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Evaluating taxation for energy efficiency in end-use sectors using elasticity analysis

This guide can be applied to evaluate the savings due to energy taxes in various end-use sectors using the method elasticity analysis. It includes guidance and explanations specific to this combination of types of policy measure, sector and method. As well as links to general guidance and explanations that can also apply to this combination.

CONTENT

1 | OF THE GUIDE–AUDIENCE, OBJECTIVES AND FOCUS

The primary **audience** for this guide concerns energy efficiency programme designers, implementers or supervisors, and evaluators looking for guidance on the evaluation process of energy savings in the scope of this guide.

Although the application of the guide will generally concern the (sub) national level, account will be taken of issues at EU level when relevant (e.g. the specific format of saving figures for the EED).

This guide is not about the preceding step in the evaluation process, the choice of the method. About this previous step in the evaluation process, see the guidance provided here. However, after presenting the capabilities and limitations of the guide at hand, the user will be offered alternatives for the method within this guide (see section 6).

The **objective** of this guide is to provide:

- Information on the scope of the guide that enables the user to decide whether this guide is suited to his/her needs, and whether complementary or additional method(s) could be needed or useful (section 2);
- Guidance about specifying the evaluation objectives and requirements (section 3);
- Guidance about key methodological choices to calculate energy savings (section 4);
- Guidance about the inputs (data requirements) and outputs of the method (energy savings metrics) (section 5)**;**
- Possible alternative methods (with pros and cons) (section 6)
- Background about evaluation results other than energy savings (section 7);
- Relevant examples, case studies and/or good practices (section 8);
- Relevant references for further reading (section 9).

The guide is intended for assessing realised (ex-post) energy savings. However, account is taken of earlier (ex-ante) evaluations of expected savings, if available (see section 4).

The **focus** of the guide is on impact evaluation, i.e. determining the energy savings, but not on how this has been reached through a step by step process with intermediate results (process evaluation).

Readers looking for the basic and general principles of energy efficiency evaluation may find the following link useful.

2 | SCOPE OF THE GUIDE – POLICY, SECTOR and METHOD

2.1 About energy taxes

Taxation for the purpose of energy efficiency improvements mainly aims at addressing market failures caused by energy consumption, by charging a tax or levy on certain type of energy sources or energy usage. The objective of the measure is to make consumers and producers pay social cost of the good (including the cost that pollution poses to society in the form of carbon emissions and green house effects). In practice direct and indirect measures are typically used. Direct measures include charges related directly to the externality. This type of measures implicitly assumes that the market failure is observable and quantifiable. An example would be taxes on carbon emissions. Indirect measures are taxes related to the consumable generating the externality (for example, the fuels generating carbon emissions) or consumables related to it (e.g. the cars which use such fuels).

The energy taxes measure is a subtype of the main policy measure type Fiscal/Tariffs. More information and examples on the different subtypes residing under the main type Fiscal/Tariffs can be found here and in the Knowledge Base of EPATEE. The focus of this guide can be enlarged to taxes based on the CO2-emission, provided that this tax can be converted to a levy per unit of energy consumption.

Many other policy measures focus on specific saving actions, but taxes influence all saving actions, not only of a technical nature, but also behavioral, where the increase of the energy costs plays a role.

Where variations in tax rates exist, separate analyses should be carried out for each group and energy type. The impact on end consumer prices should be expressed as the percentage change relative to the price including the tax. In case of taxes for intermediate actors (e.g. energy companies) it is important to know the extent to which the tax is passed on to end consumers, and any exemptions or variations in rates for particular groups of end consumers or energy type, also taking account of any offsetting allowances or subsidies. In the case that an allowance is foreseen for low income households for alleviating the impacts from an increased tax, the weighted increase of the tax that is passed on to end consumers should be estimated.

More detailed information on the evaluation of energy taxes can be found in this link.

2.2 Evaluation for a combination of policy measure types

In practice, energy taxes are implemented in parallel to all types of policy measures (from financial to standards and from information to voluntary agreements). When this guide is applied, it is assumed that the overall savings are mainly due to energy taxes. However, the evaluation concerns the combined savings effect of this policy measure and other policy measures focusing on the same energy users. For dealing with this overlap see section on Gross to Net savings.

2.3 About end-use sectors

More information and examples on the different subtypes residing under the main type **(financial incentives)** can be found here and here.

Information on (sub) sectors defined in the Toolbox can be found here, chapter 2, p.17.

The guide is capable of covering the effect of taxes for all end-use sectors, but it can also be applied to specific parts of end-use, each part having a specific level of taxation. Often the tax level is differentiated as to sector, e.g. lower for industry because of international competition. Sometimes the tax is restricted to part of the sector, e.g. below or above a certain amount of consumption, or the tax does not target all energy carriers.

Also, distinctions can be made for end-users in a sector, in order to have better elasticity values. In the residential sector, for example, a distinction can be made as to income groups or type of dwelling.

2.4 About the elasticity analysis method

Information about the various evaluation methods can be found in this link, table 1 and 2. This source also covers the combination of the method at hand with other methods, which will be dealt with below.

According to economic insights the amount of energy consumption will depend on the price of energy. A higher price will make it more attractive to invest into more efficient energy-using systems or stimulate more conscious behavior as to energy use. The introduction of a tax on delivered energy carriers has the same effect as a higher price and will lead to a lower consumption level, i.e. savings on energy consumption.

The ratio between the relative increase in the price and the relative decrease in energy demand is called the **price-elasticity**, which will normally have a value between 0 and 1. A value near 0 means that energy demand is not sensitive to higher prices (inelastic), while a value near 1 indicates a demand that is very sensitive to prices. Given the tax level and the elasticity value the method provides the total saving due to the tax.

Both short term and long-term elasticity values are applied, where the first defines the savings due to (immediate) behavioral changes and the second the savings due to investments into more efficient energy using systems when systems have to be replaced.

This guide is not about the calculation of elasticity values, but is based on the use of available elasticity data from literature. These values might have resulted from regression analysis, described in another guide on Regression analysis in the Toolbox.

Long-term elasticities should be based on analysis for at least 15 years. For the case of short-term elasticities that depict behavioural change a period of 2-3 years is adequate.

2.5 Complementary methods to determine total savings

Complementary methods are required, in addition to the primary selected method, to calculate number of actions or unitary savings as part of calculating total energy savings.

However, the method at hand provides directly the total savings, thus does not concern complementary methods.

2.6 Additional methods to increase reliability of the results

An additional method can be applied on top of the already chosen method to improve the reliability of the evaluation results and/or the cost-effectiveness of the evaluation approach.

Elasticity values can be found in literature, but these values often differ between sources, even if they concern the same sector. In order to check the elasticity values regression analysis can be applied as additional method. However, regression analysis demands data gathering on many quantities over longer periods and should be planned well ahead of the start of the evaluation.

For possible combinations with an additional method see chapter 6 here.

3 | EVALUATION OBJECTIVES and REQUIREMENTS

3.1 Meeting evaluation goals and ambition

The table shows whether this guide can be used to report on general evaluation goals or criteria. See also this document. See also this link.

General types of evaluation goals or criteria	Level of ambition	Remarks
Calculation of realized energy savings from saving actions	Limited	Elasticity analysis does not focus on specific saving actions, but can be applied to subsectors/applications
Calculation of energy savings attributed to the policy measure(s)	Fair	Method provides savings due to taxes
Cost-effectiveness of saving action (for end-users)	No	Method does not focus on individual actions with costs and benefits
Cost-effectiveness of policy (government spending)	Not relevant	No spending
CO_2-emission reduction from saving actions	Limited	See realized savings
CO_2-emission reduction attributed to the policy measure(s)	Fair	For distinction between tax per energy carrier (with own emission factor)

For more information on verification of actual energy savings and attribution/baseline/corrections, see section 4, and for cost-effectiveness and emission reduction see section 7.

3.2 Reporting expectations

Possible reporting options:

- Net savings (no Gross savings, see section 4)
- Yearly savings (no cumulative savings because no specific saving actions, with lifetimes, are regarded, see section 5)
- Short-term and long-term savings (due to respectively behavioural response and due to investments into more efficient energy using systems - see section 2).

3.3 Time frame for evaluation

The length of the period under evaluation is dependent on the active period of the policy measure, the need to monitor developments before the implementation of savings actions (in case of methods based on before/after saving actions), and the time needed to present (reliable enough) results or impacts that fit into the decision making process. In some cases, the periodicity of evaluation can be set by law.

The method does not use data on energy prices or consumption before the introduction of the energy tax. Therefore, the length of the evaluation period is equal to the active period of the energy tax (without major changes in this period).

The effect of the introduction of an energy tax will vary over time. In the short-run, the savings effect will be smaller and over time will become larger (see section on Elasticity analysis method). Therefore, short term elasticity values should be applied first and long term elasticity values later on.

Before the introduction of the energy tax the monitoring of the saving effects must be set up. This concerns the availability of data on (mean) energy prices and taxes for each group of end-users over the evaluation period, and regular monitoring of energy consumption. See also planning of evaluation in the link here.

3.4 Expertise needed for chosen method

In order to choose the right elasticity values from literature expertise is needed on the economic concept of price elasticity and its limitations as to providing sound saving effects due to the energy tax.

3.5 Boundaries for the evaluation

Because energy taxes are often introduced at national level, the method is normally applied at national level as well. This is also true for EU wide taxes that become part of national policies.

The method is also applicable to evaluate taxes at regional level, provided that energy consumption data at regional level are available.

4 | KEY METHODOLOGICAL CHOICES FOR CALCULATION OF ENERGY SAVINGS

This section deals with key methodological choices to be considered when calculating energy savings: consistency between ex-ante and ex-post evaluation, baseline, normalization and adjustment factors. These choices are important **to document** when reporting energy savings, to ensure the **transparency** of the results.

General principles of calculating realized savings using different methods can be found here and here.

For the application of the elasticity method the following issues has to be taken into account:

- In case the tax differs per group of end-users separate calculations must be made for each category. This is also valid for a flat tax on all end-users when elasticity values (sensitivity to price changes) differ per type of end-user.
- Elasticity values and tax levels are often different for fuels and electricity; therefore separate calculations must be executed for fuels and electricity.
- The higher price due to the tax has effect at short notice on daily energy using behavior, but the effect through investments into more efficient energy using systems has to wait until planned replacement of systems. Therefore, a distinction should be made between the short term elasticity and the (larger) long term elasticity.
- For ex-ante evaluations the method can only rely on price elasticity values from literature, because no observed energy consumption data are available to determine the reaction to higher prices. For ex-post evaluations an analysis can be made of price trends versus consumption trends, but that will take considerable time (for the long term elasticity) and much efforts to exclude other influences than the price change. Therefore, in ex-post evaluation it is preferable to use elasticity values from literature, provided that they reflect the case at hand as much as possible.
- Given the tax level in the evaluated period and the short- and long-term elasticity values, the method provides the total savings at short and long term notice for each category of end-users and in total.
- Contrary to most other methods used in the guides, this method does not show the composition of the savings, e.g. amount of insulation actions times the unitary savings per action, including the investments made, etc. But given an application per category, insight in the contribution per group of end-users will be provided.
- The method provides by nature the net savings due to the energy tax, thus no corrections of gross savings are needed.
- Interaction of energy taxes with other policy measures is a major issue. In order to cope with this interaction, especially over longer periods, it is recommended to either (a) only use short-run elasticities when calculating the impacts of taxation measures; or (b) use both short- and long-run elasticities to calculate the impacts of taxation measures, but not claim energy savings for any other policy measure (i.e. treating the taxation measure as the main policy measure in a bundle of policies). See also correction for double counting in the section on Gross to Net savings.

4.1 Matching method with earlier ex-ante evaluation

From the viewpoint of methodological consistency and data availability using the same method in the ex-ante evaluation and in this guide on ex-post evaluation might be an obvious choice. The method at hand complies with this choice (see previous section).

The elasticity analysis method for the ex-post evaluation can be combined with other methods for the ex-ante evaluation, depending on the evaluation objectives, timeframe and data available for the situation after implementing the actions. For possible combinations of methods applied ex-ante and ex-post, see chapter 7, calculation approaches in this link**.**

A combination of elasticity analysis ex-ante with the method regression analysis for ex-post evaluation might be the best approach (see section 6). Regression analysis provides the opportunity to calculate the effect of the tax while accounting for the effect of other policy measures.

4.2 Calculation baselines

Energy savings are defined in general as the difference between the actual situation and a reference situation without the saving actions (and without the policy measures that influence these saving actions). In case of saving actions the reference situation can be defined using various calculation baselines: Before/after, With/without, Trend, Target/control group and Minimum efficiency standards. For further background see further here.

The applicable baseline option concerns “With/without”, where the “without tax” is the baseline for the actual development in the “with tax” case. The difference between the two is the tax-level (input) and the calculated savings (output).

Sometimes, only part of the energy tax will be taken into account, e.g. on the grounds of the mandatory requirements of the EU legislation, such as the Energy tax directive, where only eligible saving effects results from national taxes above a minimum level prescribed by the directive.

4.3 Normalization factors

The calculation with the previously chosen baseline provides a change in energy consumption that should be corrected for influences on energy consumption other than the saving actions. These so-called normalization factors can be weather (with effect on consumption), the rebound effect and changes in energy using activities, such as production (industry), occupation rate (buildings) or car usage (transport).

The rebound effect is already accounted for in observed energy consumption. The same is true for the activity level, which means that relative change in energy consumption due to the tax holds also for an increased (or decreased) activity level. The remaining applicable normalization factor is weather. The savings are the result of an elasticity factor times tax level times normalized energy consumption. Therefore, actual energy consumption has to be corrected for yearly deviations from long term weather conditions (mean outdoor temperature during the heating season, expressed in heating degree days, or mean number of hot summer days for cooling).

4.4 Adjustment factors

Adjustment factors define which part of the calculated energy savings can be attributed to a policy measure or meets the definition of savings specified in the evaluation objectives or reporting requirements (see next section on "Calculating Gross and net savings). Adjustment factors can concern the Free rider effect, the Spill-over/multiplier effect, Additionality, Non-compliance and Double counting. See further here.

Here, Double counting might be relevant in case of another policy focusing on the same saving actions as evaluated with the guide at hand. But double counting can only be accounted for at a higher level than individual guides.

See this link and here and here.

The other factors are connected to either the unitary savings or the number of actions, but these quantities are not covered in the elasticity analysis method.

4.5 Calculating Gross and Net energy savings

Gross savings concern the calculated savings from saving actions using a chosen baseline and normalization factors. Net savings concern the savings attributed to policy measures or to a stakeholder (e.g. an energy company with an obligation to realise savings at their customers).

The gross savings are calculated using the baseline "Without (taxes)" and correcting for the normalization factor weather. The total gross savings are equal to the relative increase in the energy price due to the tax times the elasticity value and times the energy consumption (normalized for weather).

At short notice the savings are calculated with the (lower) short-time elasticity value; at longer term the savings are calculated with the (higher) long-term elasticity value.

When prices and/or tax differ per sector, the calculation should be executed per sector. Because tax levels and elasticity values differ for fuel and electricity, separate calculations should be executed for both.

Net savings can be determined from gross savings by applying adjustment (or gross-to-net) factors. See this link and here.

For net savings the gross savings should only be corrected for the Double counting effect, i.e. the overlap between the savings due to energy taxation and savings due to other policy measures. The overlap in the calculated savings of both policy measures cannot be processed at the level of a guide but must be corrected at the level of savings due to overall policy portfolios.

See also section 8 on Concrete examples.

5 | INPUT AND OUTPUT

5.1 Main data requirements, data sources and collection technics

Data requirements specified in the table below correspond to the calculation of energy savings, when using the baseline option With/Without.

Calculation subject	Data requirements	Possible data sources and collection technics
Energy consumption per group of end-users	Yearly values per type of energy carrier, corrected for variations in heating degree days	EU and national statistics
Energy price/tax per group of end-users	Mean prices and tax levels per type of energy carrier delivered to end-users	EU and national statistics
Elasticity of relevant energy demand to energy price	Elasticity values, short and long term	Literature (often based on regression analysis)

When insufficient data are available on elasticities for the country and sector at stake, the results for similar sectors in other countries could be used as proxies for the relevant price elasticities. As a final option and only in the documented absence of the options above, results from other sectors could be applied to the relevant sector.

Data issues with alternative method

If the alternative method Regression analysis is applied, time series data should be available on all dependent (energy consumption) and independent quantities (all explaining variables to filter out other influences than the effect of the energy tax).

If these data are not available, the method that only needs elasticity values from literature, the level of the energy tax relative to the energy price and energy consumption should be applied.

For more details about the evaluation of net energy savings, see this topical case study.

5.2 Energy savings in final terms or in primary terms

Energy savings can be expressed in final terms or in primary terms. See definitions about primary and final energy here.

With the elasticity analysis method savings in final terms can be calculated. It can also calculate savings in primary terms provided that savings at end-users are calculated for each energy carrier apart, and primary factors are available to convert the savings in final terms to savings in primary terms.

5.3 Energy savings over time

Implemented saving actions in a year lead to savings over a number of consecutive years. E.g. a more efficient boiler can save gas over its lifetime of about 15 years, insulation over up to 60 years and more efficient computers up to 5 years.

Energy savings can be calculated in different metrics in terms of time reference, for example: year-to-year, annual, cumulated annual, cumulative. See the definitions here.

The elasticity analysis method cannot provide cumulative savings because it does not provide the savings for separate saving actions (each having their own life time).

For the same reason cumulative savings according to the Energy Efficiency Directive cannot be provided, nor discounted cumulative savings (where discount factors have been defined for yearly savings over time).

6 | ALTERNATIVES FOR THE CHOSEN METHOD

6.1 Alternatives for the chosen method

Often other savings calculation methods can be applied as well, although they will all have pros and cons regarding various aspects dealt with in preceding sections.

For the method applied for this guide the only alternative is Regression analysis (see **Specific Guidance 21**).

The table below presents the pros and cons of the method at hand and of a commonly used alternative method for the same combination of policy measure and sector.

Type of method	Pros	Cons
Elasticity analysis	Simple, few data needed (elasticity values and energy consumption), only monitoring for the active period of the tax	Elasticity values sensitive to other influences than price/tax, therefore values from literature have a large margin
Regression analysis	Price/tax effect separated from other effects, both short- and long-term elasticity values calculated	Complex, data needed on all quantities in regression analysis, monitoring before and after introduction of tax

7 | ADDITIONAL EVALUATION RESULTS

7.1 Calculating avoided CO_2 emissions

Avoided CO_2 emissions can be evaluated from the energy savings by applying emission factors. Four key aspects are to be taken into account when choosing the emission factor(s):

1) Emission factors vary according to the **energy type**, so the data about energy savings need to be available per energy type.
2) Emission factors for a given type of energy **can vary over time** (especially for **electricity**).
3) Emission factors can take into account:
    a. **Direct emission factors** that take into account the emissions generated when producing the energy used;
    b. **Lifecycle emission factors** that take into account all the emissions generated from the extraction of the energy resources up to the dismantling of the energy plant.

Due to the differences that the choice of emission factor(s) can induce, it is important to document what emission factor(s) has (have) been used.

The direct reduction in CO_2-emissions can only be calculated when savings are calculated per relevant energy carrier and a specific emission factor is available for each energy carrier.

If the savings concern electricity only (e.g. appliances) the reduction in CO2-emissions can be calculated from the savings with an emission factor for electricity that takes into account the different inputs of power production. The actual factor to be applied can vary, depending on saving action(s) and sector (given varying emissions factors over day and season), year of implementation, policy considerations, etcetera.

The avoided emission of **other greenhouse gases** due to energy savings are not taken into account here, as emission reductions are generally negligible compared to that of CO_2.

When needed, **IPCC** (Intergovernmental Panel on Climate Change) provides a **detailed database of peer-reviewed emission factors.**

7.2 Calculating cost-effectiveness

Cost-effectiveness is the **ratio between costs** to achieve energy savings and the **amount of savings and possibly other benefits**.

A distinction can be made according to the point of view adopted to assess cost-effectiveness:

- Cost-effectiveness for the end-user or participant
- Cost-effectiveness for society at large
- Cost-effectiveness for the party that takes responsibility for saving targets (government or actor with an Energy Efficiency Obligation)

For more details about the different perspectives, see for example (Breitschopf et al., 2018).

For the policy measure covered in this guide no cost-effectiveness can be calculated because it concerns a top-down approach without data on saving actions with their (cost) savings, investments, etc.

7.3 Calculating other co-benefits

Possible co-benefits from saving energy concern:

- Extra employment
- Reduction of energy poverty
- Other emission reductions (NO_x, SO_2, fine particles, etc.)
- Better indoor climate
- Reduced dependency on (insecure) energy import

For the same reasons as mentioned for cost-effectiveness most of the other co-benefits cannot be calculated for this guide and method. Only reduced import dependency can be determined from the savings, provided that the effect of taxation is calculated per energy carrier type.

7.4 Other aspects of importance

One possible aspect of energy taxes to be analysed is the effect on income distribution.

8 | CONCRETE EXAMPLES

Evaluation of fiscal measures in the NEEAPs for article 7 of the EED, see this link.

The focus of this report is on energy and CO_2 taxation measures and other fiscal measures which involve a direct subsidy, e.g. in the form of grants or investment subsidies. This summary below concentrates on the part on taxes. Hereunder, we summaries some relevant elements of the report:

Chapter 2: Effectiveness of Fiscal Measures

The policy measure Energy Taxation leads to less administrative costs for implementation of saving actions than other policies, such as standards or subsidies

Financing other policy measures (e.g. subsidy schemes) from the tax receipts lowers the burden on energy users and strengthen the incentives to save energy

The weakness of taxes as incentive to implement saving actions is that it does not provide information on the saving options and their costs. Subsidy schemes do provide both the incentive and the information how to save energy.

Taxes are more effective than a subsidy, with the same incentive to invest into saving actions, because profitable subsidized action lead to a rebound effect, while taxes decrease the room for spending on all kind of energy using products and services (negative rebound effect).

Chapter 3: Framework for Evaluation of Impacts

(Elasticity analysis)

The Energy Efficiency Directive (EED) states that for taxation measures (i.e. energy and CO2 taxes), energy savings are quantified on the basis of price elasticities, which represent the responsiveness of energy demand to price changes (see EED, Annex V, part 3, point a).

(Gross and net savings)

In case of subsidies it is important to note that, to calculate an estimated “absolute” energy change as a result of the measure, it is important to compare such estimate with a situation “without” intervention (the counterfactual to be able to obtain estimates of incremental impacts). In the case of taxation measures this is typically less of a problem. This is because the elasticities are already providing the “net” effect of the change in prices.

When estimating energy savings resulting from energy or carbon taxation measures, it would not be necessary to explicitly make adjustments for the counterfactual, as the consumption that would have prevailed in the absence of the taxation measure is reflected in the baseline level of pre-tax consumption, and consumer behaviour represented by responsiveness to changes in price would implicitly be captured by the elasticity estimate.

The results for taxes exclude any underlying trends, changes in consumer’s income or cross-price effects from substitute products. However, having an idea of a counterfactual may be helpful in any case to assess any biases or omissions in the elasticities used (in particular, to assess or quantify effects, which may not be included in the elasticities being used.

(Policy baseline)

Minimum levels of taxation applicable to fuels as required in Council Directive 2003/96/EC on restructuring the Community framework for the taxation of energy products and electricity or in Council Directive 2006/112/EC on the common system of value added tax (for the taxes).

(Rebound effect)

Any rebound effects occurring in response to tax changes would in principle be captured implicitly if appropriate price elasticity estimates are used.

9 | FURTHER READING

About Energy taxation

- Evaluation of Fiscal Measures in the National Policies and Methodologies to Implement Article 7 of the Energy Efficiency Directive, Final report, Europe Economics, 19 October 2016 (elasticities for EED, various countries), https://ec.europa.eu/energy/sites/ener/files/documents/final_report_on_fiscal_measures_used_under_article_7_eed_0.pdf
- The Green Fiscal Commission (2009), The Case for Green Fiscal Reform, Final Report of the UK Green Fiscal Commission.
- 'COMETR – Competitiveness effects of environmental tax reforms', (2004-2006), FP6 Proposal 501993 funded by DG Research of the European Commission.
- Boonekamp (2007) "Price elasticities, policy measures and actual developments in household energy consumption – A bottom up analysis for the Netherlands".

About Elasticities

- Evaluation of Fiscal Measures in the National Policies and Methodologies to Implement Article 7 of the Energy Efficiency Directive, Final report, Europe Economics, 19 October 2016 (elasticities to evaluate the energy tax for the EED, various countries) in https://ec.europa.eu/energy/sites/ener/files/documents/final_report_on_fiscal_measures_used_under_article_7_eed_0.pdf

Relevant case studies

- No EPATEE case studies available.

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