THE "COST-OPTIMAL LEVELS"OF ENERGY PERFORMANCE REQUIREMENTS: RULES AND CASE STUDY APPLICATIONS

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ABSTRACT

The European energy policies about climate and energy packages, known as the "20-20-20" targets, define ambitious, but achievable, national energy requirements. The Directive 2010/31/UE, the "Commission delegated regulation (EU)" n.244/2012 and "Guidelines accompanying Commission Delegated Regulation (EU) n.244/2012" 2012/C 115/01 define a comparative methodology framework for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements to apply at "Reference Building" for EU State Member.

The aim the of Cost-Optimal Level is to supply EU Member State in order to define national energy requirements levels, economically feasible, which could reduce energy consumption until 2020.

Follow the Italian and regional laws, the UNITS 11300 standard procedures allow calculating energy building performance simulation (EPBS), and energy costs depend on these conditions. The Reference building could be 'calibrated' in order to compare it EPBS with real energy consumption.

However, the cost of improvements depends on local variable ad contract tender.

In this paper a case study application of Cost-Optimal Level, following EU procedure, is described in Italian context, in order to highlight the real and actual difficulties to apply EU rules.

INTRODUCTION

The buildings are responsible of 40% of global energy consumption of European Union, as highlighted in Directive 2001/91/CE [1] and Directive 2010/31/UE (recast) [2]. This means that the real estate industry has a great energy saving potential with respect to transport and industrial sectors.

The multiplicity of subjects (owner, lessor, builder, designer, architect, engineer, thermo-technical engineer, real estate agency, energy trader, etc.) makes it difficult. All of these actors should be coordinated in order to promote energy saving.

The European Directives define two kinds of Energy Policies: energy certification, (for stimulate owner or lessor), and energy minimum requirement (in case of new building or energy retrofit).

About energy minimum requirements, the Directive 2010/31/UE introduces a further requirement: from 2020 all new buildings must be a nearly Zero Energy Building (nZEB).

Other innovations of the Directive are reported in articles 4: "Member States shall take the necessary measures to ensure that minimum energy performance requirements for buildings or building units are set with a view to achieving cost-optimal levels." and in article 5 "Calculation of cost-optimal levels of minimum energy performance requirements" "Member States shall calculate cost-optimal levels of minimum energy performance requirements using the comparative methodology framework".

The Cost-Optimal-Level (COL) calculation procedure is defined in Annex III "Comparative methodology framework to identify cost-optimal levels of energy performance requirements for buildings and building elements" and also detailed in Delegate Regulation (EU) n. 244/2012 of 16 January 2012 [3].

The aim of Cost-optimal-level is to set up a comparative model to compare minimum energy performance requirements between EU Member States. The new requirement must be ambitious and economical achievable.

In order to compare energy requirement, all EU Member States are requested to define a "Reference Buildings" (RB), which could be individuated accordingly to European Intelligent Energy Efficiency (IEE) programs TABULA [4] and ASIEPI [5], whereas the international RB database and benchmarking is the Department of Energy (DOE) of United States.

AIMS OF THE PAPER

The balance between cost and benefit is a key-factor of Cost Optimal Level, which could be evaluated whit several kind of methodologies, in order to conform each Member State legislation and real estate industry.

The Cost-Optimal-Level approach should be used during the design of new buildings or energy retrofit, in order to compare several options and solutions. In that case, all costs are included: building, energy and maintenance costs.

The comparative methodology framework described in Delegate Regulation 244/2012 could be adopted by Member State to report for European Commission and by designers and builders to evaluate energy efficiency scenarios, and increase real estate values.

Several studies made by the Building Performance Institute of Europe report examples of adoption of the cost optimal level procedure [6, 7] for Italy and Estonia. The aim of this paper is to verify if this methodology could be applied as thermo-economic analysis in the Italian context in order to decide whether to do energy efficiency improvement project and work.

The energy efficiency measure for building may be considered the increase of real estate value related to Energy Classification improvement, for example from energy Class D to energy Class A, as described in [9, 10], or also in building and energy efficiency measure in national policies measurement [11]. In this paper, we adopt the Delegate Regulation (EU) n.244/2012 procedure and do not consider real estate value.

THE DIRECTIVE 2010/31/UE

The aim of Directive 2010/31/UE is to improve the energy performance of building in UE, in order to satisfy the "20-20-20 targets", with new requirements for 'building elements', 'technical building system' and, nearly zero energy building (only for new buildings).

All these requirements must consider the related cost-effectiveness. In Annex III a methodological framework to evaluate cost and benefit, is described.

The energy minimum requirement, defined by methodology framework of Annex III, is upgraded every 5 year, in order to follow the evolution of building construction.

The "Delegate Regulation (EU) 244/2012" and the "Guideline for calculation cost-optimal levels C 115-2012" [12] represent two frameworks that define cost-optimal level for each EU Member State. The Delegate Regulation (EU) 244/2012 describes both method and procedure, whereas the "Guideline C 115-2012" reports some Delegate Regulation enlightenment and examples of calculation.

The Reference building

In order to report the Energy Efficiency Action Plans at EU Commission, each EU Member State I requested to relate the minimum energy performance requirement with "Reference Building". The "Reference Building" is a tool to compare all the European legislation as requested by EU Commission. They are defined in Annex III as "(…) representative of their functionality and geographic location, including indoor and outdoor climate conditions. The reference building shall cover residential and non-residential building, both new and existing ones".

The reference building shall be defined for the following categories of buildings: (1) single-family buildings, (2) apartment blocks and multifamily buildings, (3) office buildings, and (4) other optional buildings: schools, hotels, restaurants, sport buildings, shopping centers or other buildings with relevant energy consumption.

The definition of Reference Building for Italy are adopted by Italian Ministry of Economic Development [13] and ENEA (Italian National Agency for New Technologies Energy and Sustainable Economic Expansion) in order to define an Italian Reference Building [14].

The report about reference building for European Commission

The "*Report Template*" is included in Annex III of Delegate Regulation (EU) 244/2012. The tables are:

- Table 1 - "Reference building for existing buildings (major refurbishment)";

- Table 2 - "Reference building for new buildings";

- Table 3 - "Example of a basic reporting table for energy performance relevant data";

- Table 4 – "Illustrative table for listing selected variants/measures", where are reported all ordinary and innovative energy efficient measure, for the same comfort level;

- Table 5 - "Energy demand calculation output table", with in attachment a calculation report and standards references used to evaluate energy performance of buildings;

- Table 6 - "Output data and global cost calculations";

- Table 7 - "Comparison table for both new and existing buildings".

The first table (reference building for existing buildings) is here reported. The case study further reported in this paper and simulated by means of specific spreadsheets, consists of the refurbishment of an existing building, and all the aforementioned table have been calculated for it.

Table 1 - "*Reference building for existing buildings (major refurbishment)*";

	Building				Heating plant system					
	Roof ithermal insulation	Wall insolation	Basement floor insolation	Windows replacement	Radiant heating (panel heating)	Boiler	Condensing Boiler	Heat pump (air/water)	Renewable Energy sources solar collector and photovoltaic	M=natural gas E=Elecricity
Scenario 0 - law requirements	X				X		X		X	M
Scenario 1	X	X	X		X		X		X	M
Scenario 2	X			X	X		X		X	M
Scenario 1+2	X	X	X	X	X		X		X	M
Scenario 3	X				X			X	X	E
Scenario 1+2+3	X	X	X	X	X			X	X	E

COMPARATIVE METHODOLOGY FRAMEWORK

The Delegate Regulation (EU) 244/2012 identifies five steps that are necessary to evaluate the cost-optimal-level:

(1) to define the start year and to evaluate an economic lifespan for building or 'building elements' or 'technical building system' following EN 15459 [15] ;

(2) to establish the "discount rate" for comparison the value of money at different times, and for both evaluation methodologies;

(3) to define the "energy carrier" or other energy cost (with and without tax), and other maintenance and operative cost;

(4) to evaluate the "energy cost trend" for energy carrier (natural gas, electricity, etc.) relate to the national contest;

(5) to define the "primary energy factor",

The cost-optimal-level for reference building could be evaluated following two economic viewpoints:

A) Financial viewpoint; it consists of evaluating the energy efficiency measure cost, expressed in cost and benefits, at the investment year. In this case, it shall be considered all the real cost at the present, including tax and incentive or other financial support.

B) macroeconomic viewpoint; it consists of evaluating the investment cost, including all environmental effects of energy efficiency measure. In this case, also the reduction of CO_2 in atmosphere and the connected economic benefit shall be considered.

Methodology

The Annex III of Delegate Regulation defines the methodology, in the following steps:

(1) definition of Buildings reference for existing and new buildings, both dwelling and not dwelling, based on geographic and climate zone;

(2) definition of Energy efficient improvement scenarios;

(3) evaluation of Energy primary of all reference buildings, for all the scenarios;

(4) calculation of cost for each scenario expressed with Net Present value (NPV) during the Life Economic Cycle (or lifespan);

(5) evaluation of effectiveness minimum Energy requirements and determination of cost-optimal-level.

ENERGY EFFICIENCY MEASURES (SCENARIOS)

In Delegate Regulation (EU) 244/2012, Annex I point 2, the energy efficiency solutions are defined as "all input parameters for the calculation that have a direct or indirect impact on the energy performance of the building, including for alternative high-efficiency systems such as district energy supply systems".

Each single measure (or scenario) should define the Energy efficiency measures. For example, a new window constitutes a new scenario as well as a new package or new refurbishment of wall and roof, or the substitution of boiler. Each scenario has to satisfy the minimum law requirements.

The "Guideline C 115-2012" at point 4.2 reports: "the number calculated and applied to each reference building should certainly not be lower than 10 packages/variants plus the reference case." and

"Various techniques can be used to limit the number of calculations. One is to design the database of energy efficiency measures as a matrix of measures which rules out mutually exclusive technologies so that the number of calculations is minimized".

It is clear that the more are the scenarios, the more cost-optimal levels are feasible.

Energy building performance evaluation

Once every package/measure for each scenario is defined, the further step consists on the energy building performance evaluation, in order to calculate the energy primary index, expressed in kWh/m^{2}year, for each scenario.

The Directive 2010/31/UE includes all energy services of building: heating, cooling, domestic hot water, ventilation and lighting. Furthermore, it includes all the energy services of building: heating, cooling, domestic hot water, ventilation and lighting.

In Italy the Energy performance methodologies follow ISO 13790 [16] with steady-state balance, based on monthly methodology. Actually the Italian standards UNITS 11300 part 1 [17], part 2 [18] and part 4 [19] consider only heating and domestic hot water evaluation and renewable energy sources. Other energy consumptions for cooling, ventilation and lighting or wiring use, are now being considered.

For these reason actually, in Italy, the Energy consumption is related only with the thermal use and not with the electric use. This differs from the procedure (and example) reported in Delegate Regulation (EU) 244/2012, and it is not possible to evaluate the electric consumption and all the photovoltaic or window shield benefit during cooling consumption.

These limitations influence the energy performance evaluation, the energy class, and nearly zero energy building defined, as described for Italian and English cases in [20, 21].

Calculation of global costs

For each measure or package, following point 4 of the aforementioned methodology framework, the global costs are calculated.

The Global Cost (Cg) is defined as "the sum of the present value of the starting investment costs, sum of running costs, and replacement costs (referred to the starting year), as well as disposal costs if applicable. For the calculation at the macroeconomic level, an additional cost-category cost of greenhouse gas emissions, is introduced".

The Global Costs are based on the "Net Present Value" (NPV) of all costs during the reference period of each scenario, which is fixed in 30 year.

The categories for evaluation of cost-optimal-level could be divided into macroeconomic viewpoint or financial viewpoint.

The macroeconomic viewpoint considers primary energy cost; besides, financial viewpoint could be based on energy primary or energy used (or energy carrier: natural gas, electricity etc.).

Costs categories

The Global Cost, expressed in NPV, is obtained summing these costs:

- starting investment cost (C_I); it means the summa of all the investment costs, that includes for example the insulation cost, the design cost and all taxes, for each scenario;

- Annual Cost (C_a); it means the summa of annual Energy Cost (C_e) and maintenance cost (C_m);

- Energy Cost (C_e), the most important variable; It means the annual energy costs scheduled and peak charges for energy, including national taxes;

- Replacement Cost (C_r); It means a substitute investment for a building elements;

- Cost of Greenhouse gas emission (C_c); it means the monetary value of environmental damage caused by CO_2 emission related to energy consumption in buildings.

The Energy Costs (C_e) are calculated for each year and for all the period; they are actualized with NPV at the starting year.

The evaluation of NPV considers the discount factor R_d that is calculated for a generic year *i,* and a discount rate *r*, with the formula:

$$R_d(i) = \left(\frac{1}{1 + (r/100)} \right)^i \quad [\%] \qquad [1]$$

The calculation period is scheduled in 30 year for residential and public buildings, and in 20 year for commercial and not residential building. The lifespan and Life Economic Cycle for each building element and for all building are based on EN 15459.

Global Cost procedure

To evaluate Global Cost, the following steps are required:

(1) definition of each scenario measure or package;

(2) evaluation of Starting Investment Cost (C_I);

(3) evaluation of annual Energy Cost $(C_e)_j$ for each energy carrier;

(4) evaluation of Maintenance $(C_m)_j$ and Functional annual cost $(C_f)_j$

(5) evaluation of Substitution $(Cs)_j$ and Disposal Cost $(C_d)_j$ for relative year;

(6) calculation of NPV for starting year

(7) evaluation of CO_2 emission and relative emission cost for greenhouse emission (only for macroeconomic viewpoint);

(8) summa of all the NPV costs;

(9) calculation of Global Cost (C_g).

The formula to evaluate Global Cost for financial viewpoint [€/period] is the following:

$$C_g(\tau) = C_I + \sum_j \left[\sum_{i=1}^{\tau} \left(C_{a,i}(j) \times R_d(i) \right) - V_{f,\tau}(j) \right] \quad [2]$$

and for macroeconomic viewpoint is [€/period] :

$$C_g(\tau) = C_I + \sum_j \left[\sum_{i=1}^{\tau} \left(C_{a,i}(j) \times R_d(i) + C_{c,i}(j) \right) - V_{f,\tau}(j) \right] [3]$$

Where:

$V_{f,\tau}(j)$ means the residual value of measure or set of measures j at the end of the calculation period (discounted to the starting year τ_0);

$R_d(i)$ means discount rate for j-year;

$C_{a,i}(j)$ is the annual cost during year i for measure or set of measures j calculated with formula [4]:

$$C_{a(i)} = C_{e(i)} + C_{m(i)} + C_{f(i)} + C_{so(i)} \text{ [€/year]} \quad [4]$$

$C_e(j)$ means energy annual cost for each energy carrier includig tax for j-year;

$C_m(j)$ means maintenance cost;

$C_f(j)$ mean operational cost;

$C_{so}(j)$ means substitution cost;

$C_{c,i}(j)$ means greenhouse gas emissions cost;

C_I means starting cost for each scenario.

The Global Cost discounted to the starting year ($C_{g,\tau}$), shall be related to floor units surface (m^2):

$$C_g = \frac{C_g(\tau)}{SU} \quad \text{[€/m}^2\text{]} \quad [5]$$

Annual Energy Cost $(C_e)_j$

The annual Energy costs represent the main value of annual cost. They directly depend on energy primary building performance, energy carrier and also energy market (or energy fee and tax). The formula is:

$$C_{e(i)} = Q_p \cdot T \quad \text{[€/year]} \quad [6]$$

Where Q_p means energy performance of building expressed in primary energy (kWh/year), and T means Energy fee or tariff included tax and/or VAT for each energy carrier expressed in €/kWh with kWh of primary energy.

The Operational Cost includes all cost for assurance, rules upgrade or improvement, energy cost, tax and fee. The Maintenance Cost includes all cost for inspection, ordinary or extra ordinary repair and safety cost.

The Operational Cost is calculated for each year. The Maintenance Cost could be divided into annual or periodic cost, for extra ordinary repair. The periodic maintenance operation could be related to inverter substitution for photovoltaic, boiler components substitution, etc. All these costs shall be anticipated and bringing up-to-date with the formula [7]:

$$C_{m(i)} = Maintenance\ Cost \cdot R_{d(i)} \quad \text{[€/year]} \quad [7]$$

In case of macroeconomic viewpoint, it is necessary to evaluate the environmental impact of greenhouse gas emissions and it monetization, for each year. The CO_2 emissions are calculated from energy building performance in relation with energy carrier and CO_2 factor values described in EN 15603 [22] Annex E or in national value.

The monetization of CO_2 emission are scheduled for 2050 scenario in 20 €/tCO_2 until 2025, 35 €/tCO_2 until 2030 and 50 €/tCO_2 after 2030.

For example, considering the starting year 2012, the monetization, for residential building is:

$$\sum_{i=1}^{\tau} C_{c,i(j)} = t_{CO2eq,a,i(j)} \cdot ((20€ * \cdot 13 \text{ year}) + (35€ * \cdot 5 \text{ year}) + (50€ \cdot * 12 \text{ year})) \quad \text{[€/year]} \quad [8]$$

Cost optimal level

The Directive 2010/31/UE in article 2 introduces the "Cost Optimal Level" that is defined as:

"'*cost-optimal level*' means the energy performance level which leads to the lowest cost during the estimated economic lifecycle". Moreover, "The cost-optimal level shall lie within the range of performance levels where the cost benefit analysis calculated over the estimated economic lifecycle is positive". Therefore, the cost-optimal-level identifies the technological solution, measure, package or scenario with shorter $C_g(\tau)$.

The optimum solution are neither the scenario with the lowest energy performance index EP, because in that case the starting cost have relevant incidence than energy cost reduction, nor the scenario with lowest Starting Investment Cost, because in that case the energy annual cost are some relevant.

The cost-optimal level is a “balance point” (figure 1 and 2) between Starting Investment Cost, and Annual Energy cost during all the period of evaluation.

The evaluation of cost-optimal level depends on a single parameter, for example transmittance, or energy performance index. It is a tool that allows defining a “cost-optimal level zone” (figure 1).

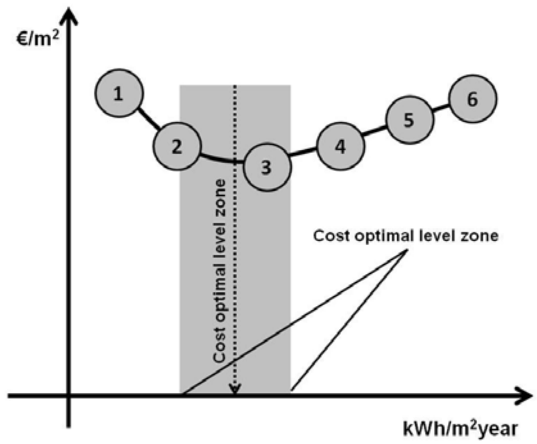

Figure 1 – Cost optimal level zone – Comparative graphics

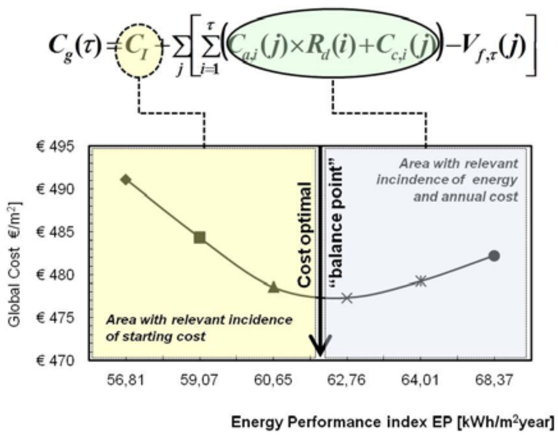

Figure 2 – Global cost and balance point scheme

THE CASE STUDY EVALUATION

In the following paragraph we describe a case study about a dwelling building: The example is related with an energy retrofit building. For this building and for each scenarios measurement, the energy performance index has been evaluated following Italian standards UNITS 11300.

The evaluation period is 30 years; the discount rate *r* is 1%, following the Italian Bank value, and the energy cost and tariff for natural gas and electricity, are based on AEEG [23] value for 2012 (second quarter year). The building material and technical plant cost, and also all relative cost about designer and construction site, are calculated by official price list by CNA [24] of Ravenna, where the building is located. In Italy the building material prices are evaluated for each province, for each year, because national value has more variability. In order to define a national methodology, we suggest individuating a regional o macro-regional value.

In this case study we do not consider National incentive about energy efficiency improvement measure or photovoltaic fee.

The building

The case study is a bi-familiar villa on 3 floors, but the energy retrofit is related only to half of the building. The structure is made of reinforced concrete and internal walls are made in bricks without insulation; also the floors are made of reinforced concrete and bricks without any insulation. The windows frames are made in wood, having single glass layer. The heat generator is a traditional boiler (not condensing) for heating and domestic hot water combined production, with radiators. The floor surface is 160.25 m^2.

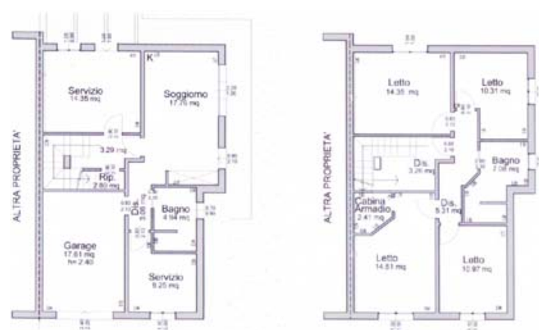

Figure 3 – The case study – ground floor (left) and first floor (right)

The graphics in figure 4 and 5 show an anomaly in cost-optimal level, because the global cost of the scenario 0, with minimum energy requirement adjustment, is the lowest scenario.

This result could depend on the initial costs, because the costs to realize the minimum energy requirement adjustment do not have the extra-cost to improve energy performance, as in other energy efficiency scenarios.

If we do not consider the “zero scenario”, the performance index EP, (which correspond the lowest Global Cost), is 54.74 kWh/m^{2}year. This could be considered the Cost-Optimal Level.

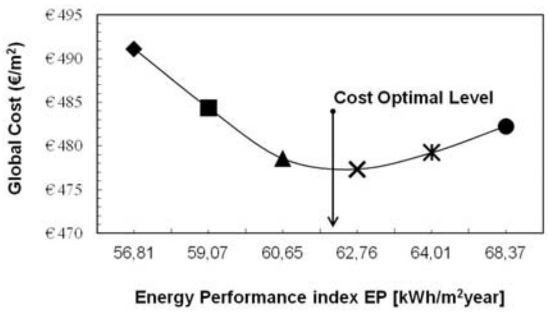

Figure 4 – The case study – Macroeconomic viewpoint

The Cost-Optimal-Level zone is between the index EP 51.16 kWh/m^{2}year ad 58.41 kWh/m^{2}year.

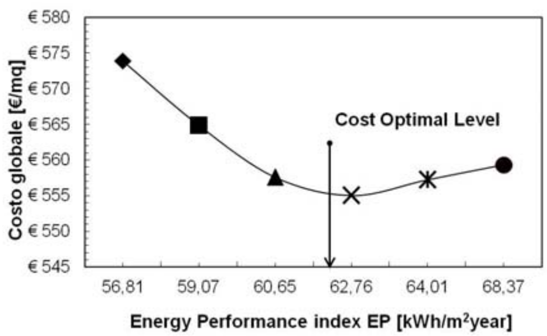

Figure 5 – The case study – Financial viewpoint

CONCLUSIONS

The cost-optimal-level is an important tool useful to compare several scenarios for the same building, and the methodology framework could be applied for real buildings and not only for reference building.

The methodology frame work could have some difficulties, as in the case study here presented. In existing buildings the relation between energy efficiency improvement and energy cost is not linear. The cost of some technologies (for example plant or renewable technologies), and also energy carrier and tariffs might be not related with the results of their application. The same consideration could be adopted for walls o roof insulation.

In the case study here presented, the insulation technologies resulted most expensive than plant technologies. This was caused by the starting costs, that did not have any extra-cost to improve energy performance, as well in other energy efficiency scenarios.

For not standardized building, some aspect must be investigated:

- It might be useful to identify the national or regional standard costs for energy retrofit technology solutions. They depend on the construction sector and not on the related energy saving, therefore they do not include material or accessories costs;
- It might be useful to define standard criteria for "energy tariff", for example following AEEG or EUROSTAT, because each energy carriers differs considerably for annual energy costs and variable;
- It might be useful to include in framework the increase of real estate values, one of the most important effect of energy improvement as describe in [25], with same criteria adopted for greenhouse emission costs.

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[23] AEEG Autorità per l'Energia Elettrica e per il gas - Regulatory Authority for Electricity and Gas

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