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Evaluation of energy efficiency measures using top-down and bottom-up indicators – methodological implications and practical experience in Slovakia

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ABSTRACT

While the EU set an overall target of 20% reduction of the EU's primary energy sources by 2020 as compared to projections, the Member states (MSs) set their individual national targets. According to the Directive 2006/32/EC and Directive 2012/27/EU, the MSs shall evaluate energy efficiency measures every three years in National Energy Efficiency Action Plans (NEEAP) and in a brief annual report on their progress towards national energy efficiency targets. According to Directive 2006/32/EC, MSs can use for this purpose top-down (TD) and bottom-up (BU) methods. While energy savings based on the BU approach are based on monitored and collected data, the TD indicators are based on statistics. The calculations for both methods are based on the European Commission's recommendations on measurement and verification methods. The aim of the paper is to show, based on the experience from preparation of the NEEAPs in Slovakia, methodological pros and cons of using each type of indicators and draw lessons learned. The paper shows that although data for TD indicators may be easier to collect, these indicators result in unrealistically high energy savings. In Slovakia, TD indicators for two years (2008, 2009) resulted in more than twice as high energy savings as the 3-year energy efficiency target for the period 2008-2010. The largest deviations occurred in transport sector. Due to these problems, Slovakia used solely the BU approach in the subsequent NEEAPs. Due to the unrealistic results, the TD indicators are not recommended for evaluation of energy efficiency measures for EU reporting purposes.

1. Introduction

While the EU set an overall target of 20% reduction of the EU's primary energy sources by 2020 as compared to projections, the Member states (MSs) set their individual national targets (EC 2006, EU 2012). According to the Directive 2006/32/EC on energy end-use efficiency and energy services (EC 2006) and Directive 2012/27/EU on energy efficiency (EU 2012) the MSs shall evaluate their achievement to reach their national energy efficiency targets every three years in National Energy Efficiency Action Plans (NEEAP) (EC 2006) and yearly in a brief annual report on progress achieved towards national energy efficiency targets (EU 2012).[1]

The energy efficiency targets (indicative) in the Slovak republic (SR) were set in line with the Directive 2006/32/EC (ESD) and officially published in the Energy efficiency strategy of the Slovak Republic (MoE SR 2007a) and 1NEEAP (MoE SR 2007b) and adjusted in 2NEEAP (MoE SR 2011; covering the period from 2011 to

[1] Note, that the Regulation 1999/2018 on governance (EU 2018b) has established new rules for reporting. Nevertheless, these do not have any effect on the aims of this paper.

2013)). New targets were set based on Article 3 (indicative) and Article 7 (mandatory) of the Directive 2012/27/EU (EED) and these were approved in 3NEEAP (MoE SR 2014). For details, see Table 1.

Table 1. Energy efficiency targets in Slovakia

Target	**Original**		**Adjusted**	
ESD targets	**% $FEC_{2001-2005}$**	**[TJ]**	**% $FEC_{2001-2005}$**	**[TJ]**
Annual target	1%	4 135	1%	3 122
Mid-term target - until 2010	3%	12 405	3%	9 366
Long-term target – until 2016	9%	37 215	9%	28 098

EED targets (Art. 7)	**[GWh]**	**[TJ]**
Annual target (FEC)	949	3 416
Cumulative target until 2020	26 565	79 695

Source: MoE SR (2007b), MoE SR (2011), MoE SR (2014)

According to Directive 2006/32/EC, MSs can evaluate the progress in achieving the targets using top-down and bottom-up methods. While the energy savings based on a bottom-up approach are calculated based on monitored and collected data, the ones based on top-down indicators are based on national statistics. The calculations for both types of methods are based on European Commission's methodology (EC 2010).

The aim of the paper is to show, based on the experience from preparation of the NEEAPs in Slovakia, the methodological pros and cons of using the two types of methods and draw lessons learned and recommendations.

The second chapter describes the methods used for evaluation of the energy savings (bottom-up and top-down method) and the advantages and disadvantages of each of the evaluation methods used. The third chapter presents the results for both evaluation methods and analyses the major challenges associated with these results. Here the paper further focuses on the results of the TD approach in the Transport sector, where the main inconsistences occur. This chapter provides some recommendations for possible methodology development. Finally, the main findings are summarized and discussed in the Conclusions and discussion section.

2. Methodology

The methodology for evaluation of energy efficiency measures in order to evaluate energy savings achieved in the reporting period was based on the European Commission (EC)'s „Recommendations on measurement and verification methods in the framework of Directive 2006/32/EC" (EC 2010) (further referred to as "Recommended methods"). A training was organized by the European Commission for national experts responsible for evaluation of energy efficiency measures in the second half 2010.

For evaluation of the energy efficiency measures of the 1NEEAP (covering the period of 2008-2010), the European Commission recommended that 20-30% of the reported energy savings should be calculated based on bottom-up approach (MoE SR 2011), while the rest of the energy savings can be evaluated through the top-down approach.

2.1. Bottom-up evaluation approach

The bottom-up (BU) method is designed to evaluate final energy savings „achieved through the implementation of energy efficiency improvement measures or programmes" in different sectors (EC 2010).

The EC's Recommended methods include bottom-up indicators and formulas for their calculation for these sectors: residential buildings, tertiary buildings including equipment and appliances used in these buildings (EC 2010). The BU approach requires rather specific data on individual projects (e.g. renovation of a building) before and after realisation of the project, which requires detailed data collection and intense cooperation with the institutions operating individual financial mechanisms.

The main advantage of this approach is that, unlike the TD approach, the BU approach provides realistic data on energy savings from individual projects that were achieved through particular energy efficiency measures.

The main disadvantage of the BU approach is that the process to set up data collection process is time-demanding and challenging. It requires methodological preparation (including developing reporting mechanism), knowledge of all individual energy efficiency programmes and financial mechanisms and the outputs of their monitoring systems (such as Information and Monitoring System, ITMS, for the Structural funds), as well as training of the representatives of different institutions responsible for these financial mechanisms. This approach requires coordination at national level and ideally establishing a well-functioning central energy efficiency monitoring system, which would be interlinked with the monitoring systems of the individual financial mechanisms. It also requires a system for checking input data from both energy and financial point of view (which shall be done at the central monitoring system).

Data collection and processing in Slovakia

The most important aspects of BU data collection in Slovakia are of institutional and data- quality nature:

a. Institutional aspects

The bottom-up calculations require specific data collected from institutions responsible for operation of the different energy efficiency measures, such as financial mechanisms etc. For this purpose, a commission including relevant ministries and institutions responsible for operation of different financial mechanisms with an impact on energy savings (so-called "Permanent inter-ministerial commission for preparation of energy efficiency action plans") was established by the Ministry of Economy of the Slovak Republic (MoE SR). For data collection, it was not possible to use the energy efficiency monitoring system (MSEE) for evaluation of 1NEEAP, as it was to start its operation only in 2011 (MoE SR 2011). In order to evaluate energy efficiency measures by individual projects, the MoE SR prepared so-called "Methodological tables" for the majority of individual measures (with both quantitative and qualitative information). For efficient data collection, representatives of the institutions were trained by MoE SR and Slovak Innovation and Energy Agency (SIEA), as most of them did not possess information on how to collect, process and/or calculate energy savings from their programmes (MoE SR 2011). Due to that, MoE SR together with SIEA were closely working with each institution in order to get objective results. The collected data were subsequently checked and cross-checked by MoE SR and SIEA (see below).

b. Data quality aspects

In most of the financial mechanisms, energy savings were not a mandatory indicator for reporting. In programmes funded by Structural funds (2007-2013), there was a horizontal indicator "energy savings", however, it was not mandatory, and thus rarely available (MoE SR 2011).[2] Due to that, energy savings achieved through implementation of such mechanisms had to be calculated based on other data available in their monitoring systems, or other data had to be collected from the responsible institutions. In many cases, where data on energy savings were limited, energy savings had to be calculated in an alternative way (MoE SR 2011), e.g. by using investment intensity of the comparable project type in the same sector.

[2] In the financial framework 2004-2006 energy savings as an indicator were not monitored at all (MoE SR 2011).

After collection of the relevant data and calculation of energy savings, the data was cross-checked. First, the data was compared to the average cost intensity ($EUR/MWh_{energy\ savings}$) of similar projects (e.g. renovation of multi-family buildings, renovation of different types of public buildings). If needed, this could involve also further cross-checking with other available information about the given programme (e.g. number of renovated buildings in the programme from the programme's website, number of renovated buildings in the given category from the Database of energy certificates[3] etc.). Second, projects, where investment intensity was out of range of the average investment intensity of a sample of comparable projects, were checked and cross-checked further individually by project (e.g. based on public data of the floor area, heated area of the particular renovated buildings and other publicly available project information). If the project data did not prove reliable even then, these were excluded from the total amount of energy savings achieved.

Due to the fact, that the monitoring systems of the financial programmes (such as ITMS of the operational programmes of the European Structural Funds) were not operated by energy specialists, this led to many incorrect data inserted into the system from energy audits or project documentation. This led to several numerical, unit conversion and other mistakes (Korytarova 2015), due to which several of the projects had to be excluded from the total amount of the reported energy savings.

2.2. Top-down evaluation approach

The top-down (TD) approach is designed to calculate final energy savings at the national level. Calculation of energy savings through this method is based on aggregated data on final energy consumption (FEC) in different sectors of the national economy and activity in these sectors.

Calculation of top-down indicators requires statistical data, which are usually available from the national statistical office and Eurostat, while some data can be retrieved from the Odyssee database. Formulas for calculation of energy savings through TD indicators are listed in Annex.

The main advantage of the top-down approach is that the data collection is rather straightforward for most indicators and does not necessitate training of governmental officials from all relevant institutions and further time-demanding check and verification of energy savings per project.

Among the main disadvantages is that TD indicators show only aggregated changes in energy consumption in sectors or subsectors. They do not allow for evaluation of an impact of a particular energy efficiency measure, especially in a sector, where several measures are implemented, and/or other factors have an impact on reduction in energy consumption. Due to this reason, they are not suitable for evaluation of individual energy efficiency measures (unless only one measure was responsible for all energy savings in the sector/subsector, without any external factors having impact on reduction in energy consumption). Moreover, some problems may occur when an indicator does indicate improvement in energy efficiency, but it is applied to the whole stock (see below).

Data collection and processing in Slovakia

Data for calculation of energy savings through the mandatory TD indicators were primarily collected from Eurostat, Statistical Office of the Slovak Republic (SOSR),[4] while some specific data were supplied by the Ministry for Transport, Construction and Regional Development of the SR (MoTCRD SR),[5] as well as the Slovak

[3] Database of energy certificates is a part of the information system INFOREG, https://www.inforeg.sk/ec/searchEC.aspx.
[4] https://slovak.statistics.sk
[5] The current name is Ministry of Transport and Construction of the SR: https://www.mindop.sk

Transport Research Institute (VÚD)[6] and the Odyssee database[7] (MoE SR 2011). The Odyssee database served mainly for cross-check of the statistical data or partial results (MoE SR 2011).

Due to the fact, that the TD approach uses official statistical data, which are available with a yearly delay, the calculations for the 2NEEAP relied on data for 2007-2009, as data for 2010 were not available at the time of preparation of the 2NEEAP (MoE SR 2011).

There were several challenges using this approach:

- unclarity about the base year – as the energy efficiency target was calculated based on the final energy consumption in 2001-2005, the suitable base year/period for evaluation of progress towards this target would be 2001-2005. However, the base year recommended by the EC was 2007 (EC 2010). Due to the fact, that this year was not representative in Slovak conditions, and thus led to unrealistic results, the Slovak republic decided to calculate the TD indicators also for the base period 2001-2005, as well as for the previous year (t-1) (MoE SR 2011).
- Limited data for preferred indicators – due to the fact, that there were very limited statistical data for input data into the preferred (and alternative) indicators (P1-P14), there was limited possibility for a cross-check for quality of the results using the recommended calculations for energy savings based on the mandatory minimum TD indicators (M1-M8).
- In general, there was a limited staff capacity to further analyse and cross-check the calculations of energy savings based on TD indicators.
- Time delay of official release of the statistical data – Slovak statistical data for the previous year (t-1) is typically officially available in late autumn of the current year (t), and thus, the previous year cannot be included in the reporting documents, which are due in April of the current year.

3. Results

This section introduces results for bottom-up and top-down calculations of energy savings in Slovakia.

3.1. Results for the bottom-up calculations

The BU approach was used for evaluation of several energy efficiency measures in the following sectors: buildings, appliances (using an own system of evaluation based on the number of appliances collected by recycling centres), public sector (including public buildings and public lighting), industry, and transport. In several cases, the calculations of energy savings had to be adjusted to the available data. The BU approach cannot be used for cross-sector energy efficiency measures, which have effect on energy savings in several sectors and/or those, for which the impact cannot be quantified (such as cross-cutting legislation, information campaigns and free provision of advice on energy savings to households).

Energy savings calculated through the BU approach in these sectors sum up to 3 689 TJ, which is about 30% of the original 3-year energy efficiency target for period 2008-2010, or 39% of the adjusted energy efficiency target for the same period (MoE SR 2011), see Table 2. This implies that the requirement of the EC to evaluate at least 30% of the target through the BU method was fulfilled.

[6] www.vud.sk

[7] https://www.indicators.odyssee-mure.eu/energy-efficiency-database.html

Table 2. Energy savings evaluated through BU approach in 2008-2010 (TJ)

Sector	Energy savings [TJ]	[% of calculated BU savings]
Buildings	498	13%
Appliances	1 013	27%
Public sector	16	0.4 %
Transport	1 176	32%
Industry	629	17%
Total	**3 689**	**100%**
		[% of target]
EE target 2008-2010	**12 405**	30%
EE target 2008-2010 – adjusted	**9 366**	39%

Source: Based on MoE SR (2011)

The largest share of energy savings calculated through BU approach comes from transport, followed by appliances, industry and buildings. These shares are influenced by availability of suitable BU data and do not necessarily correspond to the proportion of implemented policies and measures across sectors.

3.2. Result for the top-down calculations

In Slovakia, all mandatory TD indicators (M1-M8) prescribed by the EC (2010) were calculated (sectors: households, services, transport, industry) in the 2NEEAP. This approach is not suitable for highly specific measures, as for evaluation of such measures suitable disaggregated statistical data may not be available.

Major challenges revealed through the evaluation

In the 2NEEAP, the energy savings based on TD indicators are calculated for years 2008 and 2009[8] as compared to three different calculation base periods: first, energy savings are calculated as compared to the period 2001-2005, so that the evaluation is in line with the base period used for the calculation of the national energy efficiency targets under Directive 2006/32/EC (MoE SR 2011). Second, energy savings are calculated as compared to year 2007, which was recommended by the European Commission (EC 2010) to be used as a base year (MoE SR 2011). Third, energy savings are calculated also as compared to the previous year (t-1), which was used as a cross-check of the resulting energy savings calculated through TD indicators for the two previously mentioned base periods. The energy savings calculated through the TD indicators are shown in Table 3.

Table 3. Total energy savings (ES) in 2008-2009 calculated through mandatory TD indicators (TJ)

ID	Description of indicator (name and unit)	Σ ES in 2008-2009 vs. average (2001-05)[9]	Σ ES in 2008-2009 vs. 2007	Σ ES in 2008-2009 vs. previous year (t-1)
		[TJ]	[TJ]	[TJ]
M1	Non-electricity energy consumption of households in toe per dwelling adjusted for climatic conditions	48 807	-3 660	-93
M2	Electricity consumption of households in kWh per dwelling	4 797	1 212	852
	Households total	**53 604**	**-2 448**	**759**
M3	Non-electricity energy consumption of the service sector in toe per	7 169	-2 921	-367

[8] At the time of preparation of the 2NEEAP, statistical data was available only for these two years (MoE SR 2011).
[9] The table shows the sum of energy savings for year 2008 and 2009, which were calculated by TD indicators.

ID	Description of indicator (name and unit)	Σ ES in 2008-2009 vs. average (2001-05)[9]	Σ ES in 2008-2009 vs. 2007	Σ ES in 2008-2009 vs. previous year (t-1)
	employee in full-time equivalent adjusted for climatic conditions			
M4	Electricity consumption of the service sector in kWh per employee in full time equivalent	7 365	213	-613
	Services total	**14 534**	**-2 708**	**-980**
M5	Energy consumption of road vehicles in toe per car equivalent	-5 552	21 215	16 492
M6	Energy consumption of rail transport in goe/tkm	450	-134	4 049
M7	Energy consumption of inland waterways transport in koe/tkm	2 425	1 624	1 031
	Transport total	**-2 677**	**22 705**	**21 572**
M8-1+2	Energy consumption of Steel and metallurgy per unit of value added in real terms	12 707	304	-155
M8-3	Energy consumption of Chemical industry per unit of value added in real terms	3 048	510	429
M8-4	Energy consumption of Ore extraction (except fuels) industry - per unit of value added in real terms	5 869	2 683	1 862
M8-5	Energy consumption of Food, drink and tobacco industry per unit of value added in real terms	12 818	3 893	2 147
M8-6	Energy consumption of Textile, leather and clothing industry per unit of value added in real terms	2 932	20	108
M8-7	Energy consumption of Paper and printing industry per unit of value added in real terms	0	0	0
M8-8	Energy consumption of Engineering and other metal industry per unit of value added in real terms	15 177	3 928	2 106
M8-9	Energy consumption of Other non-classified industries per unit of value added in real terms	3 062	428	109
	Industry total	**55 613**	**11 765**	**6 606**
	TOTAL ENERGY SAVINGS	**121 073**	**29 314**	**27 957**[10]

Source: Based on MoE SR (2011)

The resulting energy savings calculated through TD indicators are very different for all three calculation base periods, and inconsistent (between the sectors and also in different years), and thus it is difficult to analyse them systematically. The differences between different sectors may be mainly due to sensitiveness of the indicators to the input data and their deviations and the formulas as such. Therefore, alongside with the resulting energy savings based on the TD indicators it is also important to observe the long-term trends in the final energy consumption (FEC) in the individual sectors, which is the main parameter in calculation of the indicators (MoE SR 2011).

As the FEC in the year 2007, which was recommended as a base year for the TD calculations by the EC, showed significant deviations from the trends of the FEC in Slovakia in the last 10 years (MoE SR 2011), it was not suitable as a base year. On the other side, using the average of 2001-2005 as a base period resulted in unrealistically high energy savings for some indicators and thus, it was also not suitable for the calculation. Therefore, energy savings based on the TD approach for 2008-2009 were calculated as compared to the

[10] Due to a mistake in indicator M6 (-169 TJ instead of 4 049 TJ), the correct value for total energy savings calculated for 2008-2009 as compared to the previous year (t-1) is 23 740 TJ (instead of 27 957 TJ as published in 2NEEAP). This correction has, nevertheless, no effect on the arguments included in the paper. The resulting corrected total energy savings calculated through TD indicators are still unrealistically high and inconsistent (as compared to other base periods and to the results of the BU approach).

previous year (t-1). The resulting energy savings based on this period are the lowest among the results for different calculation periods. Nevertheless, these results are still more than twice as high as the 3-year energy efficiency target (see Table 4), which is rather unrealistic for an economy in transition.

Table 4. Energy savings evaluated through TD approach in 2008-2009 (as compared to previous year)

Sector	Indicators	Energy savings [TJ]	[%of savings calculated TD]
Households	M1, 2	759	3%
Services	M3, 4	-980	-4%
Transport	M5, 6, 7	21 572	77%
Industry	M8: 1-9	6 606	24%
Total		**27 957**	**100%**

EE target 2008-2010	**12 405**
EE target 2008-2010 – adjusted	**9 366**

Source: Based on MoE SR (2011)

Based on the TD approach, the largest share on total TD energy savings stems from the transport sector, followed by industry.

Although there are several differences between how energy savings are calculated through BU and TD approaches (in the BU approach energy savings are calculated for 3 years, in the TD approach for 2 years; and BU data collection was only in its beginnings in the reported period and only accounted for 30-39% of the 3-year energy saving target), a simple comparison of the results allows for at least a glimpse into the level of magnitude of the energy savings in total and in different sectors. And, such comparison implies that the results of the two approaches are not in line with each other.

Within the TD approach, the most problematic are the results for Transport, as they show the largest deviation as compared to the BU results (mainly due to the indicator for road transport, see below). Another problematic sector is the Service sector, which shows negative energy savings based on the TD indicators, and thus implies an increase in energy consumption in this sector in 2008-2009. Nevertheless, the Services sector is a "calculated" category in the Slovak statistical procedure (i.e. it incorporates deviations in FEC that occurred in all other sectors) (MoE SR 2014), and thus, it is difficult to analyse the trend in this sector as compared to the resulting TD energy savings.

Although there are problems with the TD indicators in several sectors and analysis of the indicators in different sectors may be needed, this article focuses only on transport, where the inconsistences are most profound. Further research may focus on the TD indicators in other sectors.

Analysis of the problem in the Transport sector

The high results for energy savings calculated through TD indicators in Transport sector are a result of a calculation according to the equation by EC (2010). The improvement in energy efficiency of the road transport in the actual year (year t) as compared to the base year 2007 is applied to the total stock of road vehicles in the year t (E.1).

Equation 1. Calculation of energy savings in road transport (M5)

$$ES_t^{RV^{CAeq}} = \left(\frac{E_{2007}^{RV}}{S_{2007}^{RV^{CAeq}}} - \frac{E_t^{RV}}{S_t^{RV^{CAeq}}}\right) * S_t^{RV^{CAeq}} \quad \text{(E. 1)}$$

Where:

$ES_t^{RV^{CAeq}}$ - energy savings of road vehicles in year t (toe)

E_{2007}^{RV}, E_t^{RV} - energy consumption of road vehicles (cars, trucks and light vehicles, motorcycles, buses) in 2007 and in year t (toe)

$S_{2007}^{RV^{CAeq}}$, $S_t^{RV^{CAeq}}$ - stock of road vehicles in car equivalent[11] in 2007 and in year t

In the equation for indicator M5, the average energy efficiency improvement of the whole fleet in year t as compared to the base year 2007 is applied to the whole fleet in the year t. This may seem plausible, as the energy intensity of the fleet is calculated as an average of the whole stock of vehicles in the particular year. Nevertheless, this energy efficiency improvement is applied also to the newly added vehicles, which leads to an increase in the absolute final energy efficiency in road transport and thus, treating these as energy savings is not fully correct. The formula does not differentiate between new vehicles, new vehicles replacing the old discarded vehicles and remaining old vehicles.

This implies that the equation is not suitable to calculate energy savings properly, as it leads to overestimated energy savings. The solution to the problem could include separate consideration of the old, discarded, replaced and the new vehicles and their relative energy intensity levels. In such settings, the energy efficiency improvement of new vehicles replacing the old ones can be applied to the appropriate stock of vehicles.

The possible solutions (which should be further analysed) may be:

a. To create a database (e.g. based on a survey) of all vehicles by type and year of production with their energy intensity levels, while also the reference of an average replaced vehicle in a given year (as the stock of vehicles is constantly evolving over time). This would, however, require an intensive data collection at the national level (similar to databases and surveys that were done in Slovakia in the Appliances sector).[12] However, as such data is unlikely to be available from the official statistical sources, this approach would be classified as a bottom-up method.
b. Another possibility may be to change the current vehicle-based indicator M5 (toe/car equivalent) to an activity-based indicator that would account for the average energy efficiency improvement of the provision of services by the whole fleet of vehicles (such as toe/person-km travelled for personal transport or toe/tonne-km of goods transported for freight transport; similarly as it is done in M6, M6-1 and M6-2 for rail transport, as well as M7 for inland waterways). This way the energy efficiency improvement would be bound to the activity/service provided by the whole fleet of the subsector of transport and not to a vehicle as such. By doing so, one may be also able to better compare the energy intensity of different modes of transportation (i.e. different modes of road transport as well as other modes of transportation in general), which could give a clearer picture of energy intensity in the Transport sector (and the shifts between different modes of transport).

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[11] Car equivalent is calculated according to EC (2010) as following: 1 truck or light vehicle = 4 cars equivalent; 1 bus = 15 car equivalent; 1 motorcycle = 0.15 car equivalent.

[12] The energy savings in Appliances sector in Slovakia are calculated based on the surveys and databases (Envidom/CECED 2011) of newly sold appliances and the discarded appliances each year. First, the energy savings are calculated for the old appliances replaced by the newly bought appliances. Second, from these energy savings, the energy consumption of newly bought appliances (that were not replacing any old appliances) is subtracted (MoE SR 2011, 2014, 2017).

For comparison, further mandatory indicators for Transport sector are presented. While M6 indicates energy intensity of rail transport (see E.2), M7 calculates energy intensity of inland waterways transport (see E.3). As compared to M5, these indicators better depict energy intensity as they are activity-based and not vehicle-based.

Table 4: TD calculation of energy savings for rail and inland waterways transport

E2. Calculation of energy savings in rail transport (M6)	**E.3 Calculation of energy savings in inland waterways transport (M7)**
$ES_t^R = \left(\frac{E_{2007}^R}{T_{2007}^R} - \frac{E_t^R}{T_t^R}\right) * T_t^R$ (E.2) Where: ES_t^R- energy savings of rail transport in year t (goe) E_{2007}^R, E_t^R - energy consumption of rail transport in 2007 and in year t (goe) T_{2007}^R, T_t^R - total rail traffic in tonne-km in 2007 and in year t (t-km)	$ES_t^W = \left(\frac{E_{2007}^W}{T_{2007}^W} - \frac{E_t^W}{T_t^W}\right) * T_t^W$ (E.3) Where: ES_t^W- energy savings of inland waterways transport in year t (koe) E_{2007}^W, E_t^W- energy consumption of inland waterways transport in 2007 and in year t (koe) T_{2007}^W, T_t^W - total inland waterways traffic in tonne-km in 2007 and in year t (t-km)

Source: EC (2010)

Note, that even using activity-based indicators does not prevent the formulas from being influenced by stochastic changes, such as economic crisis or other random events and behaviours (such as economic crisis in 2009).

4. Conclusions and discussion

Due to the above-mentioned problems with TD indicators in the transport sector, which lead to unrealistically high energy savings in Slovakia in 2008-2009, the TD indicators as recommended by EC (2010) proved unsuitable for evaluation of the energy efficiency measures. This article summarized the results of the TD calculations, which were prepared for 2NEEAP, and which show the inconsistences for all sectors across different base periods as well as in comparison with the results of the BU approach. The paper focuses on the transport sector as the main source of these inconsistences. Nevertheless, there might be other issues in the calculation methods and formulas, which contribute to such inconsistent results. Further methodological developments would be necessary, if such indicators were to be one of the tools to evaluate energy efficiency measures or even fulfilment of energy efficiency targets by member states.

Due to the above-mentioned challenges encountered by using TD approach, as well as due to the EC's request to increase the share of energy savings calculated through the BU approach on the overall evaluated target, the Slovak Republic used solely the BU approach based on individual projects for evaluation of energy efficiency measures in the consequent action plans and annual reports (such as 3NEEAP, 4NEEAP and all the annual reports). For instance, in 3NEEAP (MoE SR 2014), the share of energy savings collected through the BU approach on the total 3-year target (for 2011 - 2013) increased from 39% in 2NEEAP to 81% of the [3-year] energy savings target in 3NEEAP (MoE SR 2014). The 4NEEAP reported that the 2016 [9-year] (indicative) target under the Directive 2006/32/EC was fulfilled by 93%, and all energy savings were solely evaluated through BU method (MoE SR 2017). Fulfilment of the target under Article 7 of Directive 2012/27/EU is evaluated also fully through the BU approach and varies year by year, mainly depending on the finalisation of the projects funded from the European and Investment Structural Funds (ESIF). The annual report for year 2019 (MoE SR 2020) reported that the target under the Article 7 of Directive 2012/27/EU (both annual and cumulative) was fulfilled in 2019 and the report predicts fulfilment of the 2020 target as well. All reported energy savings are based on the BU approach.

In general, evaluation of the energy efficiency measures has gradually evolved from very labour-intensive and Excel-based and yet understaffed in 2011-2014, to a more systematic practice after this period. In 2016 preparation of the NEEAPs and annual reports was delegated to the Slovak Innovation and Energy Agency (SIEA), which is also an administrator of the Monitoring System of Energy Efficiency (MSEE). While SIEA was made responsible for data collection, monitoring, evaluating and preparation of draft reporting documents under the Directive 2012/27/EU as amended, the MoE SR has continued its role as the main coordinator of the preparation of the final draft, the leader of the formal negotiations with the relevant ministries and other institutions, and the coordinator of the formal process of submission of the final draft for the approval of the Slovak Government and its submission to the European Commission. Since 2011 the MSEE has developed from a database of certain types of energy use data (especially in buildings) to one that has been gradually extended to help collection of the data for the EU energy efficiency reporting requirements. For instance, MSEE started to systematically gather data for evaluation of additional financial mechanisms (e.g. renovation of multi-family buildings and single-family houses under the State Fund for Building Renovation, renovation of public buildings financed from the Environmental Fund and Operational Program Quality of Environment (2014-2020), renovation of central governmental buildings under Article 5 of Directive 2012/27/EU). Other features have been included as well over time, as to make the data collection more efficient and systematic.

Although the EC recommended to extend the number of measures evaluated by the BU approach, some measures with a cross-sectoral impact cannot be assessed individually through projects, and the TD approach shall be applied. This includes e.g. energy and CO_2 taxes and other fiscal instruments under Art. 7(9) of Directive 2012/27/EU (which cannot be assigned to a particular project). Directive 2012/27/EU (as amended by Directive 2018/2002/EU; EU (2018a)) prescribes a set of calculation methods for evaluation of energy efficiency measures (Annex V), where most of them have BU character, except for taxation related policy measures or other measures (such as fiscal incentives, payment to a fund) and measures focusing on changing consumer behaviour.[13] Although several MSs notified energy efficiency measures in transport sector,[14] only 3% of the total energy savings notified by MSs are from this sector (Rosenow et al. 2015). One of the reasons for this may be that the evaluation of measures in this sector is problematic (Labanca and Bertoldi 2016). For transport measures (such as tax rebates, fuel taxes, modal shift, mobility reduction etc.), it is often difficult to assess that the resulting energy savings in the sector was aimed primarily at energy efficiency, and how to adjust the calculations for other (e.g. economic) factors, that have an impact on the resulting energy savings in the sector (Labanca and Bertoldi 2016). This is in line with the results of the analysis in this article and implies that, although TD methods can in principle be used for evaluation of energy efficiency measures in the transport sector, it is hardly possible to estimate the net savings just by the simple TD indicators recommended in EC (2010). Rather, further corrections regarding other factors impacting energy savings, estimation of rebound and substitution effects etc. (Labanca and Bertoldi 2016) shall be incorporated in the calculations. Nevertheless, the TD indicators in their current form based on EC (2010) are a valuable additional tool for

[13] In case of taxation measures, the calculation method depends on the type of such measures (e.g. TD methods can be used to evaluate the energy savings of cross-sectoral tax measures, while BU methods can be used for tax rebates on specific technologies (Labanca and Bertoldi 2016)). For instance, in Sweden (energy taxes have been in place from 1950s and carbon tax from 1992) dynamic simulation models are used to evaluate impact of energy and CO_2 taxes (Labanca and Bertoldi 2016). Most of their impact is assumed to be in the household and transport sectors (Labanca and Bertoldi 2016).

[14] MSs, which notified measures in transport sector: Austria, Croatia, Finland, Germany, Greece, Ireland, Latvia, Malta, The Netherlands, Portugal, Slovakia (Rosenow et al. 2015).

evaluation and explanation of trends in energy consumption over time. For this purpose, they are also gathered in the Odyssee database, where, however, these are not used for calculation of energy savings.

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Annex

Table 1: Formulas for calculation of energy savings through TD indicators (M1-M8)

ID	Indicator name	Unit	Formula
M1	Non-electricity energy consumption of households in toe per dwelling adjusted for climatic conditions	toe/dwelling	$\left[\left(\frac{E_{2007}^{H_{NON\_EL}}}{D_{2007}} * \frac{MDD_{25}^{Heating}}{ADD_{2007}^{Heating}}\right) - \left(\frac{E_t^{H_{NON\_EL}}}{D_t} * \frac{MDD_{25}^{Heating}}{ADD_t^{Heating}}\right)\right] * D_t$ $E_t^{H_{NE\_EL}}$ - Non-electricity energy consumption of households in year t $MDD_{25}^{Heating}$- Mean heating degree days over the last 25 years $ADD_t^{Heating}$- Actual heating degree days in year t D_t- Number of permanently occupied dwellings in year t
M2	Electricity consumption of households in kWh per dwelling	kWh/dwelling	$\left(\frac{E_{2007}^{H_{EL}}}{D_{2007}} - \frac{E_t^{H_{EL}}}{D_t}\right) * D_t$ $E_t^{H_{EL}}$ - Electricity consumption of households in year t
M3	Non-electricity energy consumption of the service sector in toe per employee in full-time equivalent adjusted for climatic conditions	toe/FT employee	$\left[\left(\frac{E_{2007}^{S_{NON\_EL}}}{em_{2007}^{S_{fte}}} * \frac{MDD_{25}^{Heating}}{ADD_{2007}^{Heating}}\right) - \left(\frac{E_t^{S_{NON\_EL}}}{em_t^{S_{fte}}} * \frac{MDD_{25}^{Heating}}{ADD_t^{Heating}}\right)\right] * em_t^{S_{fte}}$ $E_t^{S_{NE\_EL}}$ - Non-electricity energy consumption of the service sector in year t $em_t^{S_{fte}}$- Total number of employees in the service sector (in full-time equivalent) in year t
M4	Electricity consumption of the service sector in kWh per employee in full-time equivalent	kWh/FT employee	$\left(\frac{E_{2007}^{S_{EL}}}{em_{2007}^{S_{fte}}} - \frac{E_t^{S_{EL}}}{em_t^{S_{fte}}}\right) * em_t^{S_{fte}}$ $E_t^{S_{EL}}$- Total electricity consumption of the service sector in year t
M5	Energy consumption of road vehicles in toe per car equivalent	toe/car-eq.	$\left(\frac{E_{2007}^{RV}}{S_{2007}^{RV^{CAeq}}} - \frac{E_t^{RV}}{S_t^{RV^{CAeq}}}\right) * S_t^{RV^{CAeq}}$ E_t^{RV}- Energy consumption of road vehicles (cars, trucks and light vehicles, motorcycles, buses) in year t $S_t^{RV^{CAeq}}$ – Stock of road vehicles in car equivalent in year t **Cars equivalent:** 1 truck or light vehicle = 4 cars equivalent 1 bus = 15 car equivalent 1 motorcycle = 0.15 car equivalent
M6	Energy consumption of rail transport in grams of oil equivalent (goe) per tonne-km	goe/tkm	$\left(\frac{E_{2007}^{R}}{T_{2007}^{R}} - \frac{E_t^{R}}{T_t^{R}}\right) * T_t^{R}$ E_t^{R}- Energy consumption of rail transport in year t T_t^{R} - Total rail traffic in tonne-km in year t
M7	Energy consumption of inland waterways transport in koe per tonne-km	koe/tkm	$\left(\frac{E_{2007}^{W}}{T_{2007}^{W}} - \frac{E_t^{W}}{T_t^{W}}\right) * T_t^{W}$ E_t^{W}- Energy consumption of inland waterways transport in year t T_t^{W}- Total inland waterways traffic in tonne-km in year t
M8	Energy consumption of industrial subsectors per unit of value added in real terms (M8-1 to M8-9 for different industries)	goe/EUR	$\left(\frac{E_{2007}^{I^x}}{VA^x{}_{2007}} - \frac{E_t^{I^x}}{VA_t^{I^x}}\right) * VA_t^{I^x} * K_{2007}^{I^x}$ $E_t^{I^x}$- Energy consumption of industrial sub-sector x in year t $VA_t^{I^x}$- Value added in real terms of industrial sub-sector x in year t $K_{2007}^{I^x}$ - Share of energy consumption of industrial sub-sector x falling under the scope of Directive 2006/32/EC in 2007

Source: Based on EC (2010)

Note: (1) The above-mentioned formulas are developed for the base year 2007, which is recommended by EC (2001). Note, that in Slovakia also other calculation periods were used for TD calculations.
(2) Note, that the formulas in M1, M3 were corrected for a minor mistake (missing elements in the formulas).