Readjusting Environmental Fees for Products with a Long Lifetime: Case of PV Module Recycling Fee in the Czech Republic

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Abstract: In the Czech Republic (as in many other countries), environmental fees belong among commonly applied economic tools of environmental policy. One of the fundamental issues that accompany their practical application is setting of the correct rates of the fees in relation to the time frame and targets to be achieved by the tool application. When setting the rate of an environmental fee for a short term, the price can be adjusted flexibly based on the current situation. For some longer-term environmental policy goals, fees are employed that are collected in the form of “advance” payments years or even decades before the actual meeting of the goals (typically, recycling fees when purchasing electrical appliances, for example, so-called acquisition fees), which entails numerous risks and uncertainties that have to be taken into account when setting the optimum rate of the fee. Moreover, the chance to modify the fee substantially during the period is lost in this case.

The paper deals with readjusting the current rate of the recycling fee for PV modules (currently CZK 8.50/kg), which will be utilised in a time frame of 15-30 years after the collection. Its setting is influenced by the complexity and uncertainty of predicting future price trends and technological advancements. Using micro models and applying the precautionary principle, we propose an adjustment to CZK 5.2-7.8/kg based on the technological changes and the market situation.

Key words: Recycling fee · PV modules · Environmental policy · Micro models · Precautionary principle

JEL Classification: H210 · Q580 · Q550

1 Introduction

Act no. 165/2012 Coll. on Supported Sources of Energy entered into legal effect on 1 January 2013; it amends Act no. 185/2001 Coll. on Waste and thus introduces to the Czech legal system a responsibility of operators of photovoltaic power plants for financing the management of waste from photovoltaic modules. The Act imposes the obligation on operators of photovoltaic power plants incorporating photovoltaic modules introduced to the market before 1 January 2013 to ensure financing of the processing, reuse and disposal of electrical waste from photovoltaic modules by means of a collective system for recollection, separate collection, processing, reuse and disposal of electrical equipment and electrical waste. Therefore, all operators were required to register, by mid 2013, with collective systems, which took over the responsibility for ensuring proper handling of waste from photovoltaic modules for the operators of photovoltaic installations as of 1 January 2014. Directive 2012/19/EU specifies that at least 70% of the material has to be recycled and 80% has to be reused, meaning that only 20% of the material may be landfilled.

The minimum total amount of the contribution is defined, pursuant to Decree no. 178/2013, so as “to cover all the expected costs of ensuring handover for processing, recollection, separate collection, transport, processing and reuse and disposal of the expected amount of electrical waste from solar panels.” (Decree no. 178/2013) The current amount of the contribution has been set at CZK 8.50/kg of module. However, the collective systems and photovoltaic power plant operators consider this amount disproportionately high given the potential revenues that may flow from the recycling and reselling of the material (Černá et al., 2015). Here, the adequate setting of the contribution amount faces the problem of time inconsistency between the money collection and utilisation. The total amount should be collected from the operators in periodic instalments by the end of 2018. The majority of photovoltaic power plants in the Czech Republic were put into operation during the so-called solar boom around 2010, and their life time

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is generally assumed to be around 20 years. The utilisation of the money collected can thus be expected only around 2030, which is why these fees are classified as long-term. The regulator’s aim was to establish a tool that would help prevent a situation where photovoltaic power plants in the Czech Republic would remain without further use, nobody would be willing to remove them and there would be no resources for their removal. However, removing a power plant means not only removing the photovoltaic modules as such; the power plant additionally comprises a regulating unit, an inverter, connecting cabling, security elements, grid connecting modules, and other auxiliary structural components (such as aluminium brackets, concrete shoes, fencing), to which the regulation does not apply, and it is therefore not clear how the legislator envisages their removal if the power plant operator does not take care of them. Setting the contribution amount to be applied in the long run comes up against a large number of risks and uncertainties. Based on the problems described, the paper deals with a proposal for an adjustment to the charge, or resetting of the entire system, primarily due to the aforesaid time inconsistency between the collection and the utilisation of the fee. First we present the method using which the newly proposed fee amount should be adjusted. Then we make an enumeration of the potential risks and uncertainties that are associated with the fee in the authors’ opinion and that need to be taken into account when setting the contribution amount. In addition, we briefly introduce the contribution components, using which the final amount is set in conclusion.

2 Methods

Numerous tools are applied in order to achieve environmental policy objectives; they are divided into administrative, economic and voluntary tools. The main attendant attribute of the economic tools is the use of a pricing mechanism to regulate economic activities. The most commonly used economic tools are taxes and fees, followed by subsidies and grants, tradable permits and advance payments (Slavíková, Vejchodská, Slavík et al., 2012). A tax is “a mandatory and unreturnable, typically periodically recurring payment to the public budget without a title to equivalent and direct performance out of the public budget” (Jílková et al., 2006). In contrast to taxes, fees are “one-off payments made by a payer for specific services provided by the public sector, and their primary purpose is the full or at least partial coverage of expenditures associated with such services or coverage of other public budget expenditures” (Jílková et al., 2006).

For the purposes of this study, fees can be divided into short-term and long-term. Utilisation of the money collected in short-term fees takes place immediately after the payment. Therefore, their amount can be adjusted without major difficulty depending on changing circumstances affecting the amount. For long-term fees, the amount has to be set long in advance; here, it is up to 15-30 years. The problem is how to approach this setting so that the fee reflects the true costs and revenues and that its amount takes into account the risks and uncertainties.

The current rate (S) for calculating the minimum amount of the contribution and the minimum amount of financial resources deposited in a purpose-bound bank account is calculated, pursuant to Decree no. 178/2013, using the following formula:

\[ S = N_{os} + N_{pt} + N_{repr} + N_{adm} - P_{ds} \]

where

- \( N_{os} \) is the expected costs of recollection and handover for processing
- \( N_{pt} \) is the expected costs of transport of 1 kg of the electrical waste
- \( N_{repr} \) is the expected costs of processing using best available techniques
- \( N_{adm} \) is the expected costs of administration
- \( P_{ds} \) is the expected revenues from sale of secondary raw materials

The objective of the paper is to tackle the revenues and costs arising from future technologies, which are difficult to estimate. The proposal for a change of the amount of the recycling contribution for photovoltaic modules uses micro modelling for each of the components of the costs and revenues associated with the recycling, including the transport, administrative costs, costs of operation of collecting points, costs of disposal of residual components that cannot be recycled (landfilling, disposal of hazardous waste, etc.) et cetera. The new contribution amount should correspond to the precautionary principle, which should be inherently reflected in environmental policy in connection with long-term fees. The costs of recycling are therefore divided into the steps of the recollection process. The basic inputs for the micro model were the amounts of average revenues and costs of each component of photovoltaic modules (which differ according to the module type), obtained by a review of both domestic and international scientific literature and existing studies. This was followed by a sensitivity analysis to determine the interval for these revenue and cost items. Furthermore, the costs of transporting the panels turned out to be significant, judging based on micro models with variable module transport distance, vehicle capacity utilisation, and panel handling. The basis for the transport cost calculation was a market survey among small and large-scale hauliers. During the research, additional extensive consultations with representatives of collective systems (covering 71% of the installed output of photovoltaic power
plants) and operators of recycling plants in the Czech Republic and abroad were made by means of semi-standardised interviews, focusing on the component aspects of the contribution amount design, including the operation of collecting points, which can be regarded as a logical extension of the service offer of existing collecting points in the case of rooftop installations. Information from the collective systems was used as the basis for the calculation of their operating costs.

The modelling of revenues from sale of secondary raw materials reflected the different composition of modules with respect to both different types of modules and different manufacturers. The minimum and maximum proportions were determined for each component and their yield rate was determined based on the efficiency of techniques.

3 Research results

Determination of the adequate amount of the recycling contribution needs to take into account a number of risks and uncertainties that may significantly affect the future amounts of costs and revenues from recycling of photovoltaic modules. The contribution should reflect the amounts of future revenues and costs, which are difficult to estimate. The recycling economics (in general) is based on yielding of raw materials from the modules and their sale, which has to cover both the processor’s costs and profits. Below, we present an identification of the essential risks and uncertainties affecting the setting of the recycling contribution, followed by a design of the adjusted contribution amount reflecting these risk factors.

3.1 Risks and uncertainties associated with determining the recycling contribution amount

The essential risk factors affecting the amounts of revenues and costs of recycling a module are as follows: (i) completeness of the module delivered, (ii) module damage, (iii) content of hazardous substances and additives in the module, and (iv) commodity price trend on the secondary raw material market. The determination of the adequate fee amount is further complicated by the wide range of various types of modules (crystalline, thin-film) and their specific material composition resulting from the production technique and process. As stated, e.g., by Černá et al. (2015), the composition of panels changes over the years, as expensive components are replaced with cheaper ones.

The majority of currently installed modules include an aluminium frame and copper cabling, which represent some of the principal items of the recycling economy. Incompleteness of modules delivered for recycling (i.e., if modules without these components arrive at the recycling plant) fundamentally reduces the recycling revenue and pressure is thus exerted to utilise the resources allocated under the recycling contributions to compensate for the recycling process costs. In comparison with the EU Directive mentioned above, existing Czech legislation (Decree no. 178/2013) imposes on recycling plants an obligation to recycle (or reuse) 80% of photovoltaic module material. If recycling plants receive damaged modules, some of the technologies in selected recycling plants will not be capable of recovering the binding percentage from damaged panels, posing a risk of potential increase in the recycling costs (in its extreme form, also risk of penalty from the EU for non-compliance with the mandatory minimum rate of reuse); for some technological processes, damaged modules may mean increased handling costs. Another potentially significant risk for the module recycling economy is the content of hazardous substances in modules. Their absolute amount may not necessarily be substantial (studies differ by an order of magnitude), but as a consequence, they may pose a risk of increased costs of separation of the module components and their subsequent cleaning, or a risk of impaired competitiveness selling the separated module component as a secondary raw materials (such as glass) due to lower material purity compared to primary raw materials. That said, the evolution of the secondary raw material market itself is a key (and hard to predict) factor for the recycling economy. Prices on the secondary raw material market may change significantly in the long term due to technological change. Analogously, the input costs may change too (prices of energy, fuels for transport, etc.).

Furthermore, there is the issue of technology efficiency for larger processing volumes and different module types delivered to the plant. A particularly varied mix of modules can be expected from municipal recycling yards, where individual modules from rooftop installations (e.g., single-family houses) from different manufacturers will be deposited.

With respect to the uncertain future development on the markets, in recycling technologies and other risks, the determination of the contribution amount has to be based on current technologies. For example, future development of processing technologies for CRT screens was also expected in the past, but no major advances have been made there. With respect to the returnability of the unused part of the contribution, it is advisable to include a reserve for unfavourable developments in order to secure the module recycling.

3.2 Revenues and costs of photovoltaic model processing

Taking into account all the risks described above, it is very difficult to set an adequate amount of the fee for the long run, and a number of assumptions therefore had to be introduced for the fee amount design:
(i) the revenue calculation builds on the average yield rate of each component of photovoltaic modules, achievable using existing technologies. This rate of success in separating and cleaning the components is then significantly reflected in the selling price of the raw material, thus also the revenues from selling the recycled materials;

(ii) the prices of recycled materials are assumed to be 70% of the primary raw material market price, taking into account market volatility;

(iii) the determination of the recycling cost amount draws mostly in data obtained based on consultations in Germany and published in sources abroad. There are so far no larger facilities in the Czech Republic operating on a purely commercial basis from which we could obtain data on recycling costs (with the exception of one facility, so far in pilot operation).

The literature review indicates that the studies differ substantially in their calculated processing costs and revenues, by orders of magnitude in fact. The highest costs of processing were quoted by McDonald and Pearce (2010): CZK 47.71/kg of crystalline module. The lowest costs are quoted by Friedrichs (2015): CZK 1.08/kg for module processing in Germany. The mean costs are CZK 12/kg of module. Likewise, the estimated revenues from processing differ substantially across authors from CZK 4.80/kg to CZK 63.59/kg.

Based on our own analysis of raw material prices on world markets and interviews with representatives of different collective systems, we made an analysis of the market prices of different materials. Using current and historic prices and predictions and projects of future trends (World Bank, International Monetary Fund, Infomine and Knoema commodity information servers), we estimated the price range of the different primary raw materials relevant for photovoltaic panels on the raw material market. Graph 1 shows on the case of aluminium that there is a noticeable price volatility on the raw material markets. Based on the price interval, different module compositions and estimated yield rate proportions of different materials, we then estimated the lower and upper bounds of the selling price of separated materials from 1 kg of photovoltaic module. It must be noted that these are prices of primary raw materials and the prices of secondary raw materials may differ more or less depending mainly on the material purity and the quantity supplied, as well as other factors. The analysis indicates that there is a relatively consensual opinion on the market that the prices of secondary materials are approx. 70% of the prices of primary raw materials. Therefore, we use this information below as the assumption for determining prices on the secondary raw material market. The range of revenues from selling secondary raw materials recovered from silicon modules was predicted as CZK 10.9-37.2/kg; the range was narrower for other types. The width of the range is due not only to the different commodity prices but also the yield rate and content of these components in the panels. A certain maximum quantity of a commodity can be recovered using each of the alternative module processing technologies. The different micro modules each applied a different technology to each of the modules and determined the yield rates for them. Some studies collect these maximum yield rates and then apply the maximum yield rates for the current technologies to the total yield rate calculation. We regard this approach as inappropriate, as it does not provide adequate coverage for risks in case no major advancement is made in recycling.

**Figure 1** Projection of aluminium price trend on the primary raw material market

Source: International Monetary Fund, 2015

The consultation with representatives of operators of a recycling plant in the Czech Republic produced the estimated costs of CZK 8-9/kg of module. The literature review produced average costs of CZK 12/kg of module. The cost analysis has to take into account a number of additional costs associated with disposal of unused module components, and landfilling and disposal of hazardous waste, which were included in the modelled costs. It can be assumed based on all the information obtained that, with a positive market development, the future costs of recycling of complete unbroken photovoltaic modules could be zero (excluding collection and transport costs) or slightly positive. In a very optimistic scenario, we may even assume that modules might be purchased in future (depending on the commodity prices and further development of processing technologies). Given all the risks mentioned above, we need to work with a certain reserve for the event of unfavourable development or for incomplete or broken modules delivered
for processing, amounting to approx. CZK 1-2.5/kg. This reserve also better reflects the quoted risks associated with the content of hazardous substances in the panels and the possible contamination of other components during the panel recycling process.

The transport costs have to be determined depending on the transport distance, difficulty of module handling and the percentage capacity utilisation of the vehicles. Based on a model of the transport costs and the variables, the transport costs including loading and unloading will most probably be around CZK 1.7-2.1/kg of module.

Another major item, covered by the collective system from the recycling contribution, is the administrative costs, partly caused by the mandatory reporting obligations and partly consisting of costs included under them by the collective systems. Unfortunately, there is no specific definition of eligible items for this portion of the contribution. The administrative costs of the collective systems interviewed were CZK 0.09-0.45/kg/year. Based on the data identified, the administrative costs can be expected at CZK 2-2.5/kg for the module life time.

Uncertainty problems remain in the analysis of module collection costs; it is difficult to estimate the future development of the collecting network, whether it will expand or contract. Based on information about the current network, the approximate amount may be CZK 0.5-0.7/kg.

4 Conclusions

The determination of the adequate amount of the recycling contribution for photovoltaic panels used the micro modelling method, taking into account risks and critical analysis of the different steps in the recollection and processing. The intervals for the revenue and cost components of the recycling contribution mentioned above were determined with respect to the possible risks and uncertainties in determining the contribution amount in the long run. First and foremost, the fee is supposed to cover the costs and risks that the national government would have to bear in case the original photovoltaic power plant operator “disappeared”. With respect to the uncertain future development, we based our assumptions on current and historic prices of commodities and current recycling technologies. Adding up the individual cost items associated with the entire photovoltaic module recollection and recycling process, the resulting complete costs are CZK 5.2-7.8/kg. This alternative proposal is only slightly lower than the current setting.

In the event of there being a chance to amend the existing legislation on disposal of electrical waste from photovoltaic modules, the cost components that the contribution amount is to reflect need to be adjusted and specified precisely above all. Decree no. 178/2013, to which reference is made, also lacks a specification of the module condition upon acceptance for processing: the absence of the aluminium frame and other “external” components would jeopardise both the financial aspects and the chance of complying with legislative requirements on the percentage reuse of the modules.

The micro modelling of the cost and revenue components turned out to be indispensable for determining the amount of the recycling fee for the long run. The potential risks could be taken into account for each component and included in the costs. An appropriate example is the costs of handling of hazardous wastes comprising unreusable and unprocessable components of modules contaminated with hazardous substances.

References


Vyhláška č. 178/2013 Sb. Vyhláška, kterou se mění vyhláška č. 352/2005 Sb., o podrobnostech nakládání s elektrozařízeními a elektroodpady a o bližších podmínkách financování nakládání s nimi (vyhláška o nakládání s elektrozařízeními a elektroodpady), ve znění pozdějších předpisů.
