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Legal, environmental and economic issues with functional sales – A case of indoor lighting

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ABSTRACT

Functional sales is a business model that has steadily seen increased use. This article features, from a life cycle perspective and in a novel way, its legal, environmental, and economic implications. Functional sales has been highlighted to have the potential for promoting the use of more resource-efficient technologies, which may have a positive impact on the provided solution's environmental and economic performance. However, there are, to our knowledge, few articles published regarding the legal aspects of functional sales and still no laws regulating this type of business model, which can pose barriers to implementing functional sales. Functional sales is in uncharted territory in the legal sphere, and the lack of legal regulation can only, to a certain extent, be overcome by a contract. A contract must consider the relationship to be long-term, and evaluation is important.

In this paper, two different techniques for acquiring lighting representing product sales and functional sales are compared. The case for functional sales is based on the legal foundation of an existing public procurement, while the case for product sales is a likely alternative for lighting purposes. The study shows that there is a trade-off between environmental consequence and economic benefit and that qualitative aspects can be difficult to include in the contract and evaluation.

The conclusion is that the ordinary purchase is supported by long-established rules and regulations so that such a legal transaction (acquisition) is quite conventional and uneventful. However, if the business model changes without a proper legal foundation, the parties of such contracts will find themselves in a legal wilderness, where the outcome of civil litigations is unpredictable. There are ways to circumvent these difficulties, which is demonstrated in this article, as well as the principal advantages of functional sales.

1. Introduction

1.1. Background

The current socioeconomic system is the main cause of the depletion of natural resources (Michelini et al. 2017). The linear economic model for production and consumption relies on inexpensive and easily accessible materials and energy and is characterized by discarding the product at the end of life (Ellen MacArthur Foundation 2015). This leads to unnecessary losses of resources and energy and is not a sustainable economic model. Thus, economic models that promote resource efficiency are preferable (Barquet et al. 2016).

A concept gaining increasing attention is that of the circular economy (CE). Geissdoerfer, Savaget et al. (2017) define the CE as a "regenerative system in which resource input and waste, emission, and energy leakage are minimized by slowing, closing, and narrowing material and energy loops". Important issues when designing solutions for a CE are, for example, long-lasting design, and to re-think, reuse, reduce, maintenance, repair, reuse, remanufacturing, repurpose, refurbishing, recycling and recover (Jawahir and Bradley 2016; Lindahl 2018). However, new innovative business models (BMs) are required to transition from a linear to a circular economy and at the same time replace existing BMs and seize new opportunities, for example, as a result of technological development. One such BM is functional sales (FS). For the past 20 years (Lindahl and Ölundh 2001), it has been highlighted and steadily become more commonly used in society. FS is categorized as a result-oriented product-service system (PSS) (Tukker and

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Tischner 2006) and implies that the supplier sells the function or benefit that the product or service delivers instead of selling a product or service to its customers (Lindahl and Ölundh 2001; Mont 2002; Ölundh 2003; Hiort af Ornäs and Rexfelt 2006). In this BM, the ownership of needed products is maintained with the supplier.

Usually, the transaction is regulated between the parties by a contract that stretches over a certain period, where the supplier has the responsibility to fulfill the desired function during this period. To ensure good profitability, it is in the supplier's best interest to offer solutions that do not require extensive resources for things such as maintenance and operation. Therefore, a greater focus is on using technologies that are resource and energy efficient, and in line with that, using products with a long service life and that are easy to maintain (Lindahl et al. 2014; Tukker 2015). Thus, there is also the potential to increase resource efficiency, reduce environmental impact, and help customers streamline their processes (Lindahl et al. 2014).

However, it is sometimes taken for granted that PSS generally leads to sustainability benefits, which is not always the case (Barquet et al. 2016; Dal Lago, Corti et al. 2017). The design of the BM needs to be appropriate to avoid higher material consumption and negative rebound effects (Zink and Geyer 2017). Several studies have also been performed regarding the sustainability of the circular economy and PSS and how to evaluate this (see for example Yoon, Kim et al. (2012), Kjaer et al. (2016), Allais and Gobert (2016), Dal Lago et al. (2017), and Kjaer et al. (2018)). However, each case of a PSS BM is function-specific and scenario-dependent (Amsawa et al. 2020) and should be evaluated to ensure that environmental and economic benefits are reached (Barquet et al. 2016).

From a legal perspective, it is recognized that the legislative framework needs evolve to facilitate a recycling-oriented society, acknowledging the barriers posed by the present laws regarding recycling materials (Ghisellini et al. 2016; Pheifer 2017). As described by Witjes and Lozano (2016), another perspective shows the benefit of using the procurement process to promote new, more sustainable business models by emphasizing collaboration between procurers and suppliers. Furthermore, in Karlsson et al. (2019) tax law and related accounting law in a Swedish context is mapped identifying a lack of guidance and that it is difficult to clarify the legal position. The FS BM is still relatively new, and little is known about the legal aspects regarding the relationship between provider and customer, for example, how contracts ought to be formulated, if there are laws that regulate this new type of BM, and in what way existing and applicable legal rules have an impact on the BM. A major issue is that FS represents, from a legal perspective, a new way of making (the effects of) a product or service accessible to a market, and it bears some characteristics which are different from an ordinary sales transaction.

A change of the hitherto used BM requires the support of the legal system, which is, for the moment, lacking. Since FS is new, there is no law, and there are no court cases (that we know of) dealing with this subject. Hence there is very little literature analyzing legal questions arising from this type of BM. This article aims to illustrate the advantages of FS as well as drawbacks created by the missing legal underpinning and how it is possible to circumvent some of these drawbacks with the help of a contract. As mentioned before, an argument to implement FS is improved environmental performance, which also must be accompanied by economic benefits for it to be realized. Therefore, to ensure that a FS BM will lead to such situation, the legal dimension of designing the procurement and the succeeding contract should be coupled with the economic and environmental dimension of evaluating the implications of the legal conditions. The approach is novel insofar as almost nothing has been written about the societal prerequisites, that is, legal context, necessary to make use of the merits of FS.

An ordinary sales transaction can be described in the following manner, concentrating on its basic features: The buyer contacts the provider, an agreement is made, the product or service delivered, and money is transferred from buyer to provider. The contract mainly regulates the specifics of the product, such as its time of delivery and quality. A price is mentioned, as well as the specifics concerning the payment. There is no clause in the contract which concerns itself with the future, apart from guarantee clauses.

In contrast to the above, a contract regarding FS could not have this momentaneous character. Principally, this is because the ownership of the products, giving the sought-after result, shall stay with the supplier. This is a reason why the terminology regarding FS should be somewhat different from that used for ordinary sales, where the scope is that the ownership of a product shall be transferred from provider to buyer. In fact, a contract regulating FS should focus on the future, as the relationship between the two parties aims to be long term, and the contract should be adapted accordingly.

Furthermore, as the existing legal regulations have been formed with regard to the existing societal and often economic customs that have been in place for more than 100 years, a new BM will often lack the legal backing needed for its full implementation. In fact, some of the legal rules might even prove counterproductive when applied to a new BM. The law to be applied is the law that is regarded as binding in the country where it applies, or in other words, the law to be is not the law to be applied. New technologies and new BMs need to be accompanied by rules and regulations, which underpin the use of these novelties. These rules and regulations may be legally binding as they are issued and promulgated by a governmental body or written into a legally binding contract between two private parties. In the latter case, however, the existing law may set up boundaries for what may be contracted between the parties.

1.2. Objective

Altogether, the above implies obstacles for companies and customers that want to use FS, as the above issues become uncertainties with potential future implications, ones that may be problematic to evaluate, monitor, and not least monetarize. With this backdrop, the paper aims to shed light on and describe contractual issues related to FS. Furthermore, since a FS contract normally stipulates what is to be delivered and how this is assessed, the objective is also to highlight two potential aspects that can be measured and assessed, the environmental and the economic consequences.

2. Material and methods

2.1. Research approach

A single case study is used as a means to support the objective of the paper, including both qualitative and quantitative methods. Case studies make it possible to investigate complex issues comprehensively and effectively in a real environment (Harrison et al. 2017). The case study is mainly used to understand different problems, and because it can be flexible and applicable, it can be used in a variety of fields and for a variety of topics (Teegavarapu et al. 2008). The qualitative research on investigating the legal aspects of FS is performed using document analysis (Bowen 2009). For the quantitative analyses of the environmental and economic effects, life cycle assessment (LCA) and life cycle cost (LCC) are used to assess the efficiency and effectiveness of FS (ISO 2006; ISO 2006; IEC 2017). Even though there are some limitations with using LCA

and LCC for economic and environmental evaluations of PSS (Settani et al. 2014; Kjaer et al. 2016; Rodríguez et al. 2020), the methods are considered to provide valuable insights and input. It is a way of evaluating the consequences that underlie a contract and can be used as a basis for choosing between business models or identifying gaps that a contract can manage.

This study is limited to evaluating a specific case based on a municipal procurement of indoor lighting in school buildings. The procurement in question was one made by Bollnäs municipality during 2018–2019, a municipality in Sweden with about 27,000 inhabitants. The document included in the qualitative analysis, that is, the contract, is described in Section 2.2, and the cases that form the basis for the economic and environmental analyses are described in Section 2.3.

Lighting is a suitable example of FS, and it is interesting to study from several perspectives. Good lighting is imperative for receiving the right information about one's surroundings. It affects both cognitive abilities and biological processes in the body, and it also has an aesthetic function. Lighting is important to be able to work efficiently, have good mental and physical health, and reduce the risk for injury (Boyce 2003; Fabio et al. 2015; Zumtobel 2017; Xu and Lang 2018). In other words, lighting has several functions that it can or should fulfill. The market conditions for applying FS with regard to lighting are also considered to be good. With the potential of more efficient use, there is an opportunity for economic and environmental benefits for both suppliers and customers. In addition, a transition to this BM in the lighting industry represents a significant paradigm shift, which means that there are legal aspects that are of interest to study.

Two alternatives are evaluated and compared: one representing FS and one representing PS, see system boundaries as illustrated in Fig. 1. From a legal and contractual perspective, there is a significant difference between the alternatives concerning the ownership of the products delivering the desired service. In PS the provider sells a product, the luminaires, to the customer who in turn becomes the owner and is responsible to ensure that the function of desired lighting is fulfilled. The relationship between the participants of this kind of contract is short-term and normally comprises the transfer of products and payment, including a guarantee period. In FS the product is the service of lighting. The provider is the owner of the luminaires and responsible to ensure that the desired lighting is provided. The customer pays a periodic subscription fee for this service. This business model is accompanied with a long-term, bilateral relationship, represented by the overlapping boundaries. As part of that relationship, reoccurring evaluation of the fulfillment of the agreement, the contract, is performed that can lead to changes in the service when necessary.

2.2. Legal issues

Two situations are compared in this paper. System 1 has its foundation in an ordinary sales contract, while System 2 has its background in a FS procurement made by the Swedish municipality of Bollnäs. The material used as grounds for the analysis is primarily the tender document regarding the procurement of light, published by the Bollnäs municipality in Sweden, and the contract between the municipality and the company Brighteco AB, which was contracted to perform according to the contract (and referred to as the contract in this paper). In order to better understand the FS BM used and the included technology, data has also been collected from Brighteco AB, for example, via interviews and studies of data from the company.

The contract referred to in this paper is based on Swedish law, and since the contract is signed by Swedish legal entities (a Swedish municipality and a Swedish limited company), Swedish law is the relevant legal source. The law to be applied in a contract, however, differs from one legal system to another; an example could be the rules on when a contract becomes binding. According to Swedish law, if a party addresses an offer to enter a contract regarding the sale of chattels, this offer is binding for the party during a certain period. The contract as a whole then becomes binding when the counterpart accepts the offer, without changing or amending it. According to other legal systems, the contract as a whole becomes binding only when and if the parties are in agreement on the conditions of the contract (for example, see French law, Code civil art. 1172, 1173) – while one legal system emphasizes certain traits of the envisaged act of law, another legal system stresses other traits. Moreover, the legal system is important, even if the parties are free, at least in principle, to form their contract as they want, since the law is one of the means of deciding if the parties have different views on how a certain clause in the contract has to be understood.

As far as the author knows, there is no research in Sweden concerning the question of how a FS contract is to be designed. Of course, there are classifications of contracts, for example, contracts concerning the transfer of real estate or agreed documents used for various goods and assets. The reason for this state of the research may be that research into legal questions is backward-looking. The law to be applied has been issued sometime in the past, and the legal case and verdict to be examined have also been issued in the past. If the legal research is to be seen as a science, it has to be empirical, which means that it will, most of the time, be backward-looking. As an effect, there will be little serious research done into the legal aspects of new BMs.

However, in essence, this backward-looking method is used in this paper as well, as an already signed contract is viewed in the

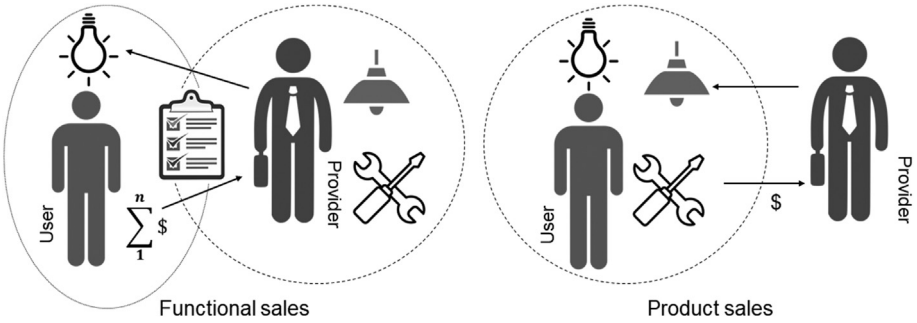

Fig. 1. The system boundaries of functional sales and product sales.

light of the law, which is applicable for commercial contracts signed by businesspersons. If the buying party had been a private customer, another set of legal rules would have to be applied to the contract. However, as this is not the case now, these rules are neglected in the paper.

2.3. Cases for the environmental and economic assessment

The case examined in the quantitative analysis is the illumination of a representative classroom with a floor area of 60 m^2. Two alternatives are being investigated, System 1 and System 2, which are described in more detail in 2.3.1 and 2.3.2 below. System 1 is a likely alternative based on information from the literature, while System 2 is based on information in the winning bid of the procurement and from the contracting company. Data for the analyses is obtained from the scientific literature, product sheets, price lists, and web pages (for example, Van Tichelen, Jansen et al. (2007), European Commission (2015), European Commission (2015), Vattenfall (2016), Fagerhult (2018), Ljuskultur (2018), Nordpool (2018), Philips (2018), Swedish Energy Agency (2018), Vattenfall distribution (2018), and from the contracting company, which provided specific data for its luminaires.

In the LCA, the system's function is to contribute to visibility that is adapted to the activity in the room. The functional unit (FU) is defined as 60 m^2 of illuminated floor area, which meets the requirements according to Swedish Standards (SIS) and recommendations for lighting (SIS 2007; SIS 2011; Ljuskultur 2018). The phases that are included in the life cycle assessment are material extraction, manufacturing, use and maintenance of installed lighting, and waste management of components that are replaced during maintenance. The system covers the luminaire and its components, as well as the luminaires' electricity use and maintenance over ten years. The operating time for the lighting is 2000 h per year (SIS 2007), and the electricity used is produced according to a Swedish electricity production mix.

The commercial program SimaPro 8.0 (SimaPro 2019) is used to perform the environmental impact assessment. Ecoinvent 3.0 (Weidema et al. 2013) is applied for the inventory of materials, energy, and emissions, and the environmental impact assessment is reported according to the Environmental Product Declaration (EPD) and with the impact categories global warming (kg CO_2eq), acidification (kg SO_2eq), eutrophication (kg PO_4eq), photochemical oxidation (kg C_2H_4 eq), and depletion of the ozone layer (kg CFC11) (EPD 2020). Allocation of the environmental impact is made according to the life length of the components in relation to the studied time period. For example, the driver's life length is 50 years; hence, the reference flow is 10/50 or 0.2 driver. For transports during installment and maintenance, the allocation is based on the assumption of an illuminated floor area in the environmental assessment in relation to an assumed total area of a typical school, that is, 60 m^2 in relation to 2000 m^2 (SKL 2018).

The evaluation of LCC is based on the customer's perspective and it is cost orientated. The net present value (NPV) is calculated, including investment or subscription cost depending on the system, and costs for operation and maintenance. It is based on a period of 10 years, with a depreciation period for investments of 15 years. Inflation is 2 percent per year (Riksbanken 2018), and the electricity price is assumed to follow the general price trend. The discount rate is set at 1.5 percent, the municipalities' and county councils' own cost for borrowing in 2019 (SKL 2018).

Table 1 includes an overview of the overall input data for the two systems used in the LCA and LCC evaluation. Assumptions about interest rates, price increases, operating time for the lighting during the year, and electricity costs per kWh are the same in both base cases. The main differences between the systems are the installed power for the lighting, the expected life length of the light source, and the maintenance intervals due to different technical solutions. Another difference is the cost components, where the cost in System 1, representing product sales (PS), consists of purchasing, installing, and maintenance, while in System 2 (FS), it is a subscription cost for the user. This fee consists of the compensation the provider of the function claims to cover its costs during the contracting period and its profit. In both systems, the consumer pays for electricity use due to the present way of measuring and invoicing electricity use in Sweden.

Table 1
Description of the input data for System 1 and System 2.

	System 1	System 2
Time period	10 yr.	10 yr.
Depreciation time	15 yr.	–
Inflation	2.0%	2.0%
Discount rate	1.5%	1.5%
Light source	T5	LED
Weight per luminaire	3.8 kg	3.9 kg
No. luminaires	14 pc.	12 pc.
Installed effect	840 W	384 W
Replacement of light source	50%	–
Operating time	2000 h/yr.	2000 h/yr.
Maintenance interval	3 yr.	5 yr.
Life length		
- Housing	50 yr	50 yr
- Driver	50,000 h	50,000 h
- Luminaire	19,000 h	15 yr

2.3.1. System 1 – product sales

System 1 represents the likely alternative for purchasing lighting at present. The investment cost is usually an important deciding factor and is often decisive for the choices that are finally taken (Pertola 2012), where short-term economic benefits outweigh long-term sustainable and energy-efficient solutions. This is supported by experience from previous procurements of lighting (Frantzell 2016). Therefore, a possible alternative in this case study is luminaires with T5 fluorescent lamps, a commonly used light source with qualities suitable for the evaluated space, and which also has a relatively low investment cost compared to a lighting solution with LED. Each T5 luminaire has two fluorescent lamps of 28W and a ballast of 4 W. The number of luminaires needed is calculated based on the recommended level of 12 W/m^2 (Ljuskultur 2018). An expected loss of luminous flux in the light source is also a factor when deciding on the number of luminaires. In this system, it is assumed to be 0.9 after 20,000 h, and a total of 14 luminaires are therefore needed in the classroom to fulfil the standard. The total installed power will be 840 W for fluorescent lamps plus ballast.

The luminaire used for the calculations is a standard solution for T5 fluorescent lamps, and the inventory data is primarily taken from scientific reports (for example, Van Tichelen et al. (2007), European Commission (2015), European Commission (2015)) and product information published by manufacturers and providers of lighting equipment. The total weight of the luminaire in System 1 is 3.8 kg, of which steel and aluminum account for 75 and 16% by weight, respectively. The glass in the fluorescent lamps contributes to 5% of weight, and the rest of the material is mainly various electronic components and plastics. The fluorescent lamps also contain a smaller proportion of substances such as triphosphorus, argon, and mercury, which per fluorescent lamp is 2, 0.2, and 0.002% by weight, respectively. The service life of the cover is 50 years and 50,000 operating hours for the driver. The life of the fluorescent lamps is assumed to be about 19,000 h, and in the base case, it is assumed that 50 percent of them will be replaced during the studied period. The replaced T5 lamps are collected and

transported by truck to a collection site and then transported to a recycling facility for further processing.

The three main components in the luminaires are assumed to be transported to Gävle for further transport and assembly on site. The driver comes from Poland, while the cover and fluorescent lamps are transported by cargo ship from China to the Gothenburg port and from there by truck. The maintenance takes place every three years, as hanging luminaires need to be inspected and cleaned more often in order not to impair the lighting. The life length of the fluorescent lamps also influences how often maintenance is needed since some of them will malfunction and be replaced.

2.3.2. System 2 – functional sales

System 2 is based on the procurement and contract between Bollnäs municipality and Brighteco AB. The proposal for the technical solution for lighting is defined by Brighteco AB regarding the number of luminaires, need for maintenance, service life of components, and characteristics of the light source. In System 2, it is assumed that 12 luminaires are needed to meet the lighting requirements in the classroom. The luminaires have a light package consisting of material from recycled LCD screens with an LED light source. The total electrical power for a luminaire is 31 W, of which the driver needs 1 W. The total weight is approximately 3.9 kg, of which steel constitutes about 67% of the weight and plastic material 25%. The rest is mainly electronic components (driver), copper, and aluminum. Some of the components consist of recycled material such as used LCD screens, recycled plastic, and recycled steel. The service life of each component is 15 years for the lighting package, 50,000 h for the driver, and 50 years for the other components. The luminaire is assembled at the company's site, and the transports needed to deliver the components to this plant are included in the analysis. Most of the transport of components and that for installation is assumed to be carried out by a EURO5 truck. The maintenance is performed by a contracted representative at or in the vicinity of the site and takes place every five years, and the transport needed is with a light-duty vehicle.

3. Contractual aspects

3.1. Results

3.1.1. Contractual aspects of system 1 – traditional sales

System 1 is based on the concept of an ordinary acquisition. This means that the contract is primarily designed for the transfer of ownership of the lamps and the appropriate fittings. Once the ownership is transferred to the buyer, the installation, maintenance, and energy usage rest with the buyer. The contract does not concern itself with these factors, only with the property changing hands as a result of the transfer of property, that is, lamps, fittings, and money.

The contract contains clauses referring to the specifics of the product and delivery of the product, including specifications of time as well as sanctions if the product does not meet the conditions posed in the contract. Every country has rules, either in law or in industry practice, which regulate these particulars, should the parties have forgotten to mention one of them or are not agreeing to the effect of a particular contract clause. Often, the only "tail" in such a contract is a guarantee by the provider or the manufacturer, stating that the product has the specifications according to the contract during a certain time. Since the acquisition depends on the transfer of money as well, there are corresponding rules concerning the payment.

The communication between the parties, should there be reservations regarding, for example, the quality of the product, is made in such a way that a complaint can be proven in court, that is, in written texts, whether it be by email or in ordinary letters. This is because complaints often are time-barred. For example, if the buyer has a complaint, he or she must put it forward within a certain time to gain access to the sanctions granted in the contract.

The sanctions for breaching the contract may vary. Sometimes, a faulty product can be replaced by a non-deficient one, or it may be repaired. If there has been a more serious breach of contract, the sanction may be the obligation to pay an indemnity or penalty.

The concept of transfer of ownership has effects on how the parties view themselves. The buyer wants to invest as little money as possible for the purchase, while the provider has the opposite notion. This constellation results in a "tug-of-war" between the parties, where the bottom line is the minimum acceptable conditions for quality, price, and details of delivery for each party.

3.1.2. Contractual aspects of system 2 – functional sales

The main difference between the BMs is of principal importance. While the BM in System 1 intends for ownership to be transferred from the provider to the buyer, the BM in System 2 presupposes that ownership of the material goods stays with the FS provider. This fact will, of course, color the agreement between the parties in different ways, changing the content of the agreement.

According to System 2, the advantages of the model are twofold. Firstly, the obligation to maintain the lighting equipment stays with the provider, giving an incentive to reduce energy usage and install luminaires with long durability, thus reducing the need to renew them, reducing the need for raw material and energy to manufacture new luminaires. Secondly, in all probability, the FS provider has more significant knowledge on lighting, how the luminaires should be installed, and how the light affects the people staying in the room, whether they would be working in a workshop or drinking coffee in a staff room.

Both these traits of System 2, not transferring ownership and the expertise of the FS provider, are leaving their mark on the contract between the parties involved. Of course, there are quite detailed technical specifications specifying the technical properties of the light procured. For example, the contract states that the lighting shall conform with the Swedish Standard (SIS 2011). However, since the FS provider shall provide light and the light must be of different quality, depending upon the particular activity which has to be illuminated, even the technical standards are not fixed. According to this basic idea, the just-mentioned Swedish standard for light may be deviated from if the parties agree in this respect. The contract is flexible in other respects as well. For example, it shall be possible to vary the intensity of the light within a frame from 0 to 500 lux.

Another example is the regulation of the color of the light: The temperature of the light shall be adjustable between at least 2700 K (±5%) and 5000 K, with a good color representation and color constancy, that is, the lighting shall give at least CRI (Ra) 80 within this span. Furthermore, the contract states that the light shall be free of flicker, defining how this will be achieved. The contract contains further clauses regarding other specifications concerning the technical details entailed, but it is probably not necessary to exemplify further.

3.1.2.1. System 2: contract, sanctions, and ownership. That the contract does not convey ownership of the lighting equipment but aims to provide the function of light has two consequences. Firstly, the contract opens for cooperation between the parties of the contract, which entails that the parties will have to communicate with each other during the duration of the contract. Secondly, this means that the contract will have quite a long lifespan, especially when compared to contracts according to System 1.

However, the contract is not only open for a dialog between the

parties to the contract, but also those who are to be subjected to the light; that is, the teachers, other staff in the schools, and pupils have been given the right to influence the quality of the lighting. From a legal point of view, this means that the parties of the contract are given the right to a third party to influence the performance. This is not common in contracts, as more often than not, only those who enter into the contract are bound by the clauses in it. Of course, some contracts are designed to give a third party a right, which stems from the contract, for example, third party liability insurance policies. In fact, together with the right to influence the quality of the lighting equipment, the FS provider bears, according to Section 2.0.1 of the contract, the obligation to inform those who work in the school of what light and lighting arrangements can achieve and what would not be possible to achieve.

This means that the word "dialog" is mentioned in a number of contract clauses, for example, when it comes to the installation of the luminaires (Clauses 2.0.2, 2.0.3, 2.0.7, and 3.7 in the contract). There are no penalties for luminaires that are not providing according to the contract, as the guarantee clause simply states that the FS provider is obliged to remedy all flaws in the function of luminaires (Clause 3.5 of the contract). However, a clause states that a penalty shall be paid, namely, if the FS provider is tardy in installing the light. This clause probably has the following background: The luminaires are to be fitted into the schools' inner ceilings, and the instalment of the inner ceilings has to be coordinated with the fitting of the light in order for the school to be usable for its intended purpose. That these activities coincide in time is, evidently, important for the municipality.

Quite contrary to the contracts that are the legal bases for System 1, there is no mention of the ownership of the equipment supplied by the FS provider. This is probably due to the particularities of Swedish law regarding real estate. In short, the law states that if something is attached to real estate by a person different from the owner of the real estate, the ownership of this thing will be transferred to the owner of the real estate if it has been attached so that it cannot be easily removed. When it comes to the luminaires fixed into the inner ceilings of the schools, these could be easily removed. This would be an argument for the ownership staying with the FS provider. However, lighting is necessary for a house to function in its intended manner, and this could be an argument for the luminaires changing their owner, the owner being the owner of the real estate. It may be that the parties to contract simply left the subject unsettled, not knowing the legal solution.

3.2. Discussion of legal framework

It can be noticed, looking at the subject matter in this case from a contractual perspective, that there are two prerequisites: Firstly, that a somewhat new technology is to be used for the illumination, and secondly, that a new and unconventional BM is to be used. In fact, there exists a connection between these two prerequisites, as the new technology makes it possible to vary the quality of the illumination, depending upon the demands, which may differ from time to time and locality to locality. Of course, it would be possible to use traditional BMs to gain the same effect, namely, that an ordinary sales contract is supplemented by a service contract.

3.2.1. Possibilities by contracting

However, the contractual solution above would have a disadvantage in that the incentive for the provider would be to sell at the highest possible price, and the service procurer would aspire to contract as many service occasions as possible. There would not exist an incentive to reduce energy use, and there would not be an incentive to introduce new technologies, if available. Maybe the service contract would stipulate that the service provider should make the adjustments of the luminaires, which could be called for, but one could not be sure that this company or person would have the same knowledge of the lighting equipment as the provider or manufacturer. Additionally, this extra service would most probably come at an extra cost.

The FS contract in this case study takes all these aspects into account. It is a flexible contract, matching the flexibility granted by the new technique. The contract makes space for the parties to adjust the lighting, depending on the wishes of those dependent on the light, to be as good as possible for the user. One could say that this contract builds upon a different view of the relationship between the contracting parties than the traditional. If the traditional contract is a result of a "tug-of-war" between the parties, this contract depends upon the cooperation and, more or less, constant communication between the contracting parties. In this sense, there are similarities to the cooperation between partners in a partnership, where the focus is (or should be) on cooperation, not competition. However, it is also apparent that the law has not been designed with this BM in mind, hence the lack of a contract clause stating who of the contracting parties is to be perceived as the owner of the luminaires.

The legal regulation is dependent upon the factors or situations that are to be regulated. The law adapts itself to the matter at hand. However, it can only do so in so far as the lawmaker[1] has envisaged these factors or situations. The law presupposes that the lawmaker has a mental picture of what is to be regulated by the legal rules, and, if this picture is not to be found in the factual circumstances where the law should be applied, it cannot be applied and is not valid for the situation at hand.

3.2.2. Limitations of contracts

The following is an example to help clarify that written above: All countries have laws or a constant case law, which clarifies at what stage of the negotiations between two or more parties the contract is binding. Behind these rules, there is a mental image of what it means that a contract is binding; it is also possible to say that the rules convey a mental image to the reader. The purchase agreement is a special kind of agreement, and since it is very common, it is regulated in all the countries we know of. The image conveyed to the reader of these rules is that one party hands money to the other party, who in his or her turn, delivers the bought merchandise. The rock-bottom image is the transfer of ownership of property from one party to another. Since the rules have this perspective on the act in question, they are not appropriate to another kind of contract, which does not concern itself with the transfer of property.

There are, of course, areas that may be regulated in contracts, but these situations are more often than not only those that concern the relation between the parties. As soon as a contract affects a third party's interests, for example, creditors, there will probably exist a legal norm that states boundaries for the freedom of contract. These rules foremost concern the question of ownership, which is an important factor in deciding who has the right to the economic quality of the asset, the "buyer" or the "seller". This is an important factor not only between the parties but also vis-à-vis a third person, for example, a bank, which has to decide if the company asking for credit has the financial strength, that is, enough assets, to repay the credit. These questions are, as far as we know, not subject to the will of the parties in a contract in any country. Rather, these are questions to be decided by law or previous case

[1] The term lawmaker should be seen as a metaphor; of course, the preparation of a law involves many persons, from the formulation of the law until the decision to accept the proposal as law.

law. The reason for this civil order is the ground rule in a state governed regarding due process of law: the possibility of a person to foresee the effects of an action. A third person, entering into an agreement with economic consequences, must be able to foresee which effects the engagement would entail.

4. Assessment of environment and cost

4.1. Life cycle assessment

Table 2 shows the relative contribution of the different stages in the life cycle of the respective lighting solution. It is the operation, that is, the electricity use, which is the main cause of the environmental effect in all the studied impact categories. For both lighting solutions, this phase constitutes about 79–99 percent of the environmental impact during their life cycle. This result is in line with previous analyses in the area (for example, Welz et al. (2011)). Regarding the components in one piece of luminaire, a hot spot for both alternatives is the housing. This may not be surprising since it constitutes a major part of the total weight of the luminaires. However, in the case of the contribution to environmental impact in relation to the % per weight of a component, the major hot spot is the driver, which is mainly due to the printed circuit board.

Although the two cases show similar results regarding the relative importance of the life cycle stages within the respective lighting solutions, a comparison of the two systems reveal substantial differences, as seen in Fig. 2. The FS-based lighting solution generally accounts for approximately 46 percent more environmental impact than the system with a BM for PS. The dominating factor that explains most of the differences in the relative comparison of the two systems is the substantially higher electricity use in System 1. During a 10-year period, it amounts to 16.8 MWh for PS with T5 luminaires compared to 7.7 MWh for FS with LED.

Another contributing reason for this difference is that more luminaires (T5) are needed in System 1 to fulfill the lighting requirements over time in the classroom. Also, 50% of the T5 fluorescent tubes are replaced during maintenance. Thus, more material is needed. Furthermore, a large part of the metals and plastics used in System 2, approximately 54% of the luminaire's total weight, emanates from recycled materials. Since virgin material is assumed to be used in luminaires in System 1, it also has an influence on the differences between the systems.

A sensitivity analysis shows that the result is robust. This evaluation includes assumptions regarding variations in operating time, number of luminaires and how many are replaced, transport distances, and if recycled materials are used or not in the components. Based on these, a "best case" for System 1 and a "worst case" for System 2 are formulated that still can be considered as a realistic situation, as seen in Table 3. With these assumptions, the two systems have approximately the same environmental impact. The difference varies between 1 and 6 percentage points, depending on the impact factor and where System 2 has the higher impact except for eutrophication.

Table 2
Relative environmental impact of the different life cycle stages for the two lighting solutions.

	System 1			System 2		
	Material	O&M	EoL	Material	O&M	EoL
Global warming (GWP100a)	10.0%	90.2%	−0.2%	9.7%	90.3%	0%
Acidification	15.0%	85.3%	−0.2%	12.5%	87.5%	0%
Eutrophication	21.5%	78.7%	−0.2%	19.7%	80.3%	0%
Photochemical oxidation	16.5%	83.7%	−0.2%	17.4%	82.6%	0%
Ozone layer depletion	1.4%	98.6%	0.0%	1.2%	98.8%	0%

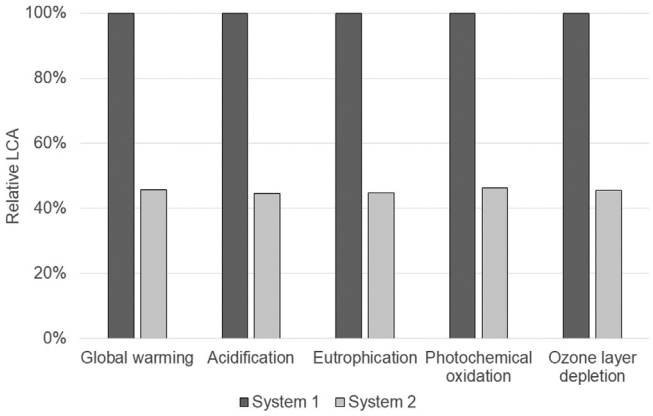

Fig. 2. Relative environmental impact of System 2 (FS) in comparison with System 1 (PS).

Table 3
Assumptions used in the sensitivity analysis.

	System 1	System 2
No. luminaires	12	15
Operating time per year (h)	1500	2500
Recycled material	Yes	Yes/No[a]
Exchange of luminaires	25%	–

[a] Recycled material is used in the frame, and virgin material is used in the lighting package.

4.2. Life cycle costing

Fig. 2 summarizes the costs incurred over a ten-year period to illuminate a classroom according to the studied cases. The investment cost in System 1 is the major cost component from a life cycle perspective, about 56 percent. This is followed by the cost of electricity usage, about 39 percent, and maintenance, with about 5 percent of the costs. For System 2, the subscription cost of the function light is the most dominant, with approximately 83 percent of the present value of the total cost during the period. The rest of the cost is due to electricity use. This cost component also contributes to the differences in the cost structure of the two systems. It makes up of a larger part for PS than for FS because of the less energy efficient luminaires and, hence, a higher energy use.

According to the assumptions made in the analysis, the option for the customer to purchase luminaires with a traditional BM is less expensive than FS for the customer, as can be seen in Fig. 3. The real costs are anonymized due to commercial confidentiality. The

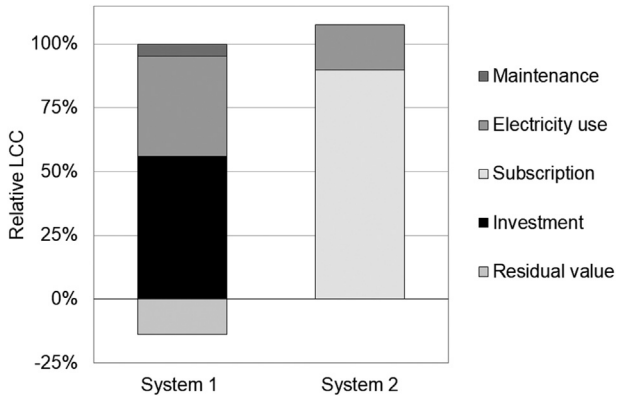

Fig. 3. Relative life cycle cost of System 2 (FS) in comparison with System 1 (PS).

difference in NPV of the costs during the 10-year period is approximately 25% higher for System 2. Altering the input data for operation time, electricity price, depreciation time, and discount rate, respectively, has a minor effect on the relative difference in costs and does not change the ranking of the alternatives. For the NPV of the two systems to be equal the discount rate should be about 9.68% The life cycle cost is also approximately the same for the two systems when the operating time is 4000 h per year instead of 2 000, that is the importance of energy efficient solutions increases with usage. Reducing the depreciation time from 15 years to 10 years, that is there is no residual value for the investment in PS, the difference in NPV decreases to 8%, still in favor of PS. In this case the NPV for the two alternatives are the same when the discount rate is 3.66% or when the operating time per year is 2700 h. Another difference between the systems is when the cost occurs; for System 1, a major part of the total cost, approximately 60 percent, is at the beginning of the period and consists of the investment cost and the cost of operation for the first year. In the following years, the cost component is between four and six percent of the total cost and is made up of periodic maintenance and electricity cost. In the case where the consumer needs a loan for the investment, the loan cost is also a component to be considered. However, it is not included in this LCC. For System 2, the cost is evenly distributed for the customer, with about 10 percent of the total life cycle cost each year during the studied period. As expected, FS leads to the customer having a consistent and, to a large extent, foreseeable expenditure each year.

4.3. Discussion of environmental and economic impact

4.3.1. Reference case

Choosing relevant reference cases is difficult, as identified in, for example, Kjaer et al. (2016), when evaluating the impact on the environment and the cost of implementing a PSS. This is also the case here, but let us entertain the possibility that a fair enough evaluation can be performed. In this paper, a likely reference case is selected as a comparison to the real case procured. A PS BM (System 1) tends to prioritize a technical system with lower initial cost over one where there are future efficiency gains. Hence, less expensive solutions tend to be favored. However, these also tend to be less energy and resource efficient. The lighting solution representing FS (System 2) is based on a situation where the sought-after function during the contract period is prioritized. The result of the assessment of environmental impact and cost shows that a solution where the indoor lighting is based on FS leads to substantially lower environmental impact, approximately half of the impact the lighting solution according to PS has. This applies, in general, to the EPD impact categories evaluated. While FS is the more beneficial alternative environmentally, the PS BM is the more beneficial regarding life cycle cost since it leads to lower costs for the customer. The overall results of the assessment of life cycle cost and environmental impact can thus be explained the following: the relatively low investment cost for the PS BM; that the luminaires in FS are fewer than in PS and they contain, to a large extent, recycled material; and that the electricity use with the FS solution is lower due to both fewer and more energy-efficient luminaires.

4.3.2. Secondary functions

However, looking closer at the two alternatives in the paper, it becomes clear that the secondary functions of the cases differ substantially and will make it more difficult to perform an equitable comparison. One aspect that is not well reflected or considered in the methods used for evaluating the differences of BMs is the adaptability of the technical solutions. The increased requirement for the flexible use of available surfaces in, for instance, offices and schools, means that there must be good opportunities to adapt to the activities, both in the short and long term. This demand for adaptability will make it more difficult to design a lighting solution according to the BM that can meet future, and often unknown, variations in the requirements, for example, lighting that needs to be adapted to new conditions in a remodeled office space or lighting that needs to be adjusted due to changed needs of the users of the function light. The two technical solutions in this study differ in this important aspect. In System 1, it is not possible to change the lighting other than to change the operating time and switch to a luminaire with a different quality of light. In System 2, the luminaire is designed so the lighting package can easily alter the quality of light without replacing it, such as light temperature, luminosity, and the direction or shielding of the light. Also, the operating time is changeable. Hence, it is a more flexible solution, especially regarding qualitative aspects.

Furthermore, lighting has several more features than just providing a certain amount of lux or lumens over a given period to ensure good visual conditions (SIS 2011). Lighting and light also influence a variety of other aspects, such as mood, health, efficiency, and cognitive ability, which, in different ways, have a bearing on productivity, comfort, and well-being. This can lead to secondary cost savings for the users that can be of great value. For example, employees doing well in a workplace will have improved job performance, reduced absenteeism, and tend to stay with their employer (Warr 1999). They are also more cooperative, more helpful, and more often on time (Harter et al. 2003). Therefore, these secondary cost savings should be included when negotiating contracts and when the fulfillment of the contracts is evaluated. Comfort, efficiency, and well-being in a workplace depend on complex relationships where several aspects interact and where the physical and mental work environment is important. In that interaction, lighting and lighting design are important components. However, these qualitative aspects are often based on subjectivity, depending on several personal variables that are difficult to measure (Al Horr, Arif et al. 2016). Since it is difficult to include aspects such as comfort, work efficiency, and well-being in an LCA and LCC, which are often used as input in a decision process, it can result in poorer performance for FS relative to PS when using only these methods for assessments in the procurement process.

5. Concluding discussion

5.1. Functional selling: risks from a legal perspective

The risks inherent in a FS agreement are also the risks inherent in any purchase agreement, that is, a description of what will happen if, for example, the function is substandard according to the contract, which time limits are to be adhered to, and what happens if the payment is late. However, the current legislation is based on and developed within the prevailing economic system, which has been in place for more than 150 years. Hence, the present laws on contracts, and as a result, the present contract regulations, are not in accordance with the particulars of the FS BM. As an effect, the FS contract will not regulate and distribute all of the risks involved and will, therefore, mirror uncertainties due to a lack of legal regulations. Thereby, the lack of relevant legal rules may become an obstacle in developing and using new BMs that can promote circularity.

One important result concerns the ownership of products, in this case, the luminaires. FS presupposes that the ownership stays with the provider of the function. However, according to Swedish law, anything of use to the function and usability of the building as such, and firmly attached to it, will, more often than not, be owned by the owner of the building and not stay in the ownership of the

company that installed it. Few providers would be willing to take the risk of losing assets. Even if bankruptcy were out of the question, problems would arise vis-a-vis a bank if the FS provider asked for a loan since the bank would not be sure of the quality of the security. However, this study focuses on the contract and the relationship between the contracting parties, leaving those questions aside. A deeper investigation would be necessary to make suggestions to the lawgiver.

5.2. Functional selling: technical advantages

As presented in this paper, new technology can make it possible to improve environmental performance. But a traditional BM promotes a competitive negotiation where the provider wants to sell at a high price, and the consumer wants to pay as little as possible. New technology often costs more than existing, and it will also likely lead to extra costs for the consumer to get a solution that fulfills a demand of a function. Since investment cost is often a determining factor in the decision-making process, this higher initial cost will probably refrain potential buyers from investing in new, more energy and resource-efficient technology. However, the FS BM, as exemplified by the contract between the parties used in the case study, highlights the cooperation and communication between them, and not competition.

A common understanding of the demands over time and the service and possibility of adapting the technology to new situations will increase the incentives to opt for effective energy and resource-efficient solutions. This is especially true if the contract concerns areas that are not the core business of the consumer, for example, technical support systems such as lighting, heat, and ventilation. Furthermore, the buyer of the function receives better quality over time if one initially plans for and installs flexible solutions with the function provided; that is, it can vary and adapt to location, occupation, and time.

For the provider, having an adaptable product also means that the service offered can solve multiple requests and demands using the same product. This will also improve resource efficiency since there is no need for multiple versions of a product, facilitating the circular actions of reuse, repair, and refurbish. The provider of the function may also benefit by being able to "educate" the buyer on using the hardware in a way that would decrease the energy use and wear of the product and, at the same time, be able to market the hardware, which would cost less to maintain. Being an expert in the field, the provider can also gain knowledge early on new products or improvements of existing products, which may further reduce the cost for the provider of the function.

Fig. 4, modified from Lindahl and Sundin (2012) and BS 8001 (2017), illustrates an example of the benefit of this type of long-term collaboration with regard to the effect on environmental impact. In a PS BM, the producer will influence the environmental impact up until the sale has taken place, which is in the area between *Provision* and *Use*. With FS, the provider is involved throughout the life cycle and has an interest in being as resource efficient as possible to be sure of making a profit. This can entail that more resources are put into the manufacturing stage if it results in a product that will last longer and require less maintenance, shown in the figure by a cumulative environmental impact that is increasing more for FS than for PS. During the use phase, this can be counteracted by more resource-efficient use, shown by a lower rate of increase for FS compared to PS. Since the provider owns the products used to deliver the function, it is also of interest to improve the circularity by reusing, remanufacturing, or recycling. As a result, there is a possibility of reducing the overall environmental impact, shown in the figure as the difference between PS and FS.

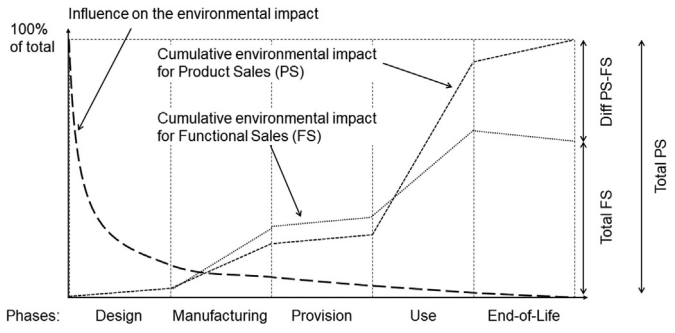

Fig. 4. The difference in the effect on the environmental impact between PS and FS. Modified from Lindahl and Sundin (2012) and BS 8001 (2017).

5.3. Functional selling: economic/legal drawbacks

However, there are some drawbacks to FS. The drawbacks appear in different areas of a company's operation but are mainly coupled to the economy since the policies, guidelines, and rules are designed for the BMs in common use. For example, when it comes to the balance sheet of the company owning the hardware that is used to accomplish the function, FS will grow and diminish the equity/profit rate. This will have an effect on assessing the profitability of the enterprise, according to how a company's profitability is assessed today. Other questions concern how these assets are to be written off (tax law) or according to which rules the audit of a company is to be done, that is, is the FS BM to be compared to operational leasing, which probably is a BM most comparable to the FS BM (rules on bookkeeping and auditing).

Other questions of an economic nature are more closely linked to the problem of ownership: A creditor may be reluctant to grant credit if it is not absolutely sure that the security given will also fulfill its purpose if the debtor is in default. Nevertheless, these credits may be necessary since the initial investment may be big for the provider, according to the FS BM. The income will not come at one time in adherence to signing the contract according to the ordinary BM of purchase, but as a steady flow during the (long) duration of the contract.

There are other problems in connection to, for example, practices in public procurement and the rules of competition law, which are both geared with the sole regard towards present-day BMs. Another problem concerns the relationship between the provider of the function and its buyer. Most probably, buying the function will cost more than the purchase only of the hardware entailing the function. This is because, in the FS BM, the customer will pay for all the resources needed to make the hardware deliver the function; in the ordinary BM "purchase", these costs will not appear on the price tag. And then, there are mental barriers to be overcome, as most people do not know of any other BM than the ordinary ones, explaining how the FS BM functions may be difficult.

5.4. Functional selling of lighting: effects for the parties involved

One of the benefits of the FS BM is its potential for adaptability, that is, the possibility to adjust to changes in requirements, new situations and occupations, and environments over time. This, however, entails higher demands on the parties involved in the contact built on FS compared to traditional BMs. In the procurement, the client needs to be able to formulate what functions are requested, especially regarding qualitative aspects. The supplier needs to be precise about how and to what extent these requests can be met. Designing the offer with a focus on the customer's

needs over time, and having an ongoing discussion with the customer, are thus important to succeed with FS. The collaborative relationship, therefore, requires a greater measure of human interaction with continuous communication between the provider of the function and the user. This promotes a long-term perspective and building of trust between the parties. The FS contracts can deliver this if they are handled well, both when they are drawn up and over time. This is diametrically different from ordinary PS, which contains a minimum of human interaction during a short-term perspective that covers the process of negotiating and selling or buying the product.

The procurement and fulfillment of each agreement need to be evaluated over time to have successful FS from both parties' perspectives. Two established methods that are often used to perform an evaluation are LCA and LCC, which assess the life cycle environmental impact and cost. These aspects are also relatively easy to measure and thereby easy to take into consideration. However, some aspects may be difficult to detect and measure, such as qualitative characteristics that can be of importance in the required function. Therefore, and as is highlighted in the article, there can be difficulties in making reasonable comparisons of the two different BMs in a procurement process. Even though the primary function is the same, lighting a room, the secondary functions can differ substantially. One solution is to evaluate two systems that have equal primary and secondary functions. However, due to the difference in the structure of the two BMs concerning the relationship between customer and provider, that is, competing (PS) or collaborating (FS), the difficulties in finding cases that can be reasonably compared will remain. Hence, a direct comparison will be challenging to perform. The presence of qualitative aspects that are subjective and differ between individuals will also make it more complicated to evaluate the fulfillment of the agreements in the FS.

When this is the case, LCA and LCC are not sufficient, and there is a need to have an assessment that uses a combination of suitable methods that can capture the criteria of importance, both to evaluate alternatives in the procurement process and to evaluate the compliance of the agreements in the FS during the contractual period. The combination of methods varies depending on the case at hand and should, therefore, be decided based on the identified functions and criteria of interest of the user. This will improve the possibility of making assessments and evaluations more accurately and equitably. Defining and describing quantitative and qualitative aspects of the function to be delivered will make the criteria visible, and it can facilitate capturing the secondary functions of the product and services provided. This can substantiate a decision to choose a FS offer that may be more expensive in direct costs but have secondary functions of value for the customer. FS can thus promote choosing a new and more resource-efficient technique.

6. Conclusions

FS seems to be positive from an environmental perspective; however, several contractual risks need to be managed to enable it to be more widely used in society so that its gains can be achieved. The contractual risks with FS include the following:

- It is not regulated in any legal system
- In some cases, it is difficult to establish who is considered to be the owner of the products delivering the function bought
- The function to be delivered is not specified enough
- The evaluation of the function is defined in an unclear manner

Since there are no legal norms regulating FS, the picture becomes blurry when you try to describe the legal implications of such contracts. What is possible to do is to use the freedom of the parties to contract and to, within the existing rules, try to come as near as possible to the concept of functional selling. It is, therefore, important to ensure that the FS contract clearly states the rights and obligations of each party. The parties to a FS contract should also keep in mind and investigate the question of ownership, even if it is most probably impossible to regulate the question in the contract.

Changing the BM will have technical consequences, and technical solutions will impact the business. A circular economy is dependent on changes in technology as well as in the business model. As a policy implication, the FS BM should be subjected to legal regulation similar to BM product sales, which has been regulated even internationally. Furthermore, the required functions, both quantitative and qualitative aspects, should be clearly stated. The possibility to upgrade to new and more resource-effective techniques should be included, and under what circumstances such a change may be made. Also, emphasis should be put on the evaluation, both with assessing alternative offers during the procurement procedure and the assessment during the contract period regarding the fulfillment of the contract. A description of what is to be evaluated and the methods to capture what the demanded function should deliver should be stated in the contract.

To conclude, there are many advantages connected to FS, as has been shown in this paper, concerning the FS of lighting. There are disadvantages as well, one of them being the lack of a legal framework. Maybe this is the most important disadvantage. Connected hereto is the disadvantage that, until now the business model FS is not comprehensively researched, particularly with the regard to its economic consequences, which have to be measured against the goals of circular economy and sustainability. It may not even be certain, that FS always is the environmentally best solution, it may be that already existing business models will prove to be better in this respect. It all depends upon what the desired function is and how it is to be delivered. Another problem may be, that it is difficult to compare different business models, since they probably will be used for different objects, with different purposes. - On the other hand, there are already in existence certain "services", which have many of the traits of the business model FS, for example the "renting" of plants to an office of a hirer, the plants taken care of by the renter. It may even be, that some of the contracts resulting from a public private partnership (PPP), from a FS point of view, could be classified as the result of an application of the business model FS.

This study, though, indicates that FS has advantages compared to traditional BM, which encourages further investigations into the pros and cons of FS compared to traditional BM. However, it is not possible to draw general conclusions from this single example, and, since every type of transaction has to be assessed on its own merit, the assessment mainly depends on the object and the parties involved. The legal rules are different, depending upon the object or situation on which these rules are to be applied. The identified difficulties to evaluate and compare BM are also in line with the previously published research, as described in the background. While it is certain, that different cases have to be treated differently, it is at the same time probable, that one will find similarities between a number of these cases. Probably some of these cases will have common traits, with regard to the "hardware" used and/or the function to be satisfied. Most likely, as research progresses, it will be possible to generalize from these individual studies in order to get a better understanding of FS and which requirements have to be fulfilled to make this business model effective. This study, though, indicates that FS has advantages compared to traditional BM, which encourages further investigations into the pros and cons of FS compared to traditional BM.

CRediT authorship contribution statement

Herbert Jacobson: Project administration, Formal analysis, of the legal aspects, Investigation, Writing - original draft, Writing - review & editing. **Annelie Carlson:** Project administration, Formal analysis, of the environmental and economic effects, Investigation, Writing - original draft, Writing - review & editing. **Mattias Lindahl:** Funding acquisition, Conceptualization, Writing - review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

Al Horr, Y., Arif, M., Kaushik, A., Mazroei, A., Katafygiotou, M., Elsarrag, E., 2016. Occupant productivity and office indoor environment quality: a review of the literature. Build. Environ. 105, 369–389.
Allais, R., Gobert, J., 2016. A multidisciplinary method for sustainability assessment of PSS: challenges and developments. CIRP Journal of Manufacturing Science and Technology 15, 56–64.
Amsawa, E., Shibata, T., Sugiyama, H., Hirao, M., 2020. Environmental potential of reusing, renting, and sharing consumer products: systematic analysis approach. J. Clean. Prod. 242, 118487.
Barquet, A.P., Seidel, j., Seliger, G., Kohl, H., 2016. Sustainability factors for PSS business models. Procedia CIRP 47, 436–441.
Bowen, G.A., 2009. Document analysis as a qualitative research method. Qual. Res. J. 9 (2), 27–40.
Boyce, P.R., 2003. Human Factors in Lighting. Taylor & Francis, London.
BS 8001, 2017. Framework for Implementing the Principles of the Circular Economy in Organizations. The British Standards Institution, Guide London.
Dal Lago, M., Corti, D., Wellsandt, S., 2017. Reinterpreting the LCA standard procedure for PSS. Procedia CIRP 64, 73–78.
Ellen MacArthur Foundation, 2015. Towards a Circular Economy: Business Rationale for an Accelerated Transition. Ellen MacArthur Foundation, UK. December 2.
EPD, 2020. The international EPD system. Retrieved 17th of August, 2020, from. https://www.environdec.com/.
European Commission, 2015a. Preparatory study on light sources for ecodesign and/or energy labelling requirements ('Lot 8/9/19'). Task 3 Use of Light Sources Energy. Final report.
European Commission, 2015b. Preparatory Study on Light Sources for Ecodesign And/or Energy Labelling Requirements ('Lot 8/9/19'). Final report, Task 4. Technologies. Specific contract No ENER/C3/2012-418 LOT1/07/SI2.668526.Energy.
Fabio, B., Chiara, B., Ornella, L.R., Laura, B., Simonetta, F., 2015. Non visual effects of light: an overview and an Italian experience. Energy Procedia 78, 723–728.
Fagerhult, 2018. Produktblad. Retrieved 2nd of November, 2018, from. www.fagerhult.com/sv.
Frantzell, M., 2016. Belysning I Offentliga Lokaler. Offentliga fastigheter.
Geissdoerfer, M., Savaget, P., Bocken, N.M.P., Hultink, E.J., 2017. The Circular Economy – a new sustainability paradigm? J. Clean. Prod. 143 (Suppl. C), 757–768.
Ghisellini, P., Cialani, C., Ulgiati, S., 2016. A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems. J. Clean. Prod. 114, 11–32.
Harrison, H., Birks, M., Franklin, R., Mills, J., 2017. Case Study Research: Foundations and Methodological Orientations, vol. 18, p. 1, 2017.
Harter, J.K., Schmidt, F.L., Keyes, C.L.M., 2003. Well-being in the workplace and its relationship to business outcomes: a review of the Gallup studies. In: Flourishing: Positive Psychology and the Life Well-Lived. American Psychological Association, Washington, DC, US, pp. 205–224.
Hiort af Ornäs, V., Rexfelt, O., 2006. Functional sales from A consumer perspective. In: Wonderground – the 2006 Design Research Society International Conference. Lisabon.
IEC, 2017. Dependability Management - Part 3-3: Application Guide - Life Cycle Costing. International Electrotechnical Commission. IEC 60300-3-3:2017.
ISO, 2006a. Environmental Management – Life Cycle Assessment – Requirements and Guidelines. International Organization for Standardization, Geneva, Switzerland. ISO 14044:2006.
ISO, 2006b. Environmental Performance Evaluation - Life Cycle Assessment - Principles and Framework. International Organization for Standardization, Geneva, Switzerland. ISO 14040:2006.
Jawahir, I.S., Bradley, R., 2016. Technological elements of circular economy and the principles of 6R-based closed-loop material flow in sustainable manufacturing. Procedia CIRP 40, 103–108.
Karlsson, O., Kjellgren, J., Kristoffersson, E., 2019. Funktionsförsäljning Och Beskattning. Skattenytt, Akademisk årsskrift, pp. 45–147, 2000-9801.
Kjaer, L.L., Pagoropoulos, A., Schmidt, J.H., McAloone, T.C., 2016. Challenges when evaluating product/service-systems through life cycle assessment. J. Clean. Prod. 120, 95–104.
Kjaer, L.L., Pigosso, D.C.A., McAloone, T.C., Birkved, M., 2018. Guidelines for evaluating the environmental performance of Product/Service-Systems through life cycle assessment. J. Clean. Prod. 190, 666–678.
Lindahl, M., Charter, M., 2018. Key Issues when Designing Solutions for a Circular Economy. Designing for the Circular Economy. Routledge, pp. 113–122.
Lindahl, M., Ölundh, G., 2001. The Meaning of Functional Sales. Life Cycle Engineering: Challenges and Opportunities: 8th International Seminar on Life Cycle Engineering. CIRP, Varna, Bulgaria.
Lindahl, M., Sundin, E., 2012. Product design considerations for improved integrated product/service offerings. In: Handbook of Sustainable Engineering. Springer.
Lindahl, M., Sundin, E., Sakao, T., 2014. Environmental and economic benefits of Integrated Product Service Offerings quantified with real business cases. J. Clean. Prod. 64 (1 February), 288–296.
Ljuskultur, 2018. Ljus och rum, Del 1 till 9. Retrieved 21st of June, 2018, from. https://ljuskultur.se/teknikbransch/ladda-ner-material/ljus-rum-pdf/.
Michelini, G., Moraes, R.N., Cunha, R.N., Costa, J.M.H., Ometto, A.R., 2017. From linear to circular economy: PSS conducting the transition. Procedia CIRP 64, 2–6.
Mont, O., 2002. Functional Thinking - the Role of Functional Sales and Product Service Systems for Function-Based Society. Naturvårdsverket, Stockholm, Sweden.
Nordpool, 2018. Historical market data. Retrieved 16th of November, 2018, from. www.nordpoolgroup.com/historical-market-data/.
Ölundh, G., 2003. Environmental and Developmental Perspectives of Functional Sales Licentiate Thesis. Royal Institute of Technology.
Pertola, P., 2012. Belysningsfrågor i byggprocessen : Orsaker till brister och förslag till en förbättrad process Licentiate thesis, monograph. KTH Royal Institute of Technology.
Pheifer, A.G., 2017. Barriers & enablers to circular business models. Whitepaper, ValueC.rixfm.se.
Philips, 2018. Produktblad T5-lysrör. Retrieved 2nd of November 2018, from. www.lighting.philips.com/main/prof/conventional-lamps-and-tubes/fluorescent-lamps-and-starters/tl5/t5-standard.
Riksbanken, 2018. Sök räntor & valutakurser. Retrieved 12th of October, 2018, from. www.riksbanken.se.
Rodríguez, A.E., Pezzotta, G., Pinto, R., Romero, D., 2020. A comprehensive description of the Product-Service Systems' cost estimation process: an integrative review. Int. J. Prod. Econ. 221, 107481.
Settani, E., Newnes, L.B., Thenent, N.E., Parry, G., Goh, Y.M., 2014. A through-life costing methodology for use in product–service-systems. Int. J. Prod. Econ. 153, 161–177.
SimaPro, 2019. LCA software for fact-based sustainability. Retrieved 8th of July, 2019, from. https://simapro.com/.
SIS, 2007. Energy performance of buildings. Energy requirements for lighting Swedish Institute for Standards SS-EN 15193–1, 2007.
SIS, 2011. Light and lighting - lighting of work place. Part 1: Indoor worl places Swedish Institute for Standards SS-EN 12464–1, 2011.
SKL, 2018a. Budgetförutsättningar För Åren 2018-2021. Cirkulärnummer 18:5, Diarienr 18/00887. Sveriges Kommuner och Landsting, 15th of February.
SKL, 2018b. Om Sambandet Mellan Skolstorlek Och Utbildningsresultat. Sveriges Kommuner och Landsting, 30th of May.
Swedish Energy Agency, 2018. En Svensk-Norsk Elcertifikatsmarknad. Årsrapport för 2017. ET 2018:7, Stockholm/Oslo.
Teegavarapu, S., Summers, J.D., Mocko, G.M., 2008. Case study method for design research: a justification. In: ASME 2008 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference.
Tukker, A., 2015. Product services for a resource-efficient and circular economy – a review. J. Clean. Prod. 97, 76–91.
Tukker, A., Tischner, U. (Eds.), 2006. New Business for Old Europe. Product Services, Sustainability and Competitiveness. Greenleaf Publishing Ltd, Sheffield, UK.
Van Tichelen, P., Jansen, B., Geerken, T., Vanden Bosch, M., VanHoof, V., Vanhooydonck, L., Vercalsteren, A., Jansen, B., 2007. Final report lot 8: office lighting. Preparatory Studies for Eco-design Requirements of EuPs, Study for the European Commission DGTREN unit D3. Contract- TREN/D1/40-2005/LOT8/S07.56452. 2007/ETE/R/115, VITO; April.
Vattenfall, 2016. Elavtal. Retrieved 16th of November, 2016, from. www.vattenfall.se/foretag/elavtal/.
Vattenfall distribution, 2018. Electricity supply prices. Retrieved 16th of November, 2018, from. www.vattenfalleldistribution.se/foretag/el-till-verksamheten/elnatspriser/.

Warr, P., 1999. Well-being and the Workplace, pp. 392–412.
Weidema, B., Bauer, C., Hischier, R., Mutel, C., Nemecek, T., Reinhard, J., Vadenbo, C., Wernet, G., 2013. Overview and Methodology. Data Quality Guideline for the Ecoinvent Database Version 3.
Welz, T., Hischier, R., Hilty, L., 2011. Environmental impacts of lighting technologies — life cycle assessment and sensitivity analysis. Environ. Impact Assess. Rev. 31, 334–343.
Witjes, S., Lozano, R., 2016. Towards a more Circular Economy: proposing a framework linking sustainable public procurement and sustainable business models. Resour. Conserv. Recycl. 112, 37–44.
Xu, Q., Lang, C.P., 2018. Revisiting the alerting effect of light: a systematic review. Sleep Med. Rev. 41, 39–49.
Yoon, B., Kim, S., Rhee, J., 2012. An evaluation method for designing a new product-service system. Expert Syst. Appl. 39 (3), 3100–3108.
Zink, T., Geyer, R., 2017. Circular economy rebound. J. Ind. Ecol. 21 (3), 593–602.
Zumtobel, 2017. The Lighting Handbook. Dornbirn. Zumtobel Lighting GmbH, Austria.