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APPROXIMATION OF EU RENEWABLE ENERGY LEGISLATION AND ENERGY EFFICIENCY LABELLING

REPUBLIC OF CROATIA

Measurement and Verification of energy savings

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Content

1. INTRODUCTION ON MEASUREMENT AND VERIFICATION OF ENERGY SAVINGS

Measurement and verification (M&V) of energy savings is absolutely crucial part of any energy efficiency policy – it captures the overall improvement in energy efficiency and assesses the impact of individual measures.

Due to its importance, M&V of energy savings finds very prominent place in the Directive 2006/32/EC on energy end-use efficiency and energy services (ESD). According to Article 4, energy savings have to be measured and verified and achievements compared with the established energy saving targets.

Annex IV of the Directive gives a general framework for energy savings M&V with the aim to develop a harmonised European-wide approach. Hereafter two different but complementary approaches, i.e. calculation methods will be described and recommendations for Croatia will be given based on the best European practice. First method is top-down approach, and there is significant progress in achieving EU-wide harmonised method in this field. The second approach is bottom-up, and this is the field where additional effort must be made on the EU level to establish a common, harmonised methodology for M&V of energy savings.

It has to be emphasised that both approaches must be combined to appropriately and as exact as possible evaluate the success of national energy efficiency policy and the magnitude of energy efficiency improvement measures' impact. The need for combination of these two approaches is stipulated in the Annex IV of the ESD also.

There is no unique approach to the M&V of energy savings, especially when it comes to the bottom-up M&V. According to the ESD, the effort should be made by the European Commission by establishing the Committee that will bring the harmonised methodology for M&V in accordance with the general framework set in the Annex IV of the ESD. Moreover, Article 15 and Annex IV of the ESD stipulate that Commission shall develop a harmonised bottom-up model, covering a level between 20 and 30 % of the annual final inland energy consumption for sectors falling within the scope of the ESD before 1 January 2008. Until 1 January 2012, the Commission shall continue to develop this harmonised bottom-up model, which shall cover a significantly higher level of the annual final inland energy consumption for sectors falling within the ESD.

However, according to the authors' knowledge until this moment (end of 2008) there is no such harmonised methodology published by the Commission. Hence, this report gives the overview of existing methods used in the EU until now, which are good basis for Croatia to develop its own bottom-up M&V approach.

2. MEASURING ENERGY SAVINGS – TOP-DOWN CALCULATIONS

A top-down calculation method means that the amount of energy savings is calculated using the national or large-scale aggregated sectoral levels of energy saving as a starting point. Adjustments of these data are then made in dependence of external influences, such as degree-days, economic structure, product mix, etc. This is actually purely statistical approach, which does not consider individual energy efficiency measures and their impact. It does not show cause and effect relationships between measures and their resulting energy savings. However, it is usually simpler and less costly and is often referred to as "energy efficiency indicators" because it gives an indication of developments.

There is a well established methodology for top-down calculations, i.e. for calculation of energy efficiency indicators developed through ODYSSEE-MURE Project[1]. It is EU-wide recognised methodology, which is also in line with Eurostat energy data collection principles. ODYSSEE methodology is based on collection of extensive data sets for not only energy consumption but also for various factors influencing it, and on calculation and monitoring of energy efficiency indicators.

2.1 ENERGY EFFICIENCY INDICATORS

There are six types of indicators defined in ODYSSEE-database that are considered for monitoring energy efficiency trends or for comparing energy efficiency performances. These are as follows.

1. **Energy intensity** – ratio between an energy consumption (measured in energy units: toe, Joule) and an indicator of activity measured in monetary units (Gross Domestic Product, value added). Energy intensities are the only indicators that can be used every time energy efficiency is assessed at a high level of aggregation, where it is not possible to characterize the activity with a technical or physical indicator, i.e. at the level of the whole economy or of a sector. Intensities are also calculated at constant structure to leave out the influence of structural changes in the economy and provide a better indicator of overall efficiency.
2. **Unit consumption or specific consumption** – relates energy consumption to an indicator of activity measured in physical terms (tons of steel, number of vehicle-km, etc.) or to a consumption unit (vehicle, dwelling …). They can either be calculated from existing statistics (unit consumption) or are available as such from surveys (specific consumption).
3. **Energy efficiency index (ODEX)** – provides an overall assessment of energy efficiency trends of a sector. They are calculated as a weighted average of detailed sub-sectoral indicators (by end-use, transport mode...). A decrease means an energy efficiency improvement. Such index is more relevant for grasping the reality of energy efficiency changes than energy intensities.
4. **Diffusion indicators** – there are three types of such indicators: (i) market penetration of renewables (number of solar water heaters, percentage of wood boilers for heating, etc.); (ii) market penetration of efficient technologies (number of efficient lamps sold, percentage of label A in new sales of

[1] ODYSSEE-MURE Project, SAVE Programme. Commission 2005, http://www.odyssee-indicators.org/

electrical appliance, etc.); (iii) diffusion of energy efficient practices (percentage of passenger transport by public modes, by non motorised modes; percentage of transport of goods by rail, by combined rail-road transport, percentage of efficient process in industry, etc.). Diffusion indicators have been introduced to complement the existing energy efficiency indicators, as they are easier to monitor, often with a more rapid updating. They aim at improving the interpretation of trends observed on the energy efficiency indicators.

5. **Adjusted energy efficiency indicators** – account for differences existing among countries in the climate, in economic structures or in technologies. Comparisons of energy efficiency performance across countries are only meaningful if they are based on such indicators. ODYSSEE indicators take, as a reference structure, the EU average. External factors that might influence energy consumption include: (a) weather conditions, such as degree days; (b) occupancy levels; (c) opening hours for non-domestic buildings; (d) installed equipment intensity (plant throughput); product mix; (e) plant throughput, level of production, volume or added value, including changes in GDP level; (f) schedules for installation and vehicles; (g) relationship with other units. Some of these factors are relevant for correction of aggregated indicators, while some are to be used for the individual facilities in which energy efficiency measures are implemented.
6. **Target indicators** – aim at providing reference values to show possible target of energy efficiency improvements or energy efficiency potentials for a given country. They are somehow similar to benchmark value but defined at a macro level, which implies a careful interpretation of differences. Two types of target indicators are considered, according to the source of improvement:
    i. Indicators of technical progress
    ii. Indicators with potential of technical efficiency ("technical potential") and higher penetration of "more efficient practices ("non technical potential")

   The target values are based on comparable indicators, adjusted to account for national circumstances: geographical differences (e.g. climate, country size), lifestyles specificities (e.g. size of dwellings, appliance ownerships), and more generally to all quantifiable differences not usually targeted by energy efficiency/ climate change policy (e.g. industry structure).

   For the indicators of technical progress, the target is defined as the distance to the average of the 3 best countries; this distance shows what gain can be achieved.

   The assessment of the potential technical and non-technical gains with these indicators is based on a graphical representation of the indicators as a function of the diffusion of the penetration of the "efficiency practice":
    i. The technical target corresponds to the distance to the average of the 3 best countries from a technical point a view;
    ii. The non technical target is represented by the distance to the average of the 3 best countries in terms of penetration of efficient practices

7. **CO_2 indicators** - In addition to energy efficiency indicators, the ODYSSEE data base defines also CO_2 indicators, which are, similarly as ODEX, used to monitor the progress in CO_2 reduction. These indicators consist of CO_2 intensities (CO_2 emissions per unit of monetary output) and unitary CO_2 emissions (per dwelling, per car, per ton of steel, etc.) All indicators are calculated in two ways:
   - Direct emissions, based on the direct emissions of fossil fuels burnt in the sector (according to the IPCC methodology)
   - Total emissions, including indirect emissions for the generation of electricity and heat consumed in the sector

2.2 DATA COLLECTION FOR TOP-DOWN CALCULATIONS

The ODYSSEE data base defines a comprehensive list of energy, production and other data for every end-use sector and at the macro-economic level that need to be collected in order to develop the energy efficiency indicators to be used for evaluating energy efficiency policy effectiveness.

Table 2-1 gives the detailed list of all data collected for the development of energy efficiency indicators.

Table 2-1 Data collected in Odyssee data base

Macro level (national)	Industry	Transport	Households	Services
Primary energy consumption • Total • Total (with climatic corrections)	**Energy consumption** • Total industry[1] • Manufacturing industry o Total by energy carrier[1] o Per industry branch[2, 3] • Construction • Mining	**Energy consumption** • Total transport[4] • Road[5] o Cars o Bus o Trucks o Light vehicles o Two-wheels • Rail o Diesel o Heavy fuel o Electricity o Passengers o Goods • Air transport o Total o Domestic • Inland navigation o Gasoline o Diesel o Heavy fuel o Total	**Energy consumption** • Total[6] • Space heating[6] • Water heating[6] • Cooking[6] • Electrical Appli-ances/Lighting o Total o Lighting	**Energy consumption** • Services[7] o Total[7] o Space heating[8] ▪ Hotels and restaurants ▪ Health ▪ Education ▪ Administration ▪ Wholesale and re-tail trade • Agriculture[7]
Final energy consumption • Total o Coal o Oil o Gas o Heat o Biomass o Electricity • Total (with climatic corrections)	**Production index** • Total industry • Per manufacturing in-dustry branch[2] • Construction • Mining • Energy	**Stock of vehicles** • Cars o Total o Gasoline o Diesel o LPG o Electric • Bus o Total o Gasoline o Diesel o LPG	**Stock of dwellings (permanently occu-pied)** • Total • Multifamily dwell-ings • Single family dwell-ings • Dwellings with in-dividual central heating	**Value added** • Services • Hotels and restau-rants • Health • Education • Administration • Wholesale and retail trade

		o Electric • Trucks o Total o Gasoline o Diesel • Light vehicles o Total o Gasoline o Diesel o LPG o Electric • Two-wheels	• Dwellings with independent heating	
Demography • Population • Households	**Value added** • Total industry • Per manufacturing industry branch[2] • Construction • Mining • Energy	**New cars** • Total • Gasoline • Diesel • LPG • Electricity	**New dwellings** • Total • Single family dwellings • Multifamily dwellings	**Floor area** • Total • Hotels and restaurants • Health • Education • Administration, public offices • Wholesale and retail trade • Private offices
GDP, value added • GDP • Value added o Agriculture o Industry o Services • Private consumption	**Production** • **Steel** o Total o Electric process o Non electric process • **Cement** o Cement o Clinker • Papers • Glass	**Kilometres** • Cars o Total o Gasoline o Diesel • Trucks • Bus • Light vehicles Two-wheels	**Floor area of dwellings** • Total • Single family dwellings • Multifamily dwellings • New dwellings • New single family dwellings • New multifamily dwellings	**Employment** • Total • Administration • Health • Education • Hotels and restaurants • Wholesale and retail trade

		Passenger traffic • Total • Road transport o Total o Cars o Collective transport • Air transport o Domestic • Total	**Stock of appliances** • Refrigerators • Freezers • Washing machine • Dish-washing machine • TV	
		Good traffic • Total • Road • Rail Inland waterways	**Rate equipment** • Refrigerators • Freezers • Washing machine • Dish-washing machine • TV	
			Degree day • Degree day • Degree-days of reference	

1. Energy consumption per energy carrier: Coal, Oil, Gas, Heat, Biomass, Electricity
2. Industry braches: chemical industry, primary metals (total, steel and non-ferrous), non metallic mineral (total, cement and glass), wood, paper and printing (total, pulp and paper), food and beverages, textile, machinery and fabricated metal (fabricated metals separately), transport vehicle, miscellaneous industries (total and rubber and plastic)
3. For every industrial branch and sub-branch energy consumption by energy carriers specified under note 1 are collected.
4. Energy consumption by fuel type (refined oil products (gasoline, diesel, LPG, jet fuel, heavy fuel, in total), biofuels, electricity and in total)
5. For every vehicle type energy consumption by fuel type specified under the note 4 is given
6. Energy consumption per energy carrier (Coal, Oil, Gas, Heat, Wood, Electricity, total, total with climatic correction)
7. Energy consumption per energy carrier (Coal, Oil, Gas, Heat, Wood, Electricity, total, total with climatic correction)
8. Consumption of electricity and total

3. MEASURING ENERGY SAVINGS – BOTTOM-UP CALCULATIONS[2]

3.1 EX-ANTE AND EX-POST APPROACH

A bottom-up calculation method means that energy savings obtained through the implementation of a specific energy efficiency improvement measure are measured in kilowatt-hours (kWh), in Joules (J) or in kilogram oil equivalent (kgoe) and added to energy savings results from other specific energy efficiency improvement measures.

There is no direct way of measuring energy use or demand savings since instruments cannot measure the absence of energy use or demand. However, the absence of energy use or demand can be calculated by comparing measurements of energy use and/or demand made before and after implementation of an energy efficiency measure. This is called an ***ex-post*** method. The ex-post schemes may be very costly but they guarantee real savings. The costs are related to the actual measurement, i.e. to the measurement equipment.

Another approach implies ***ex-ante*** method, i.e. estimate. Ex-ante approach means that certain type of energy efficiency measure is awarded with a certain amount of energy savings prior to its actual realisation. This approach has significantly lower costs and is especially appropriate for replicable measures, for which one can agree on a reasonable ex-ante estimate. On the other hand there are dangers associated with purely ex-ante schemes, like partial realisation of savings, poor additionality, etc.

Bottom-up calculations are especially important for tradable white certificate (TWC) schemes. Hence, they are not developed exactly in countries with TWC. The **Italian** system is taken as a good example, which combines ex-ante and ex-post approaches. An interesting feature in Italian M&V system is parameterised ex-ante method - they called this approach "engineering approach" as opposed to "default approach" for non parametric estimates.

Italian M&V system can be taken as a remarkable example of how complex M&V system is. In Italy, M&V procedures involve 3 different approaches:

- *Deemed or known (ex-ante) savings – default approach:* it entails simplified energy saving calculations. Savings are known in advance, limited provision of documentation, and reduced monitoring and certification procedures. It applies to measures for which energy savings are well known. This approach applies to measures that yield up to 25 toe per year in savings. Examples: CFL, m^2 insulated wall, small PV applications and high efficiency boilers.

- *Engineering estimates (hybrid ex-ante ex-post approach):* it applies to measures for which energy savings are known but they may differ depending on a number of restricted factors (e.g. availability factor or number of working hours). The set up of a hybrid approach can be more accu-

[2] This chapter is written using the report of EuroWhiteCert project: "Work package 4.1 Supply side: measurement and verification of energy efficiency projects", available at www.eurowhitecert.org

rate than a pure ex-ante methodology, without a substantial increase of the M&V costs. To avoid a large increase in the M&V costs, only the largest or unpredictable measures should be analysed through an ex-post methodology. This approach applies to measures that yield up to 50 toe per year (for ESCOs and small distributors) and 100 toe per year for large distributors in savings respectively.

- *Metered baseline method (ex-post):* it applies to measures for which energy savings need to be addressed in a case-by-case basis. It entails direct measurement of energy use, pre-approval of proposed baselines and methodologies. More documentation and procedures are involved for ex-post verification and certification. This approach applies to measures that yield up to 100 toe per year (for ESCOs and small distributors) and 200 toe per year for large distributors in savings respectively.

On the other hand, in **Great Britain** the white certificate scheme grants energy savings based entirely on an ex-ante approach. The approach is largely explained by the fact that the performance of the set of eligible technologies is well understood. The size, type and performance of the measures are well known and related estimates use best available data. M&V procedures, together with the eligibility of energy efficiency measures are thus a much less complex – this approach has decreased the administrative cost of M&V system to the competent body (in UK it is energy regulator OFGEM).

3.2 WHEN TO USE EX-ANTE / EX-POST APPROACH?

3.2.1 Ex-ante and hybrid ex-ante ex-post evaluation of energy savings

It is reasonable to derive ex-ante methods for certifying energy efficiency measures which are capable of wide replication. Deemed savings requires no in field measurement and works well for common energy saving measures such as residential measures affecting lighting, appliances, heating and insulation. For example, for residential energy efficiency measures or for energy efficient lighting in the service sector etc., it is easy to assign an average value of (independently verified) energy saving per measure, which of course will not reflect the reality in individual situations, but will reflect the energy saving when averaged over many applications.

However, for some types of energy efficiency measures, probably a simple ex-ante methodology is not enough. This situation can occur due to the lack of available data, to evaluate energy efficiency measures with no tradition in the analysed country or when the energy savings varies, depending on a number of identifiable parameters. Other kind of situation occurs in the case of large scale measures or measures applied in specific sectors. In a measure applied in the industry sector or with large predictable energy savings the error that results from an ex-ante evaluation can be of quite large. In this kind of measures it can be advantageous to use a mix of the two approaches (ex-ante and ex-post evaluation), increasing the reliability of the methodology and avoiding the high costs of pure ex-post methodology.

As already mentioned, in Italy there is TWC scheme established, hence the bottom-up procedures for M&V of energy savings in individual projects are well developed. Italian energy regulatory authority AEEG is responsible for M&V and has developed 22 forms that are used for ex-ante and hybrid ex-ante and ex-post evaluation. The Italian system includes an interesting feature of parameterised ex-ante method. They called this approach of ex-ante estimation "engineering approach" (e.g. taking hours of operation, duty cycles, etc.), as opposed to "default approach" for non parametric estimates. The engineering estimates are hybrid ex-ante ex-post method.

Examples of default estimate (pure ex-ante method)

Some examples of "default approach" are given in Table 3-1. Every energy efficiency improvement measure is awarded with appropriate physical reference unit, and predefined energy savings are expressed per that unit. If a measure is dependent on some external factor, e.g. climatic conditions, like replacement of windows or wall and loft insulation, this dependence is taken into account by dividing country in appropriate climatic zones. Similarly, for replacement of electric motors in industry with more efficient once, energy savings are estimated according to the nominal power of the motor. For domestic appliances, very simple estimation of energy savings is used, without energy rate of the existing appliance being taken into account.

Table 3-1 Selected examples of Italian ex-ante energy savings estimates

Substitution of incandescent lamps with CFLs with built-in ballast

Physical reference unit: CFL with build-in ballast
Specific gross primary energy saving (RSL) per physical reference unit: 14.6 * 10-3 toe/year/CFL

Substitution of electric water heaters with gas water heaters provided with watertight chamber and piezo-electric ignition

Physical reference unit: gas boilers with watertight chamber and piezo-electric ignition
Specific gross primary energy saving (RSL) per physical reference unit: 0.107 toe/year/water heater

Substitution of gas water heaters (open chamber and pilot flame) with gas water heaters provided with watertight chamber and piezo-electric ignition

Physical reference unit: gas boilers with watertight chamber and piezo-electric ignition
Specific gross primary energy saving (RSL) per physical reference unit: 0.063 toe/year/water heater

Substitution of simple glazing with double glazing

Physical reference unit: unit area of substituted glazing (m^2)
Specific gross primary energy saving per unit area of substituted glazing - RSL (toe 10-3/year/ m2 of substituted glazing):

	Building destination		
Climatic zone	**Household**	**Office, School, Commerce**	**Hospital**
A, B	2	2	4
C	5	5	7
D	9	8	12
E	15	13	19
F	23	19	27

Substitution of refrigerators, refrigerator-freezers, freezers, washing machines and dishwashers with analogous more efficient products Physical reference unit: appliance Specific gross primary energy saving per substituted unit:	
Class A refrigerator, class A refrigerator-freezer	RSL = 26,0 x 10-3 [toe/year]
Class A freezer	RSL = 29,0 x 10-3 [toe/year]
Class A+ refrigerator, class A+ refrigerator-freezer	RSL = 39,6 x 10-3 [toe/year]
Class A freezer+	RSL = 39,8 x 10-3 [toe/year]
Class A++ refrigerator, class A++ refrigerator-freezer	RSL = 54,5 x 10-3 [toe/year]
Class A++ freezer	RSL = 51,6 x 10-3 [toe/year]
Class A washing machine	RSL = 7,9 x 10-3 [toe/year]
Class A dishwasher	RSL = 9,2 x 10-3 [toe/year]

The engineering estimates (only requiring partial in field measurement) rely on simplified energy saving calculation and are suitable for projects where the energy saving impact is well understood. Those estimates vary depending on a limited number of identifiable parameters (e.g. number of working hours, number and type of connected loads, etc.). This approach reduces the reporting documentation to be provided and simplify the control and certification procedures. For each type of project, a specific evaluation algorithm is defined, with predefined values for some parameters while other parameters have to be measured case by case. The engineering estimates are commonly used for commercial or industrial application and are usually employed in measures like: variable speed drive application in pumping systems, cogeneration, district heating, etc.

Example of engineering estimate (hybrid ex-ante ex-post method)

Engineering estimate is set in Italian system for e.g. application in the civil sector of small co-generation systems for winter and summer air-conditioning of rooms and to produce hot water. For that energy efficiency measure an equation is set to estimate primary energy savings:

RN = RNt +RNf +RNe

where:

RNt = IREmod * EPt, EPt = 0,086 * **EFt** /(0,77 + Log10Pn)
RNf = IREmod * EPf, EPf = fE/3,0 * **EFf**
RNe = IREmod * (EPe – (fE-0,148 * Eeintroduced), Epe = fE * **Ee**
IREmod = (EP – EPc)/EP where EP = EPt + EPf + EPe, EPc = 0,086* **Ec**

The quantities marked in bold are the object of the measure.

The meaning of the above symbols is as follows.

- Ec energy content of the fuels used [MWh]
- Ee net electricity produced by the cogeneration plant and reduced of the quantity used by the systems of distribution and cooling; results Ee=EFe + Eeintroduced [MWhe]
- Eeintroduced electricity produced in overplus and given to the local grid of distribution [MWhe]
- Et total useful thermal energy produced by the plants and used only for civil needs [MWht]
- EFe electricity used by the consumer, for needs different from air-conditioning [MWhe].
- EFf refrigerating energy used directly to refresh rooms [MWhf]. For the systems considered, the losses for distribution are negligible.

EFt part of Et used directly to heat, post-heat and production of hot water for civil use [MWht]. This part is obtained as net of the part of energy used for refrigeration. For the systems considered, the losses for distribution are negligible
EPc primary energy corresponding to the fuels used by the plants [tep]
EPe primary energy corresponding to the net electricity produced Ee [tep]
EPf primary energy corresponding to the refrigerating energy provided EFf [tep]
EPt primary energy corresponding to the thermal energy provided EFt [tep]
EP total primary energy, associated to the energy of the plant, equal to EPt + EPf + EPe [tep].
ht,R efficiency of reference for the separated production of thermal energy for civil uses
ef,R energetic efficiency of the frigorific system substituted.
fT equal to: 3600/41860 = 0,0860 tep/MWh. Correcting coefficient from MWht to tep.
fE correcting coefficient of electricity in primary energy, equal to:
0,220 tep/Mwhe for the year 2005
0,210 tep/Mwhe for the year 2006
0,207 tep/Mwhe for the year 2007
0,204 tep/Mwhe for the year 2008
0,201 tep/Mwhe for the year 2009
Pn power of substituted boiler or of the supply boiler that would produce steam if a co-generation system was not used [kWt]

In UK even simpler estimations are used for eligible energy efficiency improvements measures under the Energy Efficiency Commitment and the same is valid for French TWC scheme.

In **UK** there are no conditions set for measures, i.e. savings are estimated regardless any other external condition. Before the project submission, the energy saving attributed to it is already calculated and set. It is based on standardized estimate according to the used technology; it is weighted for the used fuel type and discounted over the estimated life of the measure. Energy savings are attributed to measures by energy regulator – OFGEM.

In **France**, three conditions are set for eligible measures – the age of the heating system (before or after 1975), climatic zone (three zones are defined) and U value for walls and windows. Currently about 30 standardised measures in residential/tertiary sectors, about 10 standardised measures in industry and about 5 standardised measures in transport are in course of definition. ADEME (French Agency for Environment and Energy Management) and ATEE (Association Technique Energy Environment) are in charge of setting methodologies for calculation of the achieved savings.

3.2.2 Ex-post evaluation of energy savings - IPMVP

In large scale measures (major industrial and commercial projects) the use of ex-post methods will probably be necessary, involving the direct measurement of energy use before and after the measure. The monitoring plans are required for projects whose energy performance depends on variables and parameters that change from case to case and are therefore less predictable. This kind of approach needs the pre-approval of the proposed methodology. Extended documentation needs to be provided for ex-post validation and certification and extended control and certification procedures and need to be developed according to pre-determined criteria and format.

Before determination of how much energy is being saved by the energy conservation measure, it is necessary in an ex-post method to know how much energy was being consumed before. This energy consumption is referred to as the baseline energy use, and it is the starting point for determining energy savings. The difference between the baseline energy use and the energy use after the energy conservation measures installation is the actual project savings (Figure 3-1).

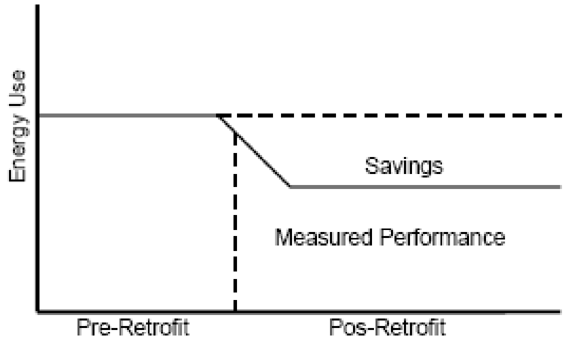

Figure 3-1 Baseline energy use and achieved energy savings

However, the baseline conditions can change after the energy efficiency measures are installed. There are few factors that could affect a project's energy savings once it is up and running:

- Changes in baseline conditions;
- Changes in equipment performance;
- Changes in the external conditions (such as the weather);
- Change in metering perimeter.

Hence, these factors must be taken into account and analysed after measure is undertaken and adjustments have to be made in order to ensure correct comparisons of the state pre- and post-retrofit.

However, the main issue with ex-post evaluation methods is their costs. Namely, detailed ex-post evaluation requires measuring number of parameters that influence energy consumption. Such measurements are rarely available and installation of additional meters could be, and usually is, costly. Hence, the costs of additional measurements should be weighed against estimated money savings. Costs of additional measurement equipment should not exceed 15 to 25% of annual energy costs in the facility where energy efficiency improvement measure is undertaken. Namely, experience shows that improved monitoring of energy consumption and variables influencing it, could bring savings of 5 to 15% in energy consumption. Respecting this figures, cost-effectiveness of the installed additional meters is ensured.

There are various approaches in ex-post evaluation of energy savings. Methods are developed by the International Energy Agency through its Demand-Side Management (DSM) Programme, ASHRAE (American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc.) has developed its guidelines for measurement of energy and demand savings and most recently CEN and CENELEC decided to set up a joint group, called the CEN/CENELEC BT/JWG "Energy Management". Its purpose is to give a proactive response to the upcoming requests from the legal field in respect of energy management and efficiency. However, the most used is **the International Performance Measurement and**

Verification Protocol (IPMVP)[3]. It defines general procedures to achieve reliable and cost-effective determination of savings. Verification of actual savings is done relative to an M&V Plan developed for each project. IPMVP discusses procedures that, when implemented, allow building owners, energy service companies (ESCOs), and financiers of building energy efficiency projects to quantify energy efficiency measure performance and energy savings.

Measurement of achieved energy savings is, according to IPMVP, determined by comparing measured energy use or demand before and after implementation of an energy savings program. In general:

Energy Savings = Baseyear Energy Use - Post-Retrofit Energy Use ± Adjustments

The "Adjustments" term (can be positive or negative) in this general equation brings energy use in the two time periods to the same set of conditions. Conditions commonly affecting energy use are weather, occupancy, plant throughput, and equipment operations required by these conditions.

This principle of energy savings' dependence on performance and usage is shown in Figure 3-2. Performance describes how much or how little energy is used to accomplish a specific task; usage describes the operating hours that a piece of equipment runs. Lighting provides a simple example: performance would be the Watts required to provide a specific amount of light; usage would be the operating hours per year. A chiller is a more complex system: performance is defined as kW/ton, which varies with load; usage is defined by cooling load profile and ton-hours. In all cases, both performance and usage factors need to be known to determine savings

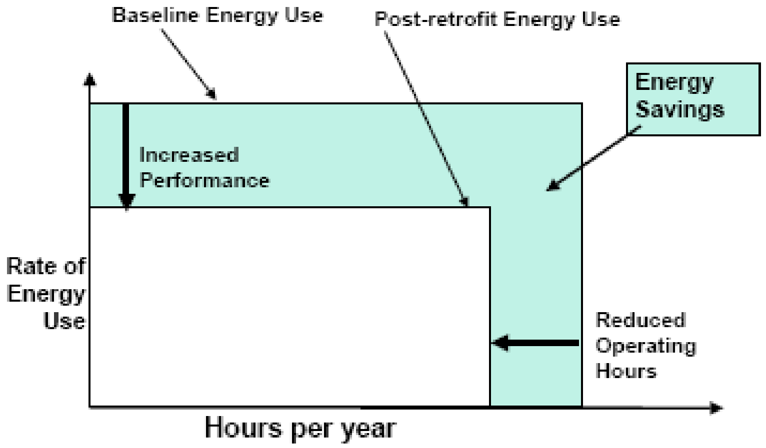

Figure 3-2 Energy savings depend on performance and usage

The basis for determination for energy savings is M&V plan for an individual project. M&V plan also forms a basis for verification of savings. A good M&V plan should:

- Identify appropriate M&V options for different energy efficiency measures;

[3] IPMVP is currently in its fourth edition and is freely available at www.evo-world.org under the Products tab

- Define the boundaries (individual energy systems or whole building) of the energy efficiency measure for savings determination, and rigorously document the facility's baseline conditions and the resultant baseline energy data;
- Specify quality control and quality assurance procedures for data collection as well as the format in which the annual M&V reports will be submitted;
- Include cost estimates for both the initial instrumentation and recurring M&V tasks.

IPVMP defines four possible M&V options, noted with letters A, B, C and D. Options A and B focus on the performance of specific energy efficiency measures. Option C assesses the energy savings at the whole-facility level by analyzing utility bills before and after the implementation of energy efficiency measure. Option D is based on simulations of the energy performance of equipment or the whole facility, permitting the determination of savings when base year retrofit data are unreliable or unavailable.

Options A and B are retrofit isolation methods. They look only at the affected equipment or system independent of the rest of the facility. Option C is a whole facility method, which considers only the total energy use while ignoring specific equipment performance. Option D can be used as either, but is usually applied as a whole facility method.

The characteristics of every IPMVP option are summarised in Table 3-2.

Table 3-2 IPMVP options

M&V Options	How Savings are Calculated	Typical Applications
Option A - Focus on physical inspection of equipment to determine whether installation and operation are to specification. Performance factors are either stipulated (based on standards or nameplate data) or measured- Key performance factors (e.g. lighting wattage or motor efficiency) are measured on a snapshot or short-term basis.- Operational factors (e.g. lighting operating hours or motor runtime) are stipulated based on analysis of historical data or spot/short term measurements	Engineering calculations or computer simulations based on metered data and stipulated operational data. [Engineering methods] [Short term monitoring]	Lighting retrofit where power draw is measured periodically. Operating hours of the lights are assumed to be one-half hour per day longer than facility occupancy hours.
Option B - Intended for individual energy efficiency measures, (retrofit isolation) with a variable load profile. - Both performance and operational factors are measured on a short-term continuous basis taken throughout the term of the contract at the equipment or system level.	Engineering calculations after performing a statistical analysis of metered data. [Engineering methods] [End-use metering]	Application of controls to vary the load on a constant speed pump using variable-speed drive. Electricity use is measured by a kWh meter installed on the electrical supply to the pump motor.
Option C - Intended for whole facility M&V where energy systems are interactive (e.g. efficient lighting system reduces cooling loads) rendering measurement of individual energy efficiency measure inaccurate.- Performance factors are deter-	Engineering calculations based on statistical analysis of whole-facility data using techniques from simple comparison to multivariate (hourly or	Multifacted energy management program affecting many systems in a facility. Energy use is measured by the gas and electric utility meters for a twelve-month base-year period and throughout

M&V Options	How Savings are Calculated	Typical Applications
mined as the whole-facility or facility level with continuous measurements.- Operational factors are derived from hourly measurements and/or historical utility meter (electricity or gas) or sub-metered data.	monthly) regression analysis. [Basic statistical models] [Multivariate statistical models]	the post-retrofit period.
Option D - Typically employed for verification of savings in new construction and in comprehensive retrofits involving multiple measures at a single facility where pre-retrofit data may not exist. - In new construction, performance and operational factors are modelled based on design specification of new, existing and/or code complying components and/or systems.- Measurements should be used to confirm simulation inputs and calibrate the models.	Calibrated energy simulation / modelling of facility components and/or the whole facility; calibrated with utility bills and/or end-use metering data collected after project completion. [Engineering methods] [Integrative methods]	Multifaceted energy management program affecting many systems in a facility but where no base-year data are available. Base-year energy use is determined by simulation using a model calibrated by the post-retrofit period data.

The general recommendation which option to use cannot be given – it strongly depends on the characteristics of the specific energy efficiency project. However, the strength of the IPMVP is its wide applicability ensured by the choice between four different options. Having four options provides a range of approaches to determine energy savings depending on the characteristics of the energy efficiency measures being implemented and balancing accuracy in energy savings estimates with the cost of conducting M&V. It has to be emphasised that regardless which option is chosen, all savings are estimates since savings cannot be directly measured.

When it comes to a selection of the specific IPMVP option, option C is mostly used. Namely, it is commonly understood that various energy efficiency improvement measures interact with each other. Reduced lighting loads, for example, can reduce air-conditioning energy consumption, but increase heating consumption. In cases where interactive effects are to be measured, M&V plans for electricity use, including cooling and heating end use will need to be developed. However, the detailed relationship between most dissimilar, interactive energy efficiency improvement measures is generally not well known, and the methods for measuring interactive effects are not cost-effective for most applications. For these reasons, when multiple energy efficiency improvement measures are installed at one site, it may be less costly to use the whole building methods of Options C (or D) than to isolate and measure multiple energy efficiency improvement measures with Options A or B. Furthermore, for option C usually utility meters are enough, hence no additional metering costs are required.

Ex-post evaluation is especially important for energy performance contracting, which is the basis for ESCO business. However, the problem with ex-pos evaluation of energy savings is their high costs. Ex-post costs are typically (option C for IPMVP) 5 % of initial cost for initial audit + 1.5 % yearly (note that costs of options A and B might be even higher since new measurement equipment is usually needed). On 10 years that makes 20 % of investment, i.e. quite high and might endanger the cost-effectiveness of the energy efficiency improvement measure. The potential domain of excellence of ex-post systems is large savings and large investments.

3.3 DATA COLLECTION FOR BOTTOM-UP CALCULATIONS

Same as for top-down calculations a certain set of data are needed for bottom-up calculations also. Which data are required depends, of course on the energy efficiency improvement measure implemented. There are several ways to collect these data, which are defined in the ESD's Annex IV. The distinction is made between measuring methods and estimation methods.

Measuring methods:

Bills from energy distribution companies/retailers

Metered energy bills may form the basis for measurement for a representative period before the introduction of the energy efficiency improvement measure. These may then be compared to metered bills for the period after the introduction and use of the measure, also for a representative period of time. The findings should be compared to a control group (non-participation group) if possible or, alternatively, normalised according to plausible external factors. **This is very common and practically the only source of data in energy efficiency projects in Croatia.**

Energy sales data

The consumption of different types of energy (e.g. electricity, gas, heating oil) may be measured by comparing the sales data from the retailer or distributor obtained before the introduction of the energy efficiency improvement measures with the sales data from the time after the measure. A control group may be used or the data normalised. **This data source is not very usual in energy efficiency projects in Croatia.**

Equipment and appliance sales data

Performance of equipment and appliances may be calculated on the basis of information obtained directly from the manufacturer. Data on equipment and appliance sales can generally be obtained from the retailers. Special surveys and measurements may also be carried out. The accessible data can be checked against sales figures to determine the size of energy savings. When using this method, adjustment should be made for changes in the use of the equipment or appliance. **This method is important for both top-down calculations, i.e. for determination of diffusion indicators and for bottom-up calculations showing the amount of energy savings achieved by appliance replacement. Anyhow, these data are not being collected in Croatia.**

End-use load data

Energy use of a building or facility can be fully monitored to record energy demand before and after the introduction of an energy efficiency improvement measure. Important relevant factors (e.g. production process, special equipment, heating installations) may be metered more closely. **These data could provide the most accurate estimations of energy savings.**

Estimation methods:

Simple engineering estimated data (non-inspection)

Simple engineering estimated data calculation without on-site inspection is the most common method for obtaining data for measuring deemed energy savings. Data may be estimated using engineering principles, without using on-site data, but with assumptions based on equipment specifications, performance characteristics, operation profiles of measures installed and statistics, etc. **This method is widely used in Croatia for estimation of energy balance in the facility being audited for identification of energy efficiency improvement possibilities.**

Enhanced engineering estimated data (inspection)

Energy data may be calculated on the basis of information obtained by an external expert during an audit of, or other type of visit to, one or several targeted sites. On this basis, more sophisticated algorithms/simulation models could be developed and be applied to a larger population of sites (e.g. buildings, facilities, vehicles). This type of measurement can often be used to complement and calibrate simple engineering estimated data. **However, during inspections (energy audits) in Croatia, the baseline energy consumption is usually determined form the utility bills.**

4. RECOMMENDATIONS FOR CROATIA

4.1 IMPROVEMENT OF NATIONAL ENERGY STATISTICS SYSTEM FOR TOP-DOWN CALCULATIONS

Croatia already participates in the ODYSSEE project through activities of the Energy Institute “Hrvoje Požar”. In 2007 a report Energy Efficiency n Croatia (1992-2004) was published as a result of Institute’s own activities, i.e. it is not official project of the Croatian state supported by the competent Ministry of Economy, Labour and Entrepreneurship (MoELE). Hence, the MoELE at this moment actually does not have the data or capacities to develop energy efficiency indicators. This should be changed, i.e. MoELE should make efforts to establish a full IT system for monitoring energy efficiency progress. This could be an integral part of the system for development of the overall national energy balance.

Activity data for three main energy efficiency indicators, i.e. energy intensities, unit consumption and ODEX could be extracted from national energy balance prescribed by the Ordinance on Energy Balance (OG 33/2003) and annual statistical reports and reports on industrial production published by CROSTAT. At this stage diffusion, adjusted and target indicators are more difficult to monitor since statistical programmes do not provide data on market penetration of renewables and/or energy efficiency technologies and other relevant activity data. It is recommended to establish new statistical programme by CROSTAT in order to track activity data required for these complementary indicators.

CO_2 indicator could be extracted from official inventory submissions to the UNFCCC.

At this point, the most recent development in Croatian legal framework has to be considered. Namely, in December 2008 the Act on Efficient End-Use of Energy has been adopted by the Croatian Parliament. This act envisages exactly the establishment of the IT system for monitoring energy efficiency. The exact features of that system and data needed to be collected to develop energy efficiency indicators will be prescribed by the special ordinance prepared by the MoELE. It is strongly recommended that ODYSSEE methodology is followed when developing this regulation in both aspects – in prescribing which data must be collected (table 2-1) and in defining which energy efficiency indicators should be calculated and monitored (chapter 2.1).

4.2 STANDARDISED BOTTOM-UP CALCULATIONS

There are no standardised bottom-up calculations in force in Croatia. Moreover, the M&V plans are rarely an integral part of the energy audits reports. The situation is supported by the fact that there is only one active ESCO in Croatia; hence there is lack of players in the energy efficiency market that would require the urgent set-up of standardised M&V procedures. Since M&V is crucial for ESCO projects, the company HEP-ESCO is starting to use the IPMVP in its projects for the contracting purposes. Besides that, the IPMVP remains quite unknown in Croatia.

However, the public money is spent for promoting energy efficiency projects in Croatia through Environmental Protection and Energy Efficiency Fund. The Fund has not yet established M&V system for projects it finances. Hence, the cost-efficiency of the financed projects cannot be evaluated, which is a serious omission in overall monitoring of energy efficiency policy in Croatia.

The most recent developments in legal framework for energy efficiency should change this situation. Namely, the new Act on Efficient End-Use of Energy stipulates that a special regulation for M&V should be developed. This regulation should contain the standardised procedure for bottom-up M&V of energy savings for projects financed from the Fund and for energy efficiency projects implemented in undertakings that have obligations for achieving energy savings according to that Act (public sector buildings, public lighting, and large energy consumers' facilities).

The general recommendations for bottom-up M&V in Croatia are actually a summary of findings given in the chapter 3. There is certainly a need for development of M&V methodology in Croatia. Since there are no official recommendations from the European Commission yet that Croatia could use, it should rely on the best EU and world experiences, especially form countries with established TWC schemes, or which the M&V is crucial. Their experience shows that ex-ante evaluation methods can be a good basis for M&V. However, purely ex-ante approach is appropriate only for well known and replicable measures, otherwise there are significant drawbacks of such approach, i.e. the accuracy of realised energy savings estimations could be low. On the other hand, purely ex-post approach has high transaction costs and can be justifiable only for large projects and projects with special technologies implemented. A hybrid method combining an ex-ante and an ex-post methodology can be more accurate than a pure ex-ante methodology, without a substantially increase of the M&V costs. To avoid a large increase in the M&V costs, only the largest or unpredictable measures deserve to be can be analysed through an ex-post methodology. The most predictable measures must be evaluated through a deemed savings methodology (pure ex-ante) or engineering estimates (hybrid ex-ante ex-post).

So, the following general conclusion and recommendation for Croatia could be given:

- For "proven" technologies, ex-ante or hybrid ex-ante ex-post methods of M&V should be applied – they can be country specific (e.g. dependant on climatic conditions), and they should be harmonised with common European methodology, in case such methodology is available,

- For less mature technologies, ex-post monitoring plans have to be developed according to a pre-defined framework and pre-determined rules. IPMVP methodology should be followed for this purpose.

The greatest experience with M&V in Europe is found in countries with established TWC schemes: Italy, UK and France. They have chosen the same philosophy of ex-ante generic savings and they are trying to enlarge their domain by making them hybrid methods. The advantage of hybrid method combining an ex-ante and an ex-post methodology is in increased accuracy without a substantially increase of the M&V costs that are accompanying ex-post methodology. Hence, Croatia should follow this best practice and use ex-post evaluation only for large and specific energy efficiency improvement measure, while for the most predictable a deemed savings methodology (pure ex-ante) or engineering estimates (hybrid ex-ante ex-post).

4.3 INSTITUTIONAL NEEDS FOR ESTABLISHMENT OF M&V

There is no TWC scheme established in Croatia nor such scheme is envisaged by the new Act on Efficient End-Use of Energy. Hence, energy suppliers are not obliged to deliver certain amount of energy savings like in Italy, UK or France. Since there is no such obligation for energy subjects, Croatian energy regulatory agency HERA practically does not have any role in energy efficiency policy unlike the regulatory authorities in the aforementioned countries, so the M&V methodology must be developed and established by another authority.

Since in Croatia MoELE is in charge for overall implementation of energy efficiency policy, one of its tasks should be also to develop standardised methods for bottom-up M&V as well as to establish an unique IT system for monitoring energy efficiency progress through top-down energy efficiency indicators. In developing M&V methodology, the Environmental protection and Energy Efficiency Fund should also take an active role and must ensure those energy efficiency projects financed from the Fund are subject to M&V.

4.4 VERIFICATION OF ENERGY SAVINGS

ESD stipulates in its Annex IV that if deemed cost-effective and necessary, the energy savings obtained through a specific energy service or other energy efficiency improvement measure shall be verified by a third party. This may be done by independent consultants, ESCOs or other market actors. For Croatia, it is recommended that legal entities entitled for verification of energy savings are nominated by the national authority, i.e. MoELE, based on the clear and transparent criteria in order to prevent possible conflicts of interest and improper notification of realised savings. Verification of energy savings could be requested by the owner/user of the facility where energy service is undertaken, by the national authority (MoELE) or by the Fund for projects financed from it.