an expected increase in demand for repair services, including the gradual upgrading of consumer electronics by way of repairs. The rise in demand for repair services is expected to rise by up to 100% by 2050 compared to the reference year 2015. [(24)]

Scientific studies indicate a prevailing positive socio-economic impact achieved by the introduction of the circular economy, accompanied by the transformation of individual sectors. The progressive loss of jobs in sectors related to raw material extraction, land filling and waste disposal will be replaced by the emergence of new jobs in the field of recycling, renovation and repair of products. We can expect a discernible shift towards jobs with higher added value and greater demand on knowledge and skills. From the perspective of EU countries, the prevailing conclusion is that there will be a partial slowdown in imports of final consumer products and input raw materials accompanied by a significant boost in local production through recycling, renovation and repairs. The low-skilled workforce from third world countries will be replaced by European production. This will contribute to and outweigh the economic downturn caused by the reduction in the production of new final consumer products and will facilitate economic growth and social stability in EU countries. (25) (26) (27)

However, according to Patricia van Loon, there is **a notable lack of studies assessing specific products and the real impact of their production within the circular economy, further diminishing the credibility of environmental assessments quantifying the real impacts of circular production and the real benefits of environmentally responsible consumer behaviour.** The results of the presented study show the urgent need to carry out additional studies that would properly assess the future life cycle of specific circular products. (28) This lack tends to be more pronounced in post-communist countries. (29)

This study **contributes to expanding the number of studies assessing the impacts of the circular economy on specific products** for the creation of local jobs, the development of domestic production and global environmental savings with respect to resources and greenhouse gas emissions.

Subject of the research

The research focuses on toner cartridges, a printing consumable used in printers operating on the principle of exposure to a photosensitive drum, generally referred to as laser printers. There are two basic types of toner cartridges as seen from the perspective of a circular versus linear economy. Refurbished toner cartridges are produced by refurbishing previously used toner cartridges. Only toner cartridges that have no technological or legislative restrictions can be refurbished. Refurbished toner cartridges are commonly produced in national economies. The second type are toner cartridges imported from abroad (typically from China). These are products of the linear economy. As such, these cartridges are not suitable for the refurbishment process and are disposed of as waste after their one-time use. See the **Definitions** chapter below for a precise definition of toner cartridge types.

Objective

This paper aims to accurately determine the time difference in the production of an average toner cartridge originating from the principles of circular economy as part of a national economy compared to the toner cartridge produced within the principles of linear economy and imported into the national economy.

The established time difference, representing the creation of a job position within the domestic economy with respect to each used refurbished toner cartridge produced by the national manufacturer, serves as the basic input for modelling the benefits of the refurbished toner cartridge industry for the national economy.

The secondary goal is to present an example of the application of the primary research objective by providing an estimate of the number of domestic jobs created through the introduction of measures preventing the import of disposable toner cartridges that do not allow for the renovation process.

Research methodology

The average time allowance for all process steps **unique to the production of a refurbished toner cartridge within the national economy will be determined.** The applicable values will be determined based on direct experiment. The employed method involves measuring the time allowance for all process steps unique to the refurbished toner cartridges required in all phases of production, extending from the entry of the collected toner cartridge into the production facility to the exit of the refurbished toner cartridge from the facility. Time allowances common to the production of refurbished toner cartridges within the national economy and the import of toner cartridges originating from the linear economy into the national economy will not be included.

The research will be carried out at the leading toner cartridge refurbishing company in the Czech Republic, KMP Bürotechnik s.r.o. This manufacturer uses the maximum proportion of technologically available machine production. Annual toner cartridge production capacity of the company is more than 500,000 units.

For each type of the toner cartridge, the experiment will be repeated for 3 passes $(sm_1; sm_2; sm_3)$ through the entire production cycle, determining the average production cycle time (system operation) for the given cartridge type $(\overline{sm})$.

$$\overline{sm} = \frac{1}{3}\sum_{i=1}^{3} sat_i$$

The average time allowance for the system steps involved in the refurbishment of all types of toner cartridges included in the experiment will be determined in the next phase of the calculation using a weighted average. The weight values will be identified based on the proportionate representation of the cartridge type volume in the production of 30 types of toner cartridges with the highest production volume $(\overline{satt})$.

$$\overline{satt} = \frac{\sum_{i=1}^{30} \overline{sm}_i * w_i}{\sum_{i=1}^{30} w_i}$$

The time allowance will be given in seconds. Overall, the time allowance will be determined for 90 units of production.

During the production, a number of production stages are completed simultaneously for multiple cartridges. Where this is the case, the time allowance for the production stage including multiple cartridge units (stg) will be determined for the entire volume (sg) and then divided by the number of cartridges processed as part of the combined production stage. The (stg). value will be included in the calculation as the input value of the time allowance for the production process of each cartridge type. In order to maintain calculation uniformity and consistency, the methodology will be equally applied to production stages involving a single cartridge $(sg = 1)$.

$$sat = \frac{stg}{sg}$$

The storage and shipping stage will not be included, as this process stage corresponds to the stage wherein the toner cartridges are imported from the linear economy. Moreover, the calculation will not include process stages related to the acquisition and storage of cartridge replacement parts, which essentially correspond to the acquisition and storage of toner cartridges originating from the linear economy.

The processing of toner cartridges once they enter the production facility involves production stages which are not inherently consistent with the methodology established above (non-system operation). This applies to the initial stage in the sorting of toner cartridges into units allocated for refurbishment and units destined for disposal as waste. The time allowance required for the identification of one toner cartridge to be refurbished will also be determined. For each type of the toner cartridge, the experiment will be repeated for 3 passes $(nm_1; nm_2; nm_3)$ through the entire production cycle, determining the average production cycle time for the given cartridge type $(\overline{nm})$.

$$\overline{nm} = \frac{1}{3}\sum_{i=1}^{3} nat_i$$

The average time allowance for the non-system stages related to all types of toner cartridges included in the experiment will be determined in the next phase of the calculation using a weighted average of 30 types of toner cartridges with the highest production volume $(\overline{natt})$.

$$\overline{natt} = \frac{\sum_{i=1}^{30} \overline{nm}_i * w_i}{\sum_{i=1}^{30} w_i}$$

The following step will be to establish the average time allowance for the production of a refurbished toner cartridge with respect to supporting jobs $(\overline{oatt})$. These are jobs related to technical, administrative and organizational activities. Business, sales and management jobs will not be included. The reason being is that similar jobs will be required even in cases where products originating from the linear economy are imported. The total time allowance applicable to all technical - administrative jobs and the average time allowance for one refurbished product will be determined. In addition, we will identify all jobs involved in the development, testing and production of toner cartridges as well as all technical and administrative jobs related to the production of refurbished toner cartridges (j). The total time allowance for all related jobs$(\overline{att})$ will be established as the product of the number of these jobs and the number of working days in 2020 (wd) converted to seconds of work

$$\overline{att} = j * wd * 8 * 60 * 60$$

The average time allowance for the production of a refurbished toner cartridge in relation to support jobs $(\overline{oatt})$ will be determined as the ratio of the total time allowance for all related jobs $(\overline{att})$ to the total production of refurbished toner cartridges in 2020(tp)

$$\overline{oatt} = \frac{\overline{att}}{tp}$$

The total average time allowance for the production of one toner cartridge $(\overline{oatt})$ will be determined as the sum of the average time allowances for system operations $(\overline{satt})$, the average time allowances for non-system operations $(\overline{natt})$ and the average time allowance for support time positions.

$$\overline{\boldsymbol{att}} = \overline{satt} + \overline{natt} + \overline{oatt}$$

Research details

Definitions

A toner cartridge is the replaceable, consumable component of printing equipment using laser printing technology, consisting of a container with toner powder that is transferred to paper via an electrostatically charged drum unit, a wiper blade to wipe excess toner from the photosensitive drum, and a waste hopper for excess powder storage.

The toner cartridge as defined above corresponds to conventional toner cartridges used in printing and multifunction laser printers operated in small and medium-sized offices and homes. This type of toner cartridge is not used in large copying machines with components that can be replaced separately.

An original (OEM) toner cartridge is a toner cartridge supplied under a trademark identical to the trademark of the printer for which it has been designed.

A refurbished/remanufactured toner cartridge is an original toner cartridge that has been used at least once and collected from the user, completely dismantled in a refurbishment facility to allow for separation of the toner hopper, the photosensitive drum, the excess toner wiper blade and the waste hopper, full removal of any residual toner powder, replacement of the photosensitive drum, reassembly of the cartridge, and refilling of the unit with toner powder in a quantity equal to the quantity used in the same type of a new original cartridge.

A compatible toner cartridge is a cartridge supplied under a trademark different from the trademark of the printer for which it has been designed.

The quality standard of toner cartridges is represented by original (OEM) toner cartridges. If the toner cartridges are properly refurbished in accordance with DIN 33870-1 and/or DIN 33870-2 standard, the print quality and yield of the print cartridges fully correspond to the original (OEM) toner cartridge and there is no negative impact on the life of the printers. DIN 33870-1 and DIN 33870-2 standards are designed to guarantee the full similarity of refurbished toner cartridges with new original (OEM) toner cartridges. In contrast, the quality of newly manufactured compatible toner cartridges is highly variable and there is no way to verify the actual quality. There is no usable quality standard. Independent tests have shown that compatible toner cartridges may pose health risks to printer users, (due to the high content of hazardous substances that they are such as Benzen, Styren, TVOC). (15)

Refurbishment process and automation options

The initial step in the refurbishment process is to collect used toner cartridges. Toner cartridge remanufacturers (refurbishing facilities) operate their own collection systems or purchase collected toner cartridges from used cartridge vendors. They obtain them through their own collection or purchase systems directly from consumers or businesses. Independent collection systems are used as standard.

Cartridges are collected in paper boxes located in publicly accessible locations with a capacity of approximately 100 cartridge units. Shipping companies transport the cartridges to the production plant where they are first separated based on their type. This initial process stage involves both system and non-system operations. Each collected toner cartridge is physically inspected and identified as original, refurbished original or compatible. Compatible toner cartridges are placed in a container destined for disposal. Original and previously refurbished original cartridges are identified as to their type and existence in the production program. Cartridges listed and/or to be listed in the production program are checked for their physical condition. All damage-free cartridges are then physically received, i.e. physically placed in the respective storage box and listed in the warehouse system database. These steps constitute system process activities. Non-system process activities are created by separating out toner cartridges that cannot be refurbished. Process activities are completed once the cartridges are separated out and handed over for disposal. This set of activities does not allow for a greater level of automation and robotics due to current technology limitations.

The cartridges are stored until a request for the production of refurbished cartridges is received. The technological prerequisite for a production request to be accommodated is a minimum of 50 cartridges in stock. The cartridges are released from the warehouse and transported to the production facility. Robotic automation of the stock-out and transport process would involve very high investment and operating costs. The initial production phase consists of removing the OEM trademarks from the cartridges. This production phase is skipped for previously remanufactured/refurbished toner cartridges of an identical remanufacturer. However, this situation did not occur in the examined sample of cartridges. OEM trademarks are removed using automated CNC machines and thermal robotic arms. Human labour is only required to operate these machines. Under the patent law in force, failure to remove the OEM trademarks from refurbished products constitutes an infringement of the OEM intellectual property. Elimination of this process step is possible through an amendment to the patent law adding a different interpretation applicable to refurbished products.

The next production step involves the complete disassembly of the toner cartridge, which is carried out in special boxes fitted with an automated toner powder suction system. The disassembly is completed using electric and air-operated tools. Given the variety of disassembly procedures for different types of cartridges, this production phase cannot be automated any further. The complete disassembly and removal of all residual toner powder is followed by the transfer of the units to the respective assembly stations using transport trucks. This step can be automated if robotic trucks are used. The entire assembly process is highly specific for each type of toner cartridge. Some toner cartridges of the same type undergo technological modifications during the life cycle of their mechanical components, especially in terms of their mounting methods. Identical types of toner cartridges may be compatible with multiple sets of replacement parts, depending on their internal design. Accordingly, replacement part requests are submitted only after the exact version of the cartridge type has been determined. Replaceable parts are released from the warehouse and delivered using hand-operated pallet trucks. This phase can be readily automated using a suitable warehouse automation system, including robotic trucks. Due to the considerable specificity of the procedures applied to the cartridge assembly, further automation is not technologically feasible. The toner cartridges are refilled in a semi-automatic process. The filling machine automatically determines the exact dose and type of the toner powder based on the toner cartridge code. Operating personnel are only required to move the cartridges to the filling head of the semi-automatic machine. This process can be streamlined by a greater level of automation using a robotic arm. The transportation of products during production can be facilitated by the use of a robotic truck.

In the next phase of production, the print set is tested. Once the cartridge is manually inserted into the printer, the print report starts automatically. The print set is then transferred to an optical print inspection device. If the sample printout meets the quality requirements, the set is secured with transport tape to prevent the toner powder from being released during shipment and the toner cartridge proceeds to the packaging and storage phase. As these production steps are also performed for compatible toner cartridges originating from the linear economy, they are not included in the calculation. In the monitored sample, no toner cartridges were rejected due to non-compliance with print quality requirements.

Table 1: Direct process steps of a toner cartridge remanufacturer in units of seconds

System operations	stg_1	sg_1	sat_1	stg_2	sg_2	sat_2	stg_3	sg_3	sat_3	$\overline{sm}$
Separation of cartridges suitable for refurbishment	24	1	24	28	1	28	23	1	23	25
Cartridge listing in the storage system	19	1	19	14	1	14	12	1	12	15
Distribution of cartridges for storage	54	8	6,75	69	3	23	58	2	29	19,6
Cartridge placement in storage	5	1	5	6	1	6	6	1	6	5,67
Production request	14	1	14	13	1	13	18	1	18	15
Request acceptance and delivery for production	1436	50	28,7	2743	100	27,4	1539	50	30,8	29
Removal of OEM trademarks	129	1	129	132	1	132	117	1	117	126
Physical transfer during production	323	50	6,46	351	50	7,02	318	50	6,36	6,61
Disassembly using a suction system	425	1	425	398	1	398	412	1	412	412
Removal of residual toner powder by suction	12	1	12	13	1	13	9	1	9	11,3
Removal of waste toner powder by suction	14	1	14	17	1	17	13	1	13	14,7
Transfer during production	53	15	3,53	66	15	4,4	62	15	4,13	4,02
Installation of the drum and other replacement components	25	1	25	22	1	22	24	1	24	23,7
Completion	761	1	761	783	1	783	830	1	830	791
Chip replacement	57	1	57	53	1	53	68	1	68	59,3
Transfer during production	73	50	1,46	81	50	1,62	77	50	1,54	1,54
Toner powder filling	45	1	45	39	1	39	42	1	42	42
Sealing	19	1	19	23	1	23	16	1	16	19,3
Transfer during production	72	50	1,44	87	50	1,74	81	50	1,62	1,6
Print set testing	19	1	19	23	1	23	15	1	15	19
Printout inspection	81	1	81	72	1	72	67	1	67	73,3
Transfer during production	323	50	6,46	312	50	6,24	374	50	7,48	6,73
$\overline{satt}$										**1721,395556**
Non-system operations	ntg_1	ng_1	nat_1	ntg_2	ng_2	nat_2	ntg_3	ng_3	nat_3	$\overline{nm}$
Separation of cartridges that cannot be refurbished	75	1	75	128	1	128	82	1	82	95
$\overline{natt}$										**1816,395556**

Source: own research by the author

This procedure was repeatedly carried out for 30 different types of toner cartridges. These 30 toner cartridge types represent a representative sample of refurbished toner cartridge production. The internal marking of the manufacturer of the refurbished toner cartridges will be used in the calculation model to preserve the possibility of identification. The individual tables will be omitted. The following table shows the $\overline{satt}$ and $\overline{natt}$ values for each cartridge type.

Table 2: Direct process steps of a toner cartridge remanufacturer for different toner cartridge types in units of seconds

Type of toner cartridges	Mass kg	$\overline{sm}$	$\overline{nm}$	$\overline{satt}$	$\overline{natt}$	$\overline{satt + natt}$
H-T193	0,1287	1721,4	95	221,544	12,2265	233,77
H-T14	0,09867	1663,74	112,453	164,162	11,0957	175,257
SA-T75	0,0858	1792,57	89,53	153,803	7,68168	161,485
H-T117	0,06864	1845,73	100,645	126,691	6,90828	133,599
H-T244	0,06006	1819,75	103,632	109,294	6,22414	115,519
H-T112	0,0429	1965,49	98,542	84,3197	4,22746	88,5471
SA-T68	0,03861	1584,46	91,654	61,1761	3,53876	64,7149
B-T56	0,03647	2374,57	103,154	86,5888	3,76151	90,3503
H-T155	0,03432	1794,73	94,653	61,5953	3,24849	64,8438
C-T19	0,03346	1853,58	99,43	62,0247	3,32713	65,3518
H-T235	0,03175	1792,73	98,624	56,9122	3,13092	60,0431
SA-T61	0,03003	1495,65	103,333	44,9145	3,10309	48,0176
H-T171	0,02574	1735,84	96,542	44,6806	2,48499	47,1656
H-T172	0,02445	1932,66	91,533	47,2593	2,23826	49,4976
H-T249	0,0236	1864,45	101,126	43,9918	2,38607	46,3779
H-T6	0,02274	1423,74	105,511	32,3716	2,39901	34,7706
C-T20	0,02145	1854,54	101,654	39,7798	2,18048	41,9603
C-T22	0,01973	1953,53	93,521	38,551	1,84555	40,3965
SA-T44	0,01888	1396,54	98,653	26,361	1,86218	28,2232
B-T86	0,01716	2634,62	96,234	45,2101	1,65138	46,8615
C-T15	0,01673	1754,64	93,643	29,357	1,56674	30,9237
H-T152	0,01587	1863,64	97,432	29,5816	1,54654	31,1282
H-T170	0,01544	1953,05	102,453	30,163	1,58229	31,7453
K-T66	0,01502	2952,63	104,453	44,3338	1,56836	45,9022
SA-T42	0,01416	1643,61	92,543	23,2686	1,31013	24,5788
SA-T92	0,0133	1512,53	97,533	20,1152	1,29709	21,4122
B-T116	0,01287	2452,01	99,115	31,5573	1,27561	32,833
C-T21	0,01201	1694,52	102,75	20,3546	1,23423	21,5888
C-T27	0,01115	1821,64	102,33	20,3186	1,14139	21,46
C-T40BX	0,0103	1791,05	95,634	18,4407	0,98465	19,4253
Checksum	**1**	**Sum of lines**		**1818,72**	**99,0287**	**1917,75**

Source: own research by the author

The average time allowance for the system stages in the refurbishment/remanufacturing of all types of toner cartridges included in the experiment, determined based on the weighted average of 30 types of toner cartridges with the highest production volume ($\overline{satt}$), is 1818.72 seconds. The average time allowance for the non-system stages in the refurbishment/remanufacturing of all types of toner cartridges included in the experiment, determined based on the weighted average of 30 types of toner cartridges with the highest production volume ($\overline{natt}$), is 99.0287 seconds.

The average time allowance for all process steps directly related to cartridge refurbishment ($\overline{satt} + \overline{natt}$) is 1917.75 seconds. **The refurbishment of a standard toner cartridge requires approximately 37 minutes of labour input.** The time allowance includes support jobs related to technical, administrative and organizational activities.

The support jobs are jobs that directly precede or follow the toner cartridge refurbishment process, as well as jobs related to toner cartridge refurbishment. The first type of support job is associated with the development and testing of new types of toner cartridges. Individual replacement parts of toner cartridges, including toner powder, are purchased from external suppliers; their development does not foster the creation of local jobs. The actual process of development of a new type of toner cartridge essentially entails the design of a time-efficient method of OEM trademark removal, cartridge disassembly, residual toner powder removal, replacement of consumable components, including their acquisition from suppliers, cartridge assembly, cartridge refilling with the appropriate amount of toner powder and subsequent testing of cartridge prototypes. Cartridge testing consists primarily of test printing in accordance with ISO/IEC 19752 for black toner cartridges and ISO/IEC 19798 with respect to colour toner cartridges. The aspects being checked during testing include the continuous print quality and the guaranteed cartridge yield. Furthermore, the print quality is examined using a high-load image method (large full-colour print areas). Any issues regarding the print quality are resolved in cooperation with relevant external suppliers. No product goes into production until it is flawless.

Additional functions include technical and economic job positions. These are mainly jobs related to machinery and production facility maintenance, as well as functions linked to labour force logistics, shift management positions, administration and human resources, payroll accounting and information technology.

The calculation of support jobs does not include jobs common to the processing of toner cartridges from both linear and circular economies. This includes business functions and positions related to company management.

Table 3: List of support jobs

Job position	**Number**
Development of new cartridge types	4
Technical maintenance	2
Administration / human resources	3
Accounting / payroll	2
Shift management	3
Information technology	1
Total number of support jobs	**15**

Source: own research by the author

The total number of jobs involved in the development, testing and production of toner cartridges as well as all technical and administrative jobs related to the production of refurbished toner cartridges (j) is 15. There were 251 working days in 2020. The total time allowance for all related jobs($\overline{att}$) is the product of the number of these jobs and the number of working days in 2020 (wd) converted to seconds of work

$$\overline{att} = 15 * 251 * 8 * 60 * 60$$

$$\overline{att} = 108\,432\,000$$

The total number of identified job positions is 15. The total labour fund of support jobs involved in the production of refurbished toner cartridges in 2020 amounted 30,120 working hours. The 2020 production totalled 375,347 units of refurbished toner cartridges. The average time allowance for the production of a refurbished toner cartridge in relation to support jobs ($\overline{oatt}$) has been determined as the ratio of the total time allowance for all related jobs $(\overline{att})$ to the total production of refurbished toner cartridges in 2020(tp).

$$\overline{oatt} = \frac{108\,432\,000}{375\,347}$$

$$\overline{oatt} = 288{,}845$$

The average time allowance for all process steps related to the production of one refurbished toner cartridge is 289 seconds after rounding.

The total average time allowance for the production of one toner cartridge ($\overline{oatt}$) has been determined as the sum of the average time allowances for system operations ($\overline{satt}$), the average time allowances for non-system operations ($\overline{natt}$) and the average time allowance for support time positions.

$$\overline{\boldsymbol{att}} = 1818{,}72 \;+ 99{,}0287 \;+ 288{,}845$$

$\overline{\boldsymbol{att}} = 2206{,}5937$ seconds = 36.78 minutes.

The total average time allowance for the production of one refurbished toner cartridge was determined at 37 minutes after rounding to the next whole minute.

Results and discussion

The primary objective of this paper was to determine the time difference between the production of a refurbished toner cartridge within the national economy (a local product of a circular economy) and the import of a disposable toner cartridge (a product of a linear economy imported to the domestic market).

The difference in the time allowance for human labour in the automated process of producing an average refurbished toner cartridge relative to the import of a disposable toner cartridge from abroad was determined at 37 minutes. The average refurbished toner cartridge contributes 37 minutes of national production to the national economy.

According to the Czech Toner Remanufacturer Association (Asociace renovátorů tonerů, z.s.), approximately 4,000,000 compatible toner cartridges are imported to the Czech Republic each year. [(30)] The full substitution of these cartridges for refurbished cartridges would create **1,221 additional jobs** under otherwise identical conditions[2].

GAIA – the Global Alliance for Incinerator Alternatives – conducted an extensive study entitled Zero Waste and Economic Recovery. The Job Creation Potential of Zero Waste Solutions, concluding that every 10,000 tons of processed waste per year will create 404 additional jobs if the waste is processed via repair and refurbishment, 115 jobs if it is recycled and 55 jobs in the case of remanufacturing, while landfilling or incineration of an equal quantity of waste will create only 2 jobs. [(31)] Considering that the average weight of a compatible used toner cartridge is 907 grams [(32)], a total of 2,971,331,605 tonnes of waste would be processed if the toner cartridges were to be refurbished[3]. 10,000 tons of waste will create 3,365 jobs[4] if toner cartridges are to be refurbished, which is 8.33 times more[5]. As shown, the refurbishment input comprises a product with a relatively low weight and a large share of human labour in the refurbishment process. Hence, the toner cartridge generates an extraordinary number of jobs.

The European Commission has been heavily involved in promoting the principles of the circular economy. An action plan for gradual implementation of the circular economy was adopted as early as in 2015. The plan included a separate plastic recycling strategy as part of a more circular economy and

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[2] $import\ of\ disposable\ toner\ cartridges/(\frac{labour\ seconds\ in\ 2020}{\overline{att}}) \rightarrow 4000000/(\frac{251*8*60*60}{2206{,}5937})$

[3] $\frac{labour\ seconds\ in\ 2020}{\overline{att}} * weight\ of\ processed\ waste \rightarrow \frac{251*8*60*60}{2206.5937} * 0.000907$

[4] $\frac{10{,}000\ tonnes\ of\ waste}{\text{volume of waste processed by one job position in the case of cartridge refurbishment}} \rightarrow \frac{10000}{2.971331605}$

[5] $\frac{indicatednumber\ of\ generated\ jobs}{\text{verified number of generated jobs}} \rightarrow \frac{404}{3365.494441}$

solutions to various plastic recycling issues, especially with respect to plastics containing hazardous substances [(33)]. One of the tools for achieving the set goals was the establishment of the European Remanufacturing Council (Conseil Européen de Remanufacture), incorporating representatives of leading European companies involved in product refurbishment and repair. [(34)] The relevant European Union institutions have sanctioned the proposed agreement on the legislative conditions for a circular economy package, a set of laws and measures designed to secure Europe's future based on resource efficiency, two years after its introduction by the European Commission. A separate strategy for plastics management was developed in conjunction with the approved agreement. [(35)] On 11 March 2020, the European Commission adopted a new circular economy action plan to further expand the scope of the original circular economy plan. The new Circular Economy Action Plan is one of the main building blocks of the European Green Deal [(36, 37)]. However, irrespective of the substantial increase in the requirements for refurbishment and recycling capacity and the support voiced by many institutions, this new Circular Economy Action Plan is still considered insufficient. The European Parliament is calling for much stricter rules on consumption and recycling. [(38)] A number of climatic legal actions have been brought forward to dispute the excessively low intermediate targets. In Germany, the Constitutional Court ruled that the current wording of the Climate Protection Act of 12 December 2019, regulating national climate protection targets and annual emissions up to 2030, is irreconcilable with fundamental human rights because the current generation is allowed higher greenhouse gas emissions under more lenient conditions, while next generations will be faced with many times higher costs associated with their reduction and will be forced to suffer the consequences of the actions of the current generation. One of the arguments put forward is the excessive generality and lack of specific tools to support the circular economy in individual sectors. [(39)]

With respect to cartridge refurbishment support, suitable tools may include the introduction of mandatory minimum public procurement quotas. A similar measure was introduced in Italy in 2014, with its scope extended to all types of public procurement in November 2019. In accordance with the legislation on new minimum environmental criteria for toner and inkjet cartridges (nuovi criteri ambientali minimi per le forniture di toner e cartucce a getto d'inchiostro e per il noleggio o la locazione di stampanti e di multifunzione), all above / below threshold procurement and directly awarded public contracts, including in cases where printing is to be provided in the form of a service, must contain a 30% share of refurbished cartridges, while the print yield and quality must be commensurate with the original print cartridges. [(40)] In 2021, France adopted a similar approach by enacting Regulation No. 2021-254 of 9 March 2021 on the mandatory inclusion of reused goods or recycled materials in public procurement contracts. This regulation stipulates a minimum proportion of refurbished toner and ink cartridges in public procurement contracts, expressed as the share of the total expenditures incurred by each contracting authority in relation to toner and ink cartridges during one calendar year, namely 20%. [(41)]

Introduction of the right to toner cartridge repair and/or a total ban on the production and import of disposable toner cartridges represent additional measures that may be needed to secure the required support.

On 25 November 2020, the European Parliament moved to address the right to repair by endorsing a document calling on the European Commission to introduce a "consumer right to repair" under the Ecodesign Directive. [(42)] Professional refurbishment of a toner cartridge in accordance with the technical standard DIN 33870 and its existing variants constitutes a repair. [(43)]. The introduction of an effective and enforceable right to repair, including compliance control mechanisms, would level the playing field between toner refurbishers and producers of disposable compatible toner cartridges.

Given a sufficient political accord, a total ban on the production and import of disposable toner cartridges – similar to the ban on a set of 10 disposable plastic products enacted by the EU Council on 21 May 2019 – can be readily enforced. EU member states have been given 2 years, from the date of publication of the approved Directive in the Official Journal of the European Union, to amend their national legislation. [(44)] The Czech government approved a government bill on the limitation of the environmental impact of selected plastic products, incorporating the rules adopted by the EU Council into the national legislation. [(45)]

Conclusions

The goal of the European Union, as defined in the European Green Deal strategy, is to transform the community into a resource-efficient economy in a manner whereby economic growth is independent of the amount of resources consumed. The existing European industry can be described as linear. In order to achieve the set goals, a transition to a circular economy is a must. (9)

Resources in a circular economy are used repeatedly. (45) One of the principles of circular products is a solution where the refurbishment process, using individual separable components of a given product, generates refurbished products in a quality that is fully comparable to that of new products. The refurbishment process fosters the development of domestic industries and generates local jobs. (46)

The toner refurbishment industry is a good example of this. Individual EU member states already have a functional print cartridge refurbishment industry. This paper aims to precisely determine the time difference between the local production of refurbished toner cartridges and the import of toner cartridge originating from the linear economy in terms of labour time and intensity.

The refurbishment of one unit of an average toner cartridge was found to contribute an extra 37 minutes of labour to the local economy. This finding is of key importance for modelling the benefits yielded by the cartridge refurbishment industry with respect to domestic production and the generation of local jobs. Patricia van Loon (and others) emphasizes the need for additional studies that would asses specific circular products with a view to creating research models of the socio-economic impacts brought about by the introduction of the circular economy. (29) The obtained results are key to facilitating the development of studies related to the cartridge refurbishment sector.

The secondary goal was a simplified application of the findings by providing an estimate of the number of domestic jobs created through the introduction of measures preventing the import of disposable toner cartridges to the Czech Republic, as an example of applying the research results. The application was found to have the potential to generate more than 1,200 local jobs. The author is aware of the considerable simplification involved in this model (the results have not been applied to the links to the European single market, to consumer preferences transferring part of consumption to original toner cartridges and to other factors affecting the results. Additionally, no analysis of multiplication effects on other sectors of the national economy was conducted.). For such models, the primary result of the study represents the baseline factor.

Additional options were also discussed, including the possibility of restricting or completely banning the import of disposable toner cartridges to European Union countries through the introduction of the "right to repair" or a regulation of the European Parliament and of the Council that would extend the list of products banned from production in and import to EU countries. These tools were found to exist. A separate study should be carried out to address the possibilities and ways of including toner cartridges in these tools.

The EU's environmental policy is currently the Union's most progressive policy as its actual implementation is becoming crucial for the entire block. (47) The high pace of its development and the possible adoption of unconventional solutions are prerequisite for introducing a total ban on the use of disposable products, provided there is a compatible substitute, as is the case with toner cartridges. At present, there is enormous room for the transition to a circular economy with only 9% of the world’s production carried out based on the circular economy principle, i.e. as much as 91% of global production relies on the linear economy.

Dedication

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Časová diference lokální produkce tiskových kazet cirkulárního a lineárního hospodářství v kontextu klimatických změn a politiky zaměstnanosti

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Summary

Příspěvek se zabývá identifikací časového rozdílu výroby náplní do tiskáren s využitím základních principů cirkulární a lineární ekonomiky v kontextu klimatických změn. Příspěvek určuje časový rozdíl ve výrobě průměrné tonerové kazety pocházející z oběhového hospodářství v rámci národního hospodářství oproti tonerové kazetě vyrobené v rámci principů lineární ekonomiky a dovezené do národního hospodářství.

Příspěvek dále uvádí příklad aplikace primárního výzkumného cíle poskytnutím odhadu počtu domácích pracovních míst vytvořených zavedením opatření zamezujících dovozu jednorázových tonerových kazet, které neumožňují proces renovace.

Bylo zjištěno, že renovace jedné jednotky průměrné tonerové kazety přispěla místnímu hospodářství o 37 minut práce navíc. Toto zjištění má klíčový význam pro modelování výhod, které přináší průmysl renovace kazet s ohledem na domácí výrobu a vytváření místních pracovních míst. Získané výsledky jsou klíčové pro usnadnění vývoje studií týkajících se sektoru renovace kazet. Odhad počtu tuzemských pracovních míst vytvořených zavedením opatření bránících dovozu jednorázových tonerových kazet do ČR má potenciál vytvořit více než 1200 místních pracovních míst.

Klíčová slova: *cirkulární ekonomika, dovoz, klima, lineární ekonomika, nezaměstnanost, odpad, ochrana životního prostředí, skleníkové plyny, snižování množství odpadu, tiskové kazety, tonery, vinice, víno, výroba, zaměstnanost.*