

# Effectiveness of financial incentives to energy efficiency- case: Croatia

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## Abstract

The Croatian Environmental Protection and Energy Efficiency Fund was established by the law in 2003 as an extra-budgetary institution, funded by “polluter pays” principle through collection of various environmental charges (for emissions of pollutants in atmosphere, motor vehicles, waste). It has become the underlying mechanism for gathering money and investing it in projects and programmes related to environmental protection, waste management, renewable energy sources and energy efficiency. Since its establishment, the Fund has co-financed through subsidies, loans and grants more than 800 energy efficiency projects. The effects, in terms of energy savings, of this co-financing scheme were evaluated using bottom-up methods. The paper presents the process of *ex-post* savings evaluation, methods used and results obtained. The costs of energy savings (€ per kWh saved) from the government point of view per measures and end-use sectors are shown. The calculation results show that the highest energy savings are achieved in the industry sector and at the same time these savings are achieved at the lowest costs from the government point of view. Measures in the public buildings, dominantly those related to the refurbishment of technical building systems (excluding building envelope) are ranked second best according to the calculated costs of saved energy, followed by eco-driving activities in the transport sector. However, although these results provide good insight in the effectiveness of public spending, the future choice of measures, which will be given priority in awarding the financial support, should not be based on government cost figures only – benefits in terms of improved living and working conditions and economic development should be accounted as well. Hence, the future work of the authors will focus on benefits and costs evaluation of energy efficiency improvements from the whole society point of view.

## Introduction

Energy efficiency is recognized as cost-effective and the most readily available tool for tackling climate change and ensuring secure energy supply. But, the desired effects in terms of achieved energy savings are still far from being reached, despite huge efforts put in preparation of sound energy efficiency policies. There are number of reasons behind this policy failure and most of them are in theory categorized as barriers causing the energy efficiency gap. The ‘gap’ has been defined as the paradox of the gradual diffusion of apparently cost-effective energy efficiency technologies (Jaffe & Stavins 1994). In simple terms, investment in energy efficiency is consistently observed to fall short of levels which informed analysts assure policy makers is both possible and economical (Eyre 1997).

One of the most common barriers analyzed in the literature and reported by various stakeholders, who are expected to undertake energy efficiency improvement (EEI) activities is the lack of access to capital. Low credit worthiness of companies/individuals makes it difficult or impossible to invest in energy efficiency. The solution to this problem is often found in establishment of funds which, by offering financial incentives to EEI measures, are initial driver of demand for energy efficient solutions. The importance of energy efficiency funds is also recognised by the Directive 2006/32/EC on energy end-use efficiency and energy services (ESD). The ESD encourages the use of funds for the development of the market for energy services and for

subsidising EEI programs and measures related to energy audits, implementation of EEI measures and metering and billing (EC 2006). The creation of such funds can constitute an appropriate tool for the provision of non-discriminatory start-up funding in developing and transforming markets towards higher efficiency.

These kinds of funds have proven themselves to be very effective in a number of Central and Eastern European (CEE) countries, i.e. countries with economies in transition. The main purpose of these funds is to provide financial and institutional support for investments in environmental protection, including energy efficiency, and in that way to more efficiently pursue the environmental and energy policy objectives. First such dedicated fund in CEE was Polish National fund for environmental protection and water management, established in 1989. It was followed by Czech and Slovak state funds for environmental protection established in 1991, and afterwards Slovenia, Hungary, Bulgaria and Romania established similar funds from which energy efficiency activities were co-financed.

The Environmental Protection and Energy Efficiency Fund<sup>1</sup> in Croatia has been established by the law in 2003 (Fund 2003). The main feature of the Fund is that it is an extra-budgetary institution, funded from various environmental charges. These charges are:

- the charge on energy production and industrial facilities for emissions into the environment (sulphur dioxide SO<sub>2</sub>, nitrogen dioxide NO<sub>2</sub> and carbon dioxide CO<sub>2</sub>);
- the charge for the environment use (charges for buildings or structures whose construction has to be subjected to the environmental impact assessment, which are prescribed by the special regulation and include energy production and storage plants, industrial, waste treatment and water management facilities, oil and gas pipelines, roads and railways, constructions for livestock farming, golf courses);
- the charges for burdening the environment with waste (charge for communal and/or no hazardous technological (industrial) waste and charge for hazardous waste);
- special environmental charges for motor vehicles (paid by all owners of motor vehicles, while performing technical inspection of a vehicle);

Apart from environmental charges, the Fund can also provide financing from international bilateral and multilateral collaboration, donations and incomes from managing own free financial assets.

Collected financial means can be allocated to the local (regional) authorities and to legal and physical entities. Financial means are allocated to the users in one of the following ways:

- Interest-free loans (grants) with repayment period of five years, with possibility for two years delay. Maximal amount that can be awarded for the project is approx. 227.000 €;
- Subventions on loan interests up to 2% of agreed interest can be approved, and the interest rate for the final user cannot exceed 4%;
- Financial aid is allocated only to local (regional) self-governments;
- Donations are usually provided from agreements with international financing institution.

It is very important to emphasise that the users of the Fund's financial support are obliged to invest their own financial means in the proposed project. The Fund can ensure up to 40% of the total investment. For regional and local self-governments in the special care areas (heavily stroked by the war) this amount can be equal up to 80% and for undeveloped areas (islands, mountain and rural areas with the average income per capita less than 65% of Croatian average) up to 60%. This way, a free rider effect is avoided.

The total amount of financial means is distributed in two types of projects: environmental protection projects and energy efficiency projects including the use of renewable energy sources (RES). Until the end of 2010 the Fund has co-financed 886 energy efficiency projects with total amount of approximately 27.7 million €.

Within the process of 2<sup>nd</sup> National Energy Efficiency Action Plan (NEEAP) development, the energy savings achieved from these projects were evaluated. The authors of this paper were the part

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<sup>1</sup> More information about the Fund can be found at: <http://www.fzoeu.hr/hrv/index.asp>

of the consortium preparing the 2<sup>nd</sup> NEEAP<sup>2</sup> and in particular engaged and responsible for calculation of energy savings resulting from the projects co-financed by the Fund. This task comprised two main activities: 1) definition of calculation methods and 2) application of these methods to the projects co-financed by the Fund. The first activity was performed within the project “Capacity building for Monitoring, Verification and Evaluation (M&V&E) of the Energy Efficiency policy in SEE countries in terms of the EU accession process”<sup>3</sup> which has been a part of regular activities of the Energy Community’s Energy Efficiency Task Force<sup>4</sup>.

The paper briefly presents the methods used for calculation of energy savings and uses the calculation results to evaluate the costs of saved energy from the government’s perspective, i.e. only in relation to the financial support given by the Fund.

## **Evaluation of energy savings – calculation methodology and lessons earned**

### **Approach taken in the definition of the calculation methodology**

The EEI projects co-financed by the Fund are classified in the following categories:

1. Energy efficiency national program and energy audits,
2. Use of renewable energy sources,
3. Sustainable buildings,
4. Clean transport,
5. Education, research and development (R&D) studies,
6. Other energy efficiency projects and programs.

Each category is divided in several typical project types, i.e. typical EEI measures and related to energy-end use sector in which they were implemented. Only first four categories of measures will be further considered in this paper. The latest two categories are soft measures that are very important for general public awareness raising, information availability and R&D in the field of energy efficiency in Croatia. But, these measures do not deliver immediate and measurable energy savings; hence will not be discussed hereafter.

Unfortunately, the system for evaluation of energy savings, i.e. measurement and verification (M&V) methods was not established prior to the implementation of projects co-financed by the Fund, so in the early 2011 the level of achieved energy savings from these projects was not known.

The solution was to develop M&V methods which will enable calculation of savings based on data available from project documentation. Obviously, bottom-up (BU) approach needed to be applied here. The work on the establishment of the methodology was performed as a part of the above mentioned regional project (Bukarica, Borković et al. 2011).

The starting point in developing M&V methods was recommendations from the European Commission (EC 2010). The recommended BU calculation model set out in the Commission’s recommendations consists of guiding principles, a set of formulas, baselines and default values for measuring final energy savings achieved through the implementation of energy efficiency improvement measures or programmes in residential (households) and tertiary (public and private organisations in the service sector) buildings, including equipment and appliances used in buildings.

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<sup>2</sup> The 2<sup>nd</sup> NEEAP was prepared for the Ministry of Economy by the expert consortium comprising University of Zagreb Faculty of Electrical Engineering and Computing and Energy Institute Hrvoje Požar.

<sup>3</sup> The project M&V&E is implemented in all Western Balkans countries and is officially a part of the Energy Community’s Energy Efficiency Task Force work program. It is implemented with the financial support of Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), Open Regional Fund for Energy Efficiency. More information on the project and its achievements can be found at the Community’s web site: [http://www.energy-community.org/portal/page/portal/ENC\\_HOME/INST\\_AND\\_MEETINGS?event\\_reg.category=E12825](http://www.energy-community.org/portal/page/portal/ENC_HOME/INST_AND_MEETINGS?event_reg.category=E12825)

<sup>4</sup> More information on Energy Community are available at: [http://www.energy-community.org/portal/page/portal/ENC\\_HOME/ENERGY\\_COMMUNITY/Facts\\_and\\_Figures](http://www.energy-community.org/portal/page/portal/ENC_HOME/ENERGY_COMMUNITY/Facts_and_Figures)

There are 11 typical building energy efficiency improvement measures identified and formulas for calculation of resulting energy savings recommended.

For recommended formulas to be applicable, default (baseline) values to be used within equations needed to be defined. Default values needed to be based on the stock or market averages, which require analysis of previous regulations (e.g. building codes), thorough knowledge of situation in the existing building stock and availability of market sales figures on equipment and systems sold (for efficiency of e.g. heating systems or unit consumption of households appliances). Because of the lack of these data, which was a huge problem in Croatia, the expert estimates, determined based on the wide consultation process with relevant stakeholders, were used. Additionally, best practice examples in BU methods from other countries were used, e.g. Austrian BU based monitoring database<sup>5</sup> and recommendations of the project “Evaluation and Monitoring for the EU Directive on Energy End-Use Efficiency and Energy Services”<sup>6</sup> (Wuppertal Inst. 2009).

However, there were also some measures, to which significant part of the Fund’s support was given that were not covered by the EC recommendations. For these measures own national methods were developed. Among them are energy audits, which were probably the most utilised measure in the previous three year period and heavily supported by the Fund. Another such measure is replacement of trucks and buses with new once complying with the Euro 5 standard<sup>7</sup>.

The classification of EEI measures and information about the BU method used for calculation of energy savings is given in Table 1.

### **Case example of method development and savings calculations – refurbishment of buildings**

The process of default values determination and energy savings calculations will be briefly discussed for the measures related to the heating supply equipment replacement in buildings and complex refurbishments of buildings (measures 2 and 8 in Table 1). The equations provided require input data related to the overall efficiency of the heating system ( $\eta$ ) and specific heating demand of the building (SHD), both before and after implementation of the EEI measure. In the ideal situation, these data will be known for every individual building in which refurbishment measure is applied. In reality, data provided by the beneficiaries of the Fund’s support were often incomplete. The default values were therefore used in the lack of project specific data. Usually, at least approximately, the period when the analysed building was constructed was known. Periods of construction are chosen according to the building codes enforced in those periods. Values for SHD prescribed by that codes are determined as default values for  $SHD_{init}$ . There are five periods defined (until 1940, 1940-1970, 1970-1987, 1987-2006, 2006-today), but also average SHD value for the building stock constructed before the newest building code (2006) was determined based on the share of buildings from each period in the total building stock (share is determined based on square meters, not number of buildings). It has to be, though, pointed out that average value was only exceptionally used. SHD after the refurbishment should be preferably the real data for the analysed building determined after the implementation of a measure through process of energy certification. However, many buildings were actually refurbished before the obligation for certification was imposed; hence data for  $SHD_{new}$  were also often unknown. Default values for this factor were determined based on the values prescribed by the latest building code. While determining default values in both cases ‘before’ and

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<sup>5</sup> Information about Austrian monitoring system are available at: <http://www.monitoringstelle.at/>

<sup>6</sup> Information and documents from EMEES project are available at: [http://www.evaluate-energy-savings.eu/emeees/en/evaluation\\_tools/index.html](http://www.evaluate-energy-savings.eu/emeees/en/evaluation_tools/index.html)

<sup>7</sup> Euro 5 standard refers to the common requirements for emissions from motor vehicles introduced by the European Commission. The regulation applies to passenger and commercial vehicles with a reference mass not exceeding 2 610 kg and covers a wide range of pollutant emissions: carbon monoxide (CO), non-methane hydrocarbons and total hydrocarbons, nitrogen oxides (NO<sub>x</sub>) and particulates (PM). More information is available at: [http://europa.eu/legislation\\_summaries/environment/air\\_pollution/128186\\_en.htm](http://europa.eu/legislation_summaries/environment/air_pollution/128186_en.htm)

‘after’, the distinction was made between residential and service sector buildings. Finer distinction, e.g. according to the type of service building, was not possible.

Default values for efficiency of heating systems were determined from recommendations of the EMEES project<sup>8</sup>. This was justified by the fact that Croatia has applied the EU eco-design regulation related to boilers and heating equipment is dominantly imported from the EU; hence the stock and market situation is similar as in the EU. Default values are provided for efficiency of system components (boiler, distribution system and heat emitter), while the total system efficiency is calculated as a product of component efficiencies.  $\eta_{init}$  (‘before’ situation) can be defined as stock baseline (aimed to calculate all savings) or market inefficient baseline (aimed to calculate additional savings or savings arising from new installation). In cases of refurbishments, we have always calculated all savings using the stock baseline value or, if available, the real project data.  $\eta_{new}$  is defined for the best available solution in the market.

In order to facilitate calculation, Excel based tool was prepared. It enables selection of project characteristics from a drop-down list (e.g. period of building construction, components of heating system replaced) based on which an appropriate default value was automatically selected as an input in calculation formula. There was also a possibility in this tool to choose the option ‘project specific data’, which enables the input of actual values related to the project. Total energy savings per building are calculated by multiplying calculated unitary final energy savings (UFES) as explained above and mathematically defined in Table 1 with total surface of the building in squared meters.

## Lessons learned and future activities

In evaluation of the projects co-financed by the Fund, default values needed to be used in many cases due to lack of or inadequate data delivered by the users after the finalisation of the project. Namely, as the Fund is primarily financial institution, much attention was given to the conformity with financial rules, but the requirements to deliver data about achieved savings or at least to provide data which would enable *ex-post* estimation of the savings were insufficient. It turned out that the users of the Fund’s support from business sector (industry and commercial services) were among those who have provided the best data on achieved savings based on own metering of energy consumption before and after the implementation of EEI measure. On contrary, the availability of data from the public sector users was very limited, which is certainly connected to the level of knowledge and care about energy efficiency in this sector. Anyhow, the process of methodology development and application was very valuable experience. It was very time and resource demanding. But on the other hand, it was important learning process, from which significant improvements in operation of the Fund were initiated, especially:

- clear requirements for users related to the data delivery both before and after the implementation of energy efficiency project are prescribed;
- establishment of system for continuous evaluation of energy and emission savings resulting from co-financed projects;
- establishment of IT support for data delivery from users and calculation of savings.

It is expected that these changes will ensure regular, at least annual, evaluation and reporting of achieved savings and enable advancement of principles for allocation of funding to the users to achieve optimal cost-benefit ratios.

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<sup>8</sup> Source: [http://www.evaluate-energy-savings.eu/emees/downloads/EMEEES\\_WP42\\_Method\\_4\\_resboilers\\_080609.pdf](http://www.evaluate-energy-savings.eu/emees/downloads/EMEEES_WP42_Method_4_resboilers_080609.pdf)

**Table 1.** Overview of typical EEI measures co-financed by the Fund with related M&V methods used for their evaluation

Nr.	EEI measure type	M&V method used for evaluation of unitary final energy savings (UFES)	EC recommended /national	Default values	Data sources	Lifetime (years)				
<b>National energy efficiency programs and energy audits</b>										
1.	Public lighting	$UFES = \frac{P_{old} - P_{new} \cdot r}{1000} \cdot n_h$ <p> <math>P_{old}</math> – installed power before replacement [W]  <math>P_{new}</math> – installed power after replacement [W]  <math>r</math> – factor related to the control strategy applied  <math>n_h</math> – number of operating hours                 </p>	national	$n_h = 4.100$ h <table border="1"> <tr> <td><math>P_{old} = 500</math> W (mercury light bulb 400 W)</td> <td><math>P_{old} = 312.5</math> W (mercury light bulb 250 W)</td> </tr> <tr> <td><math>P_{new} = 297.5</math> W</td> <td><math>P_{new} = 178.5</math> W</td> </tr> </table> <p> <math>r = 1 \dots</math> no night setback  <math>r = 0.72 \dots 50\%</math> capacity reduction between 11 p.m. and 6 a.m.  <math>r = 0.65 \dots 100\%</math> capacity reduction between 1 p.m. and 5 a.m.                 </p>	$P_{old} = 500$ W (mercury light bulb 400 W)	$P_{old} = 312.5$ W (mercury light bulb 250 W)	$P_{new} = 297.5$ W	$P_{new} = 178.5$ W	National estimation based on energy audits	15
$P_{old} = 500$ W (mercury light bulb 400 W)	$P_{old} = 312.5$ W (mercury light bulb 250 W)									
$P_{new} = 297.5$ W	$P_{new} = 178.5$ W									
2.	LPG (liquefied petrol gas) and solar energy for heating on islands	LPG: $UFES = \left( \frac{1}{\eta_{init}} - \frac{1}{\eta_{new}} \right) \cdot (SHD + SWD)$ <p>Solar:  <math display="block">UFES = \frac{USAVE}{\eta_{init}}</math> <math>\eta_{init}</math> – energy efficiency of the old heating system  <math>\eta_{new}</math> – energy efficiency of the new heating system                      SHD – specific heating demand [kWh/m<sup>2</sup>/yr]                      SWD – specific hot water demand [kWh/m<sup>2</sup>/yr]                      USAVE – average heat production per m<sup>2</sup> of solar panel [kWh/m<sup>2</sup>]                 </p>	EC recommended (combination of three methods: replacement of heating supply equipment in buildings + installation or replacement of water heating installations or solar water heating)	$\eta_{init} = 0,595$ (stock baseline) $\eta_{init} = 0,717$ (market inefficient baseline)	EMEEES project recommendations	20				
				$\eta_{new} = 0,848$	National regulation					
				SHD – different values according to the period of construction (five periods are defined) and type of building (residential or non-residential) Average for existing buildings (SHD <sub>init</sub> ) 180 for residential; 190 kWh/m <sup>2</sup> /yr for service buildings Average for new buildings (SHD <sub>new</sub> ) 85 for residential, 107.5 kWh/m <sup>2</sup> /yr for service buildings	Expert analysis, normative for water consumption, regulation and modelling					
				Residential up to 3 apartments SWD = 12,5 kWh/m <sup>2</sup> /yr Residential – multi apartment SWD = 16 kWh/m <sup>2</sup> /yr Services – tourism and catering SWD = 3.5 kWh/m <sup>2</sup> /yr Services – other SWD = 0.5 kWh/m <sup>2</sup> /yr						
		USAVE – continental area: 550 kWh/m <sup>2</sup> (flat) 660 kWh/m <sup>2</sup> (vacuum) USAVE – coastal area: 700 kWh/m <sup>2</sup> (flat) 840 kWh/m <sup>2</sup> (vacuum)	National values based on solar irradiation data							
3.	Energy	$UFES = DV \cdot TSP$	national	DV=0.05	Estimation based on	5				

<sup>9</sup> Source – Energieeffizienz Monitoringstelle: <http://www.monitoringstelle.at/Lighting.507.0.html>

	audits	DV - implemented percentage of total saving potential identified in energy audit TSP - total saving potential identified in energy audit			contacts with companies which performed audits	
4.	Individual heat metering	$UFES = E_{old} - E_{new}$ $E_{old}$ – energy consumption before implementation $E_{new}$ – energy consumption after implementation	national	No default values – only metering data for situation ‘before’ and ‘after’ are taken into account when calculating savings	Energy suppliers	5
5.	Other projects	$UFES = E_{old} - E_{new}$ $E_{old}$ – energy consumption before implementation $E_{new}$ – energy consumption after implementation	national	No default values (many different projects) – only metering data for situation ‘before’ and ‘after’ are taken into account when calculating savings	Energy consumers who implemented the measure	25
<b>Use of RES</b>						
6.	Solar thermal systems	$UFES = \frac{USAVE}{\eta_{init}}$	EC recommended	See measure nr. 2		20
7.	Heat pumps	$UFES = \left( \frac{1}{\eta_{init}} - \frac{1}{SPF} \right) \cdot (SHD + SWD - \Delta E_{other})$	national	SPF = 3 (air-water) SPF = 3.5 (water-water) SPF = 3.8 (ground-water) Other values – see measure nr.2	Research results from Germany <sup>10</sup>	15
8.	Sustainable buildings	$UFES = \frac{SHD_{init}}{\eta_{init}} - \frac{SHD_{new}}{\eta_{new}}$	EC recommended	See measure nr. 2		25
<b>Cleaner transport</b>						
9.	EURO5 program	$UFES = (FC_{old} \cdot f_{c\_old} - FC_{new} \cdot f_{c\_new}) \cdot d$ $FC_{old}$ – average consumption of old vehicle [l/100km] $FC_{new}$ – average consumption of new vehicle [l/100km] $f_{c\_old}$ – conversion factor l/100km in kWh/100km for old vehicle $f_{c\_new}$ – conversion factor l/100km in kWh/100km for new vehicle $d$ – average distance for vehicle type [km]	national	$FC_{old}$ – data for every specific vehicle $FC_{new}$ – data for every specific vehicle $f_{c\_old}$ & $f_{c\_new}$ defined for gasoline, diesel, liquefied petrol gas and compressed natural gas $d$ – defined for cars, buses, trucks and light duty vehicles (annual data)	Project specific data Annual energy report published by the Ministry of Economy ODYSSEE data base <sup>11</sup>	8
10.	Electric vehicles	$f_{c\_new}$ – conversion factor l/100km in kWh/100km for new vehicle $d$ – average distance for vehicle type [km]		$FC_{old} \cdot f_{c\_old} = 76 \text{ kWh}/100 \text{ km}$ (car equivalent) $FC_{old} \times f_{c\_old} = 3 \times FC_{new} \times f_{c\_new}$ (other vehicles)		
11.	Eco-driving	$UFES = E \cdot ER \cdot EC$ $E$ – % of drivers changing their behaviour) $ER$ – % of energy saved $EC$ – average annual energy consumption [kWh]	national	$E$ – depending on type of activity 10-67.5% $ER$ – depending on type of activity 3.8 – 7.5% $EC$ – depending on type of vehicles (cars 8.723 kWh; light duty vehicles 46.520 kWh, trucks and buses 120.720 kWh )	EMEEES project recommendations ODYSSEE data base	8

<sup>10</sup> Source of data was research done by the Fraunhofer ISE presented in various documents, all available on-line: [http://wp-effizienz.ise.fraunhofer.de/download/wp\\_effizienz\\_endbericht\\_langfassung.pdf](http://wp-effizienz.ise.fraunhofer.de/download/wp_effizienz_endbericht_langfassung.pdf);

[http://circa.europa.eu/Public/irc/dsis/chpwwg/library?l=/renewable\\_statistics\\_1/proposal\\_industry/pdf/\\_EN\\_1.0\\_&a=d](http://circa.europa.eu/Public/irc/dsis/chpwwg/library?l=/renewable_statistics_1/proposal_industry/pdf/_EN_1.0_&a=d)

<sup>11</sup> ODYSSEE data base available for registered users at: <http://www.odyssee-indicators.org/>

## Analysis of the results – energy savings achieved and related government costs

As theory determines, *ex-post* approach is applied after a certain time of the policy instrument implementation, effects of which should be evaluated to answer two key questions (Joosen & Harmelink 2006):

- What was the contribution of policy instrument in the realisation of policy targets (effectiveness of policy instruments)?
- What was the cost of policy instruments, and could targets have been reached against lower costs?

The Fund as such is an important policy instrument in Croatia. Effectiveness of its incentives to energy efficiency will be evaluated hereafter as well as costs of kWh saved from the government's perspective.

### Effectiveness of incentives – what is the contribution to the overall national indicative target?

The established methods described in the previous paragraph enabled *ex-post* evaluation of more than 800 projects falling in one of four above mentioned categories that were implemented since 2003 under the support of the Fund. According to the common interpretation of the ESD text, this is allowed under the ESD and referred to as 'early action measures'. To be able to determine whether savings are still 'alive' in 2010, for each type of measure the default lifetimes were determined. The shortest lifetime is for energy audits (five years) and eco-driving (effect of training activities is diminished by 10% every year), while for other technical measure lifetimes are in the range from 10 to 25 years. This led to the situation that energy savings from all analyzed projects were still valid for 2010. It is interesting to notice that early savings (before 2008) are equal to 446.32 TJ or more than 57% of total energy savings calculated by the end of 2010. One of the possible reasons for such high share of early savings might be in the different duration of the two periods. The other reason might lie in the sector distribution of early projects. Most of these early savings (90%) are achieved in the industry sector, and actually the most of the co-financed projects in the industry sector were implemented before 2008. 2008 was the year of the economic crises beginning, which might be the reason for fewer applications from the industry sector in the subsequent three-year period.

The results of calculation and distribution of savings per energy end-use sectors is given in Table 2. These results represent all (gross) energy savings resulting from the given financial support. There are several issues that are important in calculation of energy savings: free-rider effect, double-counting and multiplier effect. The free rider effect was not specifically treated in the calculation of savings – this issue is considered to be already addressed with the Fund's policy to provide up to 40% of total investment, and the rest needs to be secured by the beneficiary. As stipulated in the Annex IV of the ESD, double-counting should be avoided. When analyzing only projects co-financed by the Fund, there is no double counting possible as we are dealing with individual projects not related to each other. However, when calculating overall savings at national level, special care needed to be devoted to this issue. There were cases when one project received incentives from two parties, usually from the Fund and local authority; hence was reported twice. However, in the reporting requirements it was clearly asked to specify sources of financing, which enabled that the savings from these projects were accounted only once and attributed to only one party – the Fund. Finally, ESD also stipulates the necessity to evaluate multiplier effects of measures, i.e. their influence on the market. Although some multiplier effects have been noticed, especially in the public lighting systems, there was not enough data to quantify the magnitude of this effect.



**Table 2.** Annual energy savings achieved in 2010 through EEI projects co-financed by the Fund<sup>12</sup>

EEI measure type	Achieved energy savings in 2010 [TJ/yr]					Total savings [TJ/yr]
	Households	Public services	Commercial services	Industry	Transport	
<b>National energy efficiency programs and energy audits</b>						<b>686.44</b>
Public lighting		22.69				22.69
LPG and solar energy for heating on islands	0.51	1.39	1.62			3.52
Energy audits		4.74	2.47	28.16		35.36
Individual heat metering	10.08					10.08
Other projects		41.13	2.95	570.71		614.79
<b>Use of RES</b>						<b>3.61</b>
Solar thermal systems	2.32	0.76	0.17			3.25
Heat pumps	0.36					0.36
<b>Sustainable buildings</b>		5.63	2.91			<b>8.54</b>
<b>Cleaner transport</b>						<b>80.79</b>
EURO5 program					69.64	69.64
Electric vehicles					0.01	0.01
Eco-driving					11.14	11.14
<b>TOTAL SAVINGS [TJ/yr]</b>	13.27	76.34	10.12	598.87	80.79	<b>779.39</b>
<b>SHARE IN NATIONAL INTERMEDIATE INDICATIVE TARGET FOR 2010 [%]</b>						<b>11.83</b>
<b>SHARE IN NATIONAL INDICATIVE TARGET FOR 2016 [%]</b>						<b>3.94</b>

The financial incentives provided by the Fund delivered energy savings equal to approximately 12% of the desired amount at national level in the 2010, which was determined in the 1<sup>st</sup> NEEAP and equals 6.59 PJ. It has to be, however noted, that the Fund has financially supported also two huge capacity building projects in the public sector, through which energy management systems is introduced, and which have delivered significant savings as well amounting 540 TJ<sup>13</sup>. Within these projects large number of public buildings is equipped with the IT system for monitoring and analyzing energy consumption with historical data from year 2007. This enabled determination of resulting energy savings based on actually metered data. If these savings are taken into account, then it can be stated that the Fund has ensured 20% of intermediate target in 2010. Taking into account that the Fund is almost only source of financial incentives for energy efficiency in Croatia (commercial banks have just recently shown the interest for energy efficiency projects, while energy service market is still in its inception phase with only few successfully operating ESCOs; other state incentives or tax relieves do not exist and local authorities have provided incentives in limited number of cases), this is rather disappointing figure and improvements will be necessary to ensure the higher delivery of savings.

### Effectiveness of EEI measures – which measures delivered the largest energy savings?

The next question we would like to answer is: what type of EEI measures<sup>14</sup> are the most effective in terms of achieved energy savings? The answer is given in Figure 1 showing the contribution of different EEI measures to the overall energy savings achieved. Clearly, the type of

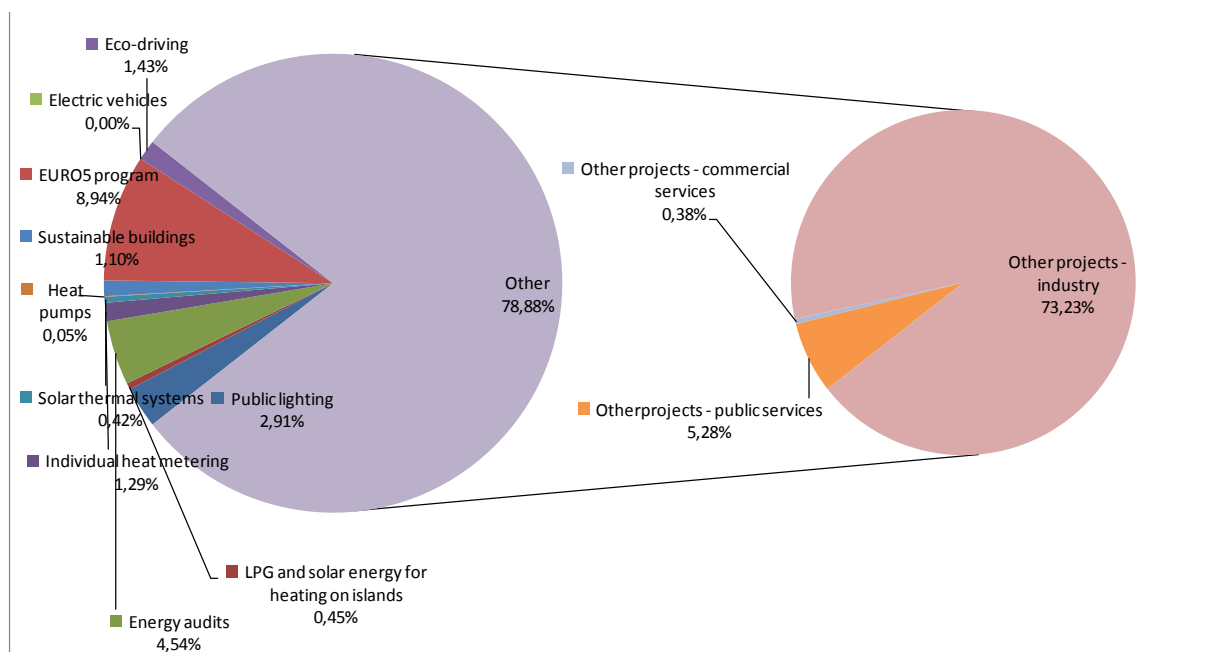
<sup>12</sup> All data are taken from the draft 2<sup>nd</sup> NEEAP for Croatia, calculated by the authors and officially reported by the Fund.

<sup>13</sup> Data taken from the draft 2<sup>nd</sup> NEEAP for Croatia, calculated by the UNDP (United Nations Development Programme) team implementing the projects on behalf of the Ministry of Economy.

<sup>14</sup> EEI measure is an expression used to denote certain type of EEI projects, i.e. a measure consists of a number of similar EEI projects.

EEI measures categorized under “other projects” delivers the largest savings and contributes with almost 80% to the overall savings achieved. Approximately 93% of these projects are implemented in the industry sector, which means that industrial projects themselves delivered almost 3/4 of total savings<sup>15</sup>. Second best ranked projects in term of energy savings are those from EURO5 program, i.e. replacement of trucks and buses, while third type of projects with the largest impact in terms of energy savings is “other projects in the public sector”. It is interesting to see what actual EEI projects are implemented under these categories. In industry, dominant were the projects related to the reconstruction or replacement of large steam industrial boilers to achieve better efficiency as well as reconstructions in the hot water or steam distribution systems. Similarly, other projects in the public sector were dominantly related to the reconstructions of boiler rooms including fuel switching from light fuel oil to natural gas in the buildings of public sector, mostly schools and hospitals. These projects did not include interventions in the building envelope.

Additionally, we have looked at the number of individual projects undertaken in every EEI measure category. This provides the insight about the size of the projects in relation to their energy savings. Figure 2 shows that there was relatively small number of projects in the industrial sector, only 3.35% of the total number of 886 projects. However, refereeing back to Figure 1, these 3.35% delivered 73.23% of savings. Similarly, refurbishment projects in the public sector constituted 2.15% of total number of co-financed projects and delivered 5.28% of overall energy savings. However, in this analysis it is justified to consider the EURO5 program as one project, although through it financial supports are awarded to more than 500 transport companies. If all projects under the EURO5 measure are considered as one project, than industrial projects make 10% of total number of projects, while public sector building refurbishment projects make 6%. Hence, it might be concluded that 16% of all co-financed projects have delivered almost 80%<sup>16</sup> of total saving. This can be considered as a good demonstration of the “80-20” rule<sup>17</sup>.

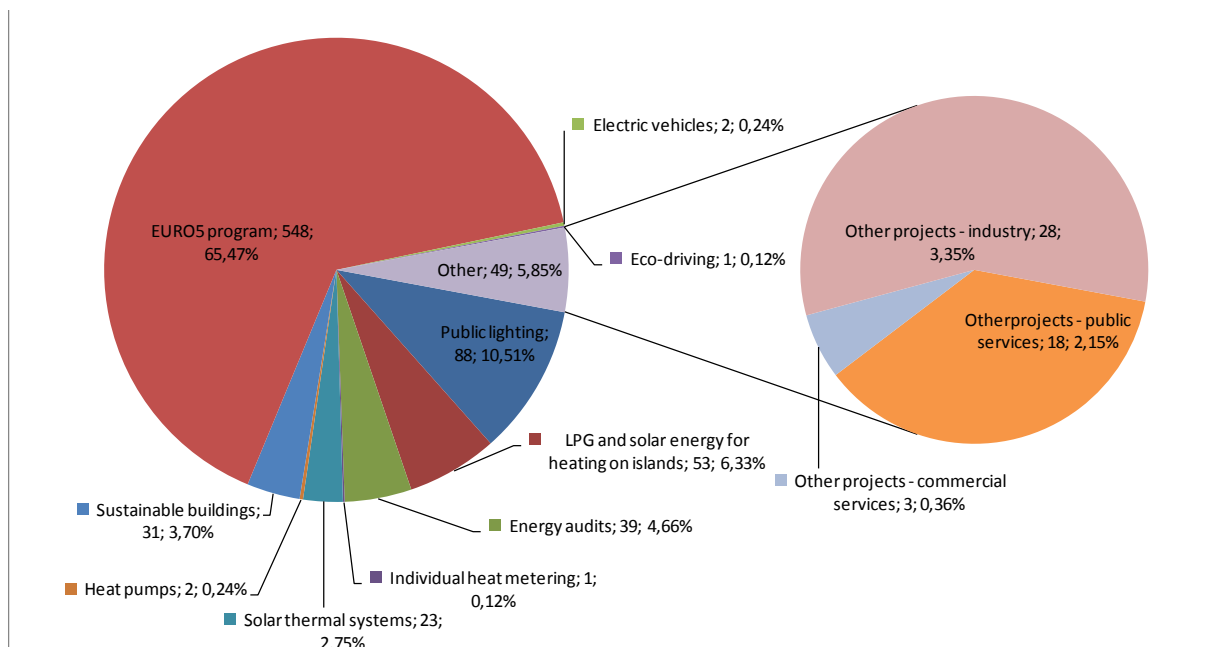


**Figure 1.** Contribution of various types of EEI measures to the overall energy savings achieved

<sup>15</sup> The statement is based on the given percentages, which multiplied (0.80x0.93) gives the result of 0.744 or almost 75%.

<sup>16</sup> 80% is an approximation of a sum of previously stated 73.23% savings from industrial projects and 5.28% from public building refurbishment projects.

<sup>17</sup> “80-20” rule or Pareto principle states that, for many events, roughly 80% of the effects come from roughly 20% of the causes.



**Figure 2.** Number of projects under various types of EEI measures supported by the Fund

### What is the price of a kWh saved?

Second question in the policy evaluation process is to determine the cost effectiveness of the policy instrument. Hereafter the cost of conserved energy associated only with the financial support provided from the Fund will be evaluated based on the following available data and assumptions:

- the total amount of money awarded from the Fund to various types of EEI measures is known and this data will be used to calculate the price of the conserved energy;
- the cost per kWh saved of the incentive is calculated as a ratio of annualized awarded financial support given by the Fund to a specific EEI measure and annual energy savings achieved by implementation of this measures – this provides estimation of public costs (the Government’s perspective) of kWh saved<sup>18</sup>;
- for determination of annualized costs the lifetime of EEI measures is used (see Table 1), i.e. the total expenditure is depreciated over the economic lifetime of the measure using a discount rate of 7%<sup>19</sup> - by depreciating the cost of incentive the fact is taken into account that the government is profiting several years from its once-only spending (AID-EE 2007).

The calculation formula used is based on standard calculation of levelized costs that is usually employed to compare energy efficiency with supply side resources (Friedrich et al. 2009):

$$c = \frac{a \cdot I}{E} = \frac{(1 + k)^t \cdot k}{(1 + k)^t - 1} \cdot \frac{I}{E}$$

where:

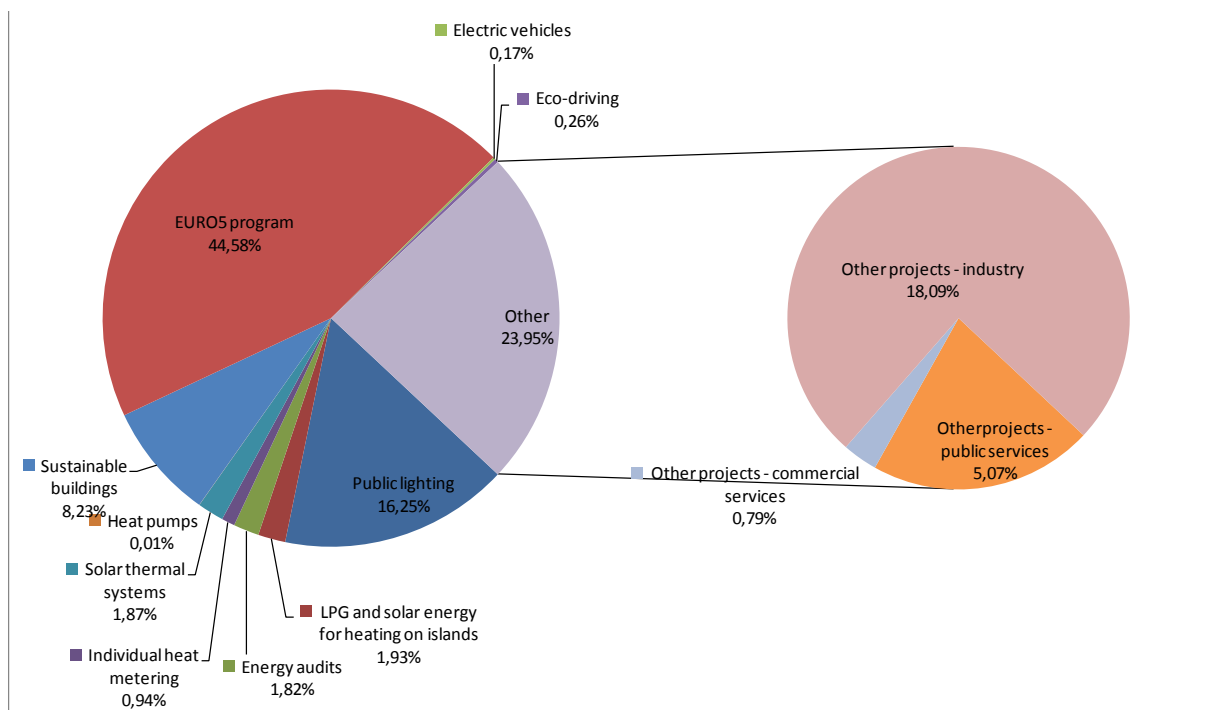
<sup>18</sup> Energy savings as represented in the previous sections are reported in TJ as this unit is used in the 1<sup>st</sup> and 2<sup>nd</sup> NEEAP. However, when determining costs of saved energy, kWh will be used. This will enable easier comparison of the results with current energy prices.

<sup>19</sup> The 7% is the discount rate as declared by the Croatian National Bank. Although in government/societal perspective usually lower discount rates are applied (e.g. 4%), the calculation is made with this rather high discount rate in order to obtain worse case results. If these results show that the costs of saved energy are lower than the costs of supplied energy, the case in favour of energy efficiency improvement investments is therefore stronger.

- a = annuity factor (capital recovery factor)
- I = investment costs (money awarded by the Fund) [€]
- E = annual energy savings [kWh/yr]
- k = discount rate
- t = lifetime of the EEI measure [yr]

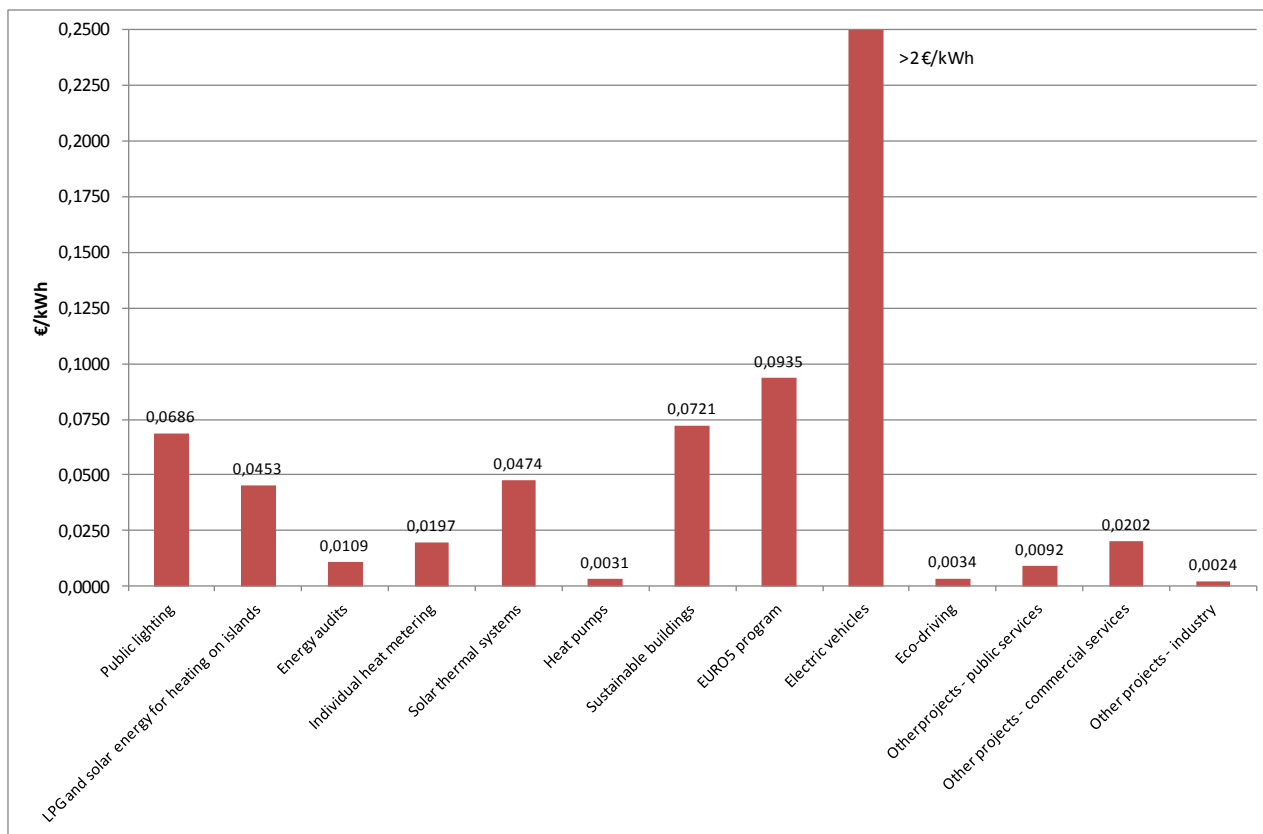
This calculation provides the cost of conserved energy from the government’s perspective only. This amount does not represent the total costs of the implemented EEI measures, as the Fund typically provides co-financing up to 40% of total investment; hence, total costs of saved energy are higher.

Figure 3 shows the allocation of the Fund’s incentives to different types of EEI measures. Again “80-20” rule can be applied, as projects in industry and public sector have received approximately 24% of all funding allocated to energy efficiency and have, as already stated delivered almost 80% of all savings. Therefore, with only a bit more than 20% of allocated money 80% of all savings were achieved. This might be a good ground for new decision making process in the Fund and new rules related to the allocation of the money. It is only reasonable to ask would it be appropriate to allocate more money to the refurbishment projects in industry and public sector in order to achieve higher energy savings at the lower public costs?



**Figure 3.** Allocation of the Fund’s incentives to various types of EEI measures

The results of costs calculation are shown in the Figure 4.



**Figure 4.** The cost of conserved energy associated to the Fund's incentives in €/kWh

The calculation results show that EEI measures with the lowest costs per saved kWh are, as expected, industrial refurbishment projects, while refurbishment projects (dominantly heating systems refurbishment) in the public sector also show low costs. As already stated, the cost calculated in this paper are the costs from the government's perspective and not total costs of the energy saved. Taking into the account the general rule of the Fund that it co-finances up to 40% of the total investment costs, we can roughly estimate that the total costs of energy savings are on average 2.5 higher than calculated. Even by doing so, the costs of energy savings in these projects, which we have previously identified as having the largest impact in terms of energy savings, are considerably lower than current average energy costs in Croatia, which are approximately 0.0305 €/kWh for natural gas and 0.0919 €/kWh for electricity. For these measures, therefore, the costs of saved energy are still significantly less than costs of consumed energy.

Surprisingly at first sight, refurbishment in public lighting did not show extremely good price of saved energy. The reason might be in the fact that incentives are related to the total investment costs which include the costs of usual refurbishment/works which would have been undertaken anyhow (some projects actually included completely new street lighting systems). The incremental cost of choosing energy-efficient options is usually much lower. Taking into account that costs of incentives are still approximately 25% less than electricity costs and that costs of electricity consumption of public lighting are borne completely by public spending, further support by the Fund might be desirable. However, in public lighting segment the cost-effectiveness of incentives versus cost-effectiveness of ESCO support should be analyzed. Due to maturity of public lighting technology, it is expected that ESCO market could deliver the savings at less costs caused by the market competition responding to the increased demand.

When it comes to the projects in category of "sustainable buildings", the results are not as desired. Sustainable buildings projects are dominantly related to the building envelope refurbishments and due to high investment cost and relatively low energy costs (natural gas is used as a reference), these projects turn out not to be profitable. However, these projects are usually

related to the works necessary for the improvement of the overall building conditions and in that case, only additional costs of more energy efficient solution selection should be taken into account. However, as nicely said in (AID-EE 2007): *“It should however be stressed that the choice of policy instruments should not be based on government cost figures only. The society and end-user perspective are just as important to take into account.”* With the aim of market transformation and improvement of living conditions, these projects should be further supported.

The cost of saved energy as a result of solar thermal systems installation is lower than the costs of electricity. This is very important as these systems replace the existing electric water heaters, which in the summer time are, together with air-conditioning, the main contributor to the daily peak load, especially in the coastal area of the country. As this peak load causes problems in the supply, there is a clear interest not only from the government perspective but also from the utility perspective to support such installations.

And finally, projects in the transport sector show the worse cost effectiveness, especially when it comes to electric vehicles. Again, in this segment also some other implications of this measure should be taken into account, as development of new technology (which may not be cost-effective in its early stage of deployment), influence on power sector and its load profile, emission reductions, etc. Additionally, the number of projects here is far too low to be able to draw reliable conclusions on cost-effectiveness of these incentives. Replacement of vehicles with new complying with the latest norms is also among the least cost-effective measures. The main aim of this support was to reduce harmful environmental pollution coming from road vehicles, which is the main societal benefit, while energy savings are only side effect of this measure. However, the cost of diesel fuel, which is dominantly used by trucks and buses targeted by the program, is now exceeding 1 €/l or 0,10 €/kWh, which makes these kind of incentives increasingly interesting. Eco-driving project (only one implemented) included not only education of professional drivers but also installment of devices to keep track of fuel consumption in vehicle fleets. Data provided by the transport company on fuel consumption prior and after the device installment showed excellent results and should be promoted and replicated further.

Other projects with low costs per saved kWh are not further analyzed as the number of such projects is too low (individual metering, heat pumps) and results therefore might not lead to the reliable conclusions.

## Conclusion

The analysis provided in this paper demonstrates the effectiveness (impact) and costs of energy saved caused by financial incentives provided by the Environmental Protection and Energy Efficiency Fund in Croatia, i.e. the costs from the government perspective. The Fund is the most important and practically the only source of state financial support for energy efficiency projects. Since its establishment the Fund has financially supported 886 energy efficiency projects and awarded for this purpose approximately 27.7 million Euro. The analysis was performed per typical EEI measures in order to demonstrate which measures provide the largest impacts in terms of energy savings and which measures provide the savings at the least costs for the government. In both cases the best results are obtained for refurbishment projects in the industry, followed by heating system refurbishment projects in the public sector. In the transport sector, eco-driving activities show the largest fuel savings at the lowest price. Based on the analysis performed, it might be recommended to focus the Fund's support to these projects. However, in the building sector, as it accounts for 40% of total energy consumption in Croatia, the focus should be on integral, deep renovations combining building envelope refurbishment and refurbishment of technical building systems (heating, cooling, ventilation and lighting) in order to deliver the largest savings and avoid existence of “missed opportunities” for energy efficiency improvements. In transport sector, which account to more than 30% of total energy consumption in Croatia, other benefits of supporting cleaner vehicles need to be

taken into account, such as reduction of pollution, technology development and impacts on electric power system. And finally, it has to be clearly emphasized that the analysis given in this paper is limited and focused only on the evaluation of government costs of saved energy. It does not take into account other benefits to the consumers and the society as a whole, such as improved living/working conditions, health, environment or productivity. The future research work of the authors will be exactly focused on evaluating benefits and costs of energy efficiency improvements from the whole society point of view.

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